Chapter 5 Effects

The potential effects of the proposed action on listed species are evaluated in this section. Under Section 7 of the ESA, Reclamation must ensure that the proposed action will not "jeopardize the continued existence of any endangered or threatened species, by reducing appreciably the likelihood of survival or recovery of a listed species in the wild or adversely modifying listed habitat appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species." The analyses in this section thus consider the potential effects the proposed action is likely to cause to listed species, including effects at all life stages, anticipated response, and cumulative effects.

Reclamation established a without action scenario as part of the environmental baseline to isolate and define potential effects of the proposed action apart from effects of non-proposed action causes. The model run representing this scenario does not include CVP and SWP operations, but does include the operations of non-CVP and non-SWP facilities, such as operation of public and private reservoirs on the Yuba, Tuolumne, and Merced rivers. The without action scenario plays the crucial role in the effects analysis of establishing the likelihood of species survival and recovery under the environmental baseline (i.e., the effects on survival and recovery from all non-proposed action causes).

The additional effects of habitat restoration, predation from invasives, water quality, and other effects on species from federal, state, and private actions are also analyzed. These effects are part of the baseline. However, in a consultation on an ongoing action, such as operation of the CVP and SWP, the baseline analysis must project a future condition without the action in order to isolate the effects of the action from the without action scenario and, in turn, a determination of whether the action is likely to jeopardize listed species and/or destroy or adversely modify critical habitat.

Included for context in the effects analysis is a current operations scenario that represents current operations of the CVP and SWP (including the 2008 and 2009 biological opinion requirements), along with federal, state, and private operations on other rivers (e.g., Yuba, Tuolumne, and Merced Rivers). The current operations scenario is included for context in the effects analysis. When appropriate, the analysis considers differences between the effects of current operations and the proposed action, because the effects of current operations provide a reasonable measure of likely future effects of similar measures in the proposed action.

The Secretary has a wide degree of discretion in determining the analytic framework and tools used to develop the biological assessment. The ESA does not impose a mandatory duty to use any specific model or scientific methodology, but merely requires that Reclamation provide to the Services "the best scientific and commercial data available or which can be obtained during the consultation for an adequate review of the effects that an action may have upon listed species or critical habitat." 50 C.F.R. § 402.14(d). In previous analyses, Reclamation has utilized a variety of technical models and other tools in preparing its biological assessment. Those efforts were not required by the ESA, which does not set a standard of absolute scientific certainty, and nor does it demand that an agency obtain new information to make its determination. Rather, the "best available data" standard only requires the agency to consider scientific information presently available. Reclamation determined that the modeling and other analytical efforts used in this biological assessment provide ample basis for the Services to conduct an adequate review of the effects of the action on the species.

5.1 Analytical Approach – Aquatic Species

The effects analysis herein is organized into potential effects from the proposed action on listed species, listed species' designated critical habitat, and Essential Fish Habitat (EFH). For the purposes of analysis of Pacific Coast Salmon EFH and effects to Southern Resident Killer Whale, also included are analyses of potential effects of the proposed action on unlisted Central Valley Fall-run/Late Fall-run Chinook Salmon ESU, Upper Klamath-Trinity Rivers Fall-run Chinook Salmon ESU, and Upper Klamath-Trinity Rivers Spring-run Chinook Salmon ESU.

For each species, the effects analysis is broken into three sections: 1) operations and maintenance, 2) conservation measures, and 3) critical habitat. In the proposed action, operations and maintenance is the Core Water Operation and includes all aspects of operating and maintaining the CVP and SWP, as described in seasonal operation to meet flood control, navigation, water supply (water right obligations, contracts, and agreements), fish and wildlife, power generation, and recreational purposes. Operation and maintenance includes the Shasta Temperature Control Device, spring pulse flows, fall and winter refill, Delta Cross Channel operations, the Tracy Fish Collection Facility and Skinner Fish Facility, and OMR management. Components of operations and maintenance also include, for example, agricultural barriers, Rock Slough intake, water transfers, and aquatic weed removal. Enhanced real-time monitoring and predictive tools also are part of operation and maintenance of the proposed action. Operations and maintenance also includes operation of a raised Shasta Dam in accordance with the criteria in the proposed action.

Conservation measures are additional actions included to address the effects of the operations and maintenance on listed species. Conservation measures include spawning and rearing habitat, cold water pool management tools, Summer-Fall Delta Smelt Habitat, Suisun Marsh Salinity Control Gate operations, Small Screen Program, predator hot spot removal, Delta Fishes Conservation Hatchery, Delta Cross Channel, Tracy Fish Facility, Skinner Fish Facility, and Shasta TCD improvements.

In the figures, WOA is the without action scenario, PA is the proposed action scenario, and COS is the current operations scenario, as modeled in CalSim. The buffers around WOA and the PA represent uncertainty.

5.2 Analytical Approach – Species Analyses

The effects analyses evaluate potential effects to life stages (for example, egg, alevin, fry, juvenile, adult) of each species based on species-specific conceptual models. The effects section is arranged by species beginning with a brief summary of the relevant conceptual model, followed by consideration of the potential effects of the proposed action.

The sub-section for each proposed action component considers the exposure of each life stage to the component, largely based on species timing summaries included in the introduction to each species section and other sources cited in the text. Consideration of exposure focuses on the extent to which a component overlaps in time and location with the life stage. Potential effects of exposure to the proposed action component on individuals of the species are then analyzed. This analysis is generally qualitative, although the potential effects of flow-dependent actions are informed to the extent possible by modeling of the various operational scenarios, and is related to the conceptual model for the life stage transition being analyzed.

5.3 Analytical Approach – Critical Habitat Analyses

The analyses of potential effects on species' designated critical habitat follow the species analyses. Potential positive and negative effects to primary constituent elements (PCEs)/physical and biological features (PBFs) of critical habitat are analyzed for the relevant components of the proposed action. These analyses often draw on the foundation provided in the species analyses. Analysis of effects to critical habitat is guided by consideration of recent analyses by USFWS (2017a) and NMFS (2017), which included refined interpretation of critical habitat PCEs/PBFs relative to the original descriptions at the time critical habitat was designated.

5.4 Analytical Approach – Essential Fish Habitat Analyses

The analysis of EFH focuses on three species groups represented by fishery management plans (NMFS 2017): Pacific Coast Salmon, Coastal Pelagic Species, and Pacific Coast Groundfish. For Pacific Coast Salmon, the analysis is informed by the species and critical habitat analyses for listed salmon, and is augmented by analysis of potential effects to unlisted Central Valley Fall-run/Late Fall-run Chinook Salmon ESU, Upper Klamath-Trinity Rivers Fall-run Chinook Salmon ESU, and Upper Klamath-Trinity Rivers Spring-run Chinook Salmon ESU. The analysis of potential effects to Coastal Pelagic Species focuses on Northern Anchovy as it is the main representative of that group that could be affected by the proposed action. Similarly, the analysis of potential effects to Pacific Coast Groundfish focuses on Starry Flounder. Potential effects of the proposed action to designated Habitat Areas of Particular Concern (HAPC) are also considered, namely complex channels and floodplain habitats, thermal refugia, spawning habitat, estuaries, and marine and estuarine submerged aquatic vegetation (NMFS 2017, p.1210).

5.5 Without Action Scenario

Under WOA conditions Sacramento River water would flow through Shasta and Keswick reservoirs with gates and river valves open, resulting in minimal storage and no control of flow release volumes or water temperatures. Water would not be transferred from the Trinity River. Sacramento River flows under the WOA scenario would generally be lower in summer and fall and higher in the winter and spring than current conditions. Similar conditions would occur on the Feather, American, Stanislaus, and San Joaquin Rivers. Higher, flashier, Delta outflows would occur in the winter and spring with lower Delta outflows in the summer and fall than current conditions. Jones and Banks Pumping Plants in the Delta would not operate. Flows would rapidly pass through channelized pathways.

Higher WOA flows in winter and spring could have both positive and negative effects on salmonids. Benefits of higher flows include lower water temperatures, increased dissolved oxygen (DO), increased habitat complexity, more rearing habitat, more refuge habitat, increased availability of prey, less predation risk, less entrainment risk, lower potential for pathogens and disease, lower concentrations of toxic contaminants, and emigration cues. Impacts from higher flows including higher stranding risk because of greater flow fluctuations, and higher contaminants loading from stormwater runoff.

Reduced flows under WOA conditions during dry fall months would have impacts on spawning adults, eggs, and alevin, and on rearing juvenile salmonids, resulting in increased temperature-dependent mortality of eggs, reduced juveniles growth rate and higher mortality of the juveniles, and a reduced population abundance.

Impacts of low flows include (Windell et al. 2017):

- Higher water temperatures and lower DO
- Reduced habitat complexity
- Less side-channel rearing habitat
- Less floodplain habitat and less connectivity of floodplains with the river mainstem
- Less refuge habitat
- Reduced availability and quality of prey organisms
- Greater crowding and competition
- Greater predation risk
- Greater entrainment risk
- Greater potential for pathogens and diseases
- Higher concentrations of toxic contaminants
- Reduced emigration cues

Under the WOA conditions, storage levels would be low and, assuming stratification developed, cold water pools would be small and unmanaged. However, unlike flows, which as noted above are expected to be similar under WOA conditions to those of an uncontrolled hydrology, water temperatures may differ from those of an uncontrolled hydrology because the shallow reservoir that would remain behind dams would absorb significant heat during warm, sunny days.

5.6 Chinook Salmon, Sacramento River Winter-run ESU

In the proposed action, the effects of the seasonal operation, as compared to WOA, include lower, more stable, flows in the fall and winter for emergence, rearing, and migration; lower flows in the spring; and higher flows in the summer. Higher flows in the summer lead to improved temperatures for Winter-run spawning, egg incubation, and emergence. Operation of the Shasta Temperature Control Device (TCD) provides for Winter-run Chinook Salmon egg incubation water temperature needs. The restoration of spawning and rearing habitat in the Upper Sacramento River, operation of weirs to inundate floodplain rearing habitat in the Yolo Bypass, tidal habitat restoration, and predator hot spot removal further increases growth and survival of Winter-run Chinook Salmon. Delta Cross Channel operations and OMR management, as part of the Core Water Operation under the proposed action, seeks to minimize and/or avoid entrainment risk. Improvements at the Tracy Fish Collection Facility and Skinner Fish Facility as part of the conservation measures associated with the proposed action reduce facility loss, a direct adverse effect of facility entrainment.

Construction of Shasta and Keswick Dams blocked access to areas of suitable temperatures for egg incubation. Temperature dependent mortality plays an important role in egg incubation and emergence. Operation of Shasta Dam for cold water pool management is required to avoid the 100 percent temperature dependent egg mortality that would occur under the WOA scenario; however, Reclamation’s ability to meet temperature needs is limited to the available cold water in any given year. In addition, reservoir releases can affect temperature only so far downstream in the Sacramento River before ambient air temperature controls. The proposed action provides for considering the primary location of Winter-run Chinook Salmon redds in most years (above the Clear Creek confluence), the critical stages within egg incubation for cold water, building cold water for the water temperature management season, and avoiding exhausting the supply of cold water before the end of the water temperature management season. The approach provides for operable parameters that incorporate the limitations on managing cold water in light of hydrologic uncertainty, balancing risks, and management experience during the most recent drought. The proposed action increases Winter-run Chinook Salmon egg to fry survival more reliably compared to the COS while minimizing restrictions on meeting project obligations to water supply, water quality, and other species.

Bank protection, dams, and lower peak flows prevents the natural replenishment and maintenance of suitable spawning habitat. Gravel augmentation and the restoration of spawning habitat under the proposed action addresses the lack of sediment continuity with dams in the degraded baseline. Flood protection reduced the historical off-channel rearing habitat of Winter-run Chinook Salmon to the limited channel areas between levees. Lower fall and winter flow reduces the inundation of potential rearing habitat for Winter-run Chinook Salmon; therefore, the proposed action restores rearing habitat in areas inundated by proposed action flows to reduce the effects from the Core Water Operation.

Real-time monitoring informs when Winter-run Chinook Salmon are likely to pass the Delta Cross Channel and provides for closures to prevent entrainment into the central and south Delta. OMR management for Winter-run Chinook Salmon establishes generally protective criteria to avoid entrainment. Additional protective measures occur based on salvage. Enhanced monitoring in real-time and predictive tools provide additional information that allows for a more flexible water operation under the proposed action when environmental criteria indicate that entrainment is less likely based on fish behavior and the effects of behavioral cues. Operation of the salvage facilities reduces the effects of entrainment due to export operations. Improvements at fish collection facilities will further reduce impacts of the proposed action as compared to WOA

Other stressors continue to impact Winter-run Chinook Salmon including harvest, contaminants, invasive species, disease, climate change. These factors will continue to reduce the ability of Winter-run Chinook Salmon to reproduce and rebuild populations in the river. Continued operation of the Livingston-Stone National Fish Hatchery provides a buffer against external risks and protects against extinction.

5.6.1 Life Stage Timing

General life stage timing and location information for Winter-run Chinook Salmon is provided in Table 5.6-1 to identify where the proposed action overlaps with the species. Additional detail regarding juvenile life stage timing at various monitoring locations is provided in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*.

Table 5.6-1. The Temporal Occurrence of Adult (a) and Juvenile (b) Winter-run Chinook Salmon in the Sacramento River and Delta (NMFS 2017, p.67).

Relative Abundance	High				Medium				Low			
a) Adults freshwater												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River basin[a,b]	Medium	Medium	Medium	Medium	Medium	Medium	Medium				Medium	Medium
Upper Sacramento River spawning[c]					Low	High	High	Medium				
Delta	Medium	Medium	Medium	Medium	Low	Low	Low					Medium
b) Juvenile emigration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Sacramento River at Red Bluff[d]	Low	Low	Low				Low	Medium	Medium	Medium	Medium	Medium
Sacramento River at Knights Landing[e]	High	Medium	Low							Low	Medium	High
Sacramento trawl at Sherwood Harbor[f]	Medium	High	High	Low							Medium	High
Midwater trawl at Chipps Island[g]	Medium	Medium	High	High	Low							Low

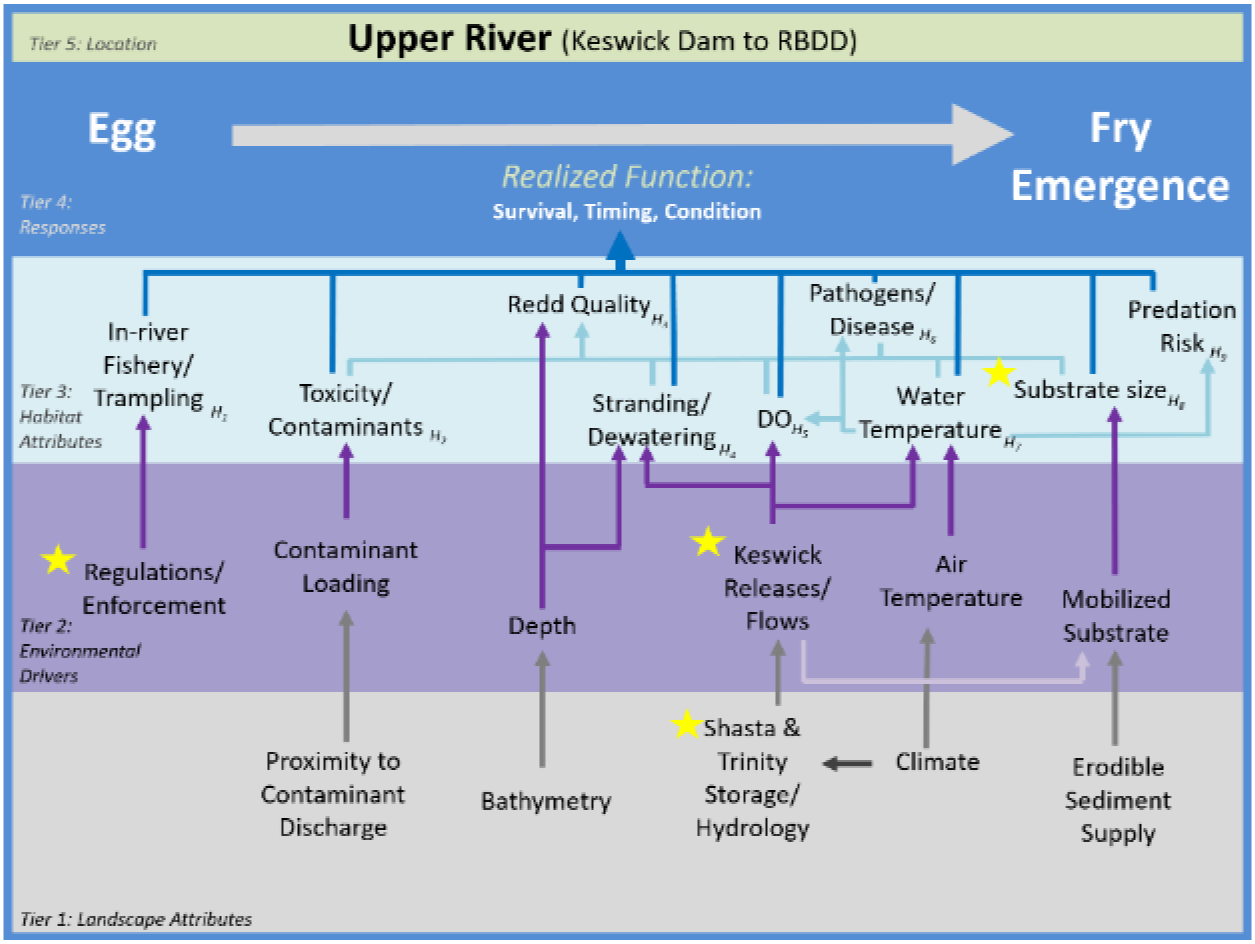
Sources: [a] (Yoshiyama et al. 1998); (Moyle 2002); [b](Myers et al. 1998) ; [c] (Williams 2006) ; [d] (Martin et al. 2001); [e] Knights Landing Rotary Screw Trap Data, CDFW (1999-2011); [f,g] Delta Juvenile Fish Monitoring Program, USFWS (1995-2012)

Note, it is likely that juvenile emigration in the Sacramento trawl at Sherwood Harbor is also high in January, as it is in December and February.

5.6.2 Conceptual Model Linkages

The Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) conceptual models describe life stage transitions of Winter-run Chinook Salmon. SAIL life stage transitions include egg and alevin mortality, egg to fry emergence, juvenile rearing to outmigrating, adult migration, and adult holding.

In the upper Sacramento River (Keswick Dam to Red Bluff Diversion Dam), the SAIL conceptual model defines the egg incubation and alevin development stage as the duration of eggs in a redd to the emergence of fry (Windell et al. 2017). The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-1.

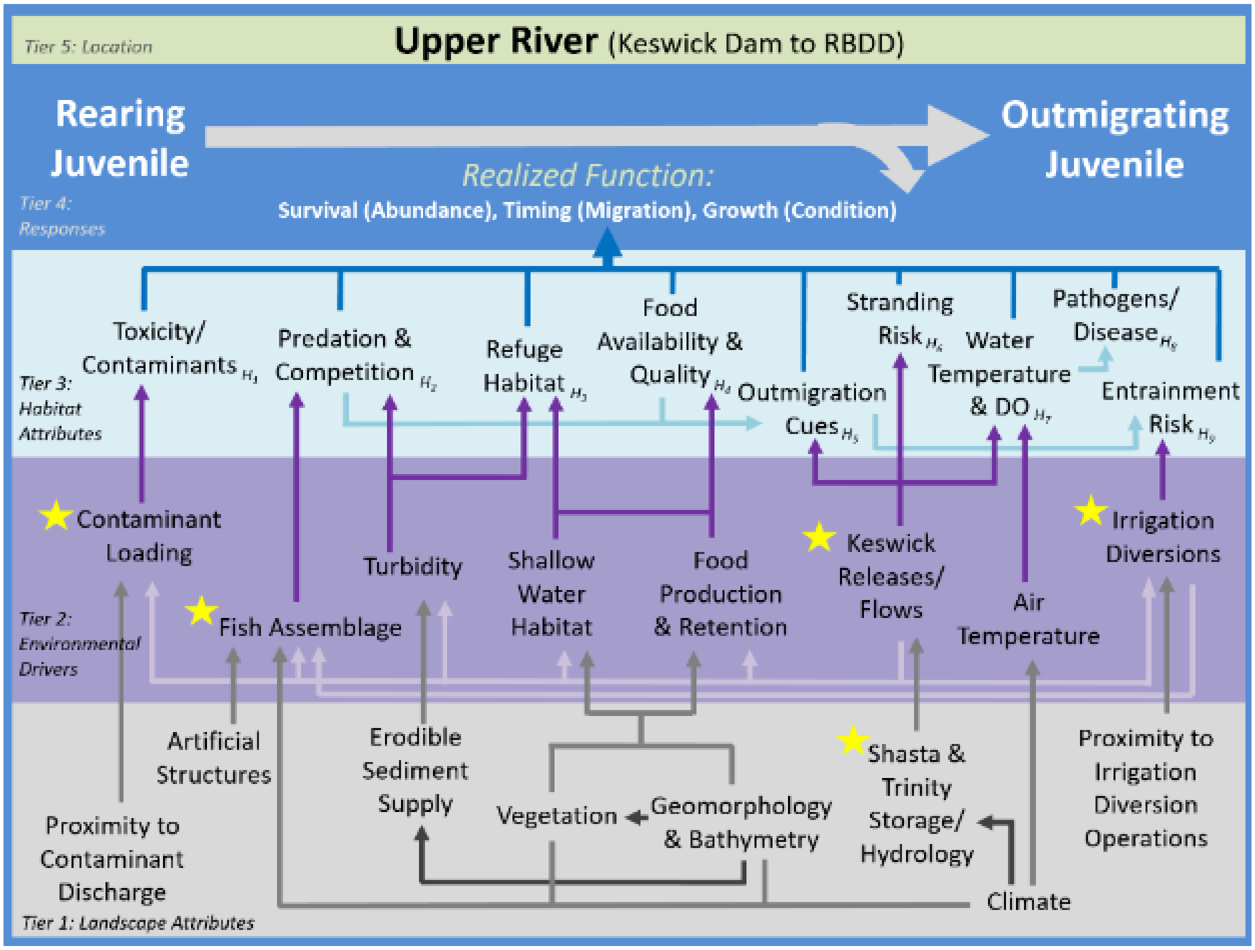


Source: Windell et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes and potential management actions discussed by Windell et al. (2017) are denoted by stars.

Figure 5.6-1. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon from Egg to Emerging Fry in the Upper Sacramento River.

As compared to WOA, egg to fry attributes relevant to the proposed action include bathymetry and redd quality (modified by habitat restoration), and the effects of Keswick releases on redd dewatering, temperature and DO (cold water pool management). Effects in the baseline include trampling, contaminants, habitat degradation, disease, air temperatures, water temperatures, and predation.

In the upper Sacramento River (Keswick Dam to Red Bluff Diversion Dam), the SAIL conceptual model defines juvenile rearing and out migration as the duration from emergence as fry to down river migration (Windell et al. 2017). The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-2.

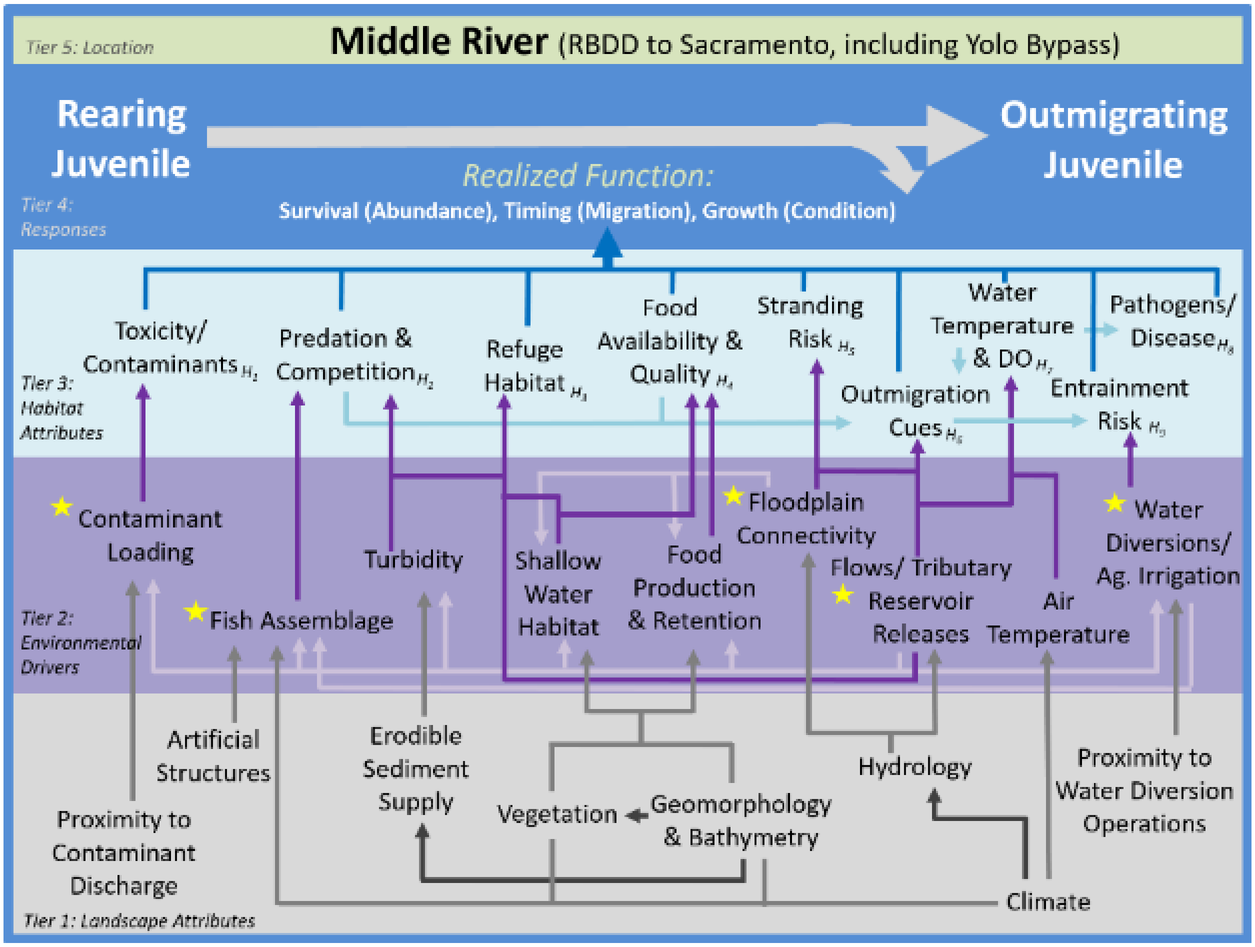


Source: Windell et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes and potential management actions discussed by Windell et al. (2017) are denoted by stars.

Figure 5.6-2. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon from Rearing Juvenile to Outmigrating Juvenile in the Upper Sacramento River.

Upper Sacramento River rearing to outmigrating juvenile attributes relevant to the proposed action include dilution (e.g., toxicity and contaminants), water temperatures (which also affect DO, food availability, predation, pathogens, and disease), river stage and flow velocity (which affect habitat connectivity, bioenergetics, food availability, and predation), entrainment and stranding risk, and potentially affects cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

Juvenile rearing and migration in the middle Sacramento River from Red Bluff Diversion Dam to the I Street Bridge and the hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-3.

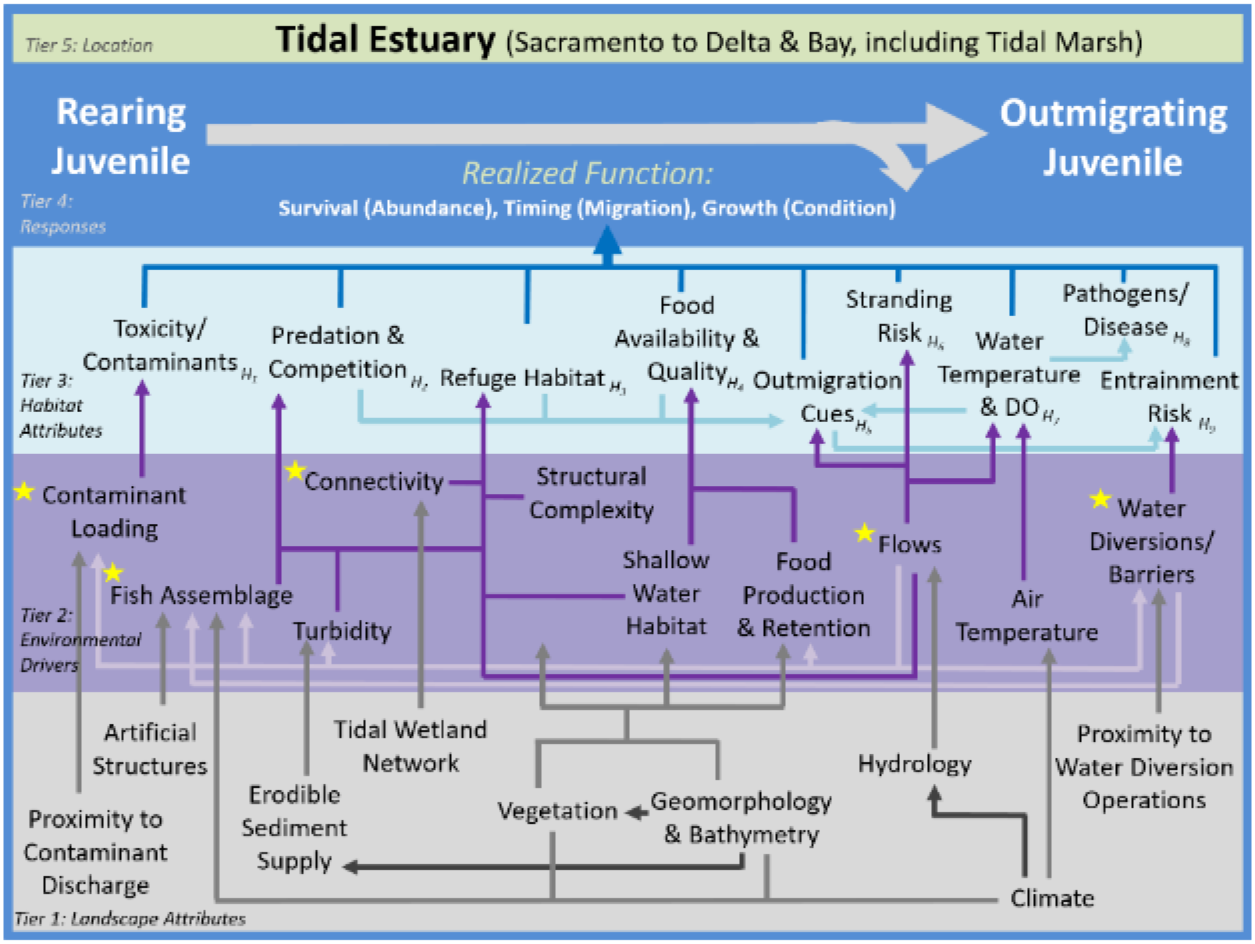


Source: Windell et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes and potential management actions discussed by Windell et al. (2017) are denoted by stars.

Figure 5.6-3. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon from Rearing Juvenile to Outmigrating Juvenile in the Middle Sacramento River.

Middle Sacramento River rearing to outmigrating juvenile attributes relevant to the proposed action include: dilution (e.g., toxicity and contaminants), water temperatures (which also affect DO, food availability, predation, pathogens, and disease), river stage and flow velocity (which affect habitat connectivity, bioenergetics, food availability, and predation), entrainment and stranding risk, and potentially affects cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

Juvenile rearing and migration in the tidal estuary and bays life stage transition includes tidal Sacramento River downstream of the I Street Bridge in Sacramento City, the Sacramento-San Joaquin Delta, and the Suisun, San Pablo and San Francisco Bays. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-4.



Source: Windell et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes and potential management actions discussed by Windell et al. (2017) are denoted by stars

Figure 5.6-4. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon from Rearing Juvenile to Outmigrating Juvenile in the Bay-Delta.

Tidal estuary and bay juvenile rearing and migration attributes relevant the proposed action include outmigration cues and entrainment risk.

The adult migration from the ocean to the upper Sacramento River life stage includes the entire Bay-Delta and Sacramento River system. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-5.

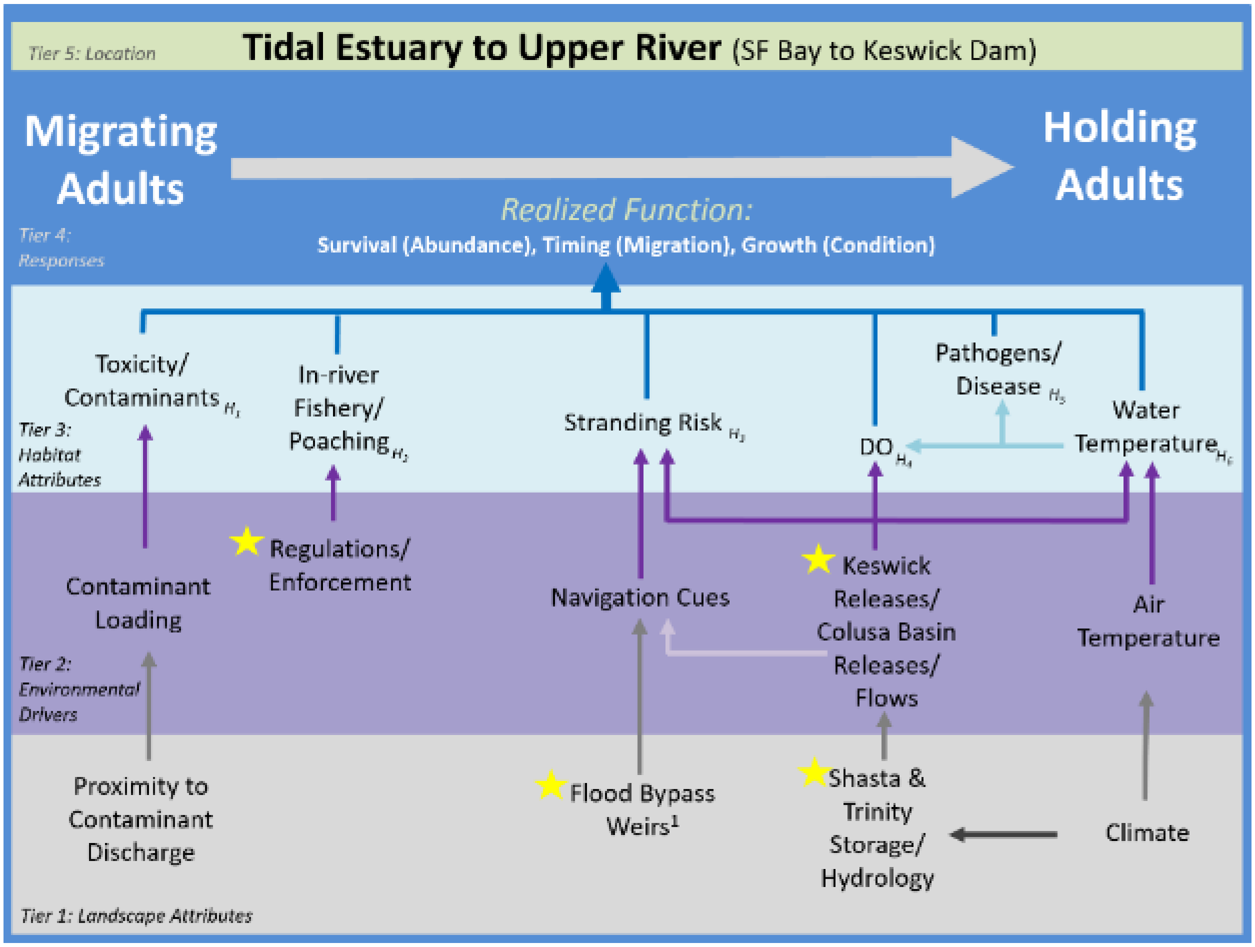


Figure 5.6-5. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon from Migrating Adults in the Bay-Delta to Holding Adults in the Upper Sacramento River.

Continuing their upstream migration from the Delta, Winter-run Chinook Salmon adults enter the middle Sacramento River and ultimately make their way to the upper River, beginning as early as December, where they hold within 10 to 15 miles of Keswick Dam until they are ready to spawn (Windell et al. 2017). Adult migration attributes relevant to the proposed action include, as indicated by the SAIL conceptual model (Figure 5.6-5), water temperature, DO, and other habitat attributes that influence the timing, condition, and survival of adult Winter-run Chinook Salmon during their upstream migration and holding in the middle and upper Sacramento River. Instream flow from Keswick Dam releases relative to flow from the lower Yolo and Sutter bypasses and agricultural drains may affect navigation cues and straying of Winter-run Chinook Salmon adults into canals and behind weirs, increasing their stranding risk (Figure 5.6-5).

The adult holding to spawning life stage in the upper Sacramento River includes Keswick Dam to the Red Bluff Diversion Dam. It also includes selecting sites for and building spawning redds. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.6-6.

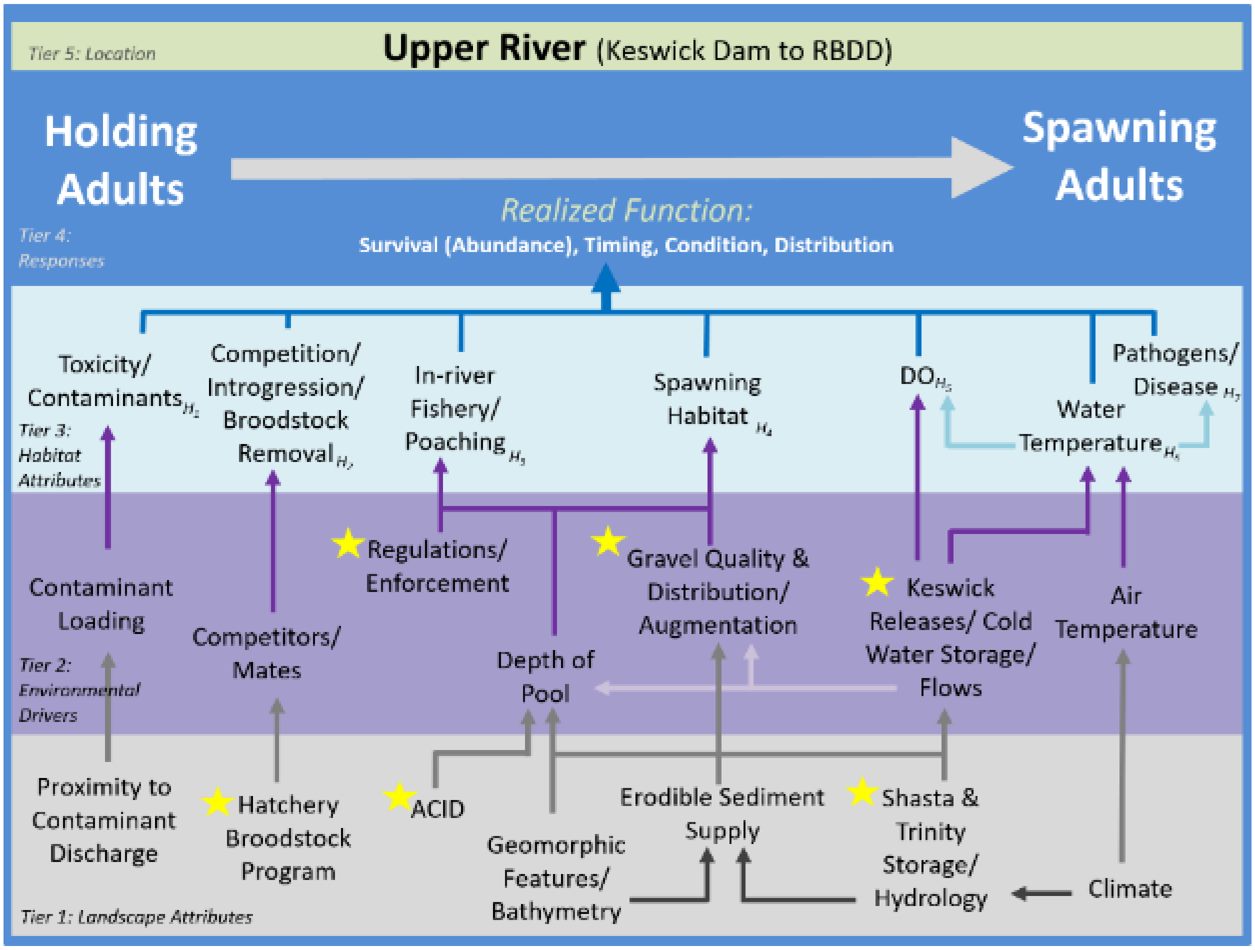


Figure 5.6-6. Conceptual Model of Drivers Affecting the Transition of Winter-run Chinook Salmon Adults from Holding to Spawning in the Upper Sacramento River.

Adult holding attributes relevant to the proposed action include primarily water temperature and DO.

The SAIL conceptual models describe the attributes affecting different life stage transitions. In the following subsections, attributes from the proposed action affecting Winter-run Chinook Salmon are discussed. These include releases from Keswick Dam and the resulting flows in the upper Sacramento River, combined with other environmental drivers, affect water temperature, DO, and other habitat attributes that influence the timing, condition and survival of eggs and alevins in the spawning redds.

5.6.3 Effects of Operations & Maintenance

Water temperatures in the upper Sacramento River during summer and fall are closely tied to flow because both are determined by operations and storage releases at Shasta and Keswick dams and transfers from the Trinity River. Under WOA conditions, there would be no Shasta and Keswick reservoir operations to control storage or releases, no transfer of water from the Trinity River Basin, and no control of flow or water temperature in the upper Sacramento River. Shasta storage levels would be reduced (Figure 5.6-7) and, assuming stratification developed, the cold water pool would be small and unmanaged. Further, the shallow reservoir that would remain behind Shasta Dam would absorb significant heat during warm, sunny days.

In the upper Sacramento River, where all Winter-run Chinook Salmon spawning occurs, modeling results showed WOA monthly mean water temperatures (HEC-5Q WOA scenario) during most of May through November spawning and incubation period would be high, ranging from ~46 degrees Fahrenheit in November, to 73 degrees Fahrenheit in July. During the peak spawning and incubation period, June through September, water temperatures would consistently exceed both the 56 degrees Fahrenheit and 53.5 degrees Fahrenheit water temperature thresholds (Figures 5-15 through 5-18 in the HEC5Q Temperatures section of Appendix D). Such conditions would make survival of incubating eggs and alevins impossible, eliminating the Winter-run Chinook Salmon population from the Sacramento River and reducing the extent of the ESU to a single population in Battle Creek.

Monthly mean water temperatures at Keswick would be high during the July through September period, ranging from ~63 degrees Fahrenheit during September to 72 degrees Fahrenheit during July and August, thereby exceeding the 61 degrees Fahrenheit water temperature thresholds in all years (Figures 5-16 through 5-18 in the HEC5Q Temperatures section of Appendix D). Water temperatures during these months would be even higher at other locations in the upper Sacramento River, ranging as high as 79 degrees Fahrenheit at Red Bluff Diversion Dam during July (Figure 10-16 in the HEC5Q Temperatures section of Appendix D). By October, the mean monthly water temperatures under the WOA scenario would be lower, remaining at or below the 61 degrees Fahrenheit in all years (Figure 5-7 in the HEC5Q Temperatures section of Appendix D). The water temperatures would remain below 61 degrees Fahrenheit from November through March (Figures 5-8, 5-10, 5-11, and 5-12 in the HEC5Q Temperatures section of Appendix D), by which time few Winter-run Chinook Salmon juveniles remain in the upper Sacramento River. The warm conditions in the upper Sacramento River during July through September would likely make survival of juvenile Winter-run Chinook Salmon impossible in the Sacramento River. Under the WOA, Winter-run Chinook Salmon could persist as a single population in Battle Creek (Phillis et al. 2018).

The low fall flows under WOA conditions would likely result in reduced conditions in juvenile Winter-run Chinook Salmon rearing habitats in the Sacramento River. During October and November, in years with dry hydrology, the flows would often fall below 3,250 cfs Keswick release for October through March as well as the target of 5,000 cfs at Wilkins Slough (note that the 3,250 cfs minimum flow is not required below the Red Bluff Diversion Dam (SWRCB 1990). As described by Windell et al. (2017), potential negative effects of the low flows include higher water temperatures and lower DO, reduced habitat complexity, less side-channel rearing habitat, less floodplain habitat and less connectivity of floodplains with the river mainstem, less refuge habitat, reduced availability and quality of prey organisms, greater crowding and competition, greater predation risk, greater entrainment risk, greater potential for pathogens and diseases, higher concentrations of toxic contaminants, and reduced emigration cues.

CalSim modeling indicates that from December through March, the first part of the period during which Winter-run Chinook Salmon adults migrate upstream through the middle Sacramento River to holding habitat in the upper River, there are low flows at Wilkins Slough and Keswick that would be low enough to create potential passage problems for immigrating adults. The most severe conditions would be at Wilkins Slough in May, when over 30 percent of years would have flows lower than the 5,000 cfs minimum flow requirement (NCWA 2014). These conditions would create poor passage conditions for adult Winter-run Chinook Salmon migrating upstream, possibly resulting in a reduction in spawning and recruitment of the new year-class.

Under WOA, upper Sacramento River flows modeled by CalSim for the December through August holding period are low in December, except in wet years, high during January through May, except in dry years, low in June, except in wet years, and low in almost every year during July and August (Figures 15-

9 through 15-17 in the CalSim II Flows section of Appendix D). In general, higher flows are likely to benefit holding adult Winter-run Chinook Salmon by affording better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, and lower risk from anglers (Windell et al. 2017). The low flows in July and August would likely be stressful to holding adults and reduce suitable areas for redd construction.

From December through April, mean water temperatures under the WOA scenario are consistently below the 61 degrees Fahrenheit threshold for holding adults and mostly below this threshold in May (Figures 5-9 through 5-14 in the HEC5Q Temperatures section of Appendix D). During June through August, however, the water temperatures are almost entirely above the threshold (Figures 5-15 through 5-17 in the HEC5Q Temperatures section of Appendix D). The water temperatures reach as high as 72 degrees Fahrenheit in July and August.

The critical temperature threshold for spawning adults are the same as those discussed previously for incubating eggs and alevins (i.e., 56 degrees Fahrenheit and 53.5 degrees Fahrenheit). These thresholds would be exceeded under the WOA scenario in almost all years from May through August, but would be exceeded only occasionally during December through April (Figures 5-9 through 5-17 in the HEC5Q Temperatures section of Appendix D). Water temperatures under the WOA scenario would be poorly suited for holding or spawning Winter-run Chinook Salmon adults during the summer months.

The COS provides context and analytical support for the potential positive and negative effects of the proposed action. Reservoir operations work with a limited resource to balance the current needs of the fish populations, cold water storage for the following year, and sufficient space for flood control in the winter and spring. During the first part of the juvenile rearing period, July through September, operations are largely dictated by needs of incubating Winter-run Chinook Salmon eggs and larvae. After September, current operations target several requirements, including stable river flows to minimize dewatering of Winter-run Chinook Salmon redds and stranding of juveniles, suitable flow and temperature conditions for Spring-run and Fall-run Chinook Salmon spawning, incubation and rearing, and conserving storage for the next year’s cold-water pool. The minimum flow requirement for the upper Sacramento River from October 1 until April 1 is 3,250 cfs from State Water Resources Control Board Water Rights Order 90-5. Delta operation under the COS seeks to support exports while minimizing and/or avoiding entrainment of listed species. Fall X2 conditions for Delta smelt are also considered under the COS (USFWS 2008).

5.6.3.1 Upper Sacramento River Seasonal Operations including Shasta Cold Water Pool Management

Under WOA conditions, there would be no Shasta and Keswick reservoir operations to control storage or releases, and no transfer of water from the Trinity River Basin. Therefore, there would be no control of flow or water temperature in the upper Sacramento River, where Winter-run Chinook Salmon spawn. Reservoir gates and river valves would be kept open, resulting in minimal storage (Figure 5.6-7). The similarity to uncontrolled flows is reflected in seasonal flows under the WOA scenario in the Sacramento River at Keswick, with low summer and fall flows and high winter and spring flows (Figures 5-7 through 5-18 in the CalSim II Flows section of Appendix D). Other locations in the Sacramento River show similar seasonal flow patterns (Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D).

Under the proposed action, flows in the upper Sacramento River result from controlled releases from Shasta and Keswick reservoirs, as well as transfers from the Trinity River. These 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, including Winter-run Chinook Salmon.

The primary difference between proposed action and current operations modeling for the Sacramento River upstream of the Delta is in operations of Shasta and Keswick reservoirs for cold water pool management and the COS requirement for Fall X2.

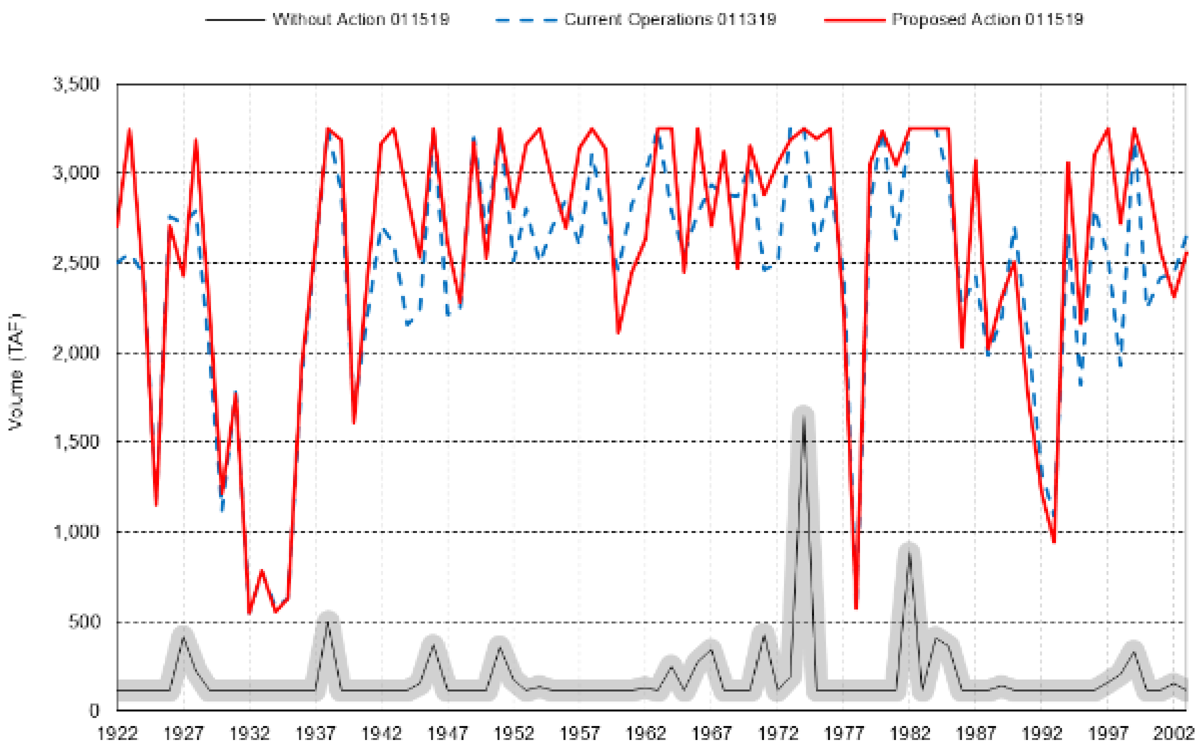


Figure 5.6-7. ShastaStorage. CalSim II Estimates of Mean Shasta Storage, 1923-2002.

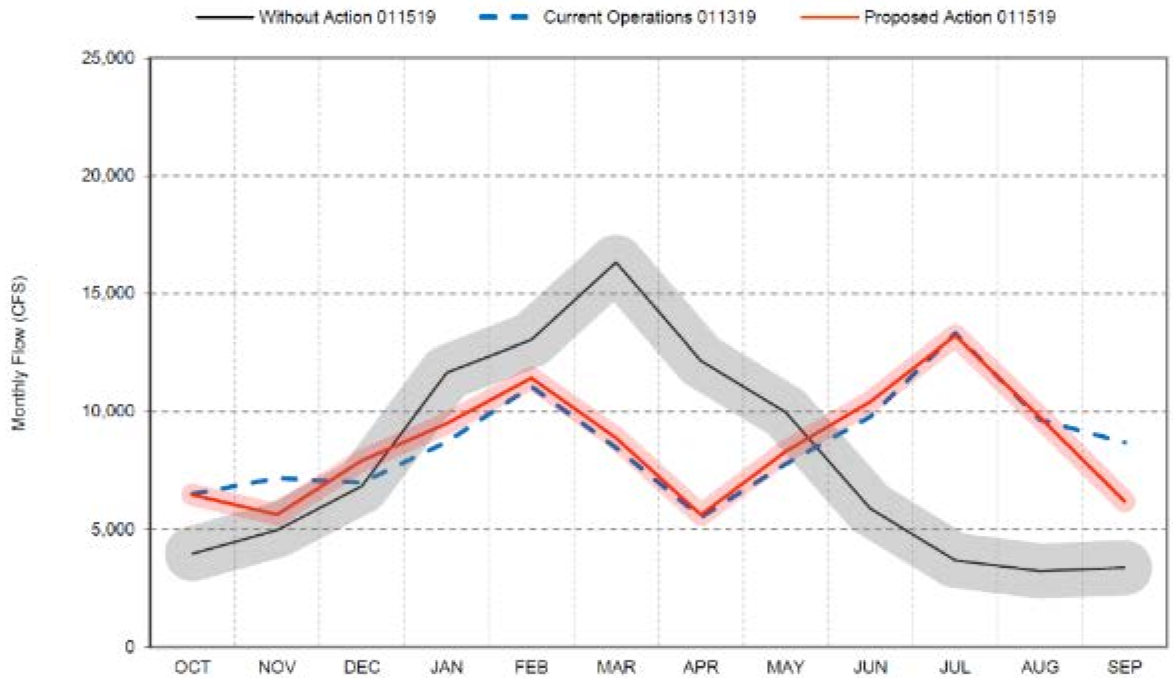


Figure 5.6-8. Calsim II Sacramento River Flow downstream of Keswick Reservoir, Long-term Average

The CalSim modeling shows large seasonal changes in the differences in upper Sacramento River flow between the WOA scenario and the proposed action. In July through October, the WOA flows are consistently well below those of the proposed action (Figures 15-16 through 15-18 and 15-7, and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D). By November there is little difference between the WOA and proposed action scenarios, except in years with the highest flows. In January, the WOA flows are higher than the proposed action at most flow levels (Figure 15-10 in the CalSim II Flows section of Appendix D) and in March the WOA flows are consistently higher than the proposed action flows (Figure 15-12 in the CalSim II Flows section of Appendix D). These seasonal changes result primarily from Shasta Reservoir storage releases under the proposed action during June through September, when uncontrolled flows are low, and diversions to Shasta Reservoir storage under the proposed action during winter and spring, when uncontrolled flows are high. Diversion to storage is higher in spring than in winter because the flood control pool in the reservoir can be reduced during spring as flood risk declines.

The differences in flows between the WOA scenario and the proposed action and COS scenarios would likely have very large effects on Winter-run Chinook Salmon juveniles and their habitats. The lower summer and fall flows under the WOA scenario would likely result in reduced conditions in juvenile rearing habitats, including less habitat complexity, side channel habitat structure, refuge habitat, and greater disease potential (Windell et al. 2017). As noted previously, the higher WOA flows in winter and spring could have both positive and negative effects on rearing juvenile Winter-run Chinook Salmon. Benefits include increased floodplain and side-channel habitat, better feeding conditions, reduced competition and predation; decreased water temperatures and increased DO; and enhanced emigration flows. Negative impacts include increased stranding risk (due to greater flow fluctuations), and increased contaminant loading from stormwater runoff. Although conditions may be suboptimal for juvenile Winter-run Chinook Salmon, the impacts of increased summer and fall flows under the proposed action and COS would be beneficial compared to the WOA. During summer and fall juvenile Winter-run

Chinook Salmon are less robust due to young age and are more sensitive to stressful conditions than other times of the year (NMFS 2009). Therefore, juveniles would be less susceptible to reduced winter and spring flows under the proposed action and COS as compared to the WOA.

CalSim modeling indicates that upper Sacramento River flows during the period of juvenile rearing in the upper Sacramento River are generally similar between the proposed action and COS (Figures 15-7 through 15-12 and 15-16 through 15-18, and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D), except for higher flows during September under the COS scenario in the upper range of flows (Figure 15-18 in the CalSim II Flows section of Appendix D). The COS flows are also higher than the proposed action flows during November (Figure 15-8 and Table 15-3 in the CalSim II Flows section of Appendix D) where Reclamation proposes to rebuild storage and cold water pool for the subsequent year.

Flow under the COS and proposed action scenario are consistently well above the WOA flow in all months of the primary spawning and incubation period, especially in dry years (Figures 15-15 through 15-18 in the CalSim II Flows section of Appendix D). Therefore, all potential adverse effects of low flows on Winter-run Chinook Salmon spawning and incubation listed above are expected to be much less severe under the proposed action or COS than under the WOA.

The low summer and fall flows under the WOA conditions would likely result in reduced conditions for spawning and incubation of Winter-run Chinook Salmon in the upper Sacramento River (Figures 15-7 through 15-9 and 15-15 through 15-18, and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D). The WOA flows range from 772 cfs in August to about 63,000 cfs in March. During dry years, the flows would often fall below the proposed action flow for October through March of 3,250 cfs.

In the uppermost section of the Sacramento River, where most Winter-run Chinook Salmon spawning occurs, flows the WOA scenario during the May through November spawning and incubation period, are generally low (Figures 15-16 through 15-18 in the CalSim II Flows section of Appendix D). Reduced flows under WOA conditions during the driest summer and fall months would have significant negative effects on rearing habitat of Winter-run Chinook Salmon juveniles. Water temperatures would be too high to successfully reproduce; hence, no juvenile Winter-run Chinook Salmon would be present under WOA.

The higher WOA flows in winter and spring could have both positive and negative effects on rearing juvenile Winter-run Chinook Salmon. The impacts of low flows listed above are generally ameliorated by higher flows, but there can be adverse effects including higher stranding risk because of increased use of flood plains combined with greater flow fluctuations, and higher contaminants loading from stormwater runoff.

The USEPA (2003) defines 61 degrees Fahrenheit as the critical seven-day average daily maximum (7DADM) water temperature for Chinook Salmon juveniles. While this source is commonly cited and used to identify general temperature thresholds for most species and life-stages in this document, it is based on data from fish in the Pacific Northwest and based on different thermal regimes with smoother average temperatures. In addition to the lack of local relevance, 7DADM has operational challenges as a compliance metric, including the fact that it will create a lag in the data (Figure 5.6-9 below). The 2017 Long-term Operations Biological Opinions (LOBO) Biennial Science Review (Gore, 2018) stated that for datasets that are not centered on the mean, the moving average will create a lag in the data that can bias the average by the previous data point, and that alternate averaging approaches should be considered in addition to 7DADM, such as a weighted moving average. Gore et al state that, “The proposed 7DADM significantly lags the observed data. However, both a 3-day and 4-day average daily maximum both follow the sharp rise in observed temperature with less lag at the temperature peak." Reclamation will continue to use this reference as a general characterization of the temperature tolerance of lifestages and species in this document, with the understanding that it is inappropriate to use as a compliance metric and that local temperature tolerance studies would be preferred, when completed.

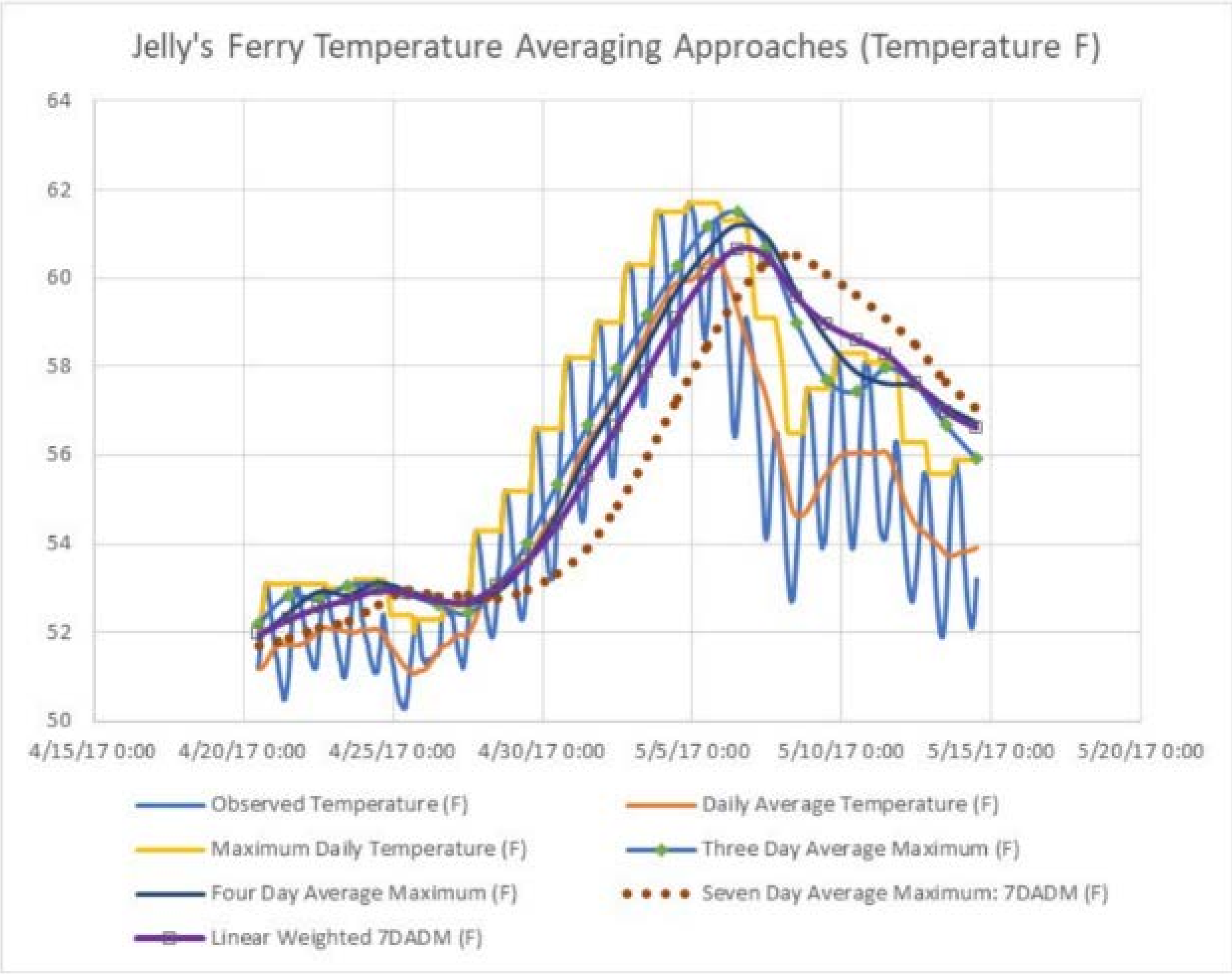


Figure 5.6-9. Comparison of Averaging Approaches that could be used to Specify Temperature at Jelly's Ferry (reproduced from the 2017 LOBO review report, Gore 2018)

The USEPA (2003) defines 64 degrees Fahrenheit as the critical 7DADM water temperature for Chinook Salmon juveniles rearing, based on Pacific Northwest fish and not considering operational limitations of 7DADM. In the middle Sacramento River below the Colusa Basin Drain, which is close to Knights Landing, the WOA scenario monthly mean water temperatures would be high during October, ranging up to 73 degrees Fahrenheit and exceeding the 64 degrees Fahrenheit threshold in about 80 percent of years (Figure 5-7 in the HEC5Q Temperatures section of Appendix D). The water temperatures would remain well below 64 degrees Fahrenheit from November through March (Figures 5-9 through 5-12 in the HEC5Q Temperatures section of Appendix D), by which time most Winter-run Chinook Salmon juveniles have migrated into the Delta.

5.6.3.1.1 Egg to Fry Emergence

Windell et al. (2017) links egg to fry survival with releases from Keswick and water temperatures. Critical water temperatures thresholds for Winter-run Chinook Salmon vary by life stage, with eggs and alevins the most sensitive to elevated temperatures. Under the WOA, there is no temperature management. The presence of a large cold water pool and the flexibility afforded by the TCD make possible the provision of much colder water under COS and the proposed action in the upper Sacramento River during the May through November spawning and incubation period than would be possible under the WOA. Under the proposed action, the river's temperatures are controlled by selective withdrawal through the TCD at Shasta Reservoir and by balancing releases between Lewiston (Trinity River) and Shasta reservoirs.

Operation of the Shasta TCD provides for cold water to maintain egg incubation and avoid temperature dependent mortality. The availability of cold water depends upon reservoir stratification and is not known until April; however, the amount of water in storage provides an indicator. Under the WOA scenario, no storage results in little cold water. Under the proposed action improvements in storage improve the ability to manage cold water for Winter-run Chinook Salmon incubation. Figure 5.6-10 shows the modeled temperature management tiers and operational parameters that influence the tiers, based on storage, for the last 19 years of the CalSim period of record. Figure 5.6-11 shows the same figure for the full 1922-2003 CalSim period of record.

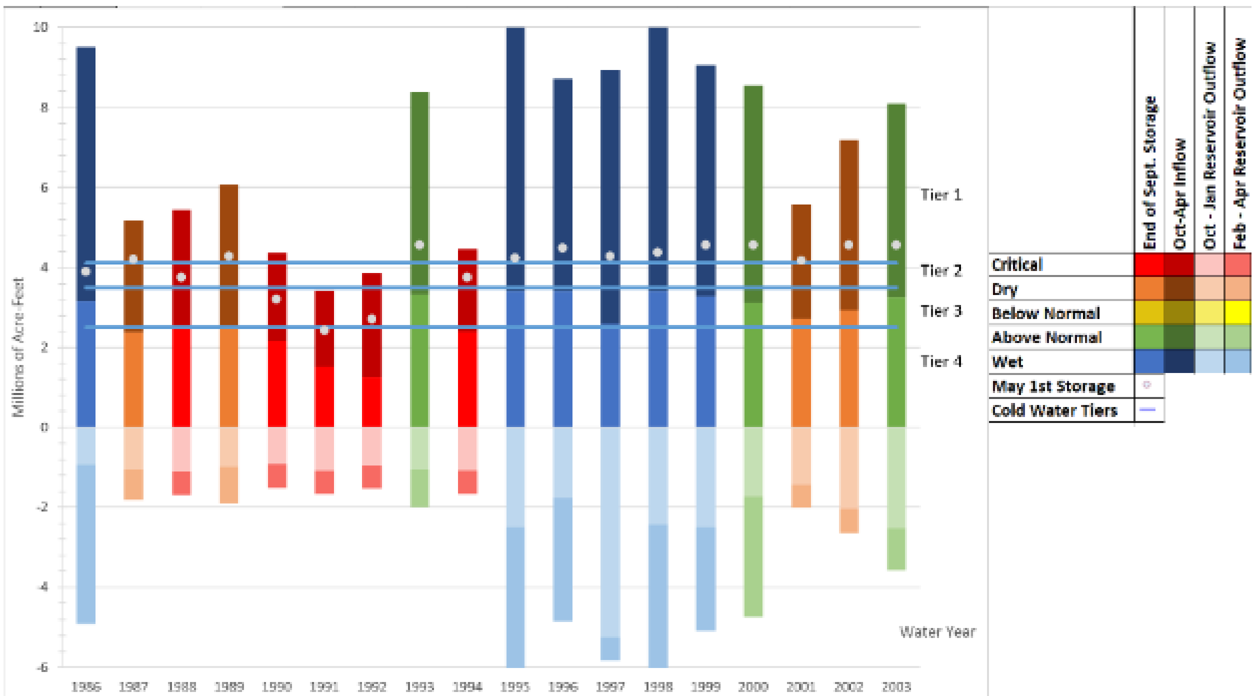


Figure 5.6-10. CalSim Prior Storage, Inflow, and Releases for May 1 Cold Water Capabilities (1986-2003 for ease of visualization)

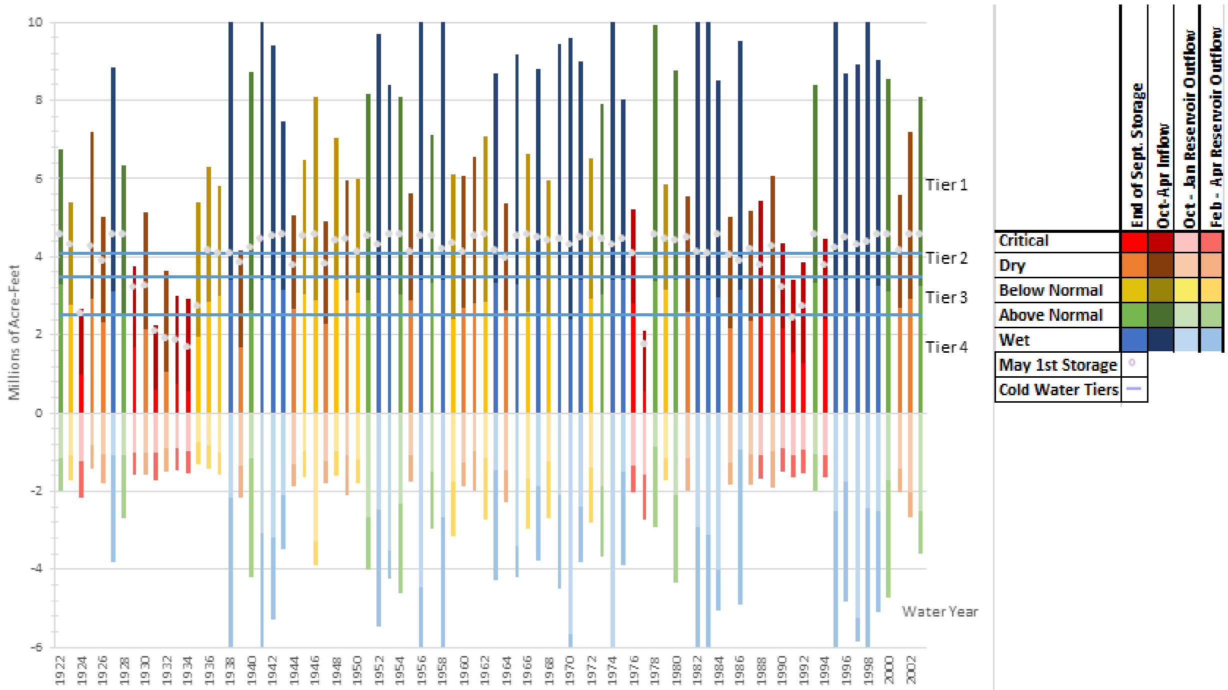


Figure 5.6-11. CalSim Prior Storage, Inflow, and Releases for May 1 Cold Water Capabilities (1922-2003)

CalSim modeling over the 1922-2003 period of record indicates Reclamation is in Tier 1 over 69 percent of the time and in Tier 4 less than 8 percent of the time (Tier 2 in 17% of the years, and Tier 3 in 7% of the years). End of September storage has little influence on the subsequent tier as releases for flood management and other purposes (e.g. dewatering) erode the storage. Actions to rebuild storage when storage is known to be low can shift operations into a higher tier, to some degree; however, the cold water resource depends primarily on inflow.

Although it does not include the altered water operations, historical data provides information to infer how operations may change under the proposed action. Figure 5.6-12 shows recent history (since 2001) that is largely not simulated within Calsim.

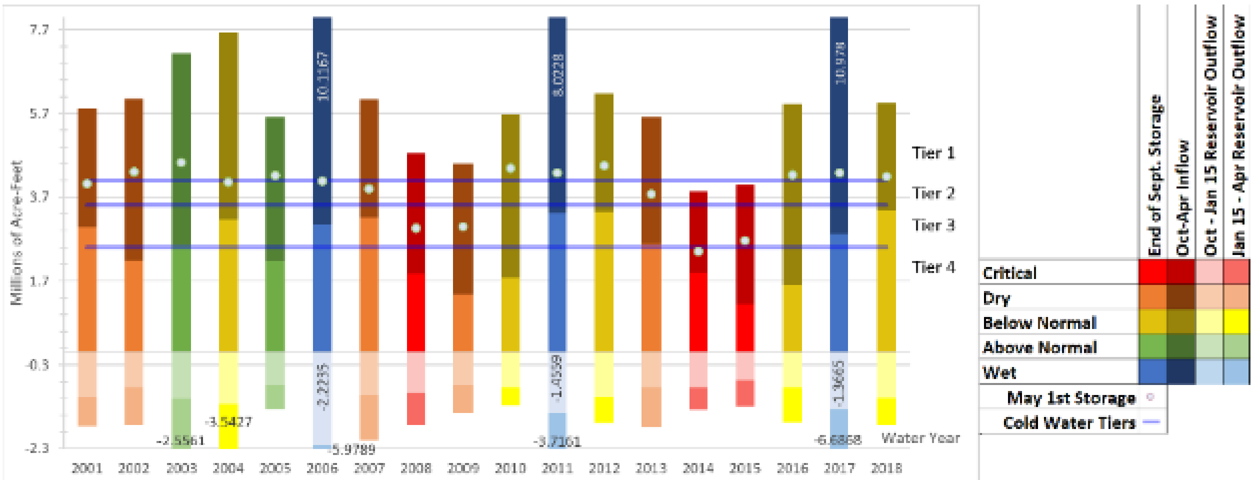


Figure 5.6-12. Historical Prior Storage, Inflow, and Releases for May 1 Cold Water Capabilities

Reviewing the end of September storages shows little ability to modify the tier in the subsequent year. Reviewing the releases (shown as negative on the Y-axis) indicates that lower releases in the fall of 2013 could have improved conditions for 2014.

The main difference in flow and water temperature management between the proposed action and COS during the June through September Winter-run Chinook Salmon spawning and incubation period would be in how the TCD would be operated to preserve sufficient cold water pool and what water temperature thresholds would be used.

Under the proposed action as modeled in the HEC-5Q temperature model, mean monthly water temperatures at Clear Creek during May through November range from roughly 48 degrees Fahrenheit in May to 67 degrees Fahrenheit in September (Figures 5.6-13 through 5.6-20).

The proposed action incorporates new water temperature management measures based on water temperatures that include a water temperature target of 53.5 degrees Fahrenheit in the Sacramento River above the Clear Creek confluence (CCR). CCR is a surrogate for the downstream-most redd. Some redds occur downstream of clear creek, however the 53.5 F target is below the 56 F threshold and cold water will propagate further downstream. Targeting CCR avoids the need to use additional cold water over areas where few redds occur.

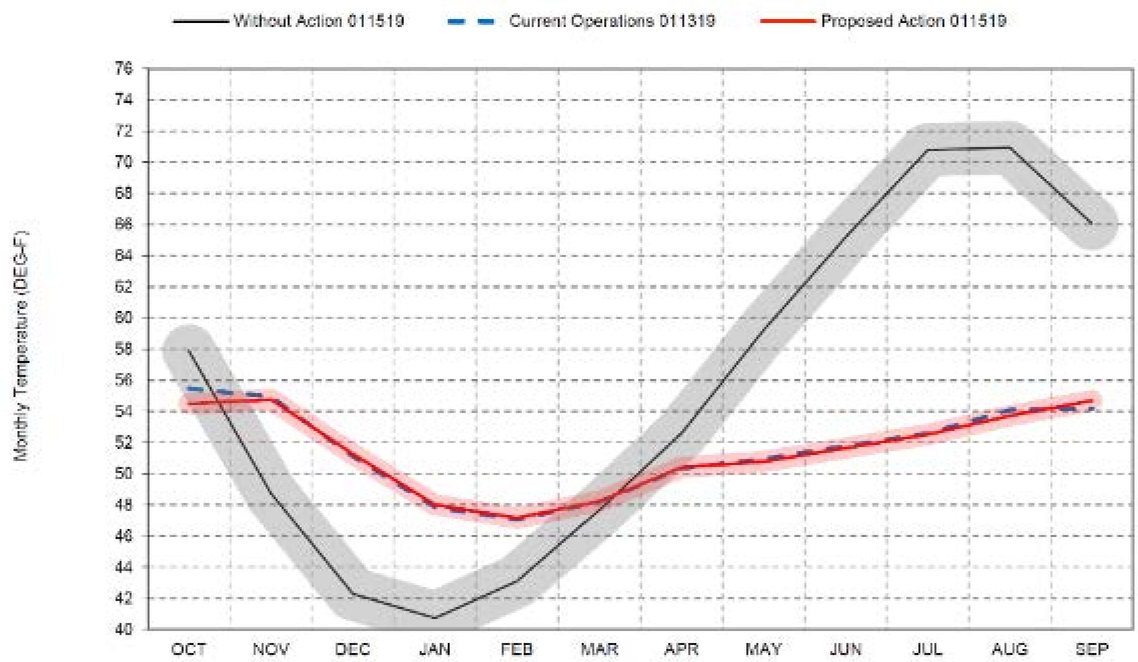


Figure 5.6-13. HEC-5Q Sacramento River Water Temperatures at Clear Creek by Monthly Average

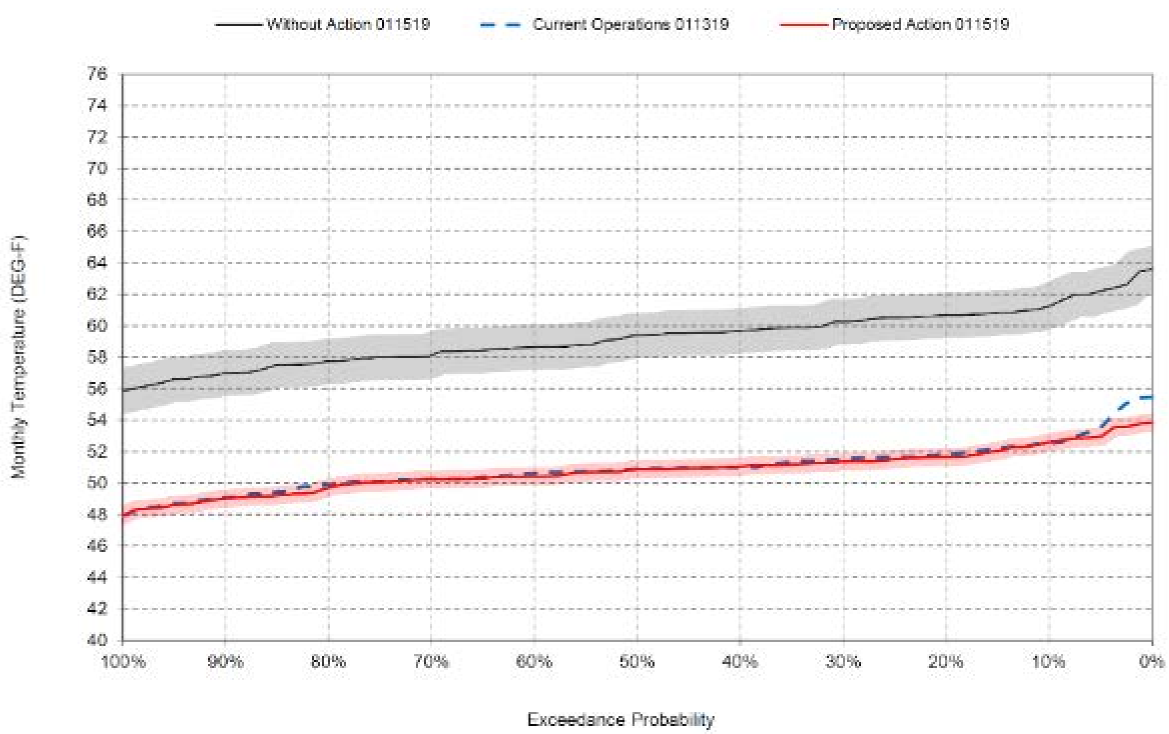


Figure 5.6-14. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, May

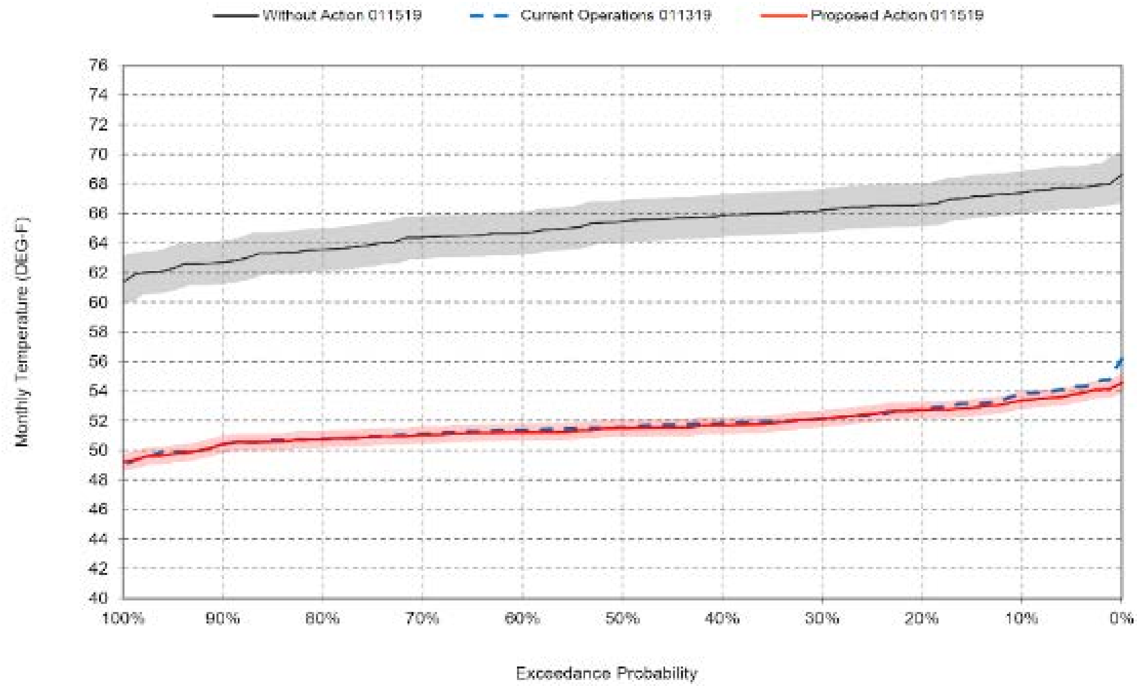


Figure 5.6-15. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, June

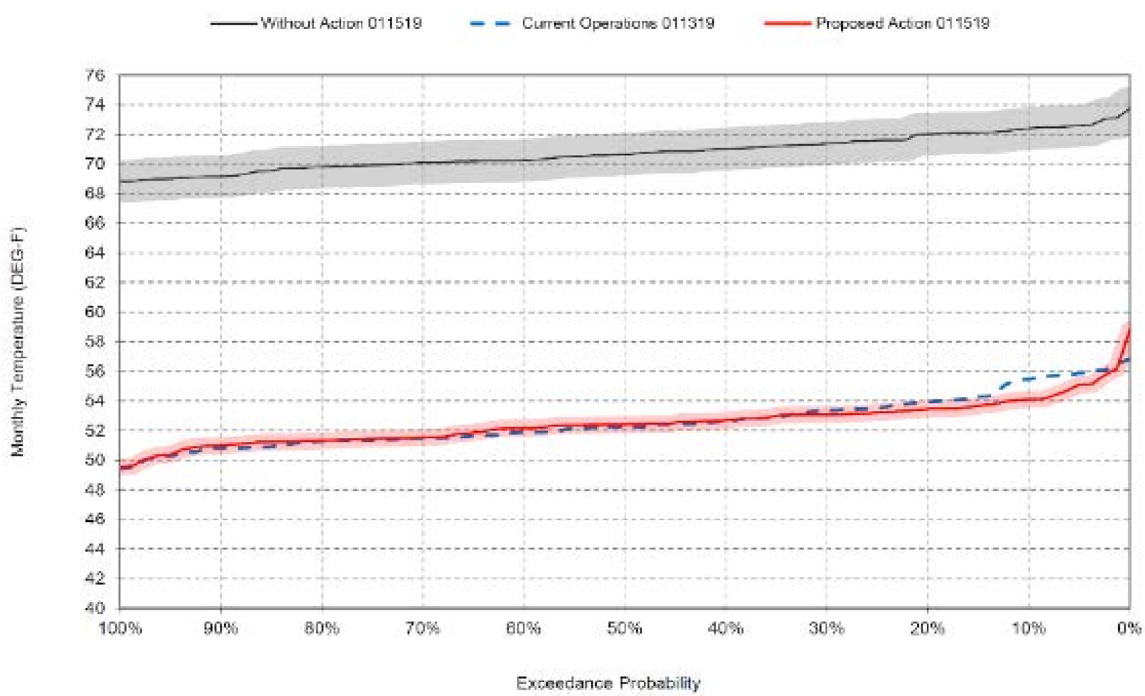


Figure 5.6-16. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, July

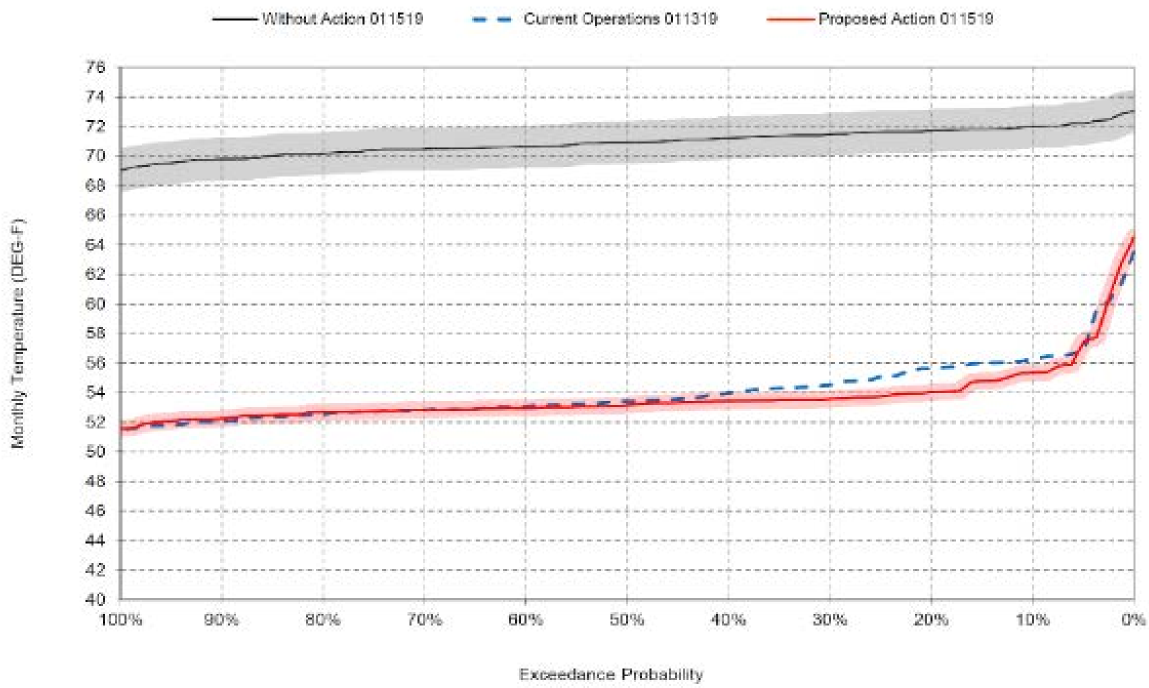


Figure 5.6-17. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, August

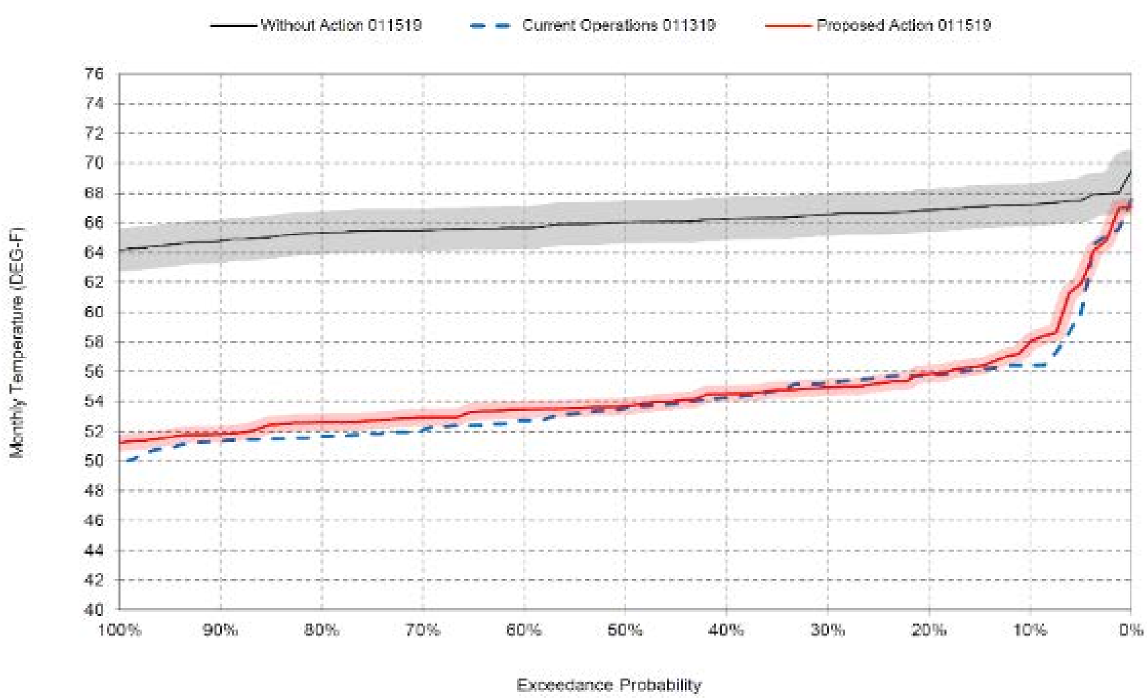


Figure 5.6-18. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, COS and proposed action scenarios, September

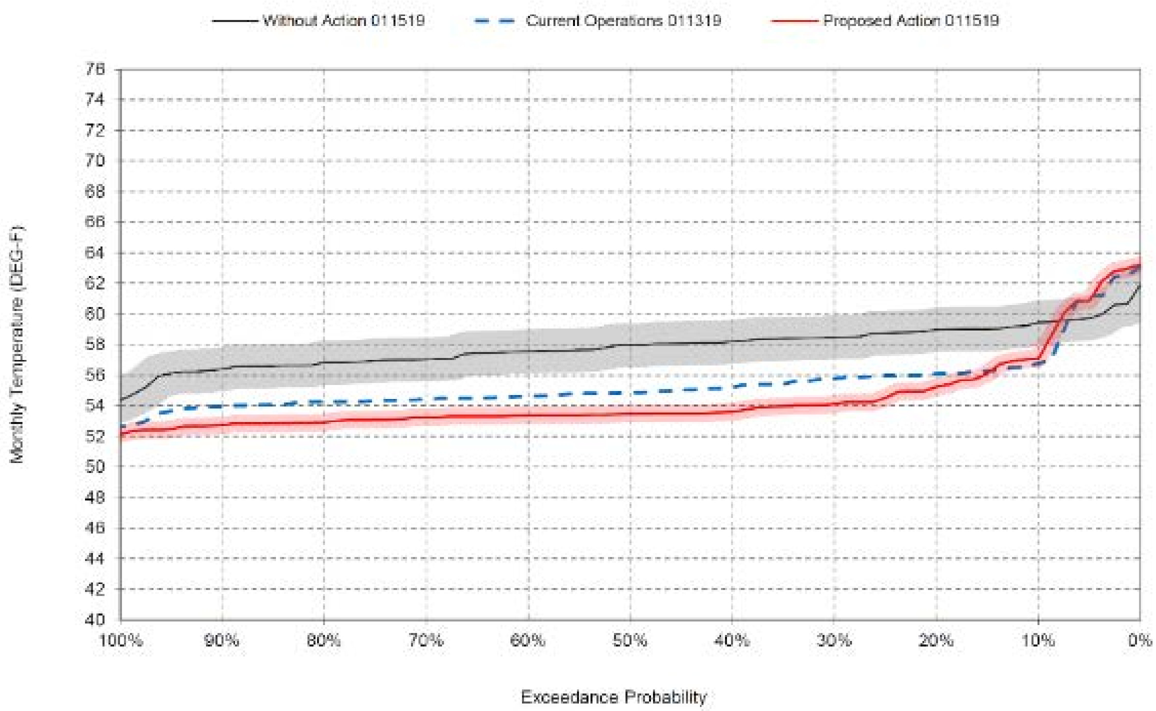


Figure 5.6-19. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, October

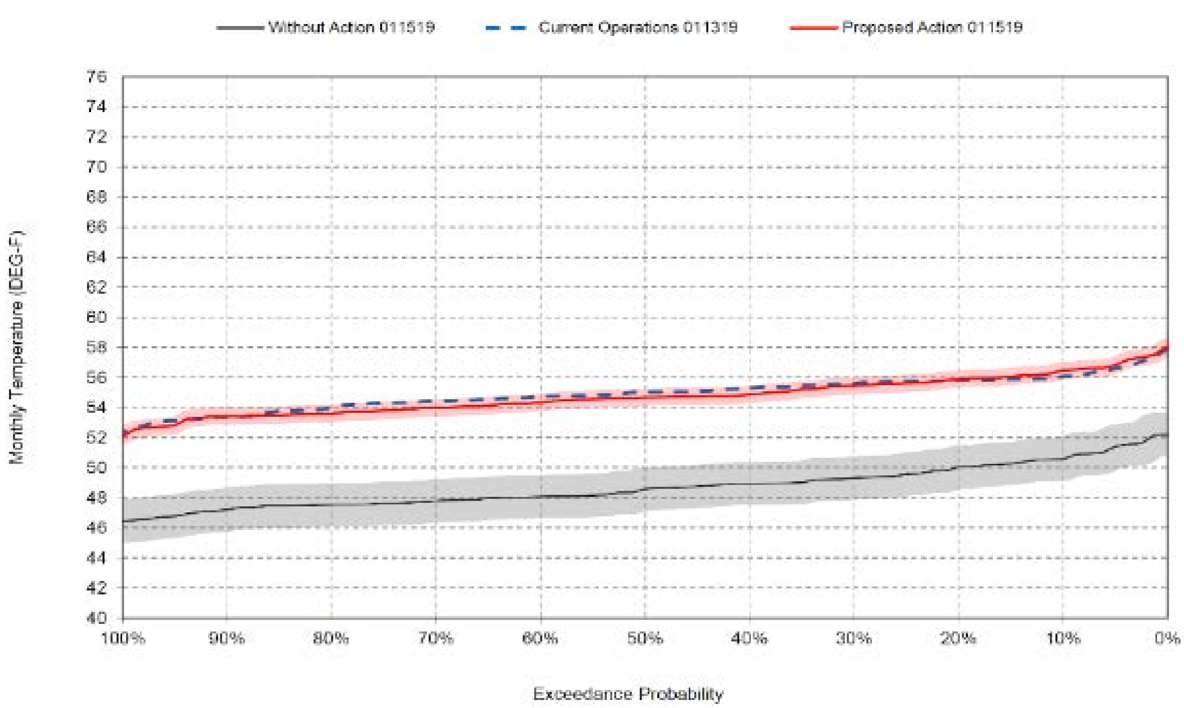


Figure 5.6-20. HEC-5Q Sacramento River Water Temperatures at Clear Creek under the WOA, proposed action, and COS scenarios, November

While the HEC-5Q model provides 6-hour data, the results presented here are monthly averages, which should reasonably estimate daily average temperatures near the Keswick Dam because operations at Shasta and Keswick dams create relatively stable summer flow and water temperature conditions. Variable weather conditions and travel time of water result in greater fluctuations around the mean further downstream of the dam. During the June through September peak spawning and incubation period, the water temperatures at Clear Creek exceed the 53.5 degrees Fahrenheit threshold in at most 30 percent of years (50% for September). During October, when the cold water pool is especially at risk of being depleted, the water temperatures would exceed the 53.5 degrees Fahrenheit threshold in about 50 percent of years. There is little difference in water temperatures among the proposed action and COS scenarios during all months except October (Figures 5.6-13 through 5.6-20). In October, temperature modeling indicates that the proposed action has an improvement over the current operations scenario in 80% of the years, and an improvement over the WOA scenario in 90% of the years, decreasing October temperatures by 1-2 degrees Fahrenheit as compared to COS, and 4-5 degrees as compared to WOA. The proposed action conserves cold water earlier in the year and is able to extend cooler temperatures into October.

Summer water temperatures under the proposed action and COS scenarios are consistently much lower than those under the WOA scenario (Figures 5.6-15 through 5.6-18). These results indicate that the proposed action and COS, relative to the WOA, provide a clear benefit to Winter-run Chinook Salmon eggs and alevins incubating in the upper Sacramento River. In view of the improved water temperature management operations planned for the proposed action, this action is expected to benefit the Winter-run Chinook Salmon eggs and alevins relative to current operations.

Martin et al. (2017) developed an egg mortality model for Winter-run Chinook Salmon on the Upper Sacramento River and performed regression on historical data to find a critical incubation temperature for eggs of 53.6 degrees Fahrenheit below which minimal mortality due to temperature occurred. The 2017 LOBO review (Gore, 2018), stated that the Martin et al. (2017) approach represents a powerful predictive model for salmon vulnerability to temperature exposure but that the results of the oxygen diffusion model should be tested under field conditions. The model is sensitive to extremely small changes in flow velocity, and it may be problematic to apply a density dependent model that lacks mechanistic basis or site-specific information. Additionally, new laboratory studies from UC Davis (Del Rio et al. 2019) affirm earlier findings (USFWS 1999) that embryo survival is not appreciably impaired at daily mean water temperatures at or near 56 °F except in conditions of hypoxia.

Newer models, described in Anderson (2018), are similar but include different assumptions and provide for more targeted water temperature management practices in the upper Sacramento River (Anderson 2018). Both the Martin et al. (2017), and Anderson (2018) models were used to estimate water-temperature related mortality of Winter-run Chinook Salmon eggs to fry under the WOA, proposed action, and COS. Martin et al applies mortality based on the season-long temperature. Anderson applies mortality based on just the temperature of the 5 days preceding hatch. The modeling was based on the HEC 5Q water temperature estimates at Keswick Reservoir under the three scenarios for the range for years (1922 to 2002) used for the CalSim and HEC 5Q modeling. Figure 5.6-21 gives the exceedance curves for the water-temperature related egg to fry mortalities under the WOA, COS, and proposed action scenarios. Separate results are given for the Martin et al. (2017) and Anderson 2018 modeling.

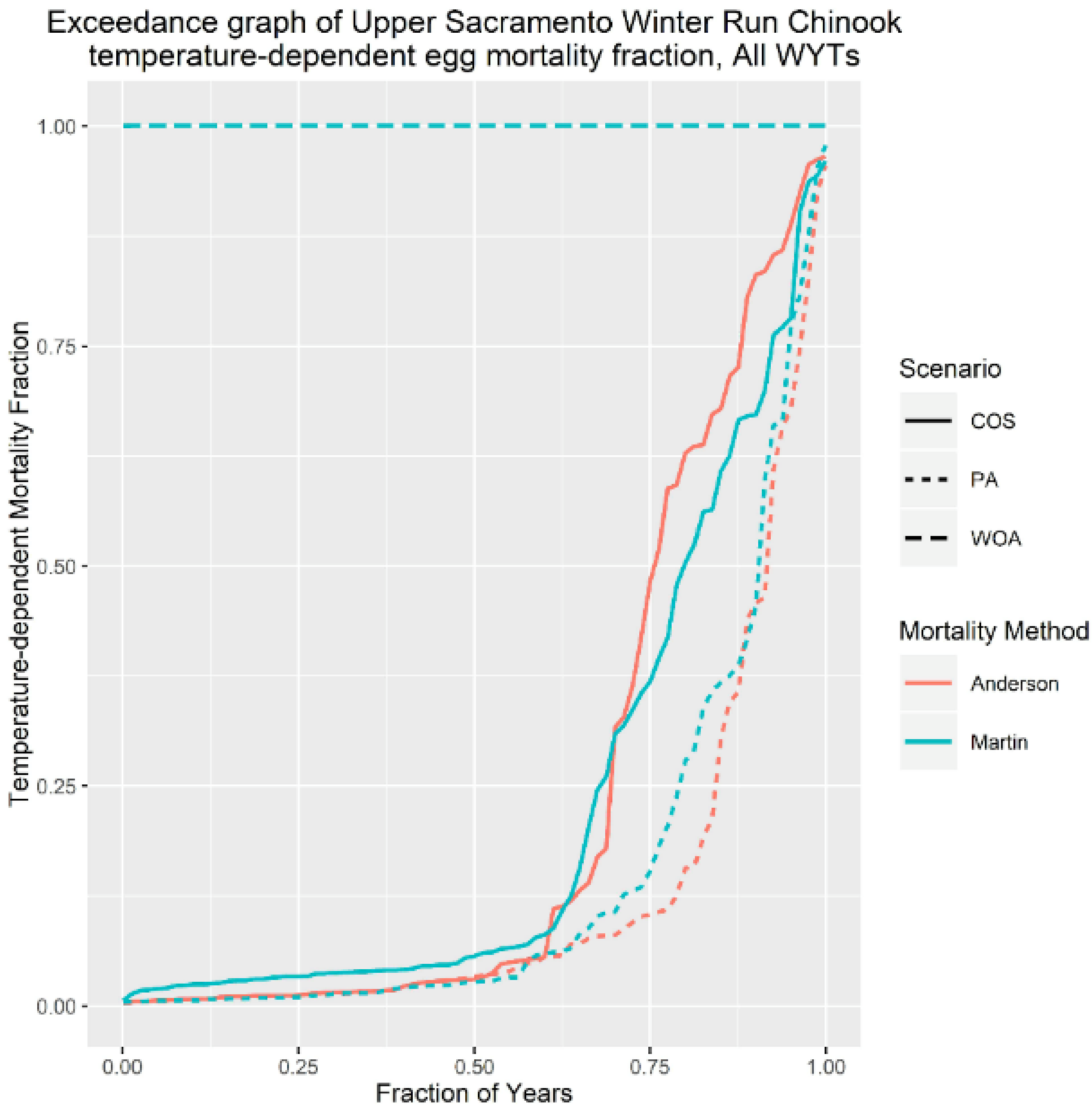


Figure 5.6-21. Exceedance curves of Upper Sacramento River Winter-run Chinook Salmon Temperature-Dependent Egg to Fry Mortality for All Water Year Types

The modeled mortality rate for the WOA scenario is 100 percent for both models used (Figure 5.6-21). This result is the same as that deduced from the HEC 5Q water temperature results presented previously in the water temperature section. Differences between the Martin and Anderson model results are generally small, but tend to show slightly higher mortalities for years with overall lower mortalities (i.e., cooler water temperatures) for the Martin model and slightly higher mortalities for years with overall high mortalities (warmer temperatures) for the Anderson model. For both models, the proposed action mortalities are less than the COS mortalities for the majority of years in all water year types, with some lower performance in some above-normal water-year types.

Figure 5.6-21 combines results for all water year types, including wet years, when there is little temperature-related mortality. This obscures the modeling results for drier years, when egg/alevin mortalities are especially high. In critically dry years, the proposed action continues to outperform current operations, with up to a 40 percent improvement in mortality above current operations in some critically dry years (Figure 5.6-22). As discussed above, the proposed action optimization of water temperatures early in the year leads to significant October improvements in temperatures driving these large improvements in temperature dependent mortality in wetter critically dry years.

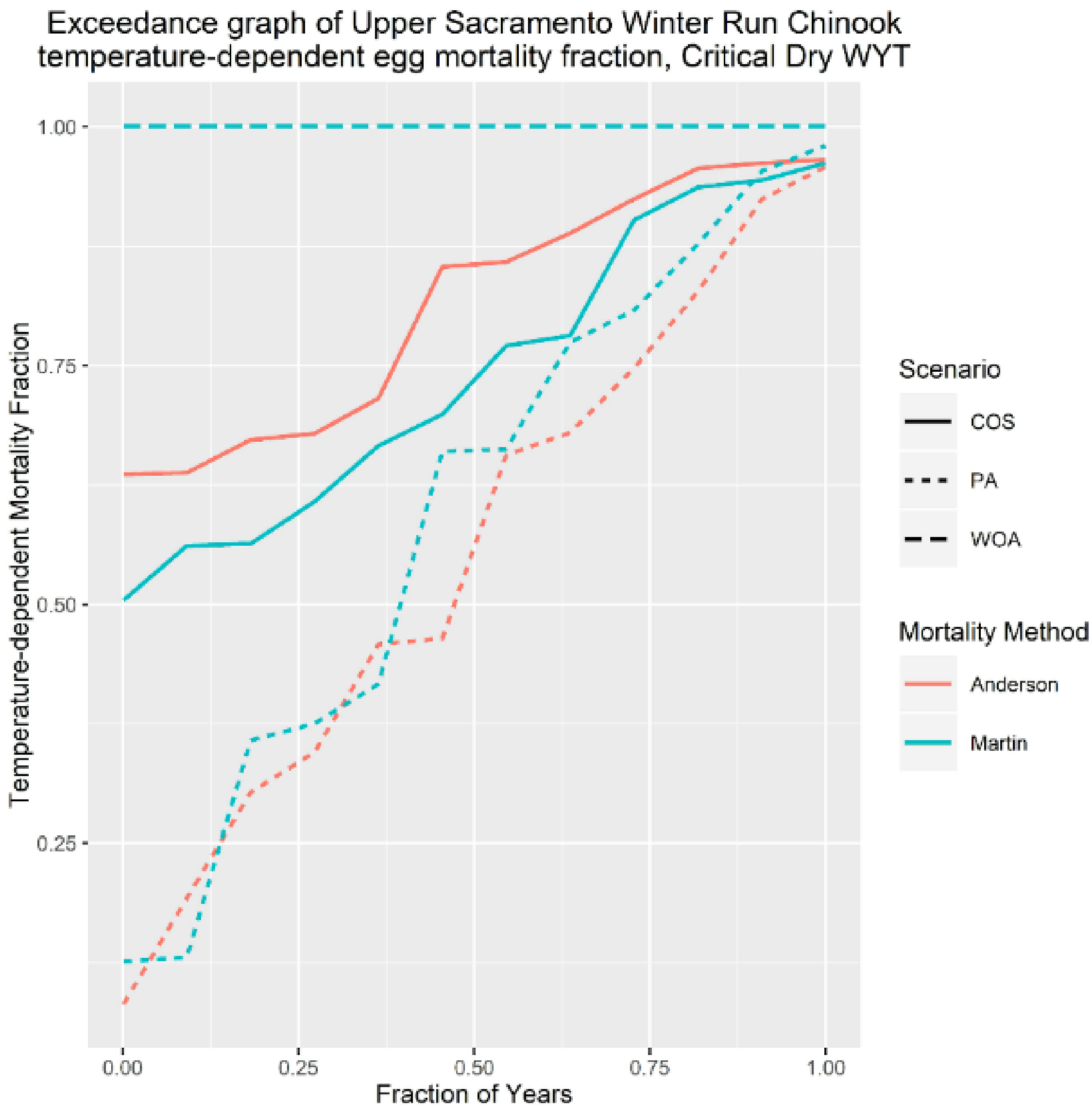


Figure 5.6-22. Exceedance curves of Upper Sacramento River Winter-run Chinook Salmon Temperature-Dependent Egg to Fry Mortality for Critically Dry Water Year Types

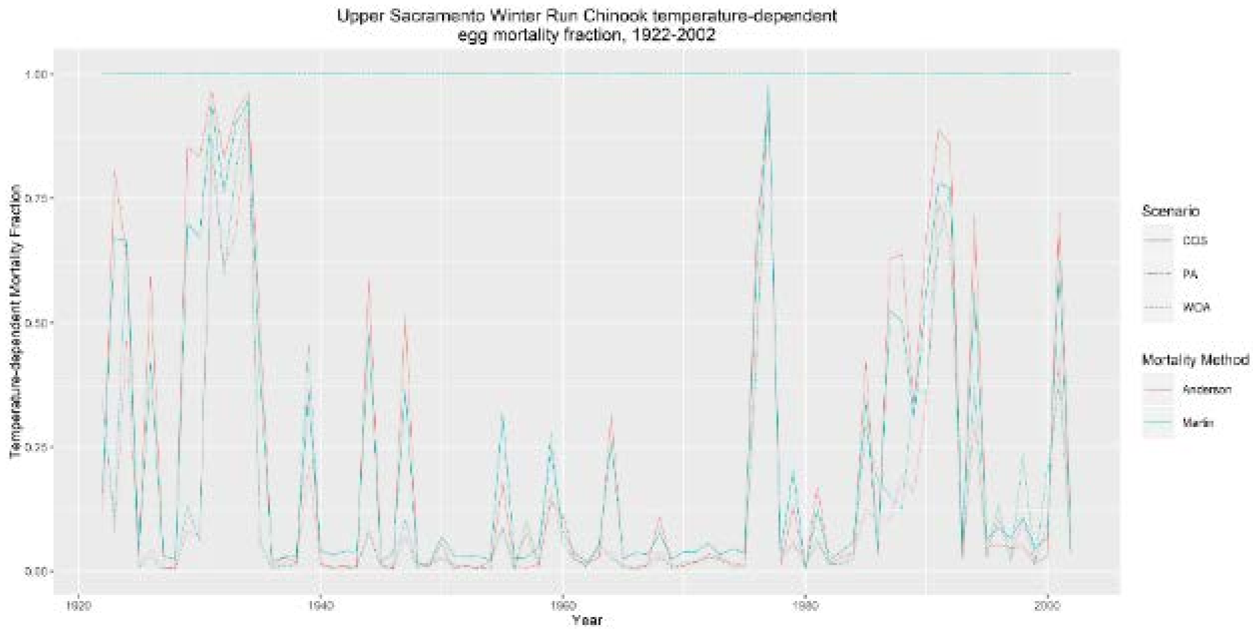


Figure 5.6-23. Estimated Winter-run Chinook Salmon Egg to Fry Average Annual Mortalities (average of Martin and Anderson mortality estimates) and HEC 5Q Estimates of June through September Monthly Average Water Temperatures at Keswick from 1922 to 2002.

The highest estimated mortality rates consistently occur during periods of high water temperatures, such as the droughts of the late 1920 through the mid-1930s, 1976 and 1977, and the late 1980s through the early 1990s (Figure 5.6-23).

The impacts of increased summer and fall flows under the proposed action compared to WOA and COS would be beneficial for egg and alevin survival. The proposed action and COS have lower May flows than WOA, at the very beginning of the spawning and incubation period. However, the proposed action and COS have higher flows than WOA during the rest of the period of egg and alevin incubation for Winter-run Chinook Salmon.

5.6.3.1.2 Rearing to Outmigrating Juveniles in Upper Sacramento River

Winter-run Chinook Salmon juveniles rear throughout the upper Sacramento (Keswick to Red Bluff) from July through March, with a peak rearing period during August through December, and emigrate from the upper river during this period (Table 5.6-1). The proportion of juveniles surviving to emigrate from the upper Sacramento River depends largely on habitat conditions, including instream flow (Windell et al. 2017). Instream flow affects other factors through dilution (e.g., toxicity and contaminants), water temperatures (which also affects DO, food availability, predation, pathogens, and disease), river stage and flow velocity (which affect habitat connectivity, bioenergetics, food availability, and predation), entrainment and stranding risk, and potentially affects cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

Water temperatures under the proposed action are consistently lower than those under the WOA scenario during May through September, moderately lower in October, similar during March and April, and above the WOA scenario from November through February (Figure 5.6-23 below). Under the proposed action as modeled in HEC-5Q, monthly mean water temperatures at Balls Ferry exceed the 61 degrees Fahrenheit threshold for rearing juvenile Winter-run Chinook Salmon only in about 5 percent of years in August, September, and October, and in no years during the other months (see Appendix D, *Modeling*). There is little difference in water temperatures between the proposed action and COS scenarios during the period of Winter-run Chinook Salmon rearing in the upper Sacramento River.

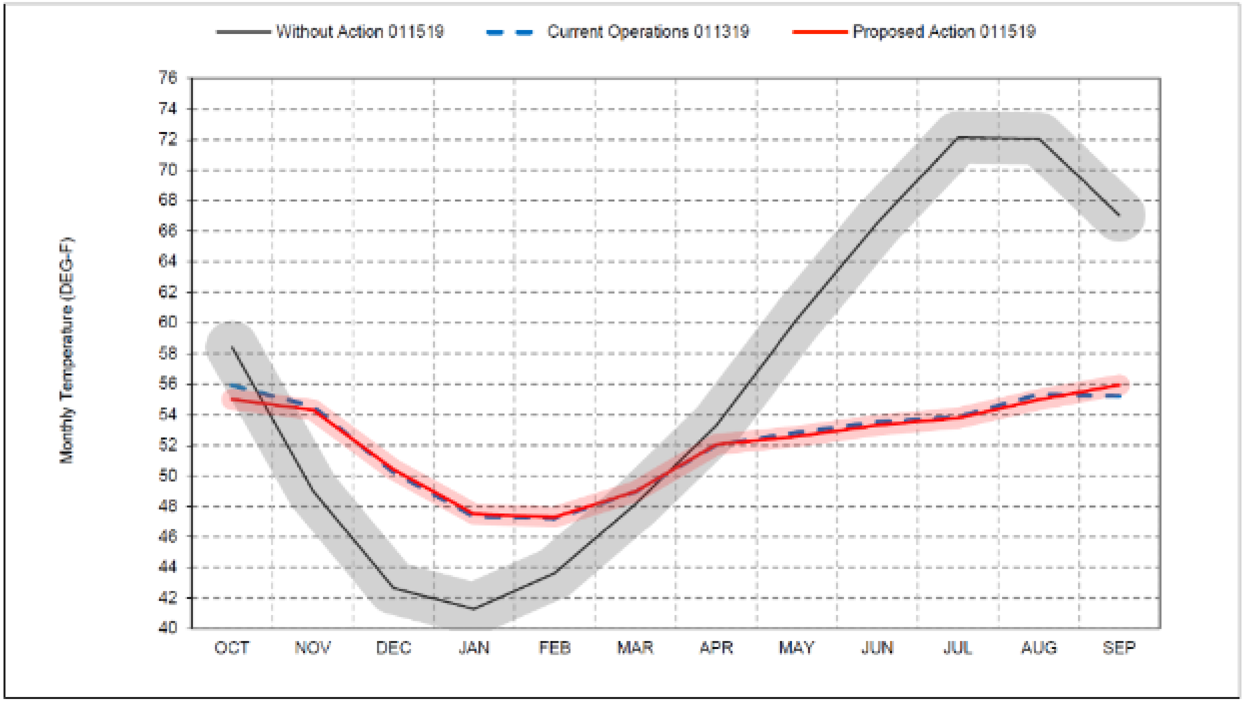


Figure 5.6-24. Sacramento River at Balls Ferry Long-term Average Temperatures

Flows during summer and fall of dry and critically dry years generally have the greatest potential to adversely affect the juvenile life stage in the upper Sacramento River because reservoir storage and cold water pool in these seasons and water year types may be insufficient to provide suitable flow and water temperature conditions in the rearing habitats. The proposed action would help protect Winter-run Chinook Salmon from water temperature extremes through the end of October in all but the driest years.

The benefits of the lower summer and fall water temperatures under the proposed action outweigh potential adverse effects of higher winter water temperatures because the summer and fall temperatures are often near critical temperature thresholds and, therefore, more of a limiting factor. Also, the juveniles are at their youngest and therefore most vulnerable during summer and fall. These results indicate that water temperatures under the proposed action provide benefits to rearing juvenile Winter-run Chinook Salmon in the upper Sacramento River relative to the WOA.

Events in recent years have demonstrated that water temperatures in the upper Sacramento River under current operations negatively impact Winter-run Chinook Salmon, perhaps including rearing juveniles. With the proposed improvements in water temperature management under the proposed action, adverse effects on Winter-run Chinook Salmon are expected to lessen.

5.6.3.1.3 Rearing to Outmigrating Juveniles in Middle Sacramento River

Many of the factors that affect rearing and outmigrating Winter-run Chinook Salmon juveniles in the middle Sacramento River are similar to those described above for the upper Sacramento River. As indicated by the SAIL conceptual model (Figure 5.6-3), flows from the upper Sacramento River and tributaries of the middle Sacramento, combined with other environmental drivers such as floodplain connectivity, food production and retention, and water diversions, affect water temperature, DO, food availability, stranding, outmigration cues and other habitat attributes that influence timing, condition, and survival of rearing juvenile Winter-run Chinook Salmon. The proportion of juveniles surviving to emigrate from the middle Sacramento River depends largely on growth and predation, which are greatly affected by habitat conditions, including instream flow (Windell et al. 2017). The main difference between the juveniles in the middle Sacramento River and those in the upper river with respect to these adverse effects is that the juveniles in the middle river would generally be less sensitive to the effects because their greater age and size would result in greater robustness.

Juvenile Winter-run Chinook Salmon spend varying amounts of time rearing in the upper Sacramento River following emergence before migrating to the middle River. They use the middle Sacramento River as rearing habitat and a migratory corridor to the Delta. The majority of Winter-run-sized juveniles occur in the middle Sacramento River from October through March (Table 5.6-1), with peak occurrence in December and January. The timing of peak migration is typically associated with the earliest occurrence of high flow storm events during the migration season (Windell et al. 2017).

Flows in the middle Sacramento River under the WOA scenario, as was true for the upper Sacramento River, would generally be low during summer and fall and higher in the winter and early spring (Figure 5.6-24 below).

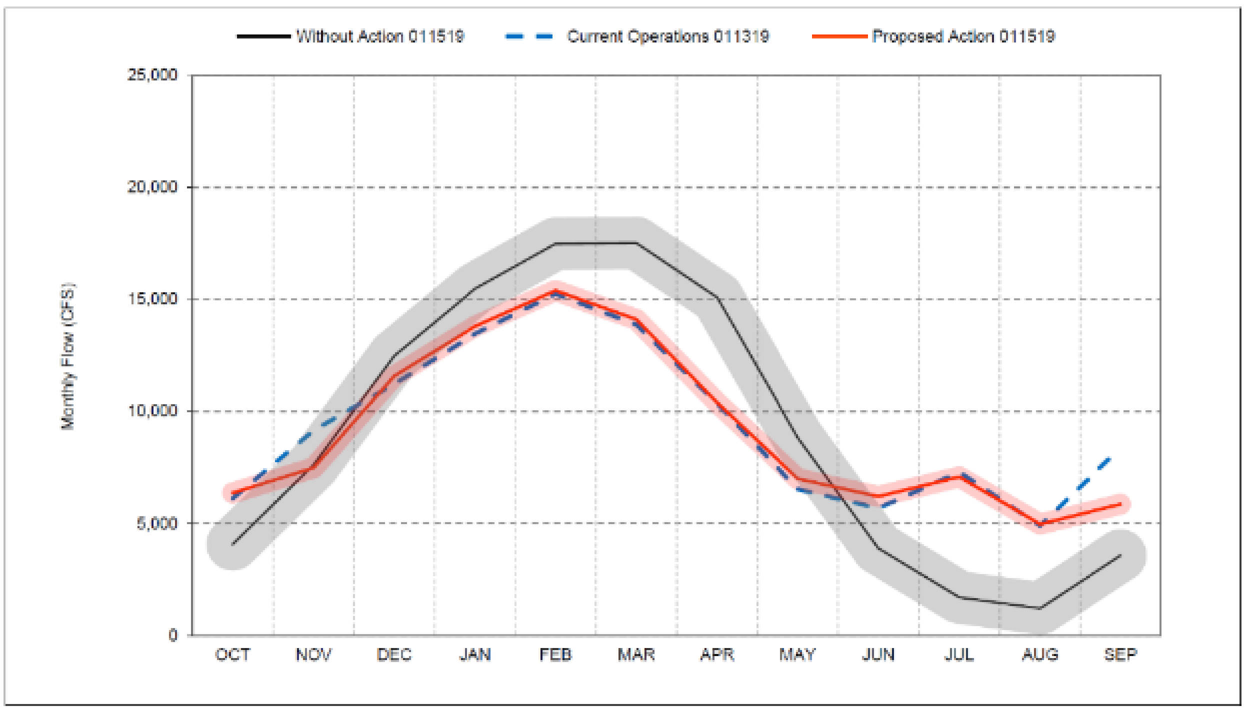


Figure 5.6-25. Sacramento River Flows at Wilkins Slough, Long-Term Average

As was true for the upper Sacramento River, the CalSim modeling results show large seasonal changes in the differences in middle Sacramento River flow between the WOA scenario and the proposed action. In October, the WOA scenario flows are below those of the proposed action except for the wettest years. By November, there is little difference in flow between the WOA and proposed action scenarios, except in the middle-high quarter of flows years, when the WOA flows tend to be moderately higher. In December through February, the WOA flows are generally similar to or higher than the proposed action and in March the WOA flows are consistently higher than the proposed action flows. These seasonal changes result primarily from Shasta Reservoir storage releases under the proposed action during June through September, when uncontrolled flows are low, and Shasta Reservoir storage releases under the proposed action during winter and spring, when uncontrolled flows are high. Diversion to storage is higher in spring than in winter because the flood control pool can be reduced during spring as flood risk declines.

The differences in flows between the WOA scenario and the proposed action would likely have large effects on Winter-run Chinook Salmon juveniles and their habitat. The higher summer and fall flows under the proposed action would likely result in improved conditions in juvenile rearing habitats, including more habitat complexity, side channel habitat structure, refuge habitat, and less disease potential. The lower proposed action flows in winter and spring, compared to WOA, could have both positive and negative effects on rearing juvenile Winter-run Chinook Salmon. Potential effects include less floodplain and side-channel habitat; poorer feeding conditions, increased competition and predation; higher water temperatures and lower DO; and reduced emigration flows. Potential benefits include lower stranding risk because of less flow fluctuations and lower contaminants loading from stormwater runoff. Although conditions may still be stressful for juvenile Winter-run Chinook Salmon, the impacts of increased summer and fall flows under the proposed action and COS would be beneficial compared to the WOA. Juveniles are younger and less robust during summer and fall and more sensitive to stressful conditions than other times of the year (NMFS 2009). Therefore, juvenile Winter-run Chinook Salmon would be less susceptible to reduced winter and spring flows under the proposed action as compared to the WOA.

Inundated floodplains of the middle Sacramento River, such as the Yolo and Sutter Bypasses, have proven particularly successful habitats for juvenile salmon growth (Katz, 2017). This success has been attributed to optimum water temperature, lower water velocity, and higher food quality and food density relative to the main channel. Reduced predator and competitor density also likely contribute to high growth rates observed for juvenile salmon rearing in floodplains (Windell et al. 2017).

CalSim modeling indicates that middle Sacramento River flows during October through March are generally similar between proposed action and COS scenario, except during September and November of above normal and wet years, for which the mean flows under the COS scenario are higher (see Appendix D, *Modeling* and Figure 5.6-24 above). Despite flow reductions compared to COS, the November proposed action flows for the middle ranges of the exceedance curves (roughly 6,000 cfs to 13,000 cfs) would generally be suitable for rearing Winter-run Chinook Salmon juveniles (USFWS 2005).

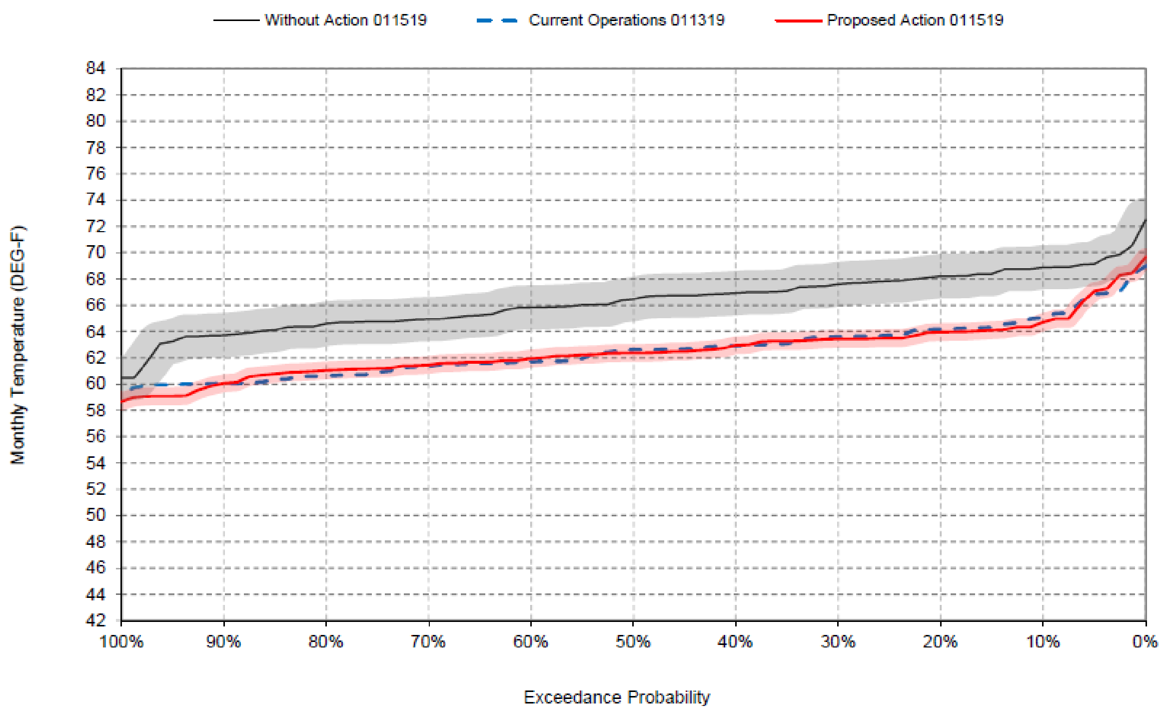


Figure 5.6-26. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, proposed action, and COS scenarios, October

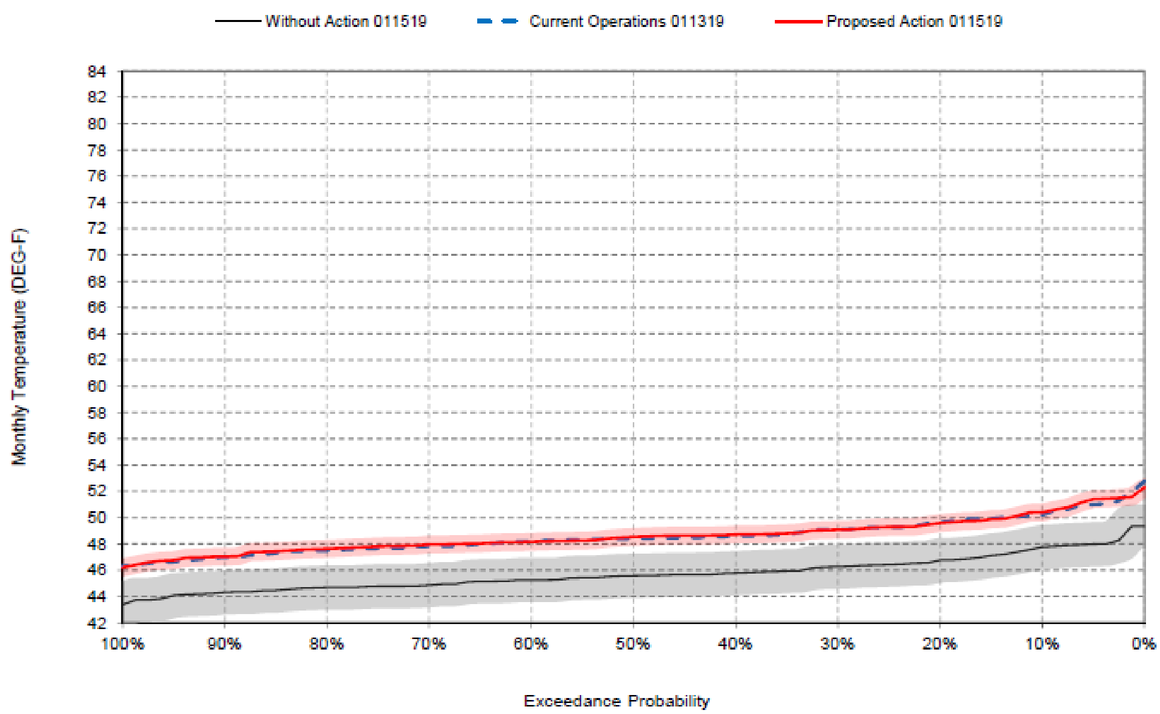


Figure 5.6-27. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, proposed action, and COS scenarios, December

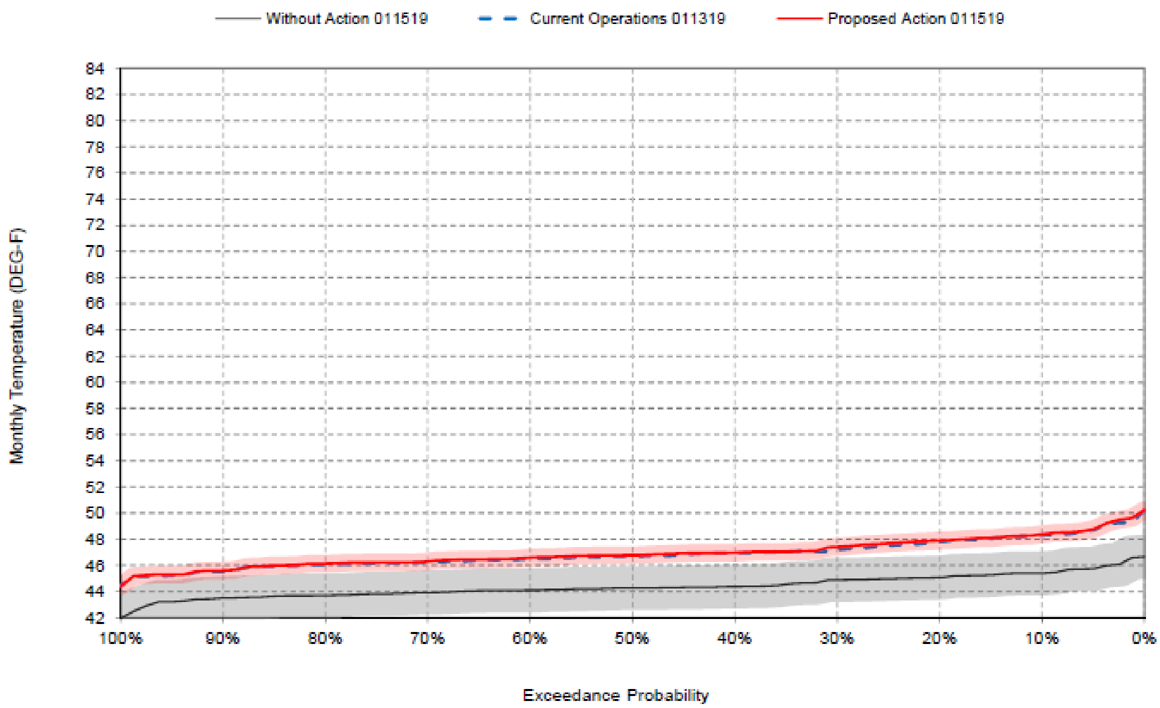


Figure 5.6-28. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, proposed action, and COS scenarios, January

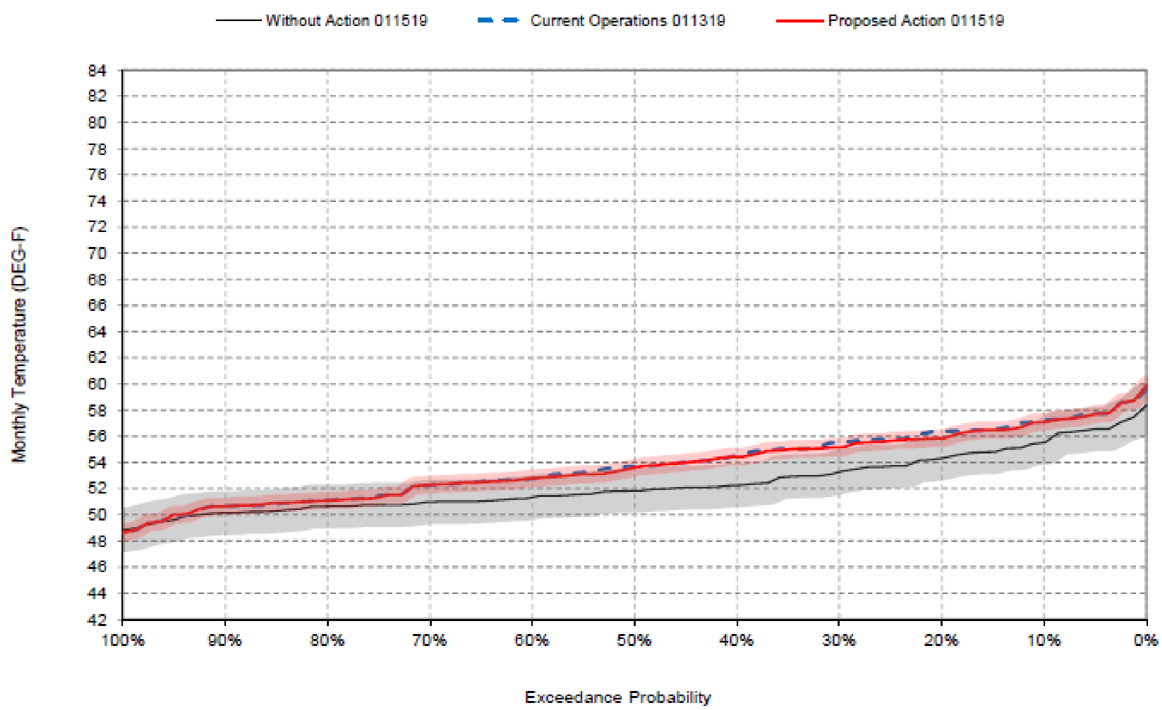


Figure 5.6-29. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, proposed action, and COS scenarios, March

Under the proposed action scenarios, monthly average water temperatures below the Colusa Basin Drain would range from about 59 to 69 degrees Fahrenheit during October, exceeding the 64 degrees Fahrenheit threshold in about a third of the years (Figure 5.6-25). From November through March, water temperatures for both scenarios would remain well below the 64 threshold (e.g., Figures 5.6-27 and 5.6-28).

Water temperatures under the proposed action are lower than those under the WOA scenario during October in most years (Figures 5.6-25), similar during March (Figure 5.6-28), and above the WOA scenario water temperatures from November through February (e.g. Figure 5.6-26 and 5.6-27). Water temperatures during most of the October through March period under the WOA scenarios and the proposed action are suitable for juvenile Winter-run Chinook Salmon that rear in and emigrate from the middle Sacramento River, therefore, Winter-run Chinook Salmon juveniles are not expected to be impacted by the proposed action water temperatures.

5.6.3.1.4 Adult Migration from Ocean to Upper Sacramento River

CalSim modeling indicates that WOA flows are generally similar to or moderately higher than proposed action during December through February (see Appendix D, *Modeling*). In March, April and May, however, the WOA flows are considerably higher than the proposed action, except for May flows in critical water years (see Appendix D, *Modeling*). The lower flows at Wilkins Slough under the proposed action during March and April, as well as January and February in drier years, would likely affect adult Winter-run Chinook Salmon migrating in the middle Sacramento River by reducing water quality and increasing stranding, straying, poaching, and disease risks (Windell et al. 2017). Conditions under the proposed action would be better in May of drier years, when flows in ten percent of WOA years are below 1,000 cfs (Figure 5.6-29). In these low WOA years, the proposed action would reduce passage problems for upstream migrating adults.

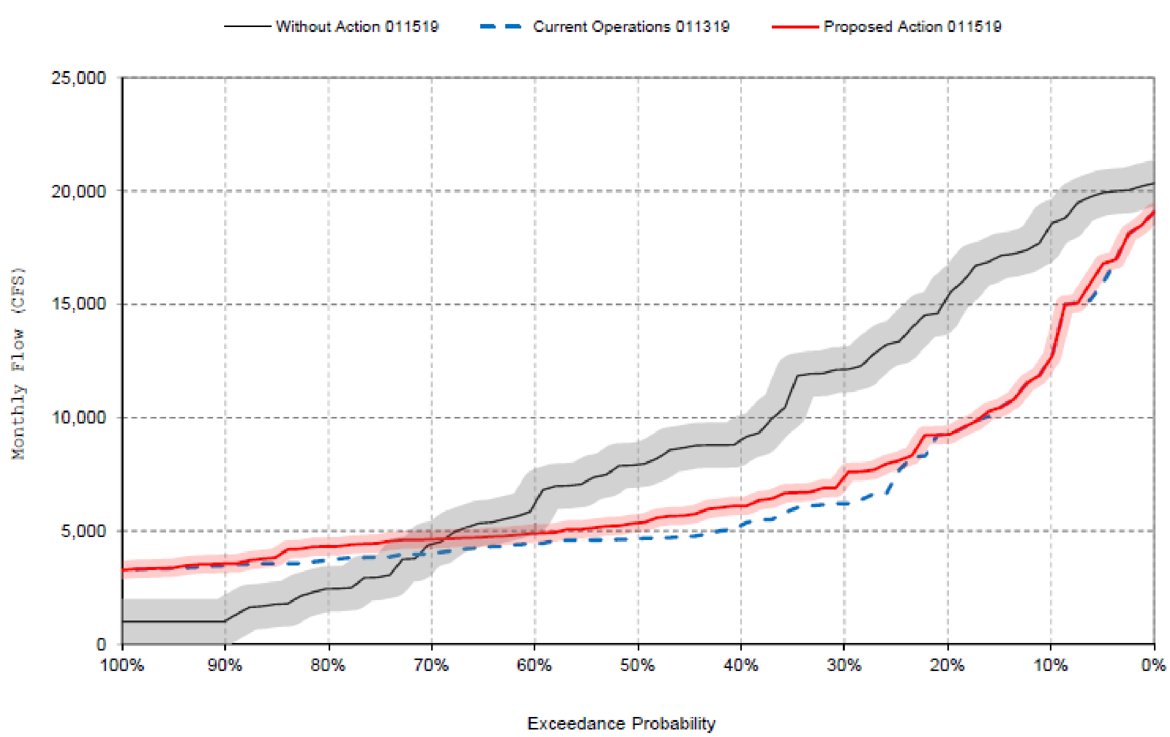


Figure 5.6-30. Modeled Sacramento River Flows at Wilkins Slough, May

In the middle Sacramento River downstream of the Colusa Basin Drain, water temperatures under the proposed action scenarios are similar to WOA water temperatures during May, except in warmer years, when the WOA water temperatures are higher (Figure 5.6-29). The proposed action water temperatures are generally above the WOA water temperatures from December through April (e.g. Figures 14-9 through 14-13 in the HEC5Q Temperatures section of Appendix D). In the upper Sacramento River at Keswick, water temperatures under the proposed action scenarios are similar to WOA water temperatures during March (Figure 5-12 in the HEC5Q Temperatures section of Appendix D), well above the WOA scenario water temperatures from December through February (e.g. Figures 5-9 through 5-11 in the HEC5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in April and May (Figures 5.6-30 and 5.6-31).

Water temperatures during December through April period are suitable for adult Winter-run Chinook Salmon immigrating in the middle Sacramento River or holding in the upper river (68 degrees). In May, however, modeled water temperatures in the middle river below the Colusa Basin Drain (at Knight's Landing) exceed the threshold for immigrating adults in a large percentage of years under the WOA scenarios and the proposed action, with a greater percentage of years exceeding the threshold under the WOA scenario. At Keswick, only about four percent of years are expected to exceed the 61 degrees Fahrenheit threshold for holding adults under the WOA scenario, and no years are expected to exceed the threshold under the proposed action and COS scenarios. The anticipated water temperature differences among the scenarios during May are expected to result in greater negative impacts on the immigrating Winter-run Chinook Salmon adults in the middle Sacramento River under the WOA conditions than under the proposed action and COS conditions.

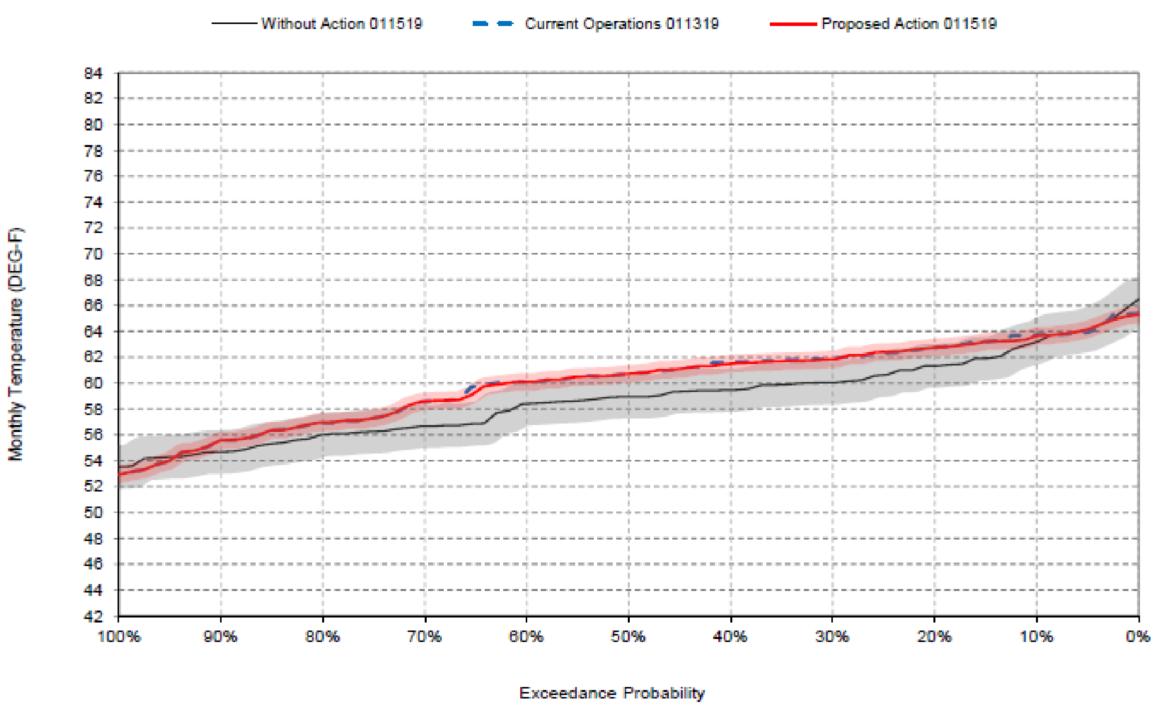


Figure 5.6-31. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, COS and proposed action scenarios, April

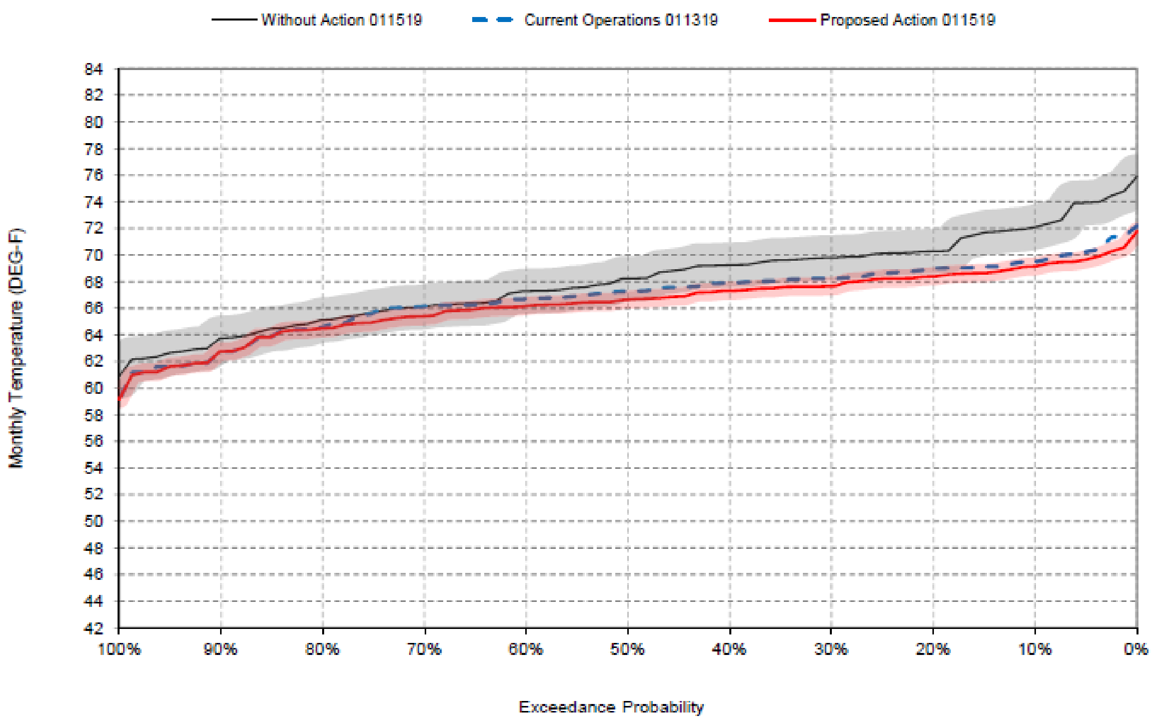


Figure 5.6-32. HEC-5Q Sacramento River Water Temperatures at Knights Landing under the WOA, COS and proposed action scenarios, May

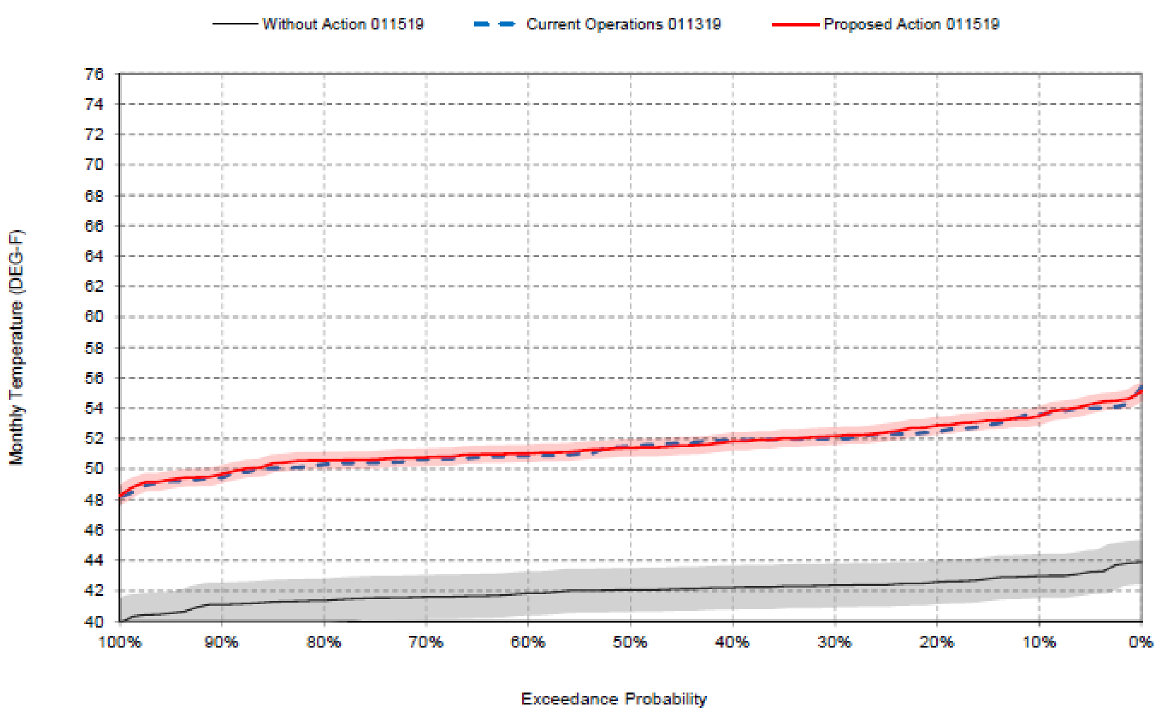


Figure 5.6-33. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, COS and proposed action scenarios, December

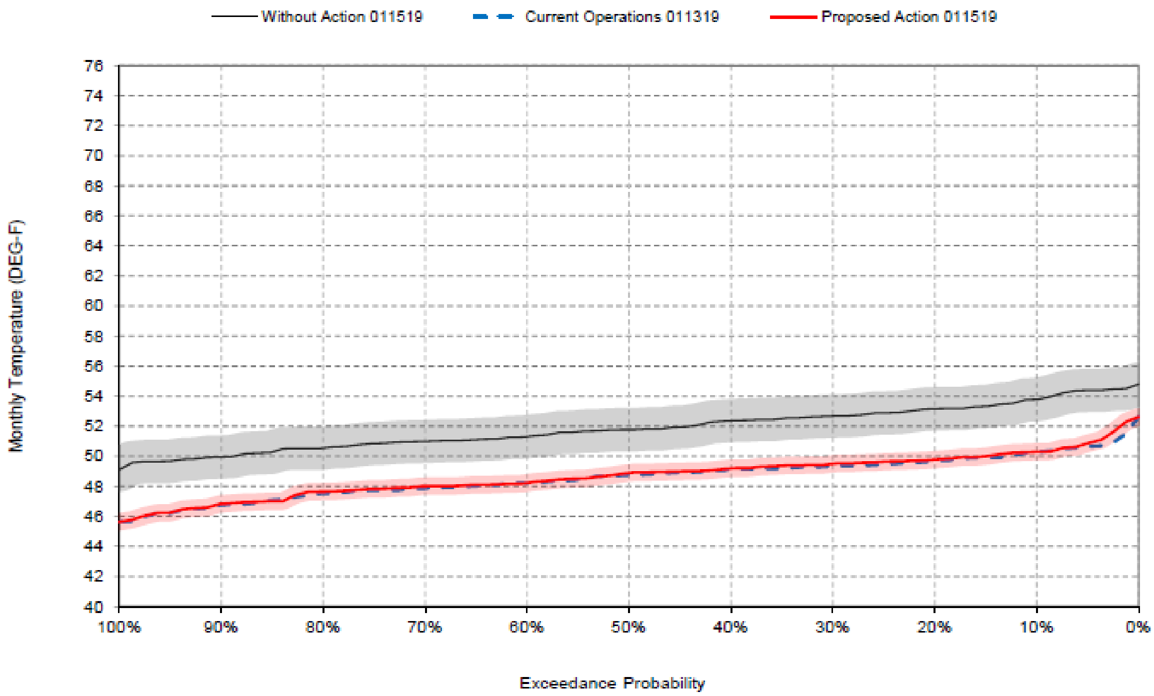


Figure 5.6-34. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, COS and proposed action scenarios, April

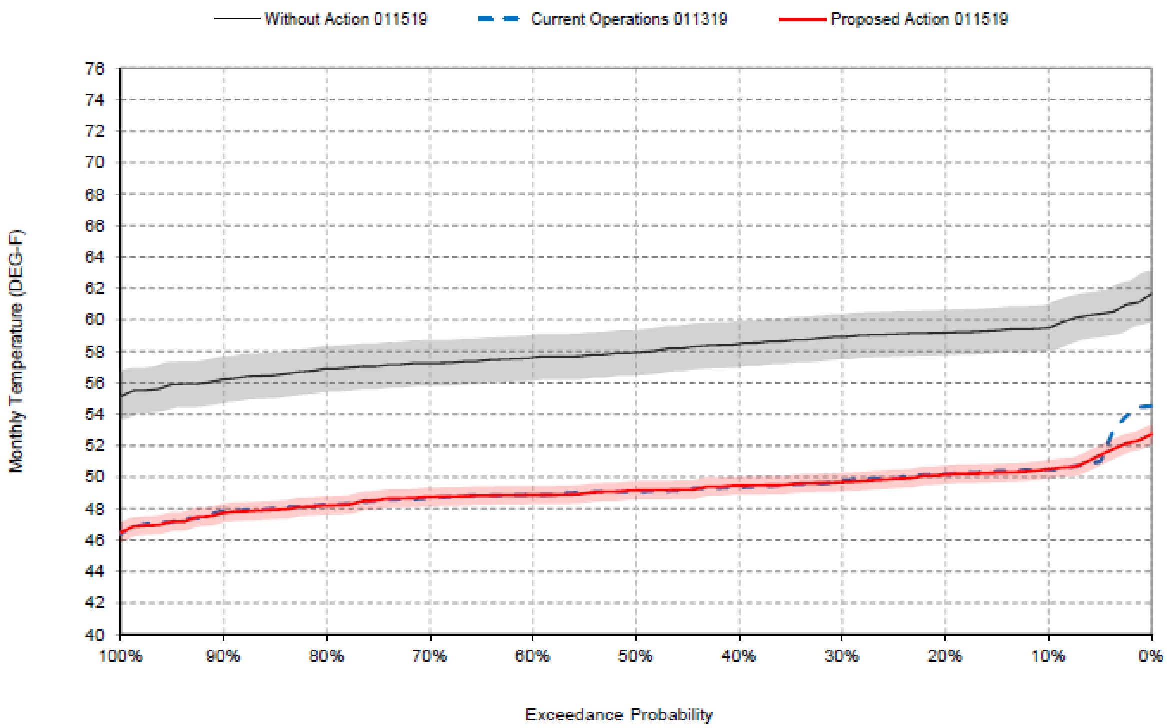


Figure 5.6-35. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, COS and proposed action scenarios, May

There are few differences in water temperatures between the proposed action and COS scenarios during any of the months that adult Winter-run Chinook Salmon migrate upstream in the middle Sacramento River or hold in the upper river (see Appendix D, *Modeling*). Under the proposed action and COS scenarios, the monthly mean water temperatures in the middle Sacramento River below the Colusa Basin Drain would be below the 68 degrees Fahrenheit threshold for immigrating adults from December through April, but would exceed the threshold in May in about 30 percent of the years (Figure 5.6-31). In the upper Sacramento River at Keswick Dam under the proposed action and COS scenarios, the average water temperatures would be well below the 61 degrees Fahrenheit threshold for holding adults from December through May (Figures 5.6-32-34). The May water temperatures in the middle Sacramento River modeled for many years under both the proposed action and COS scenarios would likely negatively impact Winter-run Chinook Salmon adults migrating at that time in the middle Sacramento River, compared to WOA.

5.6.3.1.5 <u>Adult Holding in the Upper Sacramento River</u>

As indicated by the SAIL conceptual model (Figure 5.6-6), flows from Keswick Dam releases affect water temperature, DO, and other habitat attributes that influence the timing, condition, distribution, and survival of adult Winter-run Chinook Salmon during their holding and spawning in the upper Sacramento River. The period of holding is essentially the same as that for upstream migration in the middle and upper Sacramento River, December through May. Spawning extends this period through June, July and August.

CalSim modeling also indicates that WOA flows are generally similar to or moderately higher than proposed action during December through February (Figures 15-9 through 15-11 in the CalSim II Flows section of Appendix D), are much higher than proposed action during March and April and during May of wetter years (Figures 15-12 through 15-14 in the CalSim II Flows section of Appendix D), and are lower than proposed action flows during June through August (Figures 15-15 through 15-17 in the CalSim II Flows section of Appendix D). In general, higher flows are likely to benefit holding and spawning adult Winter-run Chinook Salmon by affording better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, lower risk from anglers, and a greater area of river bed with suitable attributes for redds (Windell et al. 2017). The proposed action scenarios would have much higher flows than the WOA scenario during summer, when flow is generally low and so particularly likely to limit Winter-run Chinook Salmon holding and spawning success. Therefore, the proposed action is expected to be more protective of Winter-run Chinook Salmon than the WOA conditions.

Flows during the December through August period would generally be similar between the proposed action and COS scenario (Figure 15-9 through 15-17 in the CalSim II Flows section of Appendix D). The biggest differences among these scenarios would occur in June for the upper 70 percent of flows, when proposed action scenario flows would be slightly greater than COS flows. The differences occur over a range of flows from 8,000 cfs to 16,000 cfs, all of which are suitable for holding and spawning adults (USFWS 2003), therefore, flows are not expected to substantially affect adult Winter-run Chinook Salmon.

As noted above, the period of adult holding and spawning in the upper Sacramento River extends from December through August. In the upper Sacramento River at Keswick, water temperatures under the proposed action are similar to WOA water temperatures during March (Figure 5-12 in the HEC5Q Temperatures section of Appendix D), well above the WOA scenario water temperatures from December through February (Figure 5-9 through 5-11 in the HEC5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in April through August (Figures 5-13 through 5-17 in the HEC5Q Temperatures section of Appendix D). Water temperatures under the WOA scenario exceed the

61 degrees Fahrenheit holding threshold in almost all years during June through August and the 56 and 53.5 degrees Fahrenheit spawning threshold in almost all years during May through August. In contrast, water temperatures under the proposed action do not exceed the 61 degrees Fahrenheit holding threshold in almost all years of every month in the December through August period and do not to exceed the 56 and 53.5 degrees Fahrenheit thresholds in almost all years of all months in the period, except for 3 and 10 percent of years in July and August, respectively. These results indicate that the proposed action, relative to the WOA, provides a clear benefit to adult Winter-run Chinook Salmon individuals holding and spawning in the upper Sacramento River.

There are few differences in water temperatures among the proposed action and COS scenarios during any of the months that adult Winter-run Chinook Salmon hold and spawn in the upper Sacramento River (e.g., Figures 5-9 through 5-17 in the HEC5Q Temperatures section of Appendix D). At Keswick Dam, under the proposed action and COS, the mean water temperatures would be below the 61 degrees Fahrenheit threshold for holding adults for all months from December through August, except for the warmest one percent of years in August (Figure 5-17 in the HEC5Q Temperatures section of Appendix D). The 56 degrees Fahrenheit thresholds for spawning adults would be exceeded under the proposed action and COS scenarios only during August in about five percent of years, while the 53.5 degrees Fahrenheit threshold would be exceeded in May through August under COS, but only July and August under the proposed action. The proposed action exceeds the 53.5 degree Fahrenheit threshold 10 percent fewer years in July, and 15 percent less years in August compared to COS. In view of the improved water temperature management operations, including less releases for Delta outflow and more cold water storage, the proposed action is expected to benefit the Winter-run Chinook Salmon adults relative to the COS.

5.6.3.2 Spring Pulse Flows

5.6.3.2.1 Egg to Fry Emergence

As shown in the conceptual model, flow releases affect stranding/dewatering of redds (not applicable in the spring), dissolved oxygen, and temperature. In addition, spring pulse flows could reduce cold water pool available for Winter-run Chinook Salmon eggs, reducing egg survival. Therefore, Reclamation only proposes pulse flows if projected May 1 Shasta storage indicates a likelihood of sufficient cold water to support summer cold water pool management (likely storage greater than 4 MAF). Reclamation would not make a spring pulse release if the release would cause Reclamation to drop into a Tier 4 Shasta summer cold water pool management (i.e., the additional flow releases would decrease cold water pool such that summer Shasta temperature management drops in Tier 4), would interfere with meeting performance objectives, or would interfere with the ability to meet other anticipated demands on the reservoir.

5.6.3.2.2 Rearing to Outmigrating Juveniles in Upper and Middle Sacramento River

As indicated in the conceptual model, spring pulse flows could help trigger outmigration of Winter-run Chinook Salmon juveniles. See the Spring-run Chinook Salmon section for a discussion of benefits of spring pulses for outmigrating juveniles.

5.6.3.2.3 Adult Migration from Ocean to Upper Sacramento River

Spring pulses would have potentially beneficial effects for Winter-run Chinook Salmon adults who are migrating up the Sacramento River in the late spring. As indicated in the conceptual model, the spring pulses could cool temperatures, improved dissolved oxygen, and help avoid stranding, allowing for better passage and increased adult survival.

5.6.3.3 Fall and Winter Refill and Redd Maintenance

5.6.3.3.1 Egg to Fry Emergence

As shown in the conceptual model, flow releases affect stranding/dewatering, dissolved oxygen, and temperature. The proposed action would allow for higher fall flows than WOA, leading to less dewatering of the last few emerging Winter-run Chinook Salmon redds. The proposed action would also reduce overall instances of temperature dependent mortality compared to the COS, as reduced fall flows helps to build storage for the next year, but may result in dewatering limited redds in certain years in order to protect the next year's cold water resource. Rearing to Outmigrating Juveniles in Upper and Middle Sacramento River

Winter-run Chinook Salmon rearing and outmigrating juveniles would experience higher fall flows than under WOA, leading to more food, rearing habitat, and cover. Flows would be similar to those under COS, or lower.

5.6.3.4 Delta Seasonal Operations

Under WOA conditions, the Delta Cross channel would be closed and no CVP or SWP diversion would occur. The proposed action stores water in the fall, winter, and spring for release and conveyance through the Delta in the summer and fall.

5.6.3.4.1 Rearing to Outmigrating Juveniles in Bay-Delta

Rearing Winter-run Chinook Salmon are present in the Delta between October and May. Key habitat attributes relevant to seasonal operations in the Delta include outmigration cues and entrainment risk.

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 5.6-35 provides a simplified conceptual model of the DLO defined by the CAMT SST.

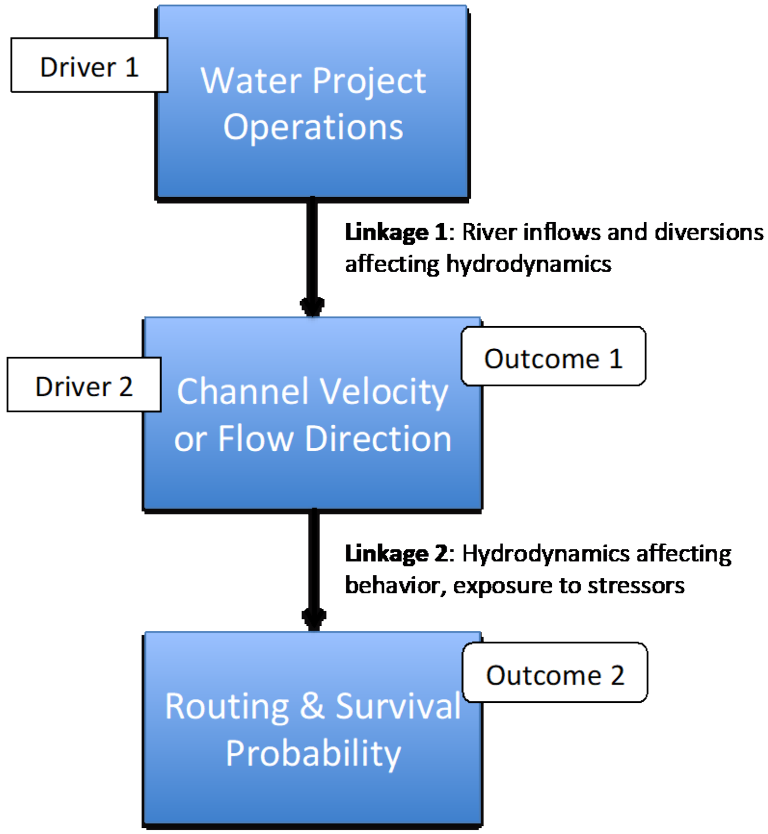


Figure 5.6-36. Conceptual Model for Far-field Effects of Water Project Operations on Juvenile Salmonids in the Delta. This CM is a Simplified Version of the Information Provided by the CAMT SST.

In order to assess the potential for water project operations to influence survival and routing, Reclamation and DWR analyzed Delta hydrodynamic conditions by creating maps from DSM2 Hydro modeling. The maps are based on a comparative metric, proportion overlap (more below), to capture channel-level hydrodynamic details as a single number for color-scale mapping of Delta channels.

The objective of the comparative metric is to summarize the water velocity time series for each channel and scenario such the channel-level comparison is captured in a single number. For the proportion overlap metric, kernel density estimates are calculated on each time series. The kernel density estimates represent a non-parametric smoothing of the empirical distribution of time series values. The proportion overlap of two kernel density estimates is calculated with the following steps: 1) calculate the total area under the curve (AUC_t) as the sum of the AUC for each density estimate, 2) calculate the AUC of the overlapping portions (AUC_o) of the two density distributions being compared, and 3) calculate the overlapping proportion of the density distributions as AUC_o/AUC_t. Proportion overlap is naturally bound by zero and one; a value of zero indicates no overlap and a value of one indicates complete overlap. Lower values of proportion overlap identify channels demonstrating larger differences in a scenario comparison.

The proportion overlap metric is best applied over relatively short time periods because seasonal and annual variation in water velocity can overwhelm differences between scenarios. Thus, Reclamation calculated proportion overlap for every DSM2 channel for two seasons (Dec-Feb, Mar-May) in each water year (1922-2003). DSM2 output was excluded from water year 1921 to allow for an extensive burn-in period. The proportion overlap was calculated based on hourly DSM2 output. Because each season was roughly 90 days, each comparison involved roughly 4,300 DSM2 values (2 scenarios * 24 hours * 90 days) for each channel.

Because the proportion overlap was calculated for each channel in each water year, the proportion overlap values were summarized prior to mapping (i.e., not feasible to map proportion overlap for every comparison in every water year). To summarize, the minimum and median proportion overlap for each channel for each water year type for each comparison was found. The minimum values represent the maximum expected effect. The median values represent the average expected effect. Note that the year with the minimum (or median) proportion overlap for one channel might not be the same year as for another channel.

5.6.3.4.1.1 Entrainment

As there are no exports under WOA, there is no entrainment risk under WOA. In the December through May period, the average total export rate, under the proposed action, is slightly higher compared to COS. Therefore, slightly higher entrainment is expected as compared to COS.

Zeug and Cavallo (2014) analyzed more than 1,000 release groups representing more than 28 million coded wire tagged juvenile fish including winter, late fall 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 between 0 and 1.5 percent (mean 0.1%) (Zeug and Cavallo, 2014). With total exports greater than 6,500 cfs, entrainment losses range between 0 and 4 percent (mean 0.25%) (Zeug and Cavallo, 2014). For December through February, the proposed action has an average total export rate similar to COS (7,988 and 7,622 cfs respectively; Figure H-1 – Appendix H, *Bay-Delta Aquatics Effects Figures*), and will therefore have similar entrainment risk. In the March through June period, total exports for the proposed action increase entrainment risk relative to COS (5,873 vs. 4,174 cfs, respectively; Figure H-2 – Appendix H, *Bay-Delta Aquatics Effects Figures*), but entrainment losses should average 0.1 percent and not exceed 1.5 percent. While entrainment risk will increase under the proposed action as compared to WOA or COS, the proposed action includes restrictions to OMR (-3,500 cfs and -2,500 cfs) when loss of Winter-run Chinook salmon or steelhead reaches 50 percent of the annual loss threshold. CalSim modeling incorporates an assumption for this cumulative salvage restriction.

According to SacPAS (Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*), between 0 and 6000 unclipped Winter-run Chinook salmon are currently salvaged at CVP and SWP fish facilities each year, and between 0 and 8000 clipped Winter-run Chinook salmon from the Livingston Stone Fish Hatchery. Salvage estimates are made by counting fish for 30 minutes every 2 hours, and multiplying by 4 to obtain the estimate for the number of fish that are entrained into Tracy Pumping Plant or eaten by predators in the canal or fish facility. Entrainment results in harassment and often mortality for juvenile Chinook salmon. Fish that are counted are salvaged and trucked back to the Delta where they are released and may complete their lifecycle.

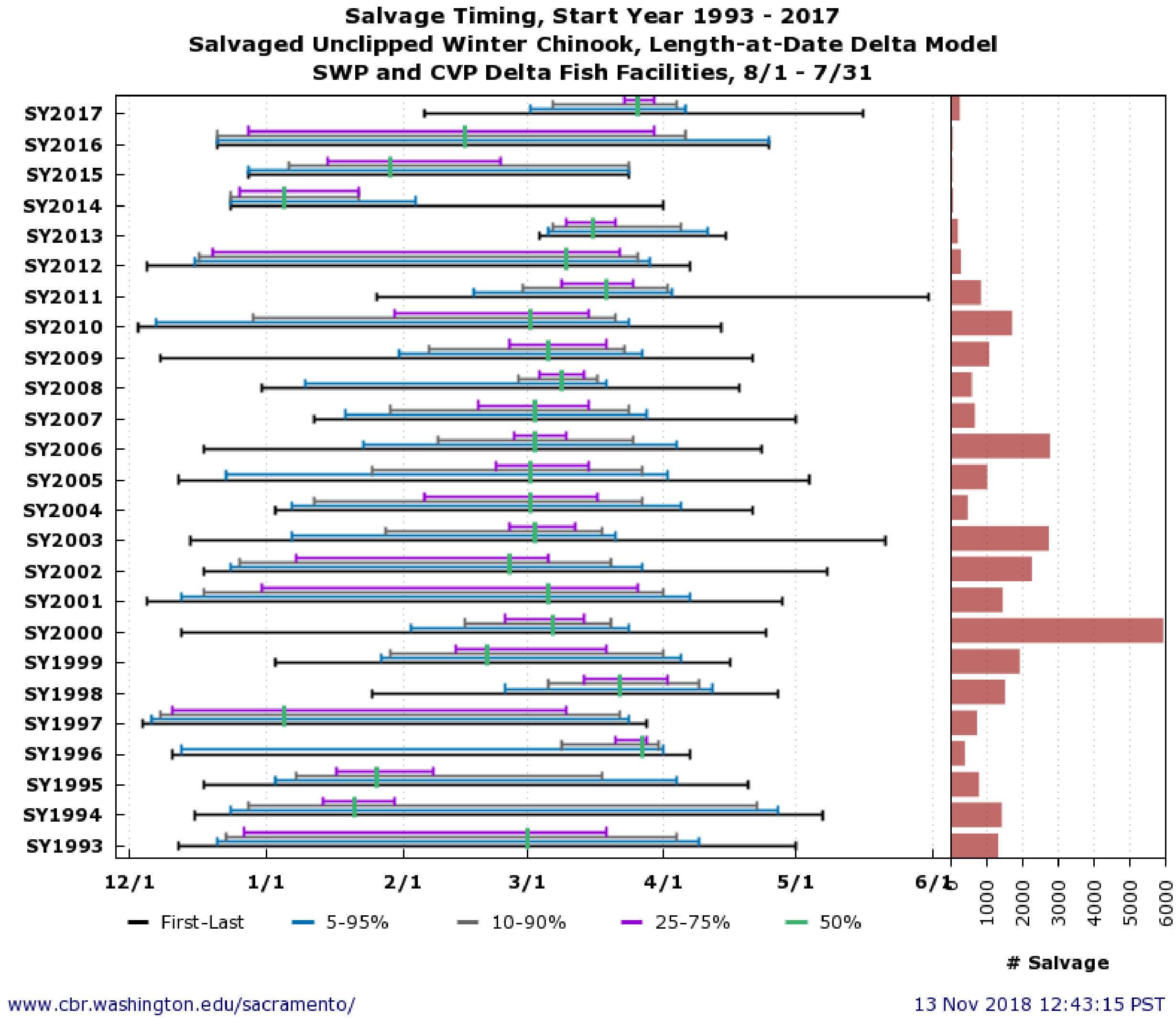


Figure 5.6-37. Juvenile Winter-run Chinook Salmon salvage at Jones and Banks Pumping Plants

5.6.3.4.1.2 Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from the proposed action were evaluated using DSM2. Juvenile Winter-run Chinook Salmon are present in the Sacramento River at Sherwood Harbor upstream of the first distributary junctions between November and March with peak abundance in February and March (Table 5.6-1).

Comparing the proposed action to WOA in the December to February period revealed velocity overlap <50% in Dry, Above Normal and Wet years and <60% in Critical and Below Normal years (Figure H-4 – Appendix H, *Bay-Delta Aquatics Effects Figures*) with higher velocities in the WOA scenario in all water year types. This pattern indicates routing into the interior Delta would be higher under the proposed action than under WOA (Perry et al. 2015). In the March to May period comparison of the proposed action revealed similar patterns of velocity overlap indicating routing into the interior Delta would be higher under the proposed action during March to May. Comparing the proposed action with WOA in March to May revealed low overlap in Sacramento River main stem velocities between the Steamboat-

Sutter Junction and the DCC-Georgiana Slough junction (Figure H-6– Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA scenario, indicating routing into the interior Delta under the proposed action would be higher than WOA.

Abundance of juvenile Winter-run Chinook Salmon at Chipps Island peaks in March and April but fish are collected between December and May (Table 5.61). During this time period, Winter-run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can potentially be exposed to hydrodynamic effects associated with the CVP and SWP that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. The December to February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin rivers between the proposed action and WOA (Figures H-7 and H-8 – Appendix H, *Bay-Delta Aquatics Effects Figures*).). Similar results were obtained when comparing the proposed action to WOA in the March to May period (Figures H-9 and H-10– Appendix H, *Bay-Delta Aquatics Effects Figures*).).

In the December to February period, velocity overlap between proposed action and COS in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was more than 50 percent in all water year types (Figure H-3 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under proposed action in all water year types in December through February indicating routing into the interior Delta would be lower relative to COS (Perry et al. 2015 described for the December-February period (Figure H-11 – Appendix H, *Bay-Delta Aquatics Effects Figures*).).

Overall, the proposed action results in lower flows in the Delta in the spring than under WOA, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the lower discharge at Freeport in the spring under the proposed action results in greater probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

5.6.3.4.1.3 Through-Delta Survival

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.

To examine potential effects of the proposed action, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, there are higher velocities under WOA than the proposed action (Figure H-12– Appendix H, *Bay-Delta Aquatics Effects Figures*). When the proposed action was compared to WOA at Steamboat Slough, overlap was moderate to high with values between 42.6 and 72.6 percent (Figure H-14– Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA in all water year types (Figure H-14– Appendix H, *Bay-Delta Aquatics Effects Figures*). In the March through May period at Walnut Grove, when the proposed action was compared to WOA, velocity overlap was variable among water year types from a low of 14.1% in Wet years to 56.9% in Critical years (Figure H-16– Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocity overlap was lower when proposed action was compared to WOA at Steamboat Slough in the March through May period (Figure H-18– Appendix H, *Bay-Delta Aquatics Effects Figures*). The lowest value occurred in Wet years (19.1%) and highest in Critical years (69.5%). In all water year types, velocities were greater under the WOA relative to the proposed action.

Overall, the proposed action results in lower flows in the Delta in the spring than under WOA, during the outmigrating juvenile time period. Survival probabilities are non-linear; however, the lower discharge at Freeport in the spring under the proposed action results in lower survival in the transition reaches. Lower flows also lead to greater probability of routing into the interior Delta, which has the lowest survival probability regardless of flow.

5.6.3.5 Delta Cross Channel Operations

5.6.3.5.1 <u>Rearing to Outmigrating Juveniles in Bay-Delta</u>

Under WOA conditions, the DCC would remain closed and Winter-run would not be entrained into the central and south Delta through the DCC. Under the proposed action, the DCC may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Winter-run Chinook Salmon in the Sacramento River at Sherwood Harbor, which is near the DCC, occurs from February through March (Table 5.6-1). Therefore, the DCC is closed for the majority of the juvenile Winter-run Chinook Salmon migration period in the Sacramento River and as such the proportion of juvenile Winter-run Chinook Salmon exposed to an open DCC would be negligible. Juvenile Chinook Salmon entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010; Perry et al. 2018).

5.6.3.6 Agricultural Barriers

Neither juvenile nor adult Winter-run Chinook Salmon are not expected to co-occur in space or time with the agricultural barriers indicating no potential impacts. After this point, in this document, if no effects are expected for a species, the proposed action component will not be discussed.

5.6.3.7 Contra Costa Water District Rock Slough Intake

CCWD's operations in the proposed action are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993; NMFS 2007; NMFS 2010; NMFS 2017; USFWS 1993a; USFWS 1993b; USFWS 2000; USFWS 2007; USFWS 2010; USFWS 2017; CDFG 1994; CDFG 2009). The subject of this consultation is the actual diversion of water through the Rock Slough Intake, covered under the 2009 biological opinion on the long-term coordinated operations of the CVP and SWP. However, since the 2009 biological opinion, the Rock Slough Fish Screen has been built, and entrainment of salmonids resulting from diverting water the into Rock Slough intake has been fully avoided. Adverse effects of fish screen operation are covered under the 2017 biological opinion.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Winter-run Chinook Salmon (NMFS 2017), approximately 18 miles from the Sacramento River via the shortest route. Designated critical habitat for Winter-run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017; NMFS 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures.

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of Winter-run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 13 juvenile Winter-run Chinook Salmon from January through May (CDFG 2002; NMFS 2017). From 1999-2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected no juvenile or adult Winter-run Chinook Salmon at the Rock Slough Headworks (Reclamation 2016; NMFS 2017).

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera 2018a), but none of the captured fish were identified as Winter-run Chinook Salmon (NMFS 2017).

NMFS issued a biological opinion in 2017 (NMFS 2017) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile Winter-run Chinook Salmon and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017). The incidental take provided in NMFS 2017 is five juvenile Winter-run Chinook Salmon per year.

5.6.3.7.1 Juveniles

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile Winter-run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmon can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in Old and Middle Rivers (OMR). Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). Mean velocity in a river channel can be calculated by dividing the flow rate by the cross-sectional area of the channel. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity). The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf (at low tide and low San Joaquin River flow) to 68,000 sf (at high tide and high San Joaquin River flow) as shown in Figure 5.6-36.

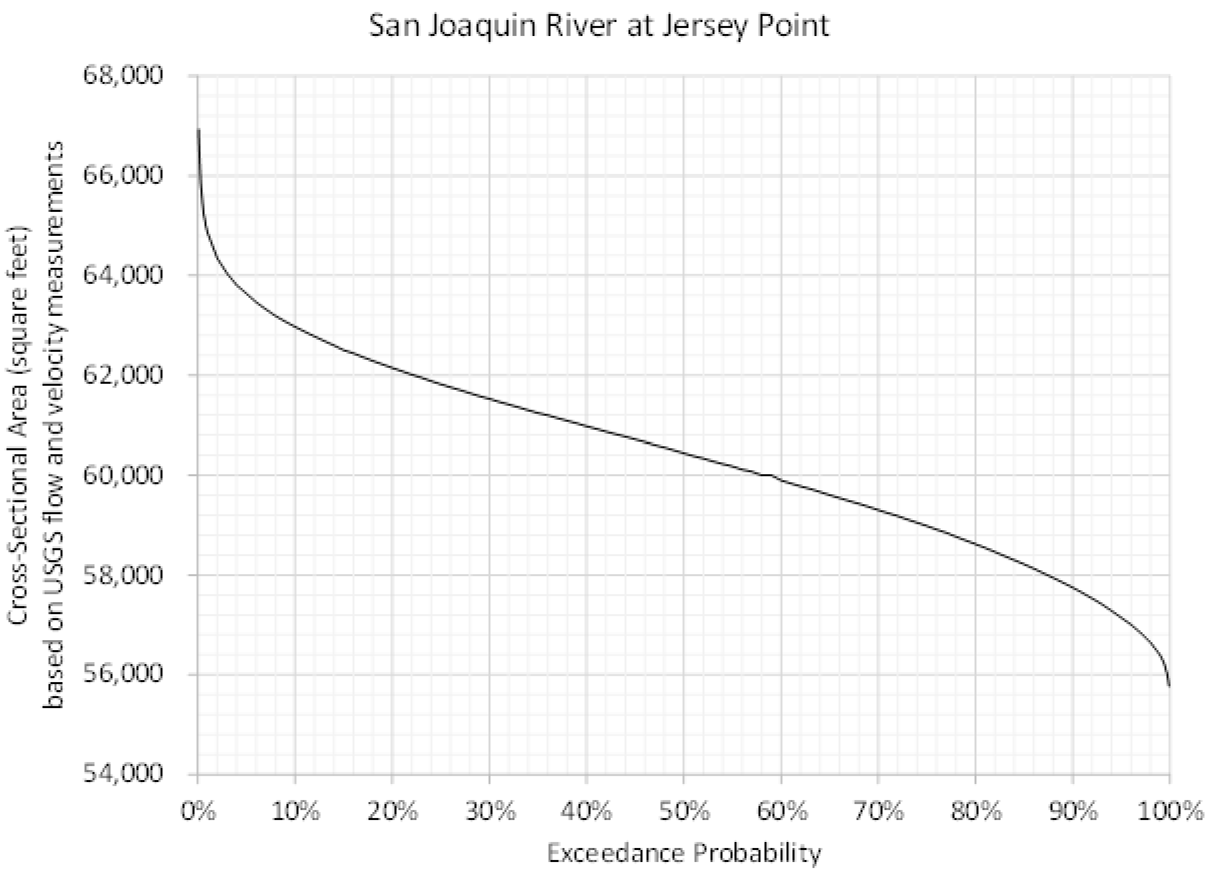


Figure 5.6-38. Cross-sectional area of the San Joaquin River at Jersey Point (Station: 11337190) Calculated from USGS Measurements of Flow and Velocity every 15 Minutes for Water Years 2014 through 2018.

The maximum effect of water diversions at Rock Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 square feet; resulting in 0.00625 feet per second (ft/sec). For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes is examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Winter-run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant articles such as phytoplankton. To examine the effect on neutrally buoyant particles, the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day is calculated. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is not significant in comparison to the tidal excursion and mixing at this location.

5.6.3.7.2 Adults

Rock Slough is poor habitat with relatively high water temperature and a prevalence of aquatic weeds. Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, and due to the poor quality of habitat within the slough, adult Winter-run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake and have never been observed in 24 years of fish monitoring (1994-2018). However, if some adults stray into Rock Slough, the water exiting the Contra Costa Canal on ebb tide may create a false attraction to adult salmon that are migrating upstream (NMFS 2017).

NMFS has advised Reclamation that salmonids will likely be less attracted to the area near the intake if tides can be reduced (Reclamation 2016). As illustrated in NMFS (2017) (Figure 10), water diversions at the Rock Slough Intake reduce the ebb tidal flows through the RSFS. Thus, the diversion of water at the Rock Slough Intake, which is the subject of this consultation, reduces the false attraction created by the ebb tides existing the Contra Costa Canal. Furthermore, it is worth noting that the ebb tidal flow in Rock Slough will be substantially reduced when the Contra Costa Canal is encased in a pipeline. This ongoing, multi-phased project (the Canal Replacement Project) is being conducted as a separate action by CCWD and has undergone separate environmental review. Completion of the Canal Replacement Project will result in tidal flows being significantly reduced at the Rock Slough Intake. Modeling of the area indicates that with only the first two phases complete, ebb flows reach up to 160 cfs, but with the Contra Costa Canal fully encased, ebb flows would be greatly muted to about 10 cfs.
Although the likelihood that adult Winter-run Chinook Salmon will be present near the Rock Slough Intake is low, a small number of fish could stray into Rock Slough, or be attracted by the flows exiting the Contra Costa Canal on ebb tides.

5.6.3.8 North Bay Aqueduct

The proposed action includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at https://www.wildlife.ca.gov/Regions/3). There should be no discernable effect to the Winter-run Chinook salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Winter-run Chinook salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

5.6.3.9 Water Transfers

Under the WOA scenaro, there is no pumping from the Delta and therefore no water transfers through Jones or Banks Pumping Plants. Under the proposed action, Reclamation is extending the water transfer window until November, from the current July through September window. This extension could result in increased flows entering the Delta and increased pumping at Jones and Banks Pumping Plants.

Egg, alevin, and fry lifestages of Winter-run Chinook Salmon do not occur in the Delta, and therefore would not be impacted by this action. Winter-run Chinook Salmon juveniles enter the Delta starting in December, and therefore would be unlikely to be exposed to increased pumping of water transfers through November. Adults returning from the ocean could possibly be in the Delta in July; however, they are strong swimmers, large fish that can avoid predators, and are unlikely to have impacts associated with direct entrainment of the pumping plants.

5.6.3.10 Clifton Court Aquatic Weed Removal

Juvenile Winter-run Chinook salmon are the only lifestage with a possibility of effects due to Clifton Court aquatic weed removal. Few if any juvenile Winter-run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Winter-run Chinook Salmon are present in the Delta between December and May with a peak in March and April (Table 5.6-1). The application of aquatic herbicide to the waters of CCF will occur during the summer months of July and August. Thus, the probability of exposing Winter-run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70 degrees Fahrenheit by mid-June. Mechanical harvesting would occur on an as-needed basis and, therefore, Winter-run Chinook Salmon could be exposed to mechanical harvesting, if entrained into the CCF.

5.6.3.11 OMR Management

The proposed action includes management of Old and Middle River reverse flows (OMR) to minimize risk of entrainment to fish species, including restricting OMR flows to -5000 cfs when between 5 and 95 percent of any salmonid species are in the Delta, or January 1 to June 30, whichever window is smaller. Delta seasonal operations above describe entrainment in more detail. Restricting OMR flows to -5,000 cfs will reduce or avoid entrainment. Triggers based on salvage that further restrict OMR will further reduce entrainment. Enhanced monitoring and predictive tools will further reduce entrainment while increasing operational flexibility. Figure 5.6-37 shows historical salvage under the COS. Salvage under the proposed action is anticipated to be similar or less.

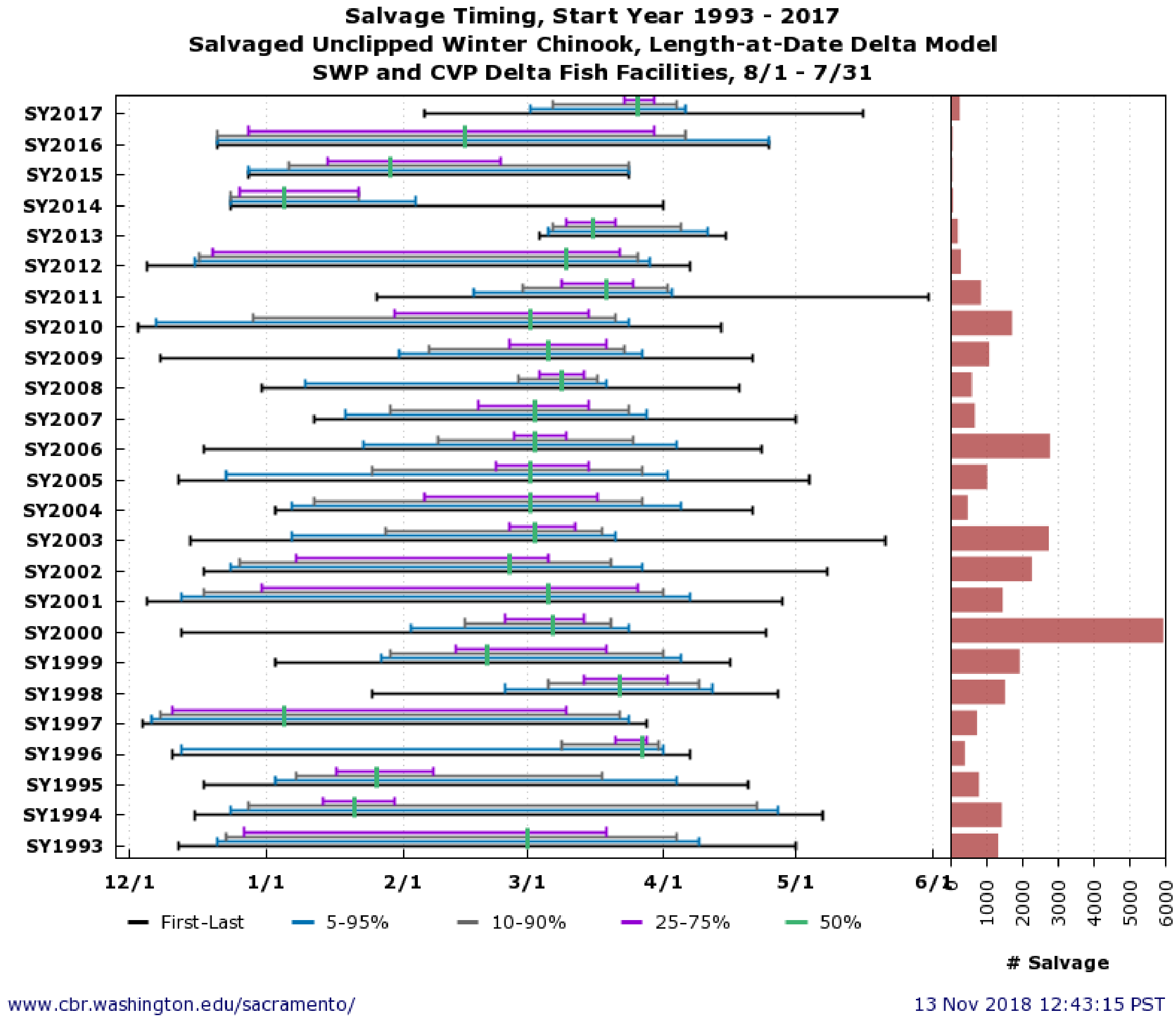


Figure 5.6-39. Salvage of Winter-run Chinook Salmon from 2009 to2018.

5.6.3.12 Operation of a Shasta Dam Raise

Reclamation would operate a raised Shasta Dam consistent with the rest of the proposed action. Therefore, effects described elsewhere in the document would also apply to the operation of a raised Shasta Dam, and there would be no operational changes.

5.6.4 Effects of Conservation Measures

The following are proposed conservation measures that are intended to offset the effects of operations and maintenance. These conservation measures would only occur due to the implementation of the Proposed Action and are beneficial in nature. The following analysis looks at the construction related effects of the measures and the benefits to the population once completed. Conservation measures would not occur under WOA.

5.6.4.1 Rice Decomposition Smoothing

Reclamation's proposed action to work with the SRS Contractors to smooth rice decomposition water demands would allow for higher fall flows than WOA, leading to less dewatering of the last few emerging Winter-run Chinook Salmon redds.

Under the proposed action, lower releases compared to the COS in late October and early November would result in late spawning Winter-run Chinook Salmon less likely to spawn in shallow areas that would be subject to dewatering during winter base flows.

Winter-run Chinook Salmon rearing and outmigrating juveniles would experience higher late fall flows than under WOA, leading to more food, rearing habitat, and cover.

5.6.4.2 Spring Management of Spawning Locations

Hendrix (2017) performed statistical analysis indicating that there is a correlation between warmer spring temperatures and later spawning Winter-run Chinook Salmon. This could result in an extended Shasta cold water pool management season beyond October 31. To offset this potential but uncertain effect, Reclamation will work with NMFS to experiment with spring temperatures and study the effects on spawning locations of Winter-run Chinook Salmon redds.

A spawning location study could result in beneficial or negative impacts to adult holding. Colder spring temperatures might allow for earlier spawning, and then emergence before temperatures have warmed in the late/summer and fall, leading to a successful life history strategy. Or, colder spring temperatures might result in Shasta Reservoir running out of cold water pool by the time of emergence, leading to mortality of Winter-run Chinook Salmon eggs or alevin.

5.6.4.3 Battle Creek Restoration

Under the Proposed Action, Reclamation would accelerate implementation of the Battle Creek Salmon and Steelhead Restoration Project. NMFS and USFWS Biological Opinions were issued in 2005 on this project, and that consultation discusses effects of Battle Creek restoration.

5.6.4.4 Lower Intakes near Wilkins Slough

5.6.4.4.1 Egg/Alevin Mortality

Egg and fry of Winter-run Chinook Salmon would not be affected by the construction of a new diversion and screens near Wilkins Slough, based Winter-run Chinook Salmon adults spawning from May through August with peak spawning during June and July (Table 5.6-1). Most spawning occurs within 10 miles of Keswick Dam (Windell et al. 2017) and spawning does not occur in Wilkins Slough. In addition, the construction of the diversion and screens would occur during an in-water work window (June 1 and October 1) so effects of construction on Winter-run Chinook Salmon eggs and fry would not occur. Replacement of the fish screens would allow for lower releases from Shasta in drought years and better preserve the cold water pool.

5.6.4.4.2 Egg to Fry Emergence

The installation of fish screens near Wilkins Slough would be beneficial to Winter-run Chinook Salmon egg and fry. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning.

Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages. The egg and fry lifestage of Winter-run Chinook Salmon, as well as the population, would benefit from this action.

5.6.4.4.3 Rearing to Outmigrating Juvniles in Upper Sacramento River

The installation of fish screens near Wilkins Slough would be beneficial to rearing and emigrating Winter-run Chinook Salmon in the Middle Sacramento River. As described earlier in rearing to outmigrating juveniles in the Upper Sacramento River. The rearing and emigrating Winter-run Chinook Salmon individuals in the middle Sacramento River, as well as the population, would benefit from this action.

Outmigrating juvenile Winter-run Chinook Salmon in the Upper Sacramento River would not be affected by the construction of a new diversion and fish screens near Wilkins Slough, based Winter-run Chinook Salmon juveniles emigrating from October through February with peak emigration occurring from December through January (Table 5.6-1). Construction of diversions and fish screens near Wilkins Slough would occur during an in-water work window (June 1 and October 1) so effects of construction on emigrating Winter-run Chinook Salmon is not expected.

If rearing Winter-run Chinook Salmon are present during the June 1 through October 1 in-water work window, individuals may be exposed to temporary disturbances associated with the construction of a cofferdam. Water quality may be temporarily disturbed, in addition to noise associated with construction of the cofferdam. Additionally, fish rescue operations may need be conducted during the period when water within the coffered area needs to be pumped. However, implementation of AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further minimize those effects.

Construction of lowering intakes at Wilkins Slough would not have effects on rearing and emigrating Winter-run Chinook Salmon in the middle Sacramento River.

5.6.4.4.4 Rearing to Outmigrating Juveniles in Bay-Delta

Rearing to outmigrating juvenile Winter-run Chinook Salmon in the Bay-Delta would not be affected by the construction of a new diversion and fish screens near Wilkins Slough, based on Winter-run Chinook Salmon juveniles emigrating from October through February with peak emigration occurring from December through January (Table 5.6-1). Construction of diversions and fish screens near Wilkins Slough would occur during an in-water work window (June 1 and October 1) so effects of construction on rearing and emigrating Winter-run Chinook Salmon in the Bay-Delta is not expected.

5.6.4.4.5 Adult Migration from Ocean to Upper Sacramento River

The installation of fish screens near Wilkins Slough would be beneficial to immigrating adult Winter-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults. Additionally, the installation of new diversions and screens that would operate at lower flows would directly benefit fish of all life stages. Individual immigrating adult Winter-run Chinook Salmon, as well as the population, would benefit from this action.

Immigrating adult Winter-run Chinook Salmon would not be affected by the construction of a new diversion and fish screens near Wilkins Slough, based on adult Winter-run Chinook Salmon immigrating through the Delta into the Sacramento River Basin between December through April (Table 5.6-1). Construction of diversions and fish screens near Wilkins Slough would occur during an in-water work window (June 1 and October 1) so effects of construction on immigrating Winter-run Chinook Salmon in the Bay-Delta is not expected.

5.6.4.4.6 Adult Holding in the Upper Sacramento River

Wilkins Slough nor the Sacramento River near Wilkins Slough does not contain the necessary cool water habitat for holding Winter-run Chinook Salmon. Therefore, construction of a new diversion and fish screens near Wilkins Slough would not affect holding Winter-run Chinook Salmon.

5.6.4.5 Shasta Temperature Control Device Improvements

If feasibility analysis leads to construction of TCD improvements, improvements to the Shasta TCD would potentially improve performance of the structure that maintains suitable temperatures for Winter-run Chinook Salmon that spawn in the upper Sacramento River (from Keswick Dam to the Red Bluff Diversion Dam) from May through August, with peak spawning during June and July (Table 5.6-1). Fry emergence occurs up to two months after eggs are spawned, so effects of water temperature and flow in the upper Sacramento River on Winter-run Chinook Salmon fry and alevins potentially occur from May through October, but occur primarily during June through September. The ability to better manage the cold water pool and cold water releases would result in increased probability and likelihood of maintaining suitable spawning, incubating, and rearing temperatures throughout the season in all but the driest years.

The improved flow management associated with the Shasta TCD improvements under the proposed action would be expected to provide some benefit to adult Winter-run Chinook Salmon adults relative to the COS and WOA.

5.6.4.6 Sacramento River Spawning and Rearing Habitat

5.6.4.6.1 Egg/Alevin Mortality

Reclamation proposes to create additional spawning habitat by injecting 40-55 tons of gravel into the Sacramento River by 2030, using the following sites: Salt Creek Gravel Injection Site, Keswick Dam Gravel Injection Site, South Shea Levee, Shea Levee, and Tobiasson Island Side Channel. This additional spawning habitat would help meet the spawning habitat needs on the Sacramento River, shown below. At least an additional 100 acres of spawning habitat is needed to support the target Winter-run Chinook Salmon doubling goal population of 110,000 returning adults. Additional gravel would lead to improved hyporheic flow to move dissolved oxygen to redds, and reduced density-dependent spawning effects (unlikely due to current low population size).

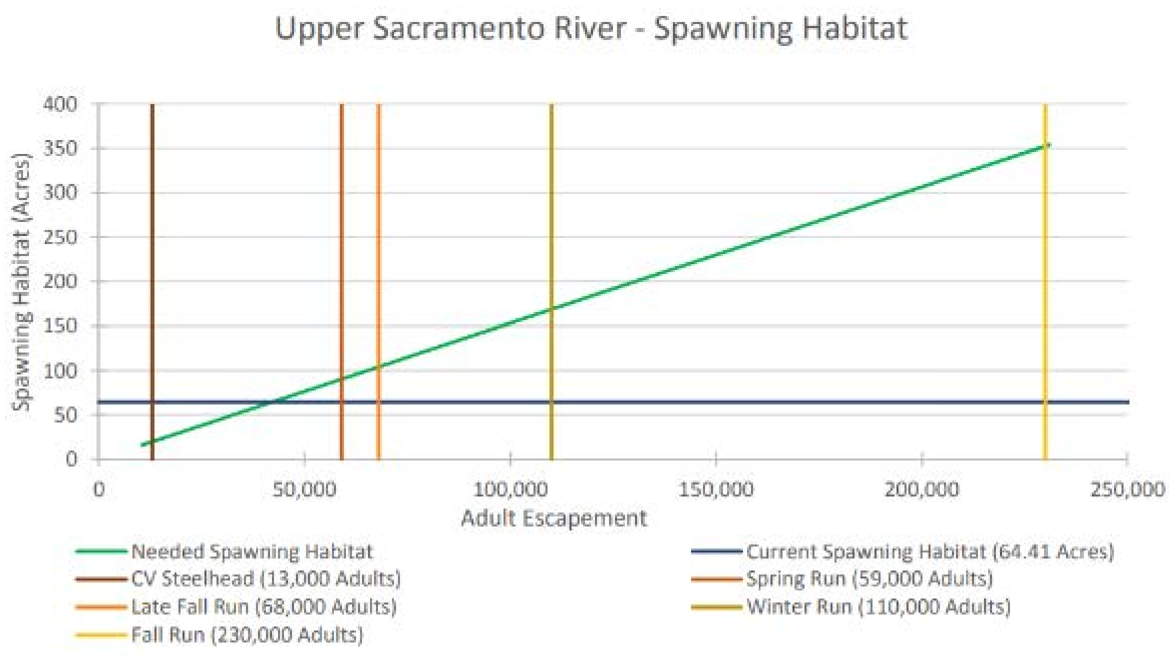


Figure 5.6-40. Spawning Habitat versus Adult Escapement

Construction of spawning and rearing habitat could affect Winter-run Chinook Salmon eggs in the river. Based on the proposed in-water work windows for the upper Sacramento River (see AMM2 *Construction Best Management Practices and Monitoring* in Appendix E, *Avoidance and Minimization Measures*), Winter-run Chinook Salmon adults, eggs, and alevins would be subject to potential adverse effects from proposed spawning (e.g, gravel augmentation) and rearing habitat (e.g., side channel) restoration projects in the upper Sacramento River associated with the proposed action. Construction activities could result in mortality of eggs and alevins by crushing if heavy equipment enters the stream channel or otherwise disturbs existing redds during in-water activities. Eggs and alevins could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality in the redd (e.g., reduced flow and dissolved oxygen from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants. Although these potential effects may be unavoidable, exposure of the Winter-run Chinook Salmon population to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of spawning adults, and the implementation of other AMMs described in Appendix E, *Avoidance and Minimization Measures*. These measures include AMM1, which requires worker awareness training, AMM2, which specifies monitoring oversight by a qualified biologist, and AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment.

5.6.4.6.2 Egg to Fry Emergence

See egg mortality above.

5.6.4.6.3 Rearing to Outmigrating Juveniles in Upper Sacramento River

Reclamation and the SRSC propose to create 40-60 acres of side channel habitat at no fewer than 10 sites in Shasta and Tehama County by 2030, including Cypress Avenue, Shea Island, Anderson River Park; South Sand Slough; Rancheria Island; Tobiasson Side Channel; and Turtle Bay. Creation of this additional 40-60 acres of rearing habitat would help increase the quantity and quality of Winter-run Chinook Salmon juvenile rearing habitat in the Upper Sacramento River. Reclamation estimates that this additional 50 acres of rearing habitat could support the progeny of 5,600 returning adult salmonids based on the relationship shown in the plot below.

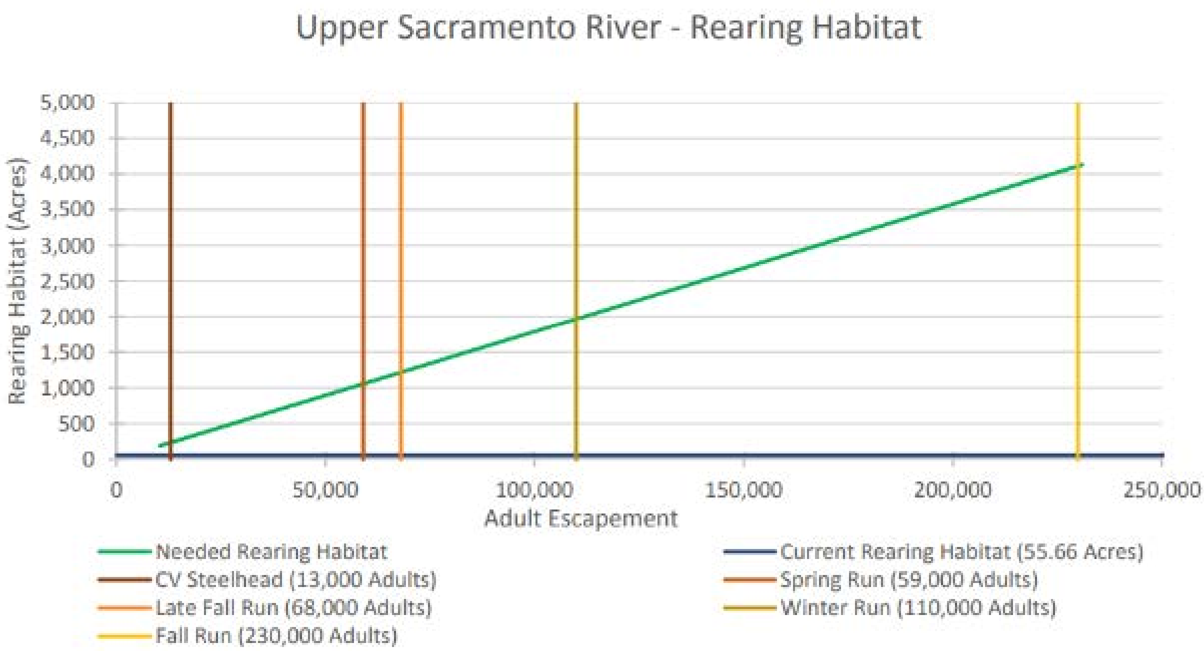


Figure 5.6-41. Rearing habitat versus Adult Escapement

Construction of spawning and rearing habitat could lead to some impacts to early rearing fry in the upper Sacramento River. See egg mortality above for a discussion of effects and minimization measures.

5.6.4.6.4 Rearing to Outmigrating Juveniles in Middle Sacramento River

See rearing to outmigrating juveniles in the Upper Sacramento River above.

5.6.4.6.5 Adult Migration from Ocean to Upper Sacramento River

Winter-run Chinook Salmon adults would not be exposed to benefits or construction impacts of spawning and rearing habitat as they are not co-located in time or space.

5.6.4.6.6 Adult Holding in the Upper Sacramento River

Additional spawning habitat could also benefit adults holding upstream. See egg mortality above.

5.6.4.7 Small Screen Program

5.6.4.7.1 Egg to Fry Emergence

No egg-to-emergence Winter-run Chinook Salmon would be exposed to fish screens since this life stage occurs within the redds and would not be exposed to fish screens. Therefore, there would be no effects from the operation of fish screens for this life stage.

Sacramento River Winter-run Chinook Salmon in the egg-to-emergence life stage may be exposed to the effects of construction of screens on water diversion intakes since this live stage occurs during the typical timing of in-water construction (July 15–October 15). Embryo and alevin development in the redd occurs in the spring through mid-October, following the mid-April to mid-August spawning period (peaking in June), lasting 10 to 14 weeks, (Vogel and Marine 1991) with fry emerge from the gravel occurring from late July to early August and continuing through October (Fisher 1994). Since spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities (Fisher 1994), there is the potential for redds to occur in the work areas or in the direct vicinity of the construction sites. However, these work areas are localized and the number of redds is expected to be low. Potential effects include the disturbance of redds and temporary, localized fine sediment disturbance and deposition in spawning and embryo incubation areas directly adjacent construction sites. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*.

5.6.4.7.2 Rearing to Outmigrating Juveniles in Upper Sacramento River

The operation of fish screens on water diversions would beneficially affect juvenile Winter-run Chinook Salmon in the upper Sacramento River by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for adverse effects to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage. Therefore, it is concluded that the operation of fish screens would result in beneficial effects for this life stage, due to the reduced risk of entrainment and injury.

Few juvenile Winter-run Chinook Salmon in the upper Sacramento are expected to be exposed to the effects of construction of screens on water diversion intakes. Since Winter-run Chinook Salmon exhibit both ocean-type and stream-type life histories, juveniles are present near year-round (Table 5.6-1) and will likely be present during the timing of in-water construction (July 15 – October 15), the work area for these projects is small, limiting exposure to construction. Potential short-term adverse effects may include temporary degradation of water quality, including increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (i.e., increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be would be minimized through the implementation of general AMMS identified in Appendix E, *Avoidance and Minimization Measures*. In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.6.4.7.3 Rearing to Outmigrating Juveniles in Middle Sacramento River

The operation of fish screens on water diversions would beneficially affect juvenile Winter-run Chinook Salmon in the middle Sacramento River by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for adverse effects to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage. Therefore, it is concluded that the operation of fish screens would result in beneficial effects for this life stage, due to the reduced risk of entrainment and injury.

Few juvenile Winter-run Chinook Salmon rearing and outmigrating in the middle Sacramento River are expected to be exposed to the effects of construction of screens on water diversion intakes. Since Winter-run Chinook Salmon exhibit both ocean-type and stream-type life histories, juveniles are present near year-round and use this reach for rearing and migration (NMFS 2014) and will likely be present during the timing of in-water construction (July 15 – October 15), the work area for these projects is small, limiting exposure to construction.

Potential short-term adverse effects may include temporary degradation of water quality, including increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (i.e., increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.6.4.7.4 Rearing to Outmigrating Juveniles in Bay-Delta

There may be some overlap Winter-run Chinook Salmon with the main late spring-fall irrigation period for small diversions. Diversion screening could reduce entrainment of late migrating individuals. It is important to note that only a small proportion of the population would be exposed.

Few if any juvenile Winter-run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Winter-run Chinook Salmon primarily migrate from November through early May (NMFS 2014), largely outside of the timing of in-water construction (July 15 – October 15). In addition, the work area for these projects is small, limiting exposure to construction.

5.6.4.7.5 Adult Migration

The operation of fish screens on water diversions would beneficially affect migrating adult Winter-run Chinook Salmon by reducing the entrainment of fish into unscreened or poorly screened diversions.

Few if any adult Winter-run Chinook Salmon are anticipated be exposed to the effects of construction of screens on water diversion intakes. The adult immigration occurs from December through July, the majority pass RBDD from January through May (peaking in mid-March) (NMFS 2009; NMFS 2014), which is largely of the timing of in-water construction (July 15 – October 15). AMMs would reduce any risk.

5.6.4.7.6 Adult Holding

The operation of fish screens on water diversions would beneficially affect adult Winter-run Chinook Salmon holding in the upper Sacramento River by reducing the entrainment of fish into unscreened or poorly screened diversions.

Adult Winter-run Chinook Salmon in may be exposed to the effects of construction of screens on water diversion intakes based on the timing of in-water construction (August–October), the May through August spawning period for (NMFS 2014). AMMs would reduce any risk.

5.6.4.8 Conservation Hatchery (Winter-run Chinook Salmon)

Expansion of Livingston-Stone National Fish Hatchery would allow increased operation to sustain Winter-run Chinook Salmon, particularly during drought years. The purpose would be to provide artificial rearing and spawning habitat when in-river environmental conditions (low flow and high temperatures) are not suitable for egg-fry life stages. Expanded hatchery production may address most SAIL CM components. Effects of increased hatchery production will depend on complex interactions between hatchery and natural-origin fish and their environment. It will be important to couple other conservation measures together with increased production to ensure that it addresses losses of natural production. For example, if in-river conditions are not conducive to migration downriver, fish produced at the hatchery may need to be trucked to a point with higher downstream survival. Livingston-Stone National Fish Hatchery operates an “integrated” hatchery program with the intention of minimizing genetic divergence between hatchery and natural components of the population by exchanging spawners between them (Paquet et al. 2011). A natural consequence of expanding numbers of hatchery fish is an increase of hatchery origin fish on in-river spawning grounds. This coupled with low survival of natural-origin fish may influence the genetic management criteria to include hatchery-origin spawners and variable numbers of males and females under drought conditions.

5.6.4.9 Adult Rescue (Yolo and Sutter Bypasses)

Existing facilities such as the updated Fremont Weir ladder and Wallace Weir fish rescue facility have improved fish passage in the Yolo Bypass and between the bypass and the river, however, there is still the potential for stranding in isolated pools when hydrologic connectivity is not possible within the Yolo Bypass. Under certain circumstances with the proposed action, adult fish rescue may still be necessary at Fremont Weir.

Under the proposed action, the Yolo Bypass Salmonid Habitat Restoration and Fish Passage project provides additional adult fish passage at different locations and additional times compared to WOA and COS. Under the WOA, these facilities would exist but would not be operated for fish passage and rescue. Additionally, under the proposed action Reclamation would undertake, fund, and/or assist in adult fish rescue operations as needed at Fremont, Wallace, and Tisdale Weirs, which would not occur under the WOA. The proposed action and COS would provide more passage and rescue and more opportunities for adult spawning Winter-run Chinook Salmon compared to the WOA.

5.6.4.9.1 Egg to Fry Emergence

The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult Winter-run Chinook Salmon, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the the number of Winter-run Chinook Salmon eggs and emerging fry in the Sacramento River from increased spawner abundance.

5.6.4.9.2 Rearing to Outmigrating Juveniles in Middle Sacramento River

Juvenile Winter-run Chinook Salmon occur in the Yolo and Sutter Bypasses when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. Although they are unlikely to occur in the bypasses during periods when flow does not overtop the weirs, proposed modifications to the Fremont Weir to increase inundation of the Yolo bypass for floodplain rearing would provide juveniles with more consistent access to the Yolo bypass. Therefore, these juveniles could be exposed to the effects of adult rescue activities if they become stranded with adults that are targeted by adult rescue activities. The number of juvenile Winter-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the timing of proposed adult rescue activities, gear type used to rescue adults, and the typical seasonal occurrence of this life stage in the Yolo and Sutter bypasses.

Individual juvenile Winter-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality during efforts to capture stranded adults, handling and transport. Injury and increased stress associated with capture, handling, and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Winter-run Chinook Salmon would be expected to be offset by benefits associated with increased numbers of adult Winter-run Chinook Salmon returning to spawning grounds.

As such, it is concluded that there will be no impacts from from adult rescue activities in the proposed action on this life stage of Winter-run Chinook Salmon (no rescue of adult Winter-run Chinook Salmon).

5.6.4.9.3 Rearing to Outmigrating Juveniles in Bay-Delta

Adult fish rescue in the Yolo Bypass and Sutter Bypasses does not affect environmental conditions such as juvenile rearing and migration in the tidal estuary and bays that influence the timing, condition and survival of juvenile Winter-run Chinook Salmon in the middle Sacramento River. This action would not have impacts to this life stage, aside from beneficial indirect effects of increased potential spawners.

5.6.4.9.4 Adult Migration from Ocean to Upper Sacramento River

Exposure of this life stage to adult rescue effects would be restricted only to those adult Winter-run Chinook Salmon that become stranded in the Yolo and Sutter Bypasses and subsequently rescued and released to the Sacramento River. Adults that migrate in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by adult rescue activities. The number of adult Winter-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the abundance of adults that stray into the bypasses and the timing and frequency of stranding events in the bypasses.

Individual adult Winter-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality, which could vary in intensity depending on the techniques used to capture individuals. Injury and increased stress associated with capture, handling and transport may affect survival of affected individuals after release. The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*). Adult Winter-run Chinook Salmon that are rescued may be exposed to detrimental effects; however, individuals would have greater opportunities for spawning success compared to WOA.

As such, it is concluded that the overall population-level effects would be beneficial on this life stage of Winter-run Chinook Salmon from adult rescue activities relative to WOA (no rescue of stranded adult Winter-run Chinook Salmon in Yolo and Sutter bypasses).

5.6.4.10 Juvenile Trap and Haul (Winter-run Chinook Salmon)

5.6.4.10.1 Rearing to Outmigrating Juveniles in Upper Sacramento River

The number of juvenile Winter-run Chinook Salmon that would be expected to be exposed to the effects of juvenile trap and haul activities would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trapping efficiency, and the typical seasonal occurrence of this life stage in the Sacramento River (Table 5.6-1). Individual juvenile Winter-run Chinook Salmon exposed to juvenile trap and haul activities would be at risk of increased stress, injury, and/or mortality. Injury and increased stress associated with handling and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release.

Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Winter-run Chinook Salmon would be expected to be offset by benefits associated with expected increased survival of the overall brood-year of Winter-run Chinook Salmon. Juvenile Winter-run Chinook Salmon would benefit from juvenile trap and haul activities relative to WOA (no trapping and hauling of juvenile Winter-run Chinook Salmon during drought years).

5.6.4.10.2 Rearing to Outmigrating Juveniles in Middle Sacramento River

If temporary juvenile collection weirs are placed in Middle Sacramento River, potential effects associated with juvenile trap and haul on this life stage would be same as those described above for the rearing to outmigrating juveniles in the upper Sacramento River life stage.

5.6.4.10.3 Rearing to Outmigrating Juveniles in Bay-Delta

Exposure of this life stage to trap and haul effects would be restricted only to those juvenile Winter-run Chinook Salmon trapped in the upper and middle Sacramento River and subsequently released to the lower Sacramento River and/or Bay-Delta. Wild juveniles that migrate in-river to the Bay-Delta (either before December 1 or that avoid capture by the temporary juvenile collection weirs after December 1) would not be affected by juvenile trap and haul activities. Potential effects associated with juvenile trap and haul on this life stage would be same as those described above in for the rearing to outmigrating juveniles in the upper Sacramento River life stage.

5.6.4.10.4 Adult Migration

Because transported juveniles are more likely to have impaired homing behavior as adults, juvenile trap and haul activities may increase the rate of straying by returning adults. Adults that stray into tributaries or that are otherwised delayed from reaching adult holding areas in the Upper Sacramento River would not be expected to spawn successfully because of the lack of suitable habitat in tributaries. Negative effects on this life stage of adult Winter-run Chinook Salmon from juvenile trap and haul activities would be small compared to WOA (no trapping and hauling of juvenile Winter-run Chinook Salmon during drought years) and would be potentially offset by benefits (increased juvenile survival and ultimately increased adult escapement) associated with the juvenile trap and haul program.

5.6.4.11 American River Spawning and Rearing Habitat

Pursuant to CVPIA 3406(b)(13), Reclamation proposes to implement the Cordova Creek Phase II and Carmichael Creek Restoration projects, and increase woody material in the American River. Reclamation also proposes to conduct gravel augmentation and floodplain work at: Paradise Beach, Howe Ave, Howe Avenue to Watt Avenue, William Pond Outlet, Upper River Bend, Ancil Hoffman, Sacramento Bar - North, El Manto, Sacramento Bar - South, Lower Sunrise, Sunrise, Upper Sunrise, Lower Sailor Bar, Nimbus main channel and side channel, Discovery Park, and Sunrise Stranding Reduction.

Juvenile Winter-run Chinook Salmon in the middle Sacramento River may use the lower American River as non-natal rearing habitat during late fall and winter. The habitat improvements in the American River would increase quality and quantity of rearing habitat available to juvenile Winter-run Chinook Salmon and be a net benefit to the population. The additional rearing habitat is not expected negatively impact juveniles. Winter-run Chinook Salmon naturally emigrate once they reach a threshold size in the spring, before temperature in the lower Sacramento River and Delta warm to inhospitable levels, indicating there should not be danger of attracting and holding juveniles in American River habitat too far into the warmer time of year.

Spawning and rearing habitat project construction occurs in the American River from July to October, outside the time when Winter-run Chinook Salmon juveniles would be present so there would be no impact on the species from construction activities.

5.6.4.12 Sacramento Deepwater Ship Channel

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall to provide foodweb benefits to Delta Smelt. Juvenile Winter-run Chinook Salmon may be exposed to the Sacramento Deepwater Ship Channel (SDWSC) component of the proposed action. Juvenile Winter-run Chinook Salmon abundance downstream of Stone Lock at Sherwood Harbor is highest in February and March, declines in April, and is moderate in November (Table 5.6-1). Juvenile Winter-run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be routed into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, if survival rates are similar, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit associated with the proposed action.

A hydrologically connected SDWSC could potentially attract adult Winter-run Chinook Salmon. If the connection is maintained there would likely not be impacts to adults. However, if the connection is not maintained there could be migratory delays and stranding.

5.6.4.13 North Delta Food Subsidies/Colusa Basin Drain Study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Winter-run Chinook salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

5.6.4.14 Suisun Marsh Roaring River Distribution System Food Subsidies Study

Under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Winter-run Chinook salmon, who are in the Delta between December and May for juveniles, and December to July for adults.

5.6.4.15 Tidal Habitat Restoration (8,000 acres)

Although migration through the Delta represents a short period, a large proportion of juvenile Winter-run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Winter-run Chinook Salmon in several aspects represented by the Winter-run Chinook Salmon conceptual model, (Figure 5.6-4) including increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Reclamation and DWR will consult on future tidal habitat restoration with USFWS and NMFS on potential effects to fish from construction-related effects.

5.6.4.16 Predator Hot Spot Removal

5.6.4.16.1 Rearing to Outmigrating Juveniles in Upper Sacramento River

Winter-run Chinook Salmon juveniles could be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer/fall when Winter-run Chinook Salmon juveniles are generally in the upper river. AMMs will be used to avoid and minimize impacts from construction including crushing, impingement, mortality, noise, and harassment.

5.6.4.16.2 Rearing to Outmigrating Juveniles in Middle Sacramento River

See rearing to outmigrating juveniles in the upper Sacramento River.

5.6.4.16.3 Rearing to Outmigrating Juveniles in Bay-Delta

Predator hot spot removal is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Winter-run Chinook Salmon. Although the proposed action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Winter-run Chinook Salmon. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012, Michel et al. 2017, Sabal et al. 2017). Winter-run Chinook Salmon juveniles in the Bay-Delta are unlikely to be exposed to the effects of construction at predator hot spot removal locations in the Sacramento River, as the in-water work window is in the summer/fall when Winter-run Chinook Salmon juveniles are generally in the upper river.

5.6.4.17 Knight's Landing Outfall Gates Fish Barrier

Reclamation and DWR's fish barrier at the Knight's Landing Outfall Gates would prevent possible entrainment of salmonids into the Colusa Basin Drain. This project would reduce entrainment and therefore increase survival of Winter-run Chinook salmon adults.

Few Winter-run Chinook salmon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.6.4.18 Delta Cross Channel Gate Improvements

The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Winter-run Chinook salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Few Winter-run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Winter-run Chinook Salmon juveniles to entrainment into the interior Delta. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased routing into the interior Delta and subsequent entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

5.6.4.19 Tracy Fish Facility Improvements

A small proportion of juvenile Winter-run Chinook Salmon are expected to be exposed to the Tracy Fish Facility (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility. Winter-run Chinook Salmon adults would not be expected to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility, based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Table 5.6-1).

Few if any juvenile Winter-run Chinook Salmon would be expected to be exposed to construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements based on lack of observed salvage during the August–October in-water work window (Figures F.2.7, F.2.8, and F.2.9 in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*). However, a few early migrants could occur during the in-water work window based on occurrence in the north Delta (Figures WR_Seines and WR_Sherwood in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*).

To the extent that the construction affects the ability of juvenile Winter-run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure 5.6-44), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate AMMs (Appendix E, *Avoidance and Minimization Measures*). There is low potential exposure because of the in-water work window, the application of AMMs, and the small scale of the in-water construction.

5.6.4.20 Skinner Fish Facility Improvements

Skinner Fish Facility improvements from predator control efforts to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile Chinook Salmon entrained into

CCF. It is important to note that only small proportions of Winter-run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014). Measures that would be implemented include electroshocking of predators, and removal of aquatic weeds. Any Winter-run Chinook salmon incidentally collected during the electrofishing will be identified, genetic tissue samples archived as permitted, and released back into CCF. Winter-run Chinook salmon that are present in the vicinity of the electrofishing boats will be exposed to the electrical current within the water column when the boats are actively fishing. However, the greater length of the predatory fish creates a greater voltage gradient along the length of the fish, and thus less voltage is needed to anesthetize the larger predatory fish in the electric field. Therefore, anticipated effects on Winter-run Chinook salmon are low. The proposed action includes measures to avoid and minimize effects on listed species of the aquatic weed removal.

5.6.4.21 Delta Fishes Conservation Hatchery

The operation of the Delta Fish Species Conservation Hatchery would not provide benefits to any life stage of Winter-run Chinook Salmon. Potential negative effects of the Delta Fish Species Conservation Hatchery include inadvertent propagation and spread of invasive or nuisance species, which could affect juvenile Winter-run Chinook Salmon through changes in food web structure, for example, in the case of invasive quagga and zebra mussels (Fera et al. 2017). Additional impacts could include reduced water quality resulting from hatchery discharge. Potential negative effects from discharged water are expected to be minimal due to the water treatment and the very small size of the discharge compared to flows in the Sacramento River near the hatchery location. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Winter-run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Winter-run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Table 5.6-1). There may be some exposure of early migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (Figures F.2.4 and F.2.5 in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*). There is low potential exposure because of the in-water work window, the application of AMMs, and the small scale of the in-water construction.

Winter-run Chinook Salmon adults would not be expected to be exposed to the effects of construction of construction of the Delta Fish Species Conservation Hatchery based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Table 5.6-1).

5.6.5 Effects of Monitoring

A number of monitoring activities described in Appendix C - Real Time Water Operations Charter, in section Routine Operations and Maintenance on CVP Activities would have the potential to capture Winter-run Chinook Salmon. Not all the existing IEP monitoring programs that target pelagic fish identify Chinook Salmon race. Of the programs that target and identify Winter-run Chinook Salmon, collective catches are less than 1% of the winter-run JPE (Table 5.6-2). Because such a small percentage of the total JPE is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Winter-run population. These monitoring programs are important for understanding entry and residence time of Winter-run Chinook Salmon into the Delta and San Francisco Estuary.

Table 5.6-2. Monitoring Programs – Winter-run Chinook Salmon

Species	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Chipps Island Trawl																		
Winter-run Chinook Salmon	136	225	112	125	319	115	42	73	69	64	47	63	76	31	53	304	89	
Sacramento Trawl																		
Winter-run Chinook Salmon	57	130	74	118	105	55	33	20	17	11	103	0	86	10	9	111	43	
DJFMP Beach Seine Survey																		
Winter-run Chinook Salmon	123	498	299	650	373	125	51	56	182	50	292	74	136	30	80	38	330	24
CDFW Mossdale Trawl																		
Winter-run Chinook Salmon	8	0	4	1	7	21	5	5	13	11	70	2	2	0	0	18	8	
EDSM KDTR Trawls																		
Winter-run Chinook Salmon	na	na	na	na	na	na	na	Na	na	na	na	na	na	na	0	30	na	
CDFW Bay Study Trawls																		
Chinook Salmon	273	117	327	115	143	115	17	130	157	215	74	134	71	65	62	236	na	
CDFW SKT Study																		
Chinook Salmon	35	1624	1364	348	822	896	603	187	300	244	219	492	632	432	347	565	124	
Totals																		
Winter-run Chinook Salmon	324	853	489	894	804	316	131	154	281	136	512	139	300	71	142	471	470	
RBDD Rotary Trap or Juvenile Production Estimate (JPE)																		
Winter-run Chinook Salmon JPE	6964626	6181925	2786832	12109474	11818006	1864521	1952614	3728444	1049385	512192	16874039							
Percent of Total																		
Winter-run Chinook Salmon	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00							

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5.7 Chinook Salmon, Sacramento River Winter-run ESU Critical Habitat

5.7.1 PBF1 – Access to Spawning Areas in the Upper Sacramento River

In the Sacramento River Basin, ancestral spawning areas for Winter-run Chinook Salmon are unreachable due to impassable barriers at Keswick and Shasta dams. Keswick and Shasta dams do not operate in the WOA scenario, but the dams would remain in place and continue to prevent Winter-run Chinook Salmon adults from accessing upstream spawning areas. Adult Winter-run Chinook Salmon access to their current spawning areas in the upper Sacramento River near Keswick Dam is affected by flow and temperature-related conditions in the middle and upper Sacramento River. Winter-run Chinook Salmon currently spawn between Keswick and Red Bluff Diversion dams, with most spawning within ten miles of Keswick Dam (Windell 2017). Low flow may interfere with upstream passage of adults and increases risk of straying and poaching. High water temperature makes habitat physiologically unsuitable for the adults, potentially excluding them entirely.

Under the proposed action, modeled flow in the middle Sacramento River during the December through May period of Winter-run Chinook Salmon adult immigration is similar to or slightly greater than COS, indicating no adverse flow-related effect of the proposed action on access to spawning areas relative to the COS. However, the proposed action flow is much lower than the WOA flow during many years, but the proposed action flow in these years is generally high enough (>~5,000 cfs) not to affect access of the adults to spawning areas. In the driest years, however, the proposed action flow is higher than the WOA flow. During May in the driest 25 percent of years, the modeled WOA flows are low enough to potentially obstruct upstream passage of adults, which is not the case under the proposed action. Therefore, modeling results indicate that the proposed action would have no adverse flow-related effect on access to spawning areas in the Winter-run Chinook Salmon critical habitat relative to the COS or WOA.

Adult Winter-run Chinook salmon are present in the Bay/Delta from December through July, with a peak occurrence in December and April. The adults use olfactory cues to find their way through the Delta to the Sacramento River upstream of the Delta, so higher Sacramento River flow may reduce straying to other rivers (Marston et al. 2012; NMFS 2016 *Submitted Ch5 EA Draft BA*). Flow in the Sacramento River at Rio Vista and Freeport during the period of adult migration through the Delta, December through July, is lower to much lower under the proposed action relative to the WOA in most years (e.g., Figures 32-9 through 32-16 in the CalSim II Flows section of Appendix D), but in dry years with low river flow, when the risk of straying is increased, flow is much higher under the proposed action than the WOA, especially for April through July. On balance, the effect of the proposed action on Winter-run upstream migration is uncertain.

Modeled water temperatures under all three scenarios would be favorable in the middle and upper Sacramento River for immigrating adult Winter-run Chinook Salmon during all of the immigration period, except during May for WOA temperatures in about 50 percent of years, and COS and proposed action temperatures in about 35 percent of years. These results indicate that the proposed action would have no adverse water temperature-related effect on access to spawning areas in Winter-run Chinook Salmon critical habitat relative to the COS or WOA.

5.7.2 PBF2 – Availability of Clean Gravel for Spawning Substrate

The proposed action includes projects to improve spawning habitat for Chinook Salmon in the upper Sacramento River, and these projects would likely enhance availability of clean gravel for Winter-run Chinook Salmon spawning substrate. Availability of clean gravel is affected by changes in flow. Transport of clean gravel downstream to areas currently used for spawning by Winter-run Chinook Salmon is blocked by Keswick and Shasta dams. While the WOA includes no operation of Keswick and Shasta dams, the dams would remain in place and continue to prevent transport of clean gravel from upstream sources.

Currently, the availability of clean gravel is a function of: 1) upstream supply from tributaries and gravel augmentation projects, and 2) flows, especially pulse flows, that are high enough for periodic flushing of fine sediment, but not so high as to transport the gravel downstream of the spawning area. The proposed action would not affect the amount of upstream gravel supply or natural pulse flows. However, flow during summer, when Winter-run Chinook Salmon spawn and egg/alvein incubation period, would be much higher under the proposed action than under WOA, and potentially would be high enough in some years to flush fine sediments from spawning substrates. Modeled flow during the winter months is lower under the proposed action than under WOA and therefore may reduce the ability to flush sediments from spawning substrate. Flow in the upper river under the WOA scenario is less regulated than that under the proposed action and COS scenarios, it is likely that natural pulse flows would be larger and more frequent under the WOA scenario. While pPulse flows are not included in the CALSIM modeling used to compare flow of the three project scenarios, spring pulse flows are included in the proposed action and could contribute to flushing of fine sediments.

The lower frequency of pulse flows would potentially result in less frequent and effective flushing of sediments from the spawning gravel under the proposed action than WOA. However, if WOA pulse flows were very large, they could result in downstream transport of gravel from the spawning area, without recruiting gravel from upstream due to blockage by Shasta and Keswick dams. Overall, the effect of the proposed action on the availability of clean gravel for spawning substrate in Winter-run Chinook Salmon critical habitat relative to WOA is uncertain.

5.7.3 PBF3 – Adequate River Flows for Successful Spawning, Incubation of Eggs, Fry Development and Emergence, and Downstream Transport of Juveniles

As discussed previously, there would be insignificant differences in flows between the proposed action and COS throughout the Sacramento River upstream of the Delta during most of the Winter-run Chinook Salmon spawning, rearing, and emigration periods; however, there would be large and significant differences in flows between the proposed action and WOA.

The months included in Winter-run Chinook Salmon spawning, incubation, rearing and emigration periods are May through March. During these months, proposed action and COS flows are similar, except for greater proposed action flow in June and lower proposed action flow in September and November. The effects of these flow differences are uncertain, with some attributes of habitat benefited and some attributes negatively affected by the higher flows.

The large differences in flow between the proposed action and WOA are expected to have substantial effects. Flows under the proposed action are much higher than WOA flows during the June through October period of spawning and egg/alevin incubation, which is expected to substantially benefit most PBFs of Winter-run Chinook Salmon spawning habitat. In contrast, proposed action flows are lower than

WOA flow during most years of the winter months, which is expected to reduce downstream transport and environmental cues of emigrating juvenile Winter-run Chinook Salmon.

5.7.4 PBF4 – Water Temperatures for Successful Spawning, Egg Incubation, and Fry Development

As discussed previously, water temperatures would not significantly differ between COS and proposed action in spawning and rearing reaches in the upper Sacramento River during Winter-run Chinook Salmon spawning and rearing periods; however, there would be large and highly significant differences in water temperatures between the proposed action and WOA, especially during the late spring, summer and early fall period of Winter-run Chinook Salmon spawning and egg/alevin incubation.

Water temperatures under the proposed action during May through September would range from roughly 10 to 20 degrees Fahrenheit lower than WOA water temperatures, with WOA water temperatures exceeding critical temperature thresholds for Winter-run Chinook Salmon eggs and alevins during May through September of almost every year, but proposed action water temperature remaining below the thresholds during those months in most years. Water temperature and DO based modeling analyses show 100 percent Winter-run Chinook Salmon egg and alevin mortality under WOA water temperature and DO conditions, as compared to less than 50 percent mortality in 75 percent of years under proposed action conditions. During late fall through early spring, the proposed action water temperatures are generally higher than the WOA temperatures, but the water temperatures under both scenarios are consistently below the critical temperature thresholds for Winter-run Chinook Salmon fry. Overall, the results indicate that proposed action has no effect relative to COS on PBF4, but would have major benefits relative to the WOA.

5.7.5 PBF5 - Habitat Areas and Adequate Prey that are not Contaminated

In Winter-run Chinook Salmon critical habitat upstream of the Delta, the proposed action is not likely to negatively impact contaminant sources. Primary sources of contamination in the Sacramento River upstream of the Delta are drainage and runoff from croplands and municipalities. Differences among the project scenarios in contaminated habitat and prey would most likely be caused by differences in flow levels, either because of differences in dilution of contaminants from drainage canals and other sources, or because of differences in contaminant loading resulting from inundation and runoff from croplands and municipal lands. The principal contaminants from croplands are fertilizers and pesticides, and these are applied to croplands primarily from late spring through early fall.

As indicated previously, differences in flows between the proposed action and COS would generally be small and, for both scenarios, modeled flow would be below levels that would cause inundation of croplands or cities. However, flow under WOA would often be much higher or much lower than proposed action flows.

During summer and early fall in drier years, flow under proposed action would regularly be two to three times as high as the corresponding WOA flow, so contaminants in the river would be much more diluted under the proposed action when compared to WOA. During winter and early spring, proposed action flow would often be lower than WOA flow, but use of fertilizers and pesticides is relatively low at these times of year. Flooding of the Sacramento River generally results primarily from pulse flows originating in unregulated tributaries of the river, which CalSim, a monthly time-step model, cannot model for purposes of comparing magnitudes or frequencies of flooding among the scenarios. However, as discussed for PBF3 regarding pulse flows for spawning gravels, Sacramento River flows would be much more controlled under the proposed action than under WOA. Therefore, lesser areas of croplands would likely be inundated under the proposed action than under WOA and inundations would be less frequent, resulting in lower contaminant loading from the runoff. Overall, the results indicate that the proposed action would not negatively impact Winter-run Chinook Salmon availability of uncontaminated habitat areas and prey relative to the COS and the WOA in the Sacramento River upstream of the Delta.

Increased habitat diversity potentially enhances food resources of Winter-run juveniles and higher flow generally increases habitat diversity. Higher flow in the Bay/Delta results in greater inundation of marshlands surrounding the Delta, Suisun Bay and San Pablo Bay, which potentially improves: 1) foodweb productivity, 2) access of juvenile Winter-run to more diverse food resources, 3) refuge of the juveniles from predators, and 4) refuge for resting from high velocity flows. Higher flows may also enhance foodweb productivity by transporting nutrients and plankton from productive habitats, including croplands and the Sutter and Yolo bypasses (DWR and Reclamation 2107 *Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project EIS/EIR*).

Winter-run juveniles are present in the Bay/Delta from December through May, with peak occurrence during February through April. During most of this period, Sacramento River flow at Freeport and Rio Vista, as well as Delta outflow, are substantially lower under the proposed action relative to the WOA (e.g. Figures 29-11 through 29-13, 32-11 through 32-13, and 41-11 through 41-13 in the CalSim II Flows section of Appendix D). Therefore, the proposed action is expected to negatively affect critical habitat in the Bay/Delta relative to the WOA, with respect to habitat diversity and food resources, but this conclusion has low certainty.

Lower, regulated winter and spring flow under the Proposed Action has the potential to positively and negatively affect other water quality factors in estuarine Winter-run critical habitat relative to the WOA. Lower January through May flows at Freeport and Rio Vista under the proposed action and lower Delta outflow (Figures 29-10 through 29-14, 32-10 through 32-14, and 41-10 through 41-14 in the CalSim II Flows section of Appendix D) would lead to less dilution of contaminants present in the Delta, Suisun Bay, San Pablo Bay and Central Bay, increasing their adverse effects, and could also reduce flushing of contaminated sediments out of the Bay/Delta, potentially reducing water and sediment quality in the critical habitat. However, as described above, lower upstream proposed action flows and reduced pulse flows expected during winter and spring would potentially reduce loading of contaminants related to runoff from inundated croplands, so the reduced upstream proposed action flows could result in better water quality in the Bay/Delta. Effects of flows on contaminants in other parts of the Delta are uncertain. Relative to the WOA, the PA has both positive and negative potential effects with respect to water quality in Winter-run critical habitat in the Bay/Delta, and the overall effect is uncertain.

Reduced winter-spring Delta inflow from the Sacramento River under the proposed action relative to the WOA (Figures 29-10 through 29-14 in the CalSim II Flows section of Appendix D) has the potential to reduce sediment supply and therefore turbidity during winter-spring. Turbidity helps juvenile salmon avoid predation (McElroy et al. 2018, Gregory and Levings 1998).

5.7.6 PBF6 – Riparian Habitat that Provides for Successful Juvenile Development and Survival

The effects of the proposed action on riparian habitat in Winter-run Chinook Salmon critical habitat upstream of the Delta are uncertain. Differences in riparian habitat would primarily result from differences in flow and its effect on riparian vegetation. As discussed previously, Sacramento River flow under the proposed action would generally be similar to flow under the COS, so differences in riparian habitat between these scenarios are expected to be insignificant. However, flow under the proposed action is generally much higher than WOA flow during summer and early fall and much lower than WOA flow during late winter and early spring. Also, as discussed for PBF5, inundation of floodplains is less likely under the proposed action. These conditions suggest that riparian vegetation would establish and grow less successfully during winter under the proposed action scenario, but the high summer proposed action flow could lead to some possible growth increases for vegetation that was able to establish in the lower spring flows. Therefore, the effect of the proposed action relative to the WOA on riparian habitat is uncertain.

5.7.7 PBF7 – Access Downstream so that Juveniles can Migrate from Spawning Grounds to San Francisco Bay and the Pacific Ocean

Emigration of juvenile Winter-run Chinook Salmon from spawning grounds to the Delta is potentially limited by flow and water temperature-related conditions throughout the Sacramento River upstream of the Delta. Winter-run Chinook Salmon juveniles emigrate from the upper and middle Sacramento River over a period of many months, beginning as early as July, shortly after the start of fry emergence, through the following March. Differences in modeled flows and water temperatures in juvenile Winter-run Chinook Salmon migration habitat are small between the proposed action and COS, but are large between the proposed action and WOA.

During the late fall through early spring period, flows under all three scenarios are high enough and water temperatures are low enough to sustain juvenile Winter-run Chinook Salmon. However, proposed action flows in many years during the winter and early spring are much lower than WOA flow and, because the WOA flows are uncontrolled, pulse flows are less frequent under the proposed action, even though the proposed action includes a spring pulse. Pulse flows stimulate juvenile salmon to initiate major downstream movement. Therefore, during these months the proposed action would adversely affect flow conditions for juvenile emigration relative to the WOA.

During the summer and early fall, proposed action flows are much higher than WOA flows, which would benefit emigrating juveniles. Water temperatures in the middle Sacramento River (Woodson Bridge gauge) are consistently below critical thresholds for emigrating Winter-run Chinook Salmon juveniles under all three project scenarios during every year from November through March. However, during July through September, the proposed action temperatures exceed the threshold in about half of the years while the WOA water temperatures exceed the threshold for juvenile Winter-run Chinook Salmon in every year . Also, the proposed action temperatures during these months are 10 to 15 degrees Fahrenheit cooler than the corresponding WOA temperatures.

Overall, the proposed action would provide less favorable conditions relative to the WOA scenario for emigrating juveniles during winter and early spring, because proposed action flows would generally be lower. The proposed action would provide more favorable conditions in the summer months compared to WOA because flows would be higher and water temperatures lower. On balance, the proposed action is not expected to adversely affect downstream access in critical habitat for juvenile Winter-run Chinook Salmon emigrating down river.

The proposed action is not expected to have effects on water temperature and dissolved oxygen concentration (DO) in critical habitat for Winter-run Chinook salmon in the Bay/Delta. These water quality parameters are major discriminators for comparing potential effects of the proposed action and the WOA on Winter-run Chinook in the Sacramento River upstream of the Delta. In the Bay/Delta, however, flow and water temperature of reservoir releases are generally considered to have little effect on water temperatures (Wagner et al. 2011, USFWS 2017b). However, this assessment has been based on experience with smaller flow and water temperature differences than those expected between the proposed action and WOA (USFWS 2017b), so the conclusion that the proposed action would have no effects on water temperature in the Bay/Delta relative to the Without Action scenario is uncertain. Other than near major effluents, DO in the Bay/Delta is primarily determined by water temperature. Juvenile Winter-run undergo smoltification before and while they reside in the Bay/Delta, so they are able to tolerate a wide range of salinities in the Bay/Delta.

Flow from the Sacramento, San Joaquin and other rivers tributary to the Delta, as well as tidal flows, affect the hydrodynamic of Delta channels and influence how juvenile Winter-run move through the Delta. The results of analyses of hydrodynamics and flow velocities to evaluate effects of the proposed action on routing of Winter-run juveniles in the Delta indicate that routing into the interior Delta, where the juveniles would be at higher risk from entrainment and reduced water quality (NMFS 2009), would be higher under the proposed action relative to the WOA.

Effects of the proposed action on entrainment of juvenile Winter-run at the Banks and Jones export facilities in the south Delta would be substantial compared to WOA, as the WOA scenario includes no exports from the Delta and therefore would have no entrainment at the south Delta facilities. The proposed action is expected to increase entrainment of individual Winter-run Chinook salmon relative to both current operations and WOA.

5.7.8 Effects of Conservation Measures

Spawning and rearing habitat restoration projects in the upper Sacramento River associated with the proposed action would be implemented for the benefit of salmonids, including Winter-run Chinook Salmon and elements of critical habitat. Construction may increase turbidity and contaminant exposure risk. Ultimately, restoration projects would improve access to spawning areas (PBF1) and availability of clean gravel for spawning substrate (PBF2). Construction may cause temporary localized adverse effects but are expected to result in long-term beneficial effects to critical habitat for Winter-run Chinook Salmon.

5.8 Chinook Salmon, Central Valley Spring-run ESU

The reduced spring flows of the proposed action, compared to the WOA, are likely to affect rearing and migrating Spring-run Chinook salmon and their habitat. Effects include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, and reduced emigration flows.

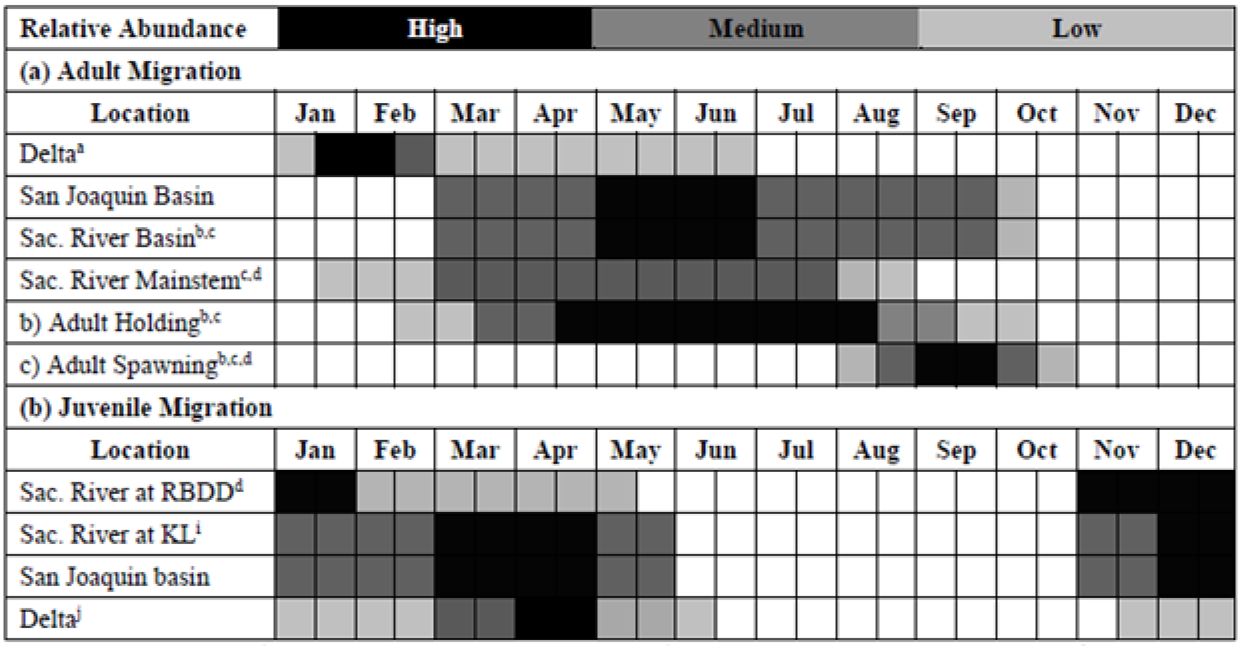
For Spring-run Chinook salmon, the proposed action includes a pulse flow in the spring from Shasta Reservoir in years when the cold water pool is likely sufficient to protect winter-run egg incubation. The pulse may improve survival for Mill, Deer, and Butte Creek Spring-run migrating through the lower Sacramento River.

In addition to the pulse flow in the spring, several conservation measures would also minimize impacts of lower spring flows on Spring-run Chinook salmon juveniles. These include spawning and rearing habitat restoration on the Sacramento River, Deer Creek, and lower San Joaquin River, tidal habitat restoration, and predator hot spot removal. Similar to winter-run Chinook salmon, OMR management establishes protective criteria to minimize and avoid entrainment based on historical salvage. Additional protective measures occur when environmental criteria indicate that entrainment is more likely and allow for more flexible operations when entrainment is less likely. The proposed action also includes conservation measures such as improvements at fish collection facilities to improve facility survival and reduce impacts of the proposed action as compared to WOA.

5.8.1 Lifestage Timing

General life stage timing and location information for Spring-run Chinook Salmon is provided in Table 5.8-1. Additional detail regarding juvenile life stage timing at various monitoring locations is provided in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*.

Table 5.8-1. The Temporal Occurrence of Adult (a) and Juvenile (b) Spring-run Chinook Salmon at Various Locations in the Central Valley (NMFS 2017, p.71).



Sources: [a]CDFG (1998); [b]Yoshiyama et al. (1998); [c]Moyle (2002); [d]Myers et al. (1998); [e]Lindley et al. (2004); [f]CDFG (1998); [g]McReynolds et al. (2007); [h]Ward et al. (2003); [i]Snider and Titus (2000); [j]SacTrawl (2015)

Note:

Yearling spring-run Chinook salmon rear in their natal streams through the first summer following their birth. Downstream emigration generally occurs the following fall and winter. Most young-of-the-year spring-run Chinook salmon emigrate during the first spring after they hatch.

5.8.2 Conceptual Model Linkages

Central Valley (CV) Spring-run Chinook Salmon populations occur in several Central Valley streams. This section considers effects of the proposed action on the Sacramento River population. The SAIL conceptual model (Figure WR_CM1) was prepared especially for Sacramento River Winter-run Chinook Salmon, but the cause and effects relationships it diagrams apply equally well to the Spring-run population in Sacramento River. This conceptual model will be referenced throughout this section to explain links between the species and the effects of the action. The primary differences in the habitat requirements between the two runs (i.e., Winter and Spring) are the duration and the time of year that the different life stages use their habitats (NMFS 2014).

Reclamation proposes to store and release water from Shasta, Keswick Whiskeytown Dams. Storing water in the upper Sacramento River watershed is landscape level attribute in the conceptual model. The resulting dam releases and the resulting flows are environmental drivers that affect habitat attributes. The flows can influence water temperature, dissolved oxygen level (DO), the amount of stranding, outmigration cues and the timing, condition and survival of rearing CV juvenile Spring-run Chinook salmon. These flows also influence the timing, condition and survival of eggs and alevins in the spawning redds, rearing juvenile CV Spring-run Chinook salmon and holding of adult CV Spring-run Chinook salmon prior to spawning in the upper Sacramento River. These habitat attributes further influence lower level attributes, such as flow affects dilution of contaminants and toxics; water temperatures affects food availability, predation, pathogens, and disease; river stage and flow velocity affects habitat connectivity, bioenergetics, food availability, and predation, entrainment and stranding risk, and potentially affects cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

These inundated floodplains of the middle Sacramento River, such as the Yolo and Sutter Bypasses, have proven particularly successful habitats for juvenile salmon growth (Katz, 2017). This success has been attributed to optimum water temperature, lower water velocity, and higher food quality and food density relative to the main channel. Reduced predator and competitor density also likely contribute to high growth rates observed for juvenile salmon rearing in floodplains (Windell et al. 2017).

The proportion of eggs surviving to emerge as fry depends largely on the quality of conditions in the redds (Windell et al. 2017). Redd quality is affected by substrate size and composition, flow velocity, temperature, DO, contaminants, sedimentation, and pathogens and diseases. Flow affects sedimentation and gravel composition of the redds and may cause redd scour, stranding or dewatering (Windell et al. 2017). Flow also affects the surface area of riverbed available for redd construction.

Eggs and emerging fry are often exposed to geomorphic flows, and spring attraction flows based on the lifestage timing. Potential effects of these geomorphic flows include increased gravel scour which could displace incubating eggs from redds, resulting in exposure to increased predation, mechanical shock and abrasion, and increased water temperature if transported out of suitable incubation habitat, if present. Geomorphic flows could also temporarily increase suspended solids and turbidity, causing sediment deposition in redds that can reduce hydraulic conductivity through the redd and result in reduced oxygen delivery to eggs, reduced flushing of metabolic waste, and entombment of alevins via a sediment “cap” that prevents or impedes emergence (Everest et al. 1987, Lisle et al. 1989). These flows are mobilize gravel and increases the overall quality of egg incubation habitat. Critical water temperatures thresholds for CV Spring-run Chinook Salmon vary by life stage, with eggs and alevins the most sensitive to elevated temperatures. Rombough (1994) indicates that eggs at hatch generally require water temperatures no greater than about 53.5 degrees Fahrenheit because at higher temperatures DO is insufficient to satisfy metabolic demands. Central Valley Spring-run Chinook salmon eggs and alevins are assumed to be similarly affected by temperature.

The proportion of juveniles surviving to emigrate from the middle Sacramento River depends largely on growth and predation, which are greatly affected by habitat conditions, including instream flow (Windell et al. 2017). The proportion of juveniles surviving to emigrate from the upper Sacramento River depends largely on habitat conditions, including instream flow (Windell et al. 2017). Central Valley Spring-run Chinook salmon juveniles rear throughout the upper Sacramento (Keswick to Red Bluff) from November through May, with a peak rearing period during November through January, and emigrate from the upper River during this period (Table 5.8-11). Flows during fall and winter of dry and critically dry years generally have the greatest potential to adversely affect the juvenile life stage in the upper Sacramento River because reservoir storage and cold water pool in these seasons and water year types may be insufficient to provide suitable flow and water temperature conditions in the rearing habitats.

Central Valley Spring-run Chinook salmon adults spawn in the Sacramento River from August through October with peak spawning during September (Table 5.8-1). Monitoring spring-run spawning in the mainstem Sacramento River is complicated due to lack of spatial/geographic segregation and temporal isolation from fall-run. Most spring-sun spawning occurs between the Anderson-Cottonwood Irrigation District Dam to Airport Road Bridge (NMFS 2017b). Fry emergence occurs up to 3.5 months after eggs are spawned (Moyle 2002), so effects of flow resulting from the proposed action in the upper Sacramento River on incubating spring-run eggs and alevins potentially occur from August through January, peaking in November and December.

Many of the factors that affect rearing and emigrating CV Spring-run Chinook Salmon juveniles in the middle Sacramento River are similar to those described above for the upper Sacramento River. Juvenile spring-run spend varying amounts of time rearing in the upper Sacramento River following emergence before migrating to the middle River. They use the middle Sacramento River as rearing habitat and a migratory corridor to the Delta. The majority of spring-run-sized juveniles occur in the middle Sacramento River at Knights Landing from November through May (Table 5.8-1), with two separate peak occurrences: December and March through April (Table 5.8-1). The two peaks may reflect differences in the timing of emigration from different Sacramento River tributaries. For instance, emigration of young-of-year juveniles from Butte Creek occurs earlier than that from Mill and Deer creeks (NMFS 2009).

Holding for adult Spring-run Chinook Salmon in the upper Sacramento River extends from late February through early October, peaking in late April through early August (Table 5.8-1).

5.8.3 Effects of Operation and Maintenance

The WOA scenario is described previously in the Winter-run Chinook salmon effects analysis. Sacramento River flows at Keswick Dam resulting from the WOA scenario were modeled in CalSim and reflect seasonal changes, with low summer and fall flows and high winter and spring flows (Figures 15-7 through 15-18 in the CalSim II Flows section of Appendix D). Flows in the middle Sacramento River under the WOA scenario would be similar to those in the upper Sacramento River, moderately low during November and May and much higher during December through April (see Appendix D, *Modeling*). CalSim modeling indicates that during the CV Spring-run Chinook holding period in the upper Sacramento River, flows at Keswick range from about 770 cfs in August to about 63,000 cfs in March, and 40 to 50 percent of years have flows below the current 3,250 cfs required minimum flow during July through September (see Appendix D, *Modeling*).

Other locations in the Sacramento River would show similar seasonal flow patterns. Modeling results of the WOA scenario indicate that flows in CV Spring-run Chinook Salmon habitat located in the Upper Sacramento during the August through January spawning and incubation period are generally low during August through November, but are high in December and January of years with wetter hydrologies (Figures 15-7 through 15-10, and 15-17 and 15-18 in the CalSim II Flows section of Appendix D).

In the WOA scenario, flows would generally be low in fall during years with dry hydrology and often fall below the currently required minimum flows for much of fall through spring (Figures 15-8 through 15-14, and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D). The proposed action flows are higher during the fall and winter when compared to WOA, which is a benefit for spawning CV Spring-run Chinook Salmon adults and incubating eggs and alevins through increased spawning and rearing habitat. Since juveniles are youngest and most sensitive in the fall and early winter, the increased habitat conditions under the proposed action as compared to WOA would lead to increased growth rate and lower mortality of the individual juveniles and an increased population abundance. The higher proposed action flows as compared to WOA in summer would be beneficial to holding adults and increase areas suitable for redd construction, as described by Windell et al. 2017. Potential adverse effects of low flows on the upper Sacramento River are included in the Winter-run Chinook Salmon effects analysis detailed above.

Higher flows during the winter under WOA would also negatively influence spawning and egg/alevin incubation. If flows are sufficiently high, they result in excessive depths and flow velocities for constructing redds, and redds that were previously built are at risk of being scoured from the bed (NMFS 2017 CWF BO). In addition, under high flows adults may build redds in areas that are later dewatered or isolated from the main river channel when the flows decline. Modeling indicates that high flow events with rapid flow fluctuations are likely to occur in the Sacramento River under the WOA scenario. The higher flows in winter and spring could have adverse effects on rearing juvenile CV Spring-run Chinook Salmon including higher stranding risk because of increased use of flood plains and greater flow fluctuations, and higher contaminants loading from stormwater runoff. In general, higher flows are likely to benefit holding adults by affording better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, and lower risk from anglers (Windell et al. 2017).

In the without action scenario, as described in the Winter-run Chinook salmon section, the water temperatures in the upper Sacramento River would be substantially warmer because the shallow reservoir that would remain behind Shasta Dam would absorb significant heat during warm, sunny days.

The USEPA (2003) gives 64 degrees Fahrenheit as the critical 7-day average daily maximum (7DADM) water temperature for rearing salmonid juveniles. Also, the USEPA (2003) gives 68 degrees Fahrenheit as the critical 7DADM water temperature for migrating salmonid adults and 61 degrees Fahrenheit for holding adults. As discussed in the Winter-run Chinook Salmon section above, this reference is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of operating to 7DADM.

Under the WOA scenario, the elevated water temperatures in late spring, summer and early fall, would be poorly suited for spring-run adults. Monthly mean water temperatures in spawning habitat (i.e., HEC-5Q WOA scenario) would be high in the latter part of summer during the spawning and incubation period, ranging from about 63 to 72 degrees Fahrenheit. The critical temperature thresholds for spawning adults are the same as those for incubating eggs and alevins: 56 degrees Fahrenheit and 53.5 degrees Fahrenheit. This water temperature regime greatly exceeds both thresholds (Figures 5-17 and 5-18 in the HEC5Q Temperatures section of Appendix D). During early fall, water temperatures would exceed the 56 degrees Fahrenheit threshold in about half of the years projected and would exceed the 53.5 degrees Fahrenheit threshold in all years projected (Figure 5-7 in the HEC5Q Temperatures section of Appendix D,Figures 5-11 through 5-18 and 5-7 in the HEC5Q Temperatures section of Appendix D). Such conditions would likely preclude survival of incubating CV Spring-run Chinook Salmon eggs and alevins. During the remaining months of the CV Spring-run Chinook Salmon spawning and incubation period of fall through winter, water temperatures under the WOA conditions would be consistently below 52 degrees Fahrenheit, suitable for incubating eggs and alevins (Figures 5-8 through 5-10 in the HEC5Q Temperatures section of Appendix D). However, Sacramento River Spring-run Chinook Salmon have largely finished spawning by mid-fall (Table 5.8-1). Therefore, unless the population successfully shifted its spawning to later in the winter, Spring-run Chinook Salmon would likely be eliminated from the Sacramento River mainstem under without action conditions.

During February through April, the first part of the CV Spring-run adult holding and spawning period in the upper Sacramento River, mean water temperatures under the WOA scenario are consistently below the 61 degrees Fahrenheit threshold for holding adults, and water temperatures are below this threshold in most years during May (Figures 5-9 through 5-14 in the HEC5Q Temperatures section of Appendix D). They are also below the threshold in all years during October (Figure 5-7 in the HEC5Q Temperatures section of Appendix D). During June through September, however, the water temperatures are above the threshold in almost every year (Figures 5-15 through 5-18 in the HEC5Q Temperatures section of Appendix D).

During the November through May period, temperature would range from about 38 degrees Fahrenheit during January to 63 degrees Fahrenheit during May (Figures 5-8 through 5-14 in the HEC5Q Temperatures section of Appendix D). Under the WOA scenario, water temperatures would exceed the 61 degrees Fahrenheit threshold only in May and the exceedences would occur in 2% of the years in the historical record. Water temperatures during the November through May period at other locations in the upper Sacramento River would generally be similar to those at Keswick Dam, but in May, water temperatures would range up to 69 degrees Fahrenheit at the Red Bluff Diversion Dam (RBDD), with about 15 percent of years exceeding the 61 degrees Fahrenheit threshold. The infrequent exceedances of the 61 degrees Fahrenheit threshold that would occur during May at some locations in the upper Sacramento River would potentially negatively impact rearing Spring-run Chinook Salmon juveniles. However, the exceedances would rarely occur. Furthermore, by May most juveniles have probably matured enough to acquire greater warm water temperature tolerance and most have emigrated from the upper Sacramento River (Table 5.8-1).

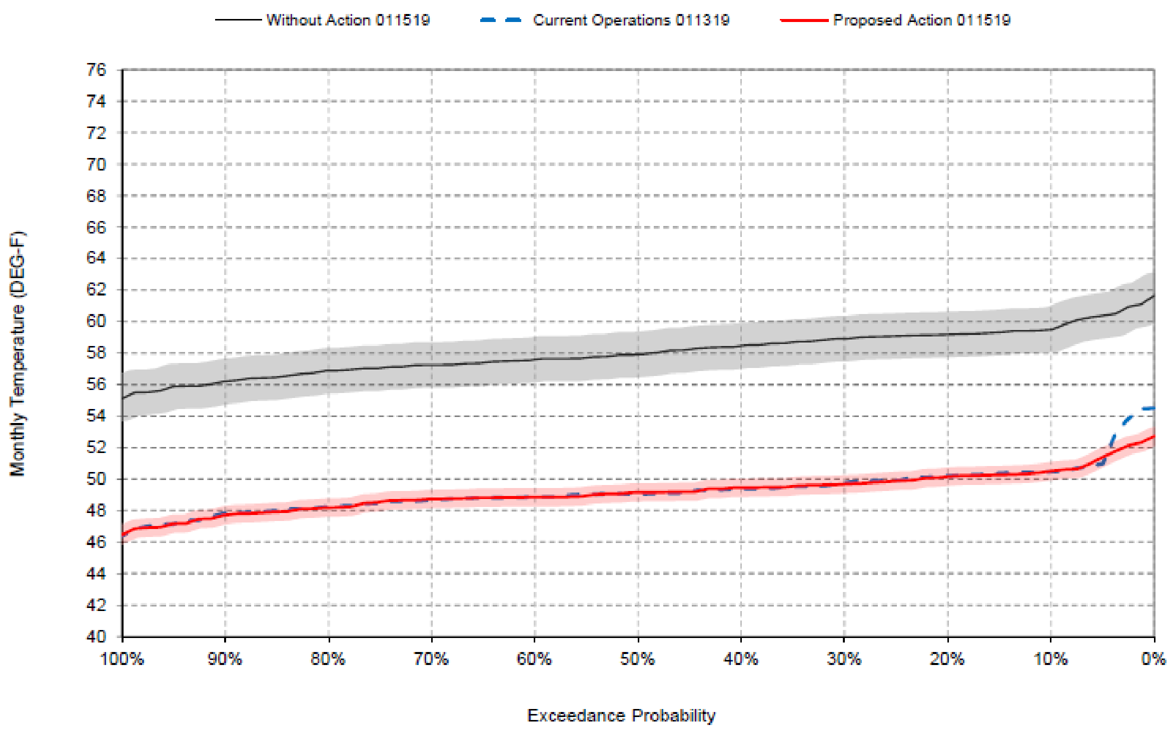


Figure 5.8-1. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, COS and proposed action scenarios, May

In the upper Sacramento River at Keswick, the WOA scenario monthly average water temperatures would be below the 61 degrees Fahrenheit threshold for holding adults from January through April and in October (Figures 5-7 and 5-10 through 5-13 in the HEC5Q Temperatures section of Appendix D), but would exceed the threshold in about 2 percent of years in May and in every year during June through September (Figures 5-14 through 5-18 in the HEC5Q Temperatures section of Appendix D). Water temperatures conditions under the WOA scenario in the summer months, June through September, would be highly stressful to adult CV Spring-run migrating upriver in the middle Sacramento River as well as those holding in the upper river.

For juveniles, the main difference between the juveniles in the middle Sacramento River and those in the upper river with respect to these adverse effects is that the juveniles in the middle river would generally be less sensitive to the effects because their greater age and size would afford them greater robustness. The low fall flows under the WOA scenario would likely result in reduced conditions in juvenile rearing habitats in the middle Sacramento River. During November and May, the flows would fall below the normal minimum flow requirements in about 37 percent of years projected.

In the middle Sacramento River below the Colusa Basin Drain, which is close to Knights Landing, the WOA scenario monthly mean water temperatures would remain below the 64 degrees Fahrenheit juvenile rearing temperature threshold from November through March (Figures 14-8 through 14-12 in the HEC5Q Temperatures section of Appendix D), but would exceed the threshold during the warmest 5 percent of years in April and the warmest 85 percent of years in May, with a maximum water temperature of 75 degrees Fahrenheit (Figures 14-13 and 14-14 in the HEC5Q Temperatures section of Appendix D).

In the middle Sacramento River at Knights Landing, the WOA scenario monthly average water temperatures would consistently be below the 68 degrees Fahrenheit threshold for immigrating adults from January through April (Figures 14-10 through 14-13 in the HEC5Q Temperatures section of Appendix D). Under the WOA scenario, water temperatures would exceed the threshold during May of about half of the years, during June through September in every year, and during October of about 20 percent of the years on record. (Figures 14-7 and 14-14 through 14-18 in the HEC5Q Temperatures section of Appendix D).

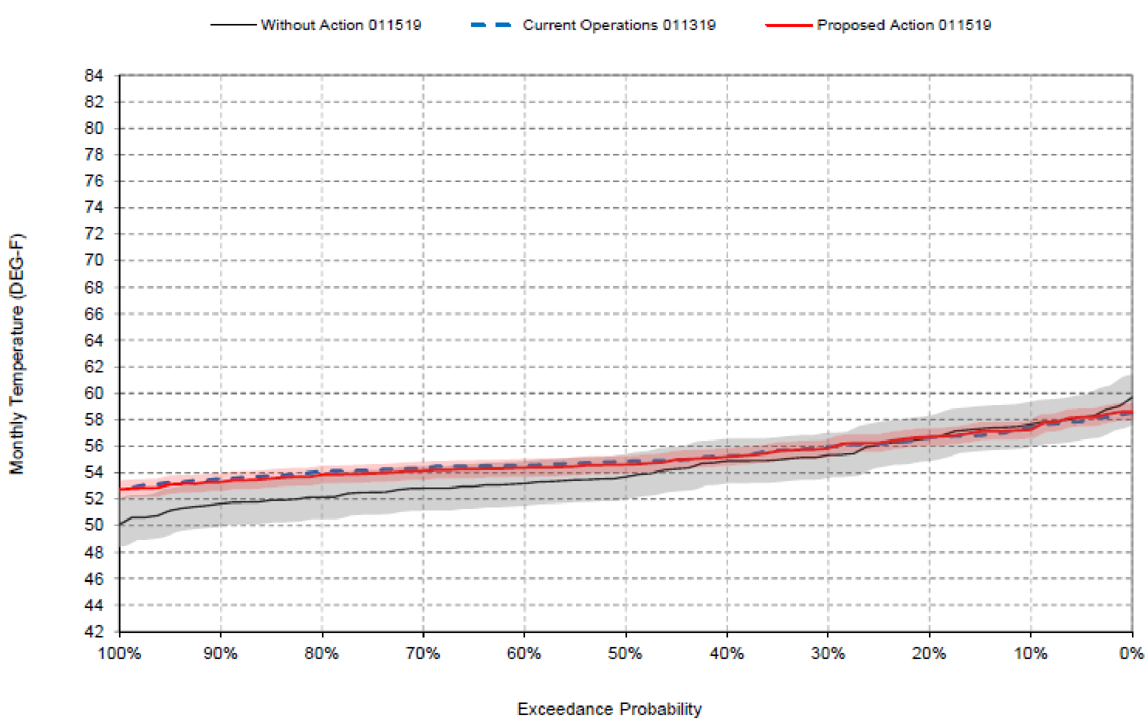


Figure 5.8-2. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, November

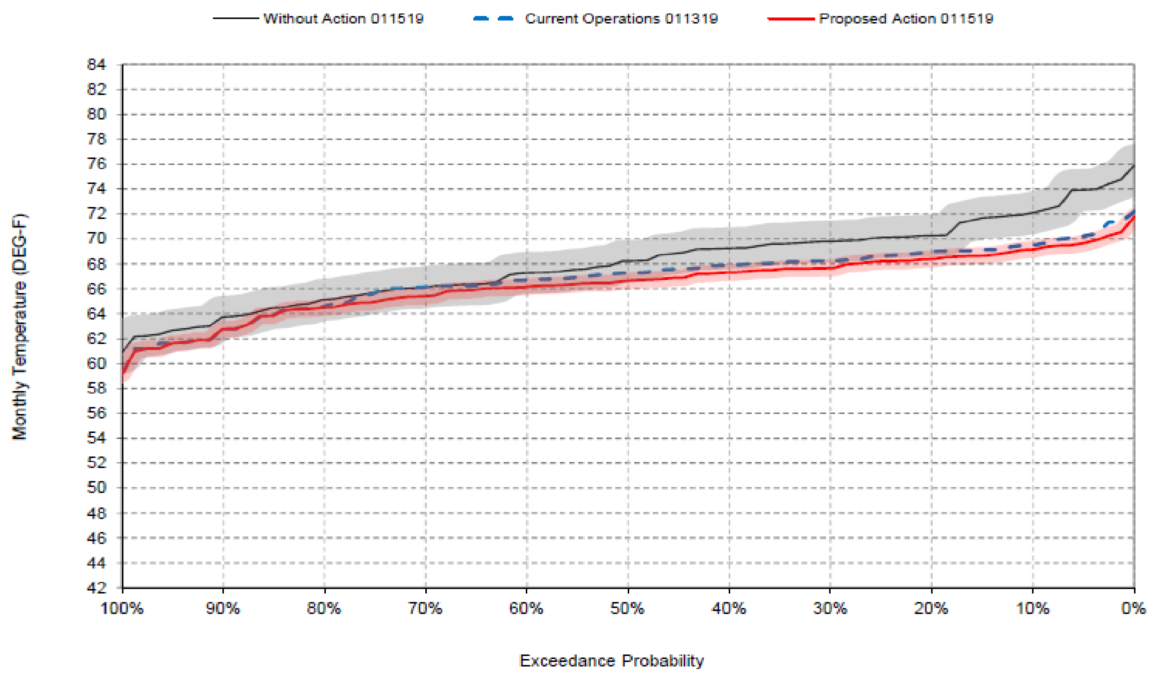


Figure 5.8-3. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, May

CalSim modeling indicates that from January through April, the first half of the period during which spring-run adults migrate upstream through the middle Sacramento River to holding habitat in the upper river, the WOA scenario flows at Wilkins Slough would range from about 2,500 cfs in April to about 24,000 cfs in March (Figures 19-10 through 19-13 in the CalSim II Flows section of Appendix D), and at Keswick, the WOA flows would range from about 3,250 cfs in all four months to about 63,000 cfs in March (Figures 15-10 through 15-13 in the CalSim II Flows section of Appendix D). During the second part of the migration and holding period (May through October), the WOA flows at Wilkins Slough would range from 0 cfs in May through August to about 20,000 cfs in May (Figures 19-7 and 19-14 through 19-18 in the CalSim II Flows section of Appendix D). At Keswick, the WOA flows would range from about 772 cfs in August to about 32,000 cfs in May (Figures 15-7 and 15-14 through 15-18 in the CalSim II Flows section of Appendix D). The lowest flows at Keswick Dam during May through August would be low enough to create potential passage problems for immigrating adults, and this is even more likely for Wilkins Slough, where flows in June through August would be about 1,000 cfs or lower in about half of the years. The effects of low flow on the middle Sacramento River and for adults holding in the upper river are expected to be similar to those described by Windell et al. 2107.

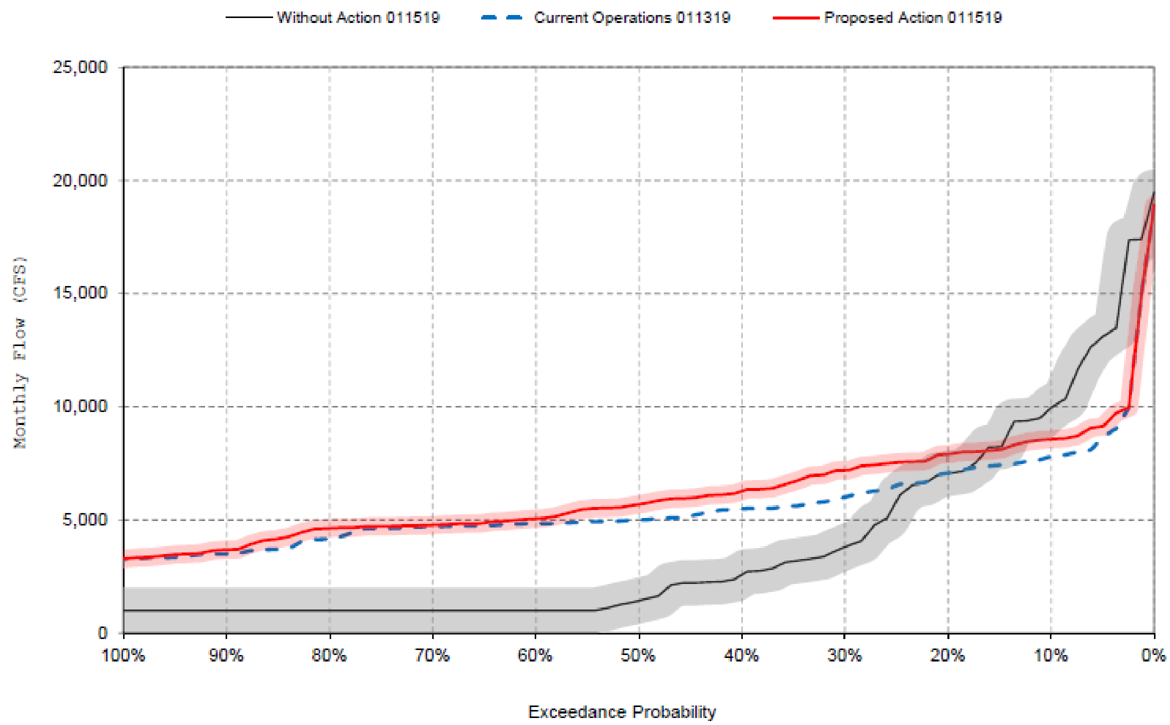


Figure 5.8-4. Modeled Sacramento River Flows at Wilkins Slough, June

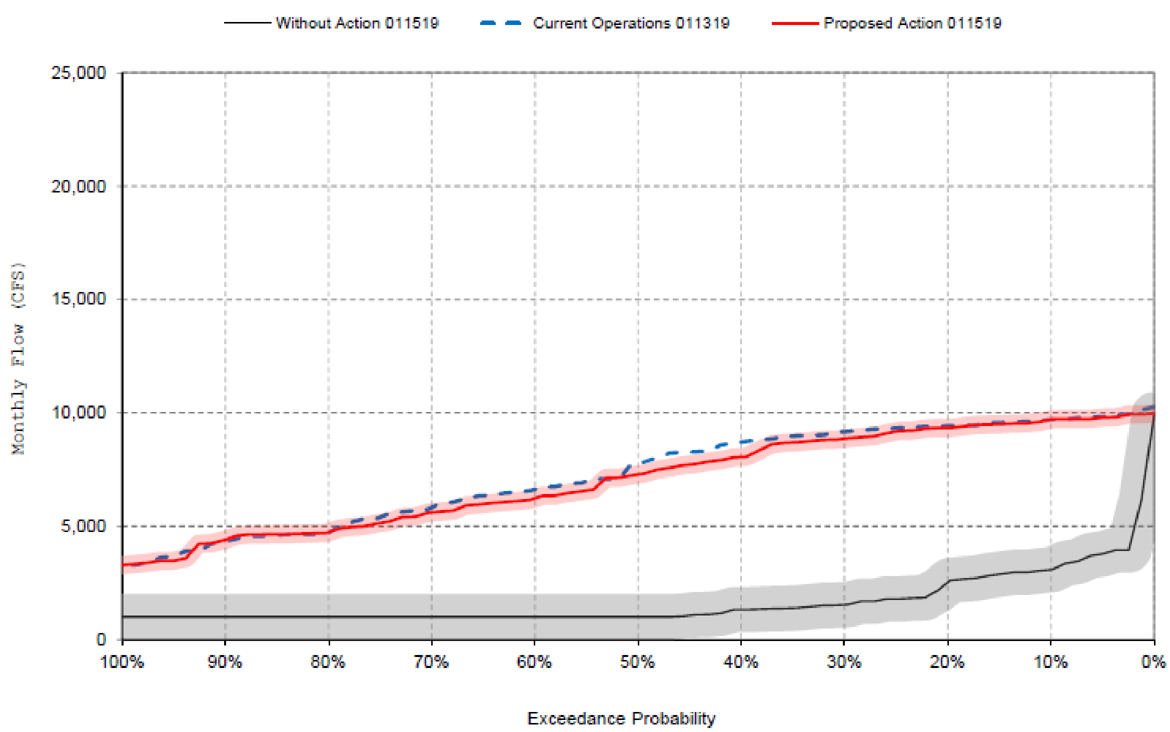


Figure 5.8-5. Modeled Sacramento River Flows at Wilkins Slough, July

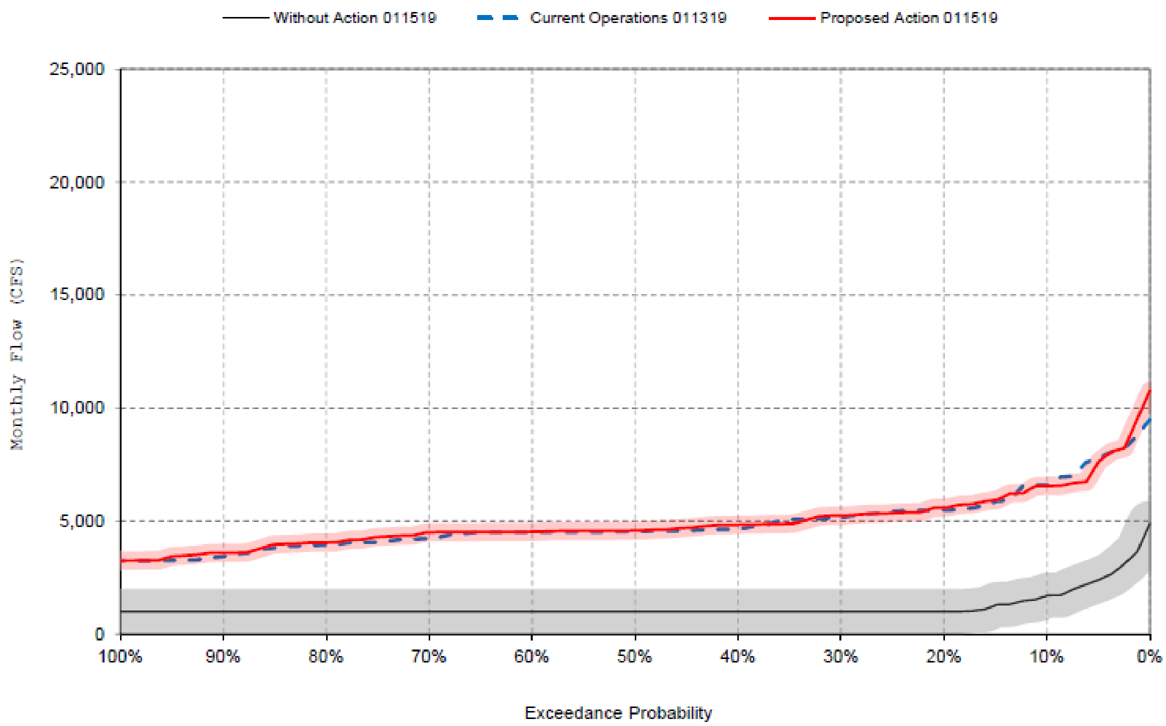


Figure 5.8-6. Modeled Sacramento River Flows at Wilkins Slough, August

5.8.3.1 Seasonal Operations of the CVP/SWP

Flows can modulate water temperature and DO concentration leading to changes in contaminant toxicity, pathogen virulence, food availability, bioenergetics and disease susceptibility. In addition, river stage and flow velocity may affect habitat connectivity, and availability which in turn may influence food availability, predation, crowding, entrainment and stranding risk, and can potentially affect cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

Flows under the proposed action are generally lower than flows under the WOA scenario during the peak seasonal timing of CV Spring-run Chinook juvenile rearing (November-May; Figure 5.8-7) in all watersheds. In particular, flows are reliably lower from January to May (Figure 5.8-7), a trend especially pronounced in wetter water year types. In contrast, flows under the proposed action are higher than WOA in the summer and fall. The likelihood of flows occurring in the proposed action that are less than the minimum instream flow requirements during these months is very low for all water year types. Lower flows during the juvenile outmigration period under the proposed action could have both beneficial and adverse effects on rearing juvenile CV Spring-run Chinook Salmon.

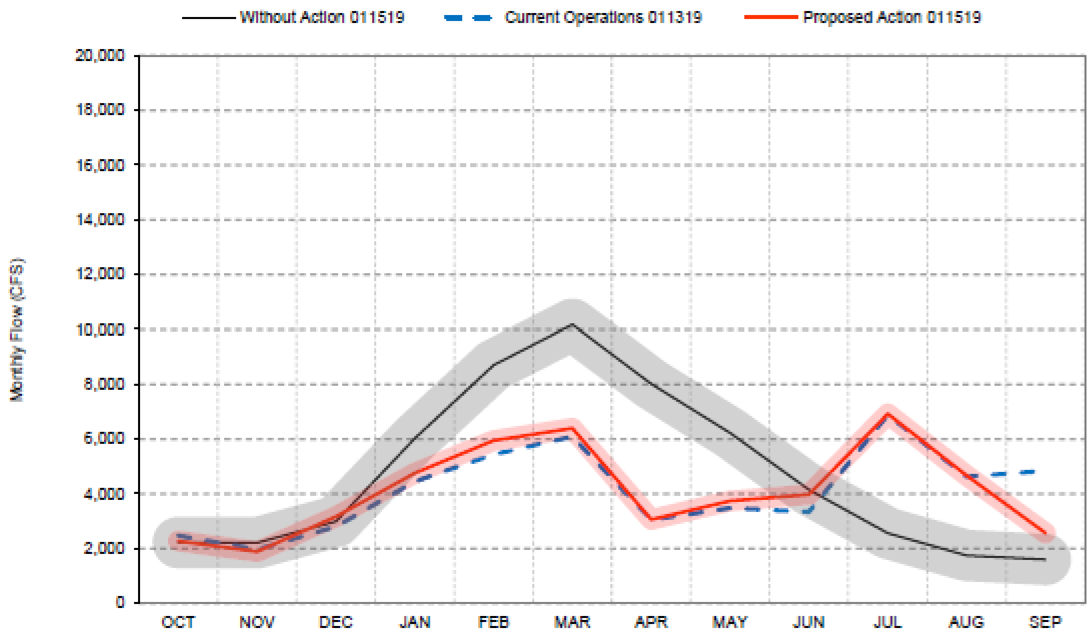


Figure 5.8-7. CalSim II estimates of Feather River Long-Term average flow below the Thermalito Afterbay in September-November and December-February.

The reduced spring flows of the proposed action, compared to the WOA, are likely to affect rearing individuals and their habitat. Beneficial effects are anticipated to be reduced stranding risk resulting from increased use of flood plain habitat and larger flow fluctuations, and reduced contaminant loading from stormwater runoff. Adverse effects include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, higher water temperatures and lower DO, and reduced emigration flows.

Several conservation measures proposed for Sacramento Winter-run Chinook salmon would offset any minimal adverse effects of reduced spring flows on Spring-run Chinook Salmon juveniles. These include spawning and rearing habitat on the Sacramento, Deer Creek and Stanislaus Rivers, cold water pool management on the Sacramento River, cold water pool management tools and infrastructure on the Sacramento River, predator hot spot removal and a small screen program.

Under the WOA scenario, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would occur. Therefore, there would be limited control of flow or water temperature in the Feather River HFC where CV Spring-run Chinook Salmon juvenile rearing occurs. Resulting water temperatures under the WOA scenario in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are similar to COS and proposed action temperatures during the November to May period, but the proposed action is up to 7 degrees cooler than the without action during the critical summer holding period for Spring-run Chinook Salmon adults (Figure 5-8-8).

The increased summer flows of the proposed action, compared to the WOA, are likely to have significant benefits for holding adults by reducing water temperatures in holding areas, and associated benefits to dissolved oxygen.

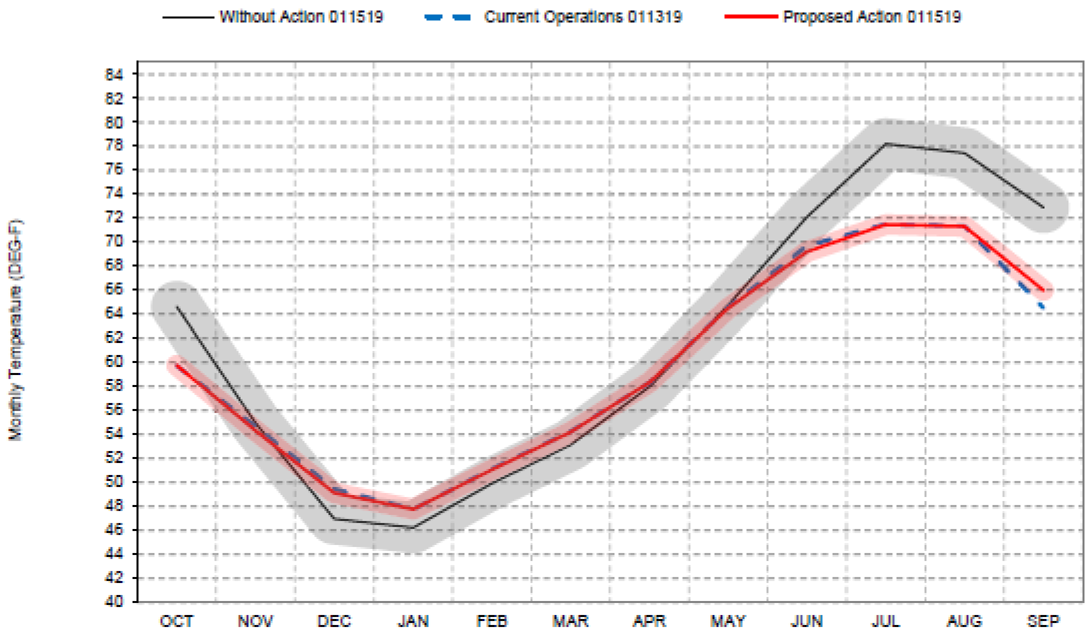


Figure 5.8-8. Long-term average RecTemp estimates of Feather River water temperature at Gridley Bridge under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

5.8.3.2 Upper Sacramento River Seasonal Operations including Shasta Cold Water Pool Management

The effects of cold-water releases on Spring-run Chinook Salmon are expected to be similar to those experienced by Winter-run Chinook, but of smaller magnitude due to the seasonal timing of Spring-run Chinook Salmon spawning and juvenile rearing and the distribution of their redds.

Under the proposed action operations, flow and water temperature management in the upper Sacramento River would be largely the same as that under COS. The primary difference between the proposed action and the COS for the Sacramento River upstream of the Delta is the water temperature management of Shasta and Keswick reservoirs, especially with respect to the TCD.

5.8.3.2.1 Egg to Fry Emergence

5.8.3.2.1.1 River Flow

During summer and fall, primary operational considerations are flows required for Delta outflows, instream demands, and temperature control for Winter-run and Spring-run Chinook Salmon spawning and incubation. Proposed action flows are well above the WOA flows for the first three months (August through October) of the spring-run spawning and incubation period (Figures 15-17, 15-18, and 15-7 in the CalSim II Flows section of Appendix D). Low flows would be less frequent under the proposed action, resulting in benefits to Spring-run Chinook Salmon spawning and incubation.

Flow during the entire August through January period rarely fall below 3,250 cfs under COS, as indicated by CalSim modeling. Modeling indicates that lowest flows under the proposed action conditions are expected to be similar to the flows of the COS scenario (Figures 15-7 through 15-10, and 15-17 and 15-18 in the CalSim II Flows section of Appendix D).

Differences in flows between the proposed action and COS are small in most months, but flows are lower in the proposed action than in the COS modeling scenario in September of years with wetter hydrology (e.g., a COS flow of about 17,000 cfs corresponds to a proposed action flow of about 12,000 cfs and a COS flow of about 10,000 cfs corresponds to a proposed action flow of about 6,000 cfs) (Figure 15-18 in the CalSim II Flows section of Appendix D). After applying the Weighted Usable Area analysis for spawning habitat of Fall-run Chinook salmon juveniles, which has been used as a surrogate for Spring-run Chinook Salmon in the Sacramento River (ICF 2016 *CWF BA Appendix 5D Methods*), the lower September proposed action flows t result in an increase in spawning habitat Weighted Usable Area for Spring-run Chinook Salmon in this month (Figure 5.8-9). Although the Weighted Usable Area analyses indicate a potential increase in rearing habitat in wetter years under proposed action flows as compared to COS flows, the reductions in flow predicted for the proposed action could potentially affect other undetermined rearing habitat attributes of spring-run juveniles than those measured for the Weighted Usable Area analyses.

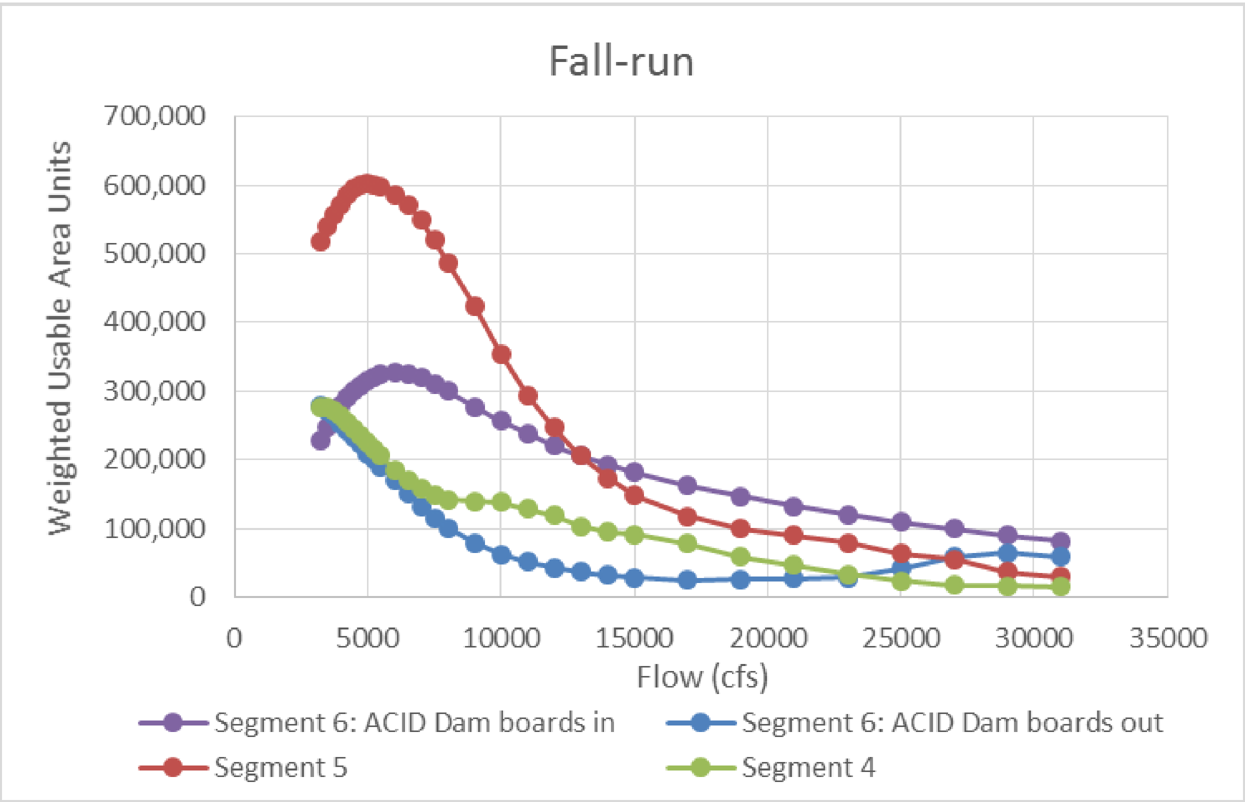


Figure 5.8-9. Spawning WUA Curves for Fall-run Chinook salmon in the Sacramento River, Segments 4 to 6. The fall-run curves were used to quantify Spring-run Chinook Salmon WUA, as discussed in the text. ACID = Anderson-Cottonwood Irrigation District.

5.8.3.2.1.2 Water Temperature

Reclamation proposes new water temperature management measures that include a water temperature maximum of 53.5 degrees Fahrenheit in the Sacramento River above the Clear Creek confluence (see below) in most years from May 15 to October 31.

The presence of a large cold water pool and the flexibility afforded by the TCD make possible the provision of much colder water under the proposed action and the COS in the upper Sacramento River during the first three months of the Spring-run Chinook Salmon spawning and incubation period than would be possible under the WOA conditions. Under the proposed action and the COS, monthly mean water temperatures at Keswick Dam range from about 50 to 66 degrees Fahrenheit during August through October (Figures 5-17, 5-18, and 5-7 in the HEC5Q Temperatures section of Appendix D). During November, water temperatures range from about 52 to 58 degrees Fahrenheit, and during December and January, they range from 43 to 55 degrees Fahrenheit (Figures 5-8 through 5-10 in the HEC5Q Temperatures section of Appendix D). While the HEC-5Q model provides 6-hour data, the results presented here are monthly averages, which should reasonably estimate daily average temperatures near Keswick Dam because operations at Shasta and Keswick dams create relatively stable summer flow and water temperature conditions. Variable weather conditions and travel time of water result in greater fluctuations around the mean further downstream of the dam.

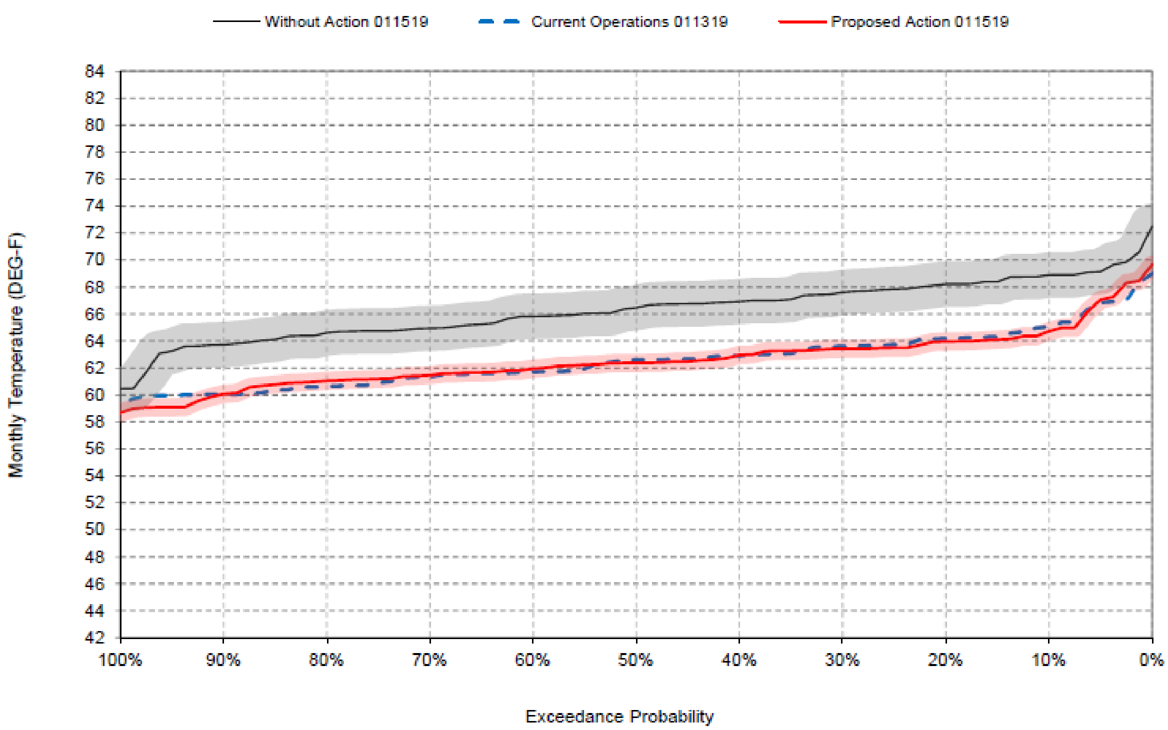


Figure 5.8-10. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA and COS scenarios, October

As discussed in the Winter-run Chinook Salmon section, the proposed action has reduced temperatures by up to 2 degrees in October of most years as compared to the COS. The proposed action water temperatures exceed the 56 degrees Fahrenheit threshold approximately 20% of the time in November (see Figure below), but otherwise rarely in the fall. The proposed action exceeds 53.5 at Keswick approximately 8% of the time in August, while under the current operations temperatures at Keswick exceed 53.5 degrees Fahrenheit approximately 23% of the time. In September, the proposed action exceeds 56 degrees Fahrenheit at Keswick 10% of the time, while under the current operations water temperatures exceed 56 degrees Fahrenheit at Keswick approximately 7% of the time. Water temperatures in December and January would be consistently below the 56 degrees Fahrenheit threshold and would exceed the 53.5 degrees Fahrenheit threshold in about 10 percent of years in December and one percent in January (Figures 5-9 and 5-10 in the HEC5Q Temperatures section of Appendix D).

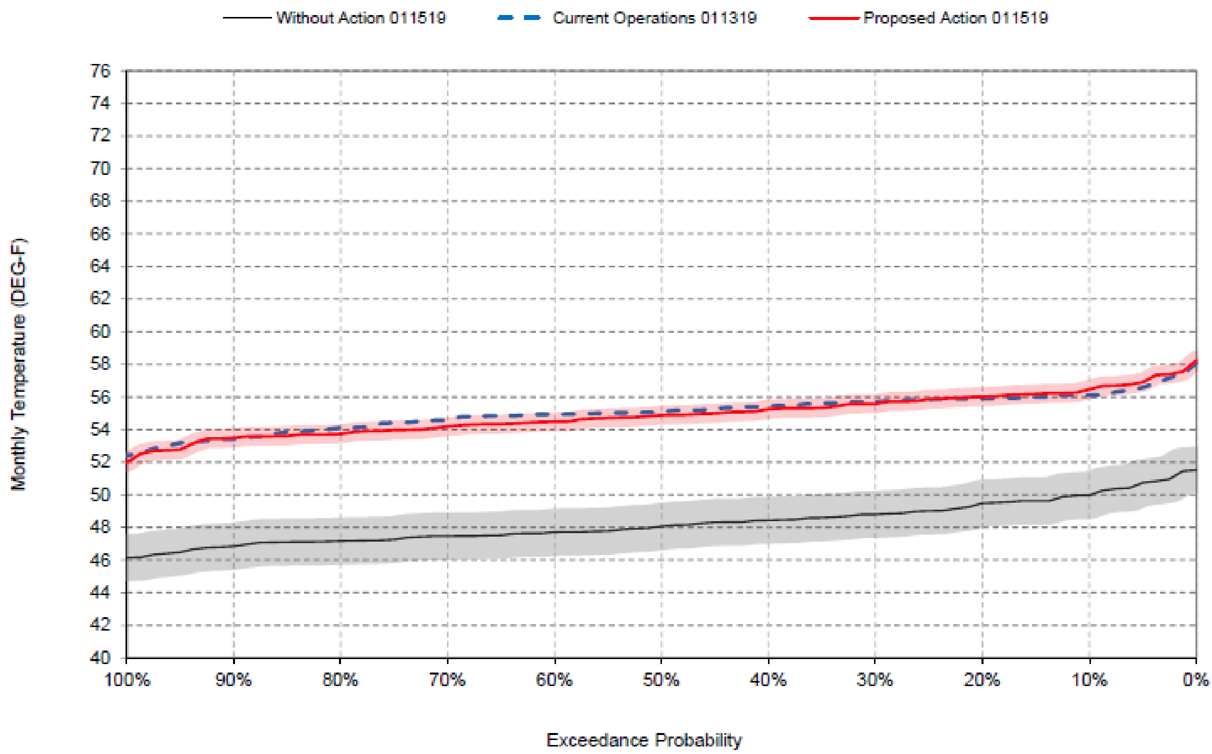


Figure 5.8-11. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA and COS scenarios, November

Water temperatures under the proposed action are much lower than those under the WOA scenario from April through October (Figures 5-13 through 5-18 and 5-7 in the HEC5Q Temperatures section of Appendix D), whereas water temperatures under the proposed action are much higher than those under the WOA scenario during November through January (Figures 5-8 through 5-10 in the HEC5Q Temperatures section of Appendix D). These results indicate that the proposed action, relative to the WOA, provides a clear benefit to Spring-run Chinook Salmon eggs and alevins incubating in the upper Sacramento River during the spawning months (August through October). During November through January, when spawning is completed but eggs and alevins remain in some of the redds, water temperatures are suitable for egg and alevin incubation under the proposed action and COS scenarios, except during November, when water temperatures exceed the 56 degrees Fahrenheit threshold in 20 percent of years and the 53.5 degrees Fahrenheit threshold in more than 80 percent of years. Under the WOA scenario, water temperatures during November through January are suitable for incubating eggs and alevins, except perhaps during January in the coldest 30 percent of years, when the mean temperatures are under 40 degrees Fahrenheit (Figure 5.8-12). Such cold water temperatures are below the suitable temperature range for maximum egg and alevin survival (Moyle 2002). As noted above, the lower water temperature under the proposed action during the Spring-run Chinook Salmon spawning months would benefit the Sacramento River Spring-run Chinook Salmon population. On balance, this effect would be much greater than the adverse effect of the higher water temperatures in November of some years under the proposed action and the COS. In view of the improved water temperature management operations planned for the proposed action, this action is expected to benefit the Spring-run Chinook Salmon eggs and alevins relative to the COS and WOA.

Under the WOA, Spring-run Chinook Salmon eggs and alevins would mostly likely be eliminated from the Upper Sacramento River. Comparatively, the proposed action and the COS are beneficial to incubating Spring-run Chinook Salmon eggs and alevins. The proposed temperature management under the proposed action is expected to improve water temperatures compared to WOA and reduce operational difficulties in maintaining river habitats.

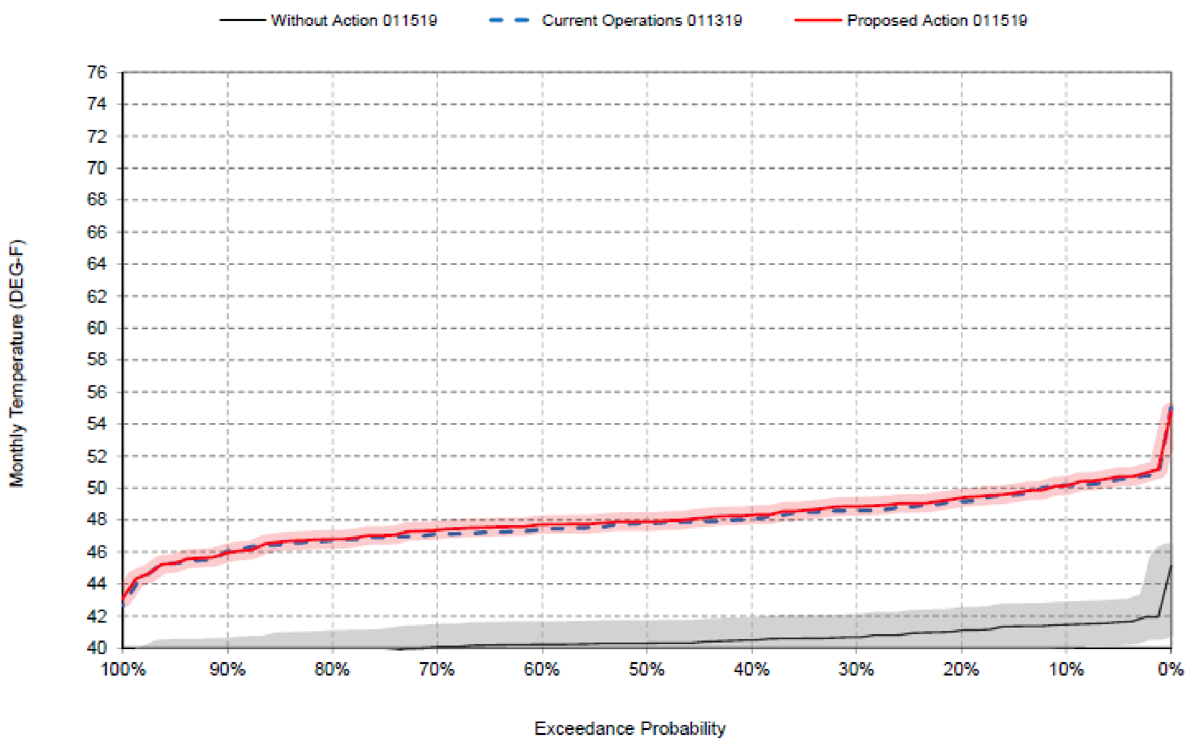


Figure 5.8-12. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the proposed action, WOA and COS scenarios, January

5.8.3.2.2 Rearing to Outmigrating Juveniles in Rivers

5.8.3.2.2.1 River Flow

Under proposed action operations, flow and water temperature management during the juvenile rearing and emigration period in the upper Sacramento River would be largely the same as that under COS. CalSim modeling indicates that upper Sacramento River flows during the November through May period of juvenile rearing in the upper Sacramento River are generally similar between the proposed action and the COS (Figures 15-8 through 15-14 in the CalSim II Flows section of Appendix D) except for higher flows during November under the COS scenario.

The CalSim modeling shows large seasonal changes in the differences between the proposed action and the WOA scenario and COS in upper Sacramento River flow. In November, there is little difference in flow between the WOA and proposed action scenarios, except in the highest flows years, when the proposed action flows tend to be higher. The COS flows are well above the WOA flows at most flow levels (Figure 15-8, and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D). In December and February, proposed action and COS flows are generally below WOA flows for years with dry hydrology, and are generally higher in wet years, except for the wettest Decembers (Figures 15-9 and 5-11 in the CalSim II Flows section of Appendix D). In January, proposed action and COS flows are generally moderately lower than the WOA flows and during March and April, they are well below the WOA flows (Figures 15-10, 15-12, and 15-13 in the CalSim II Flows section of Appendix D). In May, the proposed action and COS flows are well below the WOA flows in wetter years, and are slightly higher in drier years (Figure 15-14 in the CalSim II Flows section of Appendix D). These seasonal changes result primarily from Shasta Reservoir storage releases under the proposed action and COS during late fall, when uncontrolled flows are low, and also from diversions to Shasta Reservoir storage under the proposed action and COS scenarios during winter and spring, when uncontrolled flows are often high. Diversion to storage is higher in spring than in winter because the flood control pool in the reservoir can be reduced during spring as flood risk declines.

The flows resulting from differences between the WOA scenario and the proposed action and COA scenarios would likely impact Spring-run Chinook Salmon juveniles and their habitats, although the nature of the effect is undetermined. From January through April, WOA flows would often be nearly twice as high as the proposed action and COS flows during years with dry hydrology. The proposed action and COS flows in such years would generally be at the required minimum of 3,250 cfs. The Weighted Usable Area for rearing habitat of fall-run Chinook salmon juveniles, which has been used as a surrogate for Spring-run Chinook Salmon Weighted Usable Area analyses in the Sacramento River (ICF 2016 *CWF BA Appendix 5D Methods*), is at or near its maximum at 3,250 cfs (USFWS 2005). This flow was the lowest flow included in the USFWS study. Depending on the reach sampled in the study, flow of approximately 6,000 cfs, which is the most frequent flow level for dry hydrology under the WOA scenario, was estimated to have similar to much lower juvenile rearing habitat Weighted Usable Area than the 3,250 cfs flow (USFWS 2005). Although the Weighted Usable Area analyses indicate potentially greater juvenile rearing habitat Weighted Usable Area in dry years under the proposed action and COS scenarios than under the WOA scenario, the reductions in flow predicted for these scenarios would potentially affect other rearing habitat attributes of Spring-run Chinook Salmon juveniles than those measured for the Weighted Usable Area analyses, with potentially negative impacts to juveniles, but this conclusion is uncertain.

Proposed Action flows during January through May of years with wetter hydrology would generally be lower, and often much lower, than flows under the WOA scenario. Lower proposed action flows in winter and spring could have both beneficial and adverse effects on rearing juvenile Spring-run Chinook Salmon. Potential impacts of the proposed action as compared to WOA include less inundation of floodplain and side-channel habitat, reduced feeding conditions, increased competition and predation, higher water temperatures and higher DO, and reduced emigration flows, while benefits include lower stranding risk because of reduced use of flood plains and reduced flow fluctuations, and less contaminants loading from stormwater runoff. On balance, the effect of lower winter and spring flows during most years under the proposed action and COS scenarios relative to the WOA scenario on Spring-run Chinook Salmon juveniles and their rearing habitat is highly uncertain.

5.8.3.2.2.2 Water Temperature

Under the proposed action and COS (proposed action and COS HEC-5Q modeling scenarios), monthly mean water temperatures at Keswick during the November through May upper Sacramento River juvenile rearing period would range from about 43 degrees Fahrenheit during January and February to 54 degrees Fahrenheit in May (Figures 5-8 through 5-14 in the HEC5Q Temperatures section of Appendix D). These temperatures are well below the 61 degrees Fahrenheit critical water temperature threshold for juvenile Spring-run Chinook Salmon, indicating that water temperature conditions in the upper Sacramento River are well suited for juvenile Spring-run Chinook Salmon. It should be noted, however, that unlike conditions during summer and fall, when reservoir operations create relatively stable flow and water temperature conditions (See Winter-run Chinook salmon, *Water Temperature*), the mean monthly water temperatures in winter and spring do not fully capture the water temperature conditions to which the juvenile Spring-run Chinook Salmon would be exposed, because water temperatures often vary greatly over the course of a month, and even over a day. This caveat, however, applies to all results of all the modelling scenarios.

Water temperatures under the proposed action and COS are much higher than those under the WOA scenario during November through February (Figures 5-8 through 5-11 in the HEC5Q Temperatures section of Appendix D), are similar in March (Figure 5-12 in the HEC5Q Temperatures section of Appendix D), and are much lower than those under the WOA scenario in April and May (e.g., Figures 5-13 and 5-14 in the HEC5Q Temperatures section of Appendix D). On balance, water temperature conditions under the proposed action and the COS would provide moderate benefits relative to the WOA conditions to juvenile Spring-run Chinook Salmon rearing in the upper Sacramento River.

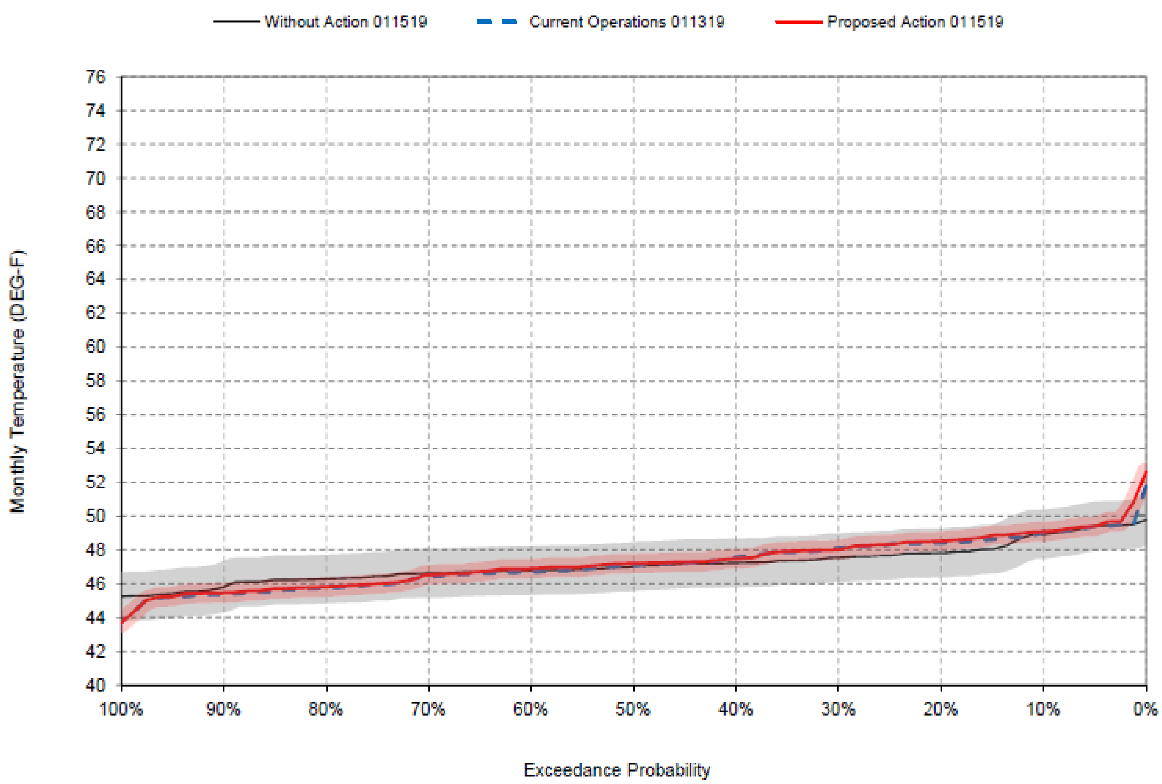


Figure 5.8-13. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, proposed action and COS scenarios, March

5.8.3.2.3 Rearing to Outmigrating Juveniles in Bay-Delta

5.8.3.2.3.1 River Flow

Similar upper Sacramento River, the CalSim modeling shows large seasonal changes in the differences in middle Sacramento River flow between the proposed action and COS and the WOA scenario. In November, there are small to moderate differences in flow between the proposed action and WOA scenarios, with lower flows under the proposed action scenario in the middle-high range of flow years, and higher flows under the proposed action scenario in the lower flow years, but the COS flows are consistently above the WOA flows in all but the highest flow years (Figure 19-8, and Tables 17-1 through 17-3, 18-1 through 18-13, and 19-1 through 19-3 in the CalSim II Flows section of Appendix D). In December through February, the proposed action flows are generally similar to or slightly lower than the WOA flows for most years (Figure 19-9 through 19-11, and Tables 17-1 through 17-3, 18-1 through 18-13, and 19-1 through 19-3 in the CalSim II Flows section of Appendix D), and in March and April, the proposed action flows are consistently lower than the WOA flows (Figures 19-12 and 19-13 in the CalSim II Flows section of Appendix D). In May, the proposed action flows are substantially lower than the WOA flows for the 60 percent of highest flow years and are substantially lower for the 25 percent of lowest flow years (Figure 19-14 in the CalSim II Flows section of Appendix D).

Flows resulting from differences between the proposed action and WOA scenario would likely affect Spring-run Chinook Salmon juveniles and their habitats. The lower November and May flows under the proposed action scenario during years with drier hydrology would likely result in reduced conditions in juvenile rearing habitats, including less habitat complexity, side channel habitat structure, refuge habitat, and greater disease potential.

The lower proposed action flows in December through April could have adverse effects on rearing juvenile Spring-run Chinook Salmon. Potential adverse effects include less floodplain and side-channel habitat, reduced feeding conditions, increased competition and predation, higher water temperatures and higher DO, and decreased emigration flows.

5.8.3.2.3.2 Water Temperature

Under the proposed action and COS modeling scenarios, monthly average water temperatures from November through March below the Colusa Basin Drain would range from about 44 to about 60 degrees Fahrenheit, thereby remaining well below the 64 degrees Fahrenheit threshold (Figures 14-8 through 14-12 in the HEC5Q Temperatures section of Appendix D). However, during April and May, water temperatures would range from about 53 to about 72 degrees Fahrenheit, exceeding the 64 degrees Fahrenheit threshold in 5 percent of years in April and about 85 percent of years in May, with a maximum water temperature of about 72 degrees Fahrenheit (Figures 14-13 and 14-14 in the HEC5Q Temperatures section of Appendix D).

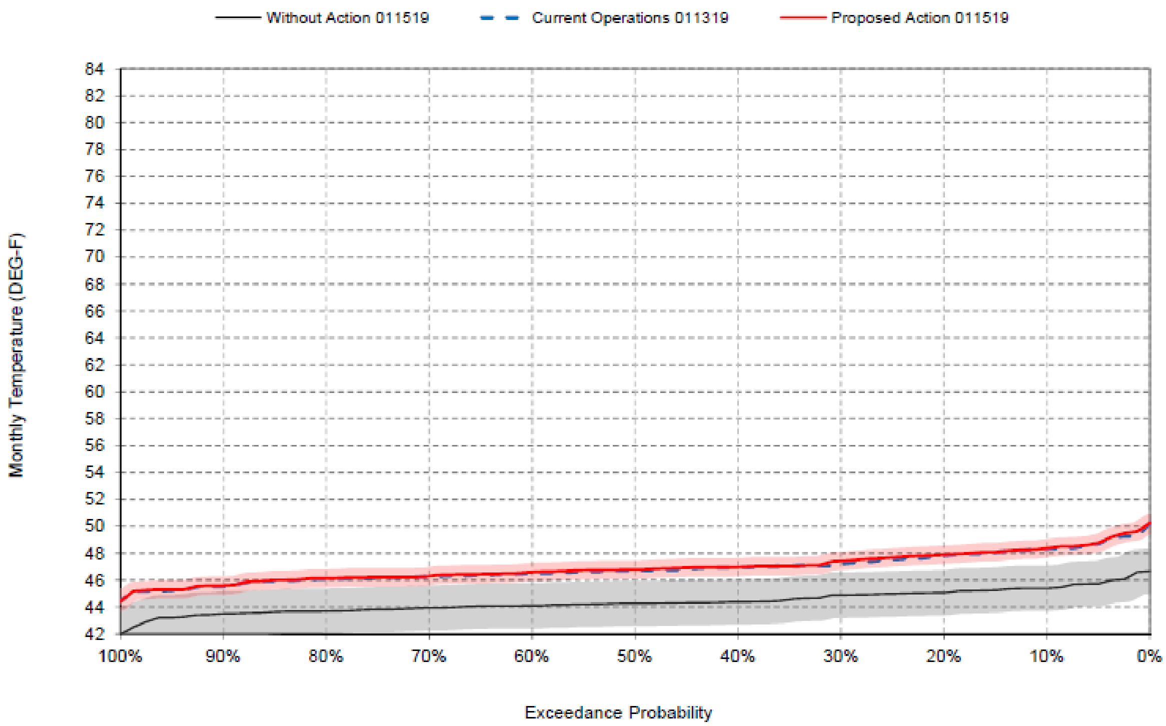


Figure 5.8-14. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, January

There is little difference in water temperatures between the proposed action and COS modeling scenarios during any of the months that juvenile Spring-run Chinook Salmon rear in or emigrate from the middle Sacramento River (Figures 14-8 through 14-14 in the HEC5Q Temperatures section of Appendix D). The maximum difference between the proposed action and COS exceedance curves is approximately 1 degree Fahrenheit in May (Figure 14-14 in the HEC5Q Temperatures section of Appendix D). Water temperatures for both scenarios exceed the 64 degrees Fahrenheit threshold for most years during May, approximately 5 percent of years in April, and no water temperature exceeding this threshold during November through March.

Water temperatures under the proposed action and COS are substantially or moderately above the WOA scenario water temperatures during most years in November through April (Figures 14-8 through 14-13 in the HEC5Q Temperatures section of Appendix D), and are moderately below the WOA scenario water temperatures during most years in May (Figure 14-14 in the HEC5Q Temperatures section of Appendix D). Water temperatures during most years in the November through April period are suitable for juvenile Spring-run Chinook Salmon that rear in and emigrate from the middle Sacramento River under the WOA and the proposed action and COS scenarios. Under all three modeling scenarios during May, however, the 64 degrees Fahrenheit threshold would be exceeded in most years, with the WOA scenario having greater exceedances than the proposed action and COS, especially in warmer years. These results indicate that water temperature conditions would too warm for juvenile Spring-run Chinook Salmon rearing and emigrating in the middle Sacramento River during May under WOA, and that the proposed action improves these conditions slightly although temperatures are still not ideal. It should be noted that May is the last month during spring or summer that Spring-run Chinook Salmon juveniles are found in the middle river, and it is likely that when water temperaturs are too high they emigrate to the ocean before May.

5.8.3.2.4 Adult Migration from Ocean to Rivers

Continuing their upstream migration from the Delta, Spring-run Chinook Salmon adults enter the middle Sacramento River as early as January and ultimately make their way to the upper river, where they hold, beginning as early as February, until they are ready to spawn (Windell et al. 2017).

CalSim modeling indicates that from January through April, the first half of the period during which spring-run adults migrate upstream through the middle Sacramento River to holding habitat in the upper river, the WOA scenario flows at Wilkins Slough would range from about 2,500 cfs in April to about 24,000 cfs in March (Figures 19-10 through 19-13 in the CalSim II Flows section of Appendix D), and at Keswick, the WOA flows would range from about 3,250 cfs in all four months to about 63,000 cfs in March (Figures 15-10 through 15-13 in the CalSim II Flows section of Appendix D). During the second part of the migration and holding period (May through October), the WOA flows at Wilkins Slough would range from 0 cfs in May through August to about 20,000 cfs in May (Figures 19-14 through 19-18 and 19-7 in the CalSim II Flows section of Appendix D), and at Keswick, the WOA flows would range from about 772 cfs in August to about 32,000 cfs in May (Figures 15-14 through 15-17 in the CalSim II Flows section of Appendix D). The lowest flows at Keswick Dam during May through August would be low enough to create potential passage problems for immigrating adults, and this is even more likely for Wilkins Slough, where flows in June through August would be about 1,000 cfs or lower in about half of the years. The effects of low flow on the middle Sacramento River and for adults holding in the upper river are expected to be similar to those described by Windell et al. 2017.

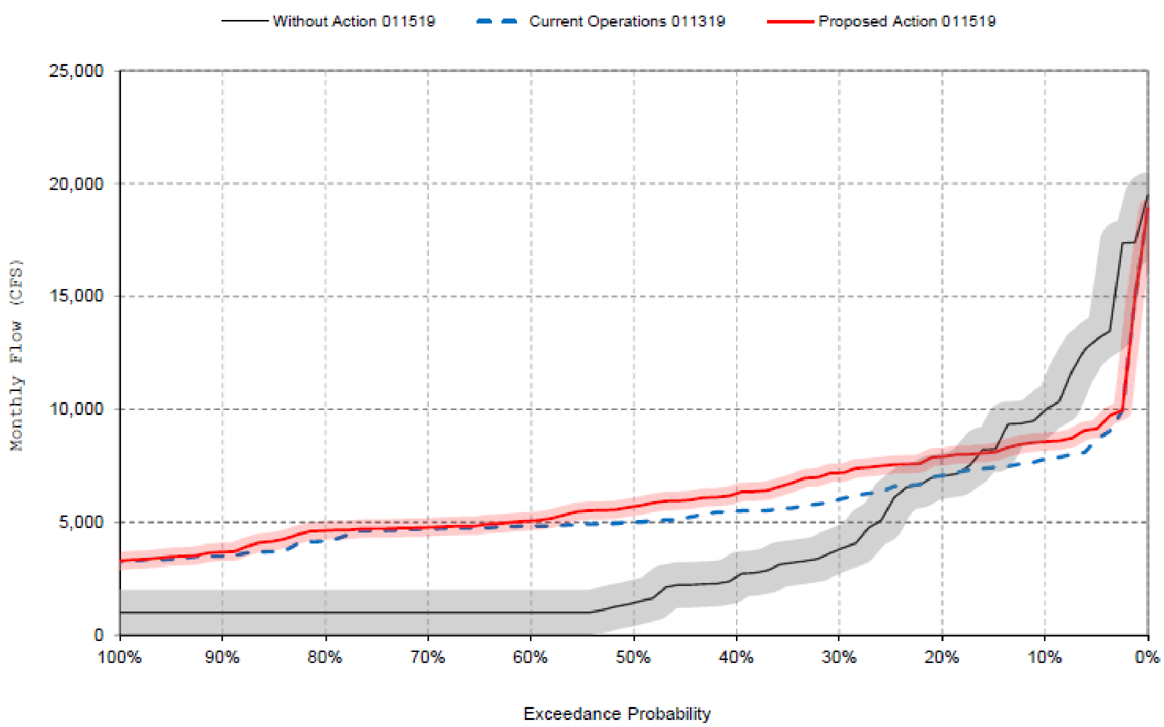


Figure 5.8-15. Modeled Sacramento River Flows at Wilkins Slough, June

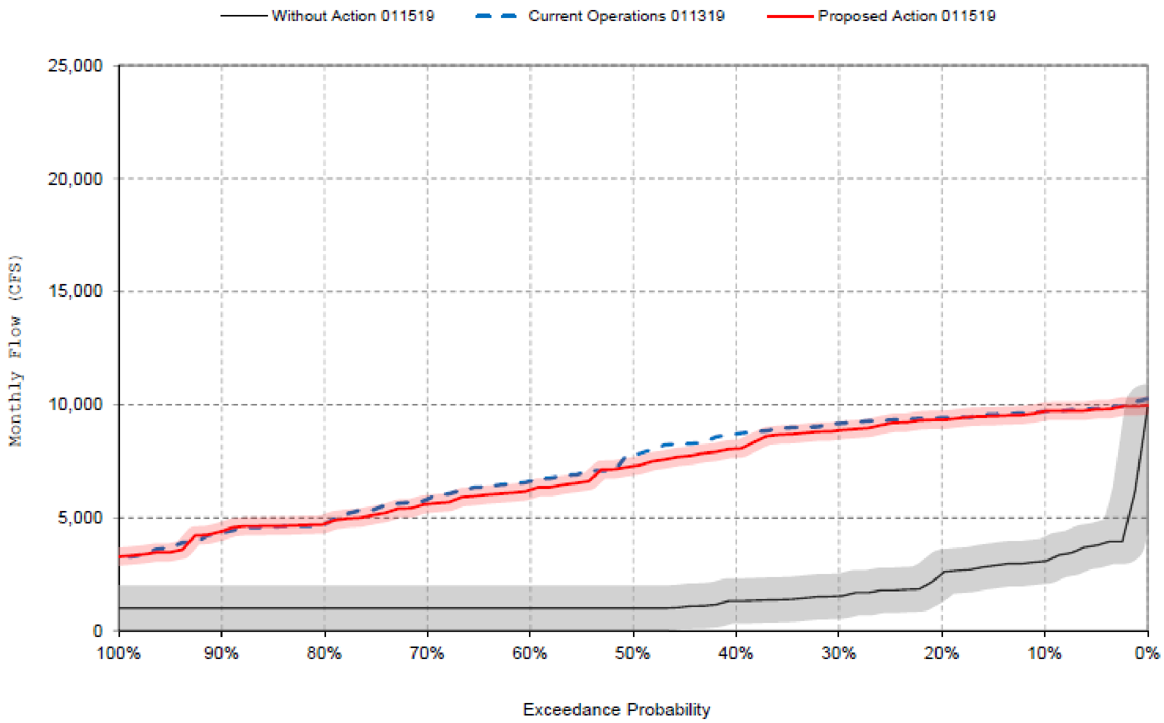


Figure 5.8-16. Modeled Sacramento River Flows at Wilkins Slough, July

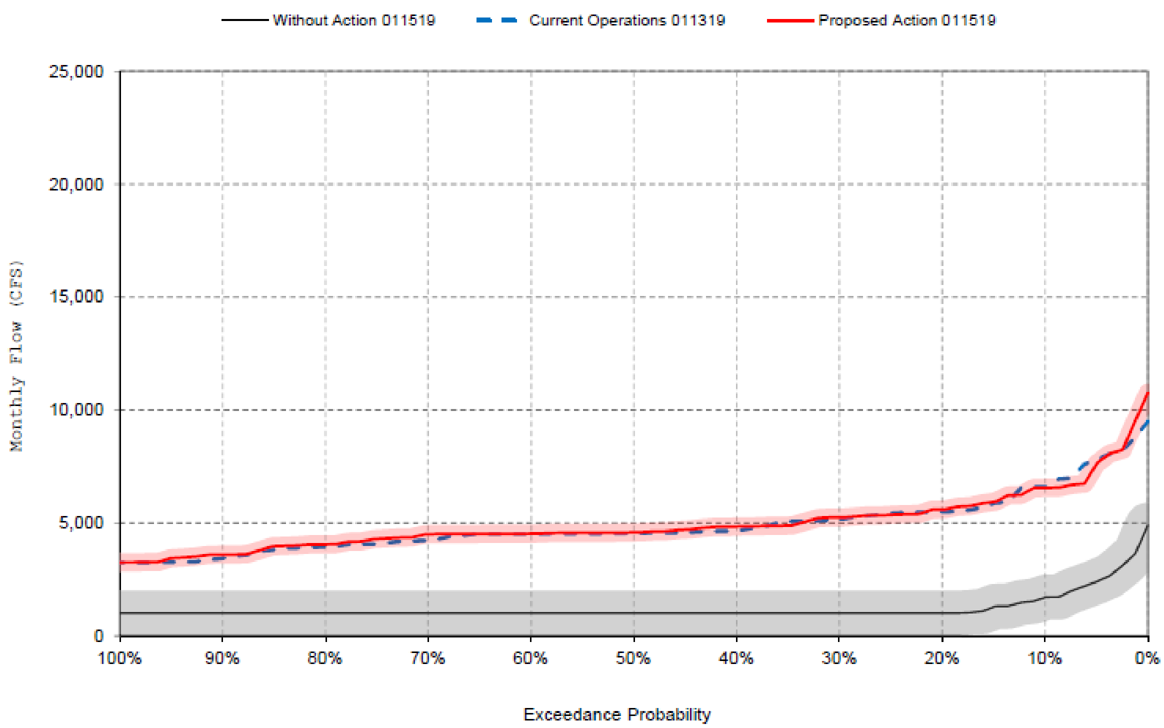


Figure 5.8-17. Modeled Sacramento River Flows at Wilkins Slough, August

During the January through October period of Spring-run Chinook Salmon immigration and holding, flows would generally be similar between the proposed action and COS (Figures 19-10 through 19-18, and 19-7; 15-10 through 15-18, and 15-7; and Tables 15-1 through 15-3, 16-1 through 16-3, 17-1 through 17-3, 18-1 through 18-3, and 19-1 through 19-3 in the CalSim II Flows section of Appendix D), except for higher flows (up to ~2,500 cfs higher) at Wilkins Slough during May and June period for the proposed action scenario for flows in the range from about 5,000 cfs to 11,000 cfs (Figure 19-14 and 19-15 in the CalSim II Flows section of Appendix D), and much higher flows (up to ~7,000 cfs) at Wilkins Slough during September for the COS scenario for flows in the range from about 8,000 cfs to 16,000 cfs (Figure 19-18 in the CalSim II Flows section of Appendix D). The differences in flow occur primarily for flows greater than 5,000 cfs, which are likely high enough to present no passage problems for upstream migrating adults. There are also substantial flow differences between the proposed action and COS at Keswick Dam during June and September (Figures 15-15 and 15-18 in the CalSim II Flows section of Appendix D), but these differences are within a range of flows (6,000 cfs to 17,000 cfs) not expected to substantively affect holding Spring-run Chinook Salmon adults.

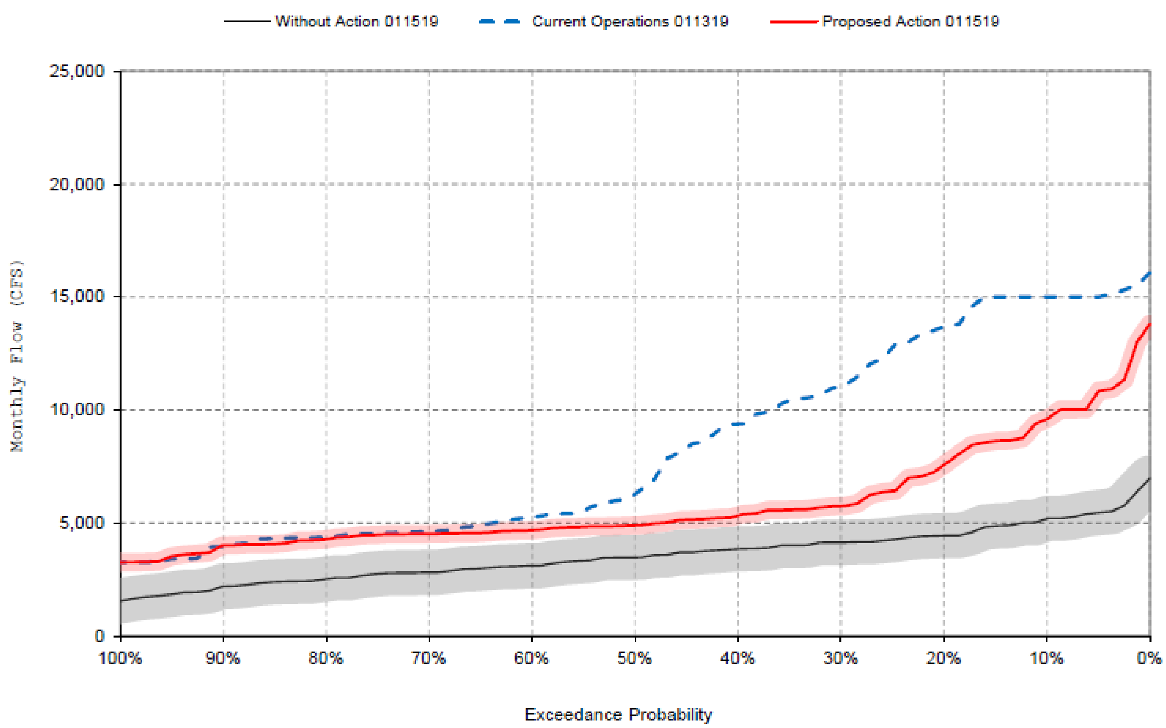


Figure 5.8-18. Modeled Sacramento River Flows at Wilkins Slough, September

The CalSim modeling shows large seasonal changes in the differences in middle and upper Sacramento River flow between the WOA, proposed action and COS. In January and February, the proposed action and COS flows are generally similar to or slightly lower than the WOA flows for most years at both Wilkins Slough and Keswick Dam (Figures 19-10, 19-11, 15-10, and 15-11; and Tables 15-1 through 15-3, 16-1 through 16-3, 17-1 through 17-3, 18-1 through 18-3, and 19-1 through 19-3 in the CalSim II Flows section of Appendix D). In March and April, the proposed action and COS flows are generally lower than the WOA flows at both locations (Figures 19-12, 19-13, 15-12 and 15-13 in the CalSim II Flows section of Appendix D). In May, the proposed action and COS flows at Wilkins Slough are substantially lower than the WOA flows for the 60 percent of highest flow years and are substantially higher for the 25 percent of lowest flow years (Figure 19-14 in the CalSim II Flows section of Appendix D), while at Keswick Dam, the proposed action and COS flows are lower than WOA flows for about 40 percent of the highest flow years and are similar in the other years (Figure 15-14 in the CalSim II Flows section of Appendix D). For the remainder of the adult immigration and holding period (June through October), the proposed action and COS flows were generally higher or much higher than the WOA flows at both locations (Figures 19-15 through 19-18 and 19-7, and 15-15 through 15-18 and 15-7 in the CalSim II Flows section of Appendix D). The higher flows during May through October in years with dry hydrologies at Wilkins Slough and Keswick Dam under the proposed action and COS relative to the WOA conditions would likely benefit adult Spring-run Chinook Salmon migrating in the middle Sacramento River and holding in the upper river by enhancing water quality and upstream passage, and reducing stranding, straying, poaching, and disease risks (Windell et al. 2017).

5.8.3.2.4.1 Water Temperature

In the middle Sacramento River downstream of the Colusa Basin Drain, water temperatures under the proposed action are similar to WOA water temperatures during May (Figure 14-14 in the HEC5Q Temperatures section of Appendix D), generally above the WOA scenario water temperatures from January through April (Figures 14-10 through 14-13 in the HEC5Q Temperatures section of Appendix D), and below the WOA scenario water temperatures during June through October (Figures 14-15 through 14-18, and 14-7 in the HEC5Q Temperatures section of Appendix D). In the upper Sacramento River at Keswick Dam, water temperatures under the proposed action and COS are similar to WOA water temperatures during March (Figure 5-12 in the HEC5Q Temperatures section of Appendix D), well above the WOA scenario water temperatures during January and February (Figures 5-10 and 5-11 in the HEC5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in all years during April through September in all but 7 percent of years in October (Figures 5-13 through 5-18, and 5-7 in the HEC5Q Temperatures section of Appendix D).

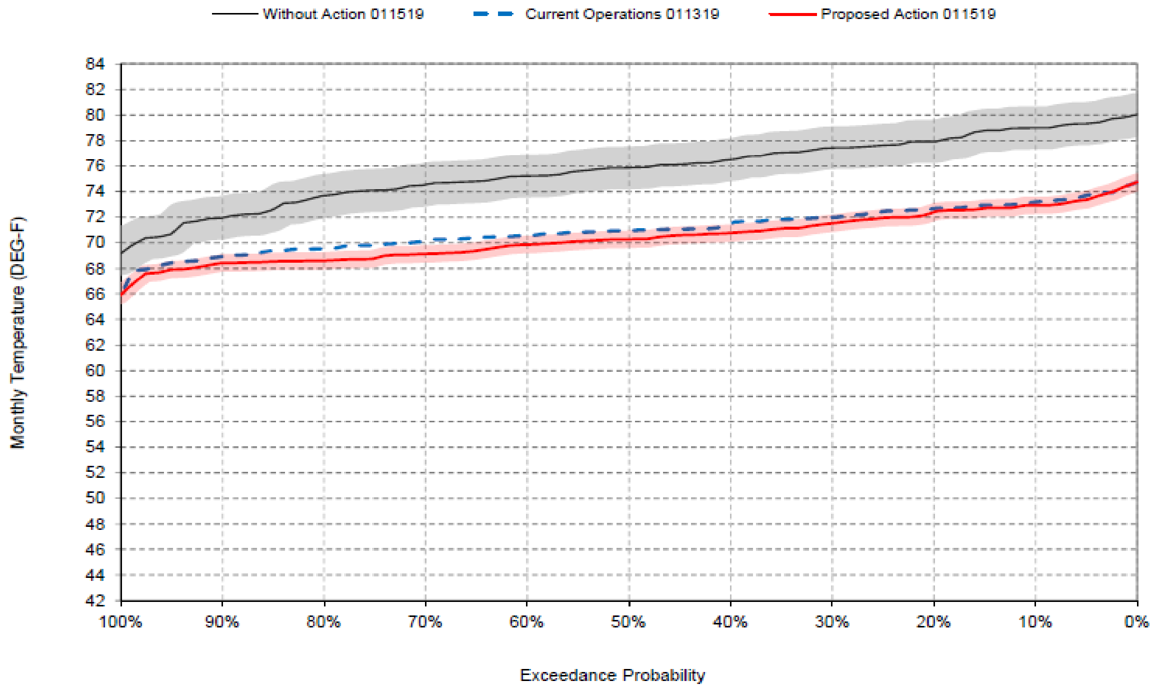


Figure 5.8-19. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, June

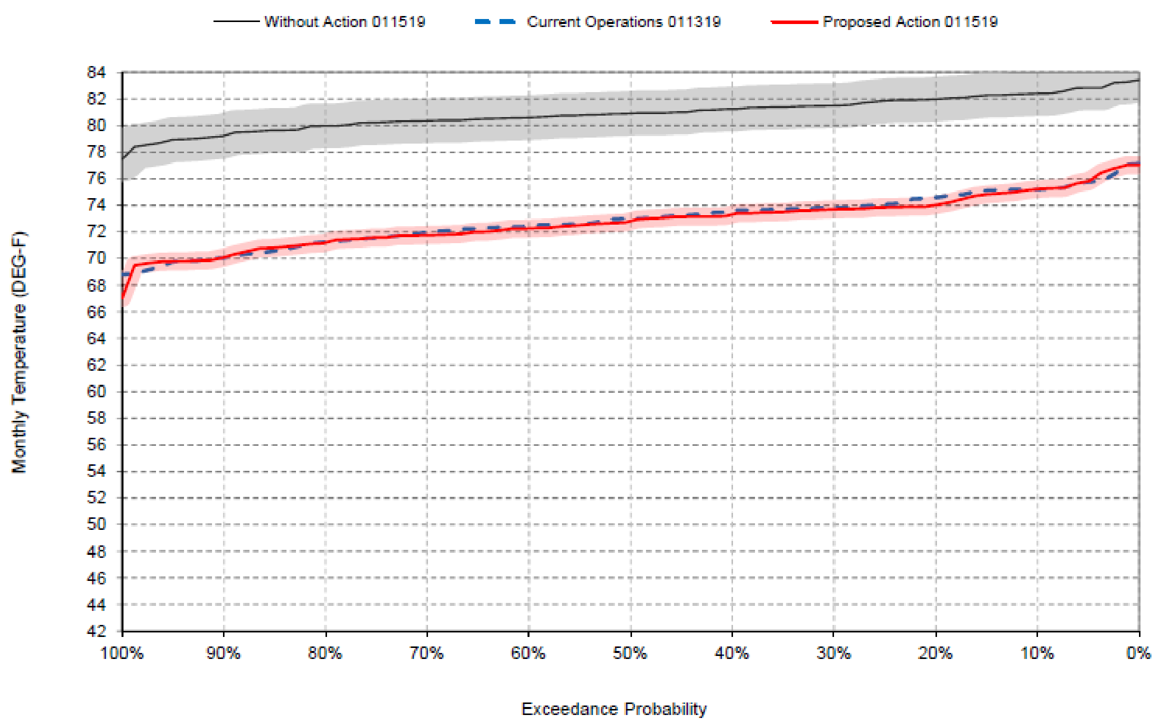


Figure 5.8-20. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, August

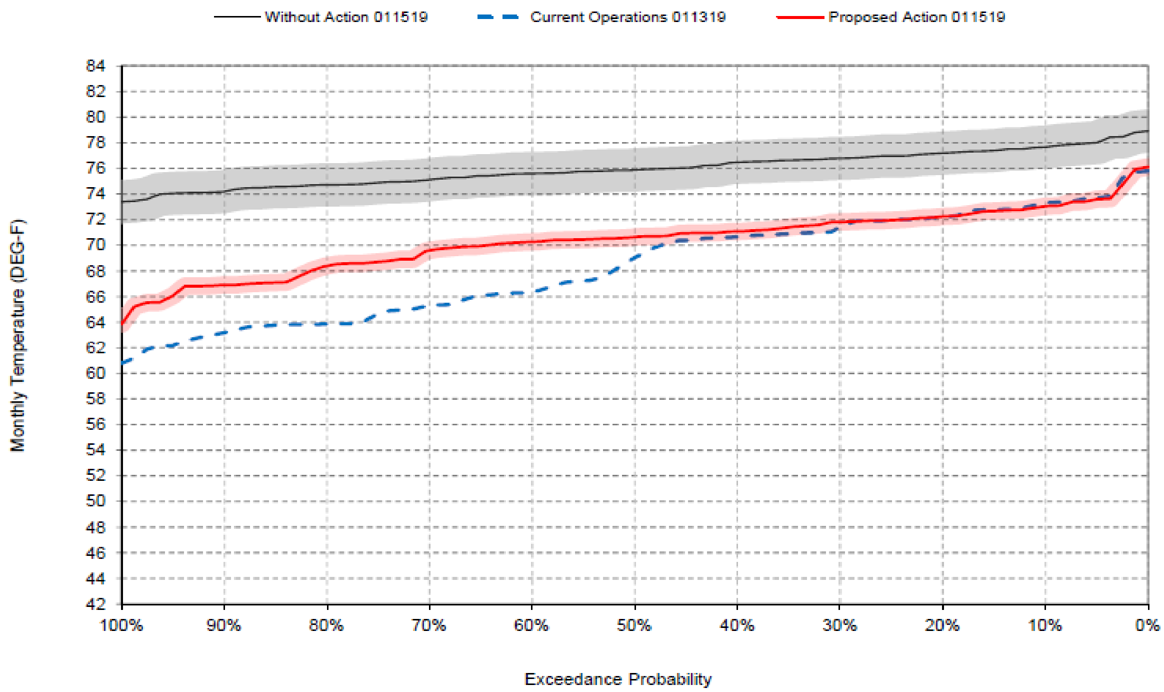


Figure 5.8-21. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, COS and proposed action scenarios, September

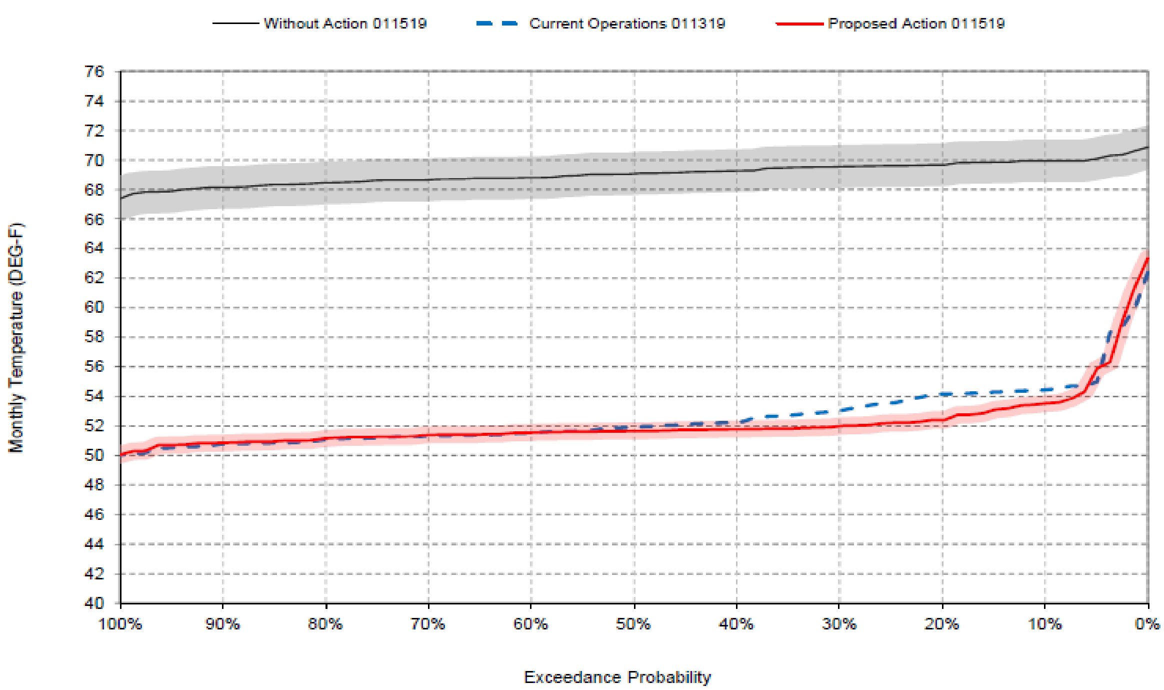


Figure 5.8-22. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the WOA, COS and proposed action scenarios, August

Water temperatures during the January through April period under all three scenarios are suitable for adult spring-run immigrating in the middle Sacramento River or holding in the upper river. However, in May, water temperatures in the middle river below the Colusa Basin Drain are predicted to exceed the threshold for immigrating adults in a large percentage of years under both the proposed action and WOA scenarios, with a greater percentage of years predicted to exceed the threshold under the WOA scenario (Figure 14-14 in the HEC5Q Temperatures section of Appendix D). During June through September, the 68 degrees Fahrenheit threshold is exceeded at Knights Landing during every year under the WOA scenario and in most years under the proposed action and COS, but the exceedances are typically much greater under the WOA scenario (e.g., Figures 14-15 through 14-18 in the HEC5Q Temperatures section of Appendix D). In October, the threshold is exceeded in much lower percentages of years, and the water temperatures are consistently higher for the WOA scenario (Figure 14-7 in the HEC5Q Temperatures section of Appendix D).

At Keswick Dam, the 61 degrees Fahrenheit threshold for holding adults is not exceeded in any years during January through April under any of the scenarios and is exceeded in only 4 percent of years in the WOA scenario in May (Figures 5-10 through 5-14 in the HEC5Q Temperatures section of Appendix D). In June through September, the threshold is exceeded in nearly every year under the WOA scenario, but in only a few years under the proposed action and COS (Figures 5-15 through 5-18 in the HEC5Q Temperatures section of Appendix D). In October, the threshold is exceeded in no years under the WOA scenario and in less than 10 percent of years under the proposed action and COS, although water temperatures under the proposed action and COS are lower than those under the WOA scenario, except in the warmest 8 percent of years (Figure 5-7 in the HEC5Q Temperatures section of Appendix D). During the summer months (June through September), when water temperatures are generally stressful for adult Spring-run Chinook Salmon in the Sacramento River, the water temperatures under the WOA conditions in both the middle and upper Sacramento River would generally be much higher than those under the proposed action or COS. It is unlikely that migrating adult Spring-run Chinook Salmon could survive the elevated water temperatures in the middle Sacramento River predicted for the summer months under the WOA modeling scenario or that eggs of the adult spring-run holding in the upper Sacramento River could survive the predicted high summer water temperatures.

5.8.3.2.5 Adults Holding in Rivers

5.8.3.2.5.1 River Flows

Flows under WOA are generally similar to proposed action and COS flows during February (Figures 15-11 in the CalSim II Flows section of Appendix D), are much higher than proposed action and COS flows during March and April and during May of wetter years (Figures 15-12 through 15-14 in the CalSim II Flows section of Appendix D), and are lower than proposed action and COSflows during June through October (Figures 15-15 through 15-18, and 15-7 in the CalSim II Flows section of Appendix D). In general, higher flows are likely to benefit holding and spawning adult Winter-run by affording better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, lower risk from anglers, and a greater area of river bed with suitable attributes for redds (Windell et al. 2017). The proposed action and COS scenarios would have much higher flows than the WOA scenario during summer, when flow is generally low and so more likely to limit Spring-run Chinook Salmon holding and spawning success. Therefore, the proposed action and COS are expected to be beneficial to Spring-run Chinook Salmon relative to the WOA conditions.

Flows during the February through October period would generally be similar between the proposed action and COS modeling scenarios (Figure 15-11 through 15-18, and 15-7; and Tables 15-1 through 15-3, 16-1 through 16-3, and 17-1 through 17-3 in the CalSim II Flows section of Appendix D). The largest differences between these scenarios would occur in June for the upper 60 percent of flows, when proposed action flows would be greater than the COS flows, and in September for the upper 50 percent of flows, when the COS flows would be greater than the proposed action flows. The differences occur over a range of flows from about 9,000 cfs (June) or 7,000 cfs (September) to about 16,000 cfs, all of which are suitable flows for holding and spawning adults (e.g., USFWS 2003), so the differences are not expected to substantially affect the adults.

5.8.3.2.5.2 Water Temperatures

In the upper Sacramento River at Keswick Dam, water temperatures under the proposed action and COS are similar to WOA water temperatures during March (Figure 5-12 in the HEC5Q Temperatures section of Appendix D), well above the WOA scenario water temperatures in February (Figure 5-11 in the HEC5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in April through October, except for the warmest Octobers (Figures 5-13 through 5-18, and 5-7 in the HEC5Q Temperatures section of Appendix D). Water temperatures under the WOA scenario are predicted to exceed the 61 degrees Fahrenheit holding threshold in almost all years during June through September, and the 56 and 53.5 degrees Fahrenheit spawning threshold in most years during May through October. In contrast, water temperatures under the proposed action and COS are predicted to exceed the 61 degrees Fahrenheit holding threshold in no years for every month in the February through October period and are rarely predicted to exceed the 56 and 53.5 degrees Fahrenheit thresholds, except for 15 to 75 percent of years during July through October. These results indicate that the proposed action, relative to the WOA, provides a clear benefit to adult Spring-run Chinook Salmon individuals holding and spawning in the upper Sacramento River. In view of the improved water temperature management operations planned for the proposed action, this action is expected to benefit the Spring-run Chinook Salmon adults relative to the WOA.

There are few differences in water temperatures between the proposed action and COS during any of the months that adult Spring-run Chinook Salmon hold and spawn in the upper Sacramento River (Figures 5-11 through 5-18, and 5-7 in the HEC5Q Temperatures section of Appendix D). At Keswick Dam, under the proposed action and COS, the mean water temperatures would be below the 61 degrees Fahrenheit threshold for holding adults for all months from February through October, except for August through October in, at most, 4 percent of years.

5.8.3.3 Spring Pulse Flows

5.8.3.3.1 <u>Egg to Fry Emergence</u>

As described in the proposed action, Reclamation will release pulse flows in the spring if projected storage on May 1 in Shasta Reservoir is above 4 MAF. If Shasta Reservoir total storage on May 1 is projected to be greater than 4 MAF, Reclamation would make a spring pulse release as long as the release would not cause Reclamation to drop into a lower Tier of the Shasta summer temperature management or interfere with the ability to meet other anticipated demands on the reservoir.

Spring pulse releases are not at the time of year of egg incubation, and rather would be timed to attract juvenile Spring-run to move downstream. However, spring pulses could benefit late redds. As indicated by the SAIL Upper River (CM1) conceptual model, flows, combined with other environmental drivers, affect water temperature, DO levels, sedimentation, substrate composition, and other habitat attributes that influence redd quality, which in turn determines egg-to-fry survival. Thus, the spring pulse could benefit late redds by increasing dissolved oxygen in the water for eggs, reducing water temperatures, and flushing fine sediment from spawning gravels. Spring pulses could cause impacts to late eggs emerging from the gravel could be exposed to redd dewatering on the ramp-down side of a spring pulse.

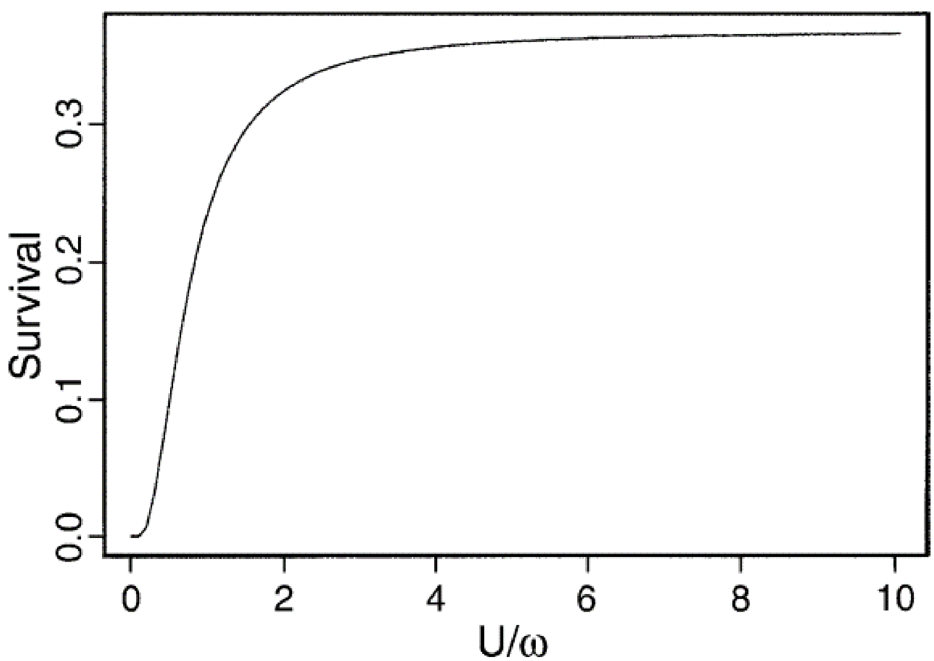
5.8.3.3.2 Rearing to Outmigrating Juveniles

Spring pulse flows would benefit juvenile salmonids by triggering their outmigration (Kjelson et al.,1981). The NMFS Southwest Fisheries Science Center has run statistical models using tagging data from Spring-run Chinook Salmon and Fall-run Chinook Salmon from 2012-2017 and found a significant increase in smolt survival is observed when Sacramento River flow at Wilkins Slough is above 9,100 cfs during the smolts outmigration period (Cordoleani et al, 2019).

One hypothesis may be that decreased travel time leads to decreased interactions with predators. The XT model (Anderson, 2005) provides an estimated equation for survival in rivers based on predation. Anderson’s XT model, re-written in terms of mostly physical parameters, is:

$$S = exp\,(-\rho\alpha\sqrt{x^2 + w^2t^2})$$

Where ρ is the predator density, alpha is the cross-sectional area, x is the travel distance, w is the random encounter velocity, and t is the travel time. Increasing flow in the Sacramento River leads to increasing river velocity, which would lead to increasing average migration velocity and decreasing travel time. Figure 5.8-23 below, reproduced from Anderson (2005), shows anticipated survival based on average migration velocity divided by the random component of the encounter velocity, w.



Anderson (2005)

Figure 5.8-23. XT Model Survival vs Average Migration Velocity *U*, divided by the Random Component of the Velocity *w*.

Shown another way, below is a plot of the X-T model for dimensionless travel time units (Figure 5,8-24). As can be seen from the plot below, reduced travel time is highly valuable for increased survival.

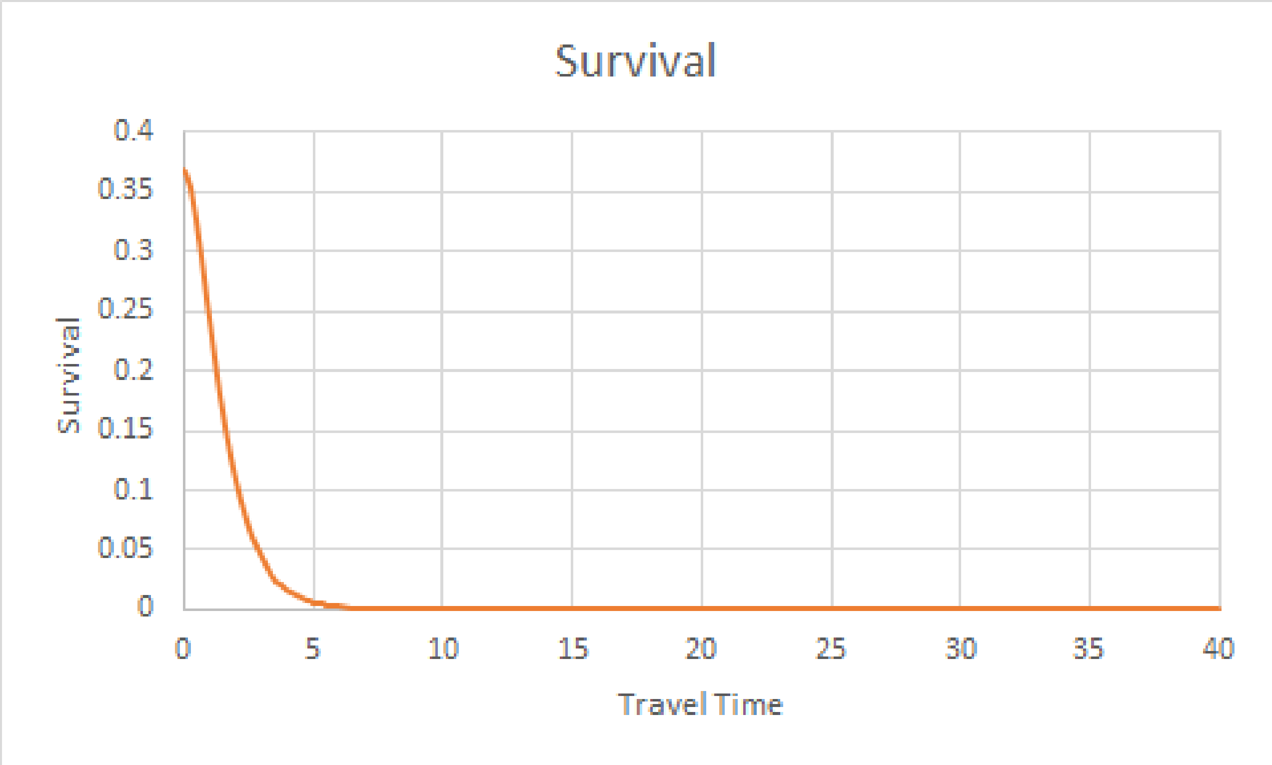


Figure 5.8-24. XT Model for Dimensionless Travel Time Units

Higher flows in the Sacramento River lead to higher velocities and lower travel times, reducing predation.

The random encounter velocity w relates to the predator perception and reaction distance. Reaction distance depends on water clarity and light level (Vogel and Beauchamp, 1999). Water clarity is often measured by Secchi disk depth. The following plots, created from data published in Snider and Titus (2000) and the Fall Mid-water trawl from CDFW, both show an inverse correlation between flow and Secchi depth. As expected, with higher flow, water clarity is less. More sediment is mobilized with higher flows, as higher flows generate more shear stress, as described by the equations of sediment transport (Shields, 1936).

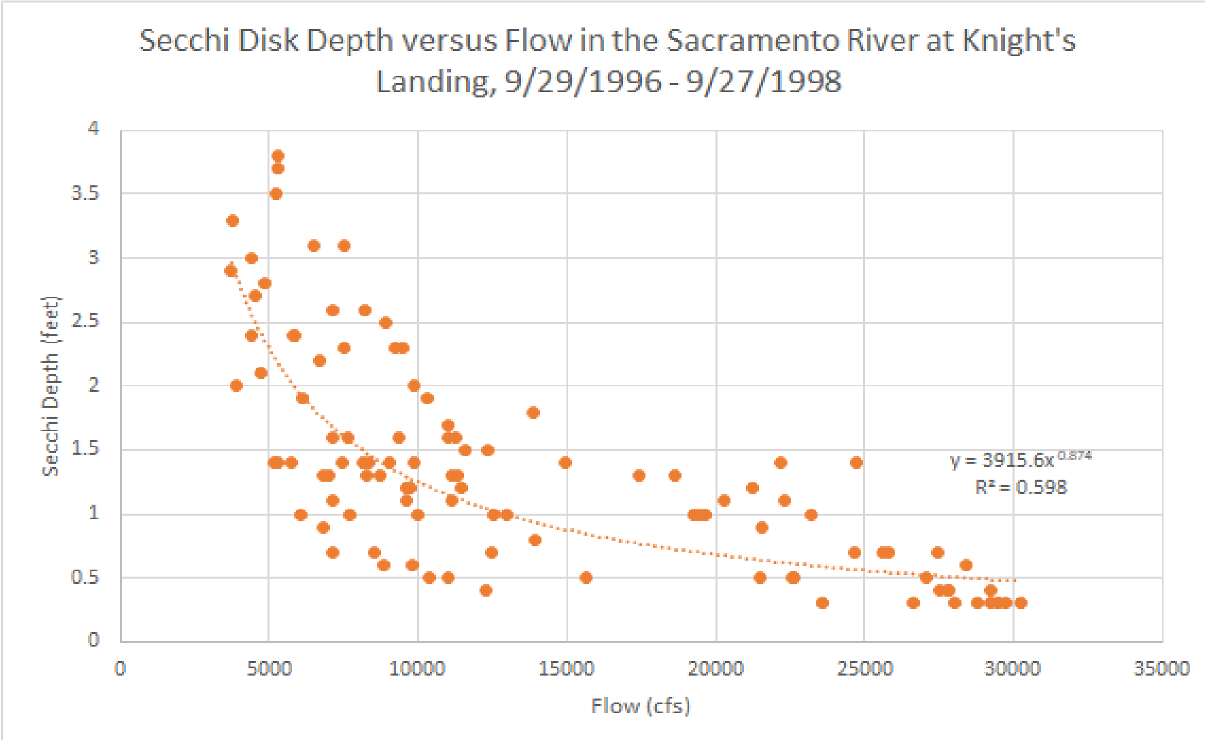


Figure 5.8-25. Turbidity vs. Flow. Data from Snider and Titus, 2000

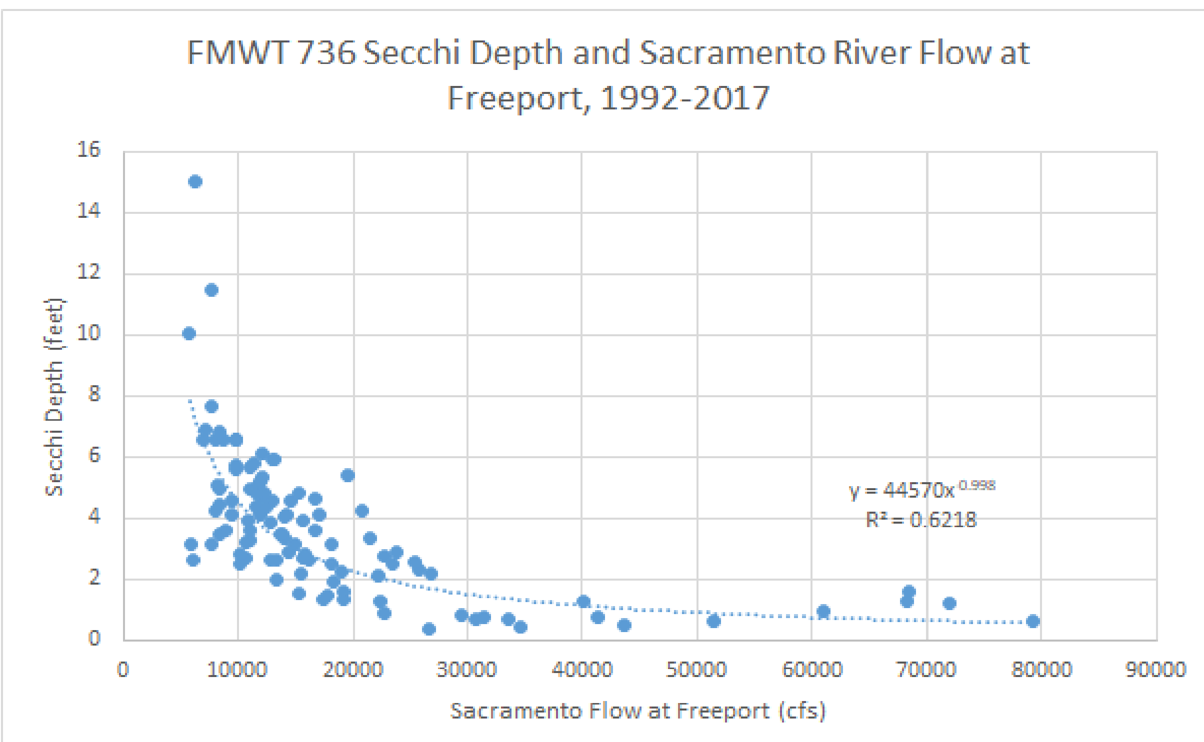


Figure 5.8-26. Turbidity vs. Flow. Data from Fall Mid-water Trawl station 736

Decreased water clarity with higher flows would reduce predator perception distance, which would increase survival according to the XT model.

5.8.3.4 Fall and Winter Refill and Redd Maintenance

Under WOA, fall flows are low. Under the proposed action, Reclamation proposes to adjust fall flows based on Shasta Reservoir storage to avoid dewatering Winter-run and Fall-run Chinook salmon redds and cold water pool impacts. Higher flows than the WOA during this September – November period could benefit rearing Spring-run Chinook Salmon by increasing the inundated area of rearing habitat, and associated food and temperature benefits.

5.8.3.5 Clear Creek Flow Releases

Spring-run Chinook Salmon inhabitat Creek Creek and is designated critical habitat for the species from the downstream of the Whiskeytown Reservoir to the confluence with the Sacramento River. Spring-run Chinook Salmon would be exposed to Reclamation's operation of Whiskeytown Reservoir and Clear Creek releases.

5.8.3.5.1 Egg to Fry Emergence

Under COS, Eggs and emerging fry are exposed to the effects of Whiskeytown temperature controls in Clear Creek, based on the timing of these controls (60°F at IGO gage June 1-September 15; 56°F at IGO gage September 15-October 31) overlapping with the seasonal occurrence of this life stage in Clear Creek (September-November; Table 5.8-1), and the presence of spawning individuals upstream of the IGO gage in Clear Creek (CDFW 2011). Development of incubating Spring-run Chinook Salmon eggs is heavily influenced by water temperature with temperatures < 54°F considered optimal, 54-58°F suboptimal, and water temperatures above 58°F causing chronic to acute stress (Stillwater Sciences 2006).

Effects of egg and fry exposure to Whiskeytown temperature controls in Clear Creek was modeled in HEC 5Q. The proposed action reduces water temperatures in Clear Creek compared to the WOA.

This temperature reduction as compared to WOA would result in an increased likelihood of achieving temperature compliance at IGO, leading to improved survival of incubating Spring-run Chinook Salmon eggs. However, any eggs incubating in Clear Creek prior to September 15 or downstream of the compliance point at IGO could be subjected to water temperatures in the chronic to acute stress range (above 58°F), especially at lower exceedance probabilities (< 50%), and certain water year types. Furthermore, the incubation period (September 15-November) temperature threshold used in this action (56°F at IGO gage) falls within the suboptimal temperature range for incubating Spring-run Chinook Salmon eggs, which could result in less than optimal survival. There are water temperature benefits of the proposed action when compared to WOA. The optimal incubation temperatures for this species are < 54°F.

5.8.3.5.2 Rearing to Outmigrating Juveniles in Rivers

Few, if any, rearing and outmigrating juveniles would be exposed to the effects of spring attraction flows given the likely timing of these flows (May-June [Clear Creek Technical Team 2018]), and the peak timing of this life stage in Clear Creek (November–February; Table 5.8-1). However, rearing juveniles would likely be exposed to the effects of geomorphic flows, which are likely to occur contemporaneously with peak storm flows in Clear Creek after January 1 (to maximize geomorphic effectiveness), since there may be rearing juveniles in Clear Creek throughout the winter, spring, and summer after emergence.

Implementing geomorphic flows that will disperse spawning gravel will minimize project effects to this population. Spawning habitat requirements for salmon are complex and involve the fulfillment of a variety of geomorphic and fluvial conditions. The geomorphic flow augmentation reestablishes sustainable sediment transport downstream of Whiskeytown Dam. This is necessary to support and maintain distinct morphological units such as backwaters, riffles and pools. The ecological goal of gravel augmentation is to create self-sustaining morphological units that have the physical characteristics necessary for the different life stages of salmonids (Pasternak 2010).

Geomorphic flow releases also have the potential to degrade water quality via increased suspended solids and turbidity, leading to direct physiological impacts on rearing and outmigrating juvenile health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility. The effects of this exposure could also include displacement of rearing fish from suitable habitat, leading to increased predation and exposure to increased water temperatures.

Studies on Clear Creek have shown that the sediment transport threshold generally occurs between 3000–3500 cfs (McBain and Trush 2001, Pittman and Matthews 2004). Events of this magnitude occurred in 50% (26 of 52) of years since Whiskeytown Dam was constructed, while daily average flows > 3000 cfs occur on 0.2% of days since WY 1965 (37 days total). Under WOA, geomorphic flows would occur whenever storage levels get high enough for spilling into the Gloryhole Spillway, but would be unlikely to occur. Proposed geomorphic flows up to the safe release capacity (approximately 900 cfs) represent approximately 30% of the flow needed to transport sediment in the absence of flows from downstream tributaries. As a result, adverse effects associated with geomorphic flow releases are expected to occur with low frequency, and be of low magnitude, compared to COS.

Few, if any, rearing and outmigrating Spring-run Chinook Salmon juveniles would benefit from the effects of Whiskeytown water temperature controls in Clear Creek given the timing of these controls (June 1-September 15 & September 15-October 31), and the peak timing of this life stage in Clear Creek (November–February; Table 5.8-1).

5.8.3.5.3 Adult Migration from Ocean to Rivers

Some migrating adults would be exposed to the effects of geomorphic flows under the proposed action given the likely timing of these flows (contemporaneous with peak storm flows after January 1 through April) and the peak timing of this life stage in Clear Creek (March-September with peak abundance May-June; Table 5.8-1). Exposure to the effects of these high flows could result in adverse effects on migrating adults if improperly shaped, however flows will be developed in coordination with the Clear Creek Implementation Team. Therefore, effects include the potential for stranding leading to increased predation, and degraded water quality from increased discharges of suspended solids and turbidity leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost) will be avoided and minimized. These flows would be uncontrolled under the WOA conditions, and thus, the species could be exposed to natural flood conditions and adverse effects stated above.

Spring attraction flows would affect a large portion of the migrating adult Spring-run Chinook population in Clear Creek given the likely timing of these flows (May-June [Clear Creek Technical Team 2018]), and the peak timing of this life stage in Clear Creek (May-June; Table 5.8-1). The anticipated time frame for spring attraction flows (May-June) suggests that spring attraction flows are very unlikely to occur during a peak storm flow event. In addition, if occurring outside of a peak storm flow event, the magnitude of spring attraction flows (10 TAF with daily release up to safe release capacity [900 cfs]) would not produce the 3000-3500 cfs needed to transport sediment in Clear Creek (McBain and Trush 2001, Pittman and Matthews 2004). These factors would reduce the likelihood of adverse effects resulting from increases in suspended solids and turbidity, which could lead to physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost). Spring attraction flows benefit migrating adult Spring-run Chinook in Clear Creek (Clear Creek Technical Team 2018), and indicate that the number of migrating adults observed and the distance of their upstream migration both increase following spring attraction flows. Adult upstream migrating salmon are attracted to increased flow and cues fish to natal habitats.

Migrating adults would also benefit from Whiskeytown water temperature controls in Clear Creek under the proposed action and COS, based on the starting date of temperature compliance (June 1) and the seasonal timing of this life stage in Clear Creek (peak abundance May-June; Table 5.8-1). The water temperature objective at the IGO gage beginning June 1 is 60°F, well under the 65°F upper bound of the suboptimal range of water temperatures for migrating adult Spring-run Chinook Salmon (Stillwater Sciences 2006), and approximately 3°F cooler than projected water temperatures in June at the IGO gage under the WOA scenario.

5.8.3.5.4 Adult Holding in Rivers

Few, if any, holding adults would be exposed to the effects of geomorphic flows given the likely timing of these flows (contemporaneous with peak storm flows after January 1) and the peak timing of this life stage in Clear Creek (March-September with peak abundance May-July; Table 5.8-1). Exposure to the effects of these high flows could result in adverse effects on holding adults if improperly shaped. Effects include the potential for stranding leading to increased predation, increased water temperature, and degraded water quality from increased discharges of suspended solids and turbidity leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost). These effects are not anticipated since flows will be shaped in coordination with the Clear Creek Implementation Team. Potential benefits of geomorphic flows included increased gravel mobilization that will increase spawning habitats and create a habitat complexity.

Spring attraction flows would affect a large portion of the holding adult Spring-run Chinook population in Clear Creek given the likely timing of these flows (May-June [Clear Creek Technical Team 2018]), and the peak timing of this life stage in Clear Creek (May-July; Table 5.8-1). These are expected to be beneficial for the species, by increasing cues that will support CV Spring-run to return natal streams. The anticipated timeframe for spring attraction flows (May-June) suggests that they are very unlikely to occur during a peak storm flow event. In addition, if occurring outside of a peak storm flow event, the magnitude of spring attraction flows (10 TAF with daily release up to safe release capacity [900 cfs]) would not produce the 3000-3500 cfs needed to transport sediment in Clear Creek (McBain and Trush 2001, Pittman and Matthews 2004). These factors would reduce the likelihood of any adverse effects resulting from increases in suspended solids and turbidity, which could lead to physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost).

Holding adults would also benefit from Whiskeytown water temperature controls in Clear Creek under the proposed action, based on the starting date of water temperature compliance (June 1) and the seasonal timing of this life stage in Clear Creek (peak abundance May-June; Table 5.8-1). The temperature objective at the IGO gage beginning June 1 is 60°F, under the 60.8°F upper limit of the optimal range of water temperatures for holding adult Spring-run Chinook Salmon (Stillwater Sciences 2006), and approximately 3°F cooler than projected water temperatures in June at the IGO gage under the WOA scenario.

5.8.3.6 Feather River

The follow section applies to the Feather River below the FREC boundary.

5.8.3.6.1 Egg to Fry Emergence

5.8.3.6.1.1 Flow Effects

Eggs and emerging fry of Spring-run Chinook would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (September-February; Table 5.8-1; NMFS 2016), minimum instream flow requirements in the HFC (Table 5.8-2), and compliance with Water Rights Decision 1641 (D-1641).

As indicated by the SAIL Upper River (CM1) conceptual model, these flows, combined with other environmental drivers, affect water temperature, DO levels, sedimentation, substrate composition, and other habitat attributes that influence redd quality, which in turn determines egg-to-fry survival. Insufficient flow during this life stage may result in higher water temperatures, lower DO in redds, and redd dewatering, each of which may lead to elevated egg mortality. Insufficient flow may also limit the habitat area available for redd construction, thereby limiting available habitat for this life stage. Excessive flow during this life stage may scour redds, and higher flows may attract spawning adults further upstream into the Low Flow Channel (LFC), where spawning habitat is less abundant, and the effects of superimposition are greater (Sommer et. al. 2001).

Table 5.8-2. Feather River High Flow Channel minimum instream flow requirements

Preceding April – July Unimpaired runoff (Percent of Normal)	High Flow Channel Minimum Instream Flow		
	Oct-Feb (cfs)	March (cfs)	April-Sept (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Under the Without Action (WOA) scenario, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Reservoir gates and diversion tunnels would be kept open, resulting in annual storage volumes less than 1,000 TAF (Figure 5.8-27). As a result, there would be limited control of flow or water temperature in the Feather River HFC, which provides habitat for this life stage. Feather River flows under the WOA scenario would be lower in the summer and fall and higher in the winter and spring compared to current operations and the proposed action (Figures 5.8-28 and 5.8-29).

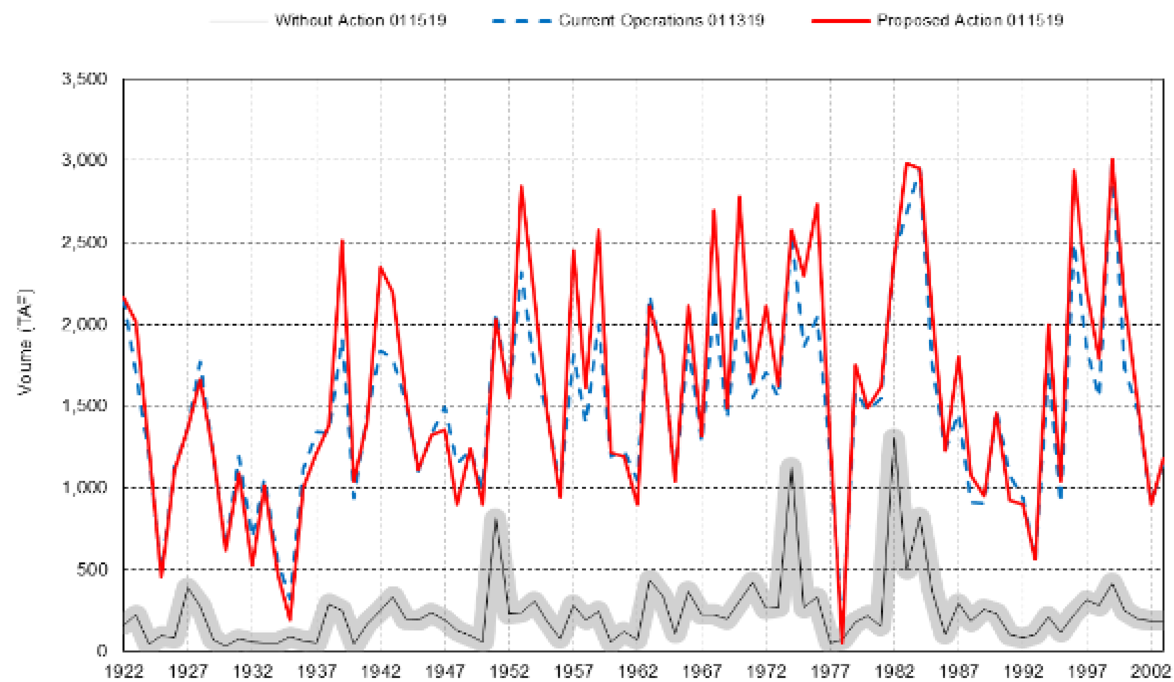


Figure 5.8-27. CalSim II estimates of mean Oroville storage (Thousand Acre-Feet [TAF]) for the period 1923–2002 under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

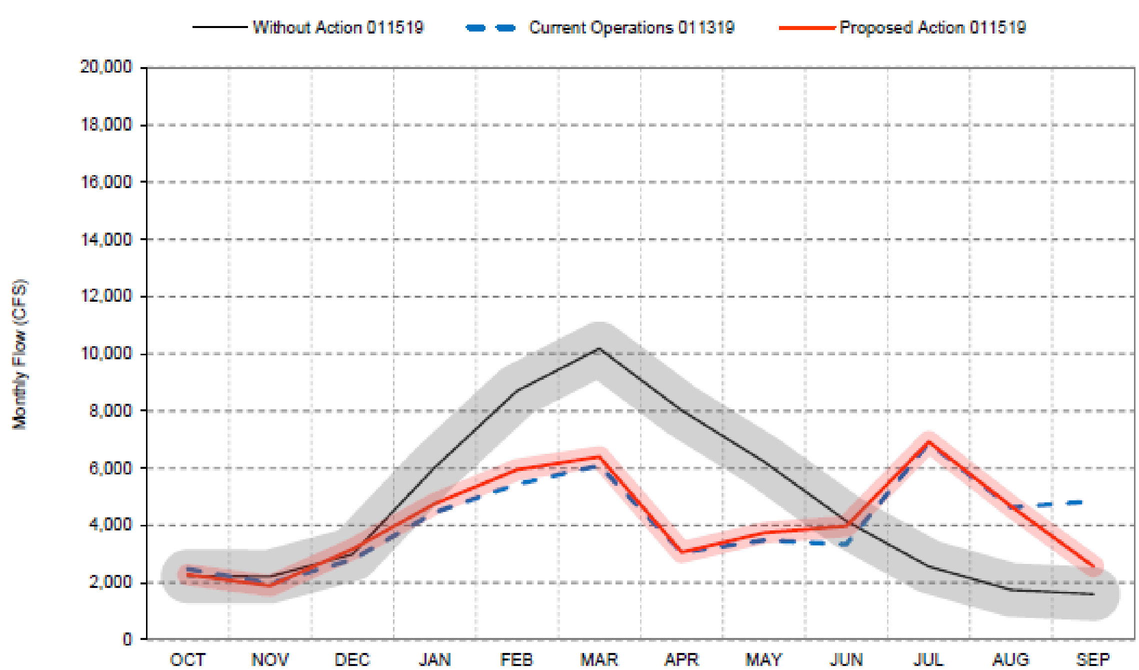


Figure 5.8-28. CalSim II estimates of Feather River long-term average flow below Thermalito Afterbay under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

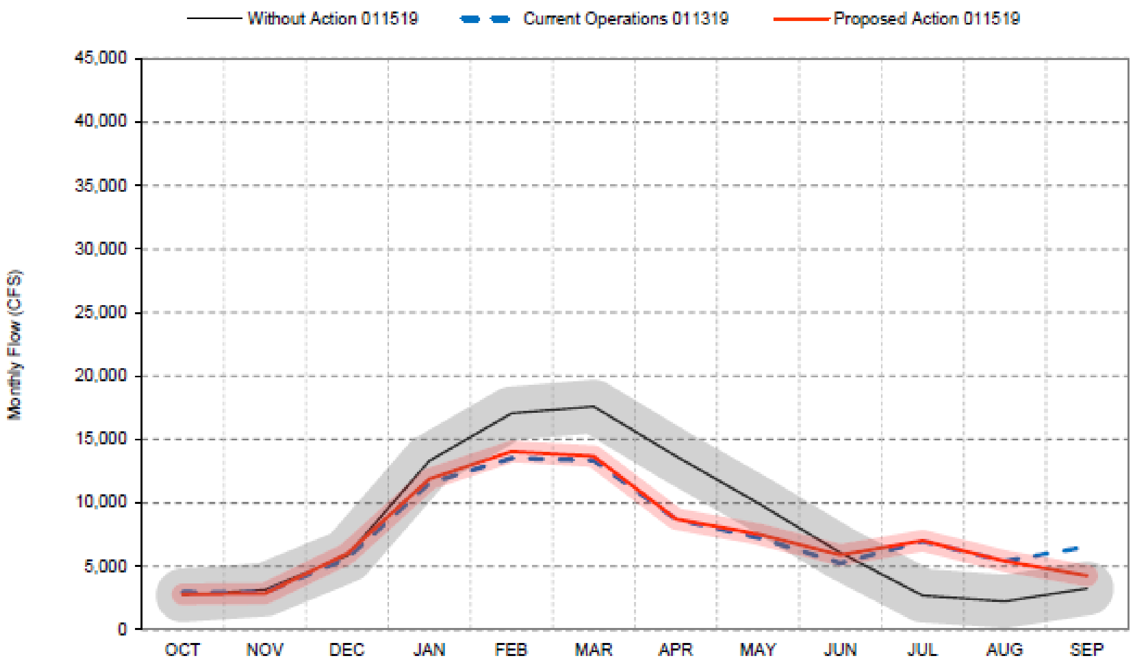


Figure 5.8-29. CalSim II estimates of Feather River mouth long-term average flow under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

Feather River flows below Thermalito Afterbay under the proposed action and COS scenario would be similar to or higher than flows under the WOA scenarios during the peak seasonal timing of Spring-run Chinook egg incubation (September-November), but would be similar or slightly lower during the months of December to February (Figure 5.8-30). Specifically, higher flows under the COS and proposed action scenarios would occur more frequently in September and October than under the WOA scenario (Figure 5.8-31). Additionally, flows under the proposed action scenario would have a lower likelihood of falling below the required minimum flow stipulated in applicable NMFS/USFWS BOs for October (1,200 – 1,700 cfs, depending on preceding April – July unimpaired runoff) and September (1,000 cfs) (Table 5.8-2 and Figure 5.8-31) as compared to WOA.

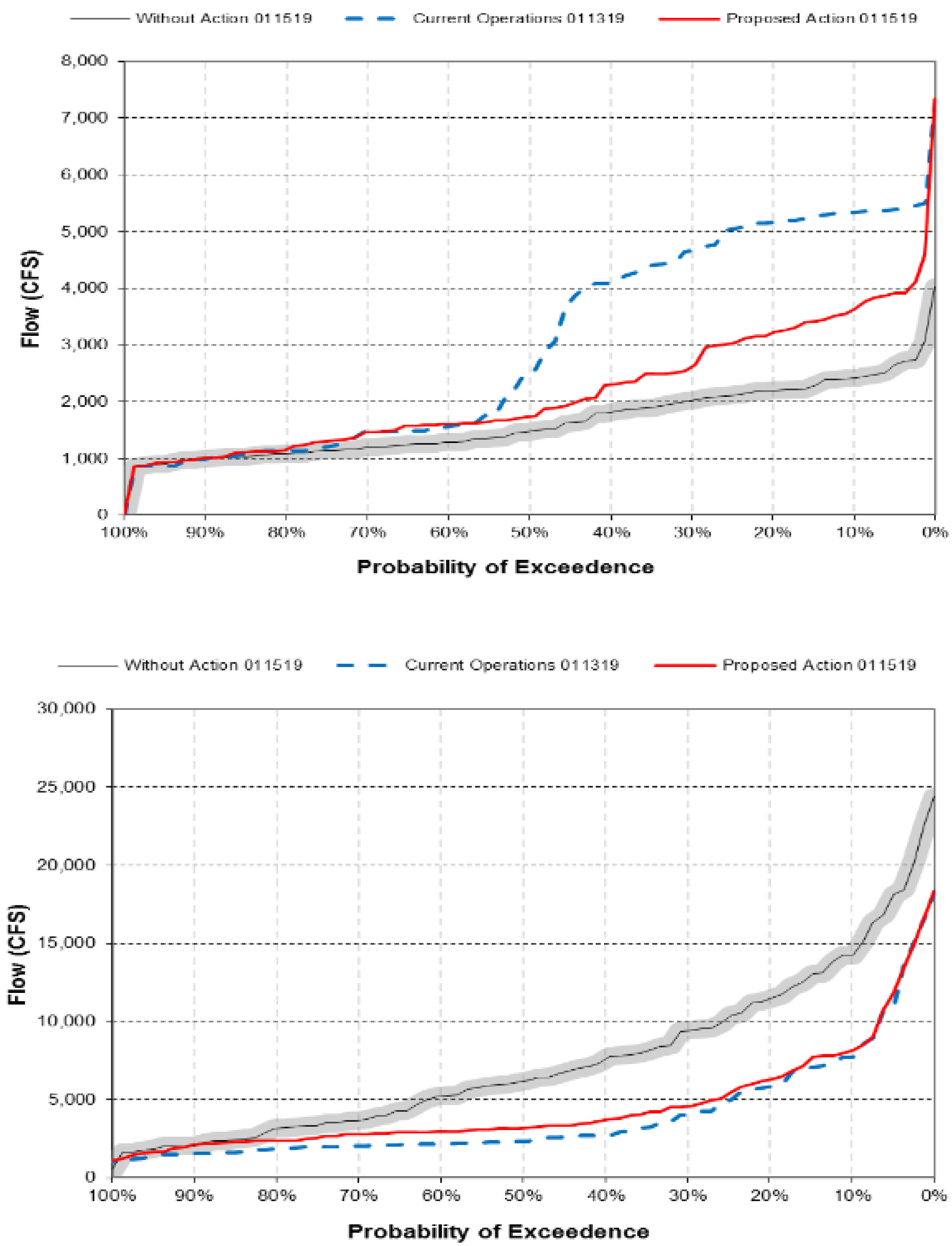


Figure 5.8-30. CalSim II estimates of Feather River flow below the Thermalito Afterbay in September-November and December-February under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

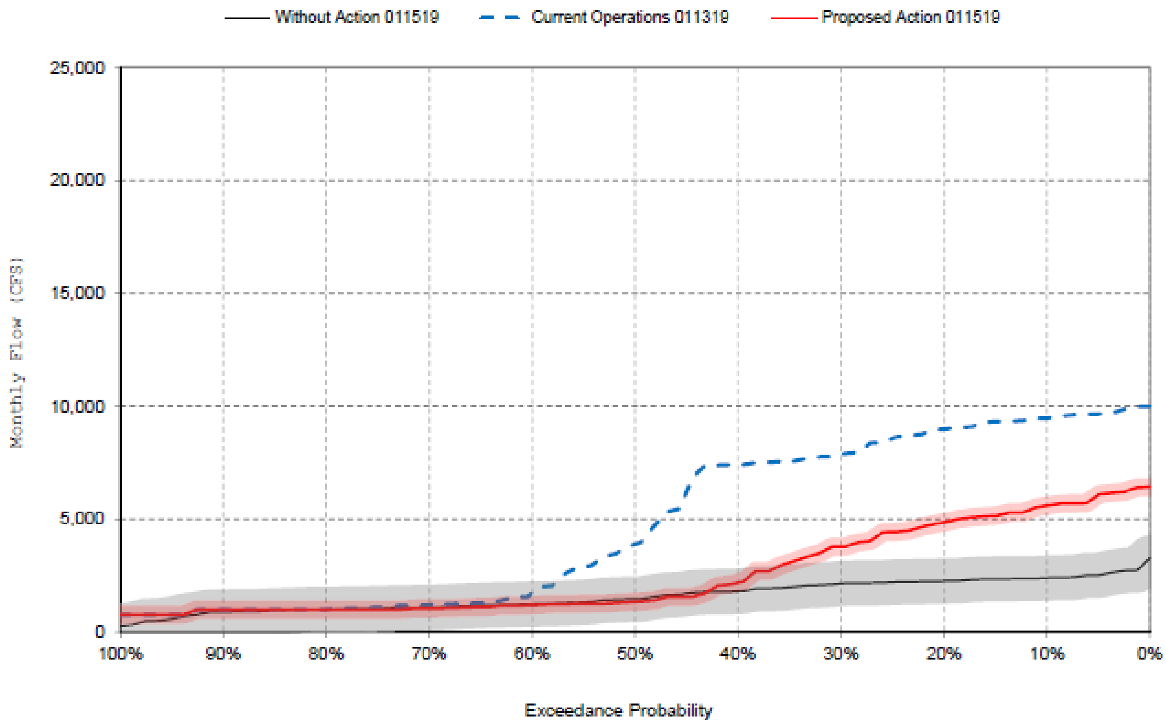


Figure 5.8-31. CalSim II estimates of Feather River flow below the Thermalito Afterbay in September and October under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

Flows in the Feather River HFC during the egg incubation period would be similar to or higher under the proposed action and COS than under the WOA scenario, and in below normal, dry, and critical water year types, flows are reliably higher under the proposed action scenario than WOA scenario in September and October (Figure 5.8-32). Importantly, CalSim II model output indicates projected flows under the proposed action and COS scenarios would increase the likelihood that September and October minimum instream flow criteria are achieved. Differences in flows between the proposed action and COS are generally small across all months except September (Figures 5.8-28, 5.8-30, and 5.8-31). However, the proposed action is anticipated to result in reliably higher flows than both WOA and COS scenarios during October of below normal, dry, and critically dry years. October is the first month of elevated minimum instream flow criteria in the Feather River HFC and a critical period for Spring-run Chinook egg incubation.

Flows below the minimum requirements (Table 5.8-2) could have a number of adverse effects on this life stage, including higher water temperatures, lower DO in redds, and potential for redd dewatering, all of which may lead to elevated egg mortality. Insufficient flow may also limit the extent of river bed available for redd construction, thereby limiting available habitat for this life stage. Conversely, the predicted flows under the proposed action scenario are considerably lower than under the WOA in January through February (Figure 5.8-28). Although these flows are not expected to effect upstream migration, and therefore superimposition in the Low Flow Channel, the lower flows during this incubation and emergence period could result in reduced redd scouringe. Because the potential adverse effects of low flows on this life stage are anticipated to be less severe, or most beneficial, under the proposed action scenario, flow-related actions under the proposed action scenario are anticipated to produce low- to medium-level population benefits for this life stage.

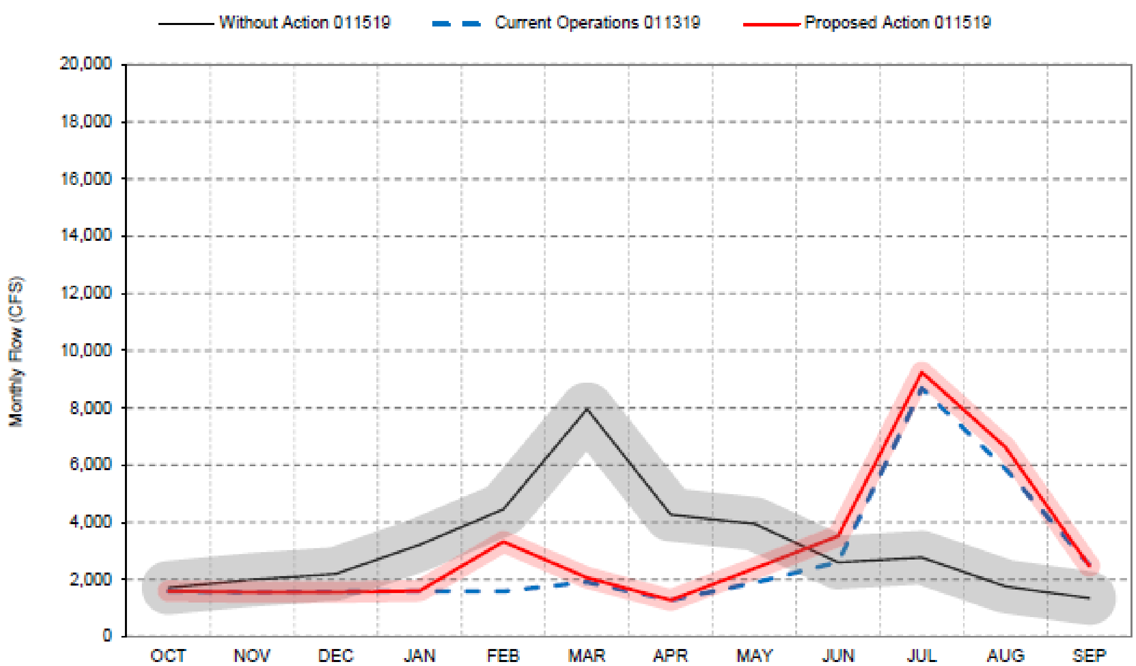


Figure 5.8-32. CalSim II estimates of Feather River flow below Thermalito Afterbay in September and October for below normal water years under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

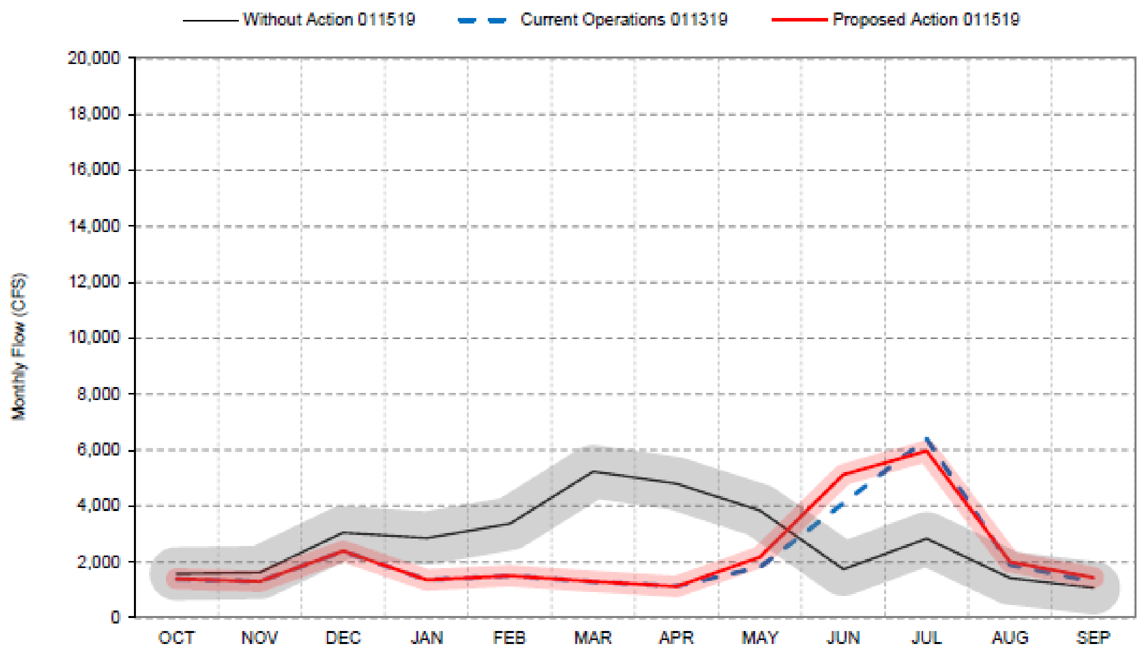


Figure 5.8-33. CalSim II estimates of Feather River flow below Thermalito Afterbay in September and October for dry water years under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

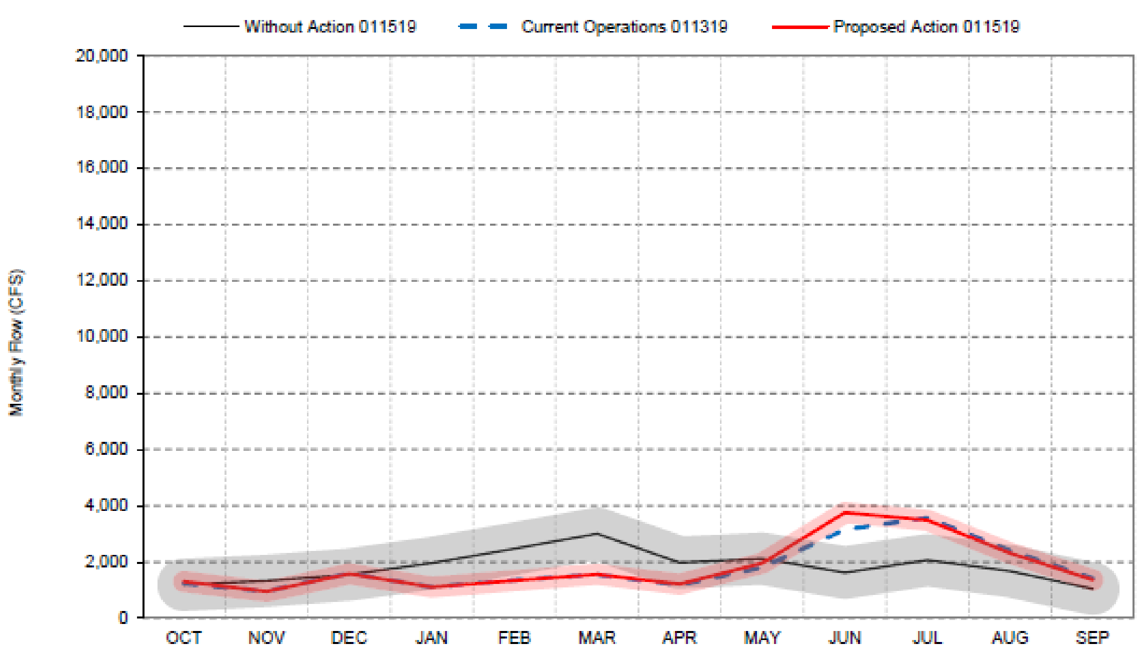


Figure 5.8-34. CalSim II estimates of Feather River flow below Thermalito Afterbay in September and October for critically dry water years under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

5.8.3.6.1.2 Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to influence condition and survival of Spring-run Chinook eggs. Effects of elevated water temperatures include an inability to satisfy metabolic demand and acute to chronic physiological stress, eventually leading to egg mortality (Stillwater Sciences 2006, Anderson 2017, Martin et al. 2017). Spring-run Chinook Salmon eggs require temperatures < 54°F for optimal development and survival and 54-58°F for suboptimal development and survival. Temperatures above 58°F may cause chronic to acute stress (Stillwater Sciences 2006).

Water temperatures in the Feather River during summer and fall are heavily influenced by flow releases from Lake Oroville, which are determined by operations and storage releases. Eggs and emerging fry of Spring-run Chinook would be exposed to the effects of operations and water releases that affect water temperatures in the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (September-February; Table 5.8-1 & NMFS 2016x), and the timing of the temperature objectives that influence flow releases (Table 5.8-3).

Water temperature objectives would be expected to be met in years when the Oroville Temperature Management Index (OTMI) is greater than 1.35 MAF and would be achieved through a combination of flow releases from Lake Oroville, and operations modifications stipulated in the Oroville Facilities relicensing Settlement Agreement (Article A108.1(b) [(*i*) curtailment of pump-back operation, (*ii*) shutter removal on Hyatt Intake, (*iii*) increase flow releases in the Low Flow Channel up to a maximum of 1,500 cfs]. If OTMI is equal to or less than 1.35 MAF, then a Conference Year is designated, triggering consultation between DWR and NMFS, USFWS, CDFW, and the SWRCB to prepare a strategic plan to manage the coldwater pool to minimize temperature exceedances at the lower FERC project boundary, while maintaining water supply and other legal obligations.

Table 5.8-3. Maximum Daily Mean Water Temperature Objectives for the HFC (NMFS BO and USFWS BO)

Maximum Daily Mean Water Temperature Objectives for the HFC (measured at the downstream FERC project boundary)	
Period	Temperature (°F)
January 1 – March 31	56
April 1 – 30	61
May 1 – 15	64
May 16 – 31	64
June 1 – August 31	64
September 1 – 8	61
September 9 – 30	61
October 1 – 31	60
November 1 – December 31	56

Under the WOA, Lake Oroville would not be operated to control storage or flow releases, and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Therefore, there would be limited control of flow or water temperature in the Feather River HFC where Spring-run Chinook egg incubation occurs. Resulting water temperatures under the WOA scenario in the HFC at Gridley Bridge, as modeled by the RecTemp temperature model, would be generally lower during the winter and higher during the summer and fall, with peak annual water temperatures of approximately 78 °F occurring in July and August (Figure 5.8-35).

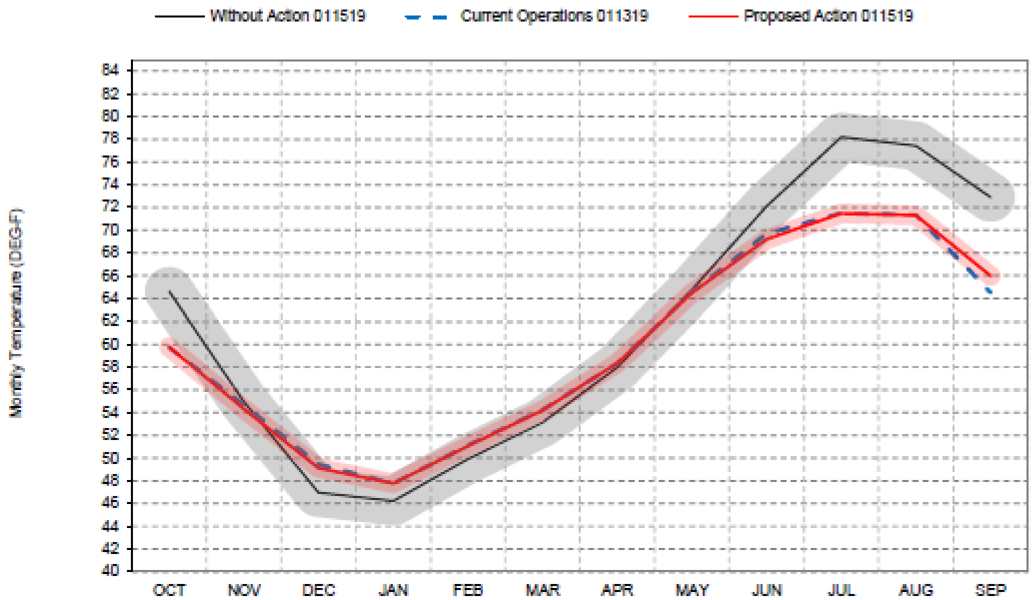


Figure 5.8-35. RecTemp average estimated Feather River water temperatures at Gridley Bridge under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

Under the proposed action and COS, operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those estimated under the WOA scenario between June and October, and water temperatures that are roughly equivalent between November and May (Figure 5.8-35). Water temperatures at Gridley Bridge under the WOA scenario would range between 60 and 78 °F in September and October, which is well above levels that may cause chronic to acute stress and would increase the likelihood of temperature-related mortality (Stillwater Sciences 206) during the peak timing of Spring-run Chinook egg incubation. Water temperatures under the proposed action and COS would be appreciably lower than under the WOA during the same period, ranging from approximately 57 to 68 °F; however, would still be suboptimal for development and survival and may also cause chronic to acute stress (Stillwater Sciences 2006). Optimum temperatures for egg incubation are reached after mid-November under all three scenarios (Figure 5.8-35). In addition, modeled water temperatures at Gridley Bridge indicate a higher likelihood of temperature compliance under the proposed action and COS (Table 5.8-3 and Figure 5.8-36 through 41).

Water temperatures exceeding the objectives and the biological thresholds for this life stage of Spring-run Chinook Salmon would have adverse effects on individuals, including acute to chronic physiological stress and increased likelihood of egg mortality. Water temperatures in the Feather River HFC during the egg incubation period under the proposed action and COS are similar to or lower than WOA water temperatures and have a higher likelihood of meeting the temperature objectives during the peak egg incubation period (September–October), which would benefit this life stage. Therefore, potential adverse effects of flow releases and water temperatures would be minimized for this life stage under the proposed action and COS scenarios, which is anticipated to produce low- to medium-level population benefits for this life stage.

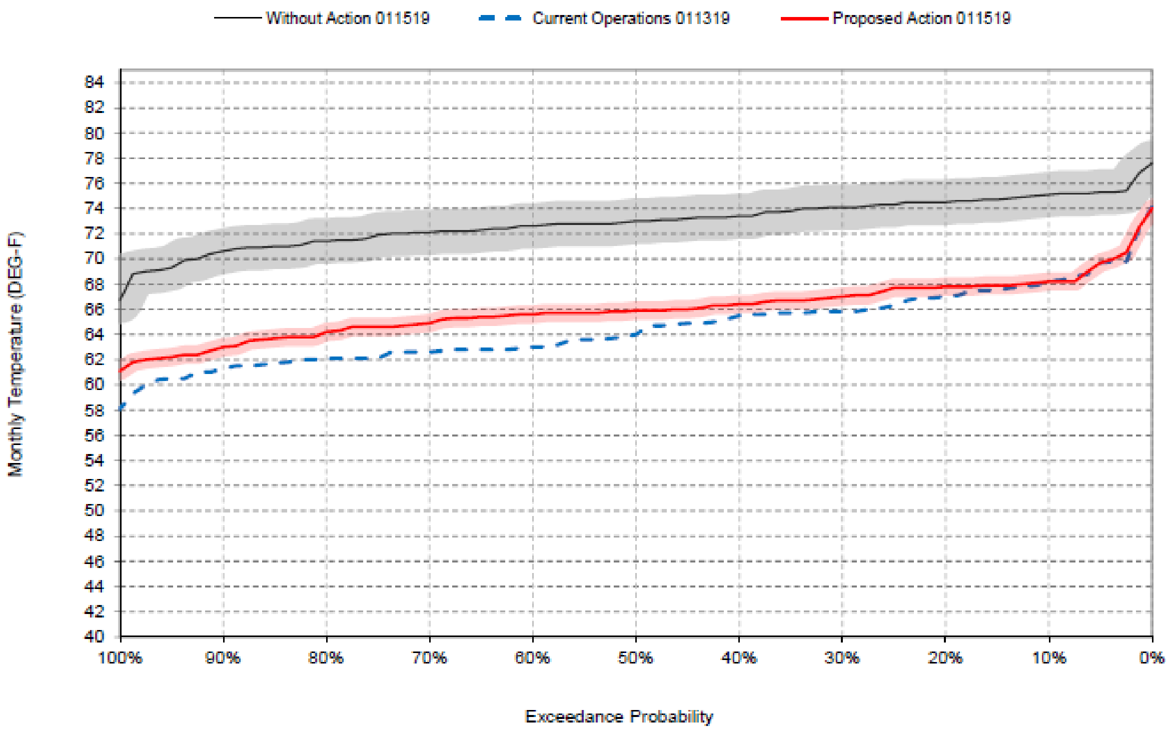


Figure 5.8-36. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in September under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

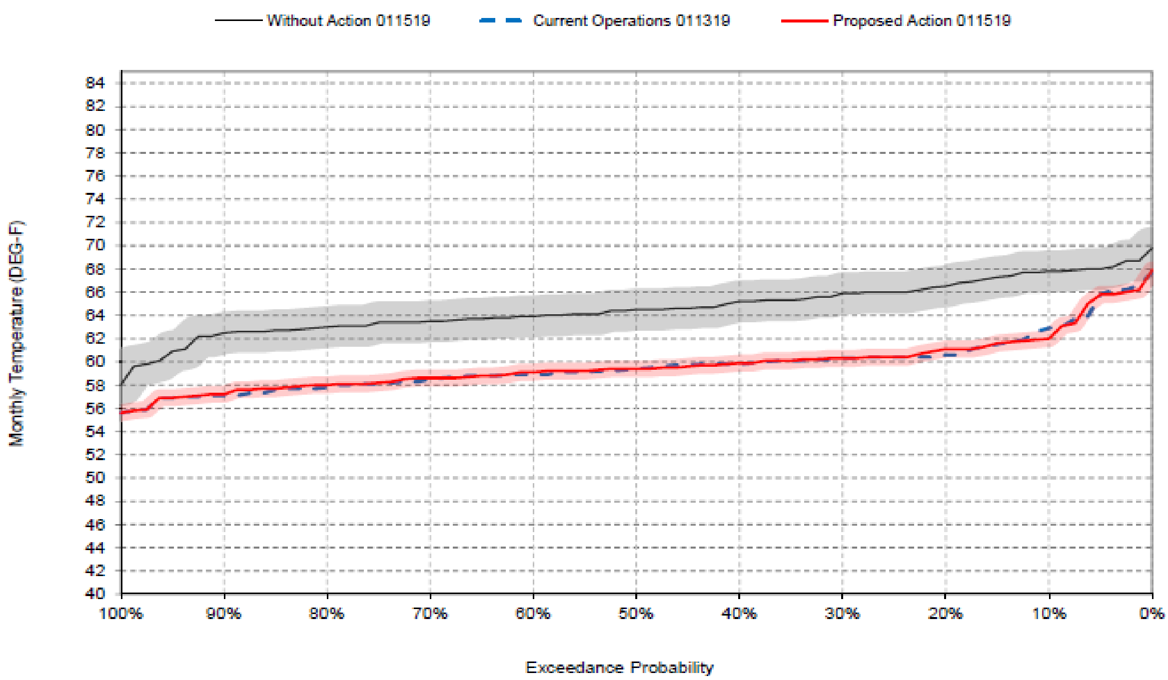


Figure 5.8-37. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in October under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

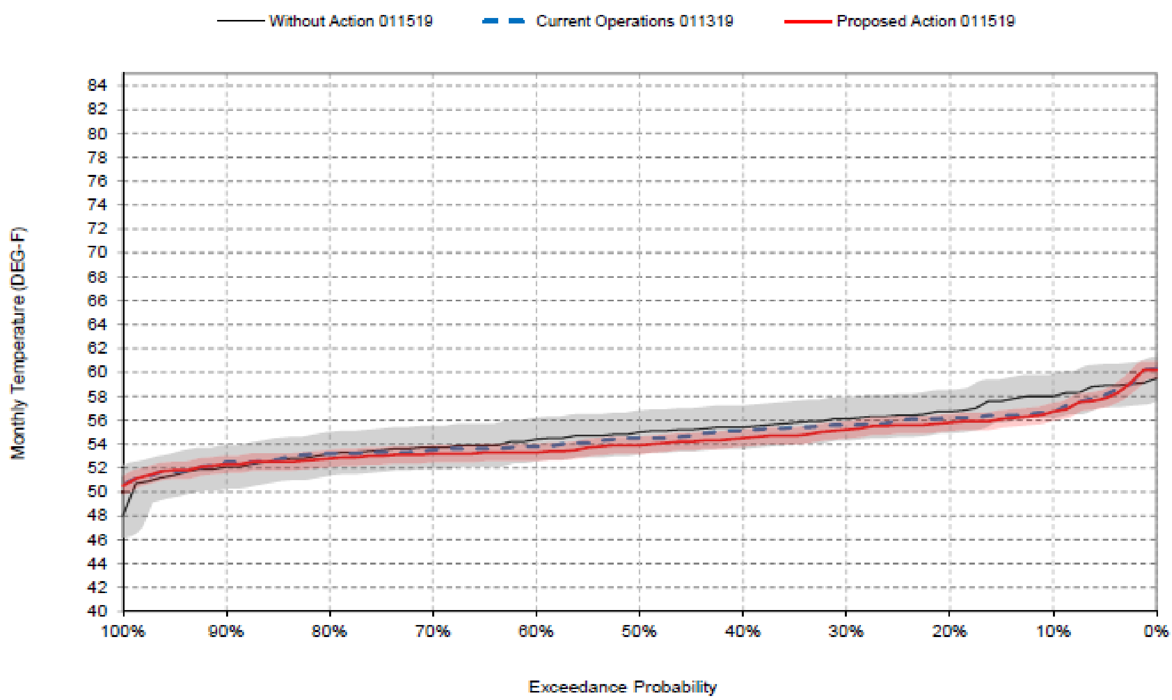


Figure 5.8-38. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in November under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

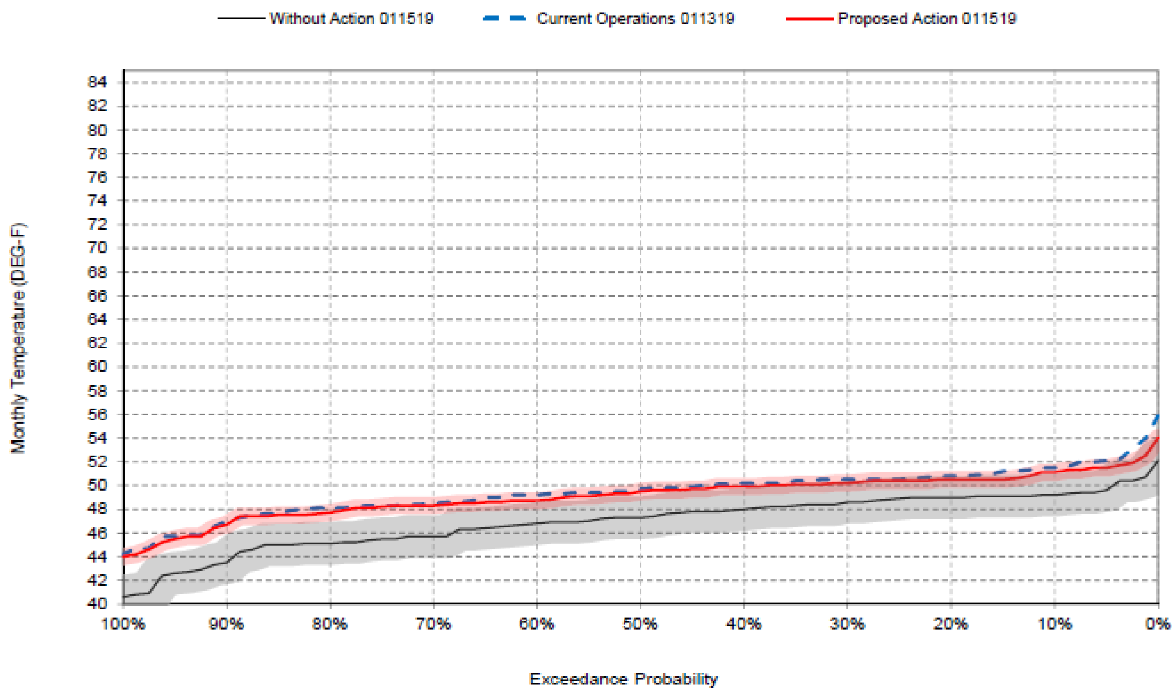


Figure 5.8-39. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in December under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

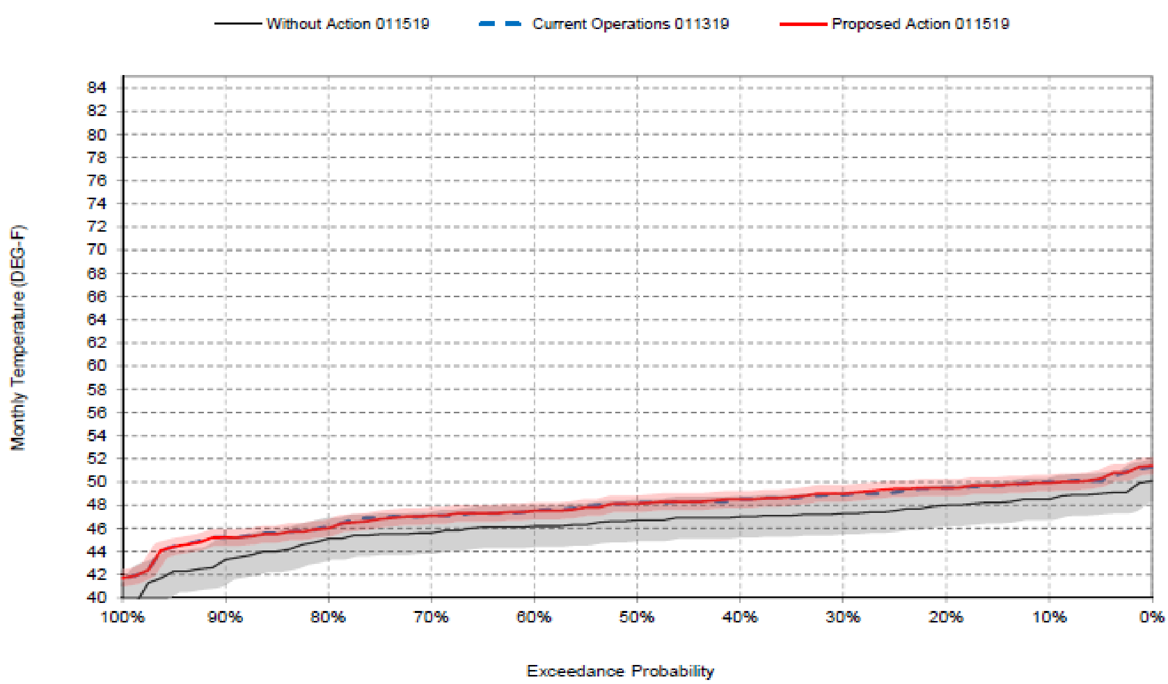


Figure 5.8-40. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in January under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

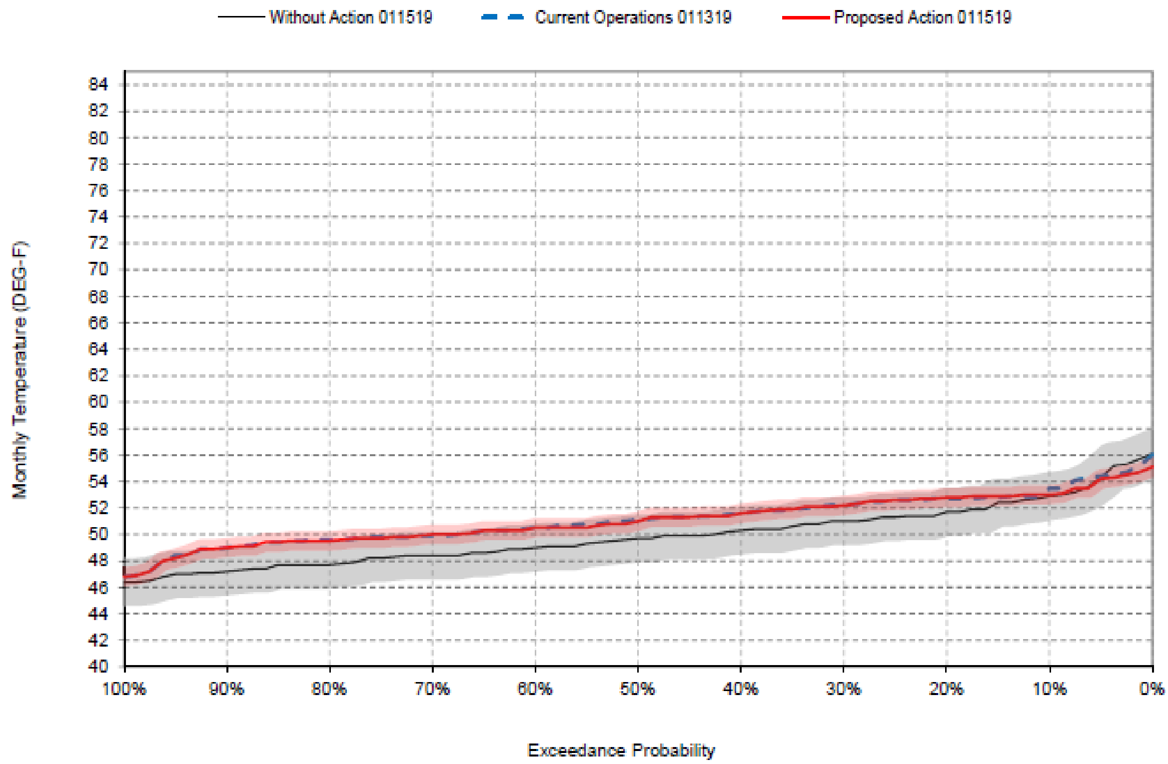


Figure 5.8-41. RecTemp estimates of Feather River water temperature exceedance probabilities at Gridley Bridge in February under the WOA (Without Action), COS (Current Operations), and proposed action scenarios.

5.8.3.6.2 Rearing to Outmigrating Juveniles in Rivers

5.8.3.6.2.1 Flow Effects

Rearing to outmigrating juvenile Spring-run Chinook would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (year-round possible with peak abundance November-May; Table 5.8-1 & NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 3), and compliance with Water Rights Decision 1641 (D-1641).

Under the Without Action (WOA), Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Reservoir gates and diversion tunnels would be kept open, resulting in annual storage volumes less than 1,000 TAF (Figure 5.8-27). As a result, there would be limited control of flow or water temperature in the Feather River HFC, which provides habitat for this life stage. Feather River flows under the WOA would approximate uncontrolled flows, with generally lower summer and fall flows and higher winter and spring flows compared to proposed action and COS (Figures 5.8-28 and 5.8-29).

5.8.3.6.2.1.1 Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of rearing individuals. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, reduction in growth due to increased metabolic demands, decreased productivity, and eventual mortality. Rearing juvenile Spring-run Chinook require temperatures < 60°F for optimal development and survival, and 60-65°F for suboptimal, with temperatures above 65°F causing chronic to acute stress (Stillwater Sciences 2006).

Water temperatures in the Feather River from November to May are relatively less influenced by flow releases from Lake Oroville than in summer and fall, given the larger flow volumes, and colder air temperatures during these months. Rearing Spring-run Chinook Salmon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (year-round possible with peak abundance November-May; Table 5.8-1 & NMFS 2016x), and the timing of the temperature objectives (year-round objectives; Table 5.8-2).

Water temperature objectives would be expected to be met in years when the Oroville Temperature Management Index (OTMI) is greater than 1.35 MAF and would be achieved through a combination of flow releases from Lake Oroville, and operations modifications stipulated in the Oroville Facilities relicensing Settlement Agreement Article A108.1(b) [(*i*) curtailment of pump-back operation, (*ii*) shutter removal on Hyatt Intake, (*iii*) increase flow releases in the Low Flow Channel up to a maximum of 1,500 cfs]. If OTMI is equal to or less than 1.35 MAF a Conference Year is designated, triggering consultation between DWR and NMFS, USFWS, CDFW, and the SWRCB to prepare a strategic plan to manage the coldwater pool to minimize temperature exceedances at the lower FERC project boundary, while maintaining water supply and other legal obligations.

Under the proposed action and COS operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May (Figure 5.8-31). Temperatures at Gridley Bridge under the proposed action are the same or higher than temperatures under the WOA from November to March, which coincides with the peak seasonal timing of rearing Spring-run Chinook. However, the risk of temperature-related stress and mortality are substantially reduced or not present during this period as temperatures remain well within the optimal range (< 60°F) for this life stage and under the Feather River HFC temperature objectives for these months. However, April and May water temperatures under the COS, and more so the proposed action, are lower than the WOA during a period at moderate risk of temperature-related stress and mortality, increasing the likelihood of temperature-related stress and mortality occurring during juvenile rearing under some conditions of the WOA. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be less severe under the proposed action and COS, especially during below normal, dry, and critically dry water year types (Figure 5.8-32). Therefore, water temperature-related actions in these scenarios are anticipated to produce low-level population benefits for this life stage.

5.8.3.6.3 Migrating Adults

5.8.3.6.3.1 Flow Effects

Migrating adult Spring-run Chinook Salmon would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (peak abundance March-June; Table 5.8-1 & NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5.8-2), and compliance with Water Rights Decision 1641 (D-1641).

As indicated by the SAIL Bay-Delta to Upper River (CM6) conceptual model these flows, combined with other environmental drivers, affect water temperature, DO, stranding, outmigration cues and other habitat attributes that influence the timing, condition and survival of migrating adult Spring-run Chinook Salmon (Johnson et. al., 2016, Windell et. al., 2017). Instream flow from Lake Oroville releases may also heavily influence the strength of navigational cues utilized by migrating adults and the propensity of these fish to stray from migratory pathways leading to high quality spawning habitat.

Feather River flows below Thermalito Afterbay under the proposed action and COS are generally approximate or are significantly lower than flows under the WOA during the peak seasonal timing of Spring-run Chinook adult migration (peak abundance March-June; Table 5.8-1 & NMFS 2016). The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios, although some risk exists under the WOA in June of critically dry years, when flows are lower under the WOA than COS and proposed action scenarios (Figure 5.8-30). Differences in flows between the proposed action and COS are less pronounced than differences between the proposed action and WOA during the March to June period, but are still significant, with relatively equal differences across the range of exceedance probabilities.

5.8.3.6.3.1.1 Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of migrating adults. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, and physiological stress potentially leading to mortality and altered migration timing and speed. Migrating adult Spring-run chinook require temperatures < 56°F for optimal survival, and 56-65°F for suboptimal, with temperatures above 65°F causing chronic to acute stress (Stillwater Sciences 2006).

Water temperatures in the Feather River during summer are heavily influenced by flow releases from Lake Oroville, which are determined by operations and storage releases. Migrating adult Spring-run Chinook Salmon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (peak abundance March-June; Table 5.8-1 & NMFS 2016), and the timing of the temperature objectives (year-round objectives; Table 5.8-2).

Under the proposed action and COS operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May. Temperatures at Gridley Bridge under the COS and proposed action are the same or lower than temperatures under the WOA from March to June, which coincides with the peak seasonal timing of migrating adult Spring-run Chinook. The risk of temperature-related stress and mortality are present during this period as temperatures are projected to be in or near the suboptimal range (<56-65°F) for this life stage from March to May and potentially above the chronic to acute stress threshold (> 65°F) in June (Figure 5.8-31). Water temperatures under the COS, and more so the proposed action, are lower than the WOA during May and June, a period at moderate to high risk of temperature-related stress and mortality, according to RecTemp model results. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be less severe under the COS, and more so the proposed action, especially during below normal, dry, and critically dry water year types (Figure 5.8-32).

5.8.3.6.4 Holding Adults

Holding adult Spring-run Chinook Salmon would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (March-September with peak abundance May-August; Table 5.8-1 & NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 7), and compliance with Water Rights Decision 1641 (D-1641). As indicated by the SAIL Bay-Delta to Upper River (CM7) conceptual model these flows, combined with other environmental drivers, affect water temperature, DO, and other habitat attributes that influence the condition and survival of holding adult Spring-run Chinook Salmon (Johnson et. al., 2016, Windell et. al., 2017).

Feather River flows below Thermalito Afterbay under the proposed action and COS both exceed and are lower than flows under the WOA during the peak seasonal timing of Spring-run Chinook holding (March-September with peak abundance May-August; Table 5.8-1 & NMFS 2016). In particular, proposed action flows are reliably lower than the WOA in May and equal to or higher than the WOA from June to August. The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios, and all water year types, except in August and September under the WOA scenario. Under this scenario the likelihood of flows declining below applicable minimum instream flows for the Feather River HFC in August and September is increased under the WOA (Figure 5.8-30). Differences in flows between the proposed action and COS are less pronounced than differences between the proposed action and WOA during the March to September period, but are still significant, with the proposed action projected to be reliably higher in May and June and the COS projected to be reliably higher in September.

Exposure to the effects of differences in flow during this life stage could include variation in water temperature and DO, and the amount and quality of holding habitat used to shelter from predators, and rest during the gamete maturation phase. Proposed Action and COS flows are lower than WOA flows in May, however, proposed action and COS action flows are not anticipated to decline below minimum instream flow standards or to a level that is anticipated to result in substantial loss of suitable holding habitat in the Feather River HFC. Proposed Action and COS flows are predominantly higher than WOA flows from June to August, which is anticipated to result in significant water temperature benefits for holding adults as this period coincides with mid- and late-summer increases in air temperature. These flows are also anticipated to improve the likelihood of adequate holding adult habitat as additional migrants enter the Feather River HFC throughout the summer. As a result, conditions for holding adult Spring-run Chinook will be improved during the majority of the peak seasonal timing of this life stage.

Water temperatures in the Feather River from May to September are heavily influenced by flow releases from Lake Oroville with increased flow releases generally mitigating some of the effects of elevated summer air temperatures on water temperature in the Feather River HFC. Under the WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Therefore, there would be limited control of flow or water temperature in the Feather River HFC where Spring-run Chinook hold prior to spawning. As a result, water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model become increasingly higher than those projected under the proposed action and as summer progresses from May to September (Figure 5.8-31).

Under the proposed action and COS scenarios operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May. Temperatures at Gridley Bridge under the COS and proposed action are the same or lower than temperatures under the WOA from May to August, which coincides with the peak seasonal timing of holding adult Spring-run Chinook. The risk of temperature-related stress and mortality are present during the majority of this period as temperatures are projected to be at or near the suboptimal range (<60.8-66.2°F) for this life stage from May to August and potentially above the chronic to acute stress threshold (> 66.2°F) in July, August, and September. June to August water temperatures under the COS, and more so the proposed action, are lower than the WOA, a period at high risk of temperature-related stress and mortality, according to RecTemp model results. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be less severe under the COS, and more so the proposed action, especially during below normal, dry, and critically dry water year types (Figure 5.8-32).

5.8.3.7 American River Seasonal Operations, including 2017 Flow Management Standard and "Planning Minimum"

Reclamation's proposed action includes a minimum release with flows that range from 500 to 2000 cfs based on time of year and annual hydrology. Reclamation's proposed action also includes a "planning minimum" to preserve storage to protect against future drought conditions and to facilitate the development of the cold water pool when possible and improve habitat conditions for steelhead and Fall-run Chinook salmon. The Flow Management Standard (FMS) also includes the provision for spring pulse flows, with the purpose of providing a juvenile salmonid (Fall-run Chinook salmon and steelhead) emigration cue before relatively low flow conditions and associated unsuitable thermal conditions later in the spring in the river, and downstream in the lower Sacramento River.

Rearing juvenile Spring-run Chinook Salmon may be present in the American River from November to May. The American River corridor downstream of the Watt Street bridge is designated critical habitat for the species.

5.8.3.7.1 Rearing to Outmigrating Juveniles in Rivers

Spring-run Chinook Salmon juveniles may be present in the American River for rearing and exposed to effects of Reclamation's water releases from Folsom Dam during their rearing period. As discussed in the conceptual model, flows affect temperatures. Excessively high water temperatures have been identified as one of the factors threatening Spring-run Chinook Salmon in the Central Valley and a factor for listing of the species. Without Reclamation's proposed action, there would be no Folsom reservoir operations to control storage or releases. The proposed action and COS would result in lower flows below Nimbus Dam during the species rearing period during average water years, with the largest difference in flow between March and May. All three modeled hydrologies (Proposed action, COS, and WOA) indicated flows spike at the beginning of February, between 6,000 cfs and 6,500 cfs. The proposed action and COS result in higher temperatures between November and February. From February to May, all three model runs indicate similar temperatures, however proposed action temperatures are lower than those under WOA.

The implementation of the proposed FMS measures would provide suitable habitat conditions in the lower American River for Chinook Salmon, particularly during drought conditions, and improve conditions for rearing to outmigrating Juveniles.

5.8.3.7.1.1 Stanislaus River Stepped Release Plan

The Stanislaus River is not designated critical habitat for Spring-run Chinook Salmon and while spring-running fish may be present, they are not currently considered part of the listed ESU. However, since no genetic testing has occurred, Reclamation is providing this analysis to ensure future coverage under the ESA if proven to be listed CV Spring-run Chinook Salmon.

A nonessential experimental population of Spring-run Chinook Salmon in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River was designated to allow reintroduction of the species below Friant Dam as part of the San Joaquin River Restoration Program (SJRRP) (78 FR 79622, December 31, 2013). Observations show that spring running Chinook occur in the Stanislaus and Tuolumne Rivers and that these fish would not be considered as experimental under the SJRRP, and as a result, they are addressed in this document.

5.8.3.7.1.1.1 Egg to Fry Emergence

Snorkel surveys (Kennedy and Cannon 2005) conducted between October 2002 and October 2004 on the Stanislaus River identified adults in June 2003 and 2004, as well as observed Chinook fry in December 2003, which would indicate likely spawning timing in late September or October. In addition, monitoring on the Stanislaus since 2003 and on the Tuolumne since 2009, has indicated upstream migration of adult spring-running Chinook Salmon (Anderson et al. 2007), and 114 adults were counted on the video weir on the Stanislaus River between February and June in 2013 with only 7 individuals without adipose fins (FISHBIO 2015). Rotary screw trap (RST) data provided by Stockton U.S. Fish and Wildlife Service (USFWS) corroborates the spring-running Chinook Salmon adult timing by indicating that there are a small number of fry migrating out of the Stanislaus and Tuolumne at a period that would coincide with spring-running Chinook emigration (Franks 2014). Recently emerged fry start to show up at rotary screw traps in late December to mid-January most years and could be indicative of spring-run or fall-run. Chinook.

Under WOA conditions, the lower level river outlets of New Melones Dam would be closed to preserve the integrity of the gate structure and the Flood Control and Industrial gate would be set fully open and assumed to pass a flow of approximately 8,000 cfs. Inflow exceeding this capacity would be stored in New Melones Reservoir until the releases exceed capacity of the outlets. If necessary, the spillway would prevent overtopping of the Dam and to protect the structural integrity of the Dam and related facilities. This spillway is not gated and would naturally flow should the reservoir reach that height. Spring-running Chinook salmon distributions are expected to be similar to WOA as Goodwin Dam would still represent a complete barrier to further upstream migration. WOA water temperatures within the Stanislaus River would represent those of unimpeded flows coming off the western Sierra Nevada that travel through the CVP storage and conveyance facilities on the Stanislaus River that would be operated only to the extent necessary to fulfill flood control operations. Operations of non-CVP facilities would still occur as they are occurring today. Modeled flows below Goodwin Dam are depicted below in Figure 5.8-42. Stanislaus Modeled Flows. The early running Chinook would likely not survive the summer and any that do survive to spawn in early fall would not successfully reproduce due to high water temperature in WOA.

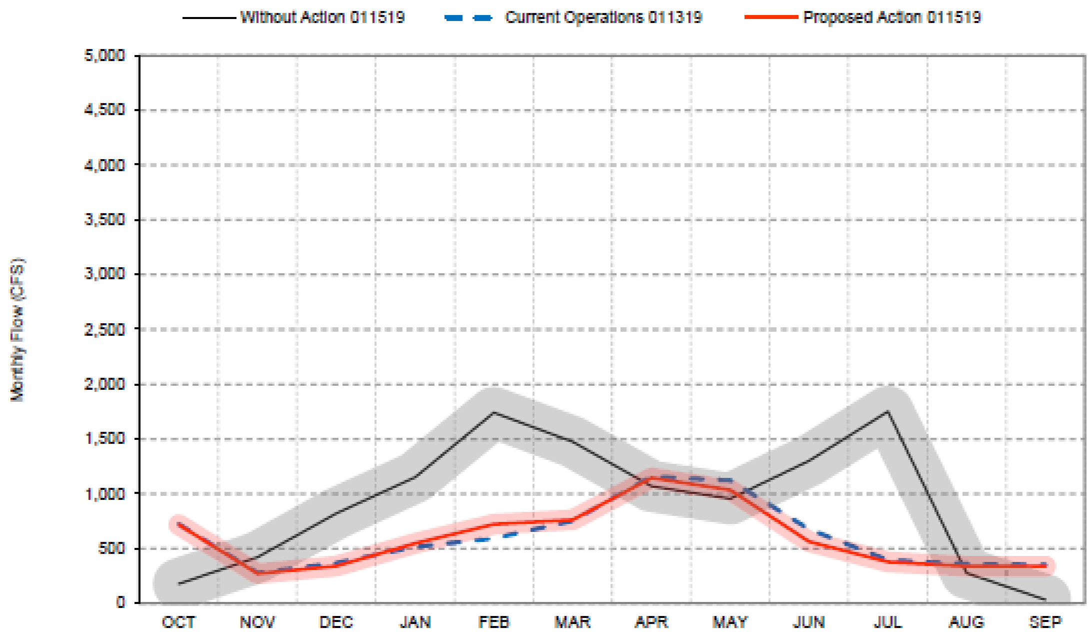


Figure 5.8-42. Modeled flows under WOA, Current Operations Scenario (COS) and Proposed Action Scenario

Current operations of New Melones under the Interim Plan of Operations (IPO), which has been in effect since 1997, were developed prior to completion of current tools to understand hydrology in the Stanislaus River Basin, and the water delivered from New Melones was overallocated in many years and was not able to consistently meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries. The primary reason for this is that the IPO requires water releases early in the season that have resulted in inadequate water available later in the season to meet water quality and/or flow requirements. Reclamation also currently operate releases from the East Side Division reservoirs to achieve a minimum flow schedule as prescribed by Appendix 2-E of the NMFS 2009 BO.

Under the proposed action, Reclamation proposes to implement the New Melones Stepped Release Plan to create a sustainable operation on the Stanislaus River that strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries.

Where adult spring-running Chinook Salmon returning to the San Joaquin River are expected to exhibit various life-history patterns on both temporal and spatial scales, the juvenile stage typically exhibits more life-history variability than adults and have a stronger dependence on riverine habitat for successful survival than adults (SJRRP 2010). A review of numerous studies performed for the SJRRP (2010) identified a range of suitable water temperatures for all life stages of salmonids. The findings of this review were compiled into Table 5.8-4: Temperature Objectives for the Restoration of Central Valley Chinook Salmon.

Table 5.8-4. Temperature Objectives for the Restoration of Central Valley Chinook Salmon

<table>
<tr><th colspan="13">Monthly Water Temperature Objectives for the San Joaquin River Restoration Program</th></tr>
<tr><th colspan="13">Spring-Run and Fall-Run Chinook Salmon</th></tr>
<tr><th>Life Stage</th><th>Jan</th><th>Feb</th><th>Mar</th><th>Apr</th><th>May</th><th>June</th><th>Jul</th><th>Aug</th><th>Sep</th><th>Oct</th><th>Nov</th><th>Dec</th></tr>
<tr><td>Adult Migration</td><td></td><td></td><td colspan="4">Optimal: ≤59°F (15°C)
Critical: 62.6 – 68°F (17 – 20°C)
Lethal: >68°F (20°C)</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Adult Holding (Spring-Run Only)</td><td></td><td></td><td></td><td colspan="6">Optimal: ≤55°F (13°C)
Critical: 62.6 – 68°F (17 – 20°C)
Lethal: >68°F (20°C)</td><td></td><td></td><td></td></tr>
<tr><td>Spawning</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="3">Optimal: ≤57°F (13.9°C)
Critical: 60 – 62.6°F (15.5 – 17°C)
Lethal: 62.6°F or greater (17°C)</td><td></td><td></td></tr>
<tr><td>Incubation and Emergence</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td colspan="5">Optimal: ≤55°F (13°C)
Critical: 58 – 60°F (14.4 – 15.6°C)
Lethal: >60°F (15.6°C)</td></tr>
<tr><td>In-River Fry/Juvenile</td><td colspan="12">Optimal: ≤60°F (15.6°C), young of year rearing; ≤62.6°F (18°C), late season rearing (primarily spring-run)
Critical: 64.4 – 70°F (18-21.1°C)
Lethal: >75 °F (23.9°C), prolonged exposure</td></tr>
<tr><td>Floodplain Rearing*</td><td colspan="12">Optimal: 55 – 68°F (13 – 20°C), unlimited food supply</td></tr>
<tr><td>Outmigration</td><td colspan="6">Optimal: ≤60°F (15.6°C)
Critical: 64.4 – 70°F (18 – 21.1°C)
Lethal: >75°F (23.9°C), prolonged exposure</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Sources: EPA 2003, Rich 2007, Pagliughi 2008, Gordus 2009.

Note:

* Floodplain rearing temperatures represent growth maximizing temperatures based on floodplain condition. No critical or lethal temperatures are cited assuming fish have volitional access and egress from floodplain habitat to avoid unsuitable conditions.

Shaded box indicates life stage is present Key:

°F = degrees Fahrenheit

°C = degrees Celsius

Source: Conceptual Models of Stressors and Limiting Factors for San Joaquin River Chinook Salmon

The New Melones SRP will be implemented similar to current operations with a default daily hydrograph, and the ability to shape monthly and seasonal flow volumes to meet specific biological objectives. The default daily hydrograph is the same as prescribed under current operations for Critical, Dry, and Below Normal water year types; Above Normal and Wet year types follow daily hydrographs for Below Normal and Above Normal year types from 2-E, respectively. As a result, flows would be reduced in Above Normal and Wet year types. This difference between the proposed action and the COS during Above Normal and Wet years, where the minimum release requirement for wetter water year types is reduced from COS to promote storage for potential future droughts and preserve coldwater pool, leads to improved cold water pool performance in droughts, benefiting Spring-running Chinook salmon eggs.

5.8.3.7.2 <u>Rearing to Outmigrating Juveniles</u>

The SRP provides improved cold water pool performance in droughts, but would reduce flow releases in Above Normal and Wet years. As discussed in the conceptual model, lower flows in wet years could result in less inundated rearing habitat, lower outmigration flows, and potentially warmer temperatures, affecting rearing to outmigrating juvenile CV Spring-running Chinook salmon.

5.8.3.8 Alteration of Stanislaus River Dissolved Oxygen Requirement

Under WOA conditions, flow would be uncontrolled through the CVP project facilities and Spring-running Chinook distribution would be similar to currently, as Goodwin Dam would represent a complete barrier to further upstream migration. There would be no temperature management. Early running Chinook spawners would likely not survive the warm water in late summer and fall and would be unable to reproduce.

Current operations are required to meet a year-round dissolved oxygen minimum of 7 mg/L, from June 1 to September 30 at Ripon to protect salmon, steelhead, and trout in the river (CDFW 2018). However, maintaining dissolved oxygen concentrations above 7 mg/L in the Stanislaus River at Ripon is challenging 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).

Reclamation proposes to move the compliance location to Orange Blossom Bridge, where the species are primarily located at that time of year. Based on multi-year observations of salmonid abundance in the River Kennedy and Cannon (2005) and Kennedy (2008) found that over-summering juvenile salmonids are primarily found upstream of Orange Blossom Bridge, which is approximately 31 miles upstream from Ripon. Dissolved oxygen monitoring at the Stanislaus River Weir (approximately 15 miles upstream from Ripon) indicates that dissolved oxygen concentrations can be 0.5-1 mg/L higher at this location than those measured at Ripon (Cramer Fish Sciences 2006a-d). Without the proposed action, there would be no water temperature management. Therefore, the proposed temperature compliance point is beneficial to the species, because the majority of salmonid eggs, alevin and/or fry are found in locations where summer dissolved oxygen levels would be expected to be maintained at or near 7 mg/L.

Juvenile spring-run Chinook are found in the Stanislaus River from Goodwin Dam downstream to Oakdale. Because the fish are located primarily at least twice this distance upstream from Ripon, the dissolved oxygen concentration is likely to be at this level or higher where the majority of these fish occur. Additionally, there should be no impact to outmigrating juvenile Spring-run Chinook Salmon since their outmigrations is from November through the end of May (Table 5.8-1). Based on the typical seasonal occurrence of this life stage in the River (mid-January – late June), no adult migrating Spring-run Chinook Salmon would be affected by the relaxation of dissolved oxygen requirements at Ripon (June 1 - September 30). As the majority of adult Chinook Salmon that are holding in the Stanislaus River from March to mid-September (Table 5.8-1) are found in locations where summer dissolved oxygen levels would be expected to be maintained at or near 7 mg/L, holding adult Spring-run Chinook Salmon are not expected to be impacted from this action . Based on the typical seasonal occurrence of this life stage in the Stanislaus River (mid-January – late June), no adult migrating Spring-run Chinook Salmon would be expected to be exposed to the effects of the alteration of dissolved oxygen requirements at Ripon.

5.8.3.9 Bay-Delta Seasonal Operations

Reclamation and DWR propose to operate the C.W. Bill Jones Pumping Plant and the Harvey O. Banks Pumping Plant. These pumping plants affect the hydrodynamics of the south and central Delta resulting in effects to Spring-run Chinook Salmon entrainment, routing and through Delta survival. Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics. See Winter-run Chinook salmon effects section for more detail concerning “far-field” and “near-field”.

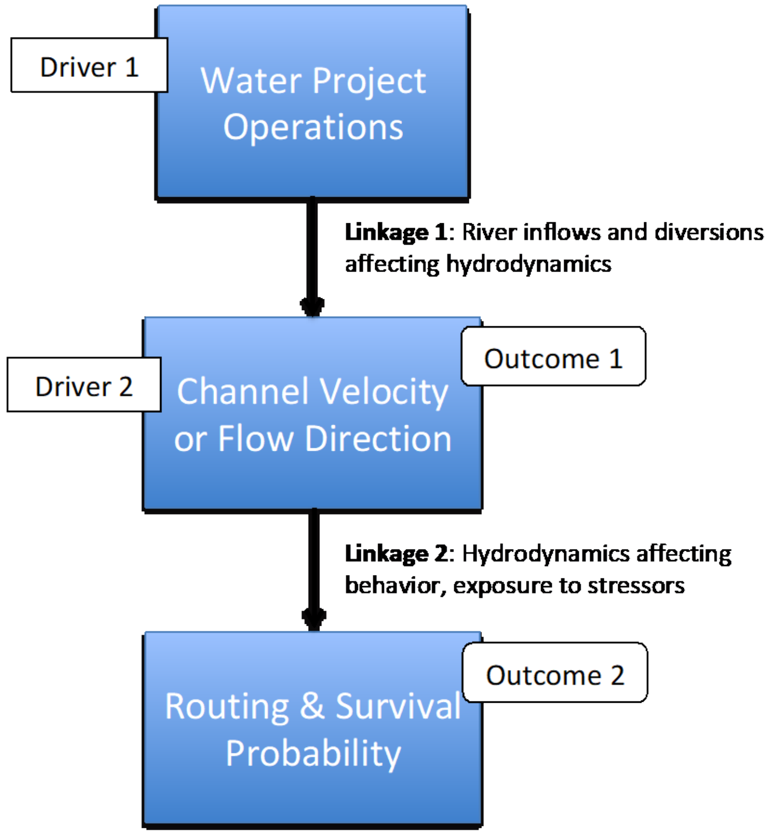


Figure 5.8-43. Conceptual model for far-field effects of water project operations on juvenile salmonids in the Delta. This CM is a simplified version of the information provided by the CAMT SST.

5.8.3.9.1 Entrainment

Among 6.8 million tagged natural origin and 2.8 million tagged hatchery origin Spring-run Chinook Salmon juveniles, entrainment loss averaged less than 0.0005% (Zeug and Cavallo, 2014). As there are no exports under WOA, there is no entrainment risk under WOA. In the December through February, the average total export rate, under the proposed action, is slightly higher difference compared to COS (366 cfs; Figure H-1 – Appendix H, *Bay-Delta Aquatics Effects Figures*) and will therefore have a similar entrainment risk. Total exports proposed in March-June are 1,699 cfs higher than COS (Figure H-2 - Appendix H, *Bay-Delta Aquatics Effects Figures*) when juvenile Spring-run Chinook Salmon are most abundant in the Delta.

According to SacPAS (Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*), between 0 and 45000 unclipped Spring-run Chinook Salmon are currently salvaged at CVP and SWP fish facilities each year, and between 0 and 9000 clipped Spring-run Chinook Salmon from the Feather River Fish Hatchery. Salvage estimates are made by counting fish for 30 minutes every 2 hours, and multiplying by 4 to obtain the estimate for the number of fish that are entrained into Tracy Pumping Plant or eaten by predators in the canal or fish facility. Entrainment results in harassment and often mortality for juvenile Chinook salmon. Fish that are counted are salvaged and trucked back to the Delta where they are released and may complete their lifecycle.

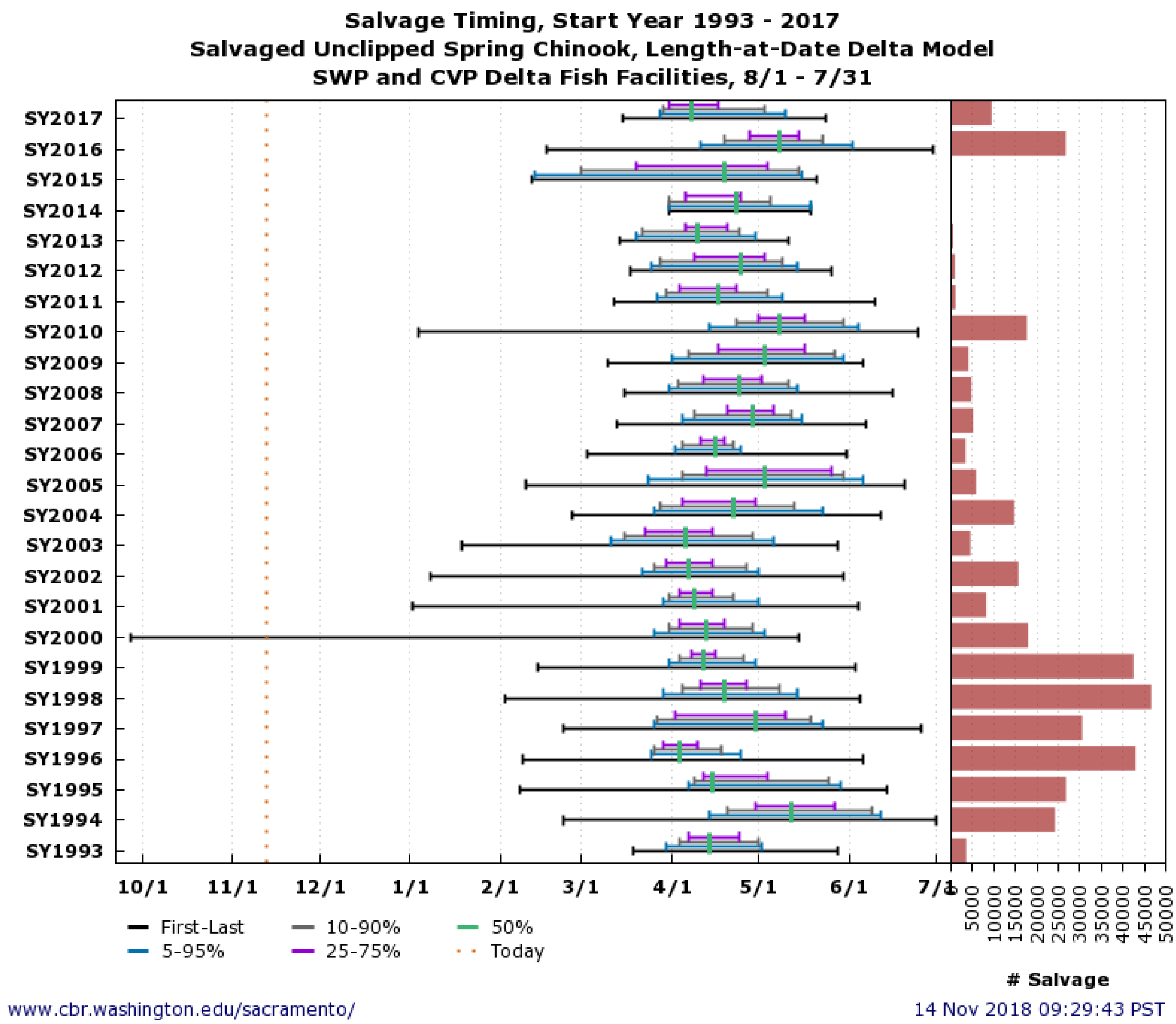


Figure 5.8-44. Salvage Data for Unclipped Spring-run Chinook at SWP and CVP Fish Facilities

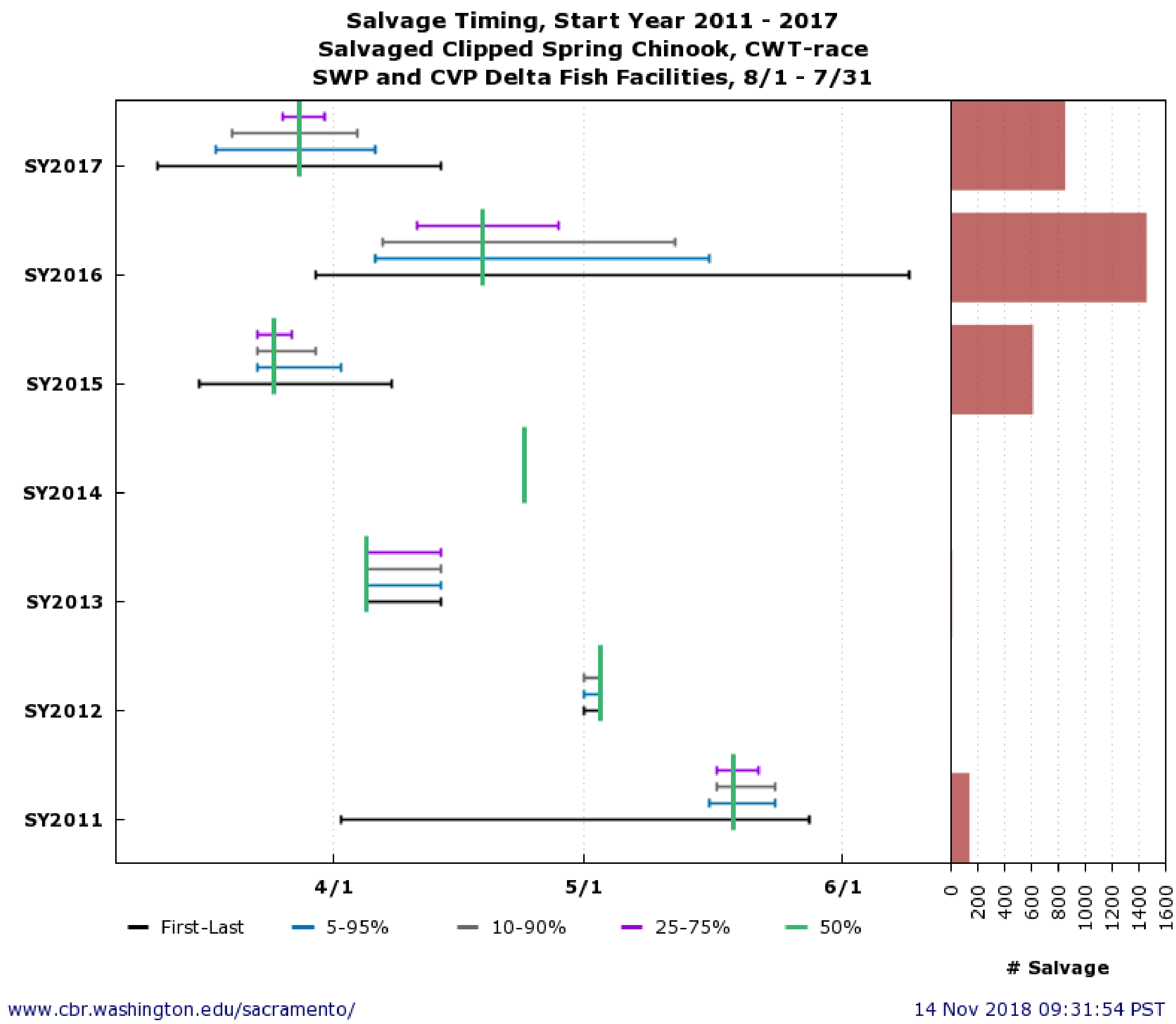


Figure 5.8-45. Salvage Data for Clipped Spring-run Chinook at SWP and CVP Fish Facilities

Although data for juvenile Spring-run Chinook Salmon originating from the San Joaquin River are limited, Zeug and Cavallo (2014) analyzed salvage of San Joaquin River-origin fall run juvenile Chinook Salmon that are found in the Delta at a similar time as Spring-run Chinook Salmon. Salvage of Fall-run Chinook Salmon originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014).

Under WOA, there are no exports and therefore no entrainment. In the December through February period, the proposed action proposes an average total export rate slightly higher than COS (366 cfs; Figure H1) and will, therefore, have a similar entrainment risk. Total exports proposed for proposed action in March-June (1,699 cfs higher than COS; Figure H2) when juvenile Spring-run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to COS. Recent acoustic studies of juvenile Fall-run Chinook Salmon in the San Joaquin River revealed that when the Head of Old River

Barrier is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

5.8.3.9.2 Routing

As stated in the Sacramento Winter-run Chinook effects section, routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Juvenile Spring-run Chinook Salmon are present in the Delta between November and early June with a peak in April (Table 5.8-1). In the December through February period, velocity overlap between proposed action and COS in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >50% in all water year types (Figure H-3 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under proposed action in all water year types indicating routing into the interior Delta would be lower relative to COS (Perry et al. 2015). Comparing proposed action to WOA in the Dec-Feb period revealed velocity overlap <50% in Dry, Above Normal and Wet years and <60% in Critical and Below Normal years (Figure H-4 - Appendix H, *Bay-Delta Aquatics Effects Figures*) with higher velocities in the WOA in all water year types. This pattern indicates routing into the interior Delta would be lower under WOA relative to proposed action or COS (Perry et al. 2015). In the March to May period, comparison of the proposed action and COS revealed similar patterns of velocity overlap as described for the December-February period (Figure H-5 - Appendix H, *Bay-Delta Aquatics Effects Figures*) indicating routing into the interior Delta would be lower under the proposed action during March-May. Comparing the proposed action with the WOA in March-May revealed low overlap in Sacramento main stem velocities between the Steamboat-Sutter Junction and the DCC-Georgiana Slough junction (Figure H-6 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA indicating routing into the interior Delta under WOA would be lower than proposed action or COS.

Spring-run Chinook Salmon originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December-February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between the proposed action and both the COS and the WOA scenarios (Figures H-7 and H-8 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Similar results were obtained when comparing the proposed action to COS and WOA in the March to May period (Figures H-9 and H-10 - Appendix H, *Bay-Delta Aquatics Effects Figures*).

Juvenile Spring-run Chinook Salmon are present in the Delta between November and early June with a peak in April (Table 5.8-1). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Old River are unlikely to experience reduced survival.

Spring–run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman’s Cut and False River. In the December-February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between the proposed action and both the COS and the

WOA scenarios (Figures H-7 and H-8 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Similar results were obtained when comparing the proposed action to COS and WOA in the March to May period (Figures H-9 and H-10 - Appendix H, *Bay-Delta Aquatics Effects Figures*).

In the December-February period, velocity overlap between proposed action and COS at the Head of Old River was >89% in Critical, Dry and Below Normal water years, >72% in Wet years, and >53% in Above Normal Years (Figure H-7 - Appendix H, *Bay-Delta Aquatics Effects Figures*). When the proposed action was compared to WOA in the December-February period, velocity overlap was >50% in Critical and Dry years and >10% in all other water year types (Figure H-8 - Appendix H, *Bay-Delta Aquatics Effects Figures*). In the March-May period, velocity overlap patterns were similar to comparisons in the December-February period (Figures H-9 and H-10 - Appendix H, *Bay-Delta Aquatics Effects Figures*).

5.8.3.9.3 <u>Through Delta Survival</u>

To examine potential effects of the proposed action, changes in velocity distributions were examined for the Sacramento River at Walnut Grove and Steamboat Slough which are both in this “transitional” region. During the December to February period at Walnut Grove, velocity distributions for proposed action relative to COS were most different in Wet Years (70.9%) with higher velocities in the proposed action. Velocities were also greater for proposed action relative to COS in Dry, Below Normal and Above Normal years although overlap was greater (≥79.6%; Figure H-11 - Appendix H, *Bay-Delta Aquatics Effects Figures*). In Critical Years, velocity distributions were almost identical (95.4%; Figure H-11 - Appendix H, *Bay-Delta Aquatics Effects Figures*). A similar pattern was apparent for the comparison between proposed action and WOA (Figure H-12 - Appendix H, *Bay-Delta Aquatics Effects Figures*); however, overlap was lower for each water year type (37.3 – 68.3%) with higher velocities under WOA relative to proposed action. At Steamboat Slough in the December to February period, there was a similar pattern where velocities under the proposed action were higher than COS in Wet, Above Normal and Below Normal years and similar in Dry and Critical years (Figure H-13 - Appendix H, *Bay-Delta Aquatics Effects Figures*). When proposed action was compared to WOA, overlap was moderate to high with values between 42.6 and 72.6% (Fig H-14 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA in all water year types (Figure H-14 - Appendix H, *Bay-Delta Aquatics Effects Figures*).

In the March through May period at Walnut Grove, velocity overlap between the proposed action and COS was ≥78.5% across all water year types with greater velocities under proposed action (Figure H-15 - Appendix H, *Bay-Delta Aquatics Effects Figures*). When proposed action was compared to WOA in the March through May period, velocity overlap was variable among water year types from a low of 14.1% in Wet years to 56.9% in Critical years (Figure H-16 - Appendix H, *Bay-Delta Aquatics Effects Figures*). In all water year types, velocities were greater under the WOA relative to the proposed action. At Steamboat Slough in the March through May period, overlap between the proposed action and COS scenarios was high with all values ≥82.2% and greater velocities under the proposed action (Figure H-17 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocity overlap was lower when proposed action was compared to WOA (Figure H-18 - Appendix H, *Bay-Delta Aquatics Effects Figures*). The lowest value occurred in Wet years (19.1%) and highest in Critical years (69.5%).

The small changes in velocity within transitional reaches of the Sacramento River and North Delta between the proposed action and WOA suggest there could be reductions in through Delta survival for Spring-run Chinook Salmon in some water year types under the proposed action.

A recent study by 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. To examine how effects of the proposed project, changes in velocity distributions were examined for the San Joaquin River at Highway 4 and the Head of Middle River which are both in the "transitional" region of the San Joaquin River. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for proposed action relative to COS exhibited high overlap in Critical, Dry and Below Normal water years (≥95.9%; Figure H-19 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Overlap values were lower in Above Normal and Wet years with values of 84.3% and 87.2% respectively. In these two water year types, velocities were higher under the proposed action relative to COS (Figure H-19 - Appendix H, *Bay-Delta Aquatics Effects Figures*). When the proposed action was compared to WOA, overlap decreased in all water year types with higher velocities under WOA (Figure H-20 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Overlap values ranged from a low of 59.6% in Above Normal years to 83.4% in Critical years (Figure H-20 - Appendix H, *Bay-Delta Aquatics Effects Figures*). At the Head of Middle River during the December-February period, overlap was high between the proposed action and COS in Critical, Dry and Below Normal water years (≥90.1%; Figure H-21 - Appendix H, *Bay-Delta Aquatics Effects Figures*). In Above Normal and Wet years overlap was lower with values of 53.6 and 75.1% respectively. Velocities were higher under the proposed action in these two water year types (Figure H-21 - Appendix H, *Bay-Delta Aquatics Effects Figures*). When the proposed action was compared to WOA, overlap was low in all water year types (≤34.9%) with higher velocities under WOA (Figure H-22 - Appendix I - Appendix H, *Bay-Delta Aquatics Effects Figures*).

Spring flow pulses descibed in the PA to achieve flows >9100 cfs at Wilkins would also provide benefits to spring run in the Delta. Spring run in the Delta would experince greater survival as flow magnitude increases from the flow pulse passing through the Delta (Perry et al. 2018). Spring run Chinook Salmon are in high and moderate abundance in the Delta during the time period when the spring flow pulses are proposed.

In the March-May period in the San Joaquin River at Highway 4, velocity overlap was high between the proposed action and COS (≥83.2%; Figure H-23 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were lower under the proposed action in Dry, Below Normal and Wet year and higher in Above Normal years (Figure H-23 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Comparing the proposed action and WOA in March-May revealed high overlap in Critical years (92.8%). In other water year types, overlap ranged between 54.5% in Wet years to 78.6% in Dry years with higher velocities under the WOA (Figure H-24 - Appendix H, *Bay-Delta Aquatics Effects Figures*). At the Head of Middle River in the March –May period, overlap between the proposed action and COS was moderate in Above Normal Years (57.7%) and high in all other water year types ≥ 73.0% (Figure H-25 - Appendix H, *Bay-Delta Aquatics Effects Figures*). In Above Normal years, velocities were higher under the proposed action and lower in all other water year types (Figure H-25 - Appendix H, *Bay-Delta Aquatics Effects Figures*). Comparison of the proposed action with WOA in March-May at Head of Middle River revealed overlap >50% in Critical years and overlap <35% in all other water year types (Figure H-26 - Appendix H, *Bay-Delta Aquatics Effects Figures* In all water year types, velocities were higher under the WOA relative to the proposed action.

5.8.3.10 Delta Cross Channel Operations

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. Significant amounts of flow and many juvenile Spring-run Chinook Salmon enter the DCC (when the gates are open) and Georgiana Slough, especially during increased Delta pumping. Mortality of juvenile salmon entering the central Delta is higher than for those continuing downstream in the Sacramento River. Juvenile Chinook Salmon which are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010) The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes. The peak migration of juvenile Spring-run Chinook Salmon in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from March-April (Table 5.8-1). Therefore, the DCC is closed to protect the majority of the juvenile Spring-run migration period in the Sacramento River and reduce the proportion of fish exposed to an open DCC.

5.8.3.11 Agricultural Barriers

The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Spring-run Chinook Salmon exposed to the agricultural barriers (Temporary Barrier Program, TBP) depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile Spring-run Chinook Salmon in the Delta is March and April (Table 5.8-1). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Spring-run Chinook Salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, acoustically tagged juvenile Chinook salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018).

5.8.3.12 Contra Costa Water District Rock Slough Intake

As discussed in Section 4.9.5, CCWD’s operations in the proposed action are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993; NMFS 2007; NMFS 2010; NMFS 2017; USFWS 1993a; USFWS 1993b; USFWS 2000; USFWS 2007; USFWS 2010; USFWS 2017; CDFG 1994; CDFG 2009). Therefore, the operation of the Rock Slough Intake for the proposed action remains unchanged from the current operations.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for CV Chinook Spring-run (NMFS 2017), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Designated critical habitat for Spring-run Chinook Salmon does not occur within Rock Slough, but is present further to the north in the Delta (NMFS 2017; NMFS 2014). Salmonids are expected to avoid the area of the Rock Slough Intake during certain times of the year based on historical water temperatures, which range from lows of about 45°F in winter (December and January) to over 70°F beginning in May and continuing to October (Reclamation 2016).

Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of CV Spring-run Chinook Salmon presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1999, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this 6-year period, CDFW captured a total of 108 juvenile CV Spring-run from March through May (CDFG 2002; NMFS 2017). From 1999-2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected a total of 11 juvenile CV Spring-run from March through May at the Rock Slough Headworks (Reclamation 2016; NMFS 2017). No adult Spring-run were collected in the vicinity of the Rock Slough Intake from 1994 through 2009 (CDFG 2002; Reclamation 2016; NMFS 2017). No juvenile or adult CV Spring-run have been collected in CCWD's Fish Monitoring Program at the Rock Slough Intake since 2008.

Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018, 47 salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera 2018a), but none of the captured fish were identified as Spring-run Chinook Salmon (NMFS 2017).

5.8.3.12.1 Rearing to Outmigrating Juveniles in the Bay Delta

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes (i.e., 10 miles from the San Joaquin River and 18 miles from the Sacramento River), juvenile Spring-run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile Spring-run can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates.

One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in OMR, and any effect that diversions at Rock Slough Intake would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the OMR corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstem of the Sacramento River or the San Joaquin River and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-run Chinook Salmon. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, we examine the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Spring-run Chinook Salmon and are not likely to affect the movement of juvenile salmonids.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-run Chinook Salmon section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

5.8.3.12.2 Adults

As discussed for adult Winter-run Chinook salmon, Rock Slough is poor habitat at a dead-end slough, with relatively high water temperature and a prevalence of aquatic weeds. Therefore, adult CV Spring-run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, if some adults stray into Rock Slough, the water exiting the Contra Costa Canal on ebb tide may create a false attraction to adult salmon that are migrating upstream (NMFS 2017). The diversion of water at the Rock Slough Intake, which is the subject of this consultation, reduces the false attraction created by the ebb tides existing the Contra Costa Canal.

5.8.3.13 North Bay Aqueduct

The proposed action includes the North Bay Aqueduct (NBA) intake in the North Delta and operation of the Barker Slough Pumping Plant. Listed salmonids may be present in the waterways adjacent to the Barker Slough Pumping Plant (monitoring data is available at). The NBA is located within designated critical habitat for Spring-run Chinook Salmon. There should be no discernable effect to the Spring-run Chinook Salmon due to the operations of the Barker Slough Pumping Facility. This is due to the infrequent presence of Spring-run Chinook Salmon in the monitoring surveys indicating a low risk of entrainment. Further, Barker Slough Pumping Facility fish screens are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment while greatly minimizing any impingement of fish against the screen.

5.8.3.14 Water Transfers

Under WOA, no pumping and Jones and Banks Pumping Plants would occur and therefore no water transfers would occur through them. Under the proposed action, Reclamation is expanding the transfer window to November from the current July to September. Expanding the transfer window could lead to increased pumping at Jones and Banks Pumping Plants, when capacity is available. The Figures below show when capacity is available under the proposed action and the COS, in terms of exceedances, years in the model period of record, and average by water year types. These values are total available, and are not filtered for the pattern on which water might be acquired for transfer. The pattern of acquisition could decrease these values, as well as reoperation of storage that might be required, or the water cost of meeting D-1641. Prior estimates indicate that approximately 50% of the capacity in the figures below would be useful for water transfers given these timing and upstream considerations. In addition, a 20-30% surcharge on acquisition might be necessary to accommodate the salinity related inefficiencies that arise in operations. Based on the figures below and these additional estimates, expanding the water transfer window could result in an additional approximately 50 TAF of pumping in most yeartypes. As more stored water is available from CVP and SWP reservoirs to pump in wetter yeartypes, most of the available capacity for transfers is in drier yeartypes (Figures 5.8-47 through 5.8-49).

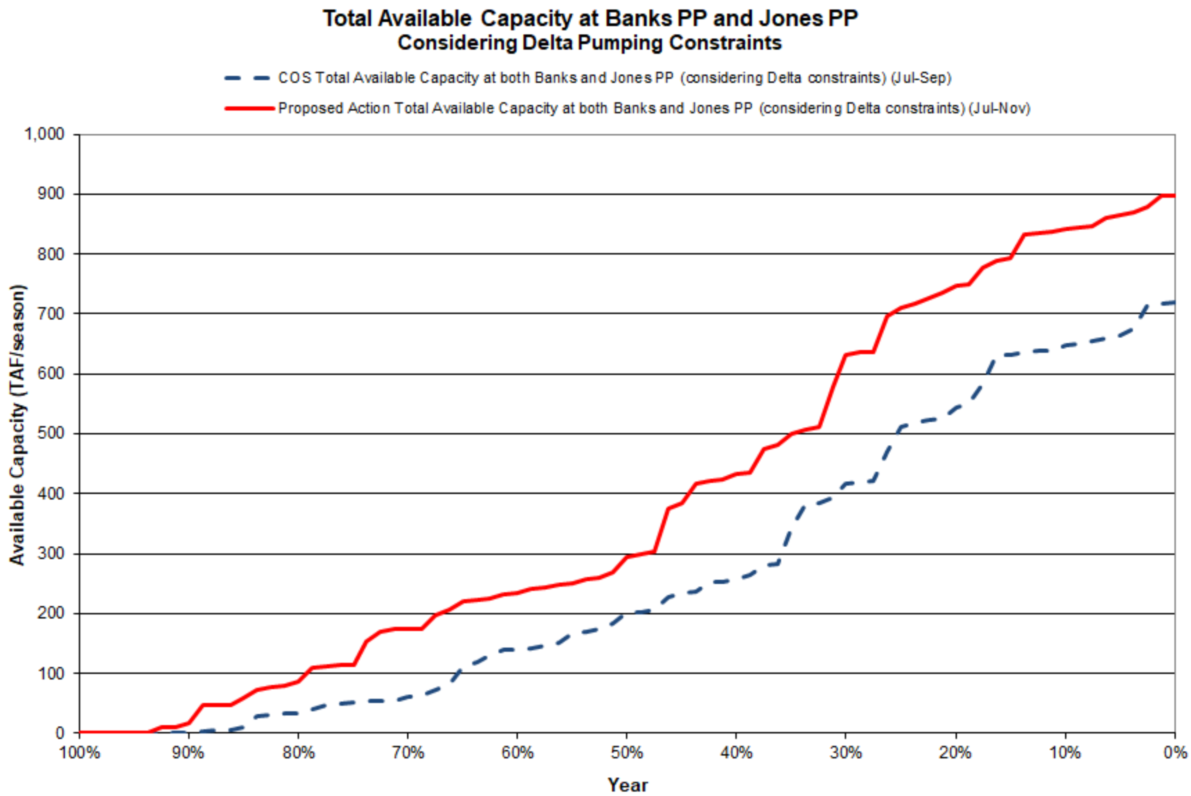


Figure 5.8-46. Exceedance of Available Capacity for Transfers at Jones and Banks under the Proposed Action and COS

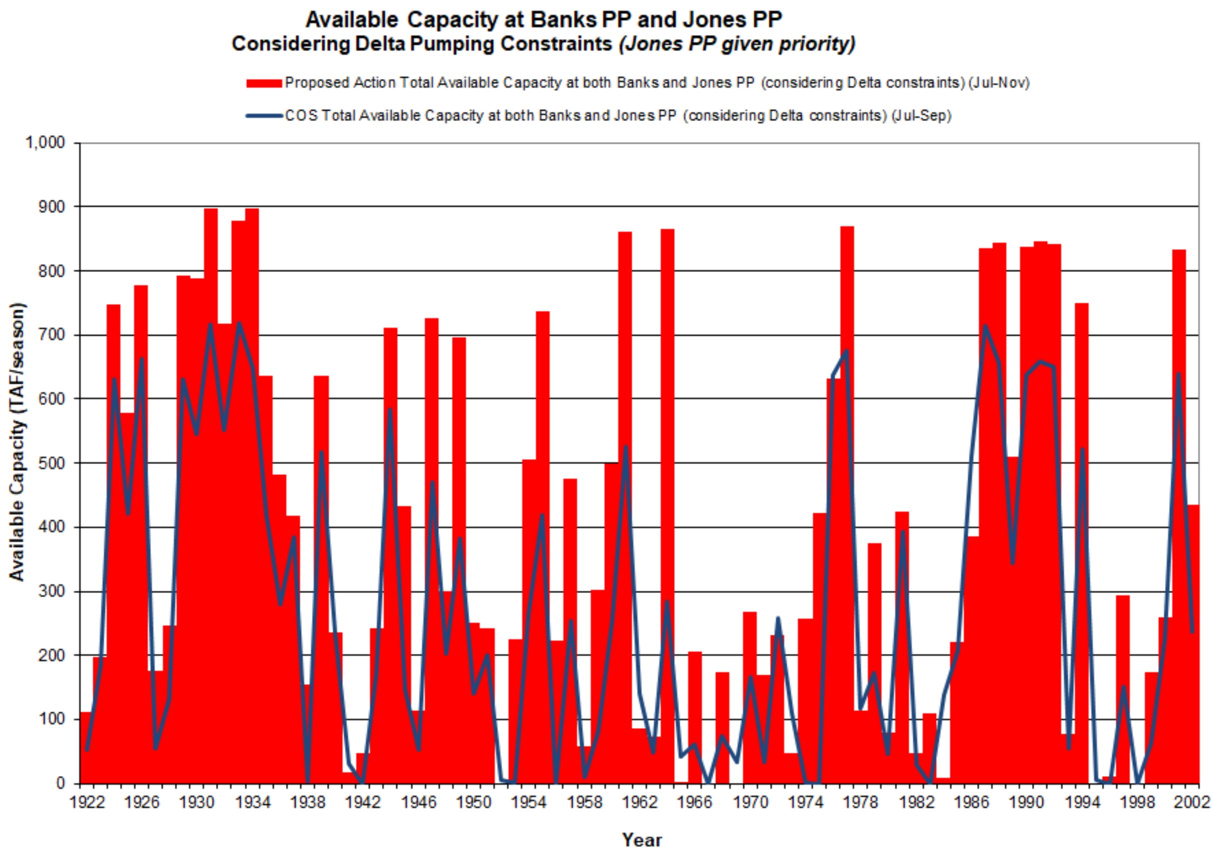


Figure 5.8-47. Modeled annual maximum available capacity for transfers under the proposed action and COS, CalSim period of record (1922-2003)

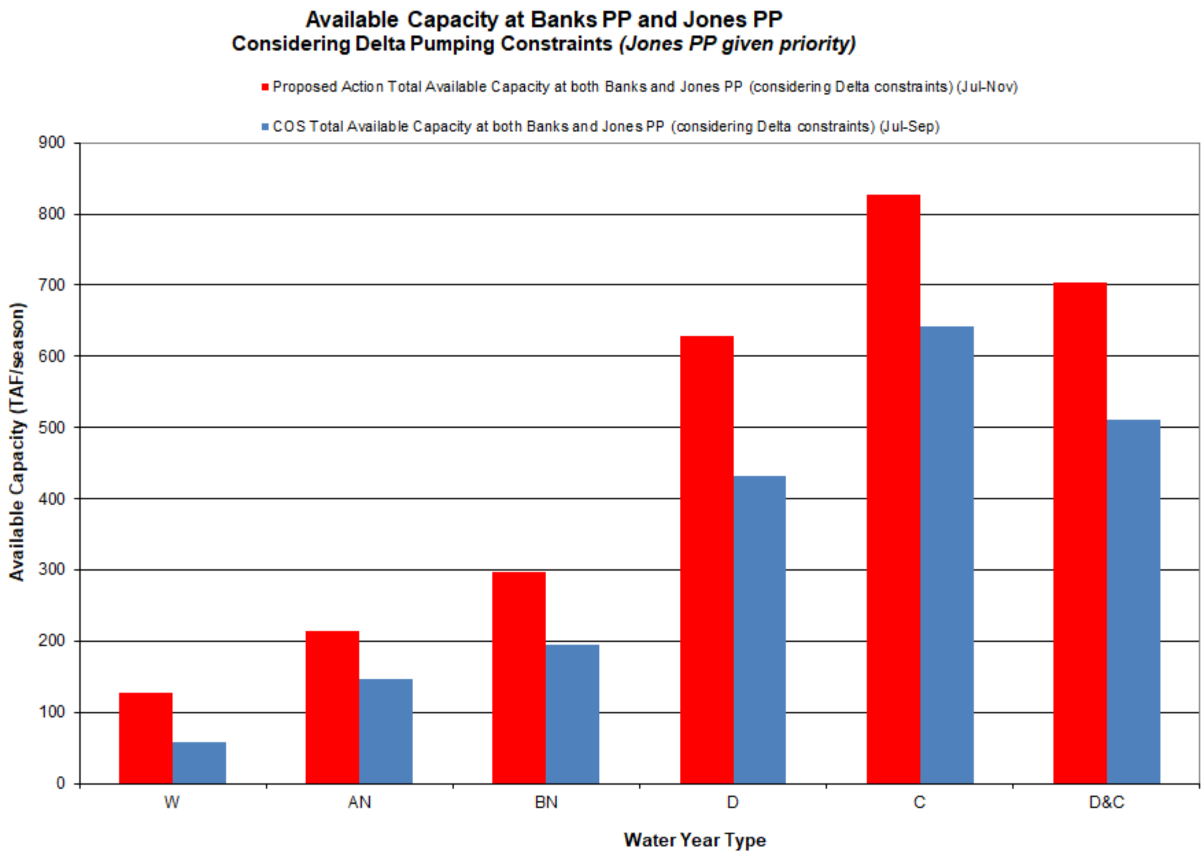


Figure 5.8-48. Water Year Type average available capacity at Jones and Banks Pumping Plants

Egg, aelvin, fry, and adult lifestages of Spring-run Chinook Salmon would not be exposed to the effects of increased water transfers as they do not occur in the Delta during July through November. Juvenile Spring-run Chinook salmon are detected at Chipps Island between December and July with the highest abundance in March-May (Table 5.8-1). Thus, only the very early or late migrants could potential be exposed to water transfers that occur during this time. These early or late migrant juvenile Spring-run Chinook Salmon could be exposed to increased effects of entrainment, routing, and decreased Delta survival (see OMR management section) as a result of the expanded water transfer window. Increased flows during conveyance in the Sacramento River could provide small survival benefits to migrating juveniles (Perry et al. 2018).

5.8.3.15 Clifton Court Forebay Aquatic Weed Control Program

Few if any juvenile Spring-run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program. Juvenile Spring-run are present in the Delta between mid-November and early June with a peak in April (Table5.6-1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the probability of exposing Spring-run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June.

Mechanical harvesting would occur on an as-needed basis and, therefore, listed salmonids could be exposed to this action, if entrained into Clifton Court Forebay. Potential direct and indirect effects to listed fish species from mechanical weed harvesters include mortality or injury from harvester strikes, entanglement in weeds lifted from the water, reduction of aquatic prey species, and temporary disturbances. Increased boat noise and disturbance of the water during harvesting, the slow speed of the harvester (approximately 2 miles per hour), and beginning harvesting closest to the edge should allow fish to to escape the area proposed for mowing. However, CV Spring-run Chinook Salmon at unlikely to be present and exposed to the adverse effects due to extreme temperatures.

5.8.3.16 Suisun Marsh Operations

5.8.3.16.1 Rearing to Outmigrating Juveniles in Bay-Delta

5.8.3.16.1.1 Suisun Marsh Salinity Control Gates

Operation of the SMSCG from October through May to meet salinity standards set by the State Water Resources Control Board and Suisun Marsh Preservation Agreement provides water quality benefits to Spring-run Chinook Salmon habitat. This beneficial operation coincides with downstream migration of juvenile Spring-run Chinook Salmon (Table 5.8-1). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile Spring run Chinook Salmon in Montezuma Slough thus, the proportion of the total run utilizing this route is unknown. Spring-run Chinook Salmon typically migrate through the estuary several months before spawning, but an extended delay in the estuary may affect their ability to access their natal spawning streams. Spring-run generally utilize high stream flow conditions during the spring snowmelt to assist their upstream migration. Rapid upstream movement may be needed to take advantage of a short duration high stream flow event, particular in dry years when high flow events may be uncommon. If the destination of a pre-spawning adult salmon is among the smaller tributaries of the Central Valley, it may be important for migration to be unimpeded, since access to a spawning area could diminish with receding flows. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

5.8.3.16.1.2 Roaring River Distribution System

As described by NMFS (2009: 437-438), the Roaring River Distribution System (RRDS)’s water intake (eight 60-inch-diameter culverts) is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 or 0.7 ft/s, so that juvenile Spring-run Chinook Salmon would be excluded from entrainment.

5.8.3.16.1.3 Morrow Island Distribution System

The Morrow Island Distribution System (MIDS) diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, its unlikely juvenile CV Spring-run Chinook Salmon will be entrained into the water distribution system, since Spring-run Chinook have not be caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor Spring-run Chinook Salmon.

5.8.3.16.1.4 Goodyear Slough Outfall

Goodyear Slough Outfall improves water circulation in the marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, Spring-run Chinook Salmon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits juvenile Spring-run Chinook Salmon in Suisun Marsh by improving water quality and increasing foraging opportunities.

5.8.3.17 OMR Management

Delta seasonal operations above describe entrainment in more detail. Restricting OMR flows to -5,000 cfs will reduce or avoid entrainment. Triggers based on salvage that further restrict OMR will further reduce entrainment. Enhanced monitoring and predictive tools will further reduce entrainment while increasing operational flexibility. Figure 5.8-50 shows historical salvage under the COS. Salvage under the proposed action is anticipated to be similar or less.

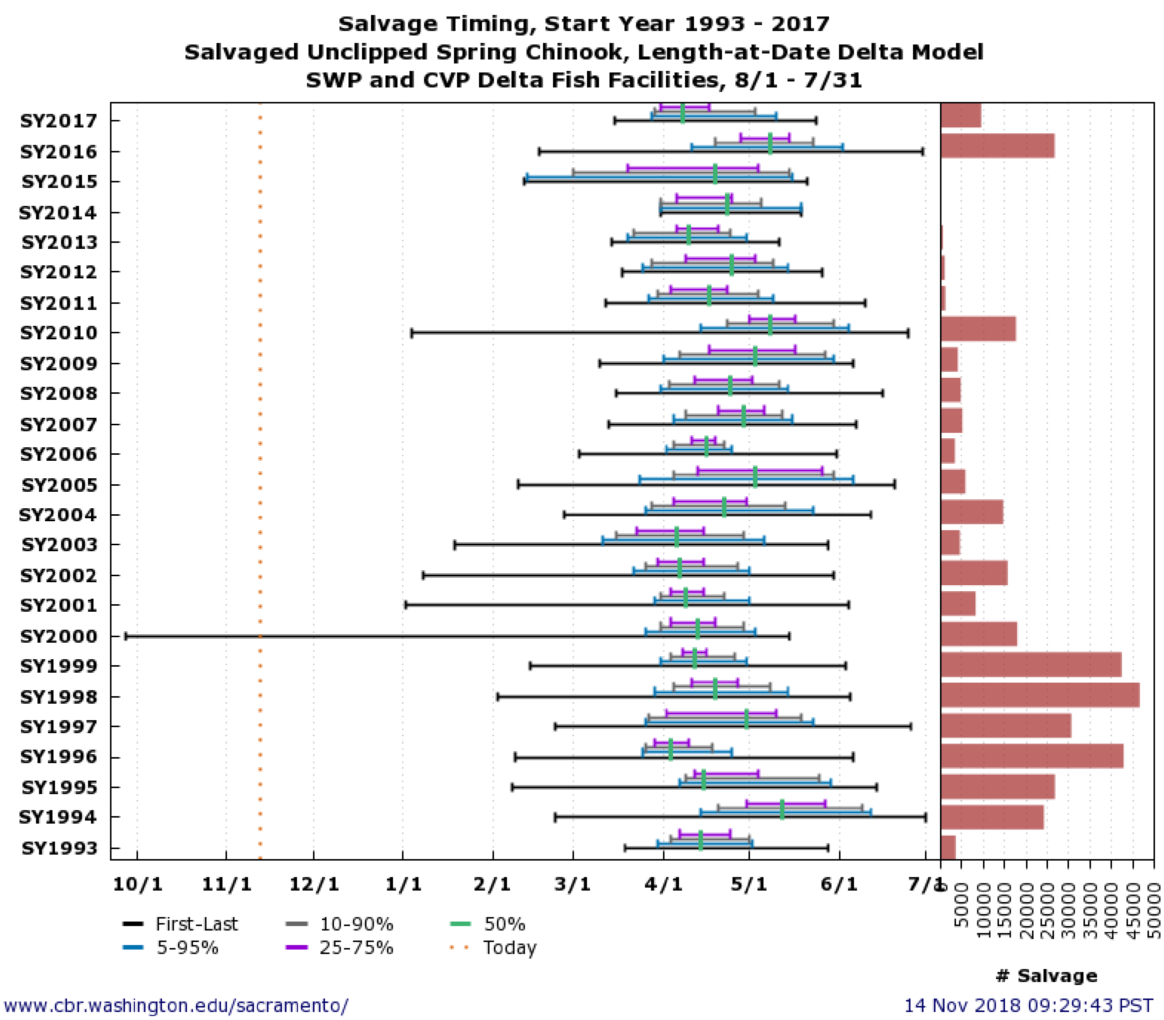


Figure 5.8-49. Salvage of Spring-run Chinook Salmon from 2009 to 2018

5.8.3.18 Operation of a Shasta Dam Raise

Reclamation would operate a raised Shasta Dam consistent with the rest of the proposed action. Therefore, effects described elsewhere in the document would also apply to the operation of a raised Shasta Dam, and there would be no operational changes.

5.8.4 Effects of Conservation Measures

The following are proposed conservation measures that are intended to offset the effects of operations and maintenance. These conservation measures would only occur due to the implementation of the Proposed Action and are beneficial in nature. The following analysis looks at not only at the construction related effects of the measures but also the benefits to the population once completed. Conservation measures would not occur under WOA.

5.8.4.1 Battle Creek Restoration

Under the Proposed Action, Reclamation would accelerate implementation of the Battle Creek Salmon and Steelhead Restoration Project. NMFS and USFWS Biological Opinions were issued in 2005 on this project, and that consultation discusses effects of Battle Creek restoration.

5.8.4.2 Lowering Intakes at Wilkins Slough

5.8.4.2.1 Egg to Fry Emergence

The installation of fish screens near Wilkins Slough would be beneficial to Spring-run Chinook Salmon egg and fry. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows would directly benefit fish of all life stages, as the lower fall flows would improve cold water pool for the subsequent summer, and allow greater flexibility for spring pulse flows in the next year. Specifically, operation of diversions with fish screens near Wilkins Slough would improve subsequent water temperatures and increase dissolved oxygen, and decrease entrainment risk.

The egg and fry lifestage of Spring-run Chinook Salmon, as well as the population, would benefit from this action.

Egg and fry of Spring-run Chinook Salmon would not be affected by the construction of a new diversion and screens near Wilkins Slough, based on Spring-run Chinook Salmon spawning from mid- to late-August through early October. Spring-run Chinook Salmon spawn in gravel beds that are often located at the tails of holding pools (OCAP BA 2008). Wilkins Slough does not contain suitable spawning habitat; therefore, effects of construction on Spring-run Chinook Salmon eggs and fry are not anticipated.

5.8.4.2.2 Rearing to Outmigrating Juveniles in Rivers

The installation of fish screens near Wilkins Slough would be beneficial to rearing and emigrating Spring-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages.

Outmigrating juvenile Spring-run Chinook Salmon in the Upper Sacramento River would not be affected by the construction of a new diversion and fish screens near Wilkins Slough under the proposed action, based spring-run juveniles emigrating from November through May with peak emigration occurring from May through (Table 5.8-1). Construction of diversions and fish screens near Wilkins Slough would occur during an in-water work window (June 1 to October 1), avoiding the emigration period; therefore effects of construction on emigrating spring-run is not expected.

Juvenile spring-run rear in natal tributaries, the Sacramento River mainstem, nonnatal tributaries to the Sacramento River, and the Delta (DFG 1998 *as cited in* OCAP BA) and emigration timing is highly variable (OCAP BA 2008). If rearing Spring-run Chinook Salmon are present in Wilkins Slough during the June 1 through October 1 in-water work window, individuals may be exposed to temporary disturbances associated with the construction of a cofferdam. Water quality may be temporarily disturbed, in addition the noise associated with construction of the cofferdam may temporarily affect juvenile Spring-run Chinook Salmon. Additionally, fish rescue operations may need be conducted during the period when water within the coffered area needs to be pumped. However, implementation of AMM's identified in the Appendix E, *Avoidance and Minimization Measures* would further minimize any effects to rearing and emigrating Spring-run Chinook Salmon.

5.8.4.2.3 Rearing and Outmigrating Juveniles in the Bay-Delta

Rearing and outmigrating juvenile Spring-run Chinook Salmon in the Bay-Delta would not be affected by the construction of a new diversion and fish screens near Wilkins Slough, based spring-run juveniles emigrating from November through May with peak emigration occurring from March through April (Table 5.8-1). Juvenile fall-run salmon may rear for up to several months within the Delta before ocean entry (Kjelson et al. 1982 *as cited in* OCAP BA). Rearing within the Delta occurs principally in tidal freshwater habitats. Wilkins Slough is located outside of the Bay-Delta; therefore, rearing and outmigrating juveniles located in the Bay-Delta would not affected by construction activities occurring during the inwater construction window from June 1 through October 1.

5.8.4.2.4 Adult Migration

The installation of fish screens near Wilkins Slough would be beneficial to immigrating Spring-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages.

Adult Sacramento River spring-run Chinook begin to leave the ocean for their upstream migration in late January to early February based on time of entry to natal tributaries (DFG 1998 *as cited in* OCAP BA 2008). Immigrating Spring-run Chinook Salmon are not expected to be affected by the construction of a new diversion and screens near Wilkins Slough, based spring-run adults immigrating into the Sacramento River Basin between March through June, with a peak from May through June (Table 5.8-1). The implementation of an in-water work window (June 1 and October 1) and other AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further minimize effects on immigrating Spring-run Chinook Salmon.

5.8.4.2.5 Adult Holding

The installation of fish screens near Wilkins Slough would be beneficial to holding Spring-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning.

Spring-run adults may hold in their natal tributaries for up to several months before spawning (DFG 1998 *as cited in* OCAP BA 2008). Pools in the holding areas need to be sufficiently deep, cool (about 64 F or less), and oxygenated to allow over-summer survival. Suitable holding habitat in Wilkins Slough is not present; therefore, holding Spring-run Chinook Salmon would not be affected by the construction of a new diversion and screens near Wilkins Slough. Implementation of AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further reduced the likelihood of effects on individuals, and populations.

5.8.4.3 Shasta TCD Improvements

5.8.4.3.1 Egg to Fry Emergence

The ability of the proposed action to better manage the cold water pool and cold water releases would result in increased probability and likelihood of maintaining suitable spawning, incubating and rearing temperatures throughout the season in all but the driest years. Therefore, the improved flow management and temperature regime associated with the Shasta TCD improvements is expected to have high-level population benefits on this life stage of Spring-run Chinook Salmon relative to the WOA and the COS.

5.8.4.3.2 Rearing to Outmigrating Juveniles

There is little difference in water temperatures between the COS and proposed action scenarios during the period of spring-run rearing in the upper Sacramento River, with differences in November the greatest, but less than one degree Fahrenheit difference.

Water temperatures during most years in the November through April period are suitable for juvenile spring-run that rear in and emigrate from the middle Sacramento River under the WOA and the COS and proposed action scenarios, so no adverse effects on the spring-run juveniles are expected for these months. Under all three scenarios during May, however, the 64 degrees Fahrenheit threshold would be exceeded in most years, with the WOA scenario having greater exceedances then the COS and proposed action scenarios, especially in warmer years (Figure SRT_L3_CDmay). These results indicate that water temperature conditions would too warm for juvenile spring-run rearing and emigrating in the middle Sacramento River during May under Without Action conditions, Current Operations, and the Proposed Action, and that conditions would be worse under the Without Action conditions than under the other two scenarios.

5.8.4.3.3 Migrating Adults

High May water temperatures in the middle River are expected for many years under the WOA, and the proposed action improves these temperatures compared to the WOA. As temperatures are still high under the proposed action, Shasta TCD improvements could provide benefits to Reclamation's ability to meet Sacramento River temperature targets and benefit adult spring-run.

5.8.4.3.4 Holding Adults

The improved flow and temperature management associated with the Shasta TCD improvements is expected to have benefits for holding adult Spring-run Chinook Salmon.

5.8.4.4 Sacramento River Spawning and Rearing Habitat

Spring-run Chinook Salmon juveniles in the Sacramento River would benefit from increased side channel habitat, gravel, and large wood resulting from habitat restoration in the Sacramento River improving their likelihood of rearing success due to an increase in total rearing habitat area and rearing habitat quality. Reclamation estimates that this additional 50 acres of rearing habitat could support the progeny of 5,600 returning adult salmonids based on the relationship shown in the plot below.

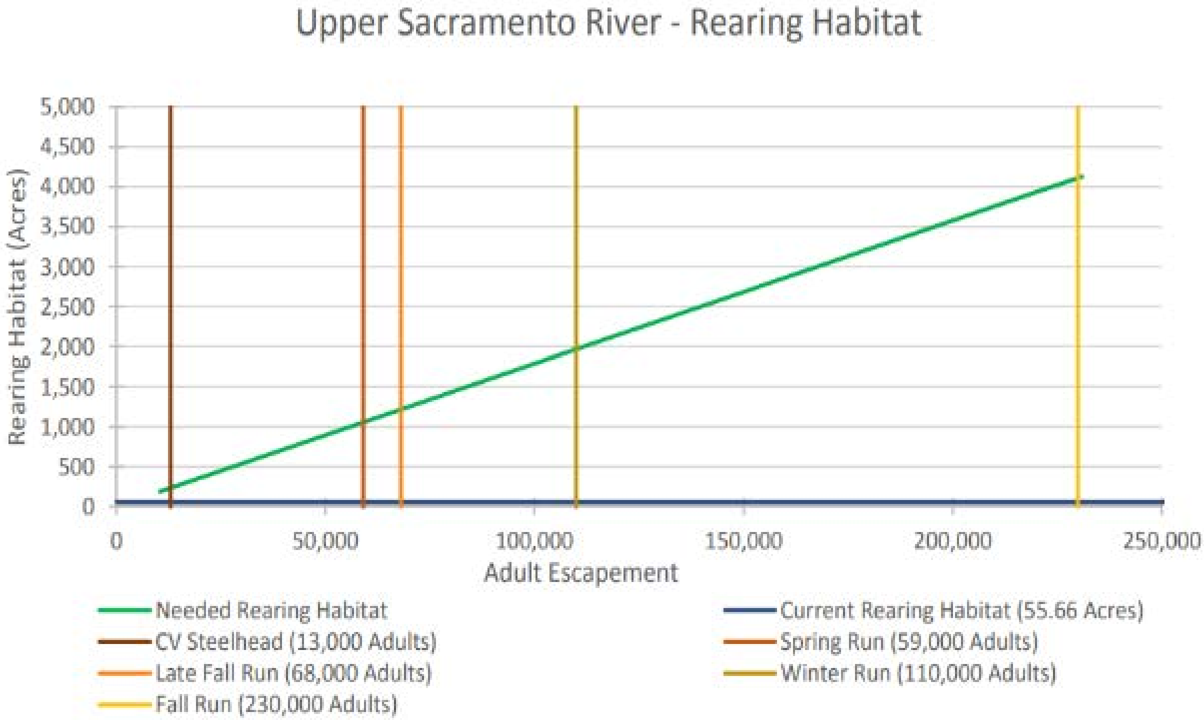


Figure 5.8-50. Adult Escapement and Rearing Habitat on the Upper Sacramento River

Few, if any, rearing and outmigrating juveniles would be exposed to construction of side channel habitat, gravel augmentation, and large wood installation, based on the timing of the in-water work window (July 1-September 30) and peak seasonal occurrence of this life stage in the Sacramento River (November-May; Table 5.8-1). Construction activities in the Sacramento River could result in mortality of this life stage by crushing if heavy equipment entered the stream channel, if individuals were stranded or isolated during dewatering, or if construction otherwise disturbed rearing juvenile habitat during manipulation of gravel, installation of large wood or creation of side channels. Individuals exposed to construction could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. Juveniles could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, reduced foraging ability caused by decreased visibility, and impeded or delayed migration caused by elevated noise levels from machinery.

However, exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. There is no overlap of the peak seasonal occurrence of this life stage and the in-water work window. Therefore this action is not anticipated to have negative effects on rearing and outmigrating juvenile Central Valley Spring-run Chinook Salmon.

5.8.4.5 Deer Creek Fish Passage

Deer Creek is a tributary of the Sacramento River with natural production of spring-run Chinook salmon and steelhead trout. There are 3 diversion dams and 4 screened diversion ditches in Deer Creek. Deer Creek Irrigation District Dam (DCID) is the uppermost dam on Deer Creek. DCID is a flashboard dam with a screened diversion. DWR and Reclamation's installation of a nature-like fishway at this site will provide Spring-run Chinook salmon and other salmonids access to approximately 25 miles of spawning habitat in Deer Creek upstream from the DCID dam.

Few, if any, rearing and outmigrating juveniles would be exposed to construction of the nature-like fishway, based on the timing of the in-water work window (July 1-September 30) and peak seasonal occurrence of this life stage in the Sacramento River (November-May; Table 5.8-1). Construction effects are the same as discussed above for Sacramento River spawning and rearing habitat. Exposure to these effects would be minimized with incorporation of the avoidance and minimization measures.

5.8.4.6 Small Screen Program

A small proportion of the Spring-run Chinook Salmon population would benefit from the Small Screen Program under the proposed action. There may be moderate overlap of the Spring-run Chinook Salmon migration with the main late spring-fall irrigation period for small diversions, and small diversion screening could reduce entrainment of late migrating individuals.

5.8.4.6.1 Egg to Fry Emergence

No egg or fry Spring-run Chinook Salmon would be exposed to fish screens since they remain in the gravel in the rivers. Therefore, there would be no effects from fish screen construction on this life stage.

5.8.4.6.2 Rearing to Outmigrating Juveniles

The operation of fish screens on water diversions under the proposed action would benefit juvenile Spring-run Chinook Salmon by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for adverse effects to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized under the proposed action since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage.

Juvenile Spring-run Chinook Salmon may be exposed to the effects of construction of screens on water diversion intakes since they will likely be present during the timing of in-water construction (July 15 – October 15). However, the work area for these projects is small, limiting exposure to construction. Spring-run Chinook Salmon exhibit a stream-type life history where juveniles typically spend a year or more in freshwater before emigrating (NMFS 2009). Thus, juveniles may be present in the Sacramento

River year-round since they reside in freshwater for 12 to 16 months (Table 5.8-1), but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000). Potential short-term adverse effects may include temporary effects to water quality as result from in-water work, resulting in increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.8.4.6.3 Rearing to Outmigrating Juveniles in the Delta

Operational benefits of screened diversions are the same as for juveniles in rivers above.

Few if any juvenile Spring-run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes. Juvenile Sacramento River Spring-run Chinook Salmon primarily from November through early May (NMFS 2014), largely outside of the timing of in-water construction (July 15 – October 15). In addition, the work area for these projects is small, limiting exposure to construction.

5.8.4.6.4 Adult Migration

Operational benefits of screened diversions are the same as for juveniles in rivers above.

Adult Spring-run Chinook Salmon may be exposed to the effects of construction of screens on water diversion intakes based on the timing of in-water construction (July 15 – October 15) and the mid-February to October seasonal occurrence of this life stage in the Sacramento River (Table 5.8-1). Effects are the same as for juveniles above, and would be minimized through AMMs.

5.8.4.6.5 Adult Holding

Operational benefits of screened diversions are the same as for juveniles in rivers above.

Adult Spring-run Chinook Salmon holding in the Sacramento River may be exposed to the effects of construction of screens on water diversion intakes based on the timing of in-water construction (July 15 – October 15), the mid-February to October seasonal occurrence of this life stage in the Sacramento River (Table 5.8-1). However, few fish will potentially be exposed to construction activities due to the localized work areas of these projects and their tendency to remain in deep cold pools in proximity to spawning areas until they are sexually mature and ready to spawn (CDFG 1998; NMFS 2009). Effects are the same as for juveniles above, and would be minimized through AMMs.

5.8.4.7 Adult Rescue

Adult rescue would primarily affect adult Spring-run Chinook Salmon. The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult Spring-run Chinook Salmon, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the abundance of Spring-run Chinook Salmon of all life stages in the Sacramento River and its tributaries.

Exposure of this life stage to adult rescue effects would be restricted only to those adult Spring-run Chinook Salmon that become stranded in the Yolo and Sutter Bypasses and subsequently rescued and released to the Sacramento River. Adults that migrate in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by adult rescue activities. The number of adult Spring-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the abundance of adults that stray into the bypasses and the timing and frequency of stranding events in the bypasses. Individual adult Spring-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality, which could vary in intensity depending on the techniques used to capture individuals. Injury and increased stress associated with capture, handling and transport may affect survival of individuals after release. The risk from these potential effects would be minimized through application of AMM8 Fish Rescue and Salvage Plan (Appendix E, *Avoidance and Minimization Measures*). As such, it is concluded that the overall population-level negative effects on this life stage of Spring-run Chinook Salmon from adult rescue activities would be low relative to the without action (no rescue of stranded adult Spring-run Chinook Salmon in Yolo and Sutter bypasses).

Juvenile Spring-run Chinook Salmon occur in the Yolo and Sutter Bypasses when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. Although they are unlikely to occur in the bypasses during periods when flow does not overtop the weirs, ongoing modifications to the Fremont Weir to increase inundation of the Yolo bypass for floodplain rearing would provide juveniles with more consistent access to the Yolo bypass. Therefore, these juveniles could be exposed to the effects of adult rescue activities if they become stranded with adults that are targeted by adult rescue activities. The number of juvenile Spring-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the timing of proposed adult rescue activities, gear type used to rescue adults, and the typical seasonal occurrence of this life stage in the Yolo and Sutter bypasses. Individual juvenile Spring-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality during efforts to capture stranded adults, handling, and transport. Injury and increased stress associated with capture, handling, and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Spring-run Chinook Salmon would be expected to be offset by benefits associated with increased numbers of adult Spring-run Chinook Salmon returning to spawning grounds. As such, it is concluded that the overall population-level negative effects on this life stage of Spring-run Chinook Salmon from adult rescue activities would be low relative to the without action (no rescue of adult Spring-run Chinook Salmon).

Given that this life stage is carried out in the upper Sacramento River and its tributaries and adult rescue activities would occur downstream in the Yolo and Sutter bypasses, there would be no direct effects on this life stage from implementing adult rescue activities.

The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult Spring-run Chinook Salmon, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the abundance of Spring-run Chinook Salmon adults holding in the upper Sacramento River and its tributaries.

5.8.4.8 Juvenile Trap and Haul

Juvenile trap and haul would only affect juvenile Spring-run Chinook Salmon. The operation of the juvenile trap and haul is targeted towards juvenile Chinook Salmon, with the goal of increasing the survival of juveniles and, ultimately, returning adults; therefore, this effort could increase the number of Spring-run Chinook Salmon of all lifestages in the Sacramento River and its tributaries.

The number of juvenile Spring-run Chinook Salmon that would be expected to be exposed to the effects of juvenile trap and haul activities would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trapping location and efficiency, and the typical seasonal occurrence of this life stage in the Sacramento River (Table 5.8-1). Individual juvenile Spring-run Chinook Salmon exposed to juvenile trap and haul activities would be at risk of increased stress, injury, and/or mortality. Injury and increased stress associated with handling and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Spring-run Chinook Salmon would be expected to be offset by benefits associated with expected increased survival of the overall brood-year of Spring-run Chinook Salmon. As such, it is concluded that the overall population-level negative effects on this life stage of juvenile Spring-run Chinook Salmon from juvenile trap and haul activities would be low relative to the without action (no trapping and hauling of juvenile Spring-run Chinook Salmon during drought years) and would be potentially offset by benefits (increased juvenile survival and ultimately increased adult escapement) associated with the juvenile trap and haul program.

Because transported juveniles are more likely to have impaired homing behavior as adults, juvenile trap and haul activities may increase the rate of straying by returning adults. Adults that stray into tributaries with unsuitable holding habitat would not be expected to survive or spawn successfully because of the lack of suitable adult holding and/or spawning habitat.

Because juvenile trap and haul would target only wild juveniles during outmigration, adult Spring-run Chinook Salmon holding in rivers would not be directly affected by juvenile trap and haul activities. However, because the purpose of juvenile trap and haul activities is to increase the survival rate of juveniles during drought years, the number of adults holding in rivers potentially would be greater relative to the without action (no trapping and hauling of juvenile Spring-run Chinook Salmon during drought years), as a result of increased juvenile survival and, ultimately, increased adult escapement.

5.8.4.9 Clear Creek Restoration Program

Reclamation proposes to enhance Chinook salmon spawning and rearing habitat within Clear Creek. This action includes placement of large woody debris and gravel augmentation.

This action is expected to enhance habitat complexity, benefiting salmonids that use Clear Creek and improving the habitat conservation value. The benefits from implementation of restoration projects include (1) complex channels and floodplain habitats, and (2) spawning habitat. In some years, over one hundred Spring-run Chinook Salmon have been observed in Clear Creek, so the restoration is anticipated to have beneficial effects to Spring-run Chinook Salmon spawning and rearing habitat over WOA, where no restoration would occur.

Construction-related effects include increased sedimentation and turbidity. As side channel creation and flood plain enhancement projects are implemented as a part of the restoration, construction-related activities have the potential to result in injury or death to listed fish species. Construction-related effects may include debris falling into the active channel, tools and/or equipment falling into the active channel or noise generated by displaced rock and sediment and the operation of construction machinery.

5.8.4.10 American River Spawning and Rearing Habitat

Spring-run Chinook Salmon juveniles in the American River would benefit from increased side channel habitat, gravel, and large wood resulting from habitat restoration in the American River improving their likelihood of rearing success due to an increase in total rearing habitat area and rearing habitat quality.

Few, if any, rearing and outmigrating juveniles would be exposed to construction of side channel habitat, gravel augmentation, and large wood installation, based on the timing of the in-water work window (July 1-September 30) and peak seasonal occurrence of this life stage in the American River (November-May; Table 5.8-1). Construction activities in the American River could result in mortality of this life stage by crushing if heavy equipment entered the stream channel, if individuals were stranded or isolated during dewatering, or if construction otherwise disturbed rearing juvenile habitat during manipulation of gravel, installation of large wood or creation of side channels. Individuals exposed to construction could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. This life stage could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, reduced foraging ability caused by decreased visibility, and impeded or delayed migration caused by elevated noise levels from machinery.

However, exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. There is no overlap of the peak seasonal occurrence of this life stage and the in-water work window. Therefore this action is not anticipated to have negative effects on rearing and outmigrating juvenile Central Valley Spring-run Chinook Salmon.

5.8.4.11 American River Drought Temperature Facility Improvements

Reclamation proposes to evaluate and implement alternative shutter configurations at Folsom Dam to allow temperature flexibility in severe droughts, thereby reducing water temperatures in the lower American River. Juvenile CV Spring-run Chinook Salmon may be present in the lower American River year-round since they reside in freshwater for 12 to 16 months (Table 5.8-1), but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000). Excessively high water temperatures have been identified as one of the factors threatening CV Spring-run Chinook Salmon in the Central Valley and a factor for listing of the species. Juveniles may reside in freshwater for 12 to 16 months, but some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000). The implementation of the proposed drought temperature management measures under the proposed action would improve Reclamation’s ability to manage temperatures in the lower American River and improve conditions for this life stage. Therefore, this proposed action may beneficially affect juvenile CV Spring-run Chinook Salmon in the American River by reducing the effects of drought conditions on water temperatures.

5.8.4.12 Stanislaus River Spawning and Rearing Habitat

5.8.4.12.1 Egg to Fry Emergence

Spring running Chinook salmon have the potential to be affected by construction activities associated with the restoration activities in the Stanislaus River. However, benefits from increased habitat complexity due to restoration is expected to offset short-term construction impacts. However, through coordination with the regulatory agencies and implementation of avoidance and minimization measures, including the implementation of an in-water work window from July 15 through October 15, effects to the egg to fry emergence life stage of early spawning Chinook salmon would be avoided by construction activities. Through snorkel surveys, Chinook fry were observed in December 2003 in the Stanislaus River (NMFS 2014), which is outside of the July 15 through October 15 in-water work window, although the eggs may have been spawned within the timing window.

5.8.4.12.2 Rearing to Outmigrating Juveniles in Rivers

The creation of side channel and rearing habitat would increase the quality and quantity of off channel rearing (and spawning areas). The habitat restoration activities would improve the riparian habitat available for juvenile Spring-run Chinook Salmon rearing. The benefit of the habitat restoration activities within the Stanislaus River would yield immediate benefits. Existing riparian vegetation would be increased with the creation of side-channel habitat, providing:

- instream object and overhanging object cover;
- new shaded riverine habitat; and
- additional area for food source.

The creation of side-channel and floodplain rearing habitat would also increase the aquatic habitat complexity and diversity within the Stanislaus River and provide additional predator escape cover. The habitat restoration would result in increased survival of juvenile spring-running Chinook Salmon in the Stanislaus River.

Reclamation will implement an in-water work window from July 15 through October 15. This is outside of the juvenile outmigration period and juveniles would not be expected to be in the river, therefore there would be no effect of spawning and rearing habitat construction on juvenile spring-running Chinook salmon.

5.8.4.12.3 Adult Migration from Ocean to Rivers

Construction activities associated with the restoration activities in the Stanislaus River may potentially affect immigrating Spring-run Chinook Salmon. However, through implementation of avoidance and minimization measures, including the implementation of an in-water work window from July 15 through October 15, immigrating spring-running Chinook Salmon would not be affected by construction activities.

5.8.4.12.4 Adult Holding in Rivers

Additional spawning and rearing habitat is unlikely to benefit Spring-run adults holding in the Stanislaus River as adult holding habitat is generally in the main channel rather than side channels and floodplains.

Construction activities associated with the restoration activities in the Stanislaus River are unlikely to affect adult holding spring-running Chinook salmon in the Stanislaus River. Through implementation of avoidance and minimization measures, including the implementation of an in-water work window from July 15 through October 15, holding spring-running Chinook Salmon would not be affected by construction activities.

5.8.4.13 Lower San Joaquin River Rearing Habitat

Lower San Joaquin Rearing Habitat restoration is expected to result in similar effects as those described above for Stanislaus River Spawning and Rearing Habitat.

5.8.4.14 Suisun Marsh Salinity Control Gates Operation

No Spring-run Chinook Salmon are detected in the Delta between June and October. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

5.8.4.15 Summer-Fall Delta Smelt Habitat

No Spring-run Chinook Salmon are detected in the Delta between June and October. Therefore, no effects would occur as a result of the Suisun Marsh Salinity Control Gate operation.

5.8.4.16 Clifton Court Predator Management

Predator control efforts at Clifton Court Forebay under the proposed action could reduce pre-screen loss of juvenile Spring-run Chinook Salmon entrained into Clifton Court Forebay. Spring-run Chinook Salmon are unlikely to be in the area during predator control efforts during the summer in-water work window.

5.8.4.17 Sacramento Deepwater Ship Channel

This action would hydrologically connect the Sacramento River with the Sacramento Deepwater Ship Channel (SDWSC) via the Stone Lock facility from mid-spring to late fall. Juvenile Spring-run Chinook Salmon abundance in the Delta is moderate in March and peaks in April (Table 5.8-1). Juvenile Spring-run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be enter into the SDWSC. There are potential benefits to Spring-run Chinook Salmon from this action. Fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar. However, estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. Also, there is potential for decreased migration time to the ocean and exposure to larger food sources of Liberty Island, but this is currently uncertain.

5.8.4.18 North Delta Food Subsidies/Colusa Basin Drain Study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on Spring-run Chinook Salmon, who are in the Delta between January – February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

5.8.4.19 Suisun Marsh Roaring River Distribution System Food Subsidies Study

Under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-run Chinook Salmon, who are in the Delta between January – February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

5.8.4.20 Tidal Habitat Restoration

A large proportion of juvenile Spring-run Chinook Salmon are expected to benefit from continuing to construct the 8,000 acres of tidal habitat restoration in the Delta under the proposed action. Benefits include increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

Few if any juvenile Spring-run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Table 5.8-1). There may be some exposure of yearling migrants that enter the Delta in the fall. Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014). This includes the following: temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity, loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Figure 5.6-4). The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.8.4.21 Predator Hot Spot Removal

Predator hot spot removal under the Proposed Action is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Spring-run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Spring-run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012, Michel et al. 2017, Sabal et al. 2017).

5.8.4.22 San Joaquin River Scour Hole Predation Reduction

Spring-run Chinook salmon outmigrating from the San Joaquin River are exposed to predation at the junction of the San Joaquin River and Old River. This action would reduce predation at this site, improving juvenile San Joaquin origin Spring-run Chinook salmon survival.

Few Spring-run Chinook Salmon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction to adjust bathymetry would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.8.4.23 Knight's Landing Outfall Gates Fish Barrier

Reclamation and DWR's fish barrier at the Knight's Landing Outfall Gates would prevent possible entrainment of salmonids into the Colusa Basin Drain. This project would reduce entrainment and therefore increase survival of Spring-run Chinook Salmon adults.

Few Spring-run Chinook Salmon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.8.4.24 Delta Cross Channel Improvements

Greater operational flexibility and increased gate reliability resulting from improvements to the Delta Cross Channel under the proposed action would reduce the risk of gate failure that could result in higher rates of entrainment of Spring-run Chinook Salmon, if left open. Seasonal closure periods would still be in place to protect Spring-run Chinook Salmon. The DCC is an older structure which requires manual operation and increased use could result in locks braking in either open or closed positions. Migrating Spring-run Chinook Salmon would benefit from faster operations that prevent straying into the central Delta and catastrophic failure of the facility. Improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment depending on operations.

Few Spring-run Chinook Salmon are expected to be exposed to in-water construction related improvements to the Delta Cross Channel due to observance of species protective work windows.

5.8.4.25 Tracy Fish Facility Improvements

A number of programmatic actions are proposed to improve salvage efficiency of TFCF, including installing a carbon dioxide injection device to allow remote controlled anesthetization of predators in the secondary channels of the Tracy Fish Facility. These actions could potentially benefit juvenile Spring-run Chinook Salmon through greater salvage efficiency.

Few if any juvenile Spring-run Chinook Salmon would be expected to be exposed to construction of the CO2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August–October in-water work window (see figures in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS:* WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race). Risks to these few individuals would be minimized through appropriate AMMs (Appendix E, *Avoidance and Minimization Measures*), the selected in-water work window, and the small scale of the in-water construction. For juvenile Spring-run Chinook Salmon that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

5.8.4.26 Skinner Fish Facility Improvements

Predator control efforts at Skinner Fish Facility under the Proposed Action to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce pre-screen loss of juvenile Spring-run Chinook Salmon entrained into Clifton Court Forebay. Spring-run Chinook Salmon are unlikely to be in the area during predator control efforts.

5.8.4.27 Delta Fishes Conservation Hatchery

As with the other proposed construction activities in the Bay-Delta, few if any juvenile Spring-run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August–October) and the typical seasonal occurrence of juvenile Spring-run Chinook Salmon in the Delta (Table 5.8-1). There may be some exposure of yearling migrants to in-water and shoreline construction of the hatchery intake and outfall, as illustrated by timing of occurrence in Sacramento seines and trawls (Figures WR_Seines and WR_Sherwood in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*). Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile Spring-run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

5.8.4.28 Effects of Monitoring

Less than 2% of the estimated Spring-run Chinook Salmon population, as indexed by the Red Bluff Rotary Screw Trap data, is collectively captured by the salmonid monitoring programs that support CVP operations (Table 5.8-5). Because such a small percentage of the estimated Spring-run Chinook Salmon juvenile production is captured in the monitoring programs, the effects of the monitoring programs are not likely to have effects to the Spring-run population.

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Table 5.8-5. Monitoring Programs – Spring-run Chinook Salmon

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Chipps Island Trawl																		
Spring-run Chinook Salmon	1229	3948	889	1880	2085	788	163	429	758	593	761	601	1311	1108	681	3882	1230	
Sacramento Trawl																		
Spring-run Chinook Salmon	197	1008	289	558	532	168	67	224	203	316	269	400	774	46	215	2734	152	
DJFMP Beach Seine Survey																		
Spring-run Chinook Salmon	429	1238	780	579	766	127	72	60	442	923	463	317	409	352	203	187	208	4
CDFW Mossdale Trawl																		
Spring-run Chinook Salmon	419	749	320	965	1042	843	480	385	159	1271	1149	644	296	70	124	1223	529	
EDSM KDTR Trawls																		
Spring-run Chinook Salmon	na	na	na	na	na	na	na	na	na	na	na	na	na	na	2	51	na	
CDFW Bay Study Trawls																		
Chinook Salmon	273	117	327	115	143	115	17	130	157	215	74	134	71	65	62	236	na	
CDFW SKT Study																		
Chinook Salmon	35	1624	1364	348	822	896	603	187	300	244	219	492	632	432	347	565	124	
Totals																		
Spring-run Chinook Salmon	2274	6943	2278	3982	4425	1926	782	1098	1562	3103	2642	1962	2790	1576	1223	8026	2119	
RBDD Rotary Trap or Juvenile Production Estimate (JPE)																		
Spring-run Chinook Salmon RPE	277477	626915	430951	615547	421436	369501	164673	438405	158966	184290	320897							
Percent of Total																		
Spring-run Chinook Salmon	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.01	0.02	0.01							

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5.9 Chinook Salmon, Central Valley Spring-run ESU Critical Habitat

Critical habitat designated for Spring-run Chinook Salmon and potentially affected by the proposed action includes the Feather and Sacramento Rivers, and Clear creek, the as well as portions of the northern Delta. The PBFs essential to the conservation of the Central Valley Spring-run Chinook Salmon ESU and the potential proposed action effects on them are water quantity, floodplain connectivity, water quality, forage, and riparian cover.

5.9.1 Effects of Operations

5.9.1.1 PBF1 – Freshwater Spawning Habitat

The proposed action includes actions to improve spawning habitat for Chinook salmon in the upper Sacramento River, and would likely benefit Spring-run Chinook Salmon spawning habitat. Spawning habitat is also affected by changes in flow and water temperature. As indicated in *Eggs to Fry Emergence*, there would be few major differences between the proposed action and cos in flow and no meaningful difference in water temperature in the spawning portion of Spring-run Chinook Salmon critical habitat during the August through January spawning and egg/alevin incubation period. However, differences between the proposed action and the WOA would be large during the first half of the spawning period, August through October. As described in *Eggs to Fry Emergence* Section, effects of these flow differences are uncertain, with some PBFs of habitat benefited and some negatively affected by the higher flows. Flow is much greater under the proposed action than the WOA during August through October, which is expected to substantially benefit most Spring-run Chinook Salmon spawning habitat PBFs. Proposed action and WOA flows are generally similar during November through January. August through October water temperature under the proposed action is much lower than WOA temperature in almost every year. The proposed action water temperature below Keswick Dam during August and September generally ranges from 10 to 18 degrees Fahrenheit lower than the corresponding WOA temperature, and the proposed action temperature is below critical thresholds for incubating eggs and alevins in most years, while the WOA temperature greatly exceeds these thresholds in every year. From November through January, water temperatures are below critical thresholds for incubating eggs and alevins in every year under both the proposed action and WOA scenarios, although the December and January in the coldest years are potentially low enough to retard egg and alevin development. These results indicate that the proposed action scenario would benefit spawning habitat of Spring-run Chinook Salmon in the Sacramento River.

5.9.1.2 PBF2 – Freshwater Rearing Habitat

As described in *Rearing to Outmigrating Juveniles in the Upper and Middle Sacramento River Section,* there would be few differences between the proposed project and COS in flow in rearing habitat of Spring-run Chinook Salmon and no meaningful difference in water temperature in the upper and middle Sacramento River during the November through May rearing period.

Differences in flow and water temperature would be large between the proposed action and the WOA. Proposed action flow is lower than WOA flow during January through April in most years, especially dry years, but is higher than WOA flow during May of dry years. Proposed action water temperature is much higher than WOA temperature from November through February and is much lower in April and May. The reductions in flow under the proposed action, especially in drier years, would likely have adverse effects on most attributes of spring-run rearing habitat in the Sacramento River. Potential adverse effects include reduced access to riparian and off-channel habitat, greater crowding and competition, and lower prey availability. The temperature differences between the proposed action and the WOA would likely not affect the rearing habitat quality. The temperatures under both the proposed action and WOA would be under critical thresholds for rearing juvenile Spring-run Chinook Salmon in almost all years. Although, the coldest water temperatures under the WOA scenario would potentially cause reduced growth of the juveniles.

5.9.1.3 PBF3 – Freshwater Migration Corridors

As described in *Rearing to Outmigrating Juveniles in the Upper and Middle Sacramento River*, and *Adult Migration from Ocean to Rivers Sections*, proposed action flows during winter and early spring (January through April) would be reduced relative to WOA conditions. Higher, more natural flows under the WOA scenario, including more frequent pulse flows, would have beneficial effects on PBFs of freshwater migratory habitat for juvenile Spring-run Chinook Salmon, including increased migration speeds, access to natural cover and low-velocity refuge habitat, and reduced exposure to predators. However, extremely low flows and higher temperatures under the WOA during May through August in dry and critically dry years would result in severe degradation of migratory habitat for adults. Although the proposed action would have negative effects on migratory habitat for juvenile spring-run in winter and early spring, maintaining 3,250 cfs or more throughout the year would avoid the extremely harsh conditions that would occur in dry and critically dry years under WOA conditions.

5.9.1.4 PBF4 – Estuarine Areas

The Bay/Delta estuarine critical habitat for Spring-run Chinook Salmon is severely degraded by altered hydrologic regimes, poor water quality, reductions in habitat complexity, and competition for food and space with exotic species (NMFS 2014a). Despite its poor condition, the estuarine habitat is of high value for the conservation of the species because it provides the only migratory corridor and area for transition to the ocean environment for juveniles, as well as adults returning to the Sacramento River. Consequently Bay/Delta food resources, water quality, refuge from predators, migratory cues, and other growth and survival factors are critically important. Potential effects of the proposed action compared to the WOA on the estuarine critical habitat of Spring-run Chinook Salmon includes changes in flow that affect hydrodynamics and routing of juvenile spring-run through Delta channels, habitat diversity, and water quality.

Routing through Delta Channels -Flow from the Sacramento, San Joaquin and other rivers tributary to the Delta, and well as tidal flows, affect the hydrodynamic of Delta channels and influence how juvenile spring-run move through the Delta. As described in the Spring-run chinook routing affects analysis, hydrodynamics and flow velocity effects of the proposed action compared to WOA indicate that routing into the interior Delta would be higher relative to the WOA. However, the differences are concerned discountable and would not substantially affect spring-run juveniles. As described in *Spring-run Chinook Salmon- Through Delta Survival section*, the overall effect of the proposed action on through-Delta survival of juvenile Spring-run Chinook Salmon resulting from differences in Delta channel flow velocities is low.

Adult Spring-run Chinook Salmon are present in the Bay/Delta from January through June, with a peak occurrence in January and February. The adults use olfactory cues to find their way through the Delta to the Sacramento River upstream of the Delta, so higher Sacramento River flow may reduce straying to other rivers (Marston et al. 2012; NMFS 2016 Submitted Ch5 EA Draft BA).

Flow in the Sacramento River at Rio Vista and Freeport during the peak period of adult migration through the Delta, January and February, is slightly lower under the PA and COS relative to the WOA (see Figure 32-11 in the CalSim II Flow section of Appendix D), but is more substantially reduced (≤ half) relative of the remaining months, March through June (e.g., Figure 32-11 in the CalSim II Flow section of Appendix D).

Habitat Diversity- Increased habitat diversity potentially enhances food resources, refuge habitat, flow velocity refuge, and other spring-run juvenile growth and mortality factors. Increased flow in the Bay/Delta likely increases habitat diversity. Higher flow results in greater inundation of marshlands surrounding the Delta, Suisun Bay and San Pablo Bay, which potentially improves: 1) foodweb productivity, 2) access of juvenile spring-run to more abundant and more diverse food resources, 3) refuge of the juveniles from predators, and 4) refuge for resting from high velocity flows. Higher flows may also enhance foodweb productivity by transporting nutrients and plankton from productive habitats, including croplands and the Sutter and Yolo bypasses (DWR and Reclamation 2107 Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project EIS/EIR).

During the March and April peak period of juvenile spring-run presence in the Delta, Sacramento River flow at Freeport and Rio Vista, as well as Delta outflow, are substantially lower under the PA and COS relative to the WOA (e.g. Figures 32-11 and 41-12 in the CalSim II Flow section of Appendix D). Flow is also lower under the proposed action in Yolo Bypass flow. Therefore, the proposed action is expected to adversely affect estuarine critical habitat relative to the WOA, with respect to habitat diversity and food resources.

5.9.2 Effects of Conservation Measures

The following analysis of designated critical habitat is programmatic. Though future ESA consultation, these actions will be refined and any potential adverse effects will minimized or avoided. These actions are beneficial in nature and are expected to improve PBFs in the long-term.

5.9.2.1 Lower American River

Spawning Habitat -The PBFs under proposed action for spawning adult Spring-run Chinook Salmon are as follows: no effects to water quantity are anticipated; a temporary increase in turbidity to the water quality is anticipated; and a temporary disturbance to substrate is anticipated. Side channel construction, gravel augmentation, and large wood installation may cause temporary adverse effects but could result long-term beneficial effects to PBFs for Central Valley Spring-run Chinook Salmon critical habitat.

Freshwater Rearing Habitat- The PBFs essential to the conservation of the Central Valley Spring-run Chinook Salmon ESU and the proposed action effects on them are water quantity, floodplain connectivity, water quality, forage, and natural cover. The PBFs under proposed action for rearing Spring-run Chinook Salmon are as follows: no effects to water quantity are anticipated; a temporary disturbance to floodplain connectivity is anticipated; a temporary increase in turbidity to water quality, no effects to forage are anticipated; and increased natural cover. Restoration including side channel construction, gravel augmentation, and large wood installation is beneficial in nature and expected to improve any PBFs for Central Valley Spring-run Chinook Salmon critical habitat.

Freshwater Migration Corridors- The PBFs essential to the conservation of the Central Valley Spring-run Chinook Salmon ESU and the potential proposed action effects on them are passage obstructions, water quality, water quantity, and cover. The PBFs under proposed action for migrating Spring-run Chinook Salmon are as follows: no effects to passage obstructions are anticipated; a temporary increase in turbidity to water quality; no effects to water quantity are anticipated; and a temporary disturbance to cover is anticipated. Side channel construction, gravel augmentation, and large wood installation is not anticipated to result in adverse impacts to any PBFs for Central Valley Spring-run Chinook Salmon critical habitat in the American River.

5.9.2.2 Clear Creek

Spawning Habitat -The PBFs essential to the conservation of the Central Valley Spring-run Chinook Salmon ESU and the potential project effects on them are water quantity and substrate. The PBFs under proposed action for spawning adult Spring-run Chinook Salmon are as follows: no effects to water quantity are anticipated; and a temporary disturbance to substrate is anticipated. Gravel mobilization is anticipated to result in no negative impacts on any PBFs for Central Valley Spring-run Chinook Salmon critical habitat.

Freshwater Rearing Habitat- The PBFs under proposed action for rearing Spring-run Chinook Salmon are as follows: no effects to water quantity are anticipated; potential beneficial effects to floodplain connectivity; temporary increase in turbidity to water quality; no effects on forage are anticipated; and no effects on cover are anticipated. Gravel mobilization is not anticipated to result in impacts to any PBFs for Central Valley Spring-run Chinook Salmon critical habitat.

Freshwater Migration Corridors- The PBFs essential to the conservation of the Central Valley Spring-run Chinook Salmon ESU and the potential proposed action effects on them are passage obstructions, water quality, water quantity, and cover. The PBFs under proposed action for migrating Spring-run Chinook Salmon are as follows: no effects to passage obstructions are anticipated; a temporary increase in turbidity to water quality; no effects to water quantity are anticipated; and no effects to cover are anticipated. Gravel mobilization is not anticipated to result in adverse impacts on any PBFs for Central Valley Spring-run Chinook Salmon critical habitat.

5.10 Steelhead, California Central Valley DPS

The increased summer and fall flows of the proposed action compared to the WOA could have benefits for juvenile CV Steelhead rearing, which occurs year-round. However, the reduced spring flows of the proposed action compared to the WOA are likely to affect rearing and migrating CV Steelhead and their habitat. Effects include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, higher water temperatures and lower DO, and reduced emigration flows. Operating the temperature control devices on Shasta and Folsom reservoirs has beneficial effects compared to WOA.

The proposed action incorporates information from the Salmonid Scoping Team and the 6-year Steelhead telemetry study to update protections for San Joaquin origin CV Steelhead. Updated science found no difference in survival from routing CV Steelhead into the San Joaquin River mainstem with the installation of HORB to a route through salvage. For Chinook salmon, updated science found a slight benefit in survival to a route through salvage. Similarly, while Vernalis flows improved CV Steelhead survival, improvements were not correlated with exports. Accordingly, the proposed action subsumes protections for CV Steelhead into OMR management. The proposed action continues the telemetry studies to further refine measures for protecting CV Steelhead, and adds a steelhead monitoring collaborative and program.

Several conservation measures proposed for Steelhead would also reduce impacts of lower spring flows on CV Steelhead juveniles. These include pulse flows from Shasta Reservoir, spawning and rearing habitat restoration on the Sacramento and Stanislaus Rivers, cold water pool management on the Sacramento River, predator hot spot removal and the small screen program. Similar to Winter-run Chinook Salmon, OMR management establishes generally protective criteria to avoid entrainment of CV Steelhead, and fish facility improvements can help further reduce the effects of the entrainment from the proposed action.

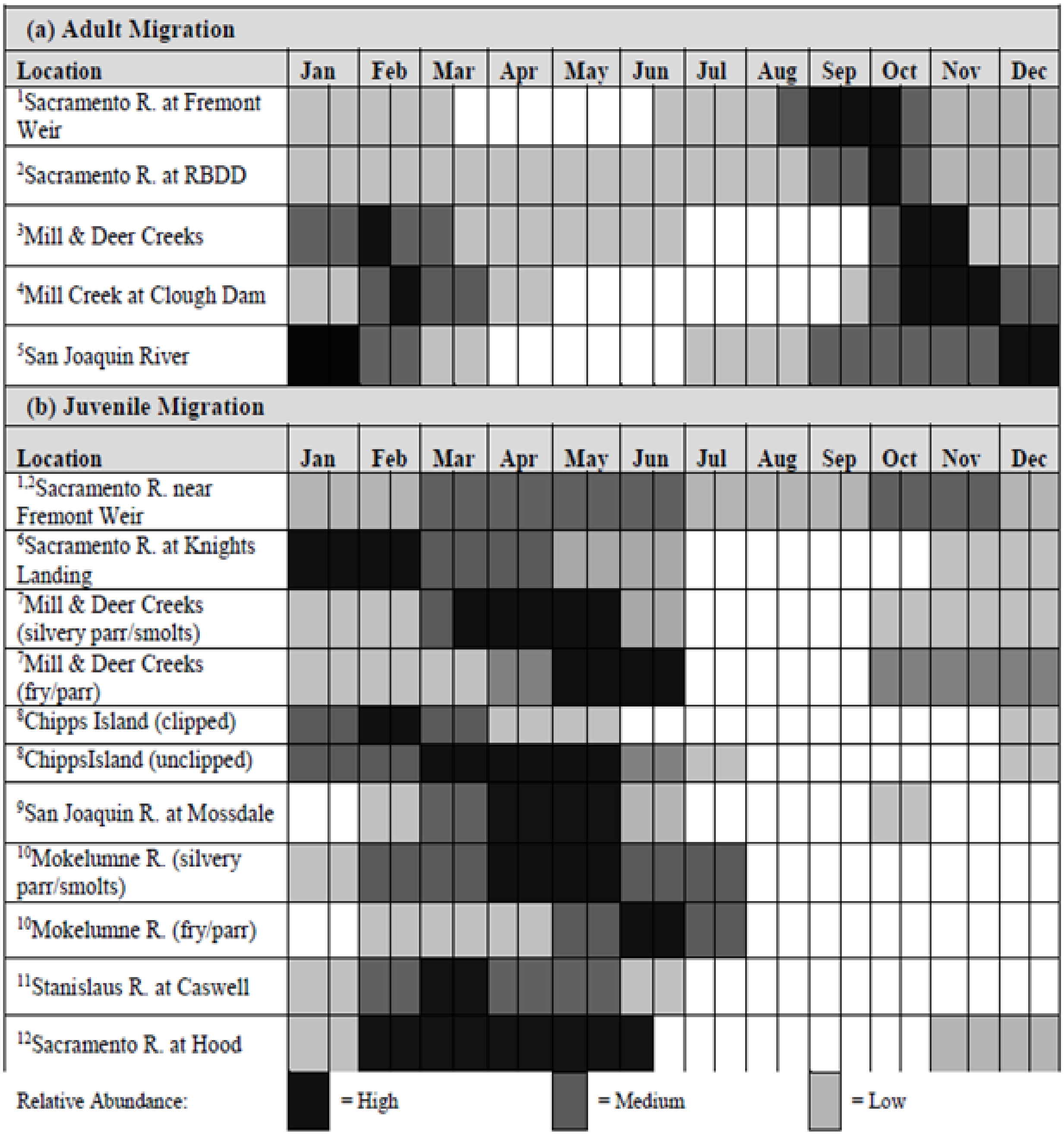
5.10.1 Lifestage Timing

CV Steelhead express a diverse array of life-history strategies including both anadromous and resident (i.e., rainbow trout) life histories. Anadromous and resident life-histories can be adopted by individuals from the same sibling cohort. Although there are general patterns regarding habitat use, migration timing, etc., CV Steelhead can hypothetically be found anywhere within their geographic distribution at all times (NMFS 2009). However, CV Steelhead are a thermally sensitive species like all other salmonids and their distribution and habitat use is generally restricted to waters below 65°F (NMFS 2002); protracted exposure to water temperatures above 75-82°F is likely lethal (Brett et al. 1982; Myrick and Cech 2005). Optimal conditions for CV Steelhead spawning and embryo incubation reportedly occur at water temperatures 52°F (NMFS 2002; SWRCB 2003), temperatures less than 56°F embryo survival has been reported as suitable (NMFS 2009). Water temperatures within the Central Valley and Delta likely control the timing and location of their distribution.

Reservoir releases, combined with other environmental drivers, affect water temperature, DO level, and other habitat attributes that influence the timing, condition and survival of eggs and alevins in the spawning redds. The proportion of eggs surviving to emerge as fry depends largely on the quality of conditions in the redd (Windell et al. 2017). Redd quality is affected by substrate size and composition, flow velocity, temperature, DO, contaminants, sedimentation, and pathogens and diseases. Flow affects sedimentation and gravel composition of the redds and may cause redd scour, stranding or dewatering. For the purposes of this biological assessment, Reclamation is analyzing effects to CV Steelhead in the Sacramento, Feather, American, and Stanislaus Rivers and the Delta.

General life stage timing and location information for CV Steelhead is provided in Table 5.10-1. Additional detail regarding juvenile life stage timing at various monitoring locations is provided in Appendix F – Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS. Note that adult abundance timing in the Delta was described by NMFS (2017, p.74) as being high from September to mid-October, medium from mid to late August and mid to late October, and low from mid-June to mid-August and November. This is essentially the same pattern as that suggested for Sacramento River at Fremont Weir in Table 5.10-1, but without the period of low abundance from December to mid-March.

Table 5.10-1. The Temporal Occurrence of Adult (a) and Juvenile (b) CV Steelhead at Locations in the Central Valley (NMFS 2017, Appendix B, p.41).



Sources: [1](Hallock 1957); [2](McEwan 2001); [3](Harvey 1995); [4]CDFW unpublished data; [5]CDFG Steelhead Report Card Data 2007; [6]NMFS analysis of 1998–2011 CDFW data; [7](Johnson and Merrick 2012); [8]NMFS analysis of 1998–2011 USFWS data; [9]NMFS analysis of 2003–2011 USFWS data; [10]unpublished EBMUD RST data for 2008–2013; [11]Oakdale RST data (collected by FishBio LLC) summarized by John Hannon (Reclamation); [12](Schaffter 1980).

Adult CV Steelhead immigration into Central Valley streams typically begins in August and continues into March. Immigration generally peaks during January and February (Table 5.10-1), and then CV

Steelhead hold until flows are high enough in tributaries to enter for spawning (Moyle 2002; McEwan 2001; NMFS 2004). Spawning occurs from December through April, with peaks from January through March in small streams and tributaries where cool, well oxygenated water is available year-round (McEwan 2001). Eggs usually hatch within four weeks, depending on stream temperature, and the yolk sac fry remain in the gravel after hatching for another four to six weeks (CDFG 1996). The majority of CV Steelhead spawn only once but are capable of completing multiple return trips to the ocean and spawning migrations. Post-spawning adults returning to the ocean are referred to as kelts. Juvenile CV Steelhead use the middle Sacramento River as a rearing and migration corridor. Rotary screw trap, beach seine, and trawl data collected during 2004 through 2017 indicate that CV Steelhead may be present year-round in the middle Sacramento River but that the majority occur during January through May (Appendix F, Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS). This period encompasses the peak emigration periods of yearling and older juveniles (smolts) from rearing areas in the upper Sacramento River and tributaries upstream of the Delta (Table 5.10-1). Therefore, individuals are present in the proposed action area throughout the year.

Historically adult CV Steelhead maintained several strategies during their migration to natal rivers in preparation for spawning. Some CV Steelhead returned several months prior to spawning to hold over in pools while sexually maturing, others sexually matured in the ocean before returning to freshwater (Williams 2006). Remaining anadromous CV Steelhead predominantly mature in the ocean (McEwan 2001).

5.10.2 Conceptual Model Linkages

CV Steelhead are present in the proposed action area throughout the year. The SAIL conceptual model (Figure 5.6-1) was prepared especially for life stage transitions of Sacramento River Winter-run Chinook Salmon, but the cause and effects relationships it diagrams apply well to the CV Steelhead population in Sacramento River. SAIL life stage transitions are the series in changes in form that an organism undergoes throughout its life cycle. SAIL life stage transitions include egg to larval, larvae to juvenile, juvenile to subadult/adult, adult to spawning, and spawning adult to egg and post-spawn adult period. The SAIL conceptual model prepared for Winter-run Chinook will be referenced throughout this section to explain links between the species and the effects of the actions. The primary differences in the habitat requirements between Winter-run and CV Steelhead are the duration and the time of year that the different life stages use their habitats.

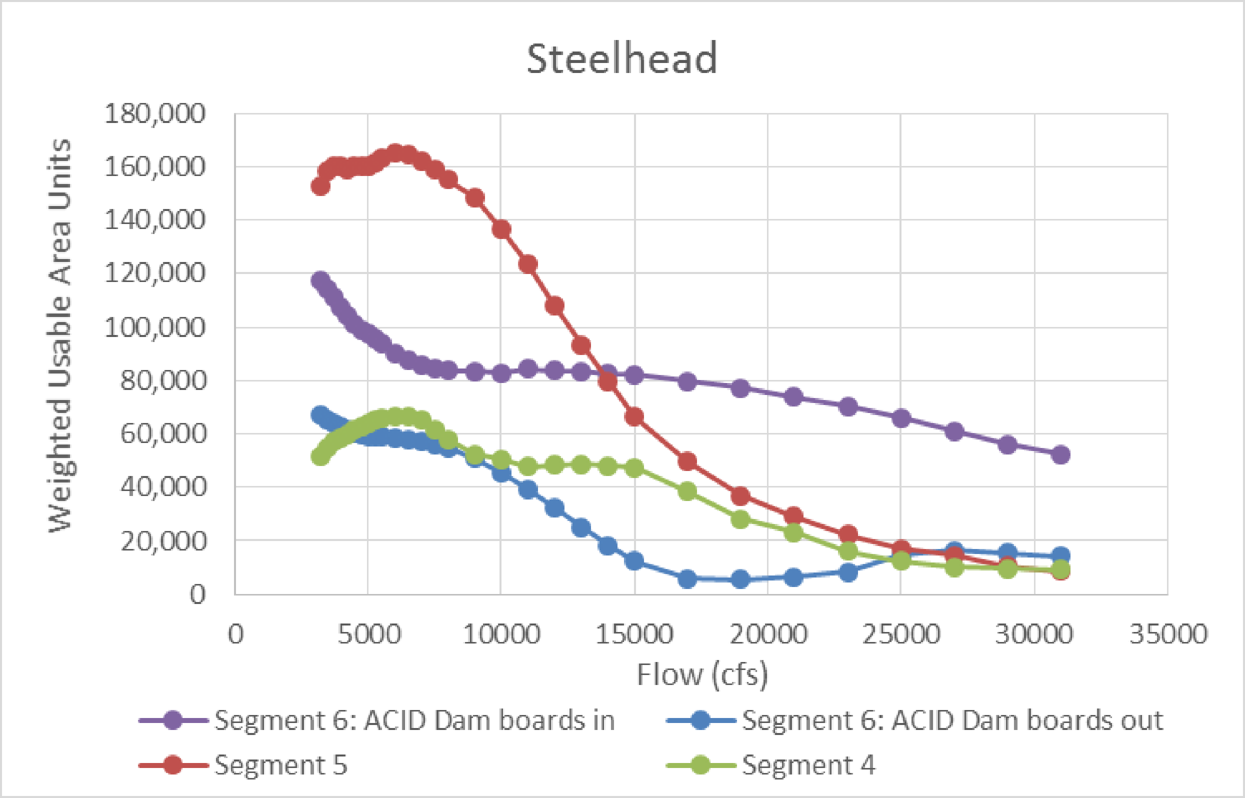
5.10.3 Effects of Operation & Maintenance

5.10.3.1 Sacramento River Seasonal Operations

5.10.3.1.1 <u>Eggs to Fry Emergence</u>

5.10.3.1.1.1 Flow Effects

Central Valley steelhead spawn downstream of dams on every major tributary within the Sacramento and San Joaquin Rivers. On the Sacramento River, steelhead generally spawn where Chinook spawn, between Keswick Dam and Red Bluff Diversion Dam. The effects of flow on available spawning area for CV Steelhead were qualitatively evaluated based on the relationships between flow and weighted usable area (WUA) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (Figure_Steelhead Spawning WUA). These relationships indicate that spawning WUA generally peaks at flows between 3,250 and 7,000 cfs and then declines at higher flows (Figure 5.10-1).



(Source: USFWS 2003)

Figure 5.10-1. Spawning WUA curves for CCV Steelhead in the Sacramento River. Segments 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam

The USFWS used Habitat Suitability Criteria (HSC) criteria from the lower American River (USFWS 2000) to model CV Steelhead habitat in the Sacramento River. The USFWS was unable to conduct a transferability test to determine whether the lower American River CV Steelhead HSC are transferable to the Sacramento River, and therefore suggested that the habitat modeling results for CV Steelhead be treated with caution (USFWS 2003).

Under WOA conditions, there would be no Shasta and Keswick reservoir operations to control storage or releases, and no transfer of water from the Trinity River Basin. Under these conditions, flows in the Sacramento River would generally respond to natural seasonal and inter-annual variation in precipitation and runoff. Consequently, flows during the CV Steelhead spawning and incubation period would generally be low initially and then increase with the onset of winter storm events. Under the WOA scenario, CALSIM modeling indicates Keswick releases during November through April would range from 3,250 cfs to 62,650 cfs (Figures 15-8 through 15-13 in the CalSim II Flows section of Appendix D). Based on the CV Steelhead spawning WUA curves for the reaches between Keswick Dam and Battle Creek, flows associated with peak spawning habitat availability (3,250 cfs to 7,000 cfs) would occur most of the time in November (96 percent) and then decline in frequency as flows increase through the winter and spring, occurring about 30 percent of the time in March and April.

Under the proposed action, Keswick releases during the CV Steelhead spawning and incubation period (November through April) would range from 3,250 cfs to 59,000 cfs (Figures 15-8 through 15-13 in the

CalSim II Flows section of Appendix D). Based on the CV Steelhead spawning WUA curves, the largest differences in spawning habitat availability would occur in November when flows within the optimum range (3,250 cfs to 7,000 cfs) are predicted to occur 86 percent of the time under the proposed action scenario and 56 percent of the time under the COS scenario (Figure 15-8 in the CalSim II Flows section of Appendix D). During the peak spawning period (January through March), the frequency of flows associated with peak spawning habitat availability would differ by less than two percent (Figures 15-10 through 15-12 in the CalSim II Flows section of Appendix D). Consequently, the availability of CV Steelhead spawning habitat under the proposed action would be similar except in November when higher flows under the proposed action scenario would reduce the number of years in which flows would be within the optimum range.

Overall, lower winter and spring flows under the proposed action are expected to increase the availability of Steelhead spawning habitat relative to WOA conditions. Compared to the WOA scenario, the proposed action would result in substantially more years in which flows would be within the range of peak spawning habitat availability (3,250 cfs to 7,000 cfs). The largest differences would occur during the peak spawning months (January through March), when flows within the optimum range would occur 63 to 70 percent of the time under and proposed action scenarios versus 29 to 54 percent of the time under the WOA scenario. In addition, lower flows under the proposed action would likely reduce the risk of redd scour and/or dewatering relative to the WOA scenario. If flows are sufficiently high, they can result in excessive depths and flow velocities, resulting in bed scour and loss of existing redds (NMFS 2017). Higher flows may also force adults to build redds in areas that are later dewatered or isolated from the main river channel when flows decline. Therefore, Keswick Dam releases under the proposed action are expected to improve spawning and incubation conditions for CV Steelhead in the upper Sacramento River relative to WOA conditions.

5.10.3.1.1.2 Water Temperature Effects

Proposed action water temperature in the upper Sacramento River apply to the period May 15 to October 31 to provide suitable temperatures for winter-run, spring-run, and fall-run Chinook salmon spawning and incubation life stages. No water temperature requirements have been established for the CV Steelhead spawning and incubation period (November through April) because water temperatures are typically within suitable ranges for these life stages and other species and life stages that are present in the upper Sacramento River during this period. This assumption was evaluated for the WOA and proposed action based on the water temperature modeling results (HEC-5Q) and the recommended criteria developed by USEPA for protection of salmonids (U.S. Environmental Protection Agency 2003) and McCullough et al. (2001). These sources indicate that a water temperature of 53°F provides a reasonable threshold for evaluating the potential for adverse temperature effects based on mean monthly modeling results.

Under the WOA scenario, there would be no Shasta and Keswick reservoir operations to control storage or releases and no transfer of water from the Trinity River Basin. Therefore, there would be no ability to control water temperatures in the upper Sacramento River. Declining solar radiation and air temperatures in October and November consistently result in suitable water temperatures for CV Steelhead spawning and incubation period through the winter and early spring. Under the WOA scenario, exceedance plots of modeled mean monthly water temperatures between Keswick Dam and Red Bluff from November through April indicate that water temperatures would remain below 53°F in all months except April (Figures 5-8 through 5-13 in the HEC5Q Temperatures section of Appendix D).

Under WOA scenario, Sacramento River water would flow through Shasta and Keswick reservoirs, similar to uncontrolled flows, resulting in no control of flow releases or water temperature management within the system. Under the proposed action, the highest elevation gates of the TCD would be used to conserve deeper, colder water for the critical summer months (Figures 5-8 through 5-13 in the HEC5Q Temperatures section of Appendix D). The largest differences in mean monthly water temperatures between the proposed action and COS would be less than 1°F in November and December. Under both scenarios, water temperatures would frequently exceed the 53°F threshold in November but would decrease in December and remain below this threshold through March.

Compared to WOA conditions, water temperatures in the upper Sacramento River under the proposed action would be higher from November through February, similar in March, and lower in April (Figures 5-8 through 5-13 in the HEC5Q Temperatures section of Appendix D). Based on the frequency of years in which water temperatures are predicted to exceed the 53°F threshold, potential adverse effects on CV Steelhead spawning and incubation under the proposed action would occur in November when mean water temperatures below Keswick Dam are predicted to range from 52°F to 58°F between Keswick Dam and Red Bluff (Figure 5-8 in the HEC5Q Temperatures section of Appendix D). However, with higher reservoir storage and water temperature management actions under these scenarios, suitable water temperatures would be maintained through the primary Steelhead spawning and incubation period (January through April). Furthermore, in contrast to the WOA scenario, lower water temperatures under the proposed action would extend the period of suitable incubation temperatures into April (Figure 5-13 in the HEC5Q Temperatures section of Appendix D).

5.10.3.1.2 Rearing to Outmigrating Juveniles

5.10.3.1.2.1 Flow Effects

The effect of flow on available rearing area for CV Steelhead was qualitatively evaluated based on the relationships between flow and weighted usable area (WUA) developed by the USFWS for the Sacramento River between Keswick Dam and Battle Creek (Figure 5.10-2). Rearing habitat WUA for CV Steelhead was not estimated directly by the USFWS but was modeled using the rearing WUA curves for late Fall-run Chinook Salmon because the juvenile rearing period is similar to that of CV Steelhead, and this substitution follows previous practice (e.g., SacEFT model, ESSA 2011). However, the validity of using the late Fall-run Chinook Salmon WUA curves to characterize CV Steelhead rearing habitat is uncertain.

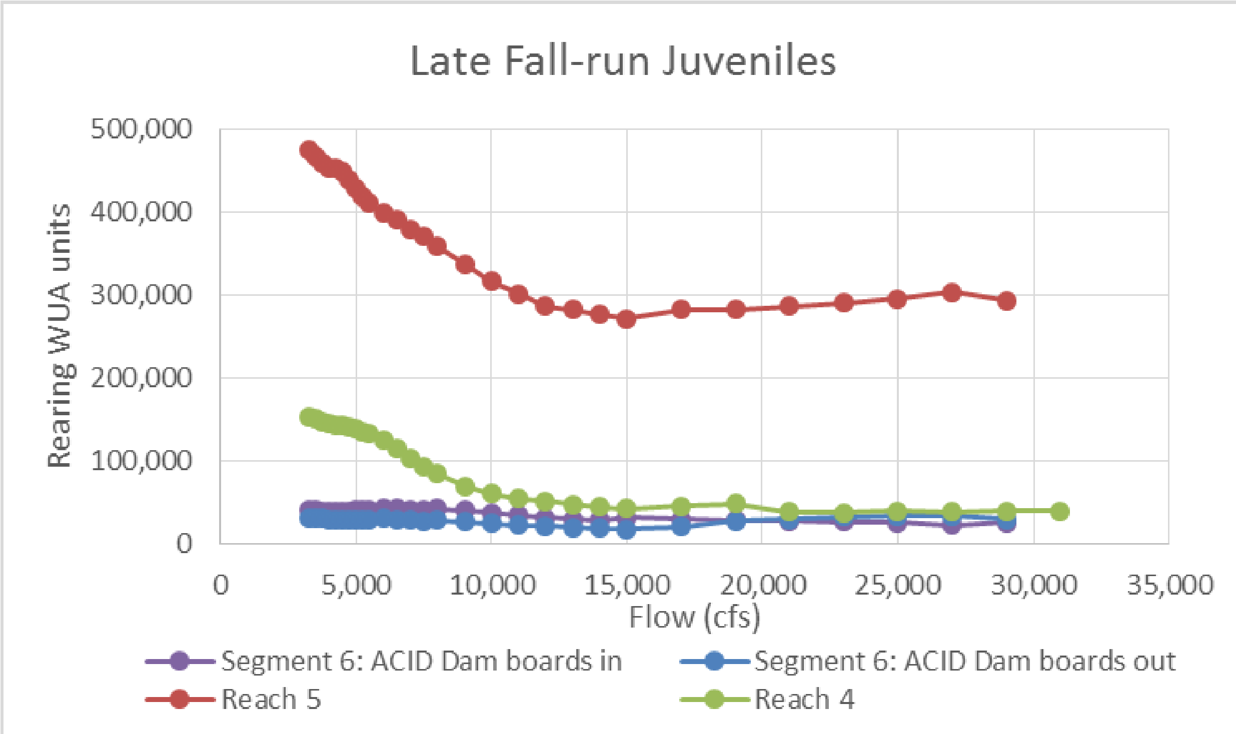


Figure 5.10-2. Rearing WUA curves for late Fall-run Chinook Salmon in the Sacramento River. Segment 4: Battle Creek to Cow Creek; Segment 5: Cow Creek to the Anderson-Cottonwood Irrigation District (ACID) Dam; Segment 6: ACID to Keswick Dam (Source: USFWS 2005).

The relationships indicate that rearing WUA in the upper Sacramento River generally peaks at or below the lowest flow studied (3,250 cfs). Similar to the effects described for Winter-run Chinook Salmon, these low flows would also reduce the quality of rearing habitat through changes in other physical and biological attributes, including high water temperatures, reduced habitat complexity (e.g., reduced side channel and floodplain connectivity), increased crowding and competition, and reduced availability and quality of prey organisms (Windell et al. 2017). Summer water temperatures would be further exacerbated by increased release temperatures due to the lack of cold water storage in Shasta Reservoir under the WOA scenario.

CALSIM modeling indicates that monthly flows in the upper Sacramento River during May through October would frequently drop below 3,250 cfs, especially during the summer of dry and critically dry years. During June through September, Keswick releases under the WOA scenario would be lower than 3,250 cfs in up to 55 percent of the years (Sac R flow below Keswick dam_aug).

Under the proposed action scenario, Shasta and Keswick reservoir operations during summer target flow and water temperature requirements for Winter-run Chinook Salmon and other anadromous fishes. CALSIM modeling indicates that flows of 3,250 cfs or more would be maintained through the spring and summer months. Compared to the COS scenario, modeled flows under the proposed action are higher in June and lower in September (Figures 15-15 through 15-18 in the CalSim II Flows section of Appendix D), but these differences would occur over a range of flows (6,000 to 17,000 cfs) that is not expected to substantially affect rearing habitat for juvenile CV Steelhead. Surrogate WUA for CV Steelhead rearing is reduced at higher flows but remains relatively stable between flows of 6,000 and 17,000 cfs (Figure_Late Fall-run Chinook WUA_Juv).

5.10.3.1.2.2 Water Temperature Effects

CV Steelhead need suitable rearing temperatures throughout the year. The USEPA-recommended 7DADM water temperature for juvenile salmonids in core rearing areas (upper reaches of natal rivers) is 61°F, although this is based on Pacific Northwest fish and hydrology and does not consider the feasibility of operating to 7DADM. Under WOA conditions, monthly mean water temperatures during May through October in the Sacramento River below Keswick Dam would range from about 53°F to 73°F, exceeding the 61°F threshold in 7 percent of years in May and 100 percent of years during June through September (Figures 5-1 through 5-6 in the HEC5Q Temperatures section of Appendix D). Water temperatures during these months would be even higher at downstream locations in the upper Sacramento River. For example, monthly mean temperatures at Bend Bridge are predicted to exceed 70°F in July in all years (Figure 5.10-3). These water temperatures would have sublethal and lethal effects on juvenile CV Steelhead throughout the upper Sacramento River, including reduced growth, delayed smoltification, desmoltification, and physiological stress which can lead to disease and increased predation mortality.

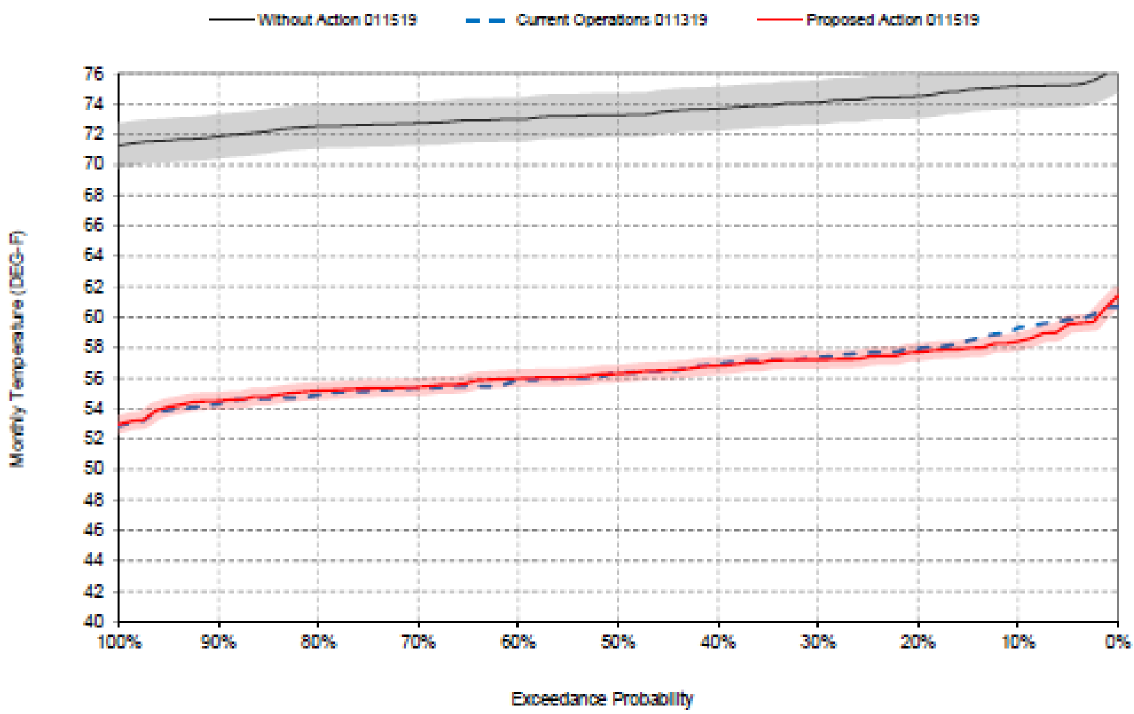


Figure 5.10-3. HEC-5Q Sacramento River Water Temperatures at Keswick Dam under the proposed action, WOA, COS, scenarios, July

Water temperatures under the proposed action would be substantially lower than those under the WOA scenario. Monthly mean water temperatures would range from about 46°F to 66°F, exceeding the 61°F threshold in less than 10% of the years in August, September and October. The proposed action would avoid or minimize exposure of juvenile CV Steelhead to sublethal and lethal temperatures, and maintain suitable water temperatures throughout their residence in the upper Sacramento River.

Under the proposed action, summer rearing conditions for juvenile CV Steelhead would be substantially improved relative to WOA conditions. Although Steelhead are adapted to low summer base flows that occurred naturally in their historical spawning and rearing habitat above impassable dams, existing populations in the upper Sacramento River and other tailwater reaches below mainstem dams are dependent on the higher, colder releases from these dams for maintenance of suitable summer rearing conditions.

5.10.3.1.3 Adult Migration from Ocean to Rivers

5.10.3.1.3.1 Flow Effects

Changes in flow potentially affect passage conditions for upstream migration of adults, including the creation of physical barriers and changes in water temperature, dissolved oxygen, and straying, stranding, and disease risk. Very low flows can affect passage by creating physical barriers or poor water quality conditions (e.g., high temperatures and/or low DO) that can block or delay adult migration. Flow thresholds for evaluating passage conditions and related problems for migrating CV Steelhead adults have not been determined for the Sacramento River. A threshold of 3,250 cfs is used in this analysis to evaluate the potential for adverse effects. Flows in the Sacramento River rarely drop below this level, and adults have not been observed experiencing migration difficulties at this flow. As such, it represents a conservative minimum flow above which fish do not experience migration difficulties.

Under WOA conditions, flows during the CV Steelhead immigration period (August through March) would generally be low until the first storm events increase flows in the fall or early winter. Under the WOA scenario, CALSIM modeling indicates that flows in the middle Sacramento River would be very low in August, especially in dry and critically dry years, resulting in poor passage conditions in most years (Figure 19-17 in the CalSim II Flows section of Appendix D). Based on a flow threshold of 3,250 cfs, flows providing suitable passage would occur about half the time in September and October, 90 percent of the time in November, and 100 percent of the time during January through March (Figures 19-12 through 19-18 in the CalSim II Flows section of Appendix D).

Under the proposed action, flows of 3,250 cfs or more would be maintained through the CV Steelhead immigration period in nearly all years (Figures 19-12 through 19-17 in the CalSim II Flows section of Appendix D). In contrast, suitable passage conditions under the WOA scenario would not occur until later in the fall, resulting in potential delays in migration and adverse impacts on migrating adults (e.g., increased exposure to high temperatures resulting in elevated pre-spawning mortality). In dry and critically dry years, suitable passage conditions may not occur until November. Consequently, the proposed action would have beneficial effects on adult CV Steelhead immigration relative to the WOA conditions.

5.10.3.1.3.2 Water Temperature Effects

The USEPA-recommended 7DADM water temperature for adult salmonids during their upstream migration is 68°F, although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of operating to 7DADM. Under WOA conditions, monthly mean water temperatures in the Sacramento River at Knights Landing in August and September would range from about 74°F to 83°F, creating a thermal barrier for upstream migration in all years (Figures 14-17 and 14-18 in the HEC5Q Temperatures section of Appendix D). Based on a threshold of 68°F, suitable water temperature for upstream migration would occur about 95 percent of the time in October, and 100 percent of the time during November through March (Figures 14-7 through 14-12 in the HEC5Q Temperatures section of Appendix D). Consequently, water temperatures under the WOA scenario would be too warm for CV Steelhead upstream migration through September, and suitable water temperatures for upstream migration would be delayed until October or November. In combination with higher flows, the proposed action would be expected to improve immigration conditions for adult CV Steelhead during the early immigration period (August through October) relative to WOA conditions.

5.10.3.1.4 Adult Holding

5.10.3.1.4.1 Flow Effects

Changes in flow potentially affect conditions for holding CV Steelhead adults, including availability of holding habitat (e.g., pools), access to cover, and suitable water temperatures prior to spawning. Flow thresholds for evaluating holding conditions for CV Steelhead adults have not been determined for the Sacramento River. In general, higher flows are likely to benefit holding adults by providing better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, and lower risk to anglers or poachers (Windell et al. 2017).

Under WOA conditions, flows during the CV Steelhead holding period (September through November) would generally be low until the first storm events increase flows in the fall or early winter. Under the WOA scenario, CALSIM modeling indicates that median flows in the upper Sacramento River would be 3,350 cfs in September, 3,700 cfs in October, and 4,800 cfs in November. Under the proposed action, flows in the upper Sacramento River in September and October would be substantially higher than those under the WOA scenario in most years (Figures 15-6 and 15-18 in the CalSim II Flows section of Appendix D). Consequently, the proposed action would likely improve holding conditions for adult CV Steelhead relative to WOA conditions, especially in dry and critically dry years.

5.10.3.1.4.2 Water Temperature Effects

The USEPA-recommended 7DADM water temperature for holding adults is 61°F, although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of operating to 7DADM. Under WOA conditions, monthly mean water temperatures in the Sacramento River below Keswick Dam would consistently exceed the 61°F threshold in September (Figure 15-18 in the CalSim II Flows section of Appendix D). Declining water temperatures beginning in September would result in suitable holding temperatures in the upper Sacramento River in October and November (Figures 15-7 and 15-8 in the CalSim II Flows section of Appendix D).

Under the proposed action, water temperatures exceeding the 61°F threshold in the Sacramento River below Keswick Dam during the CV Steelhead holding period would occur about 5 percent of the time in September and October (Figures 15-6 and 15-18 in the CalSim II Flows section of Appendix D). Compared to the COS, water temperatures under the proposed action would be up to 4°F higher in some years in August and September and up to 4°F lower in most years in October, but these differences would be limited to years in which water temperatures are well below the 61°F threshold. Compared to the WOA scenario, the proposed action would substantially improve water temperatures for adult Steelhead during their holding period in the upper Sacramento River. The benefits would occur primarily in September when Keswick Dam releases would consistently be 12°F to 13°F cooler in most years. In combination with higher flows, lower water temperatures under the proposed action would have beneficial effects on holding adults relative to WOA conditions.

5.10.3.2 Whiskeytown Reservoir Operations and Clear Creek Flows

5.10.3.2.1 Eggs to Fry Emergence

Under the proposed action, eggs and emerging fry in Clear Creek are not anticipated to be impacted as they would not be exposed to the effects of Whiskeytown water temperature controls in Clear Creek based on the timing of these controls (60°F at IGO gage June 1-September 15; 56°F at IGO gage September 15-October 31), and the seasonal occurrence of this life stage in Clear Creek (December-April; Table 5.10-1).

Under the proposed action, eggs and emerging fry would be exposed to the effects of Clear Creek geomorphic flows, and potentially spring attraction flows based on the proposed timing of these releases (after January 1 for geomorphic flows; April-June for spring attraction flows [Clear Creek Technical Team 2018]), and the seasonal occurrence of this life stage in Clear Creek (December-April; Table 5.10-1). Potential effects of these flows include increased gravel scour which could displace incubating eggs from redds, resulting in exposure to increased predation, mechanical shock and abrasion, and increased water temperature if transported out of suitable incubation habitat. Geomorphic flows could also temporarily increase suspended solids and turbidity, causing sediment deposition in redds that can reduce hydraulic conductivity through the redd and result in reduced oxygen delivery to eggs, reduced flushing of metabolic waste, and entombment of alevins via a sediment “cap” that prevents or impedes emergence (Everest et al. 1987, Lisle et al. 1989).

Studies on Clear Creek have shown that the sediment transport threshold generally occurs between 3,000–3,500 cfs (McBain and Trush 2001, Pittman and Matthews 2004). Events of this magnitude occurred in 50 percent (26 of 52) of years since Whiskeytown Dam was constructed, while daily average flows > 3,000 cfs occur on 0.2 percent of days since WY 1965 (37 days total). Proposed geomorphic and attraction flows up to the safe release capacity (approximately 900 cfs) under the proposed action represent approximately 30 percent of the flow needed to transport sediment in the absence of flows from downstream tributaries. If geomorphic flows were to achieve their intended effect (gravel mobilization) there may be short-term adverse impacts to incubating Steelhead eggs via redd scour or sediment deposition. However, the total area and overall quality of egg incubation habitat would be increased post gravel mobilization.

5.10.3.2.2 Rearing to Outmigrating Juveniles

Rearing and outmigrating juveniles would be exposed to the effects of geomorphic and spring attraction flows given the likely timing of spring attraction flows (May-June [Clear Creek Technical Team 2018]), geomorphic flows (contemporaneous with peak storm flows after January 1), and the peak timing of this life stage in Clear Creek (year-round; Table 5.10-1). Under the proposed action, some rearing and outmigrating CV Steelhead juveniles would be exposed to the effects of Whiskeytown temperature controls in Clear Creek given the timing of these controls (June 1-September 15 & September 15-October 31), and the peak timing of this life stage in Clear Creek (year-round; Table 5.10-1).

5.10.3.3 Feather River Flows

The DWR proposes flows from Oroville Dam that would affect conditions downstream of the Oroville Complex FERC boundary. These downstream effects are discussed in this section.

5.10.3.3.1 Eggs to Fry Emergence

5.10.3.3.1.1 Flow Effects

Eggs and emerging fry of CV Steelhead would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (December-May; Table 5.10-1 & NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5-SHCV-1), and compliance with D-1641.

Table 5.10-2. Feather River High Flow Channel Minimum Instream Flow Requirements

Preceding April – July Unimpaired runoff (Percent of Normal)	High Flow Channel Minimum Instream Flow		
	OCT-FEB (cfs)	MAR (cfs)	APR-SEP (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Under the WOA scenario, Oroville Dam would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Reservoir gates and diversion tunnels would be kept open, resulting in annual storage volumes less than 1,000 TAF (Figure 5.10-4). As a result, there would be limited control of flow or water temperature in the Feather River HFC, which provides habitat for this life stage. Feather River flows under the WOA scenario would approximate uncontrolled flows, with generally lower summer and fall flows and higher winter and spring flows compared to the proposed action and COS (Figures 5.10-5 and 5.10-6).

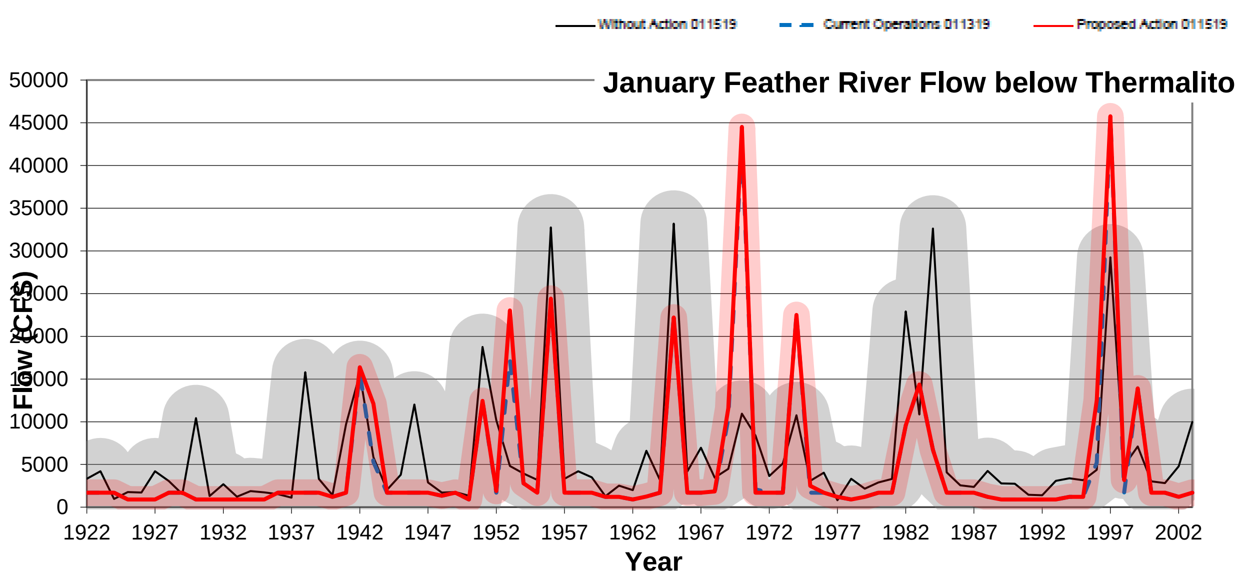


Figure 5.10-4. CalSim II estimates of mean Oroville storage (TAF) for the period 1923–2002 under WOA, COS, and proposed action.

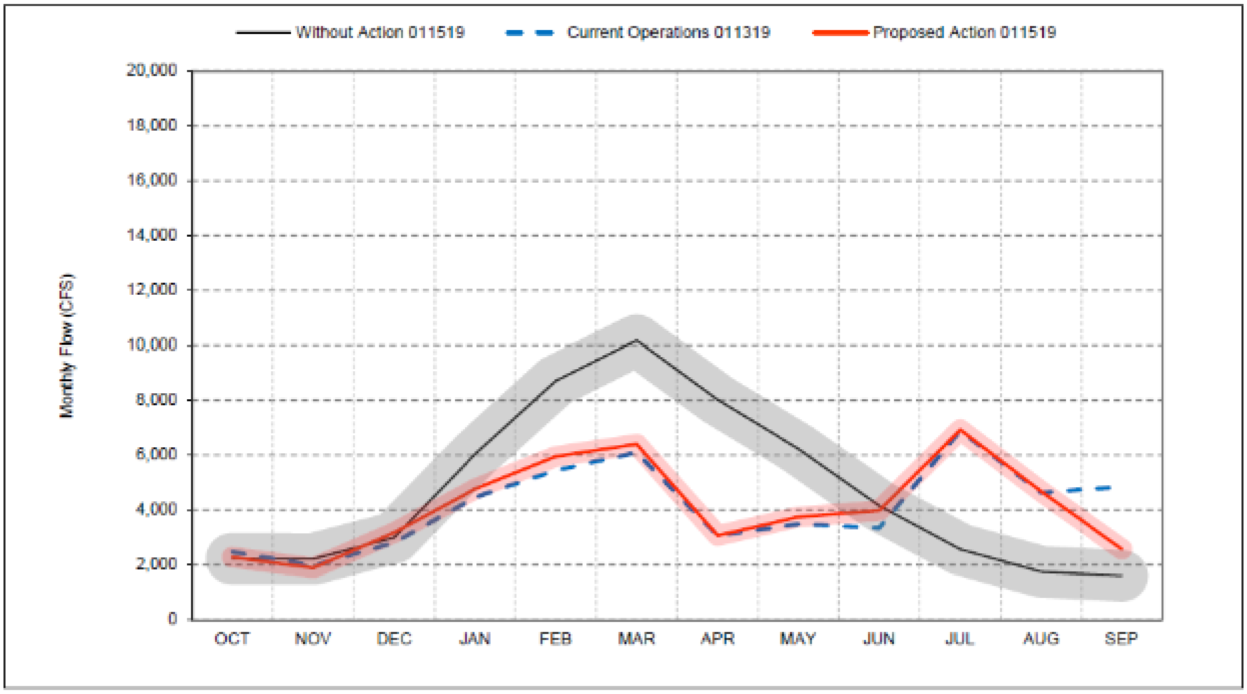


Figure 5.10-5. CalSim II estimates of Feather River long-term average flow below Thermalito Afterbay under the WOA, COS, and proposed action.

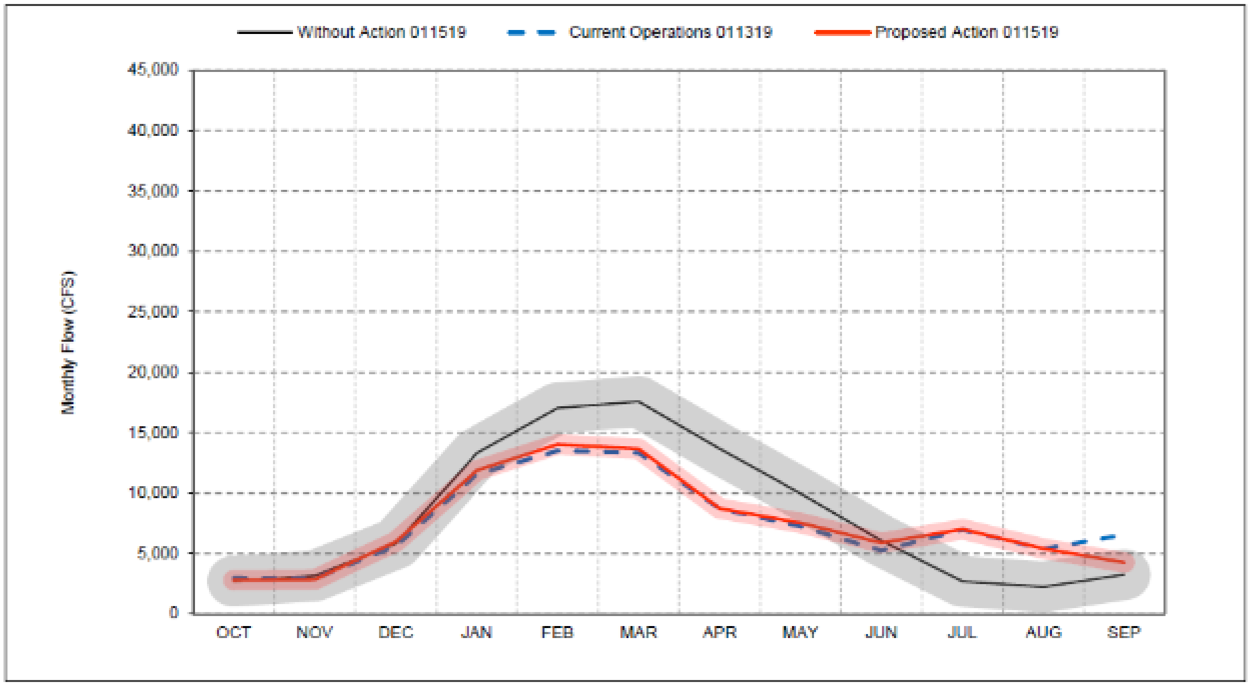


Figure 5.10-6. CalSim II estimates of Feather River mouth long-term average flow under the WOA, COS, and proposed action.

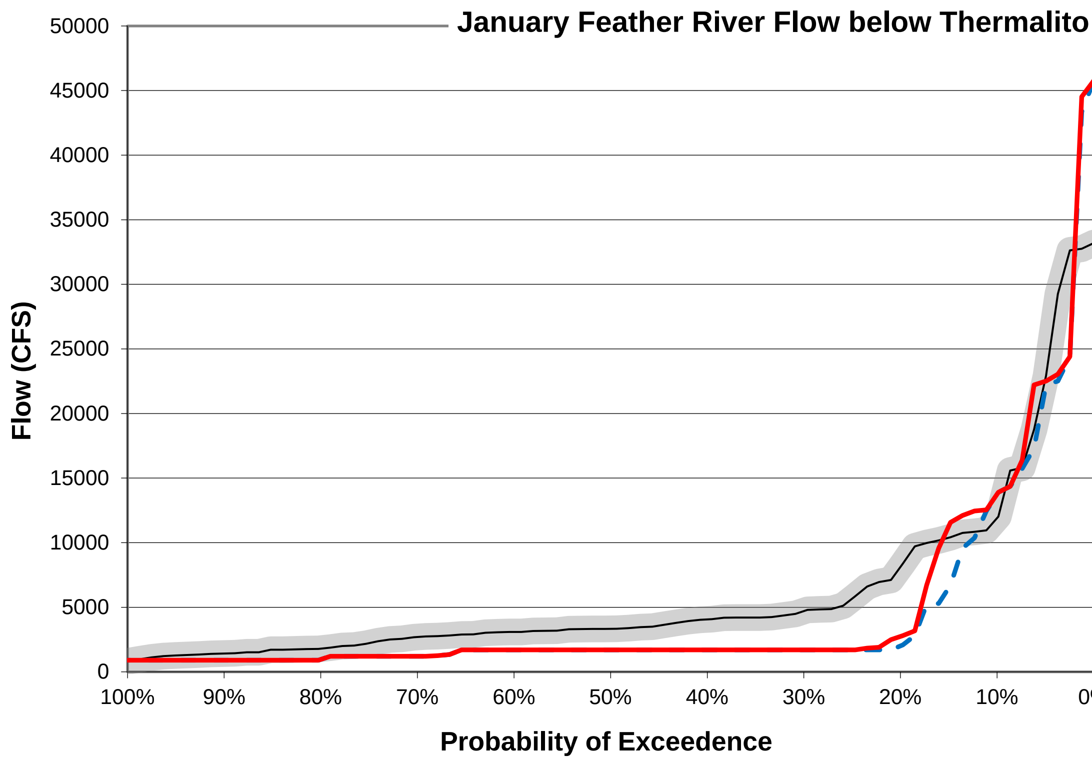


Figure 5.10-7. CalSim II estimates of Feather River flow below the Thermalito Afterbay in December-February under the WOA, COS, and proposed action.

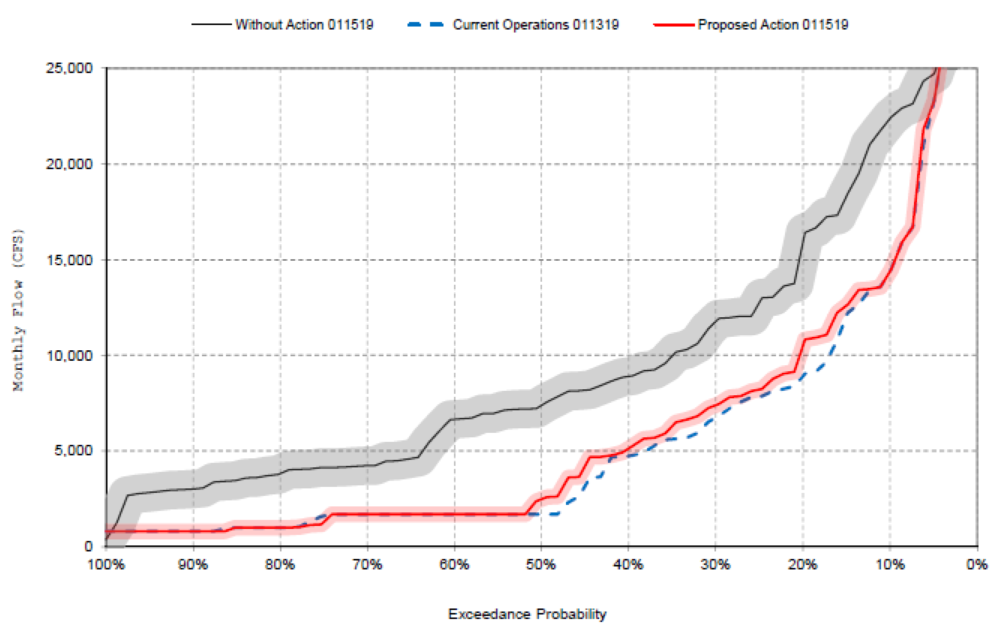


Figure 5.10-8. CalSim II estimates of Feather River flow below the Thermalito Afterbay in March, under the WOA, COS, and proposed action.

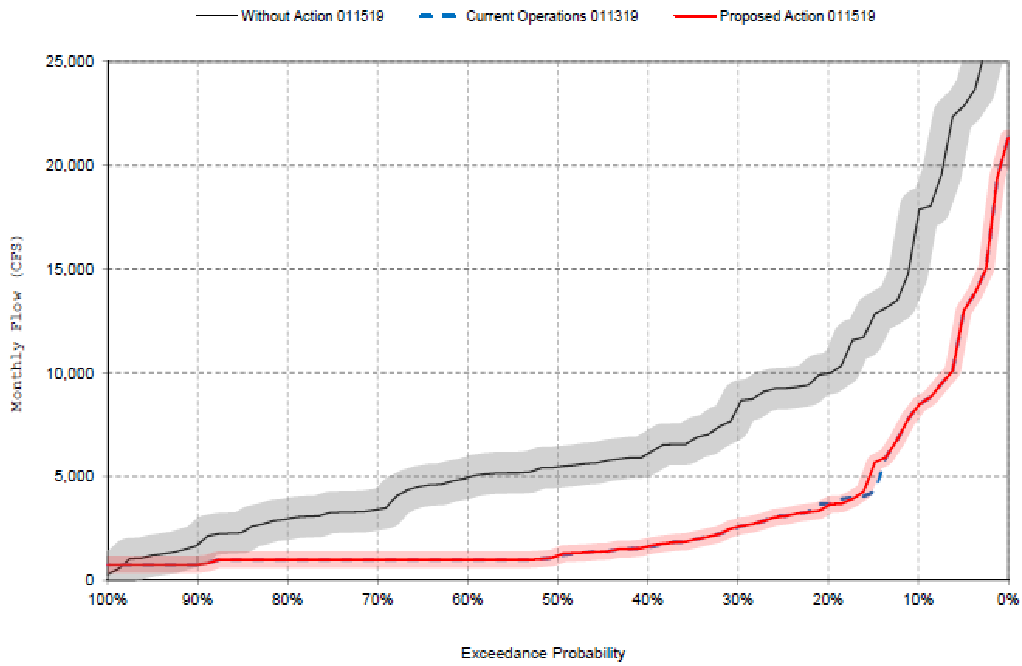


Figure 5.10-9. CalSim II estimates of Feather River flow below the Thermalito Afterbay in April under the WOA, COS, and proposed action.

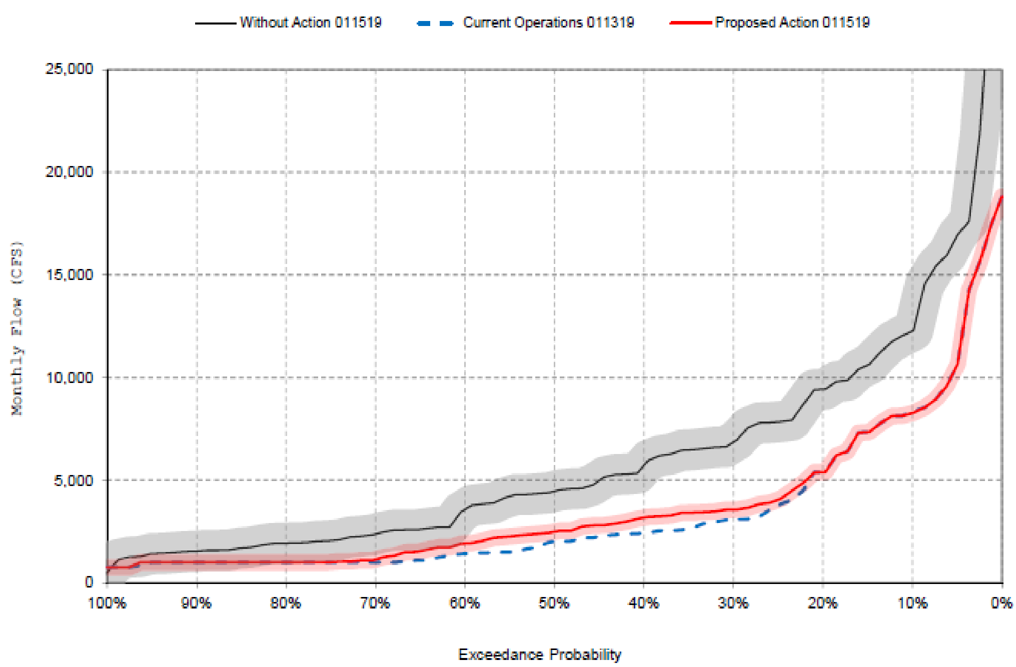


Figure 5.10-10. CalSim II estimates of Feather River flow below the Thermalito Afterbay in May under the WOA, COS, and proposed action.

Feather River flows below Thermalito Afterbay under the WOA are similar or substantially higher than flows under the proposed action during the peak seasonal timing of CV Steelhead egg incubation

(December-May) (Figures 5.10-7 through 5.10-10). Differences in flows between the proposed action and COS are minimal during the December to May period. Flows below the minimum threshold would have a number of negative effects on this life stage, including higher water temperatures, lower DO in redds, and potential for redd dewatering, all of which may lead to elevated egg mortality. Insufficient flow may also limit the extent of river bed available for redd construction, thereby limiting available habitat for this life stage. Conversely, the higher, uncontrolled flows projected to occur during this incubation and emergence period under the WOA could result in redd scouring.

Flows in the Feather River HFC under the proposed action and during the egg incubation period are lower than WOA flows, and in below normal, dry and critical water year types, proposed action flows are substantially lower than WOA flows during December-May (Figures 5.10-11 through 13). CalSim II model output indicates flows projected under the proposed action will likely meet the minimum instream flow criteria during in below normal, dry and critical water year types. In addition, proposed action flows are anticipated to result in reliably higher flows than the COS during the months of April and May, a critical period for CV Steelhead egg incubation. As a result, potential negative effects of low flows on this life stage are anticipated to be reduced under the proposed action compared to the COS. In addition, proposed action flows, although lower than WOA flows during this life stage, are projected to meet or exceed minimum instream flow requirements in the HFC while at the same time minimizing the potential negative effects of high flows.

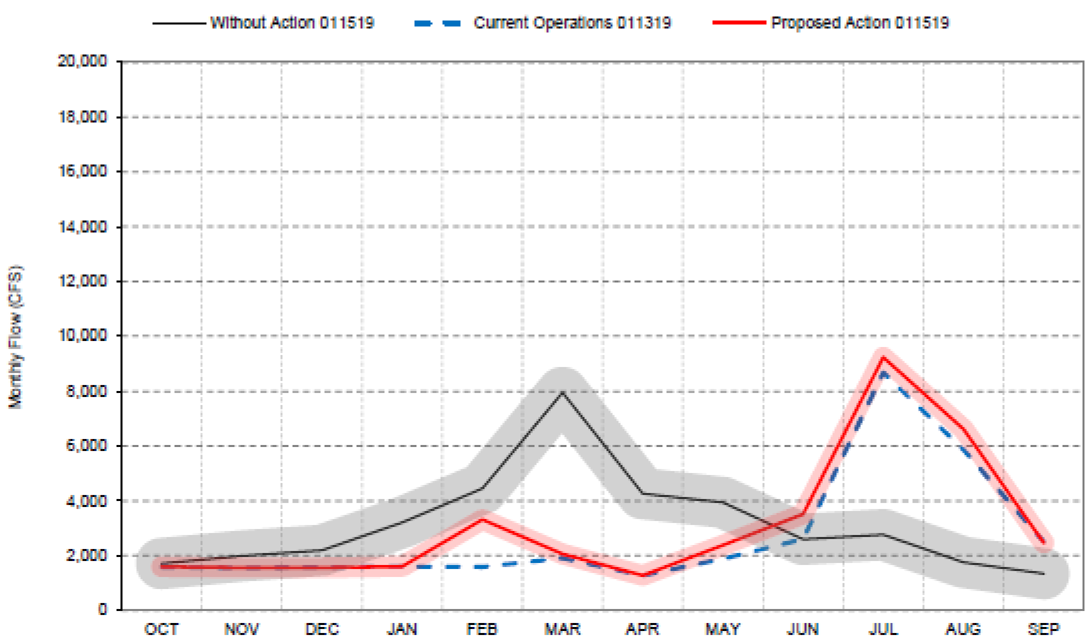


Figure 5.10-11. CalSim II Estimates of Feather River Flow below Thermalito Afterbay for below Normal Water Years under the WOA, COS, and Proposed Action

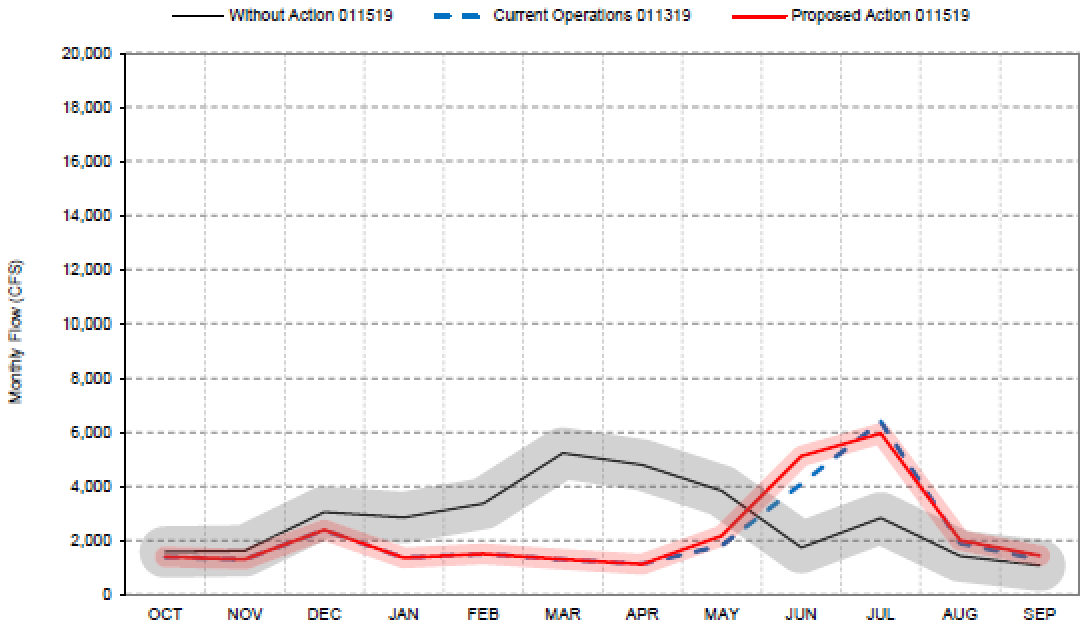


Figure 5.10-12. CalSim II Estimates of Feather River Flow below Thermalito Afterbay for Dry Water Years under the WOA, COS, and Proposed Action

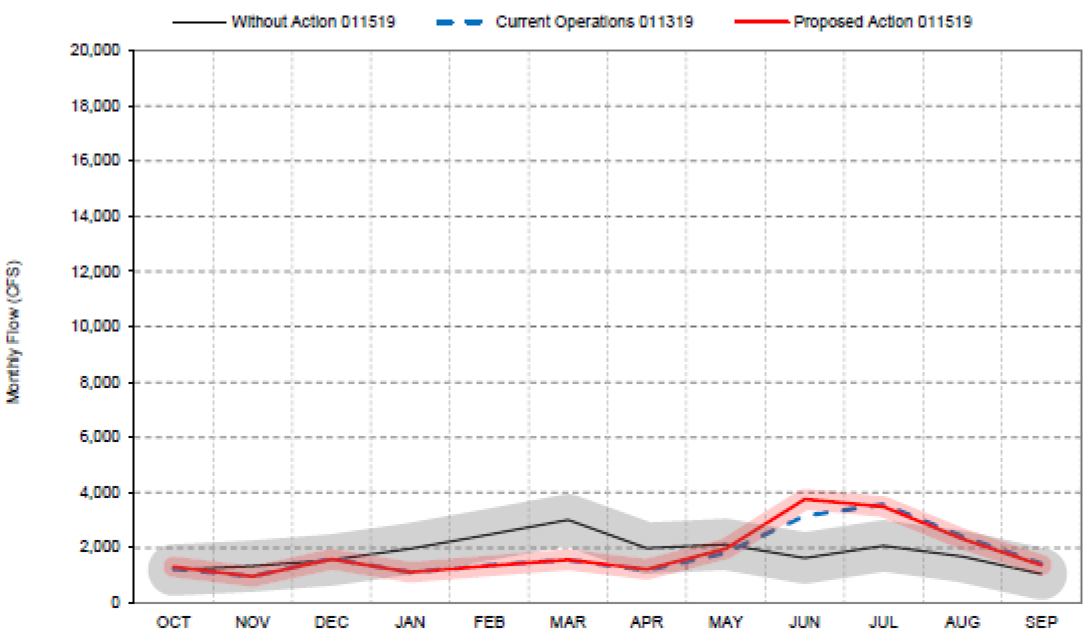


Figure 5.10-13. CalSim II Estimates of Feather River Flow below Thermalito Afterbay for critically Dry Water Years under the WOA, COS, and Proposed Action

5.10.3.3.1.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of CV Steelhead eggs. Exposure to the effects of elevated water temperatures include an inability to satisfy metabolic demand, and acute to chronic physiological stress, eventually leading to egg mortality (Stillwater Sciences 2006, Anderson 2017, Martin et al. 2017). CV Steelhead eggs require water temperatures 46-52°F for optimal development and survival, 52-55°F for suboptimal, with temperatures above 55°F causing chronic to acute stress (Stillwater Sciences 2006; U. S. Bureau of Reclamation 2008).

Under the WOA scenario, there would be limited control of flow or water temperature in the Feather River HFC where CV Steelhead egg incubation occurs. Resulting water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are generally lower during the winter months, and higher during the summer and fall with peak annual water temperatures of approximately 78 °F occurring in July and August (Figure 5.10-14).

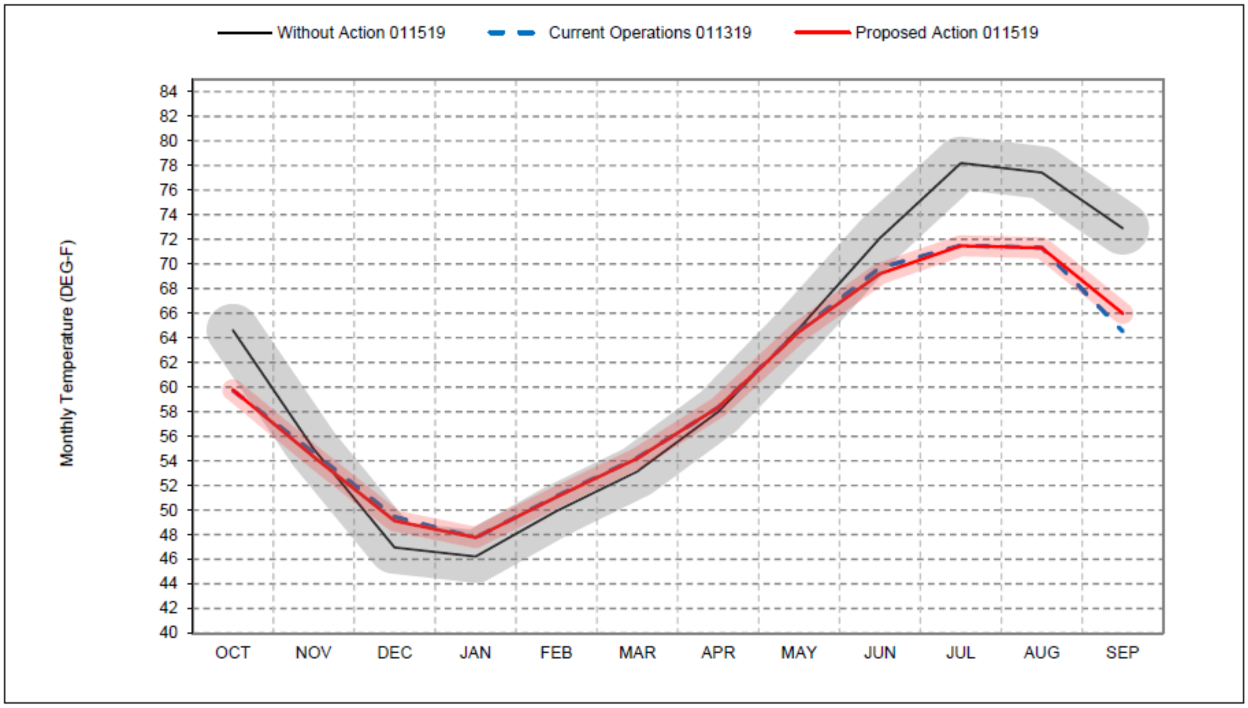


Figure 5.10-14. Long-term Average RecTemp Estimates of Feather River Water Temperature at Gridley Bridge under the WOA, COS, and Proposed Action

Under the proposed action, operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May (Figure 5.10-14). Water temperatures at Gridley Bridge under the WOA scenario are slightly higher than the proposed action during April and May, which coincides with the later part of the seasonal timing of CV Steelhead egg incubation and are slightly lower during the months of December to March when the risk of temperature-related stress and mortality are substantially reduced (Figures 5.10-15 through 18). Under most conditions near or above the 55°F threshold, the proposed action scenario would decrease the likelihood of temperature-related stress and mortality occurring during the period of egg incubation. In addition, modeled water temperatures at Gridley Bridge under the proposed action indicate better likelihood of water temperature compliance at the compliance point (lower FERC project boundary).

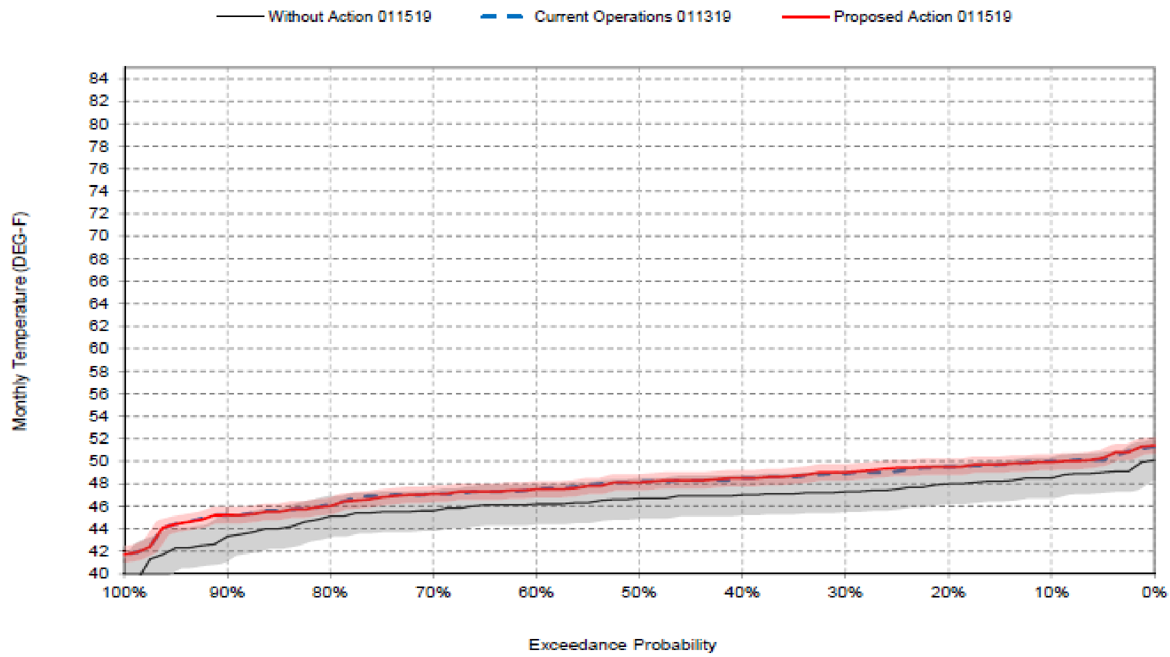


Figure 5.10-15. RecTemp Estimates of Feather River water Temperature at Gridley Bridge under the WOA, COS, and Proposed Action for January

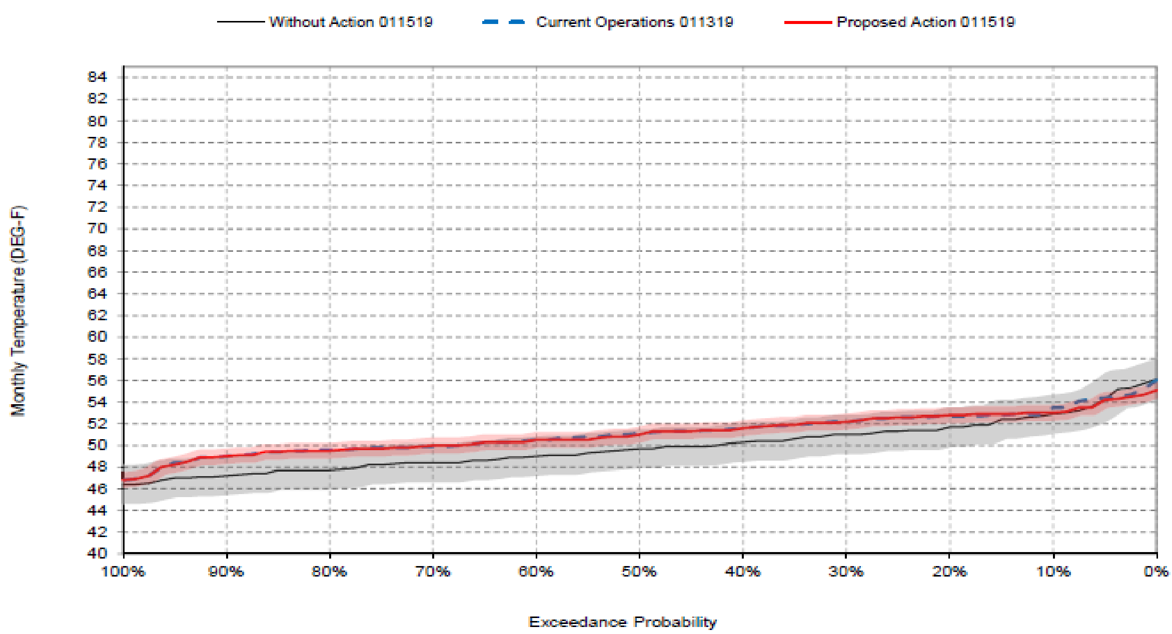


Figure 5.10-16. RecTemp Estimates of Feather River water Temperature at Gridley Bridge under the WOA, COS, and Proposed Action for February

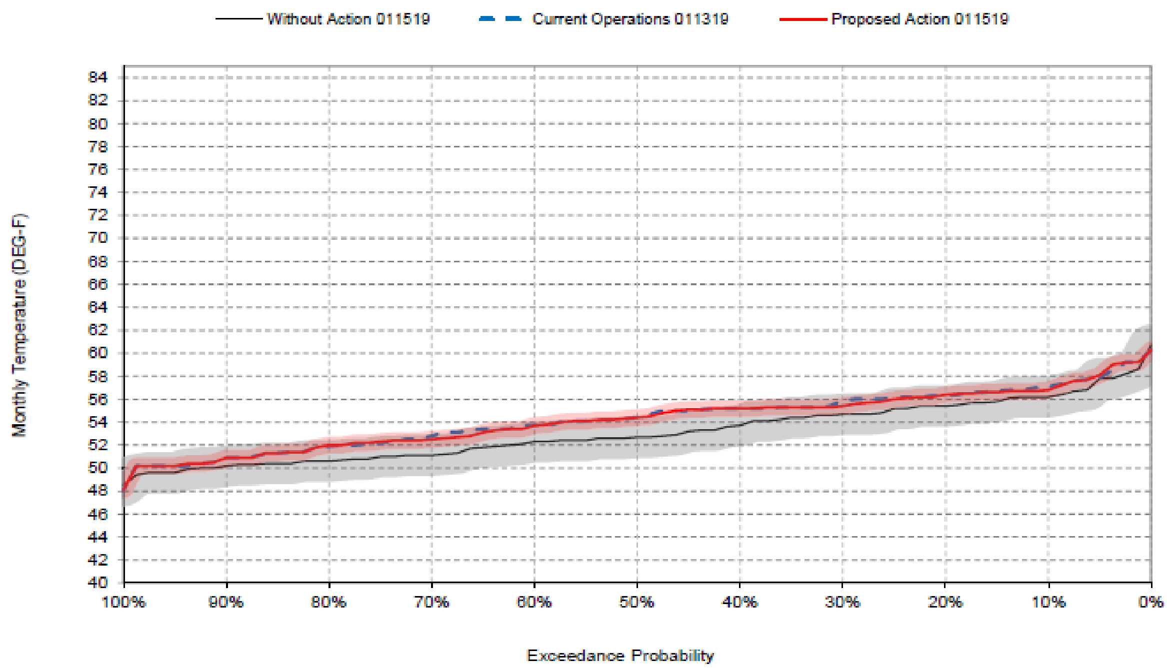


Figure 5.10-17. RecTemp Estimates of Feather River water Temperature at Gridley Bridge under the WOA, COS, and Proposed Action for March

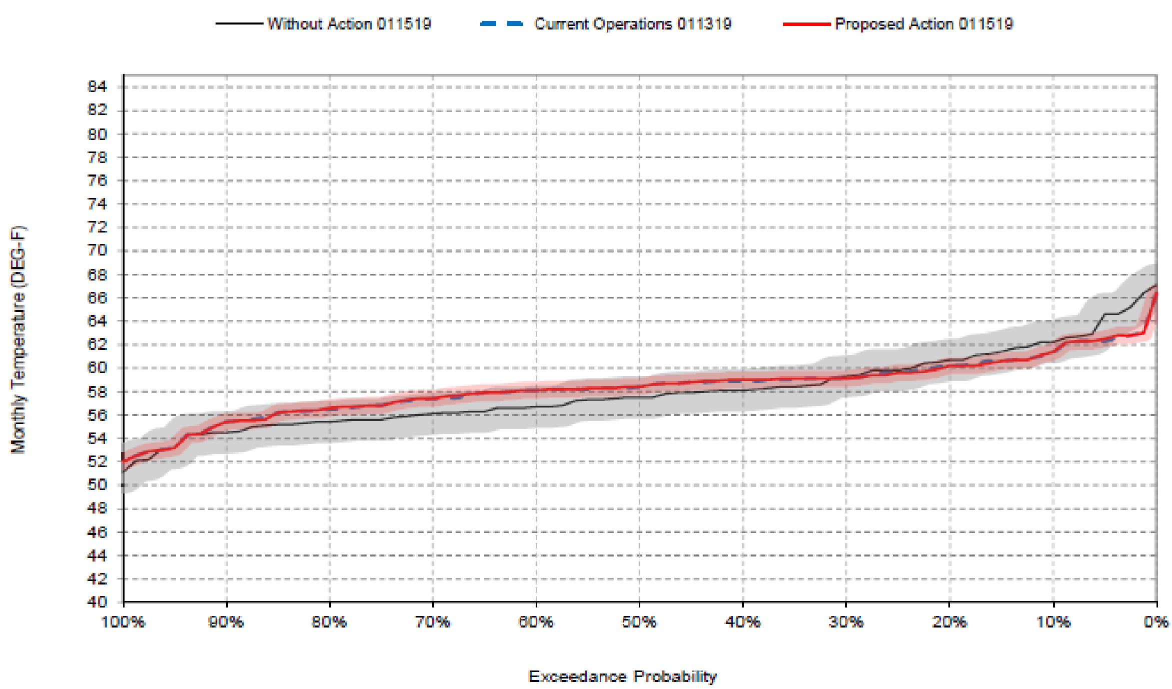


Figure 5.10-18. RecTemp Estimates of Feather River water Temperature at Gridley Bridge under the WOA, COS, and Proposed Action for April

Water temperatures exceeding the objectives and biological thresholds for this life stage of CV Steelhead would have a number of negative impacts on individuals, including acute to chronic physiological stress, potentially leading to egg mortality. Water temperatures in the Feather River HFC under the proposed action during the egg incubation period are similar to or lower than WOA water temperatures. Importantly, RecTemp model output indicates water temperatures projected under the proposed action will increase the likelihood that December to May temperature objectives are met. As a result, potential negative effects on this life stage are anticipated to be minimized under the proposed action.

5.10.3.3.2 Rearing to Outmigrating Juveniles

5.10.3.3.2.1 Flow Effects

Feather River flows below Thermalito Afterbay under the WOA generally approximate or are significantly higher than flows under the proposed action during the peak seasonal timing of CV Steelhead juvenile rearing (January-May; Figure 5.10-7 through 10). The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios. Differences in flows between the proposed action and COS are less pronounced than differences between the proposed action and WOA during the January to May period, with relatively equal differences across the range of exceedance probabilities.

Lower proposed action flows in winter and spring could have both positive and negative effects on rearing juvenile CV Steelhead. Flows can modulate water temperature and DO concentration leading to changes in contaminant toxicity, pathogen virulence, food availability, bioenergetics and disease susceptibility. In addition, river stage and flow velocity may affect habitat connectivity, and availability which in turn may influence food availability, predation, crowding, entrainment and stranding risk, and can potentially affect cues that stimulate outmigration (Windell et al. 2017, Moyle 2002). These adverse effects of low flow are generally mitigated by flow increases, but there can be adverse effects of high flows including higher stranding risk resulting from increased use of floodplain habitat and greater flow fluctuations, and higher contaminant loading from stormwater runoff.

The differences in flows between the proposed action and WOA scenario are likely to suggest beneficial impacts to rearing individuals and their habitat. Lower proposed action flows from January to May could result in both positive and negative effects on rearing CV Steelhead. Impactss include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, higher water temperatures and higher DO, and reduced emigration flows. Beneficial effects are anticipated to be an reduced stranding risk resulting from reduced use of floodplain habitat and smaller flow fluctuations, and reduced contaminant loading from stormwater runoff. The comparative magnitude of positive and negative effects of lower flows under the proposed action compared to the WOA are difficult to quantify; however, potential adverse effects of lower flows from January to May are anticipated to be minimal since projected flows during this period remain well in excess of all applicable minimum instream flows for the Feather River HFC.

5.10.3.3.2.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of rearing individuals. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, reduction in growth due to increased metabolic demands, decreased productivity, and eventual mortality. Rearing juvenile CV Steelhead require temperatures < 65°F for optimal development and survival, and 65-68°F for suboptimal, with temperatures above 68°F causing chronic to acute stress (Stillwater Sciences 2006). Water temperatures in the Feather River from

November to May are relatively less influenced by flow releases from Lake Oroville than in summer and fall, given the larger flow volumes, and colder air temperatures during these months.

Under the proposed action, operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May (Figures 5.10-11 through 13). Water temperatures at Gridley Bridge under the proposed action are the same or higher than water temperatures under WOA from January to May, which coincides with the peak seasonal timing of rearing CV Steelhead. However, the risk of temperature-related stress and mortality are substantially reduced or not present during this period as water temperatures remain well within the optimal range (< 65°F) for this life stage and under the Feather River HFC temperature objectives for these months. Additionally, summer water temperatures under the proposed action are lower than the WOA during a period at moderate risk of water temperature-related stress and mortality, decreasing the likelihood of water temperature-related stress and mortality occurring during juvenile rearing under some conditions of the WOA. As a result, potential negative effects of water temperature objectives on this life stage are anticipated to be less severe under the proposed action, especially during below normal, dry, and critically dry water year types (Figure 5.10-14).

5.10.3.3.3 Adult Migration from Oceans to Rivers

5.10.3.3.3.1 Flow Effects

As indicated by the SAIL Bay-Delta to Upper River (CM6) conceptual model these flows, combined with other environmental drivers, affect water temperature, DO, stranding, outmigration cues and other habitat attributes that influence the timing, condition and survival of migrating adult CV Steelhead (Johnson et. al., 2016, Windell et. al., 2017). Instream flow from Oroville Dam releases may also heavily influence the strength of navigational cues utilized by migrating adults and the propensity of these fish to stray from migratory pathways leading to high quality spawning habitat.

Feather River flows below Thermalito Afterbay under the WOA generally approximate or are significantly lower than flows under the proposed action during the peak seasonal timing of CV Steelhead adult migration (September and October; Table 5.10-1 & NMFS 2016). The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is low under all scenarios, although some risk exists under the WOA in September and October of critically dry years, when flows are lower under the WOA than the proposed action. (Figure 5.10-7 through 10).

Modeled flows under the proposed action during this period are higher than WOA flows, and are not anticipated to decline below minimum instream flow standards, or to a level that results in increased passage or barrier issues in the Feather River HFC. Lower WOA flows from September to October could result in both positive and negative effects on migrating adult CV Steelhead. Negative effects include a decrease in floodplain and side-channel habitat, increased competition and predation, higher water temperatures and lower DO, and diminished immigration flows. Positive effects are anticipated to be a reduced stranding risk resulting from reduced floodplain access. Because the proposed action produces only modest flow increases compared to the WOA, the proposed action is anticipated to result in the benefits listed above without dramatically increasing stranding risk.

5.10.3.3.3.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of migrating adults. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, and physiological stress potentially leading to mortality and altered migration timing and speed. Migrating adult CV Steelhead require temperatures < 52°F for optimal survival, and 52-70°F for suboptimal, with temperatures above 70°F causing chronic to acute stress (Stillwater Sciences 2006).

Under the proposed action, operations and flow releases would be managed to achieve Feather River HFC temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from September to October, and water temperatures that are roughly equivalent from November to March. Water temperatures at Gridley Bridge under the proposed action are substantially lower than temperatures under the WOA from September to October, which coincides with the peak seasonal timing of migrating adult CV Steelhead. The risk of water temperature-related stress and mortality are present during this period as water temperatures are projected to be in or near the suboptimal range (52-70°F) for this life stage in October and potentially above the chronic to acute stress threshold (> 70°F) under the WOA in September (Figure 5.10-14). Water temperatures under the proposed action are slightly higher than the WOA during November to March, a period at a moderate risk of water temperature-related stress and mortality, according to RecTemp model results. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be reduced under the proposed action, especially during below normal, dry, and critically dry water year types (Figure 5-SHCV-6).

5.10.3.3.4 Adult Holding

5.10.3.3.4.1 Flow Effects

Feather River flows below Thermalito Afterbay under the WOA equal or exceed flows under the proposed action during the peak seasonal timing of CV Steelhead holding (December-March; Table 5.10-1 & NMFS 2016). In particular, WOA flows are reliably higher than the proposed action in January through March. The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios, and all water year types. Differences in flows between the proposed action and COS are minimal during the December to March period.

Exposure to the effects of differences in flow during this life stage could include variation in water temperature and DO, and the amount and quality of holding habitat used to shelter from predators, and rest during the gamete maturation phase. Proposed action flows are lower than WOA flows in January through March; however, proposed action flows are not anticipated to decline below minimum instream flow standards or to a level that is anticipated to result in substantial loss of suitable holding habitat in the Feather River HFC. As a result, conditions for holding adult CV Steelhead will be minimally impacted during the majority of the peak seasonal timing of this life stage.

5.10.3.3.4.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of holding adults. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, and physiological stress potentially leading to mortality and delayed or poor gamete maturation. Holding adult CV Steelhead require water temperatures < 52°F for optimal survival, and 52-70°F for suboptimal, with temperatures above 70°F causing chronic to acute stress (Stillwater Sciences 2006).

Water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are slightly lower than those projected under the proposed action during

December to March (Figure 5-SHCV-4). Under the proposed action, water temperatures are slightly higher but within the optimal range during the peak seasonal timing of holding adult CV Steelhead. The risk of temperature-related stress and mortality is negligible during this period, as water temperatures are projected to be at or near the suboptimal range (<60.8-66.2°F) for this life stage only during March, the end of the peak seasonal timing of holding adult CV Steelhead. As a result, potential negative effects of water temperature on this life stage are not anticipated under the proposed action, even during below normal, dry, and critically dry water year types (Figure 5.10-11 through 13).

5.10.3.4 American River Seasonal Operations

5.10.3.4.1 <u>Eggs to Fry Emergence</u>

Under the proposed action, Reclamation proposes to adopt the minimum flow schedule and approach proposed by the Water Forum in the 2017 Flow Management Standard (FMS). Under the WOA, the 2017 FMS would not be implemented. The 2017 FMS includes a Minimum Release Requirement (MRR) with flows that range from 500 to 2000 cfs based on time of year and annual hydrology. The objective of the planning minimum is to preserve storage to protect against future drought conditions, and to facilitate the development of the cold water pool when possible to improve habitat conditions for CV Steelhead and Fall-run Chinook Salmon.

Cool water temperatures are important for embryo survival. Water temperatures reportedly must be between 41°F and 55.4°F for maximum survival (Moyle 2002). In addition, redd dewatering protective adjustments were included in the 2017 FMS to limit potential redd dewatering due to reductions in the MRR during the January through May period coincident with the embryo incubation period. The embryo incubation and alevin development period for CV Steelhead follows the December through April spawning period. Eggs usually hatch within four weeks, depending on stream temperature, and the yolk sac fry remain in the gravel after hatching for another four to six weeks (CDFG 1996). Under the proposed action, the implementation of the proposed 2017 FMS measures would provide habitat conditions in the lower American River tailored for salmonids, particularly during drought conditions and improve conditions for this life stage relative to WOA.

5.10.3.4.2 <u>Rearing to Outmigrating Juveniles</u>

Under the proposed action, the planning minimum would preserve storage when compared to WOA and COS. In addition to the MRR flows, the 2017 FMS under the proposed action includes the following water temperature objectives to provide suitable water temperatures for salmonids:

- 65°F from mid-May to mid-October to provide suitable conditions for juvenile CV Steelhead rearing in the lower American River
- 60°F or less by October 1 to provide suitable conditions for Fall-run Chinook Salmon holding and early spawning (also benefits CV Steelhead)
- 56°F or less by November 1 to provide suitable conditions for Fall-run Chinook Salmon spawning and embryo incubation (also benefits CV Steelhead)

The 2017 FMS also includes the provision for spring pulse flows, with the purpose to provide a juvenile salmonid emigration cue before potentially lower flow conditions and associated unsuitable thermal conditions later in the spring in the river, and downstream in the lower Sacramento River.

The implementation of the proposed 2017 FMS measures under the proposed action would provide suitable habitat conditions in the lower American River for CV Steelhead, particularly during drought conditions and improve conditions for this life stage. The proposed action would likely beneficially affect this life stage of CV Steelhead in the American River when compared to the WOA and COS scenarios.

5.10.3.5 Delta Seasonal Operations

5.10.3.5.1 Entrainment

ICF (2018) analyzed salvage of CV Steelhead at the CVP and SWP between 2003 and 2017 and found that salvage increased with export rate and decreased with San Joaquin River flow. Salvage also decreased with OMR flow. However, OMR is a comprised of both exports and San Joaquin River flow which complicates attempts to understand individual effects.

Average total exports for months when juvenile CV Steelhead are present in the Delta indicate zero entrainment risk under the WOA. In the December through February period, proposed action proposes an average total export rate slightly higher than COS (366 cfs; Figure H1 – Appendix H – Bay-Delta Aquatics Effects Figures) and will therefore have a similar entrainment risk. Total exports proposed for proposed action in March-June (1,699 cfs higher than COS; Figure H2 – Appendix H – Bay-Delta Aquatics Effects Figures) when juvenile CV Steelhead are most abundant in the Delta at Chipps Island (Table 5.10-1), will increase entrainment risk relative to COS.

5.10.3.5.2 Routing

Routing of juvenile CV Steelhead into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from the proposed action were evaluated using DSM2. Juvenile CV Steelhead are present in the Sacramento River at Hood upstream of the first distributary junctions between November and early June with peak abundance from February to early June (Table 5.10-1). In the December through February period, velocity overlap between proposed action and COS in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >50% in all water year types (Figure H-3 – Appendix H – Bay-Delta Aquatics Effects Figures).

Comparing proposed action to WOA in the December-February period revealed velocity overlap <50% in Dry, Above Normal and Wet years and <60% in Critical and Below Normal years (Figure H4 – Appendix H – Bay-Delta Aquatics Effects Figures) with higher velocities in the WOA in all water year types. This pattern indicates routing into the interior Delta would be lower under WOA relative to proposed action or COS (Perry et al. 2015). In the March to May period Comparison of the proposed action and COS revealed similar patterns of velocity overlap as described for the December-February period (Figure H5 – Appendix H – Bay-Delta Aquatics Effects Figures) indicating routing into the interior Delta would be lower under the proposed action during March-May. Comparing the proposed action with the WOA in March-May revealed low overlap in Sacramento River mainstem velocities between the Steamboat-Sutter Junction and the DCC-Georgiana Slough junction (Figure H6 – Appendix H – Bay-Delta Aquatics Effects Figures).

5.10.3.5.3 Through Delta Survival

A recent study by 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. To examine potential effects of the proposed action, changes in velocity distributions were examined assuming a positive correlation between discharge and mean water column velocity for the Sacramento River at Walnut Grove and Steamboat Slough, which are both in this “transitional” region. During the December-February period at Walnut

Grove, velocity distributions for proposed action relative to COS were most different in Wet Years (70.9%) with higher velocities in the proposed action. Velocities were also greater for proposed action relative to COS in Dry, Below Normal and Above Normal years although overlap was greater (≥79.6%; Figure H11 – Appendix H – Bay-Delta Aquatics Effects Figures). In Critical Years, velocity distributions were almost identical (95.4%; Figure H11 – Appendix H – Bay-Delta Aquatics Effects Figures). A similar pattern was apparent for the comparison between proposed action and WOA (Figure H12 – Appendix H – Bay-Delta Aquatics Effects Figures); however, overlap was lower for each water year type (37.3 – 68.3%) with higher velocities under WOA relative to proposed action. At Steamboat Slough in the December-February period, there was a similar pattern where velocities under the proposed action were higher than COS in Wet, Above Normal and Below Normal years and similar in Dry and Critical years (Figure H13 – Appendix H – Bay-Delta Aquatics Effects Figures).

When the proposed action was compared to WOA, overlap was moderate to high with values between 42.6% and 72.6% (Figure X14 – Appendix H – Bay-Delta Aquatics Effects Figures). Velocities were higher under the WOA in all water year types (Figure H14 – Appendix H – Bay-Delta Aquatics Effects Figures). Results of this analysis indicate that through delta survival between December-February would be higher under the proposed action relative to COS, but potentially reduced survival relative to WOA.

When comparting the proposed action to WOA in the March through May period, velocity overlap was variable among water year types from a low of 14.1 percent in Wet years to 56.9 percent in Critical years (Figure H16 – Appendix H – Bay-Delta Aquatics Effects Figures). In all water year types, velocities were less under the proposed action relative to the WOA. Velocity overlap was lower in March through May at Steamboat Slough when proposed action was compared to WOA (Figure H18 – Appendix H – Bay-Delta Aquatics Effects Figures). The lowest value occurred in Wet years (19.1%) and highest in Critical years (69.5%). These results indicate that survival under the proposed action may be reduced due to lower water velocity compared to WOA assuming water velocity scales positively and linearly with discharge.

In the March through May period at Walnut Grove, velocity overlap between the proposed action and COS was ≥78.5 percent across all water year types with greater velocities under proposed action (Figure H15 – Appendix H – Bay-Delta Aquatics Effects Figures). At Steamboat Slough in the March through May period, overlap between the proposed action and COS scenarios was high with all values ≥82.2 percent (Figure H17 – Appendix H – Bay-Delta Aquatics Effects Figures). The small changes in velocity within transitional reaches of the Sacramento River and North Delta between the proposed action and COS suggest there could be small improvements associated with the proposed action in through Delta survival in some water year types. There would potentially be a reduction in survival under the proposed action when compared to the WOA.

5.10.3.6 Delta Cross Channel Operations

Under WOA, the Delta Cross Channel would be closed, and fish would not be entrained into the central Delta. Significant flow and many juvenile CV Steelhead enter the central Delta when the DCC gates are open. Mortality of juvenile CV Steelhead entering the central Delta is higher than for those continuing downstream in the Sacramento River. The peak migration of juvenile CV Steelhead in the Sacramento River past Knights Landing, which is upstream of the DCC, occurs from January-February (Table 5.10-1). Therefore under the proposed action, the continued operation of the DCC to protect the majority of the juvenile CV Steelhead during their migration period in the Sacramento River would reduce the proportion of fish exposed to an open DCC and result in beneficial impacts to this life stage when compared to the COS. Under WOA conditions, the DCC would remain closed, which is more protective of this life stage; however, DCC operations under the proposed action attempt to minimize the potentially negative effects compared to WOA by closing the DCC gates during peak migration periods.

5.10.3.7 Agricultural Barriers

The Temporary Barriers Project (TBP) consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions and one rock barrier to improve San Joaquin River salmonid migration in the south Delta. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, Grant Line Canal near Tracy Boulevard Bridge, and the head of Old River. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30. The Head of Old River Barrier is only installed from September 16 to November 30 to improve flow and DO conditions in the San Joaquin River for the immigration of adult fall-run Chinook Salmon.

5.10.3.7.1 Rearing to Outmigrating Juveniles

The proportion of juvenile CV Steelhead exposed to the TBP depends on their annual timing of installation and removal. Due to their location, primarily juvenile CV Steelhead migrants originating from the San Joaquin River would be exposed to the TBP. The peak relative abundance of juvenile CV Steelhead in the San Joaquin River in the vicinity of the TBP (Mossdale) occurs in April and May (Table 5.10-1). If the agricultural barriers are operating as early as April 15, there is potential exposure to a large proportion of the juvenile CV Steelhead migrating down the San Joaquin River.

When the Head of Old River barrier is not in place, acoustically tagged juvenile CV Steelhead have demonstrated a high probability of selecting the Old River route (Buchanan 2018[PC1]), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile CV Steelhead migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, CV Steelhead passage past the agricultural barrier was improved (DWR 2018). Therefore, although the proposed action does not include HORB, which could result in negative impacts to CV Steelhead juvenile migration, the improvements to the agricultural barriers (including flap gates tied up from May 16 to May 31) would help to reduce the negative effect of the barriers on migrating juvenile CV Steelhead during this period relative to COS. However, juvenile CV Steelhead migrating before or after this period could be exposed to the agricultural barriers with flaps down, which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers under the proposed action on juvenile CV Steelhead depends on when they are installed and whether or not the flap gates are down.

5.10.3.8 Contra Costa Water District Rock Slough Intake

CCWD’s operations in the proposed action are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD’s intakes and Los Vaqueros Reservoir (NMFS 1993; NMFS 2007; NMFS 2010; NMFS 2017; USFWS 1993a; USFWS 1993b; USFWS 2000; USFWS 2007; USFWS 2010; USFWS 2017; CDFG 1994; CDFG 2009). The subject of this consultation is the actual diversion of water through the Rock Slough Intake, covered under the NMFS 2009 biological opinion on the long-term coordinated operations of the CVP and SWP. However, since the 2009 biological opinion, the Rock Slough Fish Screen has been built, and entrainment of salmonids resulting from diverting water into the Rock Slough intake has been fully avoided. Adverse effects of fish screen operation are covered under the NMFS 2017 biological opinion.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for CV Steelhead (NMFS 2017), approximately 18 miles from the Sacramento River via the shortest route. Fish monitoring prior to the construction of the Rock Slough Fish Screen (RSFS) indicates the timing and magnitude of CV Steelhead presence near the Rock Slough Intake. Since 1994, fish monitoring has been conducted by CDFW and CCWD consistent with the separate biological opinions and permits that govern CCWD's operations. From 1994 through 1996, CDFW conducted fish monitoring at the Rock Slough Intake and in the Contra Costa Canal up to the first pumping plant. Over this period, CDFW captured a total of 36 juvenile CV Steelhead from February to May (CDFG 2002; NMFS 2017). In the 11 years prior to construction of the RSFS (1999-2009), CCWD's Fish Monitoring Program collected a total of 15 juvenile CV Steelhead at the Rock Slough Headwords (Reclamation 2016; NMFS 2017). In addition, one adult CV Steelhead (622 mm FL, adipose fin intact) was collected and released during fish rescue efforts in November 2009, for the construction of the RSFS (Reclamation 2016). Since construction of the RSFS, one ad-clipped CV Steelhead was collected at the RSFS facility (April 24, 2012) by operation of the hydraulic rake cleaning system (Reclamation 2016; Tenera 2018a). Based on the size, the CV Steelhead was likely a hatchery released smolt (Reclamation 2016, Appendix A).

On July 3, 2017, NMFS issued a biological opinion (NMFS 2017) that considered improvements to the RSFS facility including the hydraulic rake cleaning system, operations and maintenance (O&M) of the RSFS and associated appurtenances, and administrative actions such as the transfer of O&M activities from Reclamation to CCWD. NMFS determined that the O&M of RSFS may result in the incidental take of juvenile CV Steelhead and provided an incidental take limit based upon the number of listed fish collected in the pre and post-construction RSFS monitoring (NMFS 2017). The incidental take provided in NMFS 2017 is 10 juvenile and 10 adult CV Steelhead per year.

5.10.3.8.1 Rearing to Outmigrating Juveniles

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile CV Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmonids can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. One indicator of reverse flows is the net flow in OMR. Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect OMR, and any effect that diversions at Rock Slough Intake under the proposed action would have in the OMR corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants. For juveniles that migrate down the Old and Middle River corridor that are not salvaged at TFCF or Skinner Fish Facility, any effect of Rock Slough Intake diversions would be a positive effect on OMR.

For juveniles that migrate down the mainstems of the Sacramento or San Joaquin Rivers and for juveniles that were salvaged, trucked, and released in the western Delta, the potential effect of Rock Slough diversions on the net reverse flow in San Joaquin River may be relevant. The effect of water diversions at Rock Slough Intake on the velocity in the San Joaquin River at Jersey Point is presented in the effects analysis for juvenile Winter-run. As detailed in that section, the maximum potential effect of water diversions at Rock Slough Intake (assuming diversions at the maximum permitted capacity of 350 cfs and all water diverted by the Rock Slough Intake comes from the San Joaquin River at Jersey Point) is 0.00625 ft/sec in the San Joaquin River at Jersey Point. For comparison, the velocity threshold for design of fish screens to prevent impingement of salmonids is 0.33 ft/sec, which is 50 times the maximum possible contribution from the Rock Slough diversions.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, the combined effect of all three intakes was examined. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect salmonids from diversions in the vicinity of fish screens (0.33 ft/sec) is over 21 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile CV Steelhead.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. As shown in the Winter-run section, the diversions at the Rock Slough Intake could move a neutrally buoyant particle in the San Joaquin River at Jersey Point approximately 540 ft over the course of the day. For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location. Although the diversions at Rock Slough Intake are not likely to impact juvenile CV Steelhead, the aggregate effect of all water diversions in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

5.10.3.8.2 Adult Holding

Rock Slough is a relatively slow flowing, tidal waterway which ends at the Rock Slough Extension, approximately 1,700 feet upstream from the Rock Slough Intake. Rock Slough is poor habitat with relatively high water temperature and a prevalence of aquatic weeds. Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, and due to the poor quality of habitat within the slough, adult CV Steelhead are not likely to be in the vicinity of the Rock Slough Intake. However, if some adults stray into Rock Slough, the water exiting the Contra Costa Canal on ebb tide may create a false attraction to adult CV Steelhead that are migrating upstream (NMFS 2017).

NMFS has advised Reclamation that salmonids will likely be less attracted to the area near the intake if tides can be reduced (Reclamation 2016). As illustrated in NMFS 2017 (Figure 10), water diversions at the Rock Slough Intake reduce the ebb tidal flows through the RSFS. Thus, the diversion of water at the Rock Slough Intake under the proposed action, which is the subject of this consultation, reduces the false attraction created by the ebb tides existing the Contra Costa Canal. Furthermore, it is worth noting that the ebb tidal flow in Rock Slough will be substantially reduced when the Contra Costa Canal is encased in a pipeline. This ongoing, multi-phased project (the Canal Replacement Project) is being conducted as a separate action by CCWD and has undergone separate environmental review. Completion of the Canal Replacement Project will result in tidal flows being significantly reduced at the Rock Slough Intake. Modeling of the area indicates that with only the first two phases complete, ebb flows reach up to 160 cfs, but with the Contra Costa Canal fully encased, ebb flows would be greatly muted to about 10 cfs. Although the likelihood that adult CV Steelhead will be present near the Rock Slough Intake is low, a small number of fish could stray into Rock Slough, or be attracted by the flows exiting the Contra Costa Canal on ebb tides.

5.10.3.9 North Bay Aqueduct

Under the proposed action, there would be no changes to operational criteria at the NBA's BSPP relative to current operations and WOA. Juvenile CV Steelhead could occur in the vicinity of the BSPP; however, the fish screens used at the facility are designed to protect juvenile salmonids per NMFS criteria and should prevent entrainment and greatly minimize impingement of fish against the screen itself (NMFS 2009). In addition, the location of the facility is well off the typical migration corridor of juvenile CV Steelhead (NMFS 2009: 417). No juvenile CV Steelhead have been captured during CDFW monitoring surveys from 1996 to 2004 (http://www.delta.dfg.ca.goc/data/nba).

5.10.3.10 Water Transfers

CV Steelhead juveniles could be exposed to increased entrainment, predation, and decreased through-Delta survival as a result of the expanded transfer window under the proposed action, but as the peak of the juvenile outmigration is in the spring, effects are anticipated to be minimal. No other lifestages of CV Steelhead would co-occur in time and space with water transfers from the Delta.

5.10.3.11 Clifton Court Forebay Aquatic Weed Program

Under the proposed action, the application of aquatic herbicide to the waters of CCF will occur during the summer months of July and August. Juvenile CV Steelhead abundance in the Delta peaks between March and May (Table 5.10-1). Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. As such, it is unlikely that juvenile CV Steelhead would be rearing near this location after mid-June and the potential application of aquatic herbicide would only occur well after the peak outmigration period (Table 5.10-1) and therefore CV Steelhead are not expected to be exposed to herbicide application activities.

Mechanical harvesting would occur on an as-needed basis and therefore listed salmonids could be exposed to this action, if entrained into the CCF. Potential direct and indirect effects to listed fish species from mechanical weed harvesters include mortality or injury from harvester strikes, entanglement in weeds lifted from the water, reduction of aquatic prey species, and temporary disturbances. Increased boat noise and disturbance of the water during harvesting, the slow speed of the harvester (approximately 2 miles per hour), and beginning harvesting closest to the edge should allow fish to escape the area proposed for mowing. However, CV Steelhead are unlikely to be present and exposed to the adverse effects due to extreme temperatures.

5.10.3.12 Suisun Marsh Salinity Control Gates

Operation of the SMSCG from October through May under the proposed action coincides with downstream migration of juvenile CV Steelhead (Table 5.10-1). Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. No data are available to estimate the abundance of juvenile CV Steelhead thus, the proportion of the total run utilizing this route is unknown. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

5.10.3.12.1 Roaring River Distribution System

Under the proposed action, the Roaring River Distribution System water diversion intake is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s from mid-September to mid-October (for Delta Smelt protection) or 0.7 ft/s, excluding juvenile CV Steelhead from entrainment (NMFS 2009: 437).

5.10.3.12.2 Morrow Island Distribution System

The MIDS diverts water from Goodyear Slough through three 48-inch diameter culverts during high tide. Although the MIDS intakes do not currently have fish screens, it is unlikely juvenile CV Steelhead will be entrained into the water distribution system because CV Steelhead have not been caught in past surveys. Also, the large size and better swimming ability of juvenile listed salmonids in the Delta allow these fish to avoid entrainment at MIDS. In addition, the location of the MIDS intake on Goodyear Slough further reduces the risk of entrainment. Goodyear Slough is not a migratory corridor for CV Steelhead. The operation of the MIDS under the proposed action would not impact CV Steelhead.

5.10.3.12.3 Goodyear Slough Outfall

Goodyear Slough Outfall improves water circulation in the Suisun Marsh. This structure consists of four 48-inch diameter culverts with flap gates designed to drain water from the southern end of Goodyear Slough into Suisun Bay. On flood tides, the gates reduce the amount of tidal inflow into Goodyear Slough. Due to its location and design, CV Steelhead are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall likely benefits CV Steelhead in Suisun Marsh by improving water quality and increasing foraging opportunities.

5.10.3.13 OMR Management

As shown in Figure 5.10-20 below, at CVP and SWP fish facilities in the Delta, between 0 and approximately 5000 juvenile CV Steelhead have been historically salvaged. Between 2010-2018, steelhead loss has ranged between 157 to 2852 fish. Exports are expected to increase slightly under the proposed action, and therefore salvage of CV Steelhead is also expected to increase under the proposed action. Restricting OMR flows to -5,000 cfs will reduce or avoid entrainment. Triggers based on salvage that further restrict OMR will further reduce entrainment. Enhanced monitoring and predictive tools will further reduce entrainment while increasing operational flexibility. OMR management under the proposed action will reduce the entrainment effects of the proposed action on CV Steelhead. Please see Delta seasonal operations –entrainment –for more details.

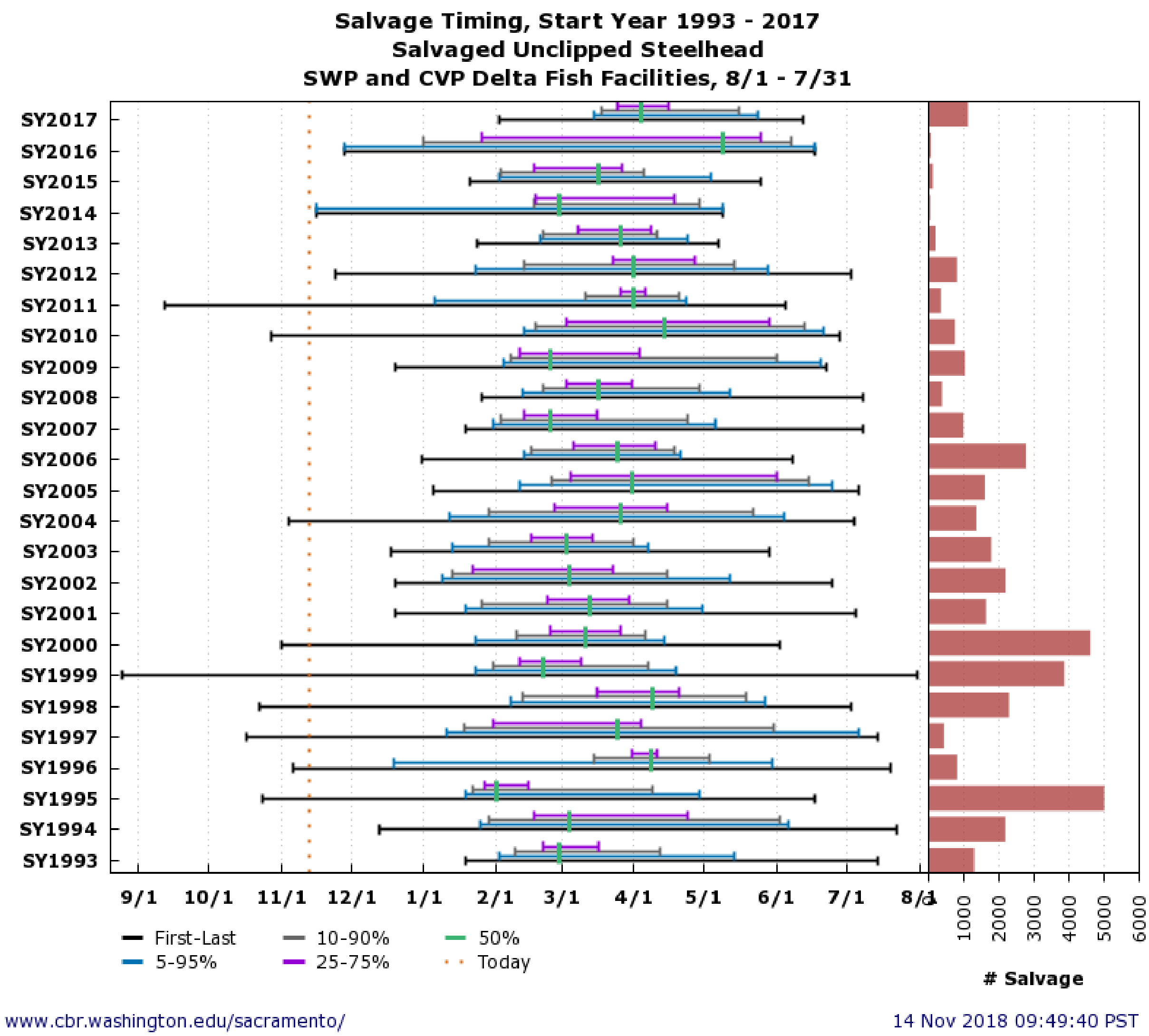


Figure 5.10-19. Sac PAS Salvage Unclipped Steelhead

5.10.3.14 Stanislaus River Operations - Stepped Release Plan

CV Steelhead in the Stanislaus River are found mostly in the reach from Goodwin Dam downstream to Oakdale (Kennedy 2008). Under the WOA, CV Steelhead distribution would be similar to the proposed action and COS as Goodwin Dam would still represent a complete physical barrier to further upstream migration. Steelhead on the Stanislaus River generally move upstream to spawn between July and March, and juvenile steelhead outmigrate between January and June (NMFS, 2014).

Under the proposed action, Reclamation proposes to implement the New Melones Stepped Release Plan to create a sustainable operation on the Stanislaus River that strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries.

5.10.3.14.1 River Flow

Modeled flows below Goodwin Dam are depicted below in Figure 5.10-21. Stanislaus Modeled Flows. Under WOA conditions, flows are highest in February and July. Flows drop below 500 cfs from August to October. August and September flows are often 0 cfs (see Figure below). April and May flows range from 0 cfs in the driest years to over 1,400 cfs in the wettest.

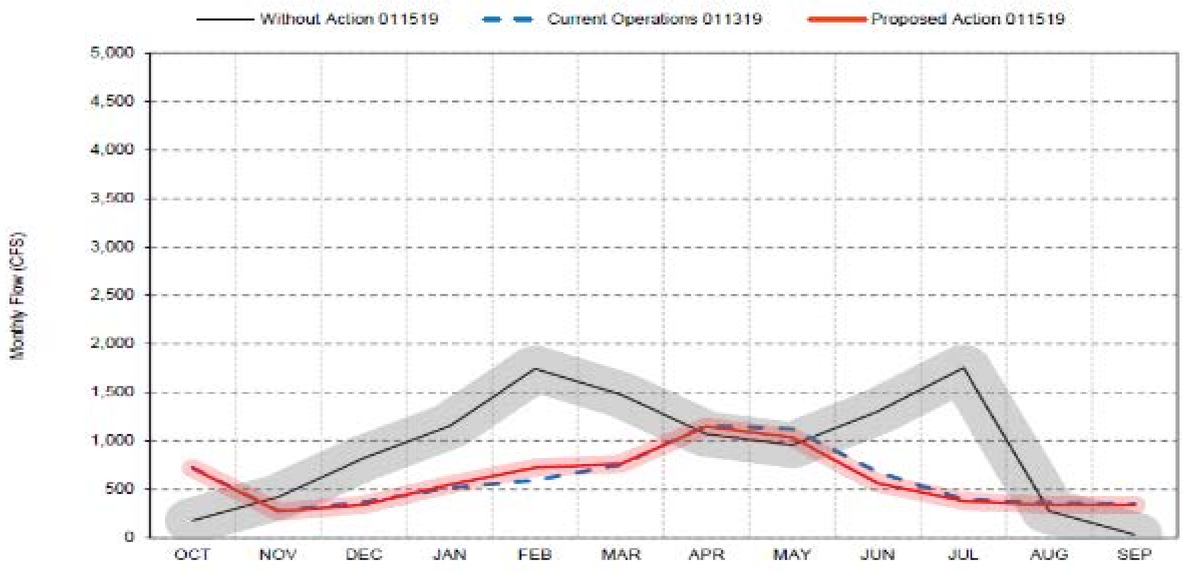


Figure 5.10-20. Stanislaus River Flow below Goodwin Dam under WOA, Current Operations Scenario (COS) and Proposed Action Scenario

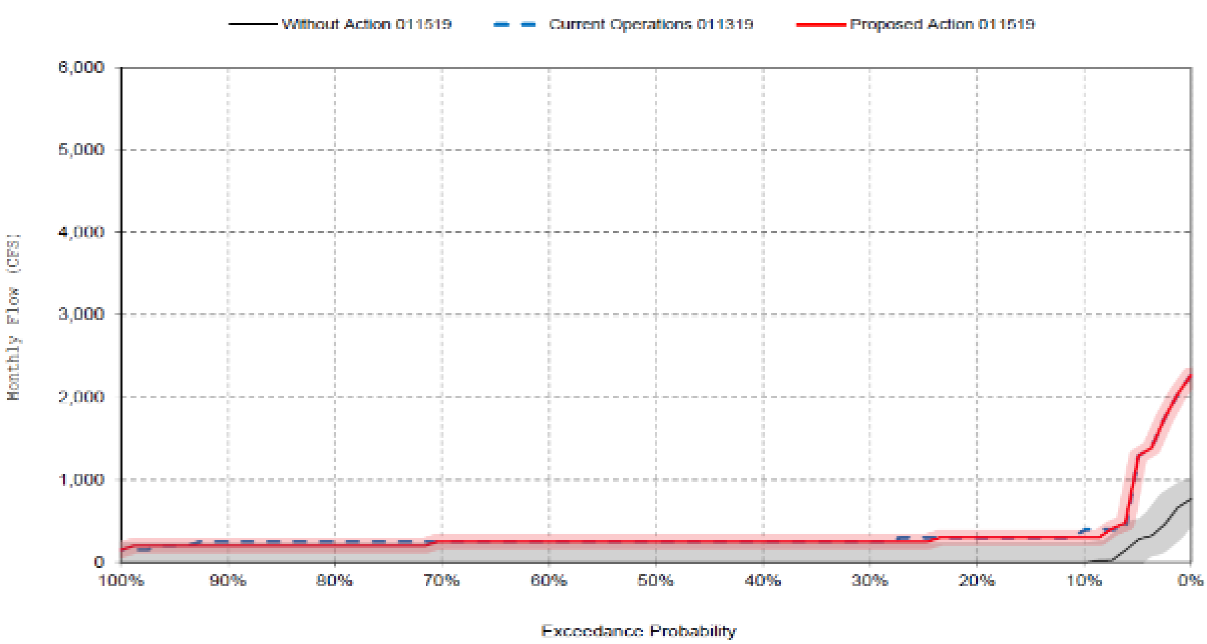


Figure 5.10-21. Stanislaus River Flows below Goodwin Dam, September Exceedance

Under the proposed action, flows are at least 200 cfs year-round in all water year types. As compared to WOA, the proposed action has lower flows in November to March and some wet June and July's (late snowmelt runoff). The proposed action has higher flows than WOA in April through October of most years.

5.10.3.14.2 Water Temperature

The Stepped Release Plan promotes increased storage at New Melones Reservoir. Over time, increased total storage would promote the development of a larger cold water pool. Recognizing that there is no ability for Reclamation to release water from different depths at New Melones, increased water depth above the static intake structure would function like a thermal cap, keeping the water below cooler. More cold water in New Melones Reservoir may lower water temperatures downstream of Goodwin Dam, which would benefit CV Steelhead in all life stages in the lower Stanislaus River.

As can be seen in Figure 5.10-23 below, the proposed action greatly decreases water temperatures in May through October as compared to WOA, and the proposed action increases temperatures between December and March as compared to WOA.

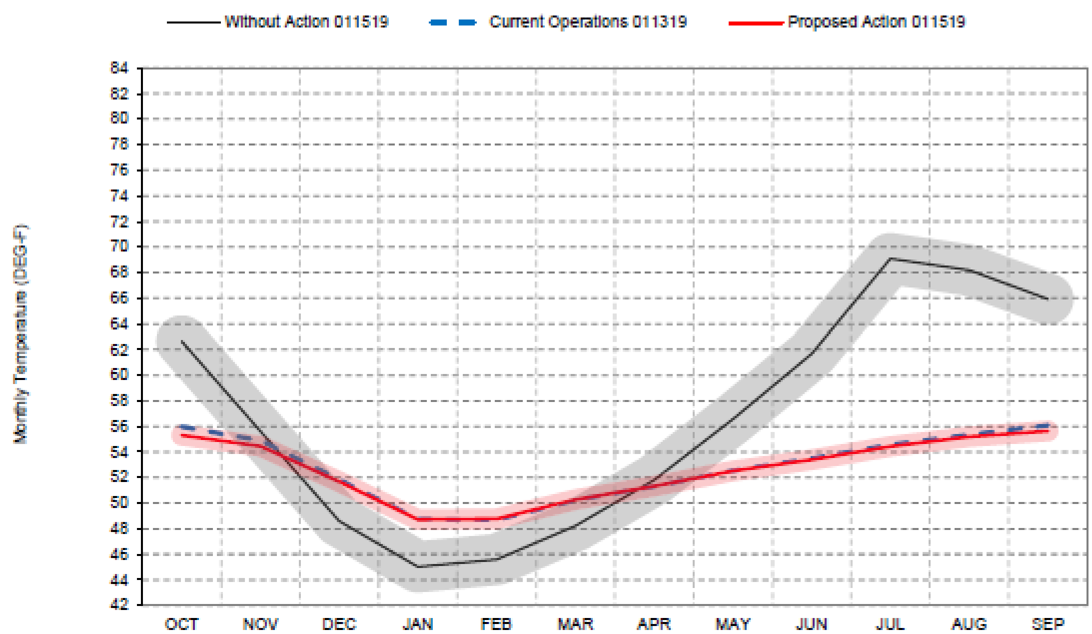


Figure 5.10-22. Stanislaus River below Goodwin Dam, Long-term Average Temperatures by Month

5.10.3.14.3 Egg to Fry Emergence (January – March)

A water temperature of 53°F provides a reasonable threshold for evaluating the potential for adverse temperature effects to spawning and egg incubation (USEPA, 2003). This reference, however, is based on Pacific Northwest fish.

Under the WOA, temperatures in the Stanislaus River below Goodwin Dam are below 53 degrees Fahrenheit between January and March in all years. Under the proposed action, temperatures are also below 53 degrees in all years, although temperatures are a few degrees higher than WOA. Therefore, proposed action is not anticipated to have impacts on the egg to fry emergence lifestage.

5.10.3.14.4 Juveniles (January – June)

Under WOA, flows in March, the peak of juvenile outmigration, range from 121 cfs to 2,380 cfs. Under the proposed action, flows during this period range from 200 cfs to 1,528 cfs. Higher flows in March under the proposed action would benefit rearing and outmigrating juvenile CV Steelhead by increasing the inundated area of rearing habitat, stimulating food production and primary productivity, increasing cover and habitat complexity, and increasing ability to avoid predators.

For juvenile rearing and outmigrating temperatures, the USEPA recommends 61 degrees Fahrenheit, although this is based on Pacific Northwest fish. Under WOA, approximately 50% of June months would exceed this threshold. Under the proposed action, all months between January and June are modeled to have Stanislaus River water temperatures below 61 degrees Fahrenheit. This would be a slight benefit of the proposed action to outmigrating juvenile CV Steelhead, avoiding temperature stress for the last outmigrats.

5.10.3.14.5 Migrating Adults (July – March)

During July through March, the WOA has flows ranging from 0 cfs in most Augusts and Septembers to approximately 6,800 cfs in occasional wetter July months. Under WOA, CV Steelhead adults would not be able to migrate up to spawning habitat below Goodwin Dam in August or September, or approximately half of July months. The proposed action flows during the CV Steelhead adult migration window range from a minimum of 200 cfs during the summer to approximately 1,500 cfs in some March months. Under the proposed action, CV Steelhead adults would be able to reach the spawning grounds in all months due to minimum 200 cfs flows. The proposed action benefits CV Steelhead by allowing adult migration during their entire window.

The USEPA-recommended 7DADM water temperature for holding adults is 68°F. Although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of operating to 7DADM, it is appropriate for comparison to monthly averaged temperature model results. Under the WOA, temperatures during the adult migration window for CV Steelhead on the Stanislaus River below Goodwin Dam range from 43.6 degrees in January in some years to 72 degrees in some July months. In the without action, temperatures would be above 68 degree Fahrenheit migrating adult threshold in 70% of July months, 60% of August months, 30% of September months, and then is below 68 degrees for the rest of the adult migration window. Temperatures would be below the 61 degrees Fahrenheit adult holding threshold in the without action in November through March in all years under the Without Action. Under the proposed action, temperatures would be below 68 degrees and below 61 degrees from July through March in all water years. The largest differences between the WOA and the proposed action are in January, where the proposed action is up to 4 degrees Fahrenheit warmer than WOA but still below CV Steelhead temperature thresholds, and in September, where the WOA is 12 degrees Fahrenheit warmer than the proposed action and exceeds adult migration as well as adult holding temperatures. Therefore, the proposed action also provides a temperature benefit to CV Steelhead, by providing optimal temperatures during their entire adult migration window.

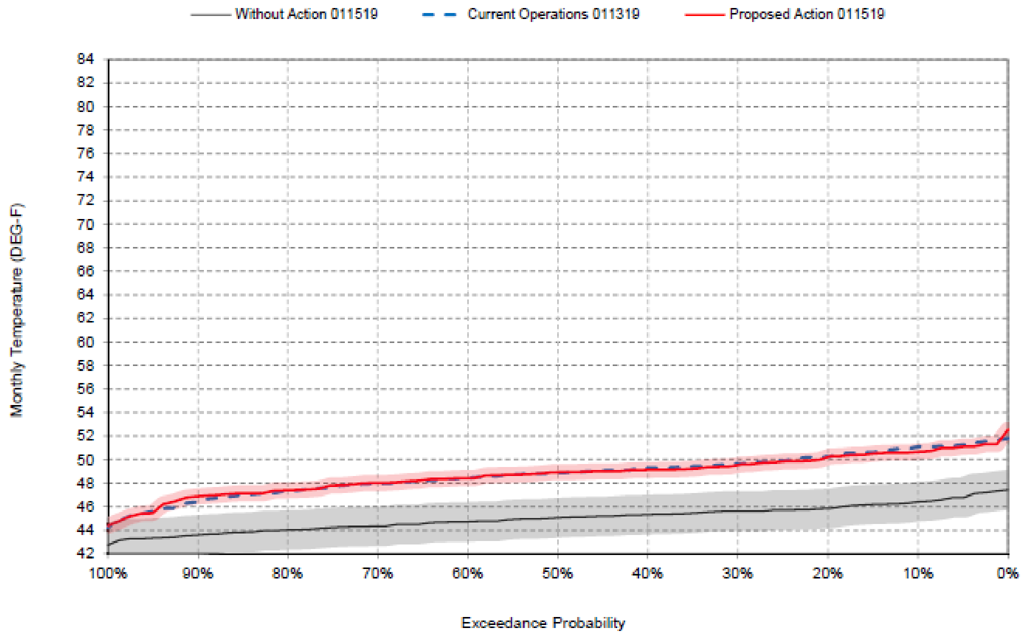


Figure 5.10-23. Exceedance Probability of January Temperatures below Goodwin Dam

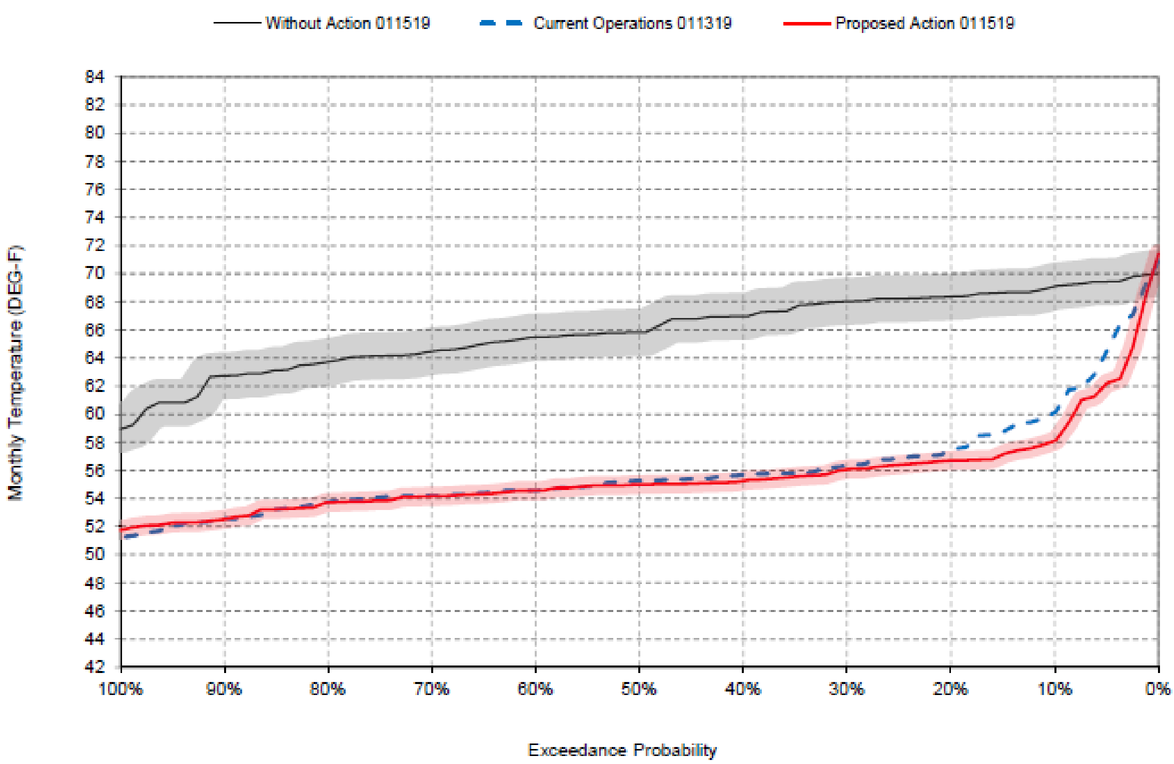


Figure 5.10-24. Exceedance Probability of September temperatures in the Stanislaus River below Goodwin Dam

5.10.3.15 Stanislaus River Dissolved Oxygen

Reclamation currently operates to meet a DO requirement on the lower Stanislaus River of 7.0 mg/L at Ripon from June 1 to September 30. Under the proposed action, Reclamation would operate to meet the same DO requirement at Orange Blossom Bridge, approximately 31 miles upstream from Ripon, where salmonids are primarily located at that time of year.

5.10.3.15.1 Rearing to Outmigrating Juveniles

Based on multi-year observations of salmonid abundance in the Stanislaus River, Kennedy and Cannon (2005) and Kennedy (2008) found that over-summering juvenile salmonids are primarily found upstream of Orange Blossom Bridge. Dissolved oxygen monitoring at the Stanislaus River Weir (approximately 15 miles upstream from Ripon) indicates that DO concentrations can be 0.5-1 mg/L higher at this location than those measured at Ripon (Cramer Fish Sciences 2006a-d). Because the fish are generally located at least twice this distance upstream, the DO concentration there is likely to be higher than at the Stanislaus River Weir. The majority of juvenile CV Steelhead are found at locations where summer DO levels would meet or exceed 7 mg/L.

5.10.3.15.2 Adult Migration from Ocean to Rivers

Based on the typical seasonal occurrence of this life stage in the Stanislaus River (mid-January to late June), adult migrating CV Steelhead would not be expected to be exposed to the effects of altering the DO requirements at Ripon.

5.10.4 Effects of Conservation Measures

The following are proposed conservation measures that are intended to offset the effects of operations and maintenance. These conservation measures would only occur due to the implementation of the proposed action and are beneficial in nature. The following analysis looks not only at the construction related effects of the measures, but also the benefits to the population once completed. Conservation measures would not occur under WOA conditions.

5.10.4.1 Lowering Intakes Near Wilkins Slough

5.10.4.1.1 Eggs to Fry Emergence

The installation of fish screens near Wilkins Slough would be beneficial to CV Steelhead. The installation of new diversions and screens that would operate at lower flows would indirectly benefit fish of all life stages. Specifically, operation of diversions near Wilkins Slough at lower flows could increase Shasta and Trinity water storage and cold-water pool. As a result, additional water may be available for Keswick releases to:

- Improve water temperatures and dissolved oxygen during egg incubation;
- Improve water quality, and subsequently increase redd quality and decrease the risks of pathogens and disease; and
- Reduce the risks of redd dewatering and stranding.

Adult migration from the ocean to spawning grounds occurs during much of the year, with peak migration occurring in the fall or early winter. Migration through the Sacramento River mainstem begins in July, peaks at the end of September, and continues through February or March (OCAP BA 2008). In the upper

Sacramento River spawning occurs between November 15 through April, peaking in November through December and during April. Fry are present for another four to six weeks within the gravel (OCAP BA 2008) prior to moving into shallow protected areas associated with the stream margin (OCAP BA 2008). Wilkins Slough does not contain suitable spawning habitat; therefore, CV Steelhead are not likely to spawn there and subsequently there is a very low potential for eggs and fry to be present. The lack of suitable habitat, implementation of an in-water work window (June 1 through October 1), and other AMM's identified in Appendix E minimizes the potential for CV Steelhead egg and fry to be affected by the action.

5.10.4.1.2 Rearing to Outmigrating Juveniles

The fish screens would directly benefit rearing and outmigrating juvenile Steelhead by reducing mortality risks from entrainment, thus increasing the survival of rearing and outmigrating juveniles, and in turn potentially increasing successful CV Steelhead recruitment. The installation of new diversions and screens that operate at lower flows would indirectly benefit rearing and outmigrating juvenile CV Steelhead. Specifically, this action could increase Shasta and Trinity water storage. As a result, additional water may potentially be available for Keswick releases and spring pulse flows that would:

- Provide access to floodplains, side channels, and refuge habitat;
- Decrease predation risks to outmigrating juveniles; and
- Increase emigration cues.

CV Steelhead rear year-round in the upper Sacramento River basin (OCAP BA 2008). Construction activities have the potential to affect rearing CV Steelhead that move downstream and through Wilkins Slough. Rearing CV Steelhead have the potential to be exposed to temporary increases to turbidity and associated decrease in DO, underwater noise associated with construction of a cofferdam for in-water work. Additionally, the installation of a cofferdam (if needed) increase the risk of mortality of Steelhead through fish rescue operations required to remove fish from the dewatered work area. Implementation of an in-water work window (June 1 through October 1), and other AMM's identified in Appendix E, aim to minimize the duration and likelihood of these potentially adverse effects to rearing CV Steelhead.

CV Steelhead emigrate downstream from the Upper Sacramento River basin between November and July, with peak emigration occurring January through March. Construction activities would not affect emigrating Steelhead as an in-water work window (June 1 through October 1) would be implemented, in addition to other standard AMM's.

5.10.4.1.3 Adult Migration from Ocean to Rivers

The installation of new diversions and screens near Wilkins Slough that would operate at lower flows would indirectly benefit migrating adult CV Steelhead. Specifically, this action could increase Shasta and Trinity water storage and cold-water pool. As a result, additional water may potentially be available for Keswick releases that would:

- Decrease water temperatures and increase DO during adult migration;
- Decrease the risks of disease and pathogens;
- Decrease concentrations of contaminants; and
- Increase migration cues and decrease straying.

Adult CV Steelhead migrate from the ocean to spawning grounds during much of the year, with peak migration occurring in the fall or early winter. Migration through the Sacramento River mainstem begins in July, peaks at the end of September, and continues through February or March (OCAP BA 2008). Implementation of an in-water work window (June 1 through October 1) would reduce the effects on migrating Steelhead; however, the onset of in-water work would occur prior to the peak of migration (end of September). Any CV Steelhead that may be present in Wilkins Slough during the onset of in-water construction activities may be exposed to temporary increases in turbidity and associated DO, and underwater noise associated with the construction of a cofferdam. Additionally, fish rescue activities may need to occur, thus increasing the risk of survival associated with moving fish within the coffered area to the mainstem of the slough. Reclamation will coordinate with the resource agencies prior to the onset of construction activities to determine if any other AMM's are required.

5.10.4.1.4 Adult Holding

Historically adult CV Steelhead maintained several strategies during their migration to natal rivers in preparation for spawning. Some CV Steelhead return several months prior to spawning and hold over in pools while sexually maturing, others sexually matured in the ocean before returning to freshwater (Williams 2006). The former life-history strategy required suitable cold-water habitat for holding. However, anadromous CV Steelhead predominantly mature in the ocean (McEwan 2001) and do not hold prior to maturation and spawning. Wilkins Slough does not contain suitable habitat (cold water) for holding nor is this a common life-history strategy expressed in CV Steelhead. Therefore, construction activities are not anticipated to affect holding CV Steelhead due to implementation of an in-water work window (June 1 through October 1) and other AMM's identified in Appendix E.

5.10.4.2 Shasta TCD Improvements

5.10.4.2.1 Eggs to Fry Emergence

Water temperature has a major influence on CV Steelhead, directly affecting survival, growth rates, distribution, and developmental rates (NMFS 2009). Steelhead embryo incubation period (i.e., January through May) occurs in the winter and spring following spawning. The implementation of the proposed Shasta TCD would improve Reclamation's ability to manage temperatures in the Sacramento River and meet water temperature requirements for CV Steelhead, improving conditions for this life stage. Therefore, this action would have high-level population benefits on this life stage of CV Steelhead.

5.10.4.2.2 Rearing to Outmigrating Juveniles

Water temperature can affect juvenile rearing and outmigration and adult immigration and holding within the Sacramento River. CV Steelhead can be found where daytime water temperatures range from nearly 32°F to 81°F in the summer, although mortality may result at extremely high (i.e., > ~73°F) water temperatures if the fish have not been gradually acclimated (Moyle 2002). Juvenile CV Steelhead in northern California rivers reportedly exhibited increased physiological stress, increased agonistic activity, and a decrease in forage activity after ambient stream temperatures exceeded 72°F (Nielsen et al. 1994). Since juvenile CV Steelhead rear in streams for 1-3 years and are present year round (Table 5.10-1), they would be affected by the effects of drought related excessively high water temperatures. The implementation of the proposed Shasta TCD would improve Reclamation's ability to manage temperatures in the Sacramento River and meet water temperature requirements for CV Steelhead.

5.10.4.2.3 Adult Migration from Ocean to Rivers

Adult CV Steelhead are affected by excessively high water temperatures due to their presence within the Sacramento River in the summer and fall. The implementation of this action would improve Reclamation's ability to manage temperatures in the Sacramento River and meet water temperature requirements for CV Steelhead, improving conditions for this life stage.

5.10.4.2.4 Adult Holding

As discussed above, the implementation of the proposed Shasta TCD would improve Reclamation's ability to manage temperatures in the Sacramento River and meet water temperature requirements for CV Steelhead, improving conditions for this life stage.

5.10.4.3 Sacramento River Spawning and Rearing Habitat

The creation of side channel and rearing habitat under the proposed action would increase the quality and quantity of off channel rearing and spawning areas in the Sacramento River. These habitat restoration activities would improve the riparian habitat available for emerging CV Steelhead fry, providing an overall benefit to the species.

Based on the proposed in-water work windows for the upper Sacramento River (AMM2), CV Steelhead adults, eggs, and alevins would be subject to potential adverse effects from proposed spawning (e.g, gravel augmentation) and rearing habitat (e.g., side channel) restoration projects in the upper Sacramento River. Construction activities could result in mortality of eggs and alevins by crushing if heavy equipment enters the stream channel or otherwise disturbs existing redds during in-water activities. Eggs and alevins could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality in the redd (e.g., reduced flow and dissolved oxygen from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants.

Although these potential effects may be unavoidable, exposure of the CV Steelhead population to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of spawning adults, and the implementation of other AMMs described in Appendix E. These measures include AMM1, which requires worker awareness training, AMM2, which specifies monitoring oversight by a qualified biologist, and AMM3-5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment.

5.10.4.4 Deer Creek Fish Passage

Deer Creek is a tributary of the Sacramento River with natural production of steelhead. DWR and Reclamation's installation of a nature-like fishway at the DCID diversion dam will provide steelhead access to approximately 25 miles of spawning habitat in Deer Creek upstream from the DCID dam.

Construction effects are the same as discussed above for Sacramento River spawning and rearing habitat. Exposure to these effects would be minimized with incorporation of the avoidance and minimization measures.

5.10.4.5 Small Screen Program

5.10.4.5.1 Egg to Fry Emergence

CV Steelhead in the egg-to-emergence life stage would not be expected to be exposed to the effects of operation or construction of screens on water diversion intakes based on the seasonal occurrence of this life stage in the Sacramento River, and the geographic location of redds away from diversions. This life stage occurs over a 2-2.5 month period from mid-February through June following the December to April Steelhead spawning period (NMFS 2009), which is outside of the timing of the in-water construction (August–October).

5.10.4.5.2 Rearing to Outmigrating Juveniles in the Rivers

The operation of fish screens on water diversions under the proposed action would benefit juvenile CV Steelhead by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for negative impacts to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage.

Juvenile CV Steelhead rearing and outmigrating in the Sacramento River may be exposed to the effects of construction of screens under the proposed action since juvenile CV Steelhead spend one to three years in freshwater prior to migration to the ocean (CDFG 1996). Juvenile CV Steelhead may be found in the work area of these projects. Potential short-term negative impacts may include temporary effects to water quality as result from in-water work, resulting in increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. CV Steelhead juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E. In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.10.4.5.3 Rearing to Outmigrating Juveniles in the Bay Delta

Fish screens under the proposed action would also benefit this lifestage in the same ways described above. Juvenile CV Steelhead outmigrating in the Bay-Delta may be exposed to the effects of construction of screens since they migrate downstream during most months of the year, with a peak emigration period in the spring and a smaller peak in the fall (Hallock et al. 1961). Juvenile CV Steelhead may be found in the work area of these projects; however, AMMs would minimize impacts.

5.10.4.5.4 Adult Migration

The operation of fish screens on water diversions under the proposed action would benefit adult migrating CV Steelhead by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. Adult CV Steelhead may be exposed to the effects of construction of screens on water diversion intakes associated with the proposed action based on the overlap of timing of in-water construction (July 15 – October 15) and the timing this life stage in the Sacramento River. AMMs would minimize effects.

5.10.4.5.5 Adult Holding

The operation of fish screens on water diversions under the proposed action would benefit CV Steelhead by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. Adult CV Steelhead holding in the Sacramento River may be exposed to the effects of construction of screens on water diversion intakes associated with the proposed action due the overlap of the timing of in-water construction (August–October), and the seasonal occurrence of this life stage in the Sacramento River. AMMs would minimize effects.

5.10.4.6 Adult Rescue

The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult CV Steelhead, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the number of CV Steelhead of all lifestages in the Sacramento River and its tributaries.

5.10.4.6.1 Egg to Fry Emergence

Given that this life stage is carried out in gravel substrates and adult rescue activities would occur downstream of CV Steelhead spawning areas in the Sacramento River and its tributaries, there would be no direct effects on this life stage from implementing adult rescue activities.

5.10.4.6.2 Rearing to Outmigrating Juveniles in Rivers

Although CV Steelhead are less likely to use floodplain habitat, including the Yolo and Sutter bypasses, than Chinook salmon, there is a potential for juveniles to occur in the Yolo and Sutter Bypasses when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. Although they are unlikely to occur in the bypasses during periods when flow does not overtop the weirs, proposed modifications to the Fremont Weir to increase inundation of the Yolo bypass for floodplain rearing would provide juveniles with more consistent access to the Yolo bypass. Therefore, these juveniles could be exposed to the effects of adult rescue activities if they become stranded with adults that are targeted by adult rescue activities.

The number of juvenile CV Steelhead that would be expected to be exposed to the effects of adult rescue activities would be based on the timing of proposed adult rescue activities, gear type used to rescue adults, and the typical seasonal occurrence of this life stage in the Yolo and Sutter bypasses. Individual juvenile CV Steelhead exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality during efforts to capture stranded adults, handling, and transport. Injury and increased stress associated with capture, handling, and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on the timing of collection, as fish collected later in the season when water quality conditions (e.g., water temperature) generally are more stressful for fish may make juveniles more susceptible to injury and stress-related effects. The risk from these potential effects would be minimized through application of AMM8, and any potential adverse effects on individual juvenile CV Steelhead would be expected to be offset by benefits associated with increased numbers of adult CV Steelhead returning to spawning grounds. As such, the overall population-level negative effects on this life stage of CV Steelhead from adult rescue activities would be low relative to WOA conditions (i.e., no rescue of adult CV Steelhead in Yolo and Sutter bypasses).

5.10.4.6.3 Rearing to Outmigrating Juveniles

Given that this life stage is carried out in the Bay-Delta and adult rescue activities would occur upstream in the Yolo and Sutter bypasses, there would be no direct effects on this life stage from implementing adult rescue activities.

5.10.4.6.4 Adult Migration from Ocean to Rivers

Exposure of this life stage to adult rescue effects would be restricted only to those adult CV Steelhead that become stranded in the Yolo and Sutter bypasses and subsequently rescued and released to the Sacramento River. Adults that migrate in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by adult rescue activities. The number of adult CV Steelhead that would be expected to be exposed to the effects of adult rescue activities would be based on the abundance of adults that stray into the bypasses and the timing and frequency of stranding events in the bypasses. Individual adult CV Steelhead exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality, which could vary in intensity depending on the techniques used to capture individuals. Injury and increased stress associated with capture, handling and transport may affect survival of individuals after release. The risk from these potential effects would be minimized through application of AMM8. As such, it is concluded that the overall population-level negative effects on this life stage of CV Steelhead from adult rescue activities would be low relative to WOA conditions (i.e., no rescue of stranded adult CV Steelhead in Yolo and Sutter bypasses).

5.10.4.6.5 Adult Holding

Given that this life stage is carried out in the upper Sacramento River and its tributaries and adult rescue activities would occur downstream in the Yolo and Sutter bypasses, there would be no direct effects on this life stage from implementing adult rescue activities.

5.10.4.7 Juvenile Trap and Haul

The operation of juvenile trap and haul is targeted towards juvenile CV Steelhead, with the goal of increasing the survival of juveniles and, ultimately, returning adults. This effort could increase the number of CV Steelhead of all lifestages in the Sacramento River and its tributaries.

5.10.4.7.1 Egg to Fry Emergence

Given that this life stage is carried out in gravel substrates and temporary juvenile collection weirs would be placed downstream of CV Steelhead spawning areas in the Sacramento River and its tributaries, there would be no direct effects on this life stage from implementing juvenile trap and haul activities.

5.10.4.7.2 Rearing to Outmigrating Juveniles in Rivers

The number of juvenile CV Steelhead that would be expected to be exposed to the effects of juvenile trap and haul activities would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trapping location and efficiency, and the typical seasonal occurrence of this life stage in the Sacramento River (Table 5.10-1). Individual juvenile CV Steelhead exposed to juvenile trap and haul activities would be at risk of increased stress, injury, and/or mortality. Injury and increased stress associated with handling and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release.

Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8, and any potential adverse effects on individual juvenile CV Steelhead would be expected to be offset by benefits associated with expected increased survival of the overall brood-year of CV Steelhead. As such, it is concluded that the overall population-level negative effects on this life stage of juvenile CV Steelhead from juvenile trap and haul activities would be low relative to WOA conditions (i.e., no trapping and hauling of juvenile CV Steelhead during drought years) and would be potentially offset by benefits (i.e., increased juvenile survival and ultimately increased adults returning to spawn) associated with the juvenile trap and haul program.

5.10.4.7.3 Rearing to Outmigrating Juveniles in Bay-Delta

Exposure of this life stage to trap and haul effects would be restricted only to those juvenile CV Steelhead trapped in the Sacramento River and subsequently released to the lower Sacramento River and/or Bay-Delta. Wild juveniles that migrate in-river to the Bay-Delta (either before December 1 or that avoid capture by the temporary juvenile collection weirs after December 1) would not be affected by juvenile trap and haul activities. Potential effects associated with juvenile trap and haul on this life stage would be same as those described for Winter-run Chinook Salmon juveniles. The risk from these potential effects would be minimized through application of AMM8, and any potential adverse effects on individual juvenile CV Steelhead would be expected to be offset by benefits associated with expected increased survival of the overall brood-year of CV Steelhead. As such, the overall population-level negative effects on this life stage of juvenile CV Steelhead from juvenile trap and haul activities would be low relative to WOA conditions.

5.10.4.7.4 Ocean Juvenile to Ocean Adult

Exposure of this life stage to trap and haul effects would be restricted only to those juvenile CV Steelhead trapped in the Sacramento River and subsequently released to the lower Sacramento River and/or Bay-Delta, and that enter the ocean. Wild juveniles that migrate in-river to the ocean would not be affected by juvenile trap and haul activities. The overall population-level negative effects on this life stage of juvenile CV Steelhead from juvenile trap and haul activities would be low relative to WOA conditions.

5.10.4.7.5 Adult Migration from Ocean to Rivers

Exposure of this life stage to trap and haul effects would be restricted only to those adult CV Steelhead that were trapped in the Sacramento River as juveniles and subsequently released to the lower Sacramento River and/or Bay-Delta as part of the juvenile trap and haul program. Ocean adults that had out-migrated in-river as juveniles would not be affected by juvenile trap and haul activities. Because transported juveniles are more likely to have impaired homing behavior as adults, juvenile trap and haul activities may increase the rate of straying by returning adults. Adults that stray into tributaries with suitable habitat may compete with native-run adults for spawning space, excavate or superimpose their redds on the redds of native-run fish, or spawn with native-run fish, thereby introducing genes from neighboring populations that have strayed into the river. However, it is concluded that the overall population-level negative effects on this life stage of adult CV Steelhead from juvenile trap and haul activities would be low relative to

WOA conditions and would be potentially offset by benefits (i.e., increased juvenile survival and ultimately increased adult escapement) associated with the juvenile trap and haul program.

5.10.4.7.6 Adult Holding

Because juvenile trap and haul would target only wild juveniles during outmigration, adult CV Steelhead holding in rivers would not be directly affected by juvenile trap and haul activities. However, because the purpose of juvenile trap and haul activities is to increase the survival rate of juveniles during drought years, the number of adults holding in rivers potentially would be greater relative to the WOA conditions as a result of increased juvenile survival and, ultimately, increased adult spawners.

5.10.4.8 Spawning and Rearing Habitat (American River)

5.10.4.8.1 Eggs to Fry Emergence

Eggs and emerging fry would benefit from increased side channel habitat, gravel, and large wood resulting from habitat restoration in the American River. Effects include an increase in total spawning habitat area, improved intragravel incubation conditions and reduced likelihood of redd superimposition. Therefore, this action would benefit this life stage of CV Steelhead.

No eggs and emerging fry would be exposed to construction of side channel habitat, gravel, gravel augmentation, and large wood installation, based on the timing of the in-water work window (July 1-September 30) and seasonal occurrence of this life stage in the American River (December-April; Table 5.10-1). CV Steelhead spawn as early as December and as late as early April with the peak in February. All fry are out of the gravel before July when construction could begin. There would be no impact from construction to this lifestage in the American River.

5.10.4.8.2 Rearing to Outmigrating Juveniles

Rearing and outmigrating individuals would benefit from increased side channel habitat, gravel, and large wood resulting from habitat restoration in the American River. Effects include an improved likelihood of rearing success due to an increase in total rearing habitat area, and rearing habitat quality.

Rearing and outmigrating juveniles could be exposed to construction of side channel habitat, gravel augmentation, and large wood installation. Juvenile CV Steelhead grow quickly in the American River and young of the year are 100 mm or larger by the time construction activity starts in the summer. These fish are often attracted by the disturbance from construction activity and are able to swim quickly to desirable locations when in close proximity to construction activities. Construction activities in the American River could result in mortality of this life stage if crushed by heavy equipment, if individuals were stranded or isolated during dewatering. This life stage could be negatively affected by degraded water quality from contaminant discharge by heavy equipment and discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., reduced ability to take in oxygen, increasing metabolic cost), and reduced foraging ability caused by decreased visibility. Outmigration timing does not overlap with construction activities so there would be no effect on outmigrating juvenile CV Steelhead.

Construction activities are temporary and exposure to effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention, and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed construction activities would be minimized.

5.10.4.8.3 Adult Migration from Ocean to Rivers

Completion of restoration activities would increase the number of CV Steelhead of all life stages within the CVP watershed. Early migrating CV Steelhead adults may be exposed to construction of side channel habitat, gravel augmentation, and large wood installation, based on the timing of the in-water work window (July 1-September 30) and seasonal occurrence of this life stage in the American River. Adult CV Steelhead are strong swimmers and able to avoid construction activities in the American River. Migrating adults could be negatively affected by degraded water quality from contaminant discharge by heavy equipment, and increased discharges of suspended solids and turbidity, leading to direct physiological or physiological impacts on fish health/performance (e.g., reduced ability to take in oxygen, increasing metabolic cost), loss of aquatic vegetation providing physical shelter, and delay in migration caused by elevated noise levels from machinery.

Construction activities are temporary and exposure to effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed construction activities would be minimized.

5.10.4.8.4 Adult Holding

Generally CV Steelhead do not hold over during the summer months though if present, holding adults could be exposed to construction of side channel habitat, gravel augmentation, and large wood installation based on the timing of the in-water work window (July 1-September 30). Holding pools are typically in deep water near mid-channel and away from shallower riffles, pool tails, and channel margins where most gravel augmentation and side channel construction would occur. When construction activities in the American River occur near holding pools, holding adults could be displaced, injured, or killed by heavy equipment strikes or disturbance of suitable habitat during manipulation of gravel or creation of side channels. Adult CV Steelhead are strong swimmers and able to avoid construction activities. Holding adults could be negatively affected by degraded water quality from contaminant discharge by heavy equipment and increased discharges of suspended solids and turbidity, leading to direct toxicological or physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost).

Exposure to effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. With application of AMM 1–5 the temporary, negative effects that may result from construction of side channel habitat, gravel augmentation, and large wood installation would affect few if any holding adult CV Steelhead. Completion of restoration activities would increase the number of CV Steelhead of all life stages within the CVP watershed.

5.10.4.9 Drought Temperature Facility Improvements (American River)

Under the proposed action, Reclamation proposes to evaluate and implement alternative shutter configurations at Folsom Dam to allow temperature flexibility in severe droughts, thereby reducing water temperatures in the lower American River. Water temperature is perhaps the physical factor with the greatest influence on CV Steelhead, directly affecting survival, growth rates, distribution, and developmental rates (NMFS 2009). Warm water temperatures have been identified as a key stressor for CV Steelhead in the American River, particularly below dams, affecting juvenile rearing and outmigration and adult immigration and holding. Since juvenile CV Steelhead rear in streams for one to three years and are present year round (Table 5.10-1), they would be affected by drought related excessively high water temperatures. The implementation of the proposed drought temperature management measures would improve Reclamation’s ability to manage water temperatures in the lower American River and meet water temperature requirements for CV Steelhead during drought conditions and improve conditions for all life stages.

5.10.4.10 Spawning and Rearing Habitat (Stanislaus River)

5.10.4.10.1 <u>Eggs to Fry Emergence</u>

Juvenile CV Steelhead occur in the Stanislaus River, but those individuals may assume a resident life history that is not ESA protected like the anadromous life history of CV Steelhead. *O. mykiss* only become CV Steelhead upon outmigrating to the ocean. The weir on the Stanislaus River has counted only 82 CV Steelhead (i.e., O. mykiss longer than 16 inches) during escapement monitoring from 2003 to 2017 (no spring monitoring occurred in 2006 and 2008; Figure 5.10-26) (FishBio2012). These fish were categorized based on length, which is a standard practice. *O. mykiss* that have reared in the ocean and become CV Steelhead are generally much larger than their resident counterpart that reared only in freshwater. The individuals detected on the Stanislaus River did not receive additional testing to determine if the individuals completed an anadromous life history or not. While less common, larger resident *O. mykiss* can occur; so, there remains a degree of uncertainty as to determining resident or CV Steelhead origins.

Habitat restoration activities would directly benefit CV Steelhead, increasing the quantity and quality of spawning habitat in the Stanislaus River. Additionally, the created side channel and floodplain habitat would provide additional refuge for outmigrating juvenile CV Steelhead.

Construction activities associated with spawning and rearing habitat restoration under the proposed action are not expected to result in any direct effects to CV Steelhead eggs or emerging fry, based on timing of in-water construction (July 15 through October 15), typical seasonal occurrence of this life stage in the Stanislaus River (December through June), and implementation of general avoidance and minimization measures.

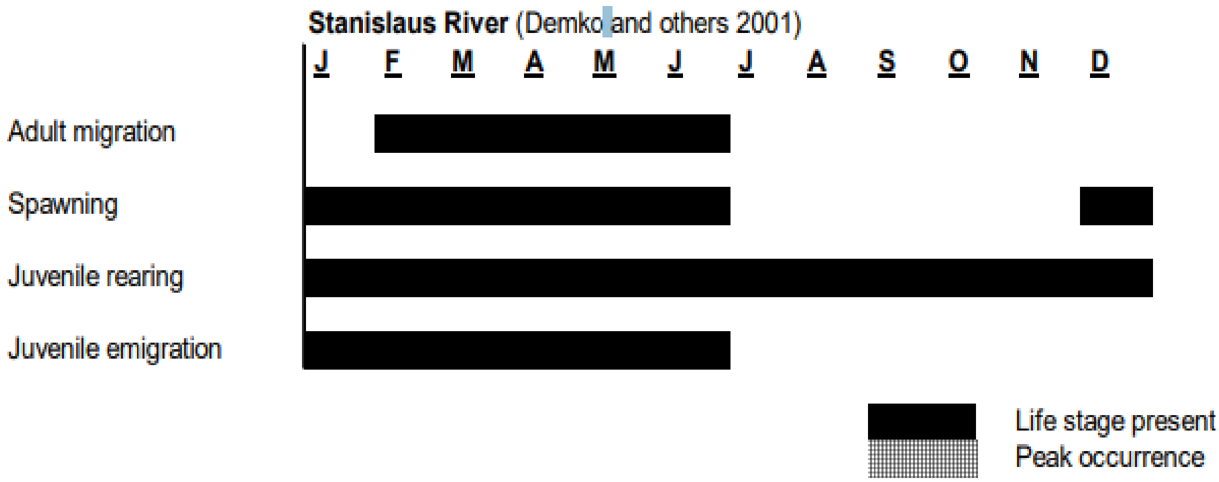


Figure 5.10-25. Stanislaus River Weir *O. mykiss* Passage (FishBio 2012)

5.10.4.10.2 Rearing to Outmigrating Juveniles

The creation of side channel and rearing habitat under the proposed action would increase the quality and quantity of off channel rearing and spawning areas in the Stanislaus River. The habitat restoration activities would improve the riparian habitat available for juvenile CV Steelhead rearing. Habitat restoration activities within the Stanislaus River would yield benefits including increasing existing riparian vegetation, providing instream and overhanging object cover, new shaded riverine habitat, and additional area for food production.

The creation of side-channel and floodplain rearing habitat would also increase the aquatic habitat complexity and diversity within the Stanislaus River and provide additional predator escape cover. The creation of side channel and floodplain habitat would increase the quality and quantity of rearing habitat available to CV Steelhead. Reclamation expects that the creation of 50 acres of side channel and floodplain habitat, would support the progeny of 2,800 adult salmon. The habitat restoration would result in an overall benefit to the CV Steelhead.

Construction activities associated with spawning and rearing habitat construction are not expected to result in impacts to CV Steelhead juveniles, based on timing of in-water construction (July 15 through October 15), typical seasonal occurrence of this life stage in the Stanislaus River (December through June), and implementation of general avoidance and minimization measures.

5.10.4.10.3 Adult Migration from Ocean to Rivers

The creation of side channel and floodplain habitat under the proposed action would increase the quality and quantity of spawning available. Additionally the placement of additional spawning gravel would create an additional 34 acres of spawning habitat available to immigrating CV Steelhead. The habitat restoration would result in an overall benefit to CV Steelhead.

Construction activities associated with habitat restoration under the proposed action will not affect immigrating CV Steelhead. Construction activities would occur during an in-water work window of July 15 through October 15, when the species is not present in the Stanislaus River. No effects would occur on CV Steelhead individuals and/or populations during this life stage.

5.10.4.10.4 Adult Holding

The construction activities under the proposed action associated with spawning habitat restoration are not expected to affect adults holding in the Stanislaus River due to the implementation of general avoidance and minimization measures. The habitat restoration activities would increase the quality and quantity of off channel habitat areas available for CV Steelhead.

5.10.4.11 Stanislaus River Temperature Management Study

As part of the proposed action, Reclamation will study approaches to improving temperature for listed species on the lower Stanislaus River, to include evaluating the utility of conducting temperature measurements/profiles in New Melones Reservoir. This study will help inform operational abilities to control temperature in the Stanislaus River, which could benefit fish in the future.

5.10.4.12 Lower SJR Habitat

Lower San Joaquin Rearing Habitat restoration is expected to result in similar effects as those described above for Stanislaus River Spawning and Rearing Habitat.

5.10.4.13 Suisun Marsh Salinity Control Gates Operation

CV Steelhead juveniles are in the Delta in the spring. Reclamation proposes to operate the Suisun Marsh Salinity Control Gate between June to October. The last few CV Steelhead juveniles could possibly benefit from increased food production due to this action in the Delta.

5.10.4.14 Summer-Fall Delta Smelt Habitat

CV Steelhead juveniles are in the Delta in the spring. Reclamation proposes to conduct actions for Summer-Fall Delta Smelt Habitat in the fall, as adult CV Steelhead are migrating upstream. Summer-Fall Delta Smelt Habitat actions are unlikely to affect adult CV Steelhead.

5.10.4.15 Clifton Court Predator Management

Clifton Court predator management under the proposed action could reduce pre-screen loss of juvenile CV Steelhead entrained into CCF; therefore, providing a benefit for all life stages of CV Steelhead.

5.10.4.16 San Joaquin Steelhead Telemetry Study

The San Joaquin Steelhead telemetry study under the proposed action would include inserting acoustic tags into San Joaquin origin juvenile CV Steelhead to track them as they move through the south Delta. Acoustic arrays would monitor their presence. This study would help fill a gap in knowledge related to CV Steelhead survival on the San Joaquin River. Only the juvenile lifestage of CV Steelhead would be affected by the study, as they are the only lifestage of fish that would be tagged. Tagged fish could have mortality associated with surgery to insert the tag, shock, and reduced swimming leading to increased predation as a result of the acoustic tag in their stomach cavity.

5.10.4.17 Sacramento Deepwater Ship Channel Food Study

Moderate to high proportions of CV Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under the proposed action. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile CV Steelhead abundance in the Delta peaks in February through May (Table 5.10-1). Juvenile CV Steelhead passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No CV Steelhead are expected to be exposed to the Sacramento Deepwater Ship Channel construction, as the in-water work window does not overlap with their occurrence in the Delta.

5.10.4.18 North Delta Food Subsidies/Colusa Basin Drain Study

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall, and does not overlap in time or space with juvenile CV Steelhead occurrence in the Delta. There would not be any effect to CV Steelhead adults.

5.10.4.19 Suisun Marsh Roaring River Distribution System Food Subsidies Study

Under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on CV Steelhead juveniles, who are in the Delta between December and July. The action is not expected to have any effect on CV Steelhead adults.

5.10.4.20 Tidal Habitat Restoration

A large proportion of juvenile CV Steelhead are expected to benefit from 8,000 acres of tidal habitat restoration in the Delta under the proposed action. Tidal habitat restoration is expected to benefit juvenile CV Steelhead in several aspects represented by the Winter-run Chinook salmon conceptual model (Figure 5.6-4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta; however, the Delta only represents a small fraction of the total migration route.

Few if any juvenile CV Steelhead would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Table 5.10-1). There may be exposure of a few late migrants, as illustrated by timing of occurrence in Chipps mid-water trawls (Table 5.10-1). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. The risk from these potential effects would be minimized through application of AMMs.

5.10.4.21 Predator Hot Spot Removal

Predator hot spot removal under the proposed action is primarily focused on providing positive effects to downstream-migrating juvenile salmonids, including CV Steelhead. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of CV Steelhead. All hotspots are limited in scale relative to overall available habitat, and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012, Michel et al. 2017, Sabal et al. 2017). However, implementation of this action would likely improve conditions for all life stages of CV Steelhead.

5.10.4.22 San Joaquin River Scour Hole Predator Reduction

Steelhead outmigrating from the San Joaquin River are exposed to predation at the junction of the San Joaquin River and Old River. This action would reduce predation at this site, improving juvenile steelhead survival.

Few steelhead are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction to adjust bathymetry would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.10.4.23 Knight’s Landing Outfall Gates Fish Barrier

Reclamation and DWR’s fish barrier at the Knight’s Landing Outfall Gates would prevent possible entrainment of salmonids into the Colusa Basin Drain. This project would reduce entrainment and therefore increase survival of steelhead adults.

Few steelhead are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.10.4.24 Delta Cross Channel Gate Improvements

Completion of DCC gate improvements would benefit CV Steelhead of all life stages within the CVP watershed systems. The peak migration of juvenile CV Steelhead in the Sacramento River past Hood, which is near the DCC, occurs from February through mid-June (Table 5.10-1). No San Joaquin River-origin CV Steelhead are expected to be exposed to the DCC construction. As previously described, juvenile CV Steelhead are largely absent from the Delta between August and November (Table 5.10-1) and, therefore, at most a few late migrants have the potential to be exposed to potential construction from improvements to the DCC under the proposed action.

5.10.4.25 Tracy Fish Facility Improvements

Small proportions of Sacramento River-origin CV Steelhead and moderate proportions of Mokelumne River and San Joaquin River-origin CV Steelhead are expected to be exposed to the Tracy Fish Facility.

However, for fish that arrive at the facility, the proposed improvements resulting in greater salvage efficiency under the proposed action are likely to increase survival of juvenile CV Steelhead.

As previously described, juvenile CV Steelhead are largely absent from the Delta between August and November (Table 5.10-1) and, therefore, none to a few late migrants or early migrants have the potential to be exposed to the effects of construction of the carbon dioxide injection device proposed for the Tracy Fish Facility Improvements. Risks of decrease CV Steelhead juvenile salvage during construction would be minimized through appropriate AMMs.

5.10.4.26 Skinner Fish Facility Improvements

Skinner fish facility improvements under the proposed action to reduce predation on listed fishes following entrainment into CCF could reduce pre-screen loss of juvenile CV Steelhead entrained into CCF; therefore, providing a benefit for all life stages of CV Steelhead.

5.10.4.27 Delta Fishes Conservation Hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) indicate that potential impacts are less than significant. Potential exposure of juvenile CV Steelhead would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities in the Delta under the proposed action, juvenile CV Steelhead are largely absent from the Delta between August and November (Table 5.10-1) which means that none to a few late or early migrants of this life stage could be exposed to Delta Fishes Conservation Hatchery construction. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.10.4.28 Effects of Monitoring

Population estimates for wild steelhead remain outstanding in the Central Valley, therefore it is difficult to quantify the effects of the monitoring on steelhead populations. However, most existing monitoring programs in the Central Valley and Delta/SF Estuary are not designed to capture steelhead, which are much larger than Chinook Salmon upon river and Delta entry. Existing programs likely have poor capture efficiency for collecting and retaining steelhead. Therefore, it is unlikely the monitoring programs have any effects to the population. Reclamation and DWR have proposed one continuing and two new steelhead monitoring programs as part of the proposed action. These include the San Joaquin Basin Steelhead Telemetry Study, which is a continuation of the 6-Year Steelhead telemetry study for the migration and survival of San Joaquin Origin Central Valley Steelhead. In addition, Reclamation and DWR will develop a Steelhead Lifecycle Monitoring Program, which will support a functioning life cycle monitoring program in the Stanislaus River and a Sacramento basin CVP tributary (e.g. Clear Creek, Upper Sacramento, American River) to evaluate how actions related to stream flow enhancement, habitat restoration, and/or water export restrictions affect biological outcomes including population abundance, age structure, growth and smoltification rates, and anadromy and adaptive potential in these two populations. The goal of this monitoring program will be to improve understanding of steelhead demographics and, when combined with other steelhead-focused parts of the Proposed Action (San

Joaquin and Delta steelhead telemetry study), inform actions that will increase steelhead abundance and improve steelhead survival through the Delta. This program would hopefully increase capture efficiency for steelhead, likely leading to some harassment of individuals. Finally, within 1 year, Reclamation will coordinate with CSAMP to sponsor a workshop for developing a plan to monitor steelhead populations within the San Joaquin Basin and/or the San Joaquin River downstream of the confluence of the Stanislaus River, including steelhead and rainbow trout on non-project San Joaquin tributaries. The plan would be delivered to the IEP for prioritization and implementation, where feasible, for actions withing the responsibility of the CVP and SWP and other members of the IEP. If the IEP is not able to implement the plan, the plan may be raised at the Director Level Collaborative Planning Meeting described under the "Governance" section of this PA for resolution.

Table 5.10-3. Monitoring Programs – Steelhead

Species	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Chipps Island Trawl																		
Steelhead	178	133	128	233	132	141	35	82	118	100	37	57	79	81	106	96	143	
Sacramento Trawl																		
Steelhead	37	36	20	9	54	42	56	62	40	40	134	12	287	16	35	44	129	
DJFMP Beach Seine Survey																		
Steelhead	36	27	28	30	42	31	25	17	26	13	13	17	45	7	6	1	20	0
CDFW Mossdale Trawl																		
Steelhead	8	17	12	7	11	41	5	1	4	5	11	26	12	28	3	0	8	
EDSM KDTR Trawls																		
Steelhead	na	na	na	na	na	na	na	na	na na	na	na	na	na	na	0	44	na	
CDFW Bay Study Trawls																		
Steelhead	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	na	
CDFW SKT Study																		
Steelhead	23	38	37	58	54	62	19	13	46	25	36	12	86	49	52	19	40	
Totals																		
Steelhead	282	251	225	425	293	317	140	175	234	183	237	124	509	181	202	160	340	
RBDD Rotary Trap or Juvenile Production Estimate (JPE)																		
Steelhead																		

5.11 Steelhead, Central Valley DPS Critical Habitat

Critical habitat for the California CV steelhead DPS was designated in 2005 and includes all river reaches accessible to steelhead in the Sacramento and San Joaquin rivers and their tributaries, the Delta, and Yolo Bypass (70 FR 52488). The geographical extent of CCV steelhead critical habitat includes the Sacramento, Feather, and Yuba rivers and Deer, Mill, Battle, and Antelope creeks in the Sacramento River; the San Joaquin River, including its tributaries but excluding the mainstem San Joaquin River above the Merced River confluence; and the waterways of the Delta. Critical habitat includes stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line or bankfull elevation (defined as the level at which water begins to leave the channel and move onto the floodplain, and generally corresponds with a discharge that occurs every 1 to 2 years on an annual flood series) (70 FR 52488).

The designated critical habitat includes PBFs that are essential for the conservation of CCV steelhead:

- Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development.
- Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large woody material, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
- Freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging large woody material, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
- Estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater; natural cover such as submerged and overhanging large woody material, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.

5.11.1 Effects of Operation

5.11.1.1 Spawning Habitat

Proposed operations under the proposed action would have largely beneficial effects on the PBFs of spawning habitat for CV steelhead. Based on relationships between flow and spawning WUA for steelhead in the upper Sacramento River (USFWS 2003), lower flows under the proposed action would substantially increase the number of years in which velocities would be within the optimum range during the primary spawning period (January through March). Furthermore, Keswick releases during the spring would be substantially cooler under the proposed action, resulting in suitable water temperatures for eggs and alevins through May.

5.11.1.2 Freshwater Rearing Habitat

Higher flows and lower temperatures under the proposed actoin would have beneficial effects on the PBFs of freshwater rearing habitat for CV steelhead. Although higher summer flows under the proposed action are associated with reductions in WUA, these flows would have positive effects on overall habitat quantity and quality. Potential benefits include increased downstream extent of suitable rearing temperatures, improved access to riparian and off-channel habitat, reduced crowding and competition, and increased prey availability. The flow-related benefits of the proposed action on critical habitat would be further enhanced by Shasta cold water management actions and cooler release temperatures at Keswick Dam to protect winter-run Chinook salmon during the summer spawning and incubation period.

5.11.1.3 Freshwater Migration Corridors

The proposed action would have both positive and negative effects on the PBFs of freshwater migration habitat for adult and juvenile CV steelhead. Lower flows during the winter and early spring (January through April) under the proposed action would have negative effects on migratory habitat for juvenile steelhead. However, higher flows and lower temperatures under the proposed action during the late spring and summer (May through September) would have beneficial effects on migratory habitat of juveniles and adults, especially in dry and critically dry years.

5.11.1.4 Estuarine Areas

The proposed action would have both positive and negative effects on the PBFs of estuarine habitat for CV steelhead. The potential for operation-related impacts on estuarine habitat would be similar to those described for freshwater rearing habitat and migration corridors above.

5.11.1.5 Effects of Maintenance

Implementation of the species avoidance and take minimization steps described in Appendix E – ROC Real-Time Water Operations Charter in section Routine Operations and Maintenance on CVP Activities would be anticipated to minimize potential negative effects to CV Steelhead critical habitats from maintenance activities.

5.11.2 Effects of Conservation Measures

5.11.2.1 Spawning Habitat

Several programmatic actions that are proposed as part of the proposed action include construction components that could affect the critical habitat PBFs of steelhead spawning habitat. These actions include proposed spawning habitat enhancement projects (e.g., gravel augmentation), rearing habitat enhancement projects (e.g., side channel creation), and installation of screens on small unscreened diversions (small screen program). Based on the proposed in-water work windows (see AMM2 *Construction Best Management Practices and Monitoring*), spawning adults, eggs, and alevins could be exposed to construction activities during November through February or mid-May, depending on the river reach. The potential effects of construction activities on steelhead spawning habitat and the proposed AMMs would be similar to those described for spring-run Chinook salmon.

5.11.2.2 Freshwater Rearing Habitat

Construction components of the programmatic actions could also affect the critical habitat PBFs of freshwater rearing habitat for steelhead. Because juvenile steelhead are present year-round in the proposed action area, juveniles would be subject to potential construction activities whenever they occur. Based on the proposed in-water work windows (see AMM2 *Construction Best Management Practices and Monitoring*), rearing juveniles could be exposed to construction activities during October through February or mid-May, depending on the river reach. The potential effects of construction activities on steelhead rearing habitat and proposed AMMs would be similar to those described for spring-run Chinook salmon.

5.11.2.3 Freshwater Migration Corridors

Several programmatic actions that are proposed as part of the proposed action could affect the critical habitat PBFs of freshwater migration corridors for steelhead. These actions include proposed tidal and channel margin restoration, spawning and rearing habitat enhancement projects, and installation of new diversions and screens. Potential exposure of migrating juveniles to construction activities would be avoided or minimized by restricting all instream activities to the proposed in-water construction window (August 31 to October 31 in the legal Delta, and June 1 to October 1 in the Sacramento River between Red Bluff Diversion Dam and the boundary of the legal Delta). However, the potential for exposure of migrating adults to these construction activities is high, especially during the peak migration period (September through October). In addition, although the proposed in-water construction windows would avoid the primary migration periods of juvenile steelhead, timing information for brood years 2004 through 2017 (Appendix F: SacPAS Summary) indicates that juveniles may sometimes occur in the middle Sacramento River and Delta during summer and early fall. However, none of the proposed construction activities would create a migration barrier or cause significant delays in migration of steelhead adults or juveniles. Based on the proposed AMMs, potential effects would be limited to temporary delays in passage resulting from behavioral effects that could occur in response to noise, turbidity, and other physical disturbances at construction sites. Other potential effects of construction activities on steelhead migration habitat would be similar to those described for spring-run Chinook salmon rearing and migration habitat. However, because most steelhead juveniles would be large, actively migrating smolts, their sensitivity to potential construction effects (e.g., injury or mortality from in-water work activities) would be lower than that of juvenile Chinook salmon.

5.11.2.4 Estuarine Areas

The proposed action includes a number of programmatic actions that could affect the PBFs of estuarine habitat for CV steelhead, including tidal and channel margin restoration, facility improvements (Delta Cross Channel Gate improvements), Delta Fish Species Conservation Hatchery, and Small Screen Program). The potential for construction-related impacts of these projects on estuarine habitat would be similar to those described for freshwater rearing habitat and migration corridors above.

5.11.2.5 Effects of Monitoring

Monitoring would have no effect on critical habitat.

5.12 North American Green Sturgeon, Southern DPS

The proposed action has lower flows than the WOA during the spring, in particular March, April, and May, in all the watersheds when adults are migrating upstream to spawn. Releases for water supply in the summer and early fall associated with the proposed action result in higher flows relative to WOA during the period of broadcast spawning. These higher flows increase: (1) spawning habitat; (2) water velocities that flush sediment from green sturgeon redds; (3) the ability to maintain adequate levels of DO in contact with green sturgeon eggs; and (4) water depth suitable for Green Sturgeon

Reclamation has included a variety of conservation measures to increase alevin and juvenile productivity of Green Sturgeon. These include spawning and rearing habitat, cold water pool management, predator hot spot removal, and a small screen program. Volitional passage past the Red Bluff Diversion Dam was achieved in 2013 and allows free movement for adult Green sturgeon throughout their spawning habitat.

5.12.1 Lifestage Timing

General life stage timing and location information for Green Sturgeon is provided in Table 5.12-1.

Table 5.12-1. Temporal Occurrence of (a) Spawning Adult, (b) Larval, (c) Young Juvenile, (d) Juvenile, and (e) Sub-adult/Non-spawning Green Sturgeon (NMFS 2017, Appendix B, p.68)

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
(a) Adult-sexually mature (≥145 cm TL females, ≥ 120 cm TL males), including pre- and post-spawning individuals.												
Sac River (rkm 332.5-451)	L / L	L / L	M / M	H / H	H / H	H / H	H / H	H / H	H / H	H / H	H / M	M / M
Sac River (< rkm 332.5)	L / L	L / M	M / M	M / M	L / L	L / L	L / L	L / L	L / L	L / L	L / L	L / L
Sac-SJ-SF Estuary	L / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	L / L
(b) Larval												
Sac River (> rkm 332.5)	– / –	– / –	– / L	M / M	H / H	H / H	H / H	M / M	M / M	L / L	– / –	– / –
(c) Juvenile (≤5 months old)												
Sac River (> rkm 332.5)	– / –	– / –	– / –	– / L	M / M	M / M	H / H	H / H	H / H	H / M	M / M	M / M
(d) Juvenile (≥5 months)												
Sac River (< rkm 391)	M / M	M / M	L / L	L / L	L / L	L / M	M / M	M / H	H / H	H / H	H / H	H / M
Sac-SJ Delta, Suisun Bay	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M
(e) Sub-Adults and Non-spawning adults												
SAC-SJ-SF Estuary	M / M	M / M	M / M	M / M	M / M	H / H	H / H	H / H	H / H	H / H	H / H	M / M
Pacific Coast	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M	M / M
Coastal Bays & Estuaries[1]	M / M	M / M	M / M	M / M	M / M	H / H	H / H	H / H	H / H	H / H	H / H	M / M

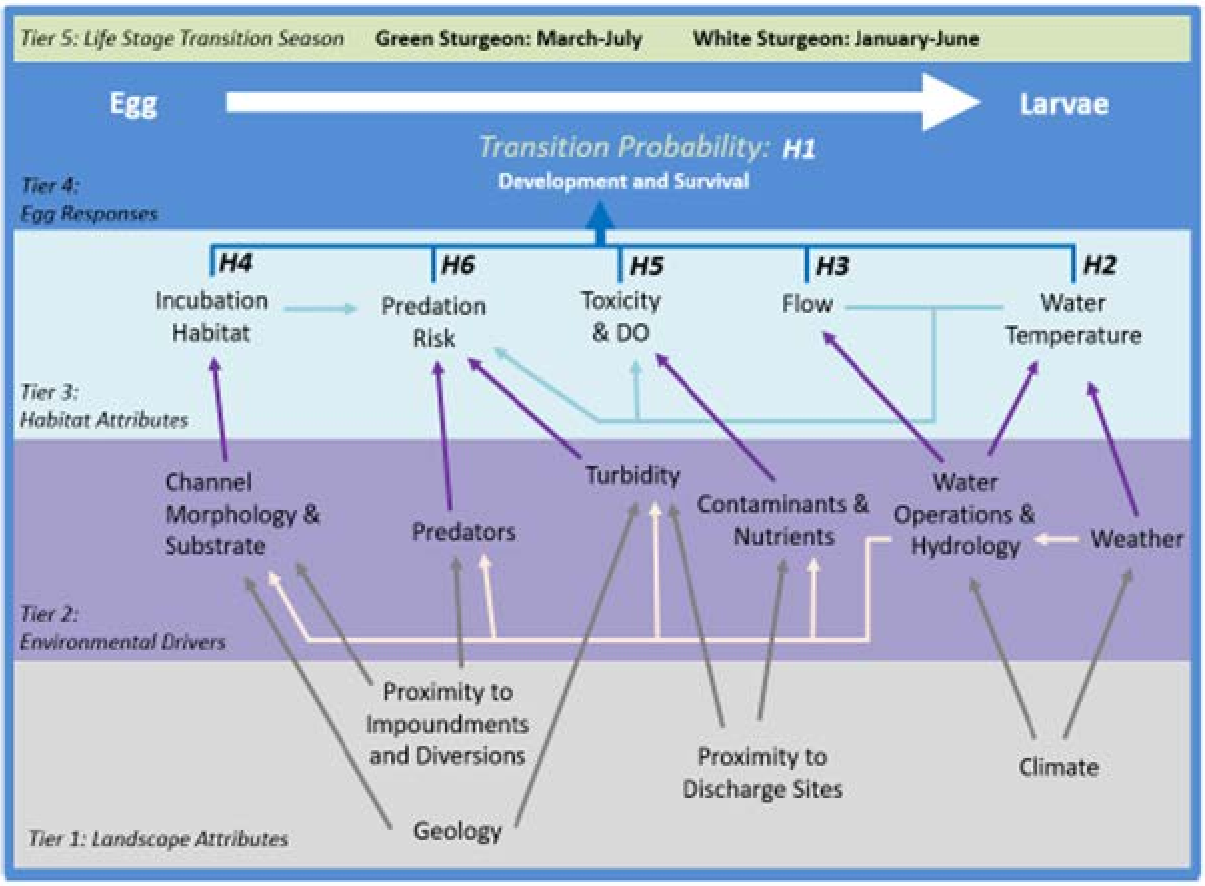
Relative Abundance: (black) = High; (dark gray) = Medium; (light gray) = Low

Sources: (a) Heublein et al. 2008; Klimley et al. 2015; Poytress et al. 2015; Mora et al. 2015; (b) Poytress et al. 2015; Heublein et al. in review; (c) Heublein et al. in review, B. Poytress, unpublished; (d) Radtke 1966; CDFG 2002, Heublein et al. in review, B. Poytress, unpublished; (e) Erickson and Hightower 2007; Moser and Lindley 2006; Lindley et al. 2008, Lindley et al. 2011; Huff et al. 2011. Outside of Sac-SJ-SF estuary (e.g. Columbia R., Grays Harbor, Willapa Bay).

5.12.2 Conceptual Model Linkages

The Salmon and Sturgeon Assessment of Indicators by Life Stage (SAIL) conceptual models describe life stage transitions of Green Sturgeon. Life stage transitions are the series of changes in form that an organism undergoes throughout its life cycle. SAIL life stage transitions include egg to larval, larvae to juvenile, juvenile to subadult/adult, adult to spawning, and spawning adult to egg and post-spawn adult period.

The egg to larval period for Green Sturgeon, as described by the SAIL Conceptual model (Heublein et al. 2017), is during March to July for the geographic area from Cow Creek to the Glenn Colusa Irrigation District diversion dam (Sacramento River) and from the Fish Barrier Dam to Shanghai Bend (Feather River). The hypothesized landscape attributes (geographically and temporal characteristics of the Central Valley and Bay-Delta that do not change over the analysis timescale), environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.12-1.



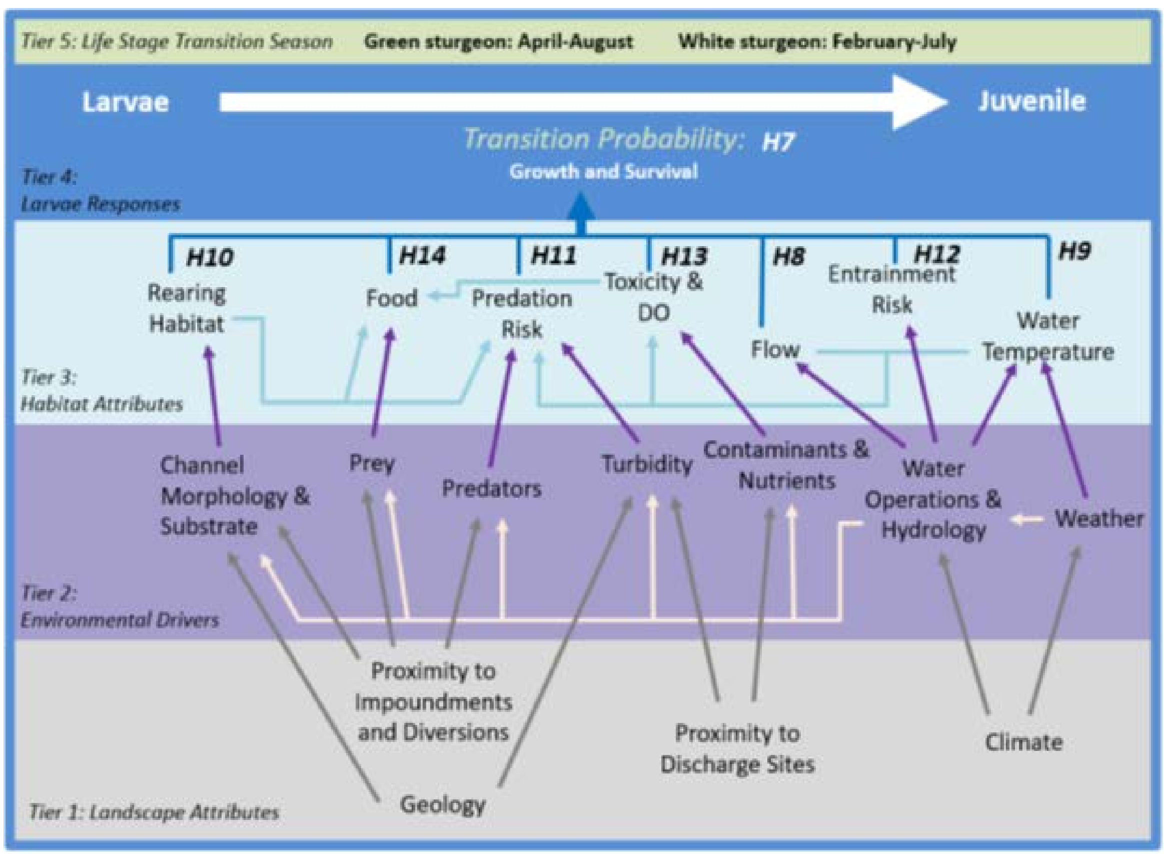
Source: Heublein et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.12-1. Conceptual Model of Drivers Affecting the Transition of Green Sturgeon from Egg to Larva

Eggs from spawning Green Sturgeon have been found in the middle and upper Sacramento River from the Glen Colusa Irrigation District oxbow (GCID) (River Mile [RM] 207) to Inks Creek (RM 265) and based on adult sightings and presence of suitable habitat, spawning is believed to extend upstream to the confluence with Cow Creek (RM 277) (Heublein et al. 2017b). Green sturgeon spawn in deep pools (averaging about 28 feet deep) (NMFS 2018).

Green Sturgeon spawn primarily from April through July, although they periodically spawn in late summer and fall (as late as October) (Heublein et al. 2009, 2017b, NMFS 2018) (Table 5.12-1). Northern DPS Green Sturgeon eggs incubate at about 60 degrees Fahrenheit from hatch to about a week after fertilization, and incubation time of southern DPS Green Sturgeon eggs is assumed to be similar (Heublein et al. 2017b). Because the incubation time for Green Sturgeon is so short, the effects analysis period for egg to larvae transition is considered to be the same as the spawning period, April through July, occasionally extending to October.

The larvae complete metamorphosis and become juveniles during April through August, as described by the SAIL Conceptual model (Heublein et al. 2017), for the geographic area from Bend Bridge (Sacramento River) and Thermalito Outlet (Feather River) to the Golden Gate Bridge. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.12-2.



Source: Heublein et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes.

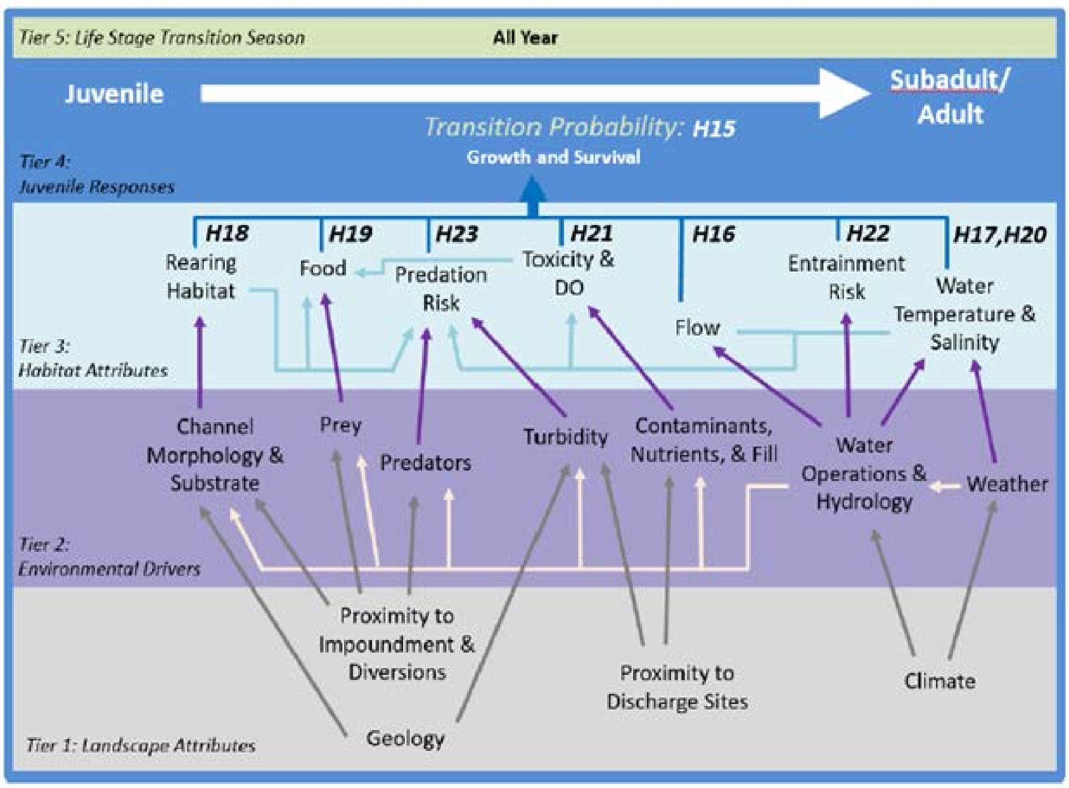
Figure 5.12-2. Conceptual Model of Drivers Affecting the Transition of Green Sturgeon from Larva to Juvenile

According to field observations, Green Sturgeon larvae begin to disperse from hatching areas at 18 days post hatch (dph), and dispersion is complete at about 35 dph (Poytress et al. 2011, cited in Heublein et al. 2017b). They begin exogenous feeding at about 15 dph. The larvae use benthic structure and seek refuge within crevices, but also forage over hard surfaces (Nguyen and Crocker 2007 cited in Heublein et al. 2017b). The juvenile stage begins when metamorphosis of the larvae is complete, typically at about 45 dph (Heublein et al. 2017b).

July is the end of the peak spawning period, so the end of the larva to juvenile period is considered to be September.

The downstream distribution of Green Sturgeon larvae in the Sacramento River is uncertain, but is estimated to extend to the Colusa area, at River Mile 157 (Heublein et al. 2017b). The larvae occur upstream to the Cow Creek confluence, which is the upstream limit of their spawning distribution (Heublein et al. 2017b).

The juvenile life stage transition, as described by the SAIL Conceptual model (Heublein et al. 2017), from complete metamorphosis to ocean migration or 75 cm fork length occurs in the geographic area from Bend Bridge (Sacramento River) and Thermalito Outlet (Feather River) to the Golden Gate Bridge. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.12-3.

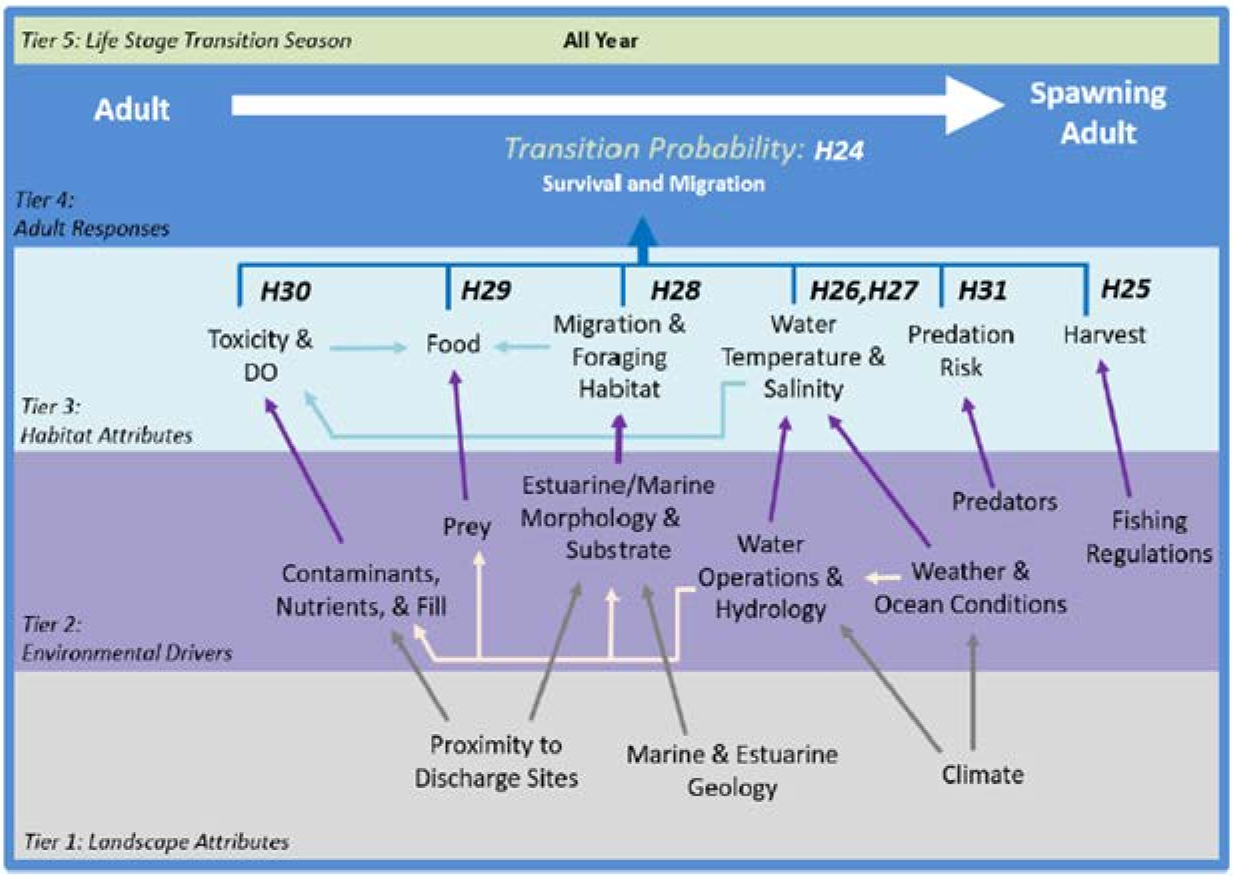


Source: Heublein et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.12-3. Conceptual Model of Drivers Affecting the Transition of Green Sturgeon from Juvenile to Subadult/Adult

The Green Sturgeon juvenile stage begins when metamorphosis of the larvae is complete, typically at about 45 dph and about 75 mm in length (Heublein et al 2017b). It is likely that juveniles rear near spawning habitat for a few months or more before migrating to the Delta (Heublein et al. 2017b). The period for juveniles less than or equal to 5 months old, considered to be the ages of most juveniles rearing in or migrating through the Sacramento River upstream of the Delta, is given in Table 5.12-1 as May through December. During most of the juvenile Green Sturgeon rearing period, the juveniles are likely to be found anywhere from the upstream spawning habitat near the Cow Creek confluence to the Delta.

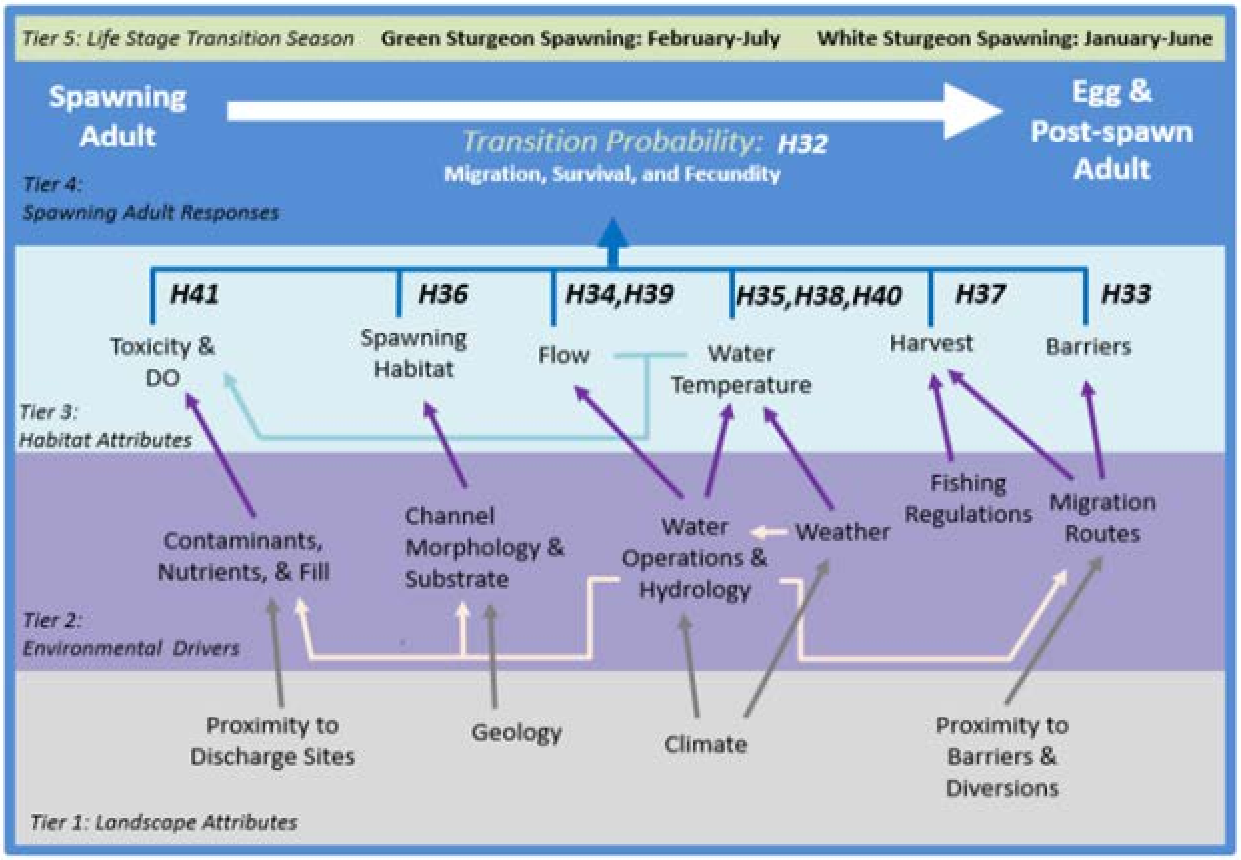
The adult to spawning adult life stage transition, as described by the SAIL Conceptual model (Heublein et al. 2017), is geographically located in California, Oregon, and Washington estuaries during May-October, as well as the nearshore marine environment all year. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.12-4.



Source: Heublein et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.12-4. Conceptual Model of Drivers Affecting the Transition of Green Sturgeon from Adult to Spawning Adult

The spawning adult life stage transition from spawning adult to egg and post-spawn adult, as described by the SAIL Conceptual model (Heublein et al. 2017), occurs in the geographic area for migration and spawning from the Golden Gate Bridge to Cow Creek (Sacramento River), Fish Barrier Dam (Feather River), and Daguerre Point Dam (Yuba River). The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.12-5.



Source: Heublein et al. (2017). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.12-5. Conceptual Model of Drivers Affecting the Transition of Green Sturgeon from Spawning Adult to Egg and Post-Spawn Adult.

Continuing their upstream migration from the Delta, Green Sturgeon adults enter the Sacramento River as early as February and ultimately make their way upstream to spawn in deep pools from the Glenn Colusa Irrigation District oxbow (GCID) to the Cow Creek confluence (Heublein et al. 2017b). 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; NMFS 2017b). 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 (Heublein et al. 2017b). Emigration may occur as early as late spring or summer and may be related to elevated flows (Heublein et al. 2009).

As indicated by the SAIL conceptual model (Figures 5.12-1 to 5.12-5), hydrologic conditions and operations of Shasta and Keswick reservoirs affect flows and water temperatures in the upper Sacramento River, which combined with other environmental drivers, affect DO, water quality, predation, and other habitat attributes that influence the timing, condition, growth, and survival of Green Sturgeon in all life stages in the Sacramento River.

Hydrologic conditions and operations of water diversions also affect entrainment risk (Verhille et al. 2014; Heublein et al. 2017a [SAIL model]; Mussen et al. 2014). The proportion of larvae surviving to the juvenile stage, as well as juveniles surviving to emigrate from the Sacramento River depends largely on habitat conditions, including instream flow (Heublein et al. 2017b). Instream flow affects other factors through dilution (e.g., toxicity and contaminants), water temperatures (which also affects DO, food availability, predation, pathogens, and disease), river stage and flow velocity (which affect bioenergetics, food availability, and predation), entrainment, and potentially affects cues that stimulate outmigration (Heublein et al. 2017b, NMFS 2017b). The proportion of eggs to hatch, during the egg to larvae lifestage, is affected by substrate composition, depth, contaminants, sedimentation, predators of the spawning habitat, as well as the other aforementioned factors (Heublein et al. 2017a [SAIL model], 2017b). In addition, instream flow from Keswick Dam releases, relative to flow from the lower Yolo and Sutter bypasses and agricultural drains, may affect navigation cues and increase straying risk of Green Sturgeon adults into these canals and behind these bypass weirs (Figure 5.12-5). Instream flows may affect sedimentation and substrate composition of the spawning habitat and may affect channel morphology (Heublein et al. 2017a [SAIL model] and 2017b). Flow and water temperature also affect the area of river bed suitable for spawning and may influence the timing of spawning (Heublein 2017a [SAIL model] and 2017b). Flows may also disperse larvae to more favorable downstream habitats (NMFS 2018). Larval abundance and distribution may be influenced by spring and summer outflow (Heublein et al. 2017b). Flows may also transport juveniles to more favorable habitats (NMFS 2018). Juvenile abundance and distribution may be influenced by winter outflow (Heublein et al. 2017b).

In addition, water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of Green Sturgeon for all life stages. The egg and larval life stages are the most sensitive to temperature exceedances outside of optimal ranges, and exposure to the effects of elevated water temperatures include elevated mortality and increased occurrence of morphological abnormalities in eggs that do hatch (Van Eenennaam et al. 2005). Thermal tolerance ranges for Green Sturgeon egg and larvae are considered optimal between 53 to 64 ^{0}F, and are suboptimal at 65 to 66 ^{0}F. Temperatures between 67 to 72 ^{0}F result in impaired fitness and temperatures greater than 73 ^{0}F are likely lethal (NMFS 2016).

The life stages of juvenile to subadult/adult Green are not particularly sensitive to temperatures below the lethal level of 73.5 ^{0}F (NMFS 2016). Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease and physiological stress potentially leading to mortality and altered migration timing and speed. Juvenile Green Sturgeon require temperatures of 58 to 66 ^{0}F for optimal survival and growth, 42 to 57 ^{0}F and 67 to 68 ^{0}F are suboptimal, and temperatures greater than 69 ^{0}F may lead to impaired fitness (NMFS 2016).

For the adult to spawning adult life stage, Green Sturgeon require temperatures between 53 °F and 64 °F for optimal survival, with temperatures from 67 °F to 72 °F leading to impaired fitness and temperatures over 73 °F being lethal. Migrating and holding Green Sturgeon require temperatures between 46 °F and 68 °F for optimal survival, with temperatures from 70 °F to 76 °F leading to impaired fitness and temperatures over 77 °F being lethal (NMFS 2016).

5.12.3 Effects of Operation & Maintenance

5.12.3.1 Seasonal Operations

Under the WOA condition, there would be no Shasta and Keswick reservoir operations to control storage or releases and no transfer of water from the Trinity River Basin. Therefore, there would be no control of flow or water temperature in the upper Sacramento River (other than upstream hydropower operations not under Reclamation control), where Green Sturgeon spawn. Reservoir gates and river valves would be kept open, resulting in minimal storage, and assuming stratification developed, the cold water pool would be small and would not be managed. Flows under these conditions, especially in the upper Sacramento River, would approximate uncontrolled flows. The similarity to uncontrolled flows is reflected in the seasonal flows modeled under the CalSim WOA scenario in the Sacramento River at Keswick, with low summer and fall flows and high winter and spring flows (Figure 5.12-6). Other locations in the Sacramento River would show similar seasonal flow patterns as illustrated by flows at the Hamilton City gauge in the middle the Sacramento River (see Appendix D, *Modeling*).

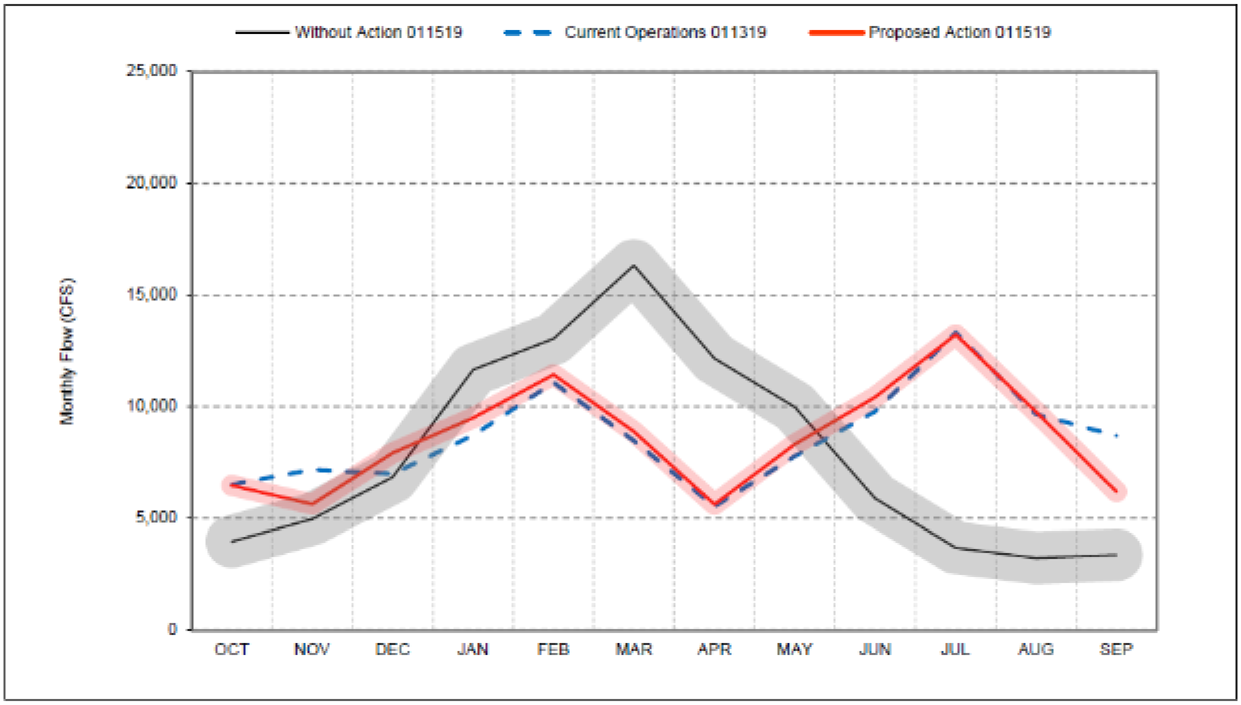


Figure 5.12-6. Flows at Keswick under the Proposed Action (PA), Current Operations (COS), and without Action (WOA)

CalSim modeling indicates that from February through April, when Green Sturgeon adults migrate upstream through the middle Sacramento River to their spawning habitats, the WOA modeling scenario mean monthly flows at Wilkins Slough would range from about 2,500 cfs in April to 24,000 cfs in March (Figures 19-11 and 19-12 in the CalSim flow section of Appendix D), and the flows at Red Bluff Diversion Dam would range from about 3,500 cfs in April to 77,000 cfs in February and March (Figures Figures 17-11 through 17-13 in the CalSim II flow section of Appendix D). From May through July, when adults have begun spawning and some are emigrating downstream, the WOA mean monthly flows at Wilkins Slough would range from 0 cfs in May through July to about 20,000 cfs in May (Figures 19-14 through 19-16 in the CalSim II flow section of Appendix D), and flows at RBDD would range from about 2,950 cfs in June to 36,000 cfs in May (Figures 17-14 through 17-16 in the CalSim II flow section of

Appendix D). Flows below about 3,250 cfs are considered to result in passage difficulties for adult Green Sturgeon in the Sacramento River (NMFS 2017b). From August through December, most of the adults remaining in the river after spawning hold for varying amounts of time and then emigrate downstream to the San Francisco Estuary. As previously noted, in occasional years Green Sturgeon may spawn until October. WOA mean monthly flows at Wilkins Slough during August through December range from a low of about 0 cfs in August to a high of 23,000 cfs in December (Figures 19-7, 19-8, 19-9, 19-17, 19-18, in the CalSim II flow section of Appendix D) and at Red Bluff from about 1,650 cfs in August to about 56,000 cfs in December (Figures 5.12-7 through 5.12-10).

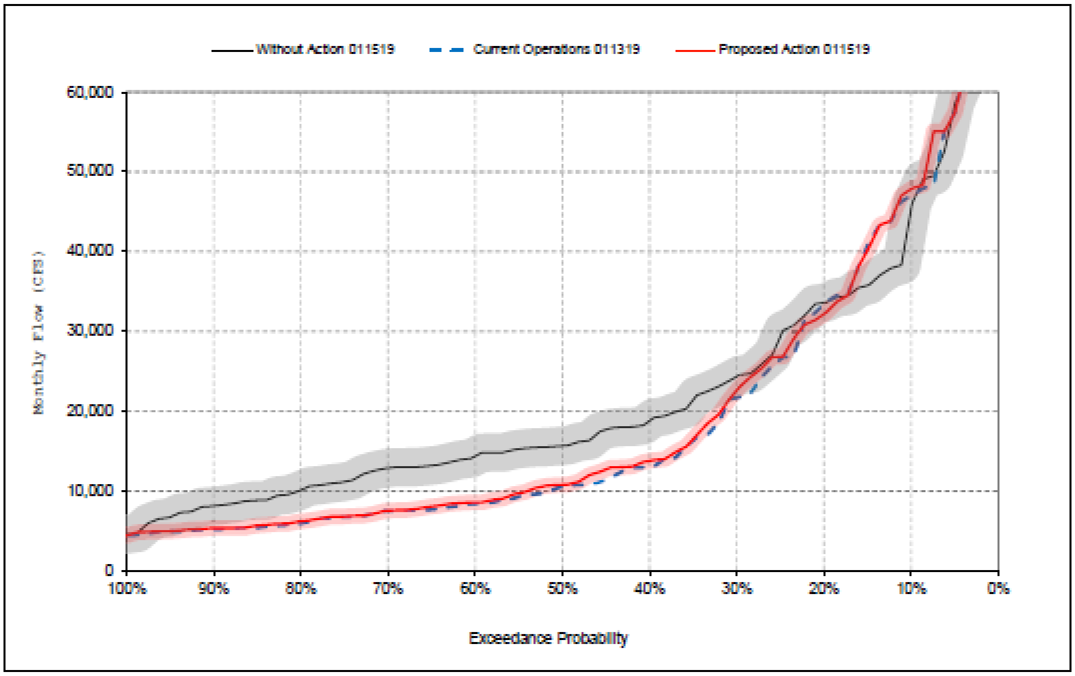


Figure 5.12-7. CalSim II Sacramento River Flows at Red Bluff, February

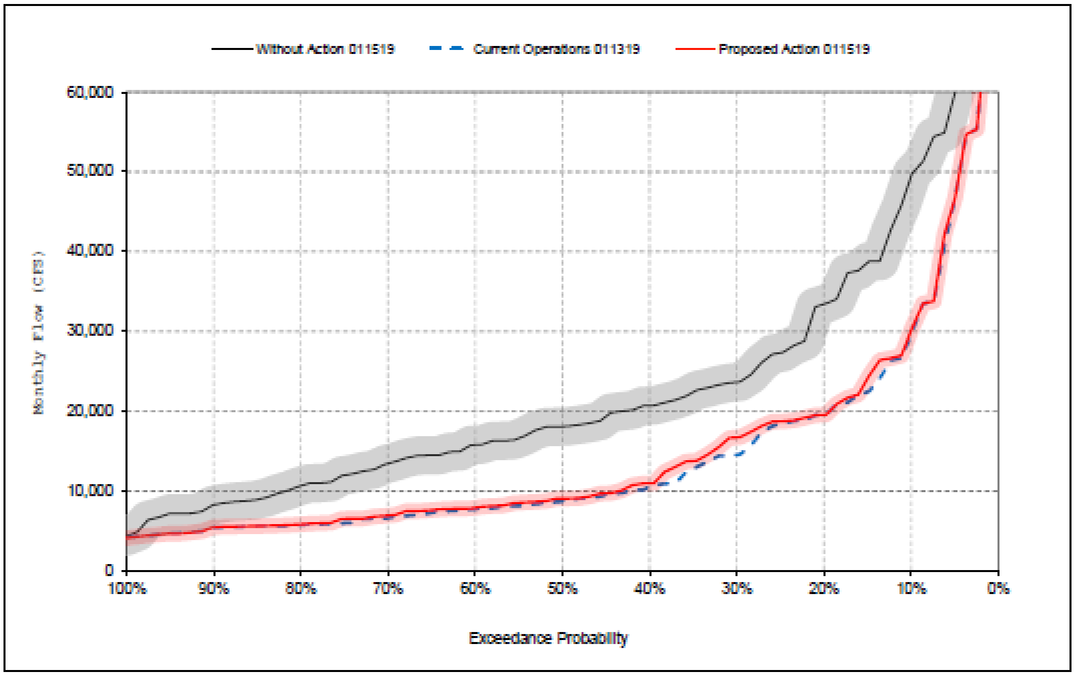


Figure 5.12-8. CalSim II Sacramento River Flows at Red Bluff, March

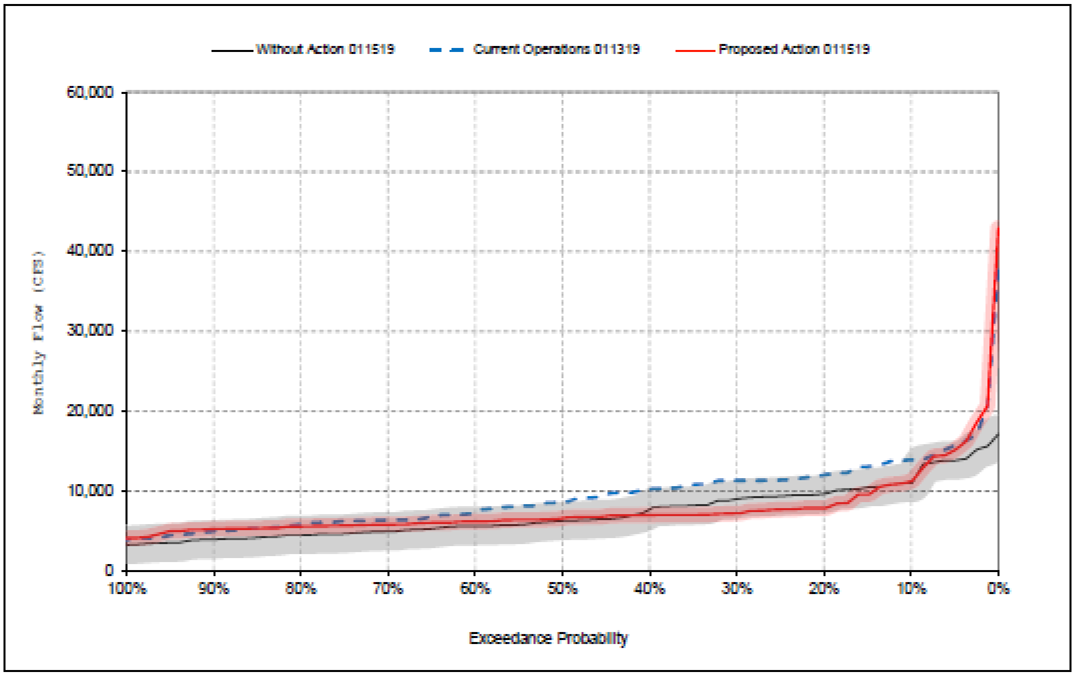


Figure 5.12-9. CalSim II Sacramento River Flows at Red Bluff, November

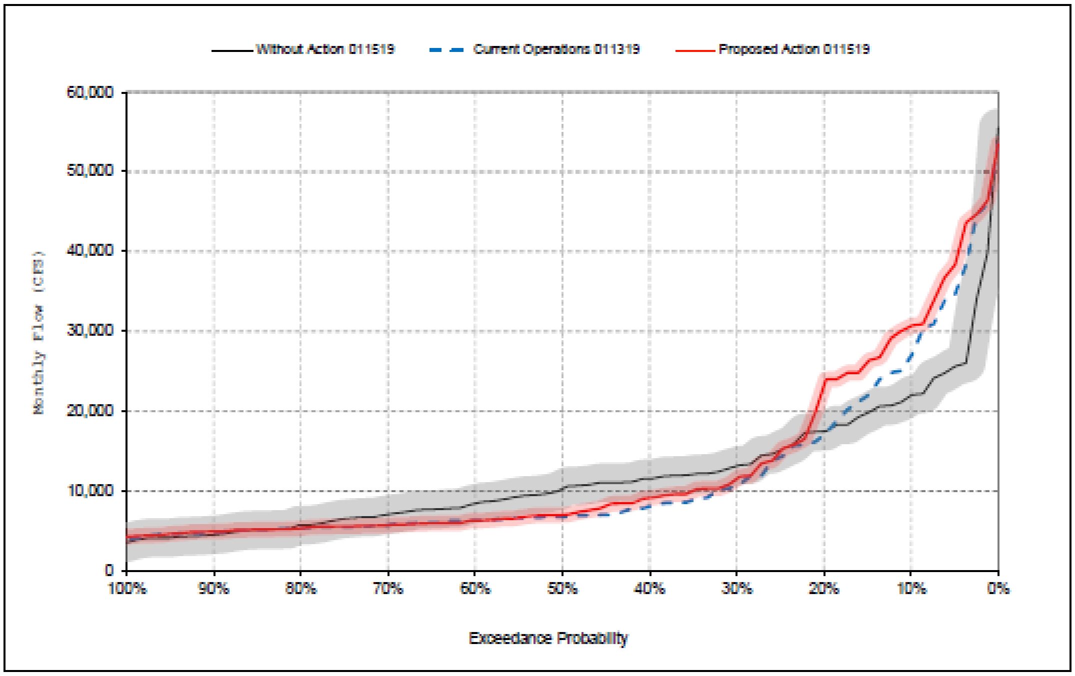


Figure 5.12-10. CalSim II Sacramento River Flows at Red Bluff, December

The very low WOA flows in some years during late spring through the fall would be likely to negatively impact migrating, spawning and holding Green Sturgeon adults. At Wilkins Slough, the mean monthly flow during June through August is less than 100 cfs in 10 to 20 percent of years, and during June through October is less than 3,250 cfs in at least 50 percent of years each month, including over 90 percent of years in July and August. These low flows would potentially cause passage problems for adults emigrating from May through November. They could also affect immigrating adults, but the peak period of immigration is generally complete by early summer. The low flows at RBDD would have potential adverse effects on spawning and holding habitats of Green Sturgeon adults, which include reduced area of river bed suitable for spawning, insufficient depths for spawning and holding habitats, reduced flushing of metabolic wastes from spawning and holding pools, and greater concentration of toxic contaminants and disease organisms.

Sacramento River water temperatures under the WOA conditions vary greatly during the May through December Green Sturgeon juvenile rearing and emigration period (see Appendix D, *Modeling*). During May and October, the mean monthly water temperatures at Woodson Bridge under the WOA modeling scenario lie within the 59 to 66 degrees Fahrenheit optimal temperature range in about 85 percent of years, with a total range of 59 to 70 degrees Fahrenheit for May and 57 and 65 degrees Fahrenheit for October. However, during June through September, the WOA mean monthly water temperatures exceed the 66 degrees Fahrenheit upper limit in every year, and during November and December, they lie below the 59 degrees Fahrenheit threshold in every year. The WOA mean monthly water temperatures would be greater than 78 degrees Fahrenheit during July and August in 25 and 10 percent of years, respectively. Temperatures exceeding 78 degrees Fahrenheit are identified as “likely lethal” (Heublein 2017b et al.). The WOA water temperatures in the upper Sacramento River (upstream of Red Bluff) would be cooler than those at Woodson Bridge, but July and August temperatures at Keswick would exceed the 66 degrees Fahrenheit threshold in every year. The November and December water temperatures at Keswick are consistently below the lower limit of the optimal temperature range for Green Sturgeon larvae (66 degrees Fahrenheit). Under the WOA conditions, Green Sturgeon juveniles are not likely to survive July and August water temperatures at Woodson Bridge and downstream. While they might be able to survive upstream of Red Bluff, they would not be able to migrate downstream until the river had cooled off later in the season.

Sacramento River water temperatures under the WOA conditions vary greatly during the April through September Green Sturgeon larval rearing and emigration period. During April, the WOA mean monthly water temperatures at Woodson Bridge are consistently below the optimal range for Green Sturgeon larvae (63 to 68 degrees Fahrenheit), ranging from 52 to 62 degrees Fahrenheit (Figure 5.12-11). During May, the WOA mean monthly water temperatures are within the optimal range in about 52 percent of years, with a total range of 59 to 70 degrees Fahrenheit (Figure 5.12-12). However, during June, the WOA mean monthly water temperatures exceed the 68 degrees Fahrenheit threshold in 90 percent of years (Figure 5.12-13) and during July through September, they exceed the threshold in every year (Figure 5.12-14 through 5.12-16). The July and August water temperatures under the WOA modeling scenario would be greater than 74 degrees Fahrenheit in all years, which is within a range of temperatures identified as “increasing chance of lethal effects”, and the highest water temperatures in these months (79 to 81 degrees Fahrenheit) are identified as “lethal” (Heublein 2017b et al.). The WOA water temperatures in the upper Sacramento River (upstream of Red Bluff) would be cooler than those at Woodson Bridge, but July and August water temperatures at Keswick would exceed the 68 degrees Fahrenheit threshold in almost every year (Figures 15-16 and 15-17 in the CalSim II flow section of Appendix D). Both April and May water water temperatures at Keswick are consistently below the lower limit of the optimal temperature range for Green Sturgeon larvae (63 degrees Fahrenheit). Under the WOA conditions, Green Sturgeon larvae would likely not be able to survive July and August water temperatures at Woodson Bridge and downstream. While they might be able to survive upstream of Red Bluff, they would not be able to survive dispersion downstream.

Sacramento River water temperatures under the WOA conditions vary greatly during the April through July Green Sturgeon spawning and egg incubation period. During April, at Hamilton City, which is at the lower end of the Green Sturgeon spawning reach in the Sacramento River, the WOA mean monthly water temperatures (HEC-5Q WOA modeling scenario) are consistently low, ranging from 52 to 62 degrees Fahrenheit (Figure 5.12-11). During May, the mean monthly water temperatures range from 59 to 70 degrees Fahrenheit, exceeding the 63 degrees Fahrenheit threshold in 56 percent of years (Figure 5.12-12), and in June and July, the water temperatures exceed the 63 degrees Fahrenheit threshold in all years, and range up to 81 degrees Fahrenheit in July (Figures 5.12-13 and 5.12-14). About 40 percent of years in June and all years in July have mean monthly water temperatures greater than 72 degrees Fahrenheit, which is identified as a likely lethal temperature for Green Sturgeon eggs by Heublein et al. (2017b). During the August through October period, the water temperatures at Woodson Bridge exceed the 63 degrees Fahrenheit threshold in all years in August, about 30 percent of years in September, and about 4 percent of years in October (Figures 5.12-15 through 5.12-17). The WOA water temperatures would be more favorable for Green Sturgeon spawning and egg incubation at more upstream locations, but even at Keswick, water temperatures in July and August would exceed the 63 degrees Fahrenheit threshold in every year and would exceed 68 degrees Fahrenheit, which is identified as “increasing chance of lethal effects” for Green Sturgeon eggs by Heublein et al. (2017b), in July of 90 percent of years (Figures Figures 5.12-13 and 5.12-14). The water temperatures in the Sacramento River under the WOA conditions, especially during July and August, would make survival of incubating eggs unlikely.

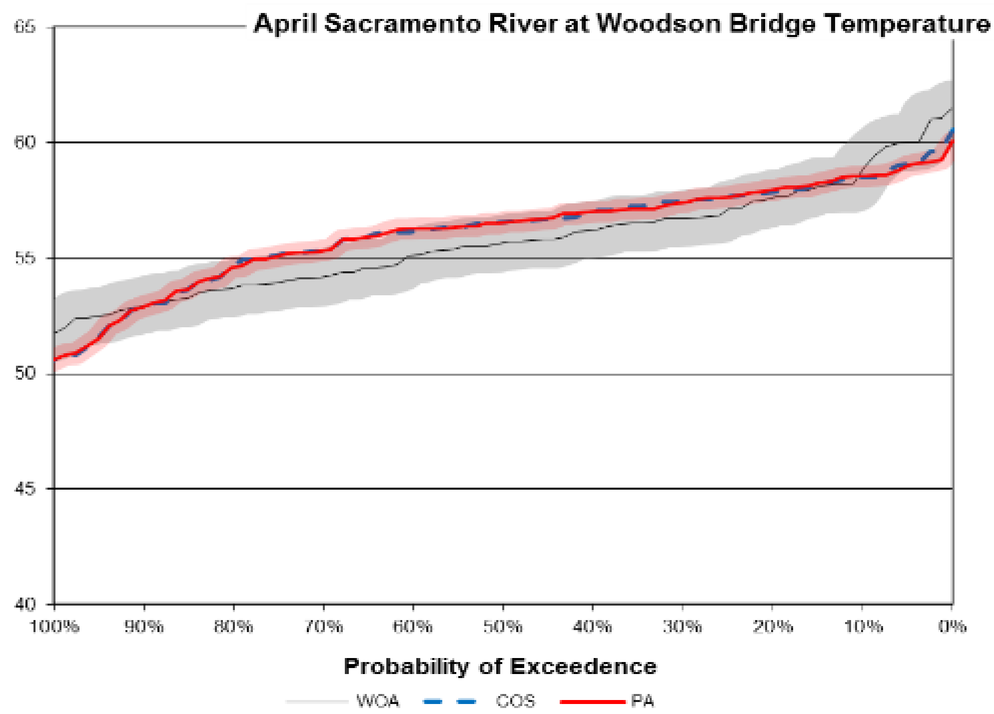


Figure 5.12-11. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed action and COS scenarios, April.

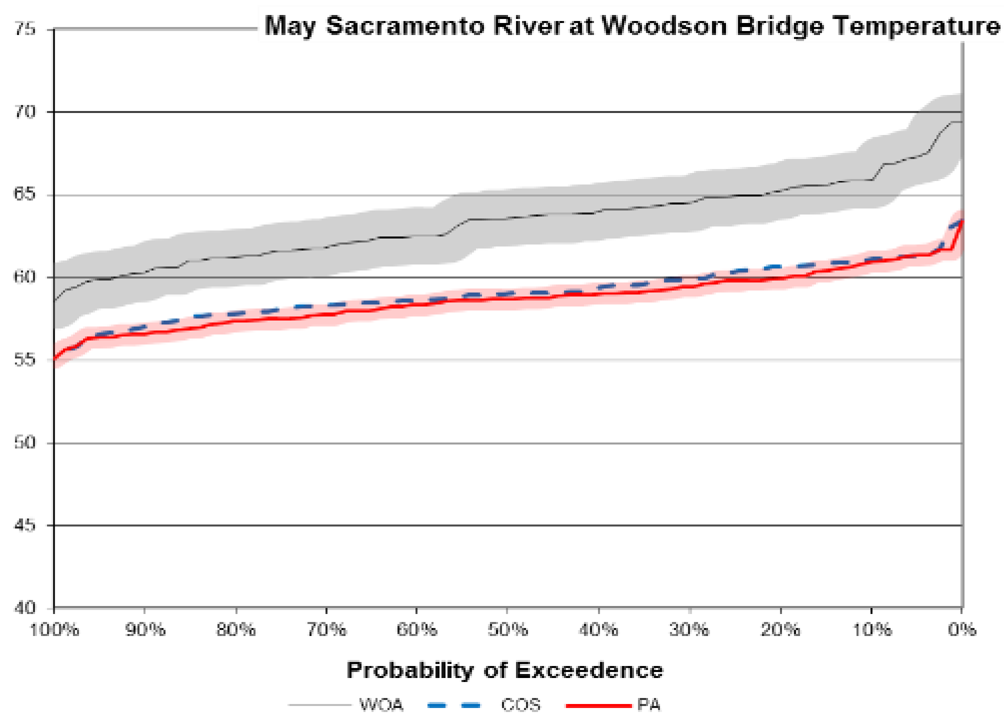


Figure 5.12-12. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed action and COS scenarios, May.

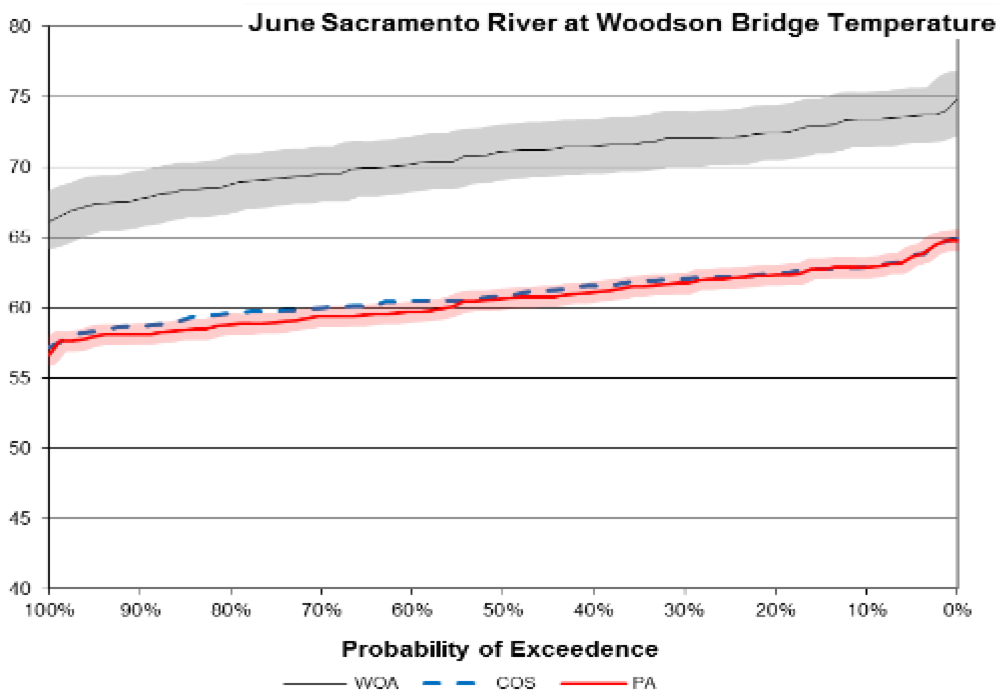


Figure 5.12-13. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Scenarios, June.

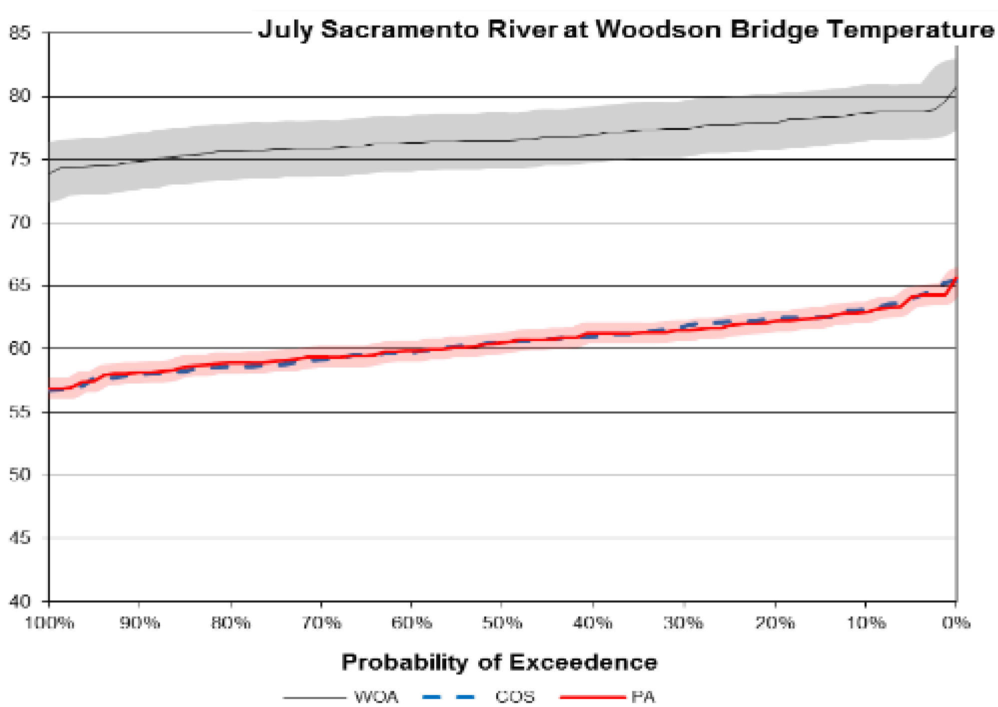


Figure 5.12-14. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Scenarios, July.

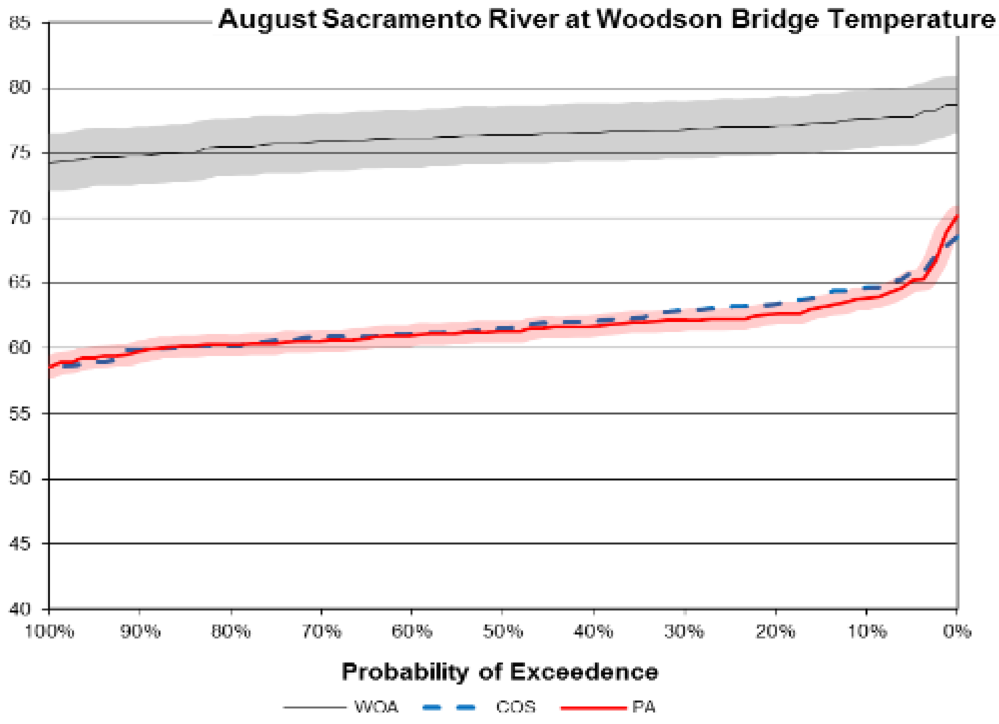


Figure 5.12-15. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Scenarios, August.

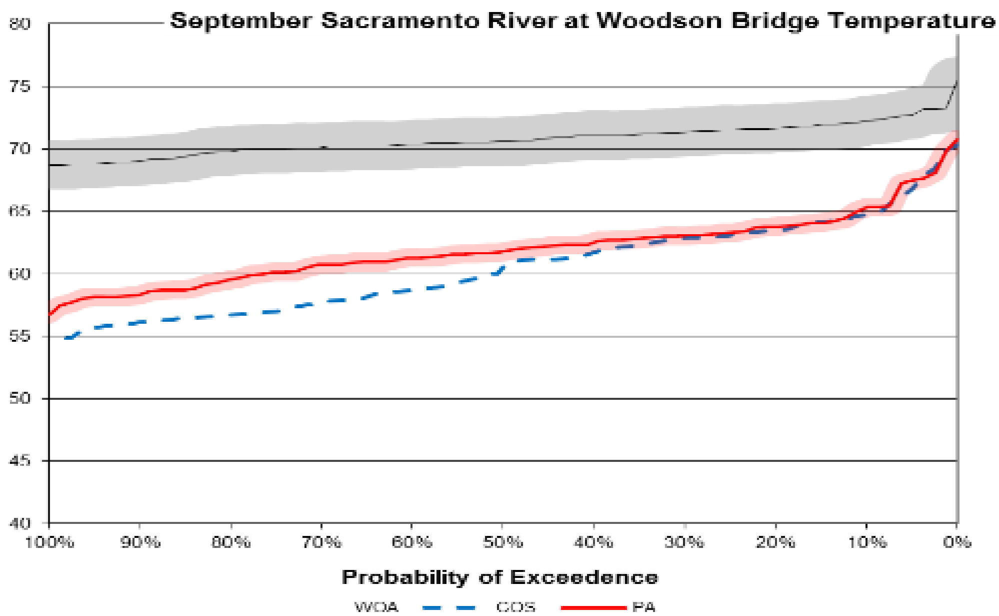


Figure 5.12-16. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Scenarios, September.

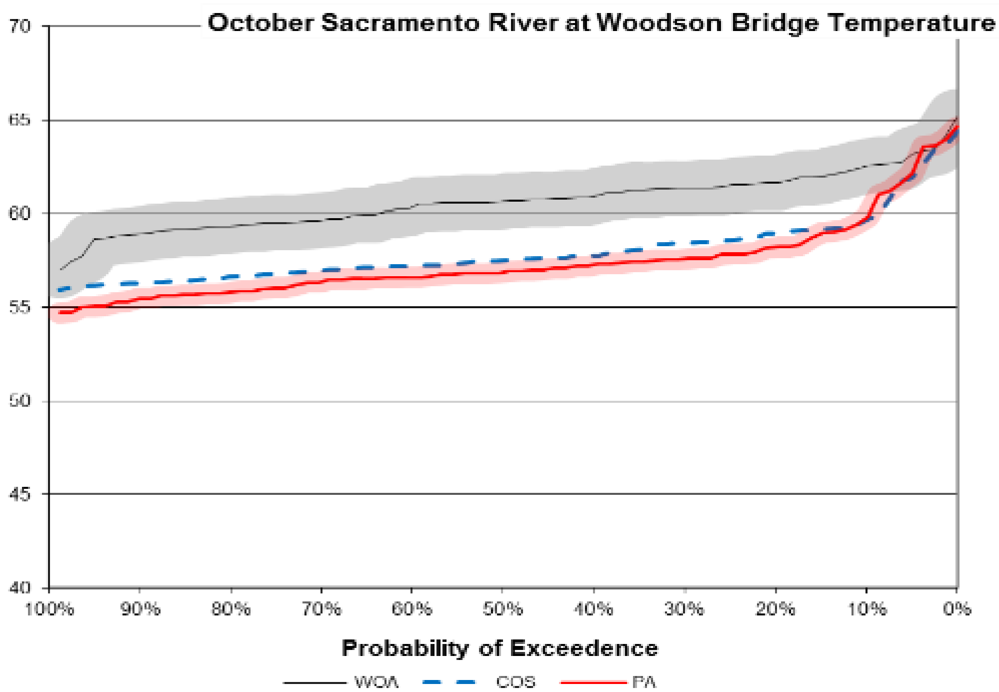


Figure 5.12-17. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Scenarios, October.

The COS is described herein to provide context for the potential positive and negative effects of the proposed action. Under COS, Shasta and Keswick reservoir operations, during most of the juvenile rearing, emigration, and larval period, primarily target flow and water temperature requirements for Winter-run Chinook Salmon and other anadromous fishes, including spring-run and fall/late fall-run Chinook Salmon, steelhead, and Green Sturgeon (NMFS 2011). Fall X2 conditions for Delta smelt are also considered (USFWS 2008). In addition, reservoir operations must balance the current needs of the fish populations with cold water storage needed to satisfy requirements in the following year, while also providing sufficient space for flood control in the winter and spring. During spring, primary operational considerations for the reservoirs in most years are to maximize storage in preparation for summer and fall releases, while during June through September, operations are largely dictated by needs of incubating Winter-run eggs and larvae. Under the proposed action, flow and water temperature management in the upper Sacramento River would be similar to the COS.

5.12.3.2 Sacramento Seasonal Operations including Shasta Cold Water Pool Management

5.12.3.2.1 Spawning Adult to Egg and Post-Spawn Adult

5.12.3.2.1.1 Flows

The CalSim modeling shows large seasonal changes in the differences in middle and upper Sacramento River flow between the proposed action and the WOA scenario. In February, the proposed action flows are generally similar to or lower than the WOA flows for most years at both Wilkins Slough and RBDD (see Appendix D, *Modeling*). In March and April, the proposed action flows are lower than WOA flows at both locations in almost every year (see Appendix D, *Modeling*). In May, the proposed action flows at Wilkins Slough are substantially lower than WOA flows for the 60 percent of highest flow years and are substantially higher for the 25 percent of lowest flow years, while at RBDD, the proposed action flows are higher than the WOA and COS flows for the highest two thirds of flow years and are slightly higher in the other years. For most of the remainder of the Green Sturgeon adult immigration, spawning and holding period (June through November), the proposed action and COS flows are generally higher or much higher than the WOA flows at both locations, but flows of all three modeling scenarios were roughly similar during November and December. The higher flows during May through October in years with dry hydrology at Wilkins Slough and Red Bluff under proposed action relative to the WOA conditions would likely benefit adult Green Sturgeon migrating, spawning and holding in the middle and upper Sacramento River by enhancing water quality and passage, and reducing disease risks (Heublein et al. 2017a[SAIL model]).

Flows during the February through December period of Green Sturgeon immigration, spawning and holding would generally be similar between the proposed action and COS at both Wilkins Slough and Red Bluff (see Appendix D, *Modeling*). Exceptions include higher flows (up to ~2,500 cfs higher) at Wilkins Slough during May and June for the proposed action scenario. The differences in flow occur primarily for flows greater than 5,000 cfs, which are likely high enough to present no passage problems for upstream migrating adults. There are also substantial flow differences between the proposed action and COS scenarios at Red Bluff during June, September and November, with higher proposed action flows in June and higher COS flows in September and November (see Appendix D, *Modeling*). These flow differences occur within a range of river flows (6,000 cfs to 17,000 cfs) not expected to substantially affect migrating Green sturgeon, but the flow reductions under the proposed action in September and November could result in reduced habitat quality in holding pool habitats. See Figures 5.12-18 through 5.12-24.

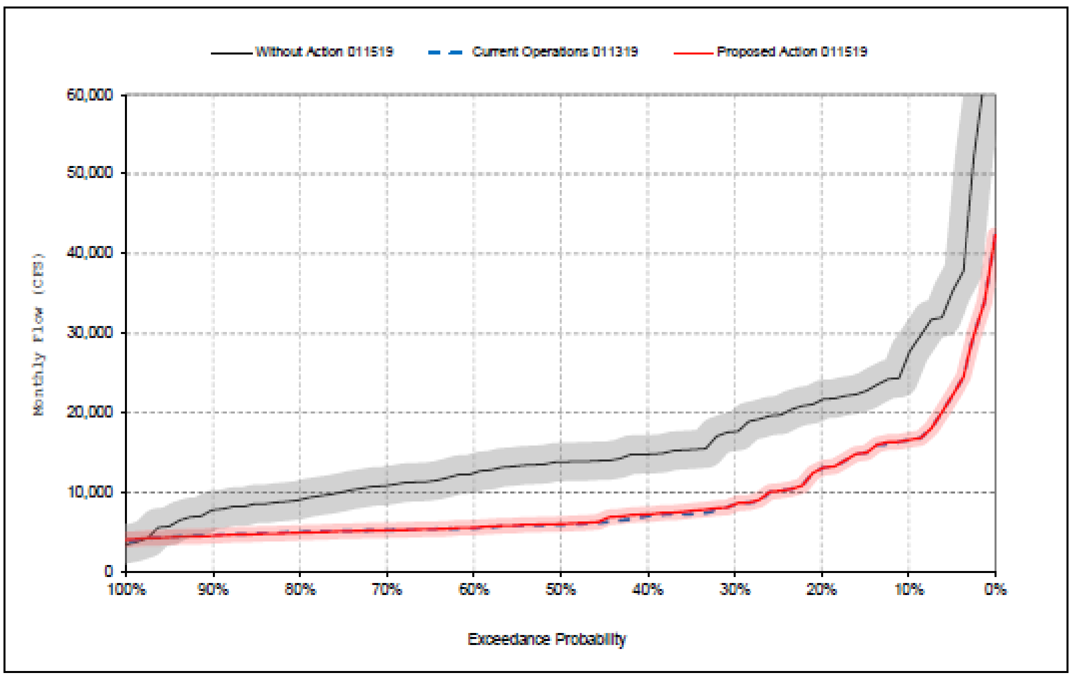


Figure 5.12-18. CalSim II Sacramento River Flows at Red Bluff, April

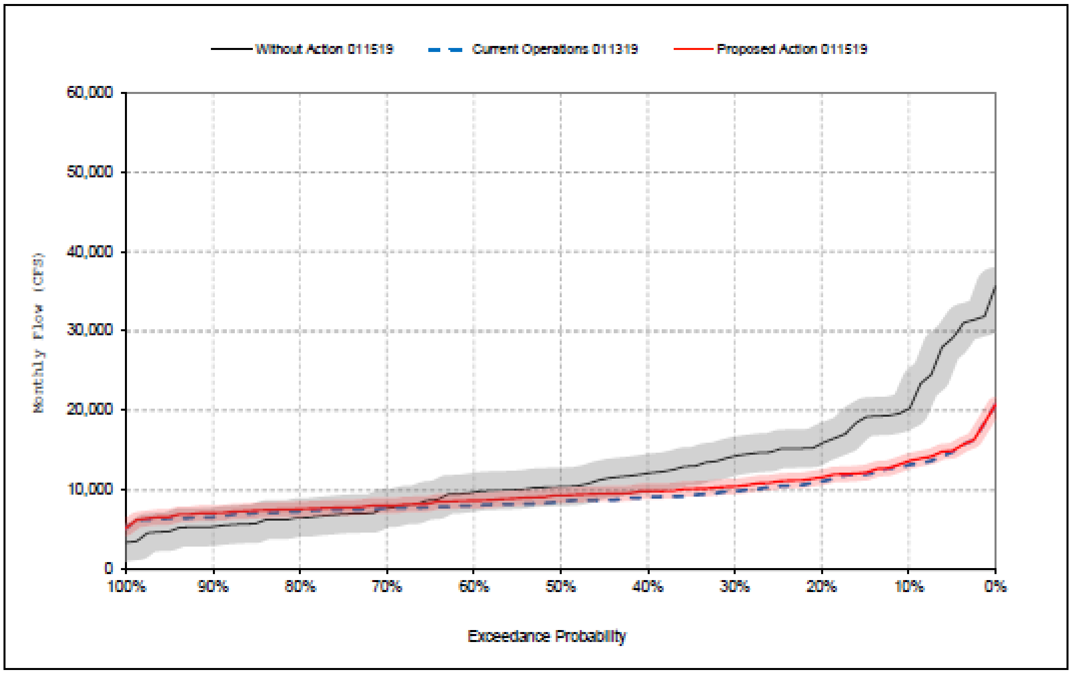


Figure 5.12-19. CalSim II Sacramento River Flows at Red Bluff, May

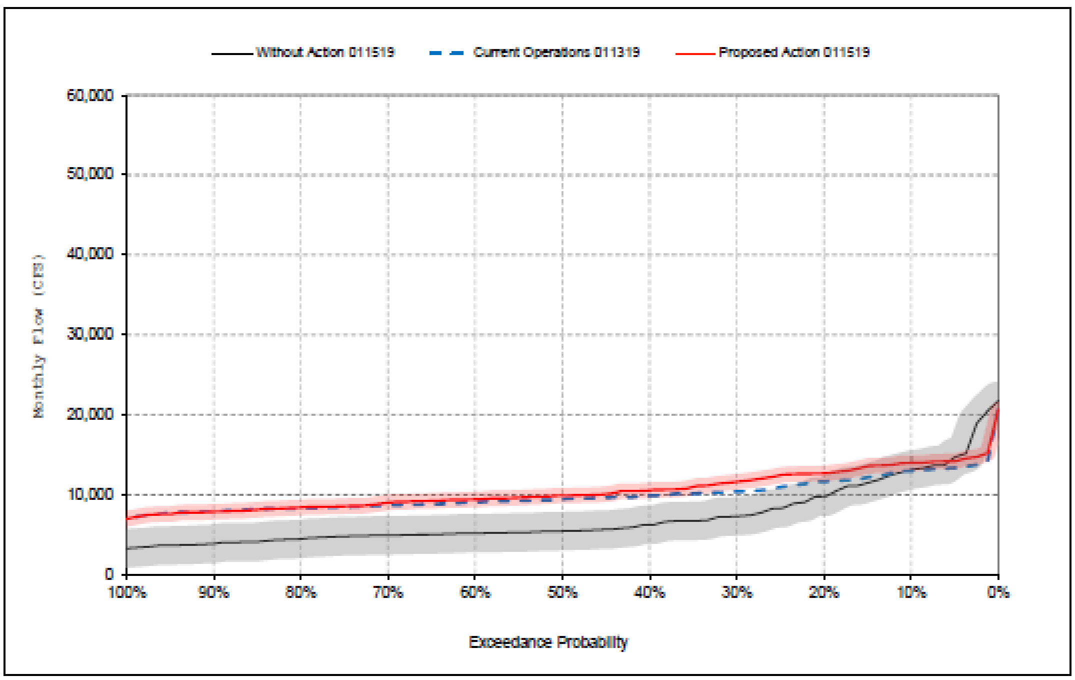


Figure 5.12-20. CalSim II Sacramento River Flows at Red Bluff, June

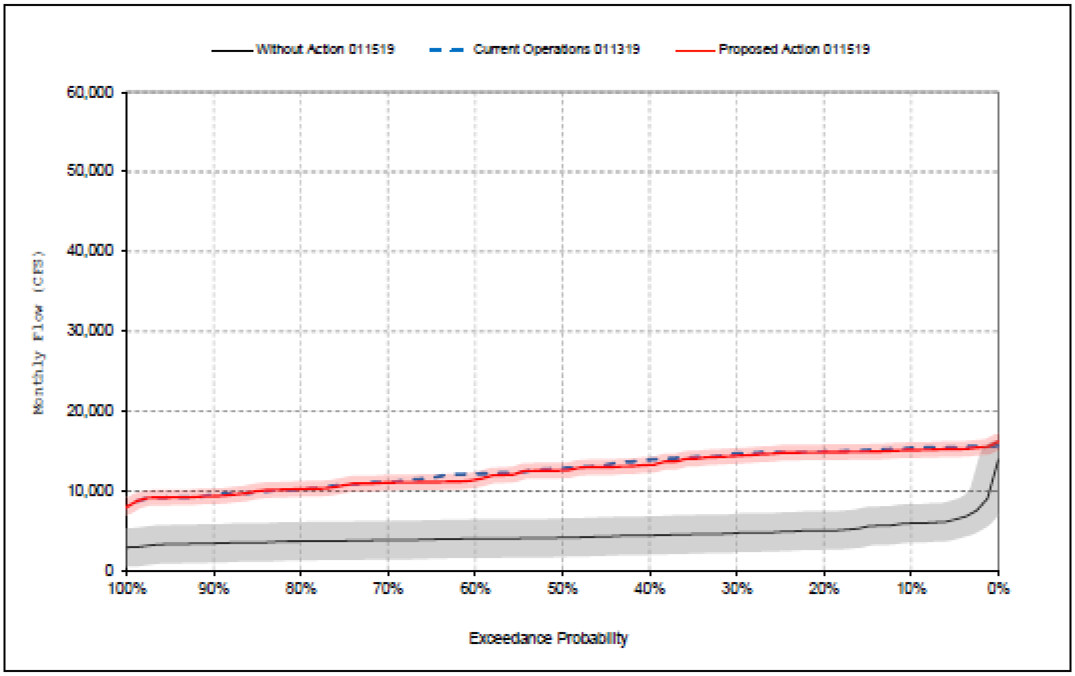


Figure 5.12-21. CalSim II Sacramento River Flows at Red Bluff, July

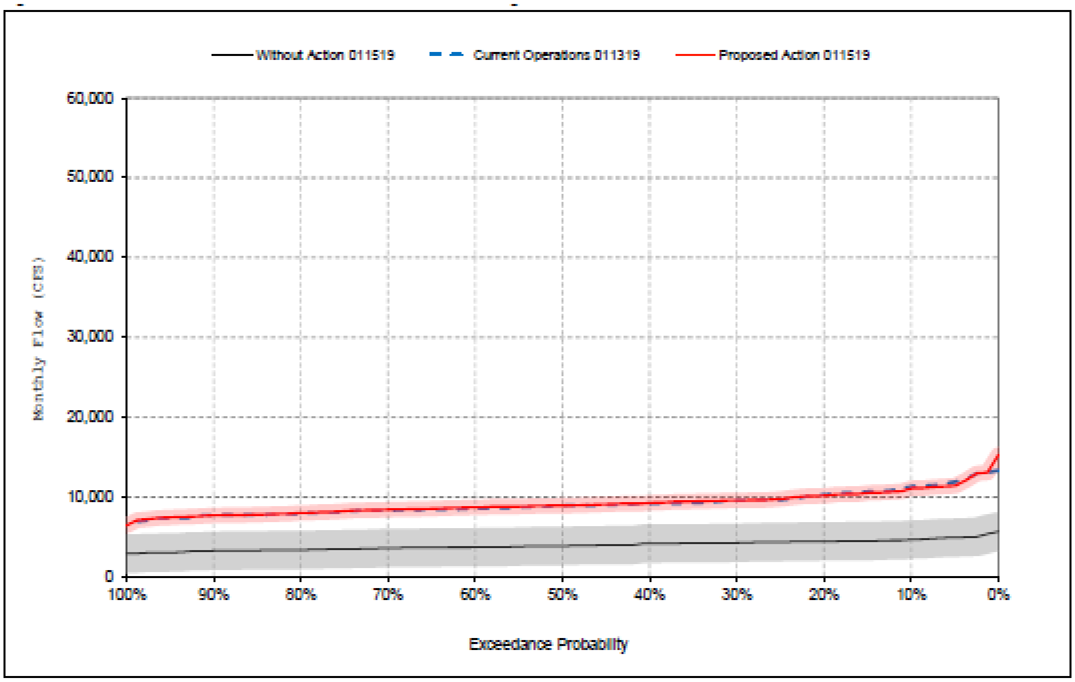


Figure 5.12-22. CalSim II Sacramento River Flows at Red Bluff, August

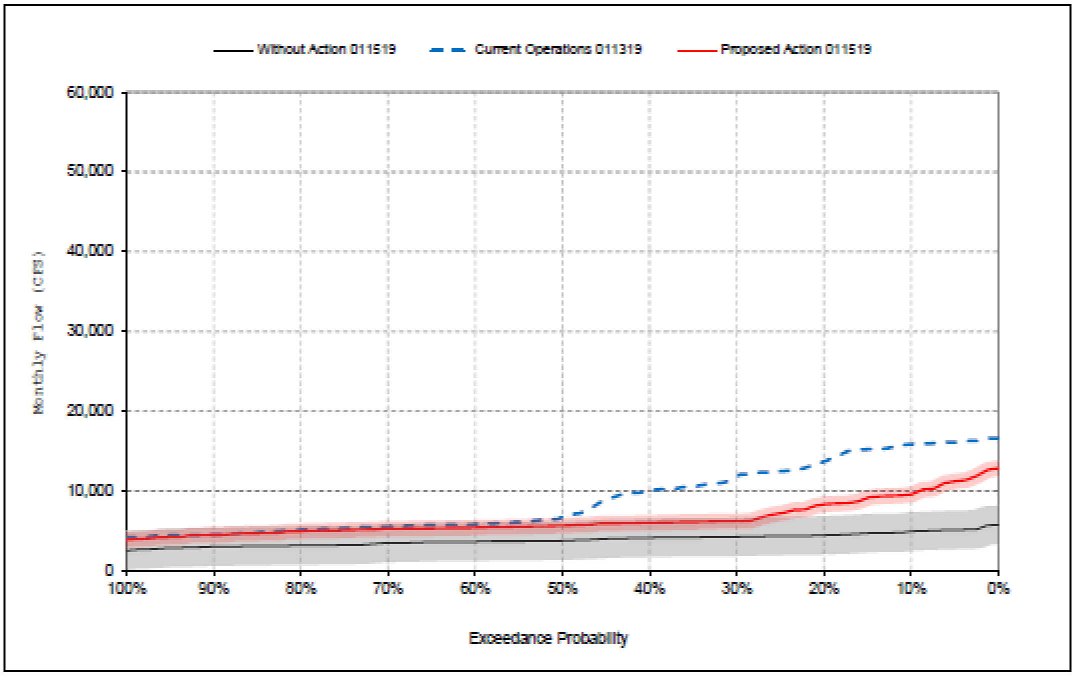


Figure 5.12-23. CalSim II Sacramento River Flows at Red Bluff, September

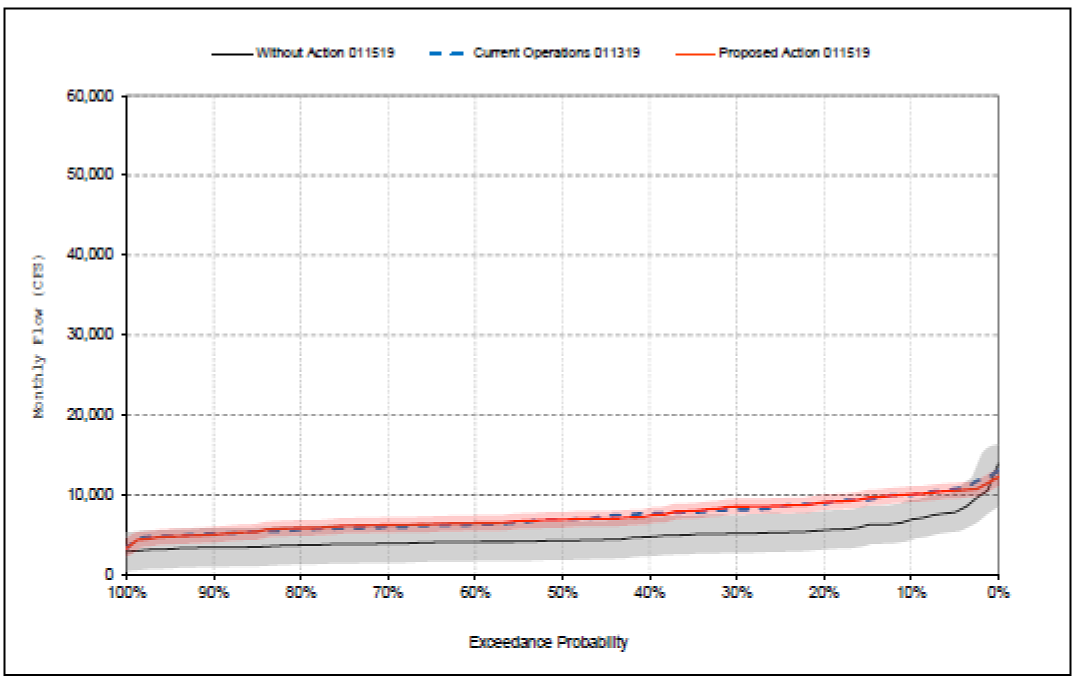


Figure 5.12-24. CalSim II Sacramento River Flows at Red Bluff, October

5.12.3.2.1.2 Water Temperature

The USEPA (2003) gives 61 degrees Fahrenheit as the critical 7DADM water temperature for Green Sturgeon adults holding, although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of operating to 7DADM. The upper limit for mean monthly water temperature of spawning adults is assumed to be similar to that given for incubating eggs, 63 degrees Fahrenheit. In addition, assuming that adults are at least as tolerant to warm temperatures as juveniles, the upper limit for mean monthly water temperatures of migrating adults, whether immigrating or emigrating, is treated as 66 degrees Fahrenheit.

In the middle Sacramento River below the Colusa Basin Drain, which is downstream of any Green Sturgeon spawning areas, the WOA modeling scenario mean monthly water temperatures during February through April and November and December would consistently fall below the 66 degrees Fahrenheit threshold for migrating adults (see Appendix D, *Modeling*). However, the water temperatures would exceed the threshold during May of about 65 percent of years, during June through September in every year, and during October of about 50 percent of the years (see Appendix D, *Modeling* and Figure 5.12-25, for example). Adults migrating downstream from May through October would potentially be negatively impacted by the high water temperatures, but most upstream immigration occurs before late spring (Heublein et al. 2009) when water temperatures are below the 66 degrees Fahrenheit threshold.

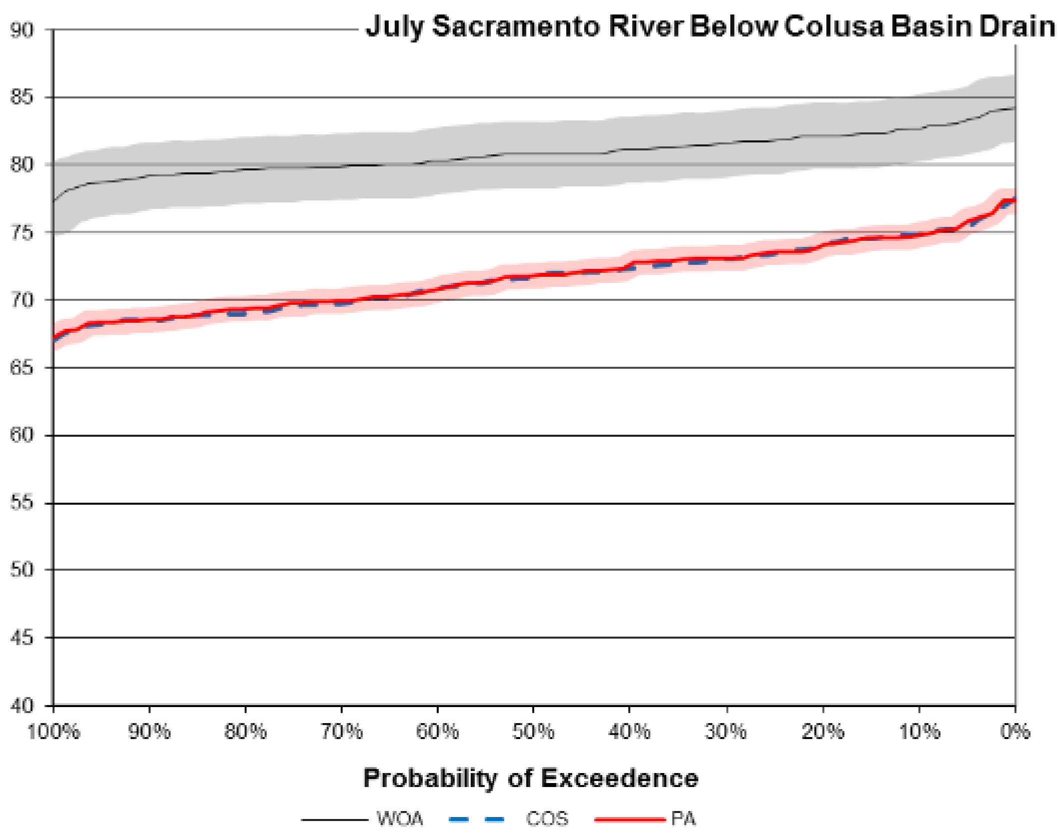


Figure 5.12-25. HEC-5Q Sacramento River Water Temperatures below Colusa Basin Drain under the WOA, Proposed Action and COS Scenarios, July

In the Sacramento River at Woodson Bridge, the WOA mean monthly water temperatures during February through April are below 68 degrees Fahrenheit threshold for migrating adults in every year. This area is located near the GCID oxbow at the most downstream, warmest section of the Green Sturgeon spawning reach. During May through July, which are the peak spawning months, mean monthly water temperatures exceed the 63 degrees Fahrenheit threshold for spawning adults during about 65 percent of the years in May and during every year in June and July (Figures 18-14 through 18-16 in the CalSim II flow section of Appendix D). During August and September, when most Green Sturgeon are holding after spawning or are emigrating downstream, the mean monthly water temperatures at Woodson Bridge under the WOA modeling scenario range from a low of 70 degrees Fahrenheit in September to a high of 81 degrees Fahrenheit in August, thus greatly exceeding the 61 degrees Fahrenheit threshold for holding adults in every year (Figures 18-17 and 18-18 in the CalSim II flow section of Appendix D). During October, the water temperatures exceed the 61 degrees Fahrenheit threshold in about 40 percent of years and during November and December, the water temperatures are well below the threshold in every year (Figures 18-7 through 18-9 in the CalSim II flow section of Appendix D.).

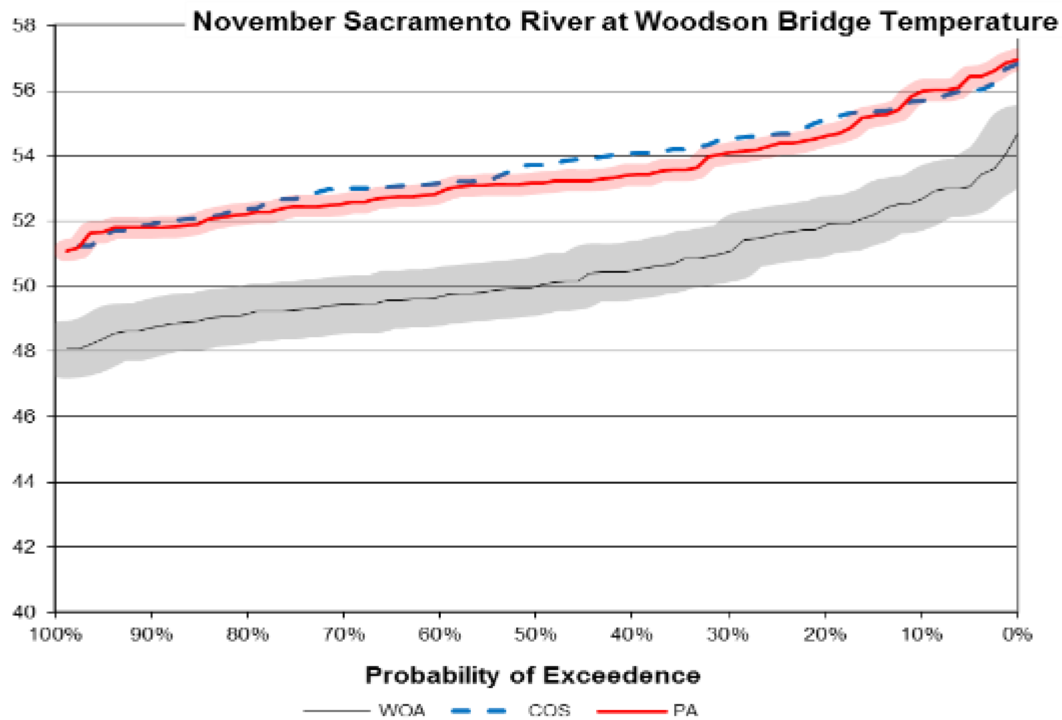


Figure 5.12-26. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, proposed Action and COS Modeling Scenarios, November

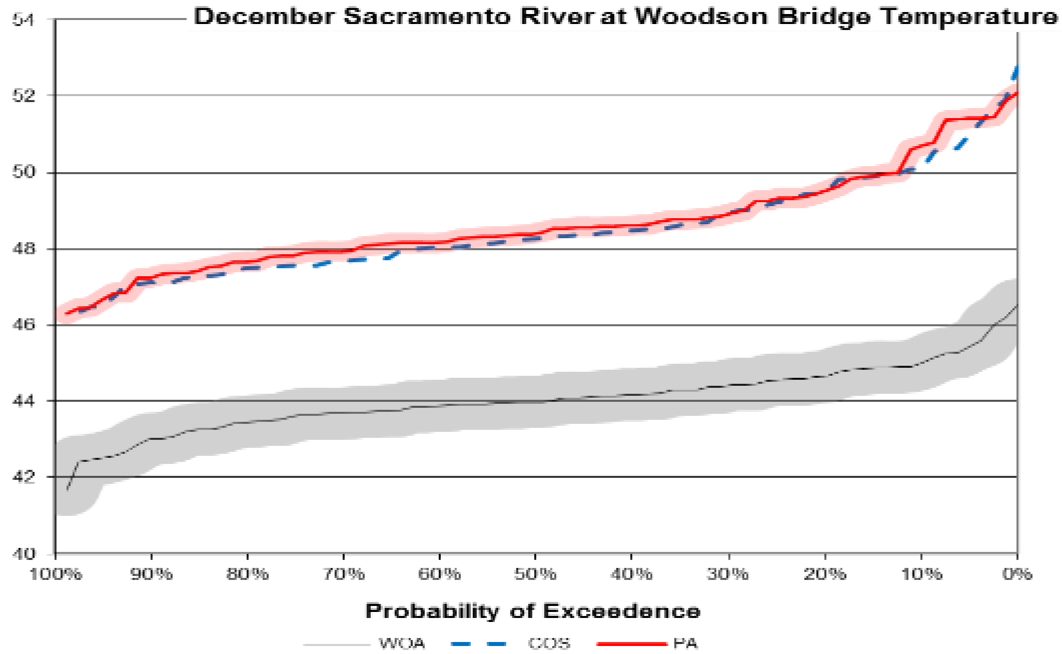


Figure 5.12-27. HEC-5Q Sacramento River Water Temperatures at Woodson Bridge under the WOA, Proposed Action and COS Modeling Scenarios, December

Water temperatures conditions under the WOA modeling scenario in the summer months, June through September, would be highly stressful to adult Green Sturgeon spawning and holding in the Sacramento River. Spawning sturgeon are particularly vulnerable to the effects of elevated water temperature, which may result in egg resorption and reduced fecundity (Heublein et al. 2017a [SAIL model]). Water temperatures in the lower reaches of spawning habitat on the Sacramento River may reach levels that cause egg resorption, affecting fertilization of eggs and survival of embryos (Heublein et al. 2017a [SAIL model]).

There are few major differences in mean monthly water temperatures between the proposed action and COS scenarios in the Sacramento River below the Colusa Basin Drain during the February through April period that most adult Green Sturgeon migrate upstream or during the later months when the sturgeon migrate downstream after spawning (see Appendix D, *Modeling*). The biggest difference occurs in September of cooler years, when water temperatures under the proposed action scenario are higher than those of the COS modeling scenarios, by up to 5 degrees Fahrenheit. The temperatures in September exceed the 66 degrees Fahrenheit threshold for migrating Green Sturgeon adults in 95 percent of years under the proposed action scenario, whereas they exceed the threshold in 65 percent of years under the COS modeling scenario. The temperature difference between the scenarios results from higher flows in wetter years under the COS modeling scenario, which, as previously noted, results from Fall X2 releases.

During the May through December spawning and post-spawn holding period for Green Sturgeon, water temperatures at Woodson Bridge, which is located in the most downstream, warmest section of the Green Sturgeon spawning reach, are generally similar between the proposed action and COS scenario, except for higher temperatures under the proposed action scenario in September, as discussed above for the Colusa Basin Drain location. Adults migrating downstream from May through September would potentially be adversely affected by the high water temperatures. Most upstream immigration occurs before late spring (Heublein et al. 2009), when water temperatures are below the 66 degrees Fahrenheit threshold. Water temperatures during warm years, especially in August and September, would likely be stressful to spawning and holding adult Green Sturgeon.

In the Sacramento River downstream of the Colusa Basin Drain, water temperatures under the proposed action are similar to WOA water temperatures during May, generally higher than the WOA modeling scenario water temperatures from December through April, and below the WOA modeling scenario water temperatures during June through October. In the Sacramento River at Woodson Bridge, water temperatures under the proposed action and COS scenarios are similar to WOA water temperatures during April (Figure 5.12-2), above the WOA modeling scenario water temperatures during February, March, November and December, and below the WOA modeling scenario water temperatures in all years during May through October (see Appendix D, *Modeling*).

Water temperatures in the Sacramento River below the Colusa Basin Drain and at the Woodson Bridge are suitable for adult Green Sturgeon immigrating in the Sacramento River during February through April under all three scenarios, so no negative effects are expected. However, under the WOA modeling scenario during the peak spawning season, May through July, water temperatures at the Woodson Bridge location, near the downstream limit of the Green Sturgeon spawning reach, exceed the 63 degrees Fahrenheit threshold for spawning adults in the majority of years during May and in all years during June and July. Under the proposed action, water temperatures during this period exceed the threshold in at most 50 percent of years (in June and July). During May through December, when most post-spawning Green Sturgeon adults are holding near spawning areas or emigrating back to the estuary, water temperatures under the WOA modeling scenario at Woodson Bridge exceed the 61 degrees Fahrenheit threshold for holding adults during about 85 percent of years in May, in every years during June through September, and in about 40 percent of years in October. The water temperatures at this location under the proposed action exceed the 61 degrees Fahrenheit threshold for holding adults in about 50 percent of years in May, about 95 to 70 percent of years in June through September, and about 10 percent of years in October. Water temperatures below the Colusa Basin Drain during this period, which would affect Green Sturgeon adults emigrating from the Sacramento River, would exceed the 66 degrees Fahrenheit threshold from migrating adults under the WOA modeling scenario in all years during June through September and well over half of years in October. Although the water temperatures below the Colusa Basin Drain exceed the threshold for emigrating adults in all or almost all years during June through September under all three scenarios, the amount by which the threshold is exceeded is consistently much greater under the WOA modeling scenario than under the proposed action.

Summer water temperatures under proposed action are consistently lower than those under the WOA, with far fewer years exceeding the 63 degrees Fahrenheit threshold for spawning adults or the 61 degrees Fahrenheit threshold for holding adults. Summer water temperatures for emigrating adults would also be lower under proposed action for emigrating adults. These results indicate that the proposed action, relative to the WOA, provide a clear benefit to adult Green Sturgeon spawning and holding in the Sacramento River, as well as those emigrating from the river.

5.12.3.2.2 Juvenile to Subadult/Adult

5.12.3.2.2.1 Flows

As noted in the Larvae to Juveniles section, there appears to be a positive relationship between annual outflow and abundance of Green Sturgeon larvae in rotary screw traps at RBDD (Heublein et al. 2017a[SAIL model], 2017b). At federal and state Delta pumping facilities, the highest juvenile Green Sturgeon collection on record occurred in a wet year (2006; Gartz 2007 cited in Heublein et al. 2017b). These findings are consistent with white sturgeon and the relationship between recruitment to age-0 and wet years (Heublein et al. 2017b). These relationships may result from flows transporting larvae and juveniles to areas with greater prey availability and/or enhancing nutrient availability to the Sacramento River and Delta/Estuary.

Green Sturgeon juveniles are believed to be highly susceptible to entrainment in unscreened diversions and impingement on screened diversions (Mussen et al. 2014, NMFS 2018). Risks of entrainment and impingement in the Sacramento River are increased because the period of juvenile presence in the river (May through December), coincides with peak period of irrigation diversions (April to September).

High WOA flows occur frequently during May and December, and these could have both positive and negative effects on rearing and emigrating Green Sturgeon juveniles (Figures 5.12-28 to 5.12-35). The impacts of low flows listed above are generally ameliorated by higher flows, but there can be adverse impacts, including higher contaminant concentrations from stormwater runoff.

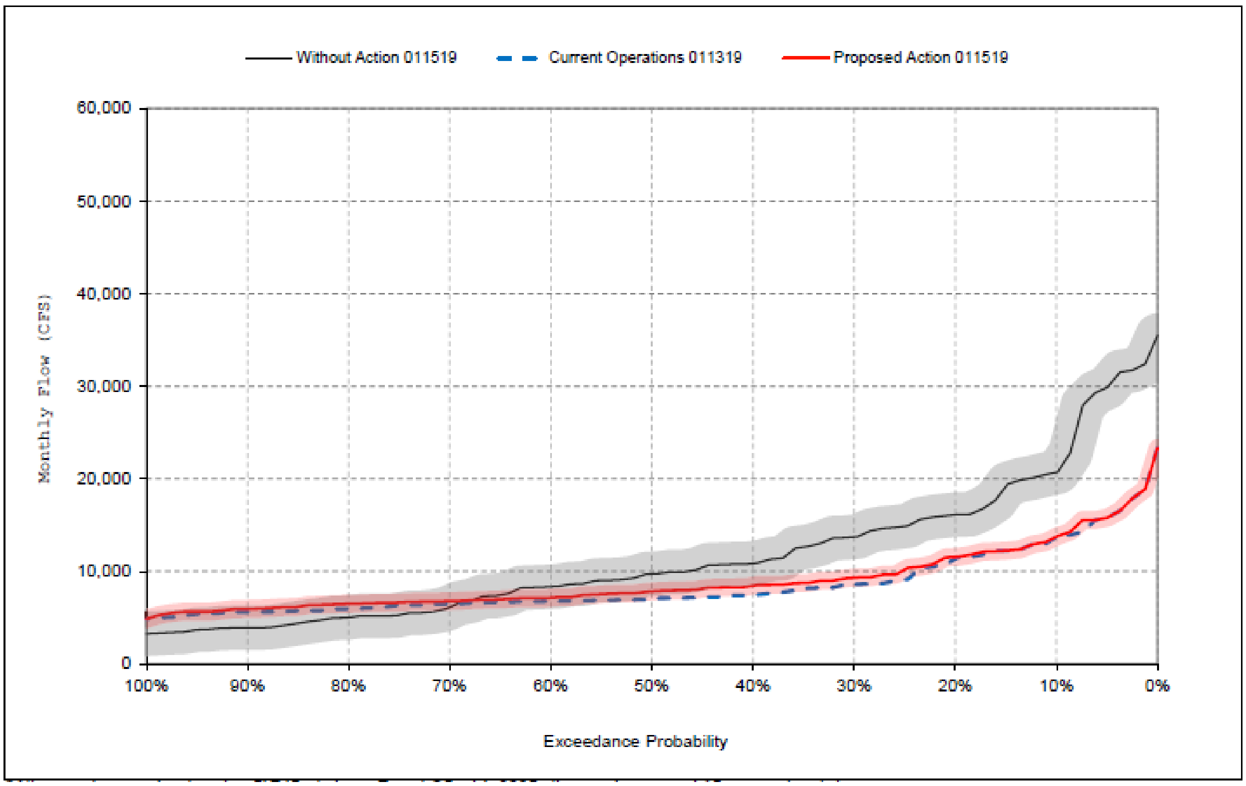


Figure 5.12-28. CalSim II Sacramento River Flows at Hamilton City, May

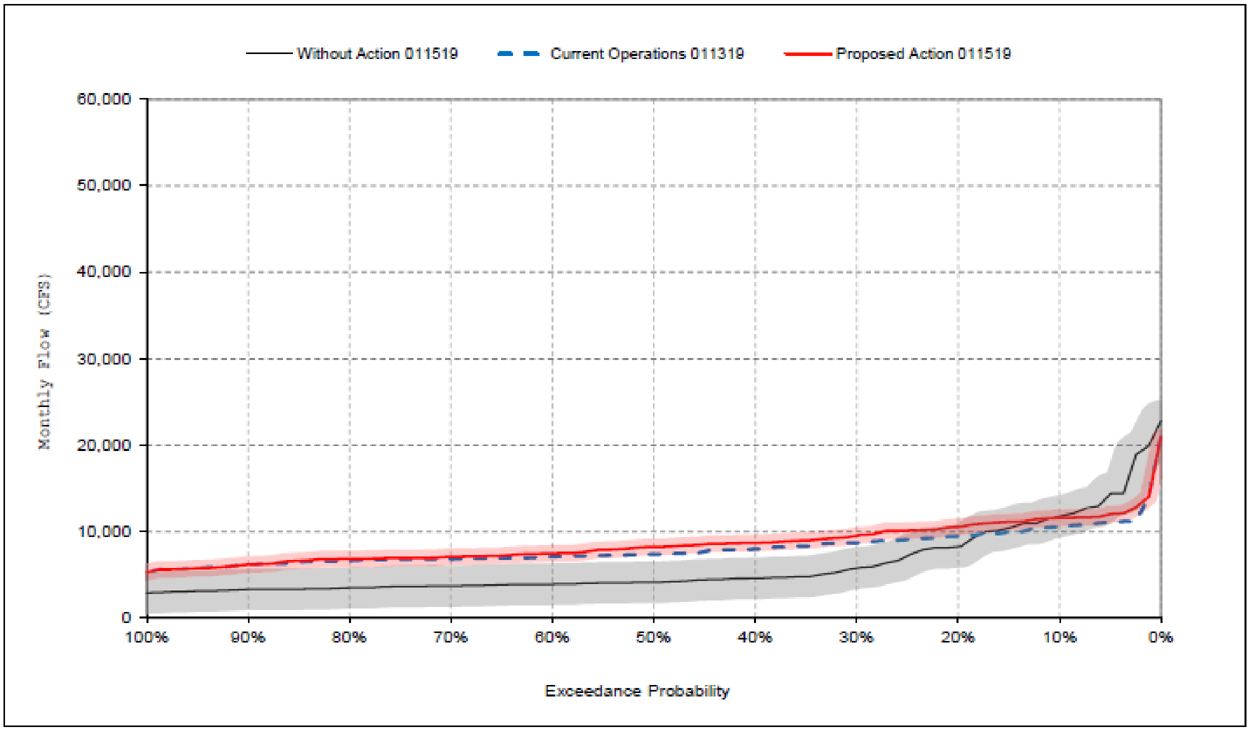


Figure 5.12-29. CalSim II Sacramento River Flows at Hamilton City, June

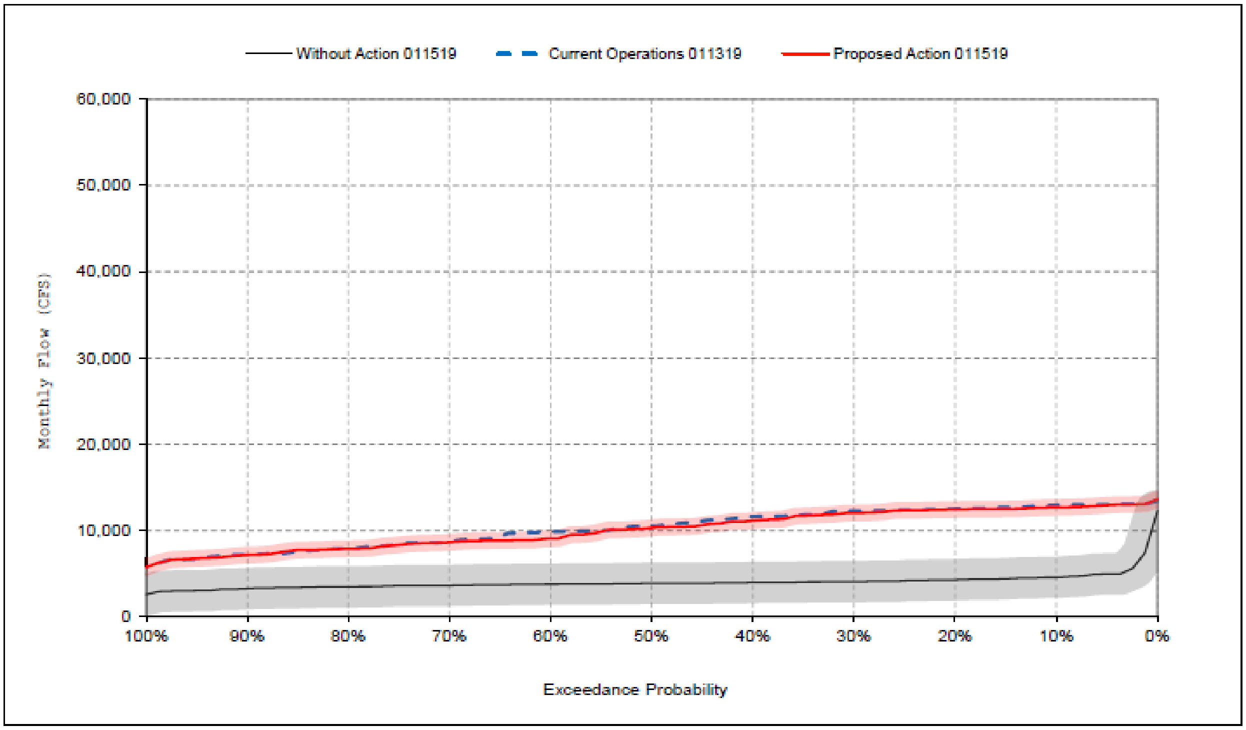


Figure 5.12-30. CalSim II Sacramento River Flows at Hamilton City, July

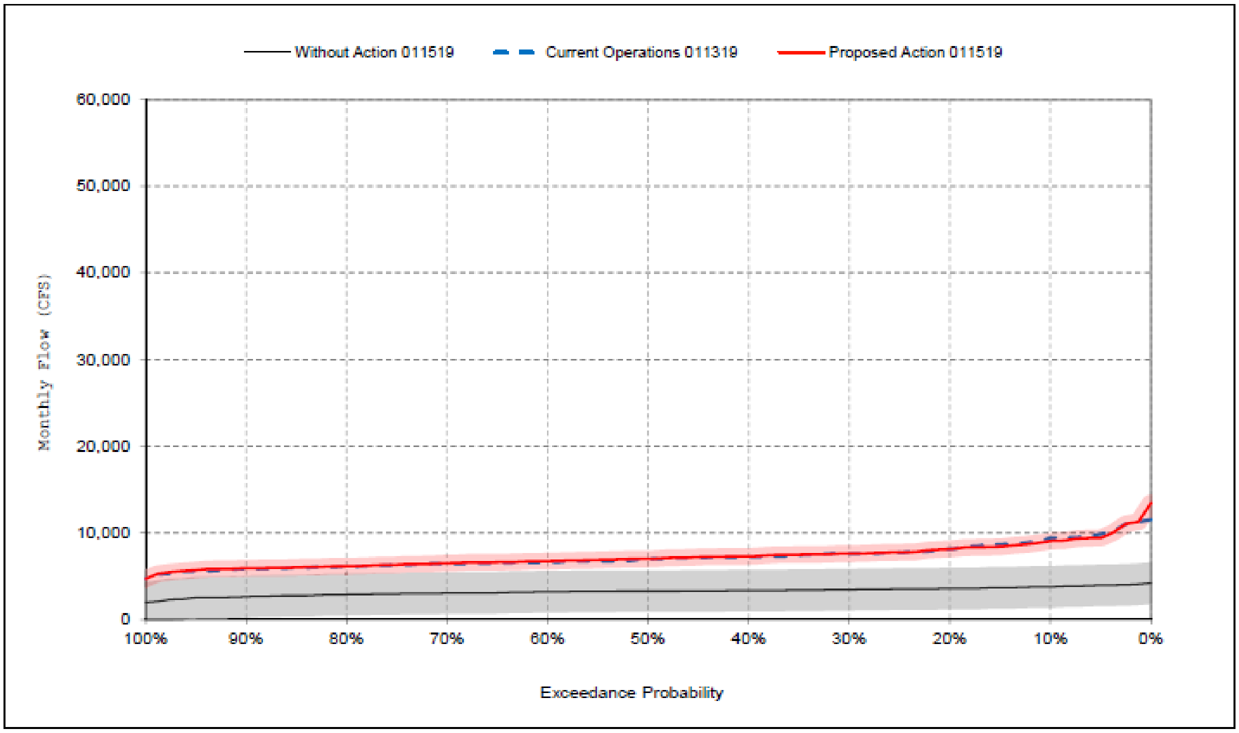


Figure 5.12-31. CalSim II Sacramento River Flows at Hamilton City, August

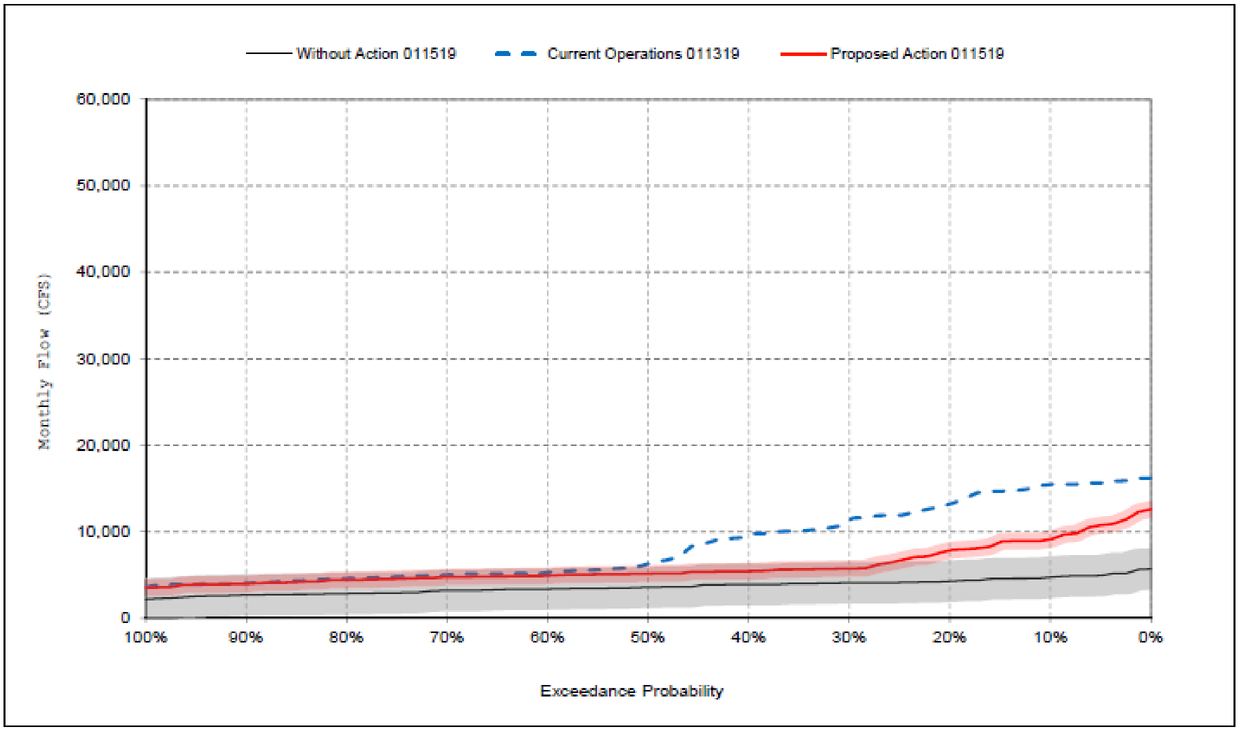


Figure 5.12-32. CalSim II Sacramento River Flows at Hamilton City, September

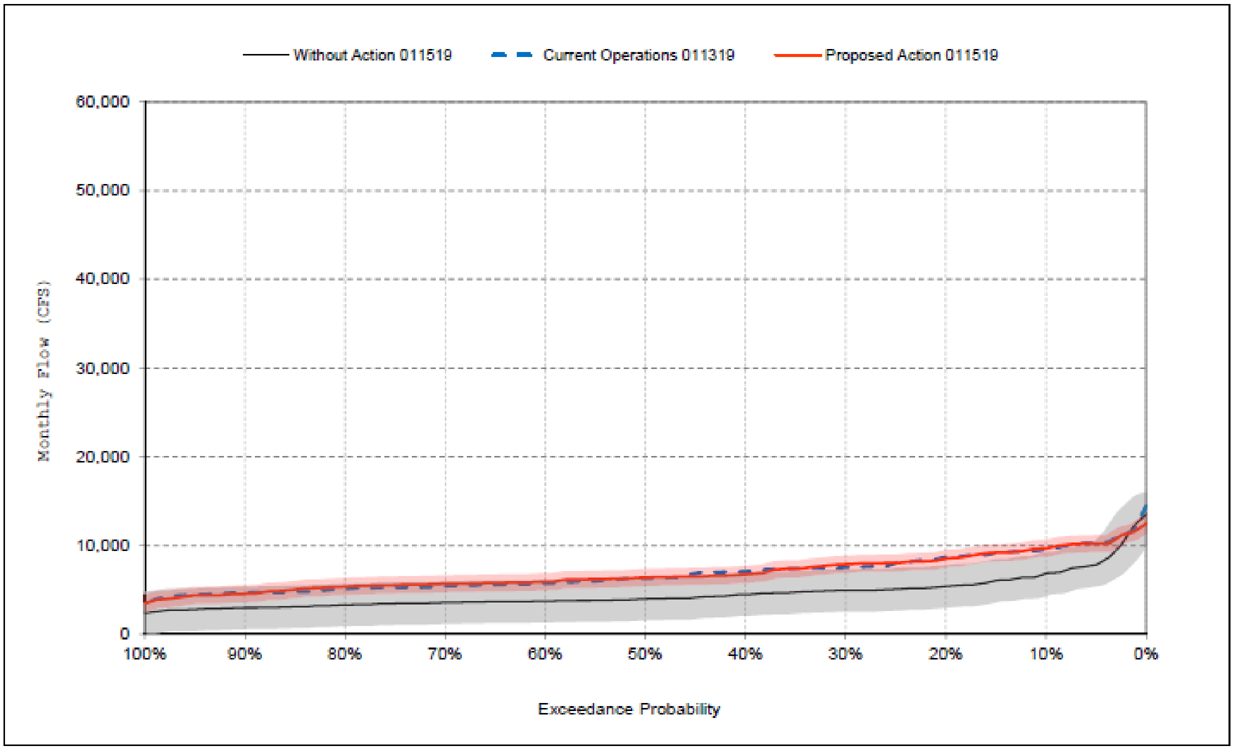


Figure 5.12-33. CalSim II Sacramento River Flows at Hamilton City, October

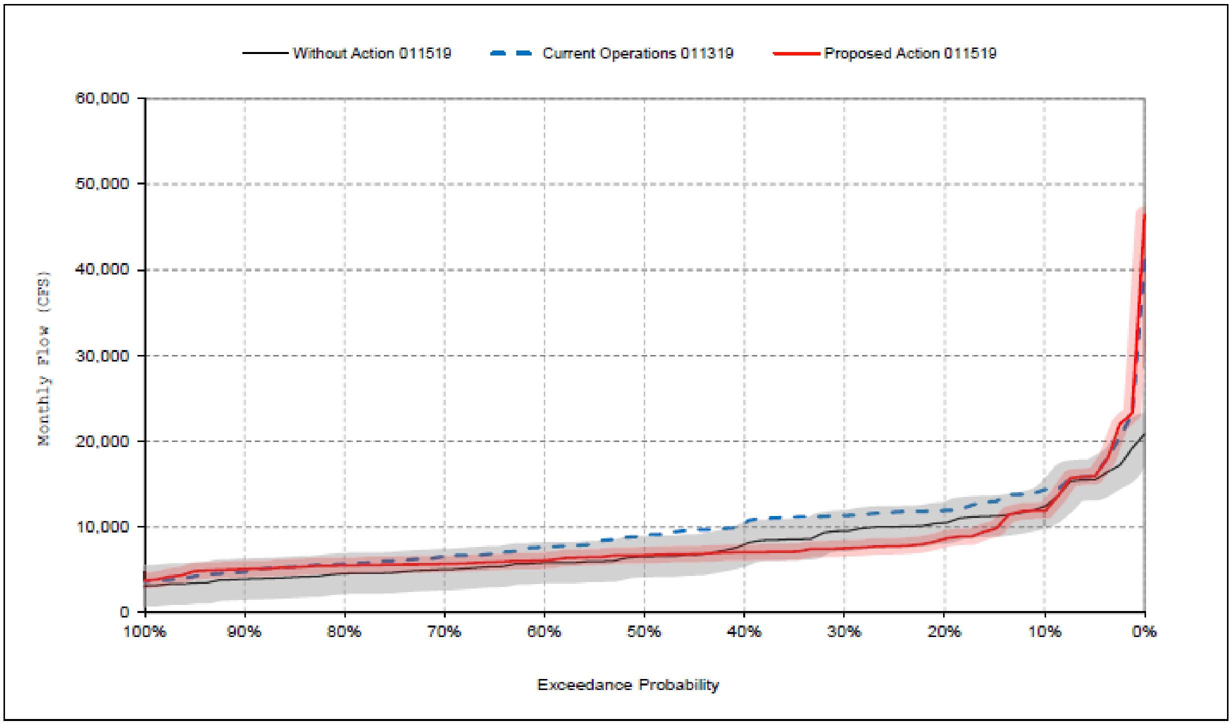


Figure 5.12-34. CalSim II Sacramento River Flows at Hamilton City, November

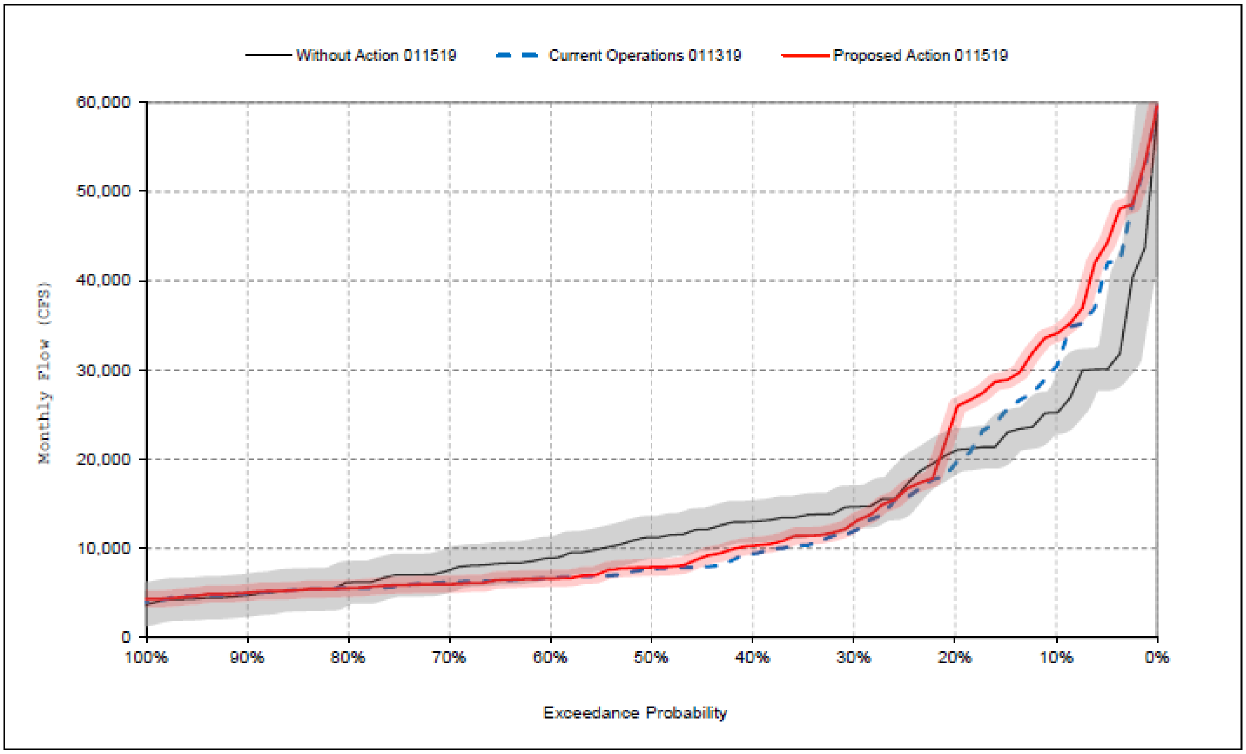


Figure 5.12-35. CalSim II Sacramento River Flows at Hamilton City, December

CalSim modeling for the Sacramento River at Hamilton City indicates that flows during the period of juvenile rearing and emigration are generally similar between proposed action and COS except, as described previously, for much higher flows during September under the COS modeling scenario in the upper range of flows (Figure 5.12-32), which result from Fall X2 releases under COS that are not included in the proposed action. Differences between proposed action and COS flows are also large in June and November (Figures 5.12-29 and 5.12-34), with higher flows for the proposed action in June and for the COS in November, but the differences are much less high than those in September.

The CalSim modeling shows large seasonal changes during the larval period between the WOA modeling scenario and the proposed action. For most years in May, the WOA flows are greater than the proposed action flows (Figure 5.12-28), but for almost all years in June through October, the proposed action flows are higher than the WOA flows (Figures 5.12-29 through 5.12-33). The WOA flows are similar to the proposed action flows in November and December (Figures 5.12-34 and 5.12-35). These seasonal changes result primarily from diversions to Shasta Reservoir storage under the proposed action scenarios during spring, when uncontrolled flows are high, and Shasta Reservoir storage releases under the proposed action scenarios during June through October, when uncontrolled flows are low.

The higher summer and fall flows under the proposed action would potentially result in improved conditions in juvenile rearing habitats, as previously described, and increase transport of the juveniles to favorable rearing habitats.

5.12.3.2.2.2 Water Temperature

Critical water temperatures thresholds have been determined for Northern DPS Green Sturgeon but not for Southern DPS Green Sturgeon, but it is assumed that the temperature tolerances of the two distinct population segments are similar (Heublein et al. 2017b). Based on laboratory studies, Mayfield and Cech

(2004) concluded that 59 to 66 degrees Fahrenheit is the optimal range of water temperatures for growth of juvenile sturgeon. This temperature range overlaps the optimal range temperatures range for Green Sturgeon eggs (below 63 degrees Fahrenheit) and larvae (63 to 68 degrees Fahrenheit)

There is little difference in water temperatures at Woodson Bridge between the proposed action and COS scenarios during the Green Sturgeon juvenile rearing and emigration period in any month except for September. During well over half of the years in September, the proposed action water temperature is greater than the COS water temperature, with a maximum difference of about 4 degrees Fahrenheit (see Figure 12-18 in the HEC 5Q Temperatures section of Appendix D).

Water temperatures under the proposed action at Hamilton City fall within the 59 to 66 degrees Fahrenheit optimal range for Green Sturgeon juveniles during most years in June through September. Temperatures exceed 66 degrees Fahrenheit under the proposed action in 5% of Junes, 8% of Julys, 15% of Augusts, and 20% of Septembers (see Appendix D, *Modeling*). Water temperatures for about 80% of the years in May, most years in June to October, and all years during November and December fall below the 59 degrees Fahrenheit threshold for juvenile Green Sturgeon optimal growth. Water temperatures under the proposed action would be suitable for survival of Green Sturgeon juveniles throughout the rearing and emigration period, although temperature in the colder months would be below the range for optimal growth.

May through October water temperatures under the proposed action are consistently lower than those under the WOA modeling scenario (See Figures 12-7, 12-14, 12-15, 12-16, 12-17 and 12-18 in the HEC5Q temperature section of Appendix D), while November and December temperatures are consistently higher than WOA temperatures (See Figures 12-8 and 12-9 in the HEC5Q temperature section of Appendix D). During June through September, the WOA water temperatures always exceed the optimal range, and during the same months, the proposed action water temperatures lie within the optimal range in most years and exceed the upper threshold (66 degrees Fahrenheit) in only a few percent of years in August and September. Only in May under the WOA modeling scenario, do the majority of years lie within the optimal temperature range. These results indicate that the proposed action provides more favorable water temperature conditions for Green Sturgeon juveniles than the WOA modeling scenario, although it also provides temperatures too cold of optimal growth in some months. As previously noted, the juveniles would be unlikely to survive water temperature conditions in the middle Sacramento River expected under the WOA scenario in July and August.

5.12.3.2.3 <u>Larvae to Juvenile (April – August)</u>

5.12.3.2.3.1 Flow

The effects of flow on Green Sturgeon larvae are poorly understood. There appears to be a positive relationship between annual outflow and abundance of Green Sturgeon larvae and juveniles in rotary screw traps at RBDD (Heublein et al. 2017a [SAIL model], 2017a). Also, there is a positive correlation between mean daily freshwater outflow (April to July) and white sturgeon year class strength (CDFG 1992 and USFWS 1995, cited in NMFS 2018). 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/Estuary.

Green Sturgeon larvae may be particularly susceptible to entrainment at water diversions. The larvae are present in areas where substantial water volumes are diverted, such as the Red Bluff Diversion Dam and Glen-Colusa Irrigation District (GCID) facilities and, due to their small size and relatively poor swimming performance, it is highly likely that entrainment effects larval survival (Heublein et al.

2017a[SAIL model]; Verhille et al. 2014). Modern fish screens are designed to reduce entrainment of juvenile salmonids, but the effectiveness of screens and facility operations in reducing larval Green Sturgeon entrainment is poorly understood. Furthermore, many small-scale unscreened diversions are present near larval habitat throughout the mainstem Sacramento River. Periods of extended low flow may reduce the effectiveness of fish protection devices and operational measures intended to reduce entrainment (Heublein et al. 2017a[SAIL model]).

Flows under the WOA modeling scenario would generally be low in summer and fall, potentially affecting the Green Sturgeon larvae. High WOA flows occur during April and May in many years, and these could have both positive and negative effects on rearing Green Sturgeon larvae. The impacts of low flows listed above are generally ameliorated by higher flows, but there can be adverse effects including higher stranding risk because of greater flow fluctuations and higher contaminants concentrations from stormwater runoff.

The CalSim modeling shows large seasonal changes during the larval period between the WOA modeling scenario and the proposed action. For all years in April and most years in May, the WOA flows are greater than the proposed action flows, but in June through September, the proposed action flows are almost always higher than the WOA flows. These seasonal changes result primarily from diversions to Shasta Reservoir storage under the proposed action during spring, when uncontrolled flows are high, and Shasta Reservoir storage releases under the proposed action during June through September, when uncontrolled flows are low.

The lower summer and fall flows under the WOA modeling scenario would potentially result in reduced conditions in larval rearing habitats, as previously described, and reduce dispersion of the larvae to favorable rearing habitats.

5.12.3.2.3.2 Water Temperature

Critical water temperatures thresholds have been determined for Northern DPS Green Sturgeon but not for Southern DPS Green Sturgeon, but it is assumed that the temperature tolerances of the two distinct population segments are similar (Heublein 2017b). Based on laboratory studies, Van Eenennaam et al. (2005) concluded that 63 degrees Fahrenheit is the minimum water temperature for optimal growth and survival of larvae and 68 degrees Fahrenheit is the maximum. This water temperature range exceeds the upper limit of optimal temperatures for Green Sturgeon eggs (63 degrees Fahrenheit)

Water temperatures under the proposed action fall below the 63 to 68 degrees Fahrenheit optimal range for Green Sturgeon larvae in most years throughout the entire April to October period of potential larval presence in the Sacramento River. During April, May and October, the mean monthly water temperatures at Hamilton City are above 63 degrees Fahrenheit in no more than about 10 percent of years, while during June through September, the water temperatures fall within the optimal range for a minimum of 50 percent of years to a maximum of 70 percent of years. The water temperatures exceed the 68 degrees Fahrenheit upper temperature threshold in at most 8 percent of years in any month.

Late spring, summer, and early fall water temperatures under the proposed action are consistently lower than those under the WOA modeling scenario, except during April, when water temperatures for all three scenarios are similar. During July through September, the WOA water temperatures always exceed the optimal range, and under the proposed action water temperatures are within the optimal range approximately half of the time at Hamilton City. Only in May under the WOA modeling scenario do the majority of years lie within the optimal temperature range. These results indicate that neither the WOA, proposed action, nor COS provide optimal water temperature conditions for Green Sturgeon larvae.

However, cooler water temperatures under the proposed action would have beneficial impacts on Green Sturgeon larvae (especially July and August) because WOA temperatures frequently approach lethal levels.

5.12.3.2.4 Egg to Larvae (March – July)

5.12.3.2.4.1 Flows

In the section of the Sacramento River where Green Sturgeon spawn, the WOA flows during the April through July period, when most Green Sturgeon spawning and egg incubation occurs, vary greatly, ranging from about 3,000 cfs for about two percent of years during July to well over 50,000 cfs for three percent of years in April. During years with dry hydrology (left-hand portion of the flow probability of exceedance plots), the July flows in about five percent of years would drop below the proposed action minimum flow of 3,250 cfs. During June in about 40 percent of years and July in about 80 percent of years, flows would be below 5,000 cfs, which is the proposed action minimum flow for the Sacramento River at Wilkins Slough.

Higher flows may also adversely impact spawning and egg incubation. If flows are sufficiently high, incubating eggs are at risk of being scoured from the river bed. Dewatering of Green Sturgeon eggs is less of a risk than it is for most fish species because eggs are generally spawned in deep water.

During the April through July Green Sturgeon spawning period, mean monthly flows at Red Bluff under the proposed action range from about 3,000 cfs for a few years in July to about 40,000 cfs in April. Flows in the majority of years during this period are moderate (~10,000 cfs to 15,000 cfs), with the percentage of years with flows under 10,000 cfs decreasing progressively from 75 percent in April to only 15 percent in July. The reductions in low flows over the course of this period reflects the increased flow releases needed for water temperature management in the river and instream demands and Delta requirements. The proposed action flow levels in most years throughout the April through July period are suitable for Green Sturgeon spawning and egg incubation, and no impacts are expected to result. During the August through October period, when Green Sturgeon spawning occurs in occasional years, the proposed action flows tend to be lower than those in April through July, but flows would drop below 5,000 cfs for only about 15 percent of years in September and no years and 5 percent of years in August and October, respectively. The late summer and fall spawning by Green Sturgeon has occurred sporadically and primarily in wetter years (NMFS 2018), so the occasional moderately low September flows (less than 5,000 cfs) under the proposed action scenarios are not expected to have any meaningful biological effect on spawning and egg incubation of the Sacramento River Green Sturgeon population.

Differences in flows between the proposed action are small in most months, but flows are moderately higher for the proposed action in June (Figures 5.12-20). The flow differences are expected for years with relatively wet hydrology (~10,000 cfs to 15,000 cfs) and, therefore, are not expected to have a meaningful effect on development or survival of incubating Green Sturgeon eggs.

During April, WOA flows are consistently well above proposed action flows (Figure 5.12-18) and likely provide more favorable conditions for Green Sturgeon spawning and egg incubation, except in the wettest years, when the WOA flows may be high enough to scour the incubating eggs. During June and July, the proposed action flows are almost always higher than the WOA flows (Figures 5.12-20 and 5.12-21) and during May, flows under the proposed action are lower than flows under the WOA modeling scenario in wetter years, but are higher than WOA flows in drier years (Figures 5.12-19). During May through July, therefore, the potential adverse impacts of low flows on Green Sturgeon spawning and egg incubation listed above are expected to occur less frequently and with less severity under the proposed action than under the WOA conditions.

5.12.3.2.4.2 Water Temperature

Critical water temperatures thresholds have been determined for Northern DPS Green Sturgeon but not for Southern DPS Green Sturgeon. It is assumed that the temperature tolerances of the two distinct population segments are similar (Heublein et al. 2017b). Based on laboratory studies, Van Eenennaam et al. (2005) concluded that 63 degrees Fahrenheit is the maximum water temperature for normal embryo development.

The presence of a large cold water pool and the flexibility afforded by the TCD under the proposed action make possible the provision of cold water in the upper Sacramento River during the summer and fall, which would benefit Green Sturgeon spawning and egg incubation. Under the proposed action, monthly mean water temperatures at Hamilton City range from about 51 to 69 degrees Fahrenheit during April through July (Figures 5.12-36 through 5.12-42). About 50 percent of years in June and July have mean monthly water temperatures exceeding the 63 degrees Fahrenheit threshold. During August and September, about 70 percent of years have mean monthly water temperatures that exceed 63 degrees Fahrenheit, but during October the frequency of exceedance is less than 5 percent (Figures 5.12-36 through 5.12-42).

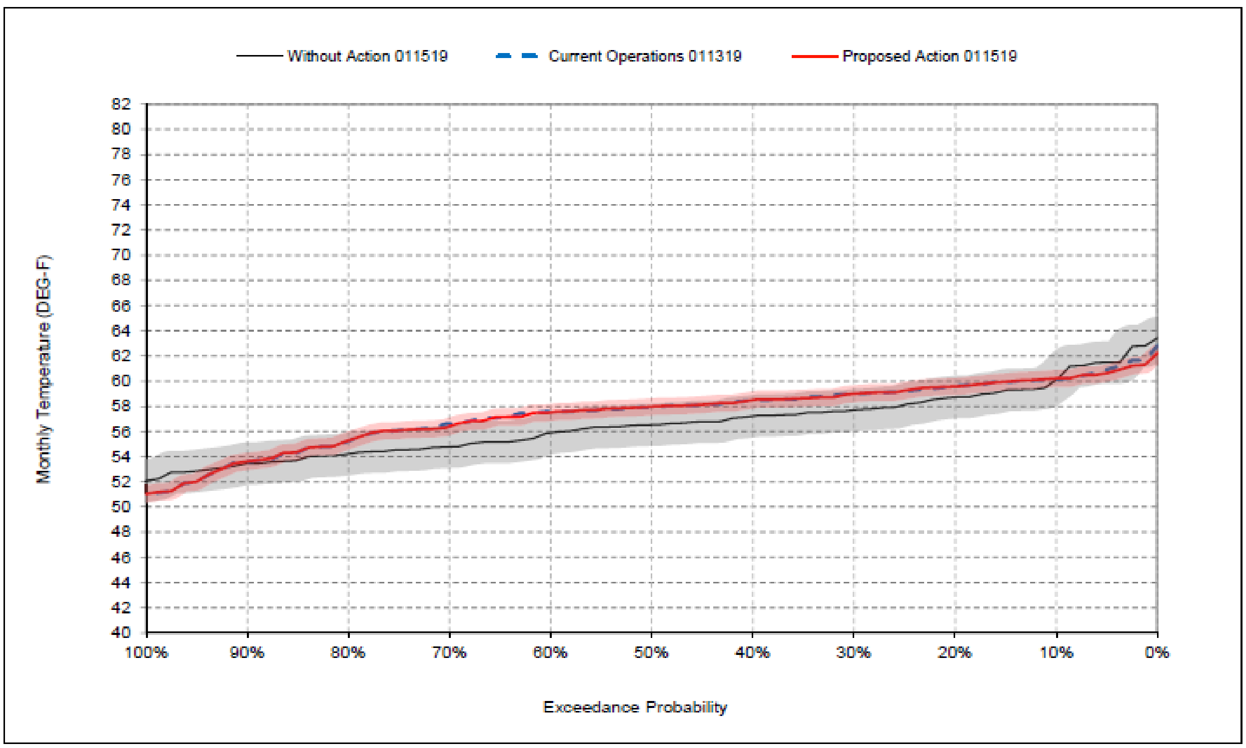


Figure 5.12-36. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, proposed Action and COS Scenarios, April

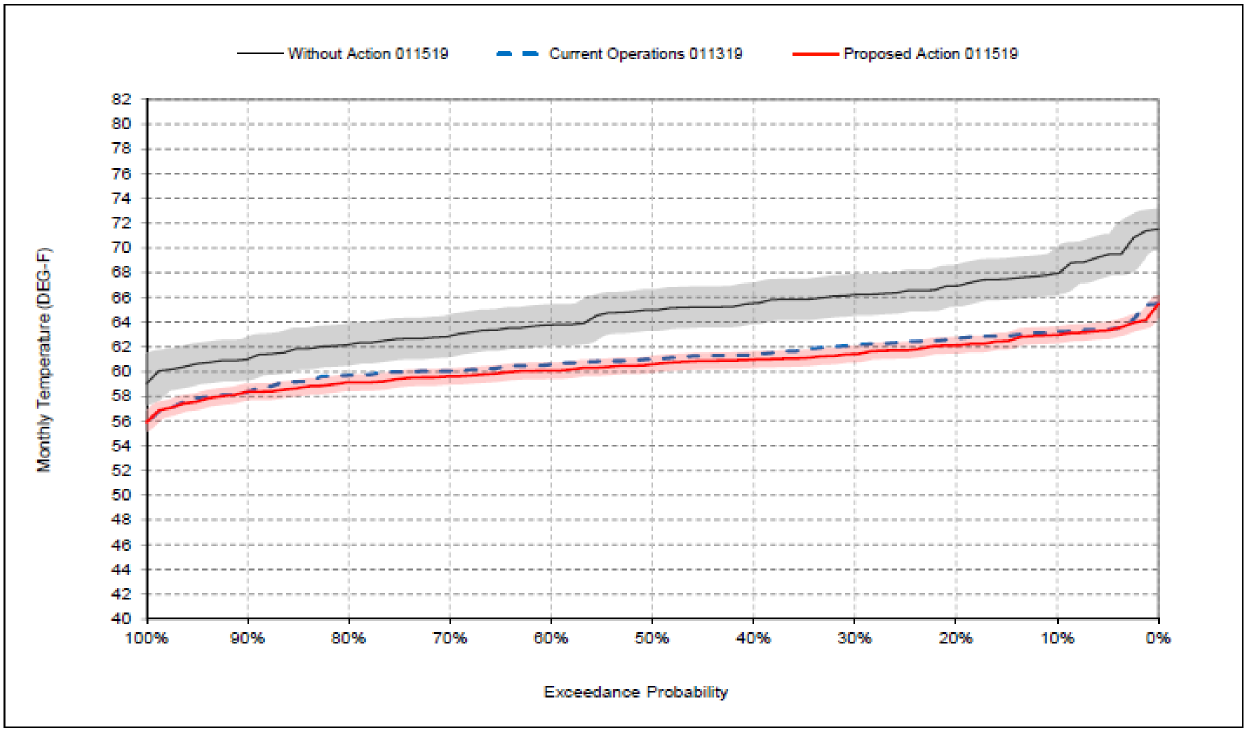


Figure 5.12-37. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, proposed Action and COS Scenarios, May

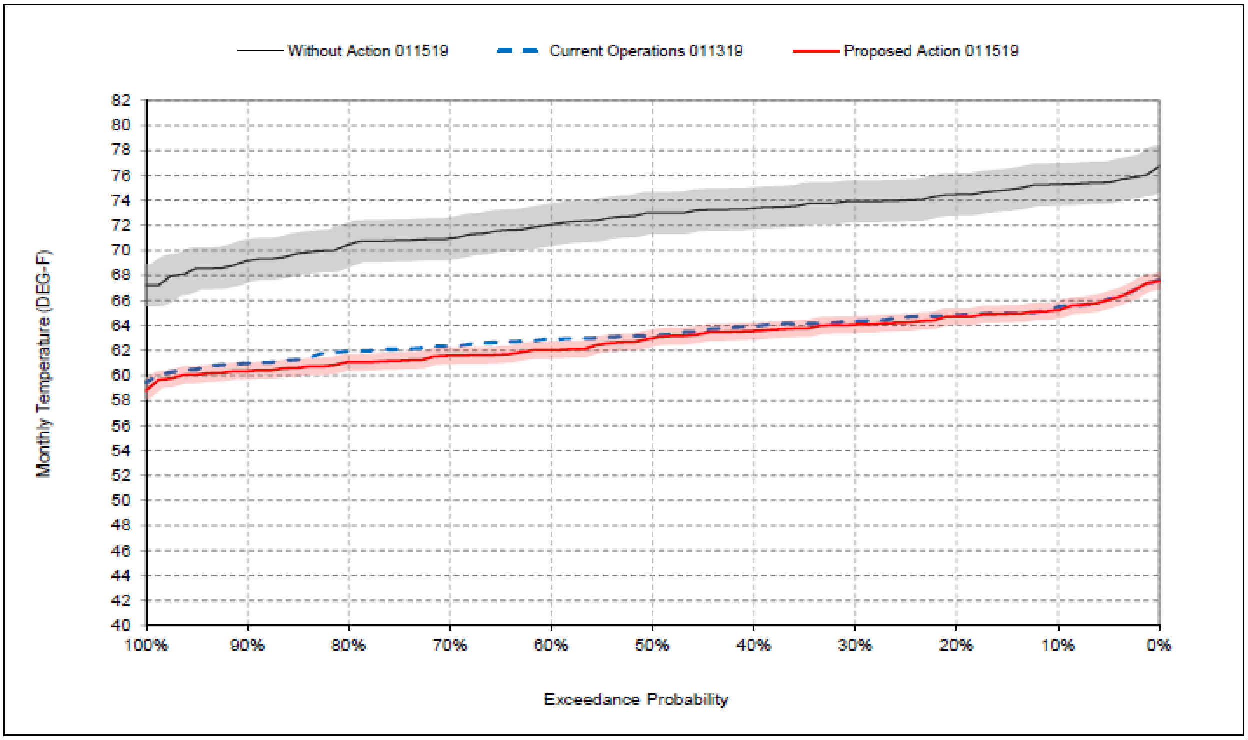


Figure 5.12-38. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, proposed Action and COS Scenarios, June

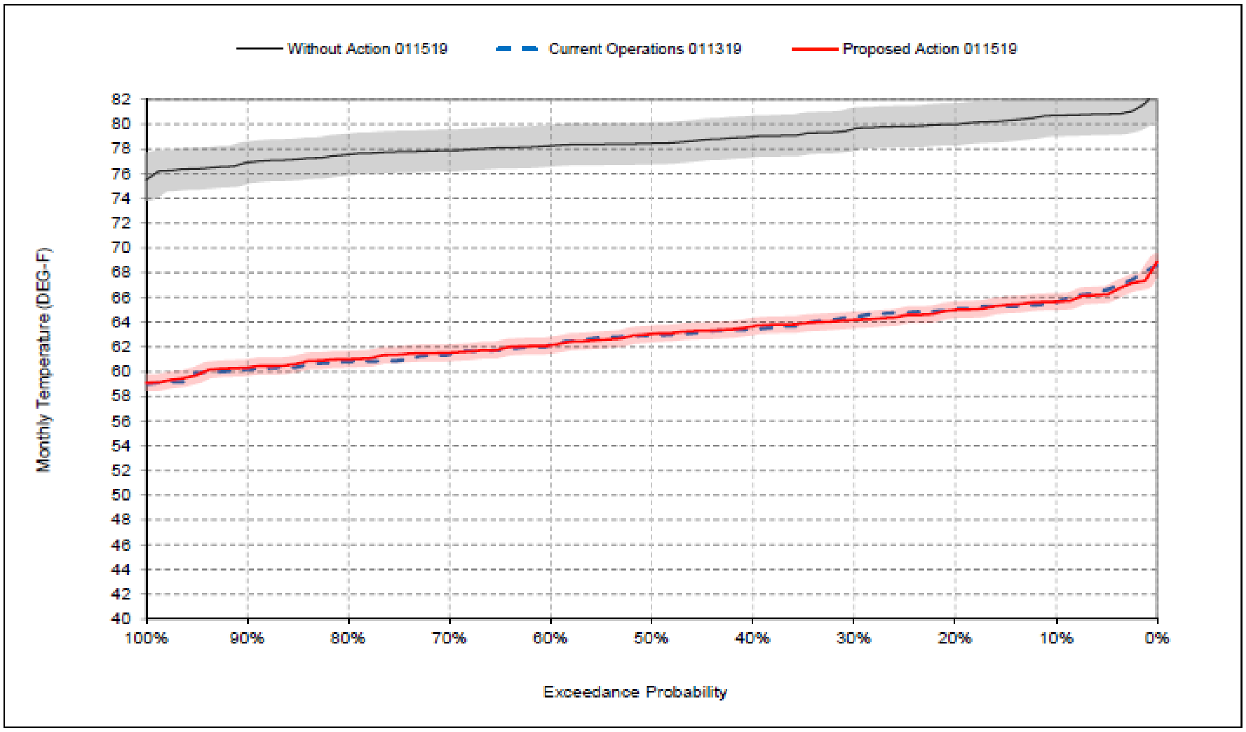


Figure 5.12-39. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, proposed Action and COS Scenarios, July

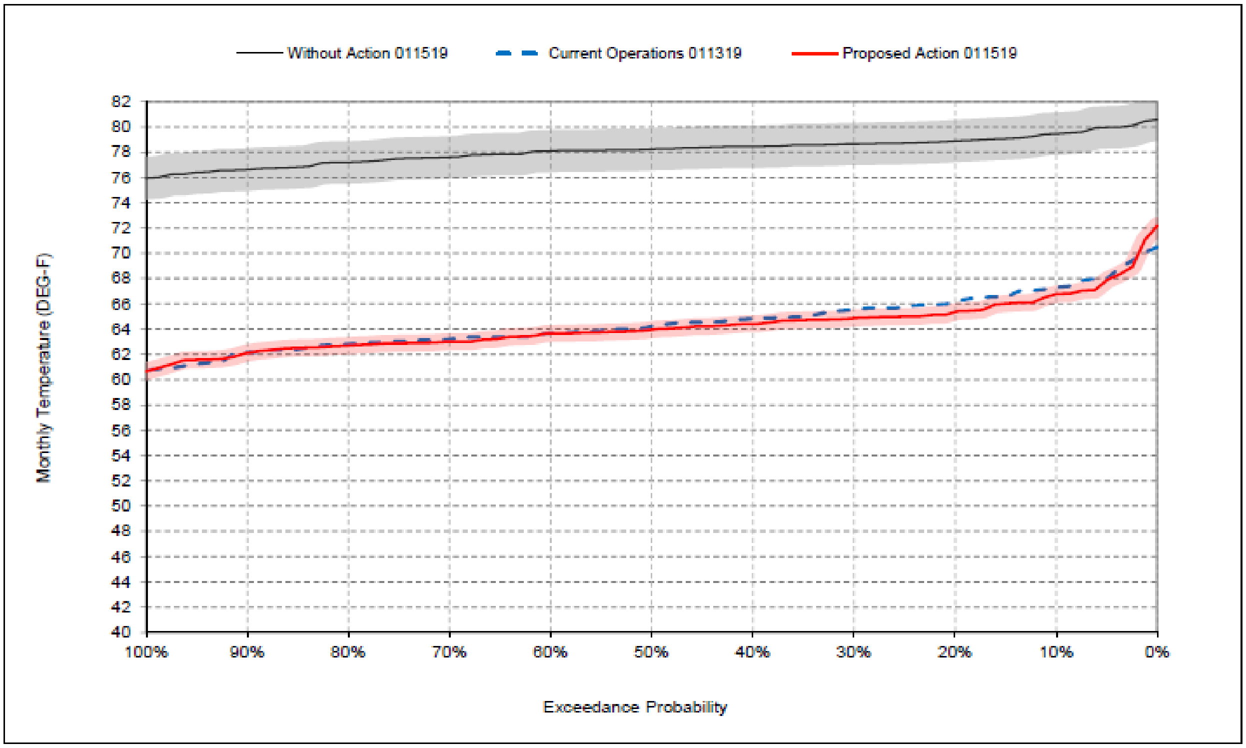


Figure 5.12-40. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, Proposed Action and COS Scenarios, August

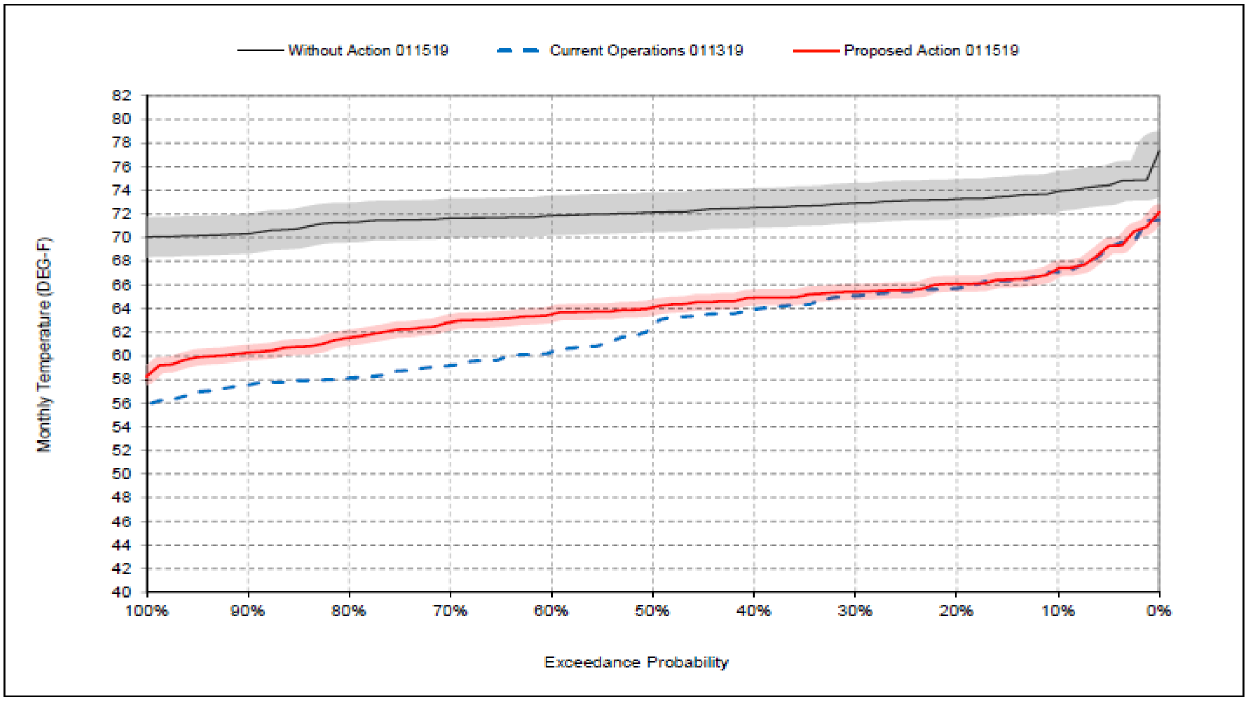


Figure 5.12-41. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, Proposed Action and COS Scenarios, September

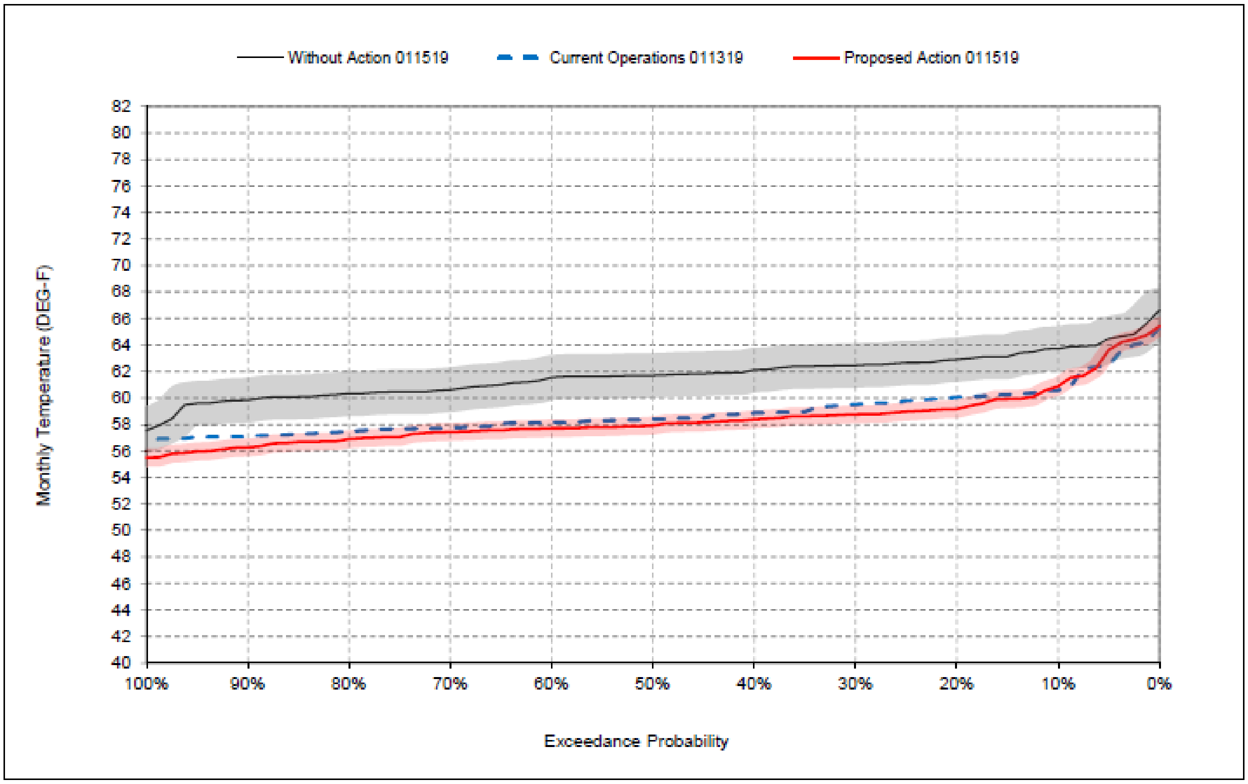


Figure 5.12-42. HEC-5Q Sacramento River Water Temperatures at Hamilton City under the WOA, Proposed Action and COS Scenarios, October

Summer water temperatures under the proposed action are consistently lower than those under the WOA modeling scenario (Figures 5.12-38 to 5.12-41), with far fewer years exceeding the 63 degrees Fahrenheit threshold. These results indicate that the proposed action, relative to the WOA modeling scenario, provide a clear benefit to Green Sturgeon spawning and egg incubation in the Sacramento River. The temperature management operations under the proposed action are likely to benefit Green Sturgeon egg survival relative to the WOA modeling scenario.

5.12.3.3 Spring Pulse Flows

Under WOA, spring pulse flows would occur naturally and more often. Under the Proposed Action, Reclamation would release spring pulse flows for juvenile salmonid outmigration when storage levels allow. These flow increases could reduce temperatures during the early portion of larval stage of Green Sturgeon, which could help keep temperatures below the 63 degree Fahrenheit threshold for Green Sturgeon egg development.

5.12.3.4 Fall and Winter Refill and Redd Maintenance

Under WOA, fall flows would be low. Under the Proposed Action, Reclamation would adjust fall flows based on Shasta storage levels to avoid redd dewatering of fall-run and winter-run Chinook salmon redds and avoid cold water pool impacts. Higher flows in the fall could negatively affect the juvenile lifestage of Green Sturgeon, but reducing temperatures further below the 63 to 68 degree optimal range for Green Sturgeon juvenile development.

5.12.3.5 Feather River

5.12.3.5.1 Egg to Larvae (March – July)

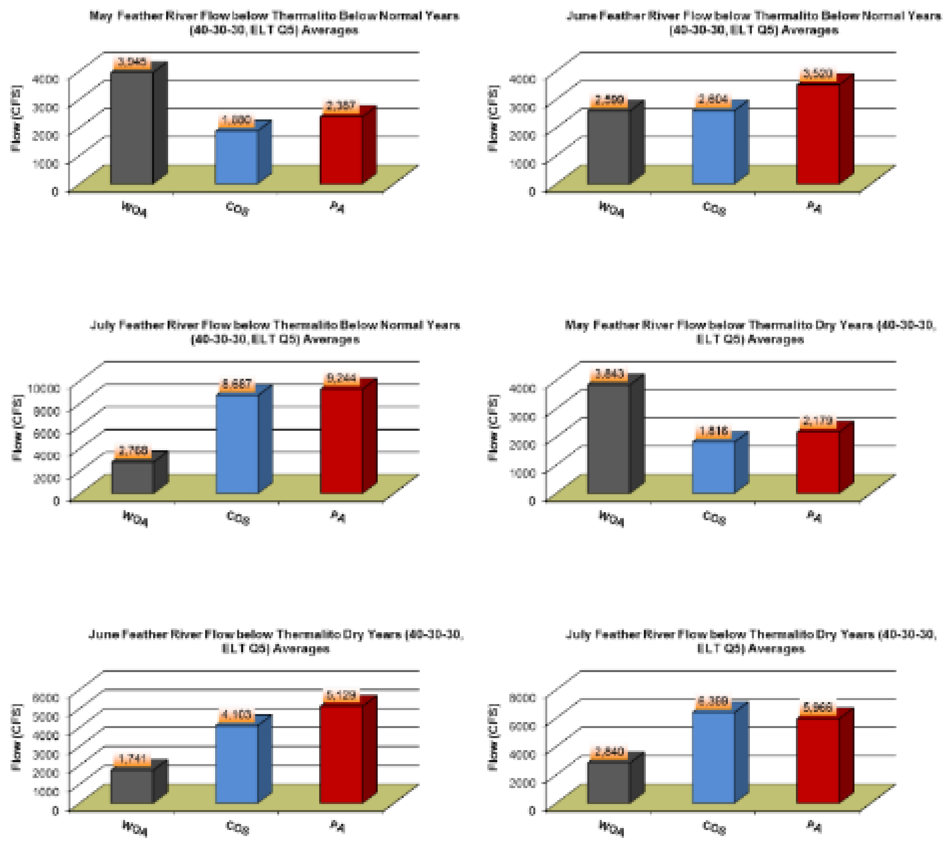
Eggs and larvae of southern DPS Green Sturgeon would be exposed to the effects of Oroville Dam releases and resulting flows in the high flow channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary proposed in the proposed action, based on the seasonal occurrence of this life stage in the Feather River (May to July; NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5.12-2), and compliance with Water Rights Decision 1641 (D-1641).

Table 5.12-2. Feather River High Flow Channel minimum instream flow requirements

Preceding April – July Unimpaired runoff (Percent of Normal)	Oct-Feb (cfs)	March (cfs)	April-Sept (cfs)
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Under the WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Reservoir gates and diversion tunnels would be kept open, resulting in annual storage volumes less than 1,000 TAF (see figure from Spring-run section). As a result, there would be limited control of flow or water temperature in the Feather River HFC, which provides habitat for this life stage. Feather River flows under the proposed action would be generally higher in the summer and fall and lower in the winter and spring compared to the WOA (see figures in Spring-run section).

Flows in the Feather River HFC under the proposed action during the May to July egg incubation, larval development, and early larval rearing period are lower in May during all water year types, and similar or higher in June and July in below normal, dry, and critically dry water years; flows in July are higher under the proposed action during all water year types (Figure 5.12-43). Importantly, CalSim II model output indicates June and July flows projected under the proposed action will increase the likelihood of minimum instream flow compliance in June and July of many drier water year types, minimizing potential exposure to low flows (Figure 5.12-43). As a result, potential adverse impacts of low flows on this life stage are anticipated to be less severe under the proposed action. Therefore, flow-related actions in the proposed action are anticipated to produce benefits for this life stage.



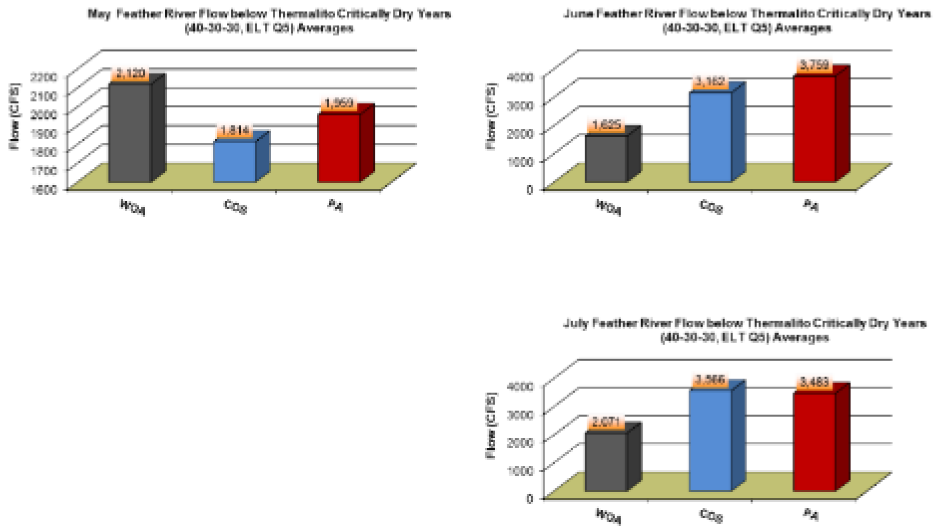


Figure 5.12-43. CalSim II estimates of Feather River Flow below the Thermalito Afterbay in May–July under the WOA, Proposed Action, and COS Scenarios.

5.12.3.5.1.1.1 Temperature Effects

Eggs and emerging fry of southern DPS Green Sturgeon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (May-July; NMFS 2016), and the timing of the temperature objectives (year-round objectives; Table 5.12-3). Water temperature objectives would be expected to be met in years when the Oroville Temperature Management Index (OTMI) is greater than 1.35 MAF and would be achieved through a combination of flow releases from Lake Oroville, and operations modifications stipulated in Article A108.1(b) [(*i*) curtailment of pump-back operation, (*ii*) shutter removal on Hyatt Intake, (*iii*) increase flow releases in the Low Flow Channel up to a maximum of 1,500 cfs]. If OTMI is equal to or less than 1.35 MAF a Conference Year is designated, triggering consultation between DWR and NMFS, USFWS, CDFW, and the SWRCB to prepare a strategic plan to manage the coldwater pool to minimize temperature exceedances at the lower FERC project boundary, while maintaining water supply and other legal obligations.

Table 5.12-3. Maximum Daily Mean Water Temperature for the HFC.

Period	**Temperature**
January 1 – March 31	56
April 1 – 30	61
May 1 – 15	64
May 16 – 31	64
June 1 – August 31	64

Period	Temperature
September 1 – 8	61
September 9 – 30	61
October 1 – 31	60
November 1 – December 31	56

Water temperatures in the Feather River during summer and fall are heavily influenced by flow releases from Lake Oroville which are determined by operations and storage releases. Under the WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Therefore, there would be limited control of flow or water temperature in the Feather River HFC from the Thermalito After Bay Outlet Pool downstream to the vicinity of the Gridley Bridge, where spawning occurs (NMFS 2016). Resulting water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are generally lower during the winter months, and higher during the summer and fall with peak annual water temperatures of approximately 78 °F occurring in July and August (see figures in Spring-run section).

Under almost all conditions, the WOA scenario would increase the likelihood of temperature related stress and mortality during the months of June and July. In addition, modeled water temperatures at Gridley Bridge under the proposed action indicate the proposed action would increase the likelihood of temperature compliance at the compliance point (lower FERC project boundary). Temperature objectives at the compliance point in April to July (maximum daily mean water temperatures of 61 ^{0}F in April, 64 ^{0}F May to July) fall within the optimal range of Green Sturgeon egg and larval temperature tolerances (NMFS 2016).

Water temperatures exceeding the objectives would have a number of adverse impacts on this life stage, including acute to chronic physiological stress, eventually leading to egg and larval mortality. Water temperatures in the Feather River HFC under the proposed action during the egg and larval development period are similar to or lower than WOA water temperatures. Importantly, RecTemp model output indicates water temperatures projected under the proposed action will increase the likelihood that May to July water temperatures will be less likely to reach lethal levels (> 73 ^{0}F) (see figures in spring-run section). As a result, potential adverse impacts of water temperature objectives on this life stage are anticipated to be less severe under the proposed action. Therefore, water temperature-related actions in these scenarios are anticipated to produce benefits for this life stage.

5.12.3.5.2 Larvae to Juvenile (April – August)

Larval rearing to juvenile southern DPS Green Sturgeon would be exposed to the effects of Oroville Dam releases and resulting flows in the HFC of the Feather River downstream of the Oroville Complex FERC boundary proposed in the proposed action, based on the seasonal occurrence of this life stage in the Feather River (May–October; Table 5.12-1), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5.12-2), and compliance with Water Rights Decision 1641 (D-1641).

Feather River flows below Thermalito Afterbay under the WOA are generally greater than the proposed action during the months of May and June and are less then the proposed action during the months of July through October during the larval to juvenile period of southern DPS Green Sturgeon (see figures in Spring-run section). Proposed action flows exceed WOA flows during the months of June through September, a period of peak abundance for this life stage. In addition, the likelihood of projected flows under all scenarios declining below the required minimum flow for April–September (1,000 cfs depending on preceding April—July) is very low (Figure 5.12-44).

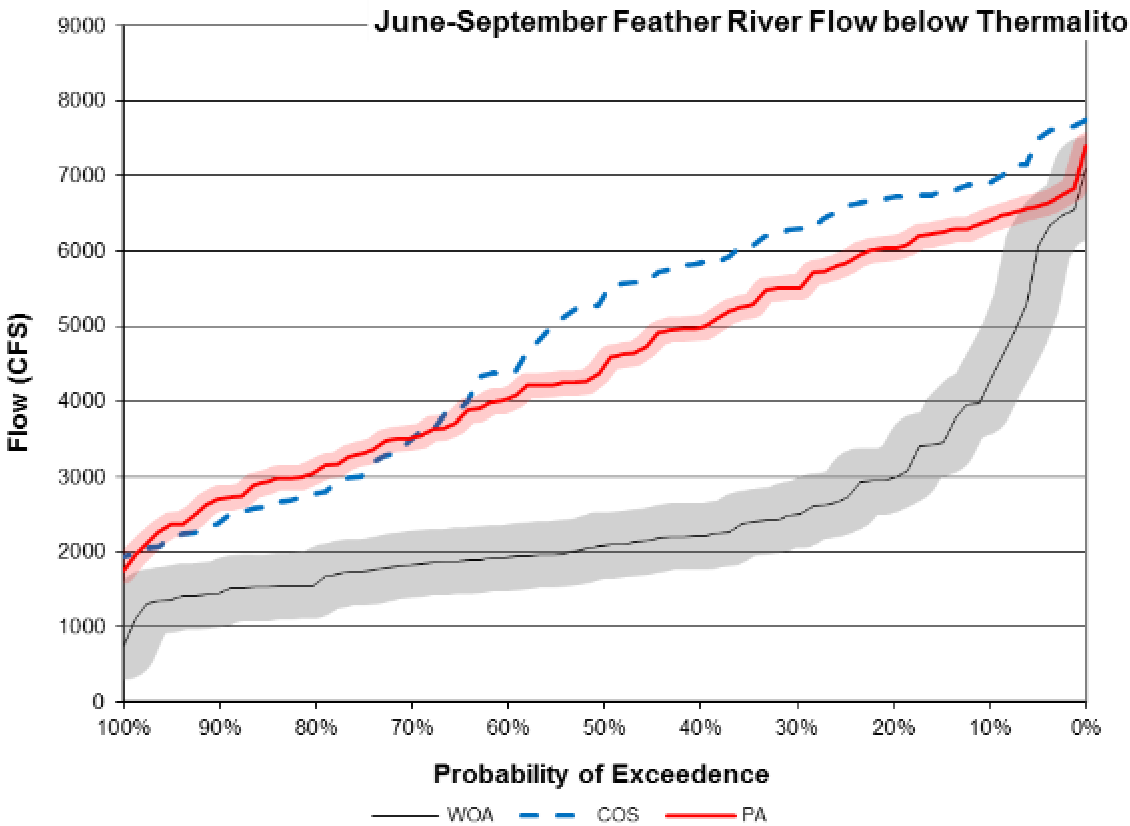


Figure 5.12-44. CalSim II Estimates of Feather River Flow below the Thermalito Afterbay in June–September under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) Scenarios.

5.12.3.5.2.1.1 Temperature Effects

Larval and juvenile life stages of Green Sturgeon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (May to October; NMFS 2016), and the timing of the temperature objectives (year-round objectives; Table 5.12-2).

Water temperatures on the Feather River at Gridley Bridge under the proposed action during the months of May to October are lower than the impaired fitness temperature tolerance limit (72 ^{0}F) for larvae in all water year types but dry and critically dry years when July and August temperatures exceed this threshold. However, the proposed action provide substantial temperature reductions compared to the WOA under these conditions (see Figures 3-1 through 3-6 in the RecTemp Temperature Results section of Appendix D, *Modeling*).

In addition, modeled water temperatures at Gridley Bridge indicate the proposed action would increase the likelihood of temperature compliance at the compliance point (lower FERC project boundary). As a result, potential adverse impacts of water temperature objectives on this life stage are anticipated to be less severe under the proposed action. Therefore, water temperature related actions in these scenarios are anticipated to produce benefits for this life stage compared to the COS.

5.12.3.5.3 Juvenile to Subadult/adult in Bay-Delta

Juvenile to subadult/adult southern DPS Green Sturgeon would be exposed to the effects of Oroville Dam releases and resulting flows in the HFC of the Feather River downstream of the Oroville Complex FERC boundary proposed in the proposed action, based on the occurrence of this life stage in the Feather River (year round; NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5.12-2), and compliance with Water Rights Decision 1641 (D-1641).

The differences in flows between the WOA scenario and the proposed action scenarios may affect the development, survival and downstream migration of juvenile Green Sturgeon to the subadult/adult phase. Lower proposed action flows compared to WOA flows from January to June could reduce migration cues and conditions resulting in harmful impacts on juvenile Green Sturgeon foraging conditions, water temperatures and DO, toxicity, and habitat area. Higher flows under the proposed action from July to September could similarly benefit juvenile to subadult Green Sturgeon during these months. The comparative magnitude of positive and negative impacts under the proposed action are difficult to quantify, however impacts of lower flows under the proposed action from January to June are anticipated to be minimal since projected proposed action flows during this period remain well in excess of all applicable minimum instream flows for the Feather River HFC.

Therefore, the proposed action will have no negative impacts on juvenile to subadult Green Sturgeon.

5.12.3.5.3.1 Temperature Effects

Juvenile and subadult/adult southern DPS green sturgeon would be exposed to the impacts of water temperature objectives for the Feather River HFC, based on the year-round occurrence of this life stage in the Feather River (NMFS 2016), and the timing of the temperature objectives (year-round objectives; Table 55.12-3). Water temperature objectives would be expected to be met in years when the Oroville Temperature Management Index (OTMI) is greater than 1.35 MAF and would be achieved through a combination of flow releases from Lake Oroville, and operations modifications stipulated in Article A108.1(b) [(*i*) curtailment of pump-back operation, (*ii*) shutter removal on Hyatt Intake, (*iii*) increase flow releases in the Low Flow Channel up to a maximum of 1,500 cfs]. If OTMI is equal to or less than 1.35 MAF a Conference Year is designated, triggering consultation between DWR and NMFS, USFWS, CDFW, and the SWRCB to prepare a strategic plan to manage the coldwater pool to minimize temperature exceedances at the lower FERC project boundary, while maintaining water supply and other legal obligations.

Water temperatures in the Feather River from March to June are relatively less influenced by flow releases from Lake Oroville than in late summer and fall, given the larger flow volumes, and cooler air temperatures during these months. Under the WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Therefore, there would be limited control of flow or water temperature in the Feather River HFC where this life stage occurs. However, resulting water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are similar to proposed action water temperatures from March to May, with small differences projected in June. Water temperatures under the WOA in the Feather River HFC at Gridley bridge as modeled by the RecTemp temperature model are significantly higher in July to September and are above the lethal limits of temperature tolerance of this life stage (Figure 5.12-44). There are no temperature-related stress and mortality impacts under the proposed action. These impacts produce a substantial reduction in projected water temperatures compared to the WOA

5.12.3.5.4 Adult to Egg and Post-Spawn Adult

5.12.3.5.4.1 Flow Effects

Spawning adult to egg and post-spawn adult Green sturgeon would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrences of these life stages in the Feather River (March-August with peak seasonal occurrence March-May; NMFS 2016), minimum instream flow requirements in the high flow channel of the Feather River (year-round requirements; Table 5.12-2), and compliance with Water Rights Decision 1641 (D-1641).

Instream flow from Lake Oroville releases may influence upstream and downstream passage of physical barriers on the Feather River.

Proposed action flows during this period are lower than WOA flows, however flows are not anticipated to decline below minimum instream flow standards or to a level that results in any increased passage or barrier issues in the Feather River HFC. A potential passage barrier exits at the Sunset Pumps Rock Weir (RM 28.5), which require flows of 2,500–3,000 cfs for passage. Flows below the Thermalito Afterbay and at the Feather River mouth are well above this threshold during the peak seasonal timing of this life stage (Figures 21-1 and 22-1 in the CalSim II Flows section of Appendix D, *Modeling*). Post-spawning downstream migration is triggered by increased flows (6,150–14,725 cfs) in the late summer (NMFS 2016) and long-term average flows below Thermalito Afterbay and at the Feather River mouth are slightly below this during the months of July and August. However, flows are significantly higher under the proposed action than under the WOA (Figures 21-1 and 22-1 in the CalSim II Flows section of Appendix D, *Modeling*).

Differences in flow between the WOA, proposed action, and COS are likely to impact migrating adults and their habitat. Higher WOA flows from March to May could result in positive impacts on migrating, spawning, and post-spawning adults in the Feather River, including increased migration success and an increase in spawning habitat. However, flows at the Thermalito Afterbay and at the Feather River mouth during this period are not expected to be sufficiently low to create substantial negative impacts. Increased flows under the proposed action during July to August are expected to have beneficial impacts on post-spawn adults. As a result of these offsetting impacts, there are not expected to be any negative impacts on spawning adult to egg and post-spawn adult Green Sturgeon.

5.12.3.5.4.2 Temperature Effects

Spawning adult to egg and post-spawn adult Green sturgeon would be exposed to the impacts of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (March to August with peak seasonal occurrence March to May; NMFS 2016), and the timing of the temperature objectives (year-round objectives; Table 5.12-3).

Temperatures at Gridley Bridge under the proposed action are similar to temperatures under the WOA from March to May, which coincides with the peak seasonal timing of Green Sturgeon upstream migration and spawning. The risk of temperature-related stress and mortality during this period is low as temperatures are projected to be equal to or lower than the optimal ranges for migrating, spawning, and holding Green Sturgeon (Figure 3-1 in the RecTemp Temperature Results section of Appendix D). Reduced water temperatures under the proposed action from July to August are expected to produce temperature benefits for post-spawn adults. Therefore, water temperature-related actions in the proposed action are anticipated to produce benefits for this life stage.

5.12.3.6 American River Seasonal Operations, 2017 FMS and "Planning Minimum"

North American Green Sturgeon are not known to occur in the American River and their historical distribution in the American River is not known (Beamesderfer et al. 2004). However, there is the potential for juvenile rearing in the lower reaches of the American River near the confluence with the Sacramento River (NMFS 2009). If the North American Green Sturgeon do occur in the American River, the proposed action would likely provide beneficial effects to North American Green Sturgeon relative to WOA through increased fall flows increasing inundated habitat.

5.12.3.7 Delta Seasonal Operations and OMR Management

Hydrodynamic changes associated with river inflows and South Delta exports have been suggested to negatively impact southern DPS Green Sturgeon in two distinct ways: 1) "near-field" mortality associated with entrainment to the export facilities, 2) "far-field" mortality resulting from altered hydrodynamics. 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"). A similar analysis is not available for southern DPS Green Sturgeon.

5.12.3.7.1 <u>Entrainment</u>

As described by NMFS (2009: 386), impacts to the migratory corridor function of juvenile and sub-adult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend one to three years rearing in the Delta environment before transitioning to their marine life history stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. In the conceptual model, it is hypothesized that higher rates of exports may result in higher rates of entrainment. However, estimating entrainment risk from raw salvage data is not possible due to a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage.

Juvenile southern DPS Green Sturgeon (> 5 mo) are present in the Delta all year and sub-adults are most abundant from June through November. As there are no exports under WOA, there is no Green Sturgeon entrainment risk under WOA. In the June through September period under the proposed action Reclamation proposes an average total export rate slightly higher than COS (41 cfs; Figure H-27 – Appendix H, *Bay-Delta Aquatics Effects Figures*) and will, therefore, have a similar entrainment risk. Total exports proposed for proposed action in September-November (121 cfs higher than COS; Figure H-28 – Appendix H, *Bay-Delta Aquatics Effects Figures*) are unlikely to measurably increase entrainment risk relative to COS. Relative to WOA, the proposed action significantly increases entrainment risk.

Juvenile white and green sturgeon are infrequent at the TFCF, but may occur in the facility salvage year-round. Salvage is expected to be similar and slightly higher than COS under the proposed action.

5.12.3.7.2 Routing

Juvenile Green Sturgeon (>5 mo) are present in the Delta all year and sub-adults are most abundant from June to November (Table 5.12-1). Juvenile Green Sturgeon swim and behave quite differently and have distinct body morphologies and habitat associations in the Delta compared to outmigrating salmonids, so it is hypothesized that juvenile Green Sturgeon have different routing-hydrology survival relationships. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. It is highly uncertain how Green Sturgeon routing would change with the proposed action.

5.12.3.7.3 Through Delta Survival

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green Sturgeon reside in the Delta for one to three years suggesting they encounter a variety of daily, seasonal, and annual hydrological conditions. The majority of Green Sturgeon in the Delta are likely not surviving through the Delta per se, but using these habitats for rearing and foraging. Per NMFS (2009: 338), Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways. For juvenile outmigrating Green Sturgeon present in these regions, increasing negative velocities under the proposed action may result in lower survival. However, as described above, there is a lower probability of juvenile Green Sturgeon residing in this area.

5.12.3.8 Delta Cross Channel Operations

Delta Cross Channel operations under the proposed action are changed to allow Reclamation to predict water quality exceedances and open the DCC if D-1641 criteria are predicted to be exceeded. This results in greater opening times of the DCC.

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. If juvenile Green Sturgeon are exposed to the open DCC gates, they could be entrained into the central/south Delta and exposed to biological and physical conditions in this area, including potentially greater predation. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta.

5.12.3.9 Agricultural Barriers

Agricultural Barriers (Temporary Barrier Project, TBP) are included in the proposed action and consists of three rock barriers across south Delta channels to improve water levels for agricultural diversions. The temporary rock barriers are installed and removed at Middle River near Victoria Canal, Old River near Tracy, and Grant Line Canal near Tracy Boulevard Bridge. The TBP is operated based on San Joaquin River flow conditions. The agricultural barriers at Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

Juvenile Green Sturgeon are present in the Delta in all months of the year. However, little is known about their spatial distribution. When the south Delta agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up (May 16 to May 31), outmigrating Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). It could be inferred that passage of outmigrating juvenile Green Sturgeon may also be improved when flap gates are tied up. Therefore, the potential negative effects of the agricultural barriers under the proposed action depends on when they are installed and whether the flap gates are down or tied up.

5.12.3.10 Contra Costa Water District Operations

As discussed in Chapter 4, CCWD's operations in the proposed action are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993; NMFS 2007; NMFS 2010; NMFS 2017; USFWS 1993a; USFWS 1993b; USFWS 2000; USFWS 2007; USFWS 2010; USFWS 2017; CDFG 1994; CDFG 2009). The operation of the Rock Slough Intake for the Proposed Action remains unchanged.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory routes for southern DPS Green Sturgeon (NMFS 2017), approximately 18 miles from the Sacramento River and 10 miles from the San Joaquin River via the shortest routes. Water temperatures in Rock Slough range from lows of about 40 degrees F in winter (December and January) to over 70 degrees F beginning in May and continuing through October (NMFS 2017).

A review of the 24 years of fish monitoring data (1994-2018) near the Rock Slough Intake both pre- and post-construction of the Rock Slough Fish Screen (RSFS) showed that southern DPS Green Sturgeon have never been observed in Rock Slough (CDFG 2002; Reclamation 2016; NMFS 2017; Tenera 2018b, ICF 2018).

5.12.3.10.1 <u>Juvenile to Subadult/Adult</u>

It is unlikely that juvenile and sub-adult Green Sturgeon would be present in Rock Slough due to the shallow depth, warm water temperatures, and low DO which make the area unsuitable habitat during most of the year. Currently, there is not a reliable measure of juvenile southern DPS Green Sturgeon population abundance in the Delta, nor is there a reliable estimate of the relative fraction of the population utilizing the area near the Rock Slough Intake (NMFS 2017). The Rock Slough intake maximum capacity is 350 cfs for the maximum annual diversion of 195 TAF.

5.12.3.10.2 <u>Adult to Spawning Adult</u>

Adult Green Sturgeon are unlikely to be present near the Rock Slough Intake since they typically prefer to migrate upstream through the mainstem Sacramento River and adult Green Sturgeon have not been observed spawning in the San Joaquin River (Jackson and Van Eenennaam 2013). It is unlikely that Green Sturgeon will be entrained into the Rock Slough Intake, and unlikely to be impacted by operations.

5.12.3.10.3 <u>Spawning Adult to Egg and Post-Spawn Adult</u>

Since it is unlikely that adult Green Sturgeon will be present near the Rock Slough Intake, it is also unlikely that eggs or post-spawn adults will be present in the area.

5.12.3.11 North Bay Aqueduct

Overall, the modeled exports in the proposed action represent a significant increase in export levels and, thus, a greater risk to Green Sturgeon in the waters adjacent to the pumping facility compared to their historical vulnerability (NOAA 2009). However, Green Sturgeon are expected to be fully screened out of the facilities by the positive barrier fish screen in place at the pumping facility.

5.12.3.12 Water Transfers

As discussed under the Spring-run Chinook Salmon water transfer section, while there is no pumping from the Delta for the CVP or SWP under WOA, under the proposed action Reclamation proposes to expand the transfer window to November. This extended transfer window could result in approximately 50 TAF of additional pumping per year in most years, with associated entrainment, routing, and through-Delta survival impacts. Please see the OMR management section for a discussion of the effects of pumping.

Juveniles older than 5 months, sub-adults, and adult Green Sturgeon could be exposed to the effects of increased pumping due to water transfers. Although southern DPS Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). Therefore, there are no negative impacts of increased pumping at Jones and Banks Pumping Plants due to water transfers under the proposed action.

Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year (Table 5.12-1). Thus, some portion of the population would be exposed to this action. Increases in Delta inflow during water transfers may have benefits for juvenile Green Sturgeon. However, there is no information on relationships between flow and juvenile Green Sturgeon ecology.

5.12.3.13 Clifton Court Forebay Aquatic Weed Control Program

Few southern DPS juvenile Green Sturgeon Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program as part of the proposed action. Although southern DPS juvenile Green Sturgeon are present in the Delta in all months of the year, Green Sturgeon are likely to be found in the main channels of the Delta and the larger interconnecting sloughs and waterways, with western Delta waterways having a higher likelihood of presence than eastern Delta waterways (NMFS 2009:338). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the likelihood of exposing juvenile Green Sturgeon to the herbicide is very low. Mechanical harvesting would occur on an as-needed basis and, therefore, juvenile Green Sturgeon could be exposed to this action, if entrained into the Forebay.

5.12.3.14 Suisun Marsh Facilities

Under WOA, the Suisun Marsh facilities would be left open, resulting in a more saline and variable Suisun Marsh.

5.12.3.14.1 Suisun Marsh Salinity Control Gates

Operation of the SMSCG from June through October under the proposed action coincides with a portion of the downstream migration of juvenile southern DPS Green Sturgeon, as well as adult southern DPS Green Sturgeon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. During full gate operation, the flashboards are installed and the radial gates open and close twice each tidal day. Green Sturgeon are thought to successfully pass through either the boat lock or through the gates during periods when the gates are open. NMFS (2009) determined that operation of the SWSCG is unlikely to produce conditions that support unusually high numbers of predators, change habitat suitability or availability for rearing or migration of juvenile and adult Green Sturgeon. Green Sturgeon are strong swimmers and therefore the operation of the Suisun Marsh Salinity Control Gate will have no impact on adults or juvenile Green Sturgeon.

5.12.3.14.2 Roaring River Distribution System

The low screen velocity at the intake culverts combined with a small screen mesh size are expected to successfully prevent Green Sturgeon from being entrained into the RRDS under the proposed action. (NOAA 2009).

5.12.3.14.3 Morrow Island Distribution System

The MIDS intakes under the proposed action do not currently have fish screens, and juvenile Green Sturgeon are more prone to entrainment than other species such as white sturgeon (Poletto et al. 2014). However, fisheries monitoring performed in 2004-05 and 2005-06 identified entrainment of 20 fish species, none of which were Green Sturgeon (NOAA 2009). Presence of Green Sturgeon in the area of the MIDS intake is not well studied or documented, but it if Green Sturgeon are present they may potentially avoid entrainment as they do not typically swim along the surface where the diversion is located.

5.12.3.14.4 Goodyear Slough Outfall

Due to its location and design, Green Sturgeon are not likely to encounter this structure or be negatively affected by its operation. Improved water circulation by the operation of the Goodyear Slough Outfall under the proposed action likely benefits juvenile Green Sturgeon in Suisun Marsh by improving water quality and increasing foraging opportunities (NOAA 2009).

5.12.3.15 Maintenance Activities

Under WOA, no maintenance would occur as the CVP and SWP are not operating. Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Green Sturgeon adults from maintenance activities.

5.12.3.16 Operation of a Shasta Dam Raise

Reclamation would operate a raised Shasta Dam consistent with the rest of the proposed action. Therefore, effects described elsewhere in the document would also apply to the operation of a raised Shasta Dam, and there would be no operational changes.

5.12.4 Effects of Conservation Measures

The following are proposed conservation measures that are intended to offset the effects of operations and maintenance. These conservation measures would only occur due to the implementation of the Proposed Action and are beneficial in nature. The following analysis examines the construction related effects of the measures but also the benefits to the population once completed. Conservation measures would not occur under WOA.

5.12.4.1 Lowering Intakes in Wilkins Slough

5.12.4.1.1 Egg to Larvae (March – July)

The installation of fish screens near Wilkins Slough under the proposed action would be beneficial to Green sturgeon. The fish screens would prevent fish entrainment at diversions, thus, increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages. Specifically, operation of diversions with fish screens near Wilkins Slough would decrease entrainment risk.

Green sturgeon egg and fry, as well as the population, would benefit from this action.

In the southern DPS, adult Green Sturgeon begin their upstream spawning migrations into the San Francisco Bay in March and reach Knights Landing on the Sacramento River during April (Heublein et al. 2006 *as cited in* OCAP BA 2008). Based on the distribution of sturgeon eggs, larvae, and juveniles in the Sacramento River, DFG (2002 *as cited in* OCAP BA 2008) indicated that Green Sturgeon spawn in late spring and early summer in the upper Sacramento River. Peak spawning is believed to occur between April and June (OCAP BA 2008). Construction activities under the proposed action would occur during an in-water work window (June 1 through October 1); therefore, effects on Green Sturgeon eggs and fry are not anticipated.

Additionally, preferred spawning habitats are thought to be deep, cool pools with turbulent water and large cobble (DFG 2002; Moyle 2002; Adams et al. 2002 *as cited in* OCAP BA 2008). Wilkins Slough does not contain suitable spawning habitat; therefore, the potential for egg or fry to be present is low.

5.12.4.1.2 Larvae to Juvenile (April – August)

The installation of fish screens near Wilkins Slough would be beneficial to Green Sturgeon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning.

Larval Green Sturgeon are present within the Sacramento River between May and August, with a peak from June through July, both at RBDD and GCID (OCAP BA 2008). Larval Green Sturgeon have the potential to be exposed to construction activities as the larvae migrate downstream from the upper Sacramento River; however, implementation of AMM's identified in Appendix E, *Avoidance and Minimization Measures* would minimize those effects.

Juvenile Green Sturgeon (greater than 10 months old, younger than 3 years old) are located in the Bay-Delta (OCAP BA 2008). Wilkins Slough is not located in the legal Delta. Wilkins Slough is not tidally influenced; therefore, no effects to juvenile Green Sturgeon are expected due to construction activities associated with construction of diversions and screens.

5.12.4.1.3 Juvenile to Subadult/Adult

The installation of fish screens near Wilkins Slough would be beneficial to Green Sturgeon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults.

Juvenile to subadult/adult Green Sturgeon are located in the Bay-Delta; and therefore are located outside of the action area.

5.12.4.1.4 Adult to Spawning Adult (May – October)

The installation of fish screens near Wilkins Slough would be beneficial to Green Sturgeon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning.

Adults migrate upstream primarily through the western edge of the Delta into the lower Sacramento River between March and June (Adams et al. 2002). Adult Green Sturgeon do not spawn every year, and are believed to spawn every three to five years. Green sturgeon spawn in late spring and early summer above Hamilton City, possibly up to Keswick Dam (Brown 2007). Peak spawning is believed to occur between April and June. Wilkins Slough is outside of known spawning habitat; therefore, construction activities would not affect spawning adults. Additionally, implemented of an in-water work window and other AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further reduce effects to adults and spawning adults.

5.12.4.1.5 Spawning Adult to Egg and Post-Spawn Adult

The installation of fish screens near Wilkins Slough would be beneficial to Green Sturgeon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning.

5.12.4.2 Shasta TCD Improvements

5.12.4.2.1 Egg to Larvae (March – July)

The implementation of the proposed Shasta TCD improvements under the proposed action would improve Reclamation's ability to manage flows, and water quality (e.g., water temperatures and DO) in the Sacramento River that would be suitable for Green Sturgeon, improving conditions for their eggs and larvae.

5.12.4.2.2 Larvae to Juvenile (April – August)

The implementation of the proposed Shasta TCD improvements under the proposed action would improve Reclamation's ability to manage flows, and water quality (e.g., water temperatures and DO). However, under the proposed action, summer flows are kept cold for Winter-run Chinook salmon, which results in temperatures that are too cold for Green sturgeon juvenile rearing.

5.12.4.2.3 Juvenile to Subadult/Adult

The implementation of the proposed Shasta TCD improvements under the proposed action would improve Reclamation's ability to manage flows, and water quality (e.g., water temperatures and DO).

Juvenile to subadult/adult Green Sturgeon are located in the Bay-Delta; and therefore are located outside of the action area for the improvements.

5.12.4.2.4 Adult to Spawning Adult (May – October)

The Shasta TCD improvements under the proposed action would not be expected to have an effect on adult Green Sturgeon.

5.12.4.2.5 Spawning Adult to Egg and Post-Spawn Adult

The implementation of the proposed Shasta TCD improvements under the proposed action would improve Reclamation's ability to manage flows, and water quality (e.g., water temperatures and DO) in the Sacramento River that would be suitable for Green Sturgeon, improving conditions for spawning and post-spawning adults.

5.12.4.3 Spawning and Rearing Habitat (Sacramento River)

Reclamation proposes to create additional spawning habitat by injecting 40-55 tons of gravel into the Sacramento River by 2030, using the following sites: Salt Creek Gravel Injection Site, Keswick Dam Gravel Injection Site, South Shea Levee, Shea Levee, and Tobiasson Island Side Channel. As green sturgeon are broadcast spawners in deep pools, adding spawning gravel would not benefit Green Sturgeon. Addition of rearing habitat could provide benefits to green sturgeon juveniles.

Construction of spawning and rearing habitat could affect Green Sturgeon larvae in the river. Based on the proposed in-water work windows for the upper Sacramento River (see AMM2 *Construction Best Management Practices and Monitoring* in Appendix E, *Avoidance and Minimization Measures*), Green Sturgeon would be subject to potential adverse effects from proposed spawning (e.g, gravel augmentation) and rearing habitat (e.g., side channel) restoration projects in the upper Sacramento River associated with the proposed action. Construction activities could result in mortality of larvae or juveniles by crushing if heavy equipment enters the stream channel or otherwise disturbs larvae or juveniles during in-water activities. Larvae and juveniles could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality (e.g., reduced flow and dissolved oxygen from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants. Although these potential effects may be unavoidable, exposure of the Green Sturgeon population to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of spawning adults, and the implementation of other AMMs described in Appendix E, *Avoidance and Minimization Measures*. These measures include AMM1, which requires worker awareness training, AMM2, which specifies monitoring oversight by a qualified biologist, and AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment.

5.12.4.4 Small Screen Program

Under WOA, small diversions would not be screened. Under the proposed action, Reclamation would work with partners to screen small diversions on the Sacramento River and Delta.

5.12.4.4.1 Egg to Larvae (March – July)

No egg to larvae North American Green Sturgeon would be benefited by fish screens under the proposed action since they remain in the stream substrate and would not be exposed to fish screens. Therefore, there would be no effects from fish screen construction for this life stage.

Few if any North American Green Sturgeon in the egg-to-larvae life stage are expected to be exposed to the effects of construction of screens on water diversion intakes based on the seasonal occurrence of this life stage in the Sacramento River. This period follows spawning, which generally occurs between March and July, with peak spawning believed to occur between April and June (Adams et al. 2002). The embryos incubate for a period seven to nine days before hatching as larvae (Van Eenennaam et al. 2001; Poytress et al. 2012).

5.12.4.4.2 Larvae to Juvenile (April – August)

The operation of fish screens on water diversions would have a beneficial effect on larvae to juvenile North American Green Sturgeon in the Sacramento River by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for adverse impacts to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage. Therefore, it is concluded that the operation of fish screens under the proposed action would result in beneficial effects for this life stage, due to the reduced risk of entrainment and injury.

North American Green Sturgeon in the larvae to juvenile life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River throughout the year (Table 5.12-1). After hatching, larvae and juveniles migrate downstream toward the Sacramento-San Joaquin Delta and estuary, where they may encounter work area of these projects; however, these work areas are localized and the number of fish is expected to be low. Potential short-term adverse impacts may include temporary effects to water quality as result from in-water work, resulting in increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.12.4.4.3 Juvenile to Subadult/Adult

Southern DPS Green Sturgeon are expected to be present in the Delta during the main irrigation period for small diversions (late spring-fall). Diversion screening under the proposed action could reduce entrainment of individual Green Sturgeon. However, there is currently no information on the proportion of juvenile Green Sturgeon that are entrained into small unscreened diversions. North American Green Sturgeon in the juvenile to subadult/adult life stage may be exposed to the effects of construction of screens since they are present in the Sacramento River year-round (Table 5.12-1). Effects are the same as described above for juveniles. AMMs would minimize risk.

5.12.4.4.4 Adult to Spawning Adult (May – October)

Few, if any Adult North American Green Sturgeon are expected to be exposed to the effects of operation of screens on diversion intakes under the proposed action. Spawning Green Sturgeon inhabit deep pools in large, turbulent, freshwater river mainstems (Moyle et al. 1992), and thus, they are not likely to encounter the small screen diversions. Few, if any Adult North American Green Sturgeon are expected to be exposed to the effects of construction of screens. The timing of the adult upstream migration for spawning (February–July; Figure 5.12-4) largely avoids the July 15 – October 15 in-water construction work window as described avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. AMMs would minimize risks.

5.12.4.4.5 Spawning Adult to Egg and Post-Spawn Adult

Effects are the same as for Adult to Spawning Adult, above.

5.12.4.5 Adult Rescue

The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult Green Sturgeon, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the number of Green Sturgeon of all life stages in the Sacramento River.

Exposure of this life stage to adult rescue effects would be restricted only to those adult Green Sturgeon that become stranded in the Yolo and Sutter Bypasses and subsequently rescued and released to the Sacramento River. Adults that migrate in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by adult rescue activities. The number of adult Green Sturgeon that would be expected to be exposed to the effects of adult rescue activities would be based on the abundance of adults that stray into the bypasses and the timing and frequency of stranding events in the bypasses. Individual adult Green Sturgeon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality, which could vary in intensity depending on the techniques used to capture individuals. Injury and increased stress associated with capture, handling and transport may affect survival of individuals after release. The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*).

Juvenile Green Sturgeon larvae could be incidentally captured by gear used to rescue adult salmonids and sturgeon during implementation of adult rescue activities. The number of juvenile Green Sturgeon that would be expected to be exposed to the effects of adult rescue activities would be based on the timing of proposed adult rescue activities, gear type used to rescue adults, and the typical seasonal occurrence of this life stage in the Yolo and Sutter bypasses. Individual juvenile Green Sturgeon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality during efforts to capture stranded adults, handling, and transport. Injury and increased stress associated with capture, handling, and transport may reduce disease resistance or swimming ability in juveniles, thereby adversely impacting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make juveniles more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Green Sturgeon would be expected to be offset by benefits associated with increased numbers of adult Green Sturgeon returning to spawning grounds.

5.12.4.6 Juvenile Trap and Haul

Green Sturgeon larvae metamorphose into juveniles at lengths of 62 to 94 mm (Deng et al. 2002). Therefore, larger Green Sturgeon larvae in the vicinity of temporary juvenile collection weirs could be incidentally captured by gear used to trap juvenile salmonids during implementation of juvenile trap and haul activities. The number of Green Sturgeon larvae that would be expected to be exposed to the effects of juvenile trap and haul activities would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trap location and efficiency at collecting Green Sturgeon larvae, and the typical seasonal occurrence of this life stage in the Sacramento River (Table 5.12-1). Because gear type and location would be focused on trapping juvenile salmonids, and not Green Sturgeon, few Green Sturgeon individuals would be expected to be collected in the traps. Individual Green Sturgeon larvae exposed to juvenile trapping activities would be at risk of increased stress, injury, and/or mortality during capture and subsequent handling. The risk of these effects to this life stage could be greater for smaller (younger) larvae which may be more susceptible to injury and stress than larger (older) larvae. In addition, larvae collected later in the season when water quality conditions [e.g., water temperature] may be more stressful for larvae and may make larvae more susceptible to injury and stress-related effects associated with capture and handling than larvae captured and handled earlier in the season when water quality conditions generally are more suitable. However, the risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*). Because Green Sturgeon larvae and juveniles spend an extended period rearing in the river before migrating to the Delta, it is assumed that any larval Green Sturgeon trapped during juvenile trap and haul activities would be returned to the Sacramento River rather than be transported to the Delta and released.

Juvenile Green Sturgeon larvae in the vicinity of temporary juvenile collection weirs could be incidentally captured by gear used to trap juvenile salmonids during implementation of juvenile trap and haul activities. The number of juvenile Green Sturgeon that would be expected to be exposed to the effects of juvenile trap and haul activities would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trap location and efficiency at collecting juvenile Green Sturgeon, and the typical seasonal occurrence of this life stage in the Sacramento River (Table 5.12-1). Because gear type and location would be focused on trapping juvenile salmonids, and not Green Sturgeon, few juvenile Green Sturgeon individuals would be expected to be collected in the traps. Individual Green Sturgeon juveniles exposed to juvenile trapping activities would be at risk of increased stress, injury, and/or mortality during capture and subsequent handling. The risk of these effects to this life stage could be greater for smaller (younger) juveniles which may be more susceptible to injury and stress than larger (older) juveniles. In addition, juveniles collected later in the season when water quality conditions [e.g., water temperature] may be more stressful for juveniles and may make juveniles more susceptible to injury and stress-related effects associated with capture and handling than juveniles captured and handled earlier in the season when water quality conditions generally are more suitable. However, the risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*). Because juvenile Green Sturgeon rear in-river for an extended period before migrating to the Delta, it is assumed that any juvenile Green Sturgeon trapped during juvenile trap and haul activities would be returned to the Sacramento River rather than be transported to the Delta and released.

Because of their large size and benthic behavior, adult Green Sturgeon are not expected to be vulnerable to capture during implementation of juvenile trap and haul activities.

5.12.4.7 American River Spawning and Rearing Habitat

Pursuant to CVPIA 3406(b)(13), Reclamation proposes to implement the Cordova Creek Phase II and Carmichael Creek Restoration projects, and increase woody material in the American River. Reclamation also proposes to conduct gravel augmentation and floodplain work at: Paradise Beach, Howe Ave, Howe Avenue to Watt Avenue, William Pond Outlet, Upper River Bend, Ancil Hoffman, Sacramento Bar - North, El Manto, Sacramento Bar - South, Lower Sunrise, Sunrise, Upper Sunrise, Lower Sailor Bar, Nimbus main channel and side channel, Discovery Park, and Sunrise Stranding Reduction. As green sturgeon are broadcast spawners in deep pools, adding spawning gravel would not benefit Green Sturgeon. Addition of rearing habitat could provide benefits to green sturgeon juveniles.

Construction of spawning and rearing habitat could affect Green Sturgeon larvae in the river. Based on the proposed in-water work windows for the American River (see AMM2 *Construction Best Management Practices and Monitoring* in Appendix E, *Avoidance and Minimization Measures*), Green Sturgeon would be subject to potential adverse effects from proposed spawning (e.g, gravel augmentation) and rearing habitat (e.g., side channel) restoration projects in the American River associated with the proposed action. Construction activities could result in mortality of larvae or juveniles by crushing if heavy equipment enters the stream channel or otherwise disturbs larvae or juveniles during in-water activities. Larvae and juveniles could also be negatively impacted by increases in suspended sediment, turbidity, and contaminant exposure risk, leading to indirect impacts on individuals from reductions in habitat quality (e.g., reduced flow and dissolved oxygen from increases in sediment deposition) or direct impacts from sublethal and lethal exposures to contaminants. Exposure of the Green Sturgeon population to construction effects would be low based on the limited extent of proposed restoration projects relative to the overall distribution of spawning adults, and the implementation of other AMMs described in Appendix E, *Avoidance and Minimization Measures*. These measures include AMM1, which requires worker awareness training, AMM2, which specifies monitoring oversight by a qualified biologist, and AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment.

5.12.4.8 Tracy Fish Collection Facility

Upgrades to the TFCF under the proposed action will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish, and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

5.12.4.9 Suisun Marsh Salinity Control Gates Operation

Under the proposed action, Reclamation would operate the Suisun Marsh Salinity Control Gate more frequently to provide freshwater to Suisun Marsh for Delta Smelt. This action could increase food in Suisun Marsh, which could have food web effects that benefit Green Sturgeon juveniles. Operation of the SMSCG from June through October under the proposed action coincides with a portion of the downstream migration of juvenile southern DPS Green Sturgeon, as well as adult southern DPS Green Sturgeon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators. Adult Green Sturgeon are strong swimmers and therefore the operation of the Suisun Marsh Salinity Control Gate is unlikely to affect adult or juvenile Green Sturgeon.

5.12.4.10 Clifton Court Predator Management

Predator control efforts under the proposed action can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently.

5.12.4.11 Sacramento Deepwater Ship Channel Study

5.12.4.11.1 Larvae to Juvenile (April – August)

This study would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018). Juvenile southern DPS Green Sturgeon are present in the Delta in every month of the year with a similar frequency (Table 5.12-1). Juvenile Green Sturgeon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of Green Sturgeon survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough. This would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem.

5.12.4.11.2 Juvenile to Subadult/Adult

As described above, juvenile Green Sturgeon may potentially be entrained into the DWSC. Fish entering the SDWSC would not, however, be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar between the SDWSC and the Sacramento main stem

5.12.4.12 Suisun and Colusa Basin Food Subsidies

Provision of north Delta or Suisun Marsh food subsidies by routing drain water would occur in summer/fall and therefore could provide food benefits to Green Sturgeon juveniles, who are in the Delta in the fall.

5.12.4.13 Tidal Habitat Restoration

5.12.4.13.1 Juveniles

A large proportion of juvenile southern DPS Green Sturgeon are expected to be exposed to continuing to implement the 8,000 acres of tidal habitat restoration in the Delta under the proposed action. Tidal habitat restoration is expected to benefit juvenile Green Sturgeon in several aspects represented by the Green Sturgeon juvenile conceptual model (Figure 5.12-3) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta.

5.12.4.13.2 Adults

The timing of the adult Green Sturgeon upstream migration for spawning (February-–July; Figure 5.12-5) avoids the August–October in-water construction work window for tidal and channel margin restoration under the proposed action. Benefits would be the same as described for juvenile Green Sturgeon.

5.12.4.14 Predator Hot Spot Removal

Predator hot spot removal under the proposed action is primarily focused on providing positive effects to downstream-migrating juvenile salmonids. It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the rearing and migratory corridors of juvenile Green Sturgeon.

5.12.4.15 San Joaquin River Scour Hole Predation Reduction

It is currently unknown if predation on juvenile Green Sturgeon in the Delta is limiting their productivity. If so, reduction in predation at this specific hot spot could increase survival.

Juvenile or sub-adult green sturgeon could potentially be exposed to construction effects of this action. Construction effects would be minimized with worker awareness training and other measures in Appendix E, Avoidance and Minimization Measures.

5.12.4.16 Knight's Landing Outfall Gates Fish Barrier

Reclamation and DWR's fish barrier at the Knight's Landing Outfall Gates would prevent possible entrainment of green sturgeon into the Colusa Basin Drain. While entrainment of green sturgeon unto the Colusa Basin Drain is already unlikely, this project would further reduce possible entrainment.

Few green sturgeon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. The timing of the adult Green Sturgeon upstream migration for spawning (February-–July; Figure 5.12-5) avoids the August–October in-water construction work window. Impacts of construction would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.12.4.17 Delta Cross Channel Gate Improvements

Little is known about the migratory behavior of juvenile Green Sturgeon in the Sacramento River basin. It is likely that juvenile Green Sturgeon (larger than the 75 mm) will not enter the Delta prior to their first winter and thus would not be exposed to the open DCC gates. It is likely that these fish will enter the Delta sometime in the winter or spring following their hatching upriver and encounter both types of gate configurations as they enter the Delta. More information is required to accurately assess the migratory movements of juvenile Green Sturgeon in the river system, as well as their movements within the Delta during their rearing phase in estuarine/Delta waters. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

5.12.4.18 Tracy Fish Facility Operations and Improvements

5.12.4.18.1 Larvae to Juvenile (April – August)

Upgrades to the TFCF will aim to minimize the effects of the salvage process on listed fishes, in particular juvenile salmonids and Green Sturgeon. Salvage improvements will improve survival of salvaged fish and potentially allow reduction of the expansion factors used to extrapolate take estimates from observed salvage.

As previously described, juvenile Green Sturgeon can occur in the Delta year-round (Table 5.12-1; Figure 5.12-3) and, therefore, have the potential to be exposed to the effects of construction of the CO_2 injection device proposed for the Tracy Fish Facility Improvements. If construction affects the efficiency of Green Sturgeon salvage (which is an element of entrainment risk; Figure 5.12-3), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.12.4.18.2 Adult to Spawning Adult (May – October)

As with other proposed construction in the Delta under the proposed action, the timing of adult Green Sturgeon occurrence in the Delta could overlap with CO_2 injection device construction as part of Tracy Fish Facility Improvements. Application of AMMs and the small scale of the in-water construction would minimize the potential for any effects to individual adult Green Sturgeon. As adult sturgeon are not salvaged, no benefits of this action are expected for this lifestage.

5.12.4.18.3 Spawning Adult to Egg and Post-Spawn Adult

As previously described for tidal habitat restoration, the timing of the adult Green Sturgeon upstream migration for spawning (February–July; Figure 5.12-5) avoids the in-water work window (August to October) for CO2 injection device construction for the Tracy Fish Facility Improvements under the proposed action.

5.12.4.19 Skinner Fish Facility Improvements

Skinner Fish Facility improvements under the proposed action, which involve predator control efforts, can reduce predation on listed fish species, following their entrainment into Clifton Court Forebay. This could also reduce pre-screen loss of juvenile southern DPS Green Sturgeon. It is unknown what proportion of juvenile Green Sturgeon are entrained into CCF but individuals are salvaged infrequently. Thus, the proposed action is not likely to negatively impact juvenile Green Sturgeon.

5.12.4.20 Delta Fish Species Conservation Hatchery

None of the Green Sturgeon life stages would benefit from the Delta Fish Species Conservation Hatchery under the proposed action. As with the other proposed construction activities in the Delta, the year-round occurrence of juvenile Green Sturgeon in the Delta (Table 5.12-1; Figure 5.12-3) means that this life stage, as well as the timing of the adult Green Sturgeon occurring in the Delta during May to October, could be exposed to Delta Fish Species Conservation Hatchery construction under the proposed action. The in-water work constructing the hatchery intake and outfall could result in a small number of individuals experiencing effects such as temporary loss of habitat leading to predation, degraded water quality, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas. The risks from these potential effects would be minimized with through the application of AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.12.4.21 Effects of Monitoring

Population estimates for Green Sturgeon also remain outstanding in the Central Valley. Similar to steelhead, the existing monitoring programs very rarely catch green sturgeon because most monitoring programs are not designed to capture them. Similar to steelhead, it is unlikely the monitoring programs have an effect to the population.

Table 5.12-4. Monitoring Programs – Green Sturgeon

Survey	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Chipps Island Trawl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sacramento Trawl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
DJFMP Beach Seine Survey	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CDFW Mossdale Trawl	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
EDSM KDTR Trawls	na	na	na	na	na	na	na	na	na	na	na	na	na	na	0	0	na
CDFW Bay Study Trawls	0	0	3	1	2	0	1	2	2	0	0	3	4	1	0	1	na
CDFW SKT Study	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Total Green Sturgeon	0	0	3	1	2	0	1	2	2	0	0	3	4	1	0	1	na
RBDD Rotary Trap or Juvenile Production Estimate (JPE)	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

5.13 North American Green Sturgeon, Southern DPS Critical Habitat

Critical habitat for the southern DPS of North American Green Sturgeon, was designated in 2008 and includes the Sacramento River, lower Feather River, and lower Yuba River in California; the Sacramento-San Joaquin Delta and Suisun, San Pablo, and San Francisco bays. Critical habitat includes stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line or bankfull elevation (defined as the level at which water begins to leave the channel and move onto the floodplain, and generally corresponds with a discharge that occurs every 1 to 2 years on an annual flood series). For bays and estuarine areas, critical habitat includes the lateral extent of the mean higher high water (MHHW) line. (73 FR 52084).

The designated critical habitat includes PBFs that are essential for the conservation of Green Sturgeon, southern DPS. The critical habitat designation includes separate list of PBFs for riverine and estuarine habitat.

The specific PBFs essential for the conservation of the Southern DPS freshwater riverine systems include:

1. *Food resources.* Abundant prey items for larval, juvenile, subadult, and adult life stages. Food resources are important for juvenile foraging, growth, and development during their downstream migration to the Delta and bays. In addition, subadult and adult Green Sturgeon may forage during their downstream post-spawning migration, while holding within deep pools, or on non-spawning migrations within freshwater rivers. Subadult and adult Green Sturgeon in freshwater rivers most likely feed on benthic prey species similar to those fed on in bays and estuaries, including shrimp, clams, and benthic fishes.
2. *Substrate type or size (i.e., structural features of substrates).* Substrates suitable for egg deposition and development (e.g., bedrock sills and shelves, cobble and gravel, or hard clean sand, with interstices or irregular surfaces to “collect” eggs and provide protection from predators, and free of excessive silt and debris that could smother eggs during incubation), larval development (e.g., substrates with interstices or voids providing refuge from predators and from high flow conditions), and subadults and adults (e.g., substrates for holding and spawning).
3. *Water flow.* A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages. Such a flow regime should include stable and sufficient water flow rates in spawning and rearing reaches to maintain water temperatures within the optimal range for egg, larval, and juvenile survival and development. Sufficient flow is needed to reduce the incidence of fungal infestations of the eggs. In addition, sufficient flow is needed to flush silt and debris from cobble, gravel, and other substrate surfaces to prevent crevices from being filled in (and potentially suffocating the eggs and to maintain surfaces for feeding. Successful migration of adult Green Sturgeon to and from spawning grounds is also dependent on sufficient water flow. Spawning success is associated with water flow and water temperature. Post-spawning downstream migrations are triggered by increased flows.
4. *Water quality.* Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures would include stable water temperatures within spawning reaches. Suitable salinity levels range from fresh water for larvae and early juveniles to brackish water for juveniles prior to their transition to salt water. Adequate levels of dissolved oxygen are needed to support oxygen consumption by fish in their early life stages. Suitable water quality would also include

water containing acceptably low levels of contaminants that may disrupt normal development of embryonic, larval, and juvenile stages of Green Sturgeon. Water with acceptably low levels of such contaminants would protect Green Sturgeon from adverse impacts on growth, reproductive development, and reproductive success.

5. *Migratory corridor.* A migratory pathway necessary for the safe and timely passage of southern DPS fish within riverine habitats and between riverine and estuarine habitats (e.g., an unobstructed river or dammed river that still allows for safe and timely passage). Safe and timely passage requires that no human-induced impediments, either physical, chemical or biological, alter the migratory behavior of the fish such that its survival or the overall viability of the species is compromised (e.g., an impediment that compromises the ability of fish to reach their spawning habitat in time to encounter con-specifics and reproduce). Unimpeded migratory corridors are necessary for adult Green Sturgeon to migrate to and from spawning habitats, and for larval and juvenile Green Sturgeon to migrate downstream from spawning/rearing habitats within freshwater rivers to rearing habitats within the estuaries.
6. *Water depth.* Deep (≥ 5 m) holding pools for both upstream and downstream holding of adult or subadult fish, with adequate water quality and flow to maintain the physiological needs of the holding adult or subadult fish.
7. *Sediment quality.* Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of elevated levels of contaminants (e.g., selenium, polyaromatic hydrocarbons (PAHs), and organochlorine pesticides) that may adversely impact Green Sturgeon.

The specific PBFs essential for the conservation of the southern DPS Green Sturgeon in estuarine areas include:

1. *Food resources.* Abundant prey items within estuarine habitats and substrates for juvenile, subadult, and adult life stages. Prey species for these life stages within bays and estuaries primarily consist of benthic invertebrates and fishes, including crangonid shrimp, burrowing thalassinidean shrimp (particularly the burrowing ghost shrimp), amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for the rearing, foraging, growth, and development of juvenile, subadult, and adult Green Sturgeon within the bays and estuaries.
2. *Water flow.* Within bays and estuaries adjacent to the Sacramento River (*i.e.*, the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds. Sufficient flows are needed to attract adult Green Sturgeon to the Sacramento River to initiate the upstream spawning migration.
3. *Water quality.* Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages. Suitable water quality includes water with acceptably low levels of contaminants (*e.g.*, pesticides, organochlorines, elevated levels of heavy metals) that may disrupt the normal development of juvenile life stages, or the growth, survival, or reproduction of subadult or adult stages.
4. *Migratory corridor.* A migratory pathway necessary for the safe and timely passage of southern DPS fish within estuarine habitats and between estuarine and riverine or marine habitats. Within the bays and estuaries adjacent to the Sacramento River, unimpeded passage is needed for juvenile Green Sturgeon to migrate from the river to the bays and estuaries and eventually out into the ocean. Passage within the bays and the Delta is also critical for adults and subadults for

feeding and summer holding, as well as to access the Sacramento River for their upstream spawning migrations and to make their outmigration back into the ocean.

5. *Water depth.* A diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Subadult and adult Green Sturgeon occupy a diversity of depths within bays and estuaries for feeding and migration. Juveniles occur primarily in shallow waters for rearing and foraging. Thus, a diversity of depths is important to support different life stages and habitat uses for Green Sturgeon within estuarine areas.
6. *Sediment quality.* Sediment quality (*i.e.*, chemical characteristics) necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of elevated levels of contaminants (*e.g.*, selenium, PAHs, and organochlorine pesticides) that can cause adverse impacts on all life stages of Green Sturgeon.

5.13.1 Freshwater Riverine Systems

5.13.1.1 Food Resources

Availability of food resources for Green Sturgeon in the Sacramento River would potentially be affected by changes in flow and water temperature, although the nature of the effects is difficult to predict. Higher flow generally produces greater habitat complexity, potentially resulting in greater diversity and density of prey, although higher flow can also reduce foodweb productivity. Increased water temperature potentially stimulates foodweb productivity, leading to higher densities of prey species, but large temperature increases may physiologically stress prey species, ultimately leading to reduction in food resources. Larval and juvenile Green Sturgeon are more vulnerable to reductions in food resources than adults. Sturgeon larvae and juveniles typically feed on insect larvae, amphipods, mysids and other benthic invertebrates (Muir et al. 2000). Differences in flow and water temperatures between the proposed action and COS would be too small to cause any important differences in food resources for Green Sturgeon. In contrast, the differences in flow and water temperatures between the proposed action and the WOA would be sufficiently large to produce substantial changes in food resources. However, the nature of these changes and how they would impact the different life stages of Green Sturgeon feeding in the Sacramento River is highly uncertain. Probably the most significant environmental change resulting from the WOA scenario, would be the much higher late spring, summer and early fall water temperatures, as described throughout Section 5.15, *North American Green Sturgeon, southern DPS.* The period of high water temperatures overlaps with the period of maximum occurrence of Green Sturgeon larvae and juveniles in the river (Figure 5.12-1). The predicted increases in temperature are potentially large enough to result in major changes in the prey species that would dominate the benthic invertebrates on which the Green Sturgeon feed. However, while these changes would potentially reduce growth and survival of the Green Sturgeon larvae and juveniles, this conclusion is uncertain. Overall, the impacts of the proposed action relative to COS and the WOA scenario on food resources in Green Sturgeon critical habitat are expected to have no impact, but this conclusion is uncertain.

5.13.1.2 Substrate Type or Size

The proposed action includes projects to improve spawning habitat for Chinook Salmon in the upper Sacramento River, and these projects would likely benefit substrate type or size in Green Sturgeon spawning habitat. River substrate type and size can also be affected by changes in flow. Very high flows scour bottom sediments, potentially creating the types of deep holes that Green Sturgeon favor for spawning, although such flows could also remove suitable spawning gravels from spawning habitat. High, but less extreme flows flush sediments from gravels, which may improve Green Sturgeon spawning and egg incubation habitat. Overall, high flows are expected to improve river substrates for Green

Sturgeon. Differences in flow between the proposed action and COS would generally be minor, as described throughout Section 5.15, *North American Green Sturgeon, Southern DPS,* and would not be large enough to effect meaningful changes in substrate type or size. The differences in flow between the proposed action and the WOA would often be large, but only the wet-year winter and spring flows would be high enough to scour sediments. WOA flows during such years are generally higher than proposed action flows and would therefore be more likely to result in improved Green Sturgeon spawning habitats. However, proposed action flow during the late spring and summer months, when Green Sturgeon spawn, is much higher than WOA flow, and likely high enough to flush sediments from the gravel substrates, thereby improving conditions for incubating embryos. These results indicate that, relative to the WOA, the proposed action would adversely impact Green Sturgeon substrate type and size in Green Sturgeon spawning habitat during winter and early spring, but benefit the suitability of the substrate for incubating embryos during summer. However, this conclusion is uncertain.

5.13.1.3 Water Flow

As described throughout Section 5.15, *North American Green Sturgeon, Southern DPS*, differences in Sacramento River flow between the proposed action and COS would generally be minor, but differences in flow between the proposed action and the WOA would be large enough to potentially affect all life stages of Green Sturgeon. Proposed action flow is generally higher than WOA flow during late spring, summer and early fall, when Green Sturgeon spawn, the eggs incubate, and the larvae and juveniles rear, disperse and migrate downstream. Post-spawn adults also emigrate during this period. Proposed action flow is generally similar or lower than WOA flow during late fall, winter, and early spring. Juveniles and adults continue emigrating through December, and by February adults enter the river and begin migrating upstream to holding and spawning habitat. The higher proposed action flows during late spring, summer and early fall would potentially benefit spawning, eggs, larvae, and juveniles in a number of ways, including increased water depth for holding and spawning habitat, reduced fine sediment deposition on incubating eggs, greater dispersion of larvae and juveniles, reduced crowding and competition, improved migration habitat and migration cues, reduced entrainment risk, and lower contaminant concentrations in the river. There is evidence that abundance of Green Sturgeon larvae and juveniles is positively related to annual outflow (Heublein et al. 2017a [*SAIL model*]). WOA flow in the middle Sacramento River is predicted to be low enough in many years during summer to adversely impact emigrating juveniles and adults. Reduced flows under the proposed action during winter and early spring would potentially have adverse impacts on immigrating adults, but the flows would consistently be high to prevent passage problems. Overall, the proposed action is not expected to adversely impact flow conditions in Green Sturgeon critical habitat.

5.13.1.4 Water Quality

In the critical habitat designation final rule for Green Sturgeon (October 9, 2009, 74 FR 52300), the Water Quality PBF includes “temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages”. These factors could potentially be affected by changes in flows and increases in water temperatures in the Sacramento River. As described throughout Section 5.15, *North American Green Sturgeon, Southern DPS,* differences in Sacramento River flow and water temperature would generally be minor between the proposed action and COS, but would be large enough between the proposed action and WOA to potentially impact all life stages of Green Sturgeon. Differences in flow are described above in Section 5.16.2.1.3, *Water Flow* and differences in water temperature are described in Section 5.16.2.1.3, *Water Temperature*. Higher spring, summer and fall flows under the proposed action would dilute contaminants present in the Green Sturgeon critical habitat, reducing their adverse impacts. Water temperatures under the proposed action would be much lower than WOA temperatures during spring, summer and early fall, when the presence of

Green Sturgeon eggs, larvae, and young juveniles peaks in the river. High water temperatures result in reduced DO. The young life stages of Green Sturgeon are especially vulnerable to high water temperatures and low DO. During June and July, predicted water temperatures in many years reach levels that are likely lethal to Green Sturgeon embryos. Overall, the proposed action is expected to have no impact on water quality of the Green Sturgeon critical habitat relative to the COS, and to substantially benefit water quality relative to the WOA.

5.13.1.5 Migratory Corridor

The middle Sacramento River is the main migratory corridor for Green Sturgeon critical habitat upstream of the Delta. Principal potential impacts of the proposed action on this corridor are instream flow and water temperature. Flow may affect upstream and downstream passage of migratory adults, dispersal and emigration rates of juveniles, and concentration of contaminants. Water temperature potentially affects growth and survival of adult and juvenile sturgeon in the migratory corridor. As described above in Section 5.16.2.1.3, *Water Flow*, flow in the middle Sacramento River under the proposed action is generally similar to COS flow, but is reduced relative to WOA flow during many years in winter and spring, when adult Green Sturgeon migrate upstream to holding and spawning areas in the middle and upper river. The flow under both scenarios are high enough to eliminate passage problems. Flow in the middle river is much higher under the proposed action than under WOA conditions during summer through fall, when larvae are dispersed downstream in the migratory corridor and juveniles and post-spawned adults migrate downstream. Adequate flow is essential to quickly move larvae and juveniles to critical rearing habitats before they starve (Muir et al. 2000). Flow in the middle river under the WOA scenario is often low enough to interfere with downstream passage of emigrating adults. The low flow may also concentrate contaminants in the river, which are likely to be highest in the late spring through early fall because this is the primary season for treating croplands with fertilizer and pesticides.

Predicted water temperatures in the middle Sacramento River migratory corridor of Green Sturgeon differ little between the proposed action and the COS scenarios, but proposed action temperatures are much lower than WOA temperatures during the late spring through early fall, and are much higher during late fall through early spring. The potential impact of water temperature is much greater during late spring to early fall than in the late fall to early spring because temperatures in the latter period under both scenarios are below levels that are stressful to Green Sturgeon. Temperatures in late spring to early fall regularly exceed critical thresholds for Green Sturgeon under the WOA scenario but rarely do so under the proposed action.

Overall, the proposed action would have no negative impact relative to COS on migratory corridor habitat in Green Sturgeon’s Sacramento River critical habitat, and would have largely beneficial effects relative to the WOA scenario.

5.13.1.6 Depth

The proposed action would potentially have two different types of effects on depths for Green Sturgeon critical habitat in the Sacramento River: 1) the proposed action would potentially reduce the number and depth of pools suitable for Green Sturgeon holding and spawning by reducing unregulated high discharge scouring flows and 2) the proposed action could increase the depth of water in these pools by increasing the level of more moderate flows in the river. The proposed action is not expected to have either of these effects relative to the COS scenario. However, relative to the WOA scenario, the proposed action would potentially reduce the number and/or depth of pools suitable for Green Sturgeon holding and spawning and would increase the depth of water in the pools. The main difference between the WOA scenario and the proposed action, is that Sacramento River flow is not regulated under the WOA scenario and the river would therefore experience a more natural flow regime, including a higher frequency of pulse flows strong enough to scour deep holes in portions of the river bottom. In contrast, the river is regulated under the proposed action scenario, including high flow releases from Shasta Reservoir during summer and early fall when most Green Sturgeon hold and spawn, which results in deeper water levels in the spawning pools. The higher flows would potentially improve water quality in the pools as well, by more effectively flushing out fine sediments, metabolic wastes and other contaminants. Therefore, the proposed action would potentially adversely impact the availability of deep pools for Green Sturgeon holding and spawning, but would benefit the quality of the pool habitats available.

5.13.1.7 Sediment Quality

High levels of fine sediments in the Sacramento River upstream of the Delta can adversely impact Green Sturgeon by smothering spawning substrates, which may increase mortality of embryos (Kock et al. 2006. Effects of Sediment Cover on Survival and Development of White Sturgeon Embryos. *Nor. Am. J. Fish. Manag*. 26: 134-141). However, more moderate levels provide essential habitat for small burrowing invertebrate organisms, such as chironomid larvae and other benthic invertebrates that may be important prey of Green Sturgeon larvae and young juveniles (Muir et al. 2000). Sacramento River flow is predicted to be much higher under the proposed action than the WOA scenario during the late spring and summer when most Green Sturgeon spawning occurs, which would likely improve spawning habitat. The availability of habitat with fine sediment deposits for burrowing benthic invertebrate prey is presumably related to the overall sediment supply, which depends mostly on stormwater runoff and imports from unregulated tributaries during major flows. The proposed action would have little effect on imports from tributaries, but it potentially would reduce inundation flows and subsequent stormwater runoff because unregulated pulse flows from upstream of Shasta Dam would potentially be larger and more frequent under the WOA scenario. Also, it is possible that imports of fine sediments from upstream of Shasta Dam would be higher under the WOA scenario because more of the fine sediment that currently deposits in Shasta Lake might be carried through the reduced reservoir and the fully open Shasta Dam. Overall, the proposed action is expected to improve conditions regarding fine sediment in Green Sturgeon spawning habitat, but may adversely impact fine sediment habitat for prey organisms of larval and juvenile Green Sturgeon. Both of these conclusions are uncertain.

5.13.2 Estuarine Habitats

Young-of-the-year Green Sturgeon juveniles emigrate from the Sacramento River into the Bay/Delta several months after hatching. They disperse to all parts of the Bay/Delta and rear there for a year or more before entering the ocean as subadults (Heublein et al. 2017b). Adults and subadults visit the Bay/Delta sporadically, and are most commonly found in summer and fall. Spawning Green Sturgeon enter the Bay/Delta from the ocean from late winter to spring and ascend the Sacramento River with minimal staging and feeding in the estuary (Heublein et al. 2009).

The principal potential effects of the proposed action on southern DPS Green Sturgeon in the Bay/Delta are changes related to flow, flow routing, and entrainment.

5.13.2.1 Food Resources

Juvenile southern DPS Green Sturgeon are present in the Delta all year and sub-adults are most abundant from June through November. When juvenile Green Sturgeon enter the estuary from the Sacramento River, their diet shifts to larger benthic food items, though they remain generalists and opportunists. Mysid shrimp and amphipods (Corophium) were observed to be the primary food items in juvenile (Israel et al. 2008). Adult and subadult Green Sturgeon in the Columbia River estuary, Willapa Bay, and Grays

Harbor feed on crangonid shrimp, burrowing thalassinidean shrimp, amphipods, clams, juvenile Dungeness crab (*Cancer magister*), anchovies, sand lances (*Ammodytes hexapterus*), lingcod (*Ophiodon elongatus*), and other fishes. It expected that the diet of adult and subadult Green Sturgeon in the Bay/Delta would be similar.

Changes in Delta inflow resulting from the proposed action potentially impact prey of Green Sturgeon in the Bay/Delta Green Sturgeon critical habitat. Sacramento River flow at Freeport and Rio Vista, which are important rearing and migratory habitat areas for Green Sturgeon juveniles, subadults and adults, would be higher under the proposed action than under the WOA during many months, but particularly during July and August of all but the wettest years (e.g., Figures 5.13-1 and 5.13-2). The increased flow would result in greater depths and would likely lead to greater diversity in habitats, both factors that would potentially increase the diversity and productivity of Green Sturgeon food resources.

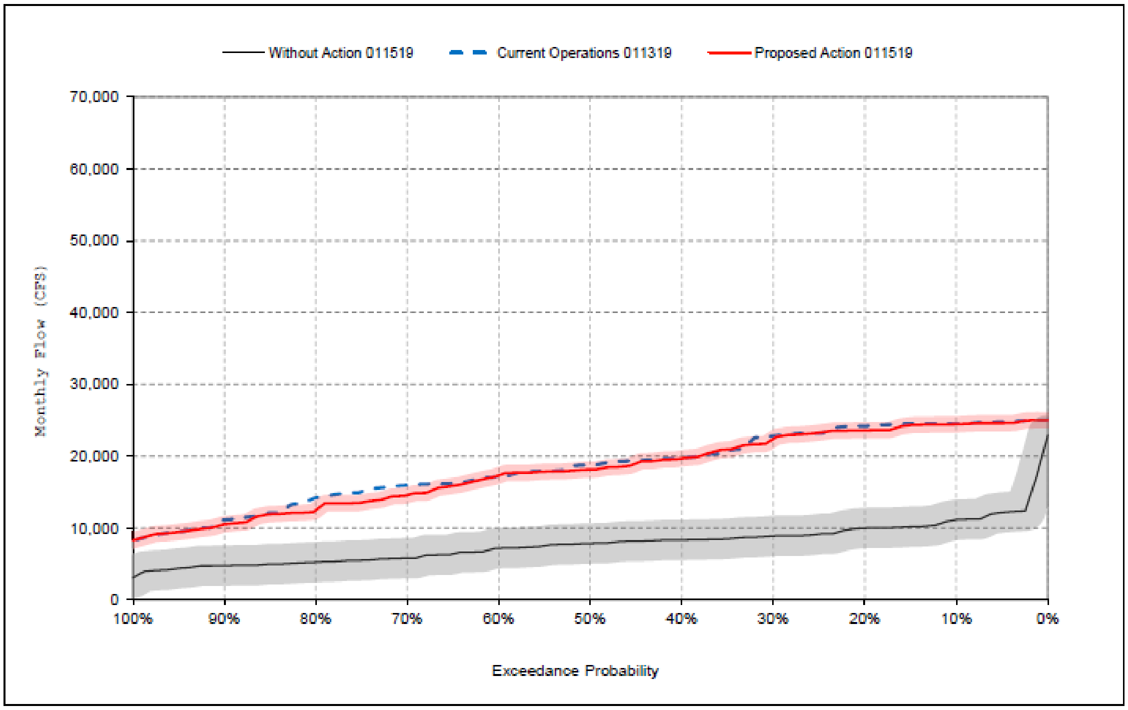


Figure 5.13-1. CalSim II Sacramento River Flows at Freeport, July

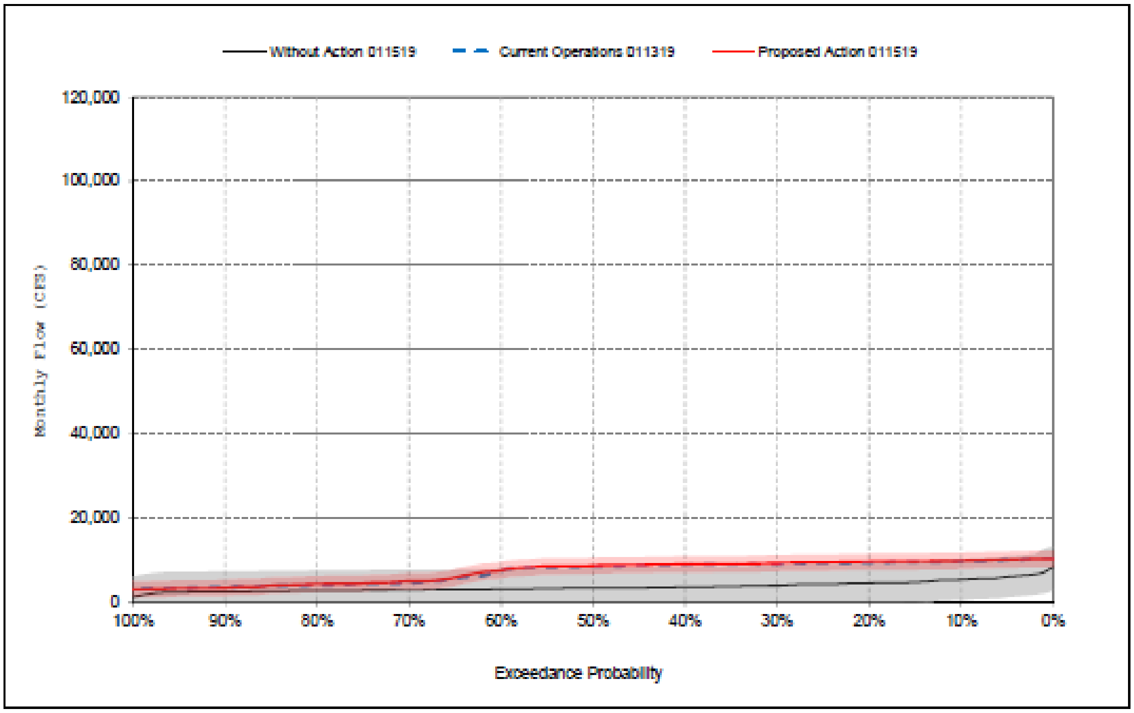


Figure 5.13-2. CalSim II Sacramento River Flows at Rio Vista, August

However, operation of the proposed action’s proposed SMSCG operations during June to October of wet, above normal and below normal water years (reducing salinity to improve habitat conditions in the relatively food-rich Suisun Marsh, the proposed action’s proposed tidal restoration, and various programmatic actions would potentially enhance foodweb productivity in the Bay/Delta and result in greater food resources for Green Sturgeon.

5.13.2.2 Water Flow

Little is known about the relationship between survival of juvenile Green Sturgeon and Delta hydrology. Green sturgeon juveniles are thought to reside in the Delta for 1-3 years, so they encounter a variety of hydrological conditions. The juveniles are present in the Delta all year and sub-adults are most abundant from June-November (Table 5.12-1).

The effects of the proposed action on flow in Green Sturgeon estuarine critical habitat were evaluated by analyzing the effects of flow changes on Delta hydrodynamics, with potential effects on how fish are routed through Delta channels. The results indicate that routing into the interior Delta, where Green Sturgeon would be at higher risk from entrainment and reduced water quality (NMFS 2009), would be higher under the proposed action and the COS relative to the WOA, but the difference was likely not high enough to substantially mpact Green Sturgeon. The proposed action on through Delta survival of juvenile Green Sturgeon has no impact, so the proposed action is not expected to adversely impact water flow for Green Sturgeon in the Delta.

Sacramento River flow at Freeport and Rio Vista, which are important rearing and migratory habitat areas for Green Sturgeon juveniles, subadults and adults, would be higher under the proposed action than under the WOA during many months, but particularly during July and August of all but the wettest years (e.g., Figures 5.13-1 and 5.13-2). As noted above, the higher flows would potentially improve Green Sturgeon food resources. They would also potentially improve water quality and depth conditions in the Green Sturgeon critical habitat (see below).

Potential negative impacts on river flow could occur as a result of tidal restoration effects on channel hydrodynamics, although modeling and design of restoration would be done so as to minimize such impacts.

5.13.2.3 Water Quality

In the critical habitat designation final rule for Green Sturgeon (October 9, 2009, 74 FR 52300), the Water Quality PBF includes “temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages”. The proposed action is expected to have no impact on water temperature and DO in the estuarine critical habitat for Green Sturgeon. As described throughout the analysis of the effects to the species, these water quality parameters are major discriminators for comparing potential impacts of the proposed action and the WOA on Green Sturgeon in the Sacramento River upstream of the Delta. In the Bay/Delta, however, flow and water temperature of reservoir releases are generally considered to have little effect on water temperatures (Wagner et al. 2011, USFWS 2017b). This assessment, however, has been based on experience with smaller flow and water temperature differences than those expected between the proposed action and WOA (USFWS 2017b), so the conclusion that the proposed action would have no impacts on water temperature in the Bay/Delta is uncertain. Other than downstream of major effluents, DO in the Bay/Delta is primarily determined by water temperature. Juvenile Green Sturgeon have developed a tolerance for a wide range of salinities by the time they move into the Bay/Delta, so this water quality parameter is not expected to impact estuarine critical habitat for Green Sturgeon (Heublein et al. 2017b).

The proposed action has the potential to positively and negatively affect other water quality factors in the Green Sturgeon estuarine critical habitat relative to the WOA conditions. Higher summer flows under the proposed action at Freeport and Rio Vista (e.g., Figures 5.13-1 and 5.13-2) would dilute contaminants present in the mainstem Sacramento River, reducing their adverse impacts. Impacts of flows on contaminants in other parts of the Delta are uncertain. The increase in high unregulated Sacramento River flows, including pulse flows, expected during winter and spring under the WOA, would potentially increase loading of contaminants related to runoff from inundated croplands. However, the increase in high flows under the WOA would also flush contaminated sediments downstream from the Bay/Delta, potentially increasing water quality and sediment quality in the critical habitat. Thus, the proposed action has both positive and negative potential impacts with respect to water quality in Green Sturgeon estuarine critical habitat and the overall impact is uncertain.

Relative to the WOA, reduced winter-spring inflow to the Delta under the proposed action (e.g., Figures 29-9 through 29-14 in the CalSim II Flows summary in Appendix D, *Modeling*) has the potential to reduce sediment supply and therefore turbidity during winter to spring, as well as during summer and fall when resuspension of sediment supplied in the winter and spring produces turbidity. Impacts of turbidity on Green Sturgeon, if any, are unknown.

The year-round occurrence of juvenile Green Sturgeon in the Delta means that this life stage could be exposed to Delta Fishes Conservation Hatchery operations. Any water discharged from the facilities into the Sacramento River would be treated and subject to regular monitoring of water quality within the FTC for fish health, so there are not likely to be impacts on water quality associated with discharges from the FTC.

The Delta Fishes Conservation Hatchery including marinas would house a number of boats. Boat motors introduce metals, hydrocarbons, and other pollutants into the Sacramento River. These compounds can have a negative effect on the water quality for Green Sturgeon in the system, including affecting pH and DO. These increased pollutants have been associated with the impaired development and survival of juveniles (Soule et al. 1991; Von Westerhagen et al. 1987). In some instances, motorboat traffic can increase turbidity and nutrients in the water column, decreasing water quality. Increased boat traffic may negatively impact the designated Green Sturgeon critical habitat by disturbing sediment and decreasing water quality and food resources, and possibly limiting space and access for rearing or resident fish. Safe passage through critical habitat might also be compromised for migrating Green Sturgeon. The potential sites currently have very high boating and shipping traffic and the relatively small output from the ERS marina would not dramatically increase the amount of pollutants, turbidity, and nutrients to which Green Sturgeon would be exposed. Furthermore, the proposed action would not change the overall number of boats in the region, only their harbor location. Therefore there would be no negative impacts on juvenile Green Sturgeon critical habitat.

During summer/fall, there is the potential for impacts to flow, flow velocity, and water clarity under the proposed action to negatively impact water quality in the critical habitat relative to the WOA by increasing the potential for harmful algal blooms, although this is uncertain. Reclamation and DWR’s proposal includes programmatic elements that could limit potential negative impacts from harmful algal blooms.

5.13.2.4 Migratory Corridor

The effects of combined exports present an entrainment issue that could delay migration or decrease survival or population viability through entrainment into the South Delta facilities.

As discussed in Section the analysis of entrainment, impacts to the migratory corridor function of juvenile and sub-adult Green Sturgeon critical habitat from south Delta exports are less clear than for juvenile salmonids because Green Sturgeon spend one to three years rearing in the Delta environment before transitioning to their marine subadult life stage. During this Delta rearing phase, Green Sturgeon are free to migrate throughout the Delta. Estimating entrainment risk from raw salvage data is hamstrung by a lack of information on the number of juvenile Green Sturgeon potentially exposed to salvage. However, it can be inferred that higher rates of exports will result in higher rates of entrainment.

Juvenile southern DPS Green Sturgeon are present in the Delta all year and sub-adults are most abundant from June through November. Average total exports for months when Green Sturgeon juveniles are present in the Delta indicate zero entrainment risk for the WOA scenario. In the June through September period, the proposed action has an average total export rate slightly higher than COS (Figure H-27 – Appendix H, *Bay-Delta Aquatics Effects Figures*) and will therefore have a similar entrainment risk. Total exports proposed for the proposed action in September through November (Figure H-28 – Appendix H, *Bay-Delta Aquatics Effects Figures*) will only slightly increase entrainment risk relative to COS. Therefore, the proposed action would potentially adversely impact entrainment of Green Sturgeon in the Delta relative to the WOA, but would have a minor impact relative to the COS.

5.13.2.5 Depth

Juvenile southern DPS Green Sturgeon are present in the Delta all year and sub-adults are most abundant from June through November. One of the PBFs for Green Sturgeon estuarine critical habitat is a diversity of depths for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Sacramento River flow at Freeport and Rio Vista, which are important rearing and migratory habitat areas for Green

Sturgeon juveniles, subadults and adults, would be much higher under the proposed action than under the WOA during most months, but particularly during July and August of all but the wettest years (e.g., Figures 29-16 and 32-17 in the CalSim II flow section of Appendix D). These differences would likely afford the three Green Sturgeon life stages a greater diversity of depth. Therefore, the proposed action is expected to benefit Green Sturgeon critical habitat in the Bay/Delta relative to the WOA with respect to depth.

5.13.2.6 Sediment Quality

Fine sediments provide essential habitat for burrowing invertebrate organisms such as shrimp, clams, amphipods, worms, and insect larvae that are important prey of Green Sturgeon juveniles, subadults and adults. The availability of habitat with fine sediment deposits is presumably related to the overall sediment supply, which depends mostly on stormwater runoff and imports from unregulated tributaries during major flows. The proposed action would have little impact on imports from tributaries, but it potentially would reduce inundation flows and subsequent stormwater runoff because unregulated pulse flows from upstream of Shasta Dam would potentially be larger and more frequent under the WOA scenario. Also, it is possible that imports of fine sediments from upstream of Shasta Dam would be higher under the WOA scenario because more of the fine sediment that currently deposits in Shasta Lake might be carried through the reduced reservoir and the fully open Shasta Dam. Therefore, the proposed action may adversely impact fine sediment habitat for prey organisms of Green Sturgeon in their estuarine critical habitat. These conclusions are uncertain. Implementation of tidal and channel margin restoration would provide additional sand substrate for Delta Smelt spawning habitat (USFWS 2017, p.111), which would contribute to offsetting the potential negative impact of the proposed action on sediments for Green Sturgeon prey habitat.

5.14 Killer Whale, Southern Resident DPS

Ford et al. (2016) confirmed the importance of Chinook Salmon to Southern Residents in the summer months using DNA sequencing from whale feces. The researchers found that more than 90 percent of the whale’s inferred diet consisted of salmonids; almost 80 percent was Chinook Salmon. Bellinger et al. (2015) estimated that Central Valley Chinook SSalmon made up about 22 percent of the Chinook Salmon sampled off the Oregon coast and about 50 percent of those sampled off the California coast (south to Big Sur). While this apex predator certainly eats a variety of other species as well, Central Valley Chinook Salmon (all runs) can be estimated to make up approximately 40% of the killer whale diet when killer whales are off the California coast, and 18% of the killer whale diet when the killer whales are off the Oregon coast.

As discussed by NMFS (2017, p.831), individual-level effects to killer whale from changes in Chinook Salmon prey could include changes in areas searched for prey and consequent changes in energy expended for such searches, resulting in changes in energy intake and the risk of nutritional stress. Changes in energy consumption and nutritional stress could lead to changes in body size, condition, and growth; and changes in reproductive and survival rates for adults (NMFS 2017, p.831).

The southern distinct population segment of killer whales is thought to move with the seasonal abundance of salmonids returning to natal rivers to spawn from early summer through fall. There are correlations between the occurrence of southern residents and commercial and sport Salmon fishery catches in US waters off southeastern Vancouver Island and in Puget Sound (Heimlich-Boran, 1986). This population of killer whales is commonly found off southeastern Vancouver Island and in Puget Sound, Washington, from late spring to late fall (Ford, 2006, Osborne 1999). The winter distribution of Southern Resident

Killer Whales is poorly known. K and L pods have been observed off the mouth of the Columbia River and in Monterey Bay, California, associated with local production of Chinook Salmon (Wiles 2004; Balcomb 2006).

The reduced flows in the spring of the proposed action, as compared to the WOA, are likely to affect rearing and migrating Fall-run Chinook Salmon, which could possibly reduce juvenile production. Effects include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, and reduced emigration flows. To reduce these effects, Reclamation has included a variety of conservation measures including fall and winter refill and redd maintenance, spawning and rearing habitat restoration on the Sacramento, American, Stanislaus, and lower San Joaquin rivers, tidal habitat restoration, and predator hot spot removal. The proposed action also includes conservation measures such as improvements at fish collection facilities to improve facility survival and reduce impacts of the proposed action on Killer Whale prey as compared to WOA. In addition, as discussed above, Chinook Salmon from the Central Valley are a relatively small portion of the killer whale diet, between 18 – 40%.

5.14.1 Effects of Operation

The proposed action relative to WOA has potential beneficial and negative effects on Chinook Salmon stocks which form part of the diet of SRKW. Potential beneficial effects of the proposed action to killer whale prey relative to the WOA would occur because reservoir storage under the proposed action allows summer/fall releases to maintain favorable water temperature conditions for early life stages, as exemplified for Winter-run Chinook salmon in the Sacramento River below Keswick Dam. Potential negative effects to killer whale prey generally could occur during winter and spring, particularly the latter, which coincides with the main period of juvenile downstream migration and is when flow is often appreciably lower under the proposed action compared to the WOA, which could increase the duration of juvenile travel time and decrease survival.

Conservation measures under the proposed action generally would be expected to have overall beneficial effects on Chinook Salmon stocks from the Central Valley relative to WOA, although some temporary negative effects are also possible, as discussed in Chinook Salmon effects sections.

Studies have suggested that most Chinook salmon in the coastal ocean off California appear to be of hatchery origin (Barnett-Johnson et al. 2007; Johnson et al. 2016). The potential effects of the proposed action on Central Valley Chinook Salmon stocks would be expected to be zero to minimal on hatchery-origin juvenile Chinook Salmon released downstream of the Delta. 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 2018).

While the proposed action is likely to negatively impact individual Central Valley Chinook salmon from operation of the export facilities, this reduction is not expected to result in decreased overall ocean abundance or availability of prey for killer whale, when weighed against hatchery production. The proposed action is expected to be beneficial to Central Valley Chinook salmon due to flow and temperature management as compared to without the operation of the CVP and SWP.

Due to the generally medium priority (18-41% of the diet, only when off the coast of California and Oregon) of the Central Valley stocks that could be affected by proposed action among many stocks contributing to the SRKW diet, and the contribution of hatchery-origin Chinook Salmon released downstream of the potential influence of proposed action, population-level effects of the proposed action to SRKW prey species are not expected.

5.14.2 Effects of Maintenance

Implementation of the species avoidance and take minimization steps under the proposed action described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Chinook Salmon stocks from maintenance activities.

5.14.3 Effects of Conservation Measures

Construction components of the proposed action have the potential to affect Chinook Salmon stocks, which form part of the diet of SRKW. The various proposed construction activities would generally benefit Chinook salmon stocks in the long-run, through increased operational flexibility and habitat restoration. The conservation measures potentially could also result in negative effects to individual fish such as: temporary loss of aquatic and riparian habitat leading to increased predation and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. These potential effects would be minimized through restriction of in-water work to windows limiting exposure by reducing potential for spatiotemporal overlap, and implementation of other AMMs to minimize the potential for effects when species do overlap with in-water work.

5.14.4 Effects of Monitoring Activities

Monitoring activities described in Appendix C, *ROC Real Time Water Operations Charter* in section *Monitoring Program for Core CVP and SWP Operation* would result in capture of individual juvenile Chinook salmon that otherwise could have reached the ocean and become prey for SRKW. However, the extent of this capture is limited relative to the overall abundance of juvenile Chinook salmon. In addition, the priority of the Chinook salmon stocks is low to moderate relative to other stocks for the SRKW diet.

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

The reduced spring flows of the proposed action, compared to the WOA, are likely to affect rearing and migrating Fall-run Chinook Salmon, which could possibly reduce juvenile production and affect Killer Whale prey. Effects include a decrease in floodplain and side-channel habitat, reduced foraging conditions, increased competition and predation, and reduced emigration flows.

Reclamation has included fall and winter refill and redd maintenance as well as smoothing rice decomposition, to consider keeping flows higher in the fall for avoiding Fall-run redd dewatering when Shasta Reservoir storage allows.

In addition to the fall and winter redd maintenance and smoothing of rice decomposition, several conservation measures for Winter-run Chinook salmon, Spring-run Chinook salmon, or steelhead would incidentally minimize impacts on Fall-run Chinook Salmon. These include spawning and rearing habitat restoration on the Sacramento, American, Stanislaus, and lower San Joaquin rivers, tidal habitat restoration, and predator hot spot removal. OMR management establishes protective criteria to minimize and avoid entrainment based on historical salvage. Additional protective measures occur when environmental criteria indicate that entrainment is more likely and allow for more flexible operations when entrainment is less likely. The proposed action also includes conservation measures such as improvements at fish collection facilities to improve facility survival and reduce impacts of the proposed action on Killer Whale prey as compared to WOA.

5.14.5.1 Life stage Timing and Location

General life stage timing and location information for Fall-run and Late Fall-run Chinook Salmon is provided in Tables 5.14-1 and 5.14-2. Additional detail regarding juvenile life stage timing at various monitoring locations is provided in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS.*

Table 5.14-1. The Temporal Occurrence of Adult and Juvenile Fall-run Chinook Salmon at Locations in the Central Valley (DWR and Reclamation 2016, p.11A-103).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]						Medium	High	High	High	High	High	Medium
Sacramento River Basin[2]							Low	Low	Low	High	High	High
San Joaquin River[2]								Low	Low	High	High	Low
Juvenile												
Sacramento River at Red Bluff[3]	High	High	High	High	Medium	Medium	Medium	Low	Low	Low	Low	Medium
Delta (beach seine)[4]	High	High	High	High	Medium	Medium	Low	Low	Low		Low	Medium
Mossdale (trawl)[4]	Medium	High	High	High	High	Medium						
West Sacramento River (trawl)[4]	Medium	High	High	High	High	Low	Low	Low	Low		Low	Low
Chipps Island (trawl)[4]	Medium	Medium	Medium	High	High	High	Low	Low	Low	Low	Low	Low
Knights Landing (trap)[5]	High	High	High	High	High	Low	Low	Low	Low	Low	Low	Medium

Relative Abundance: [dark shading] = High; [medium shading] = Medium; [light shading] = Low

Note: Darker shades indicate months of greatest relative abundance.

Sources:

[1] State Water Project and Federal Water Project fish salvage data 1981–1988.

[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991.

[3] Martin et al. 2001.

[4] U.S. Fish and Wildlife Service 2001b.

[5] Snider and Titus 2000.

Table 5.14-2. The Temporal Occurrence of Adult and Juvenile Late Fall-run Chinook Salmon at Locations in the Central Valley (DWR and Reclamation 2016, p.11A-104).

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult												
Delta[1]	High	High	High	Medium	Medium					Medium	Medium	Medium
Sacramento River Basin[2]	High	High	High	Medium						Medium	Medium	Medium
Juvenile												
Sacramento River at Red Bluff[3]	High	High	High	High	Medium	Low	Low	High	High	High	High	Medium
West Sacramento River (trawl)[4]	Medium	Low		Low		Low	Low	Low	Low	Medium	High	High
Delta (beach seine)[4]	High	Medium		High	High	Medium	Low				Low	High
Chipps Island (trawl)[4]	Medium	Low			Low	Low	Low	Low	Low	Low	Medium	High
Knights Landing (trap)[5]	Medium	Low		Medium	Medium	Low				Low	Medium	High

Relative Abundance: [dark] = High; [medium] = Medium; [light] = Low

Note: Darker shades indicate months of greatest relative abundance.

Sources:

[1] Moyle 2002.

[2] Yoshiyama et al. 1998; Moyle 2002; Vogel and Marine 1991.

[3] Martin et al. 2001.

[4] U.S. Fish and Wildlife Service 2001b.

[5] Snider and Titus 2000.

5.14.5.2 Conceptual Model Linkages

Central Valley Fall-run/Late Fall-run Chinook Salmon populations occur in several Central Valley streams. The SAIL conceptual model (Figure 5.6-1) was prepared specially for Sacramento River Winter-run Chinook Salmon, but the cause and effects relationships it diagrams apply equally well to the Fall-run and Late Fall-run races in Sacramento River. The primary differences in the habitat requirements between the Fall-run/Late Fall-run Chinook Salmon and Winter-run Chinook Salmon are the duration and the time of year that the different life stages use their habitats, as well as spawning locations within the Sacramento River (see Chapter 2, Species Accounts). Releases from Keswick Dam and the resulting flows in the upper Sacramento River, combined with other environmental drivers, affect water temperature, dissolved oxygen level (DO), and other habitat attributes that influence the timing, condition and survival of eggs and alevins in the spawning redds. The proportion of eggs surviving to emerge as fry depends largely on the quality of conditions in the redd (Windell et al. 2017). Redd quality is affected by substrate size and composition, flow velocity, temperature, DO, contaminants, sedimentation, and pathogens and diseases. Flow affects sedimentation and gravel composition of the redds and may cause redd scour, stranding or dewatering (Windell et al. 2017). Flow also affects the surface area of river bed available for redd construction.

Fall-run adults spawn in the Sacramento River and eggs and alevins are in the gravel primarily between September and December with a peak during October through December (Table 5.14-1). Spawning occurs between Keswick Dam to Red Bluff Diversion Dam primarily, although spawning occurs as far down as Princeton (Reclamation 2017).

Late Fall-run Chinook Salmon spawn in the Sacramento River and eggs and alevins are in the gravel primarily between December and June with a peak during January through March (Table 5.14-1). Spawning occurs between Keswick Dam and Red Bluff Diversion Dam, with the majority of spawning between Keswick Dam and Red Bluff (Reclamation 2017).

Fry emergence occurs up to 3.5 months after eggs are spawned (Moyle 2002), so effects of flow in the upper Sacramento River on incubating fall-run eggs and alevins potentially occur from September through April and on incubating Late Fall-run Chinook Salmon eggs and alevins potentially occur from December through August.

As indicated by the SAIL conceptual model (Figure 5.6-2), releases from Keswick Dam and the resulting flows in the upper Sacramento River, combined with other environmental drivers, affect water temperature, DO, stranding, outmigration cues and other habitat attributes that influence the timing, condition and survival of rearing juvenile Fall-run/Late Fall-run Chinook Salmon. The proportion of juveniles surviving to emigrate from the upper Sacramento River depends largely on habitat conditions, including instream flow (Windell et al. 2017). Instream flow affects other factors through dilution (e.g., toxicity and contaminants), water temperatures (which also affects DO, food availability, predation, pathogens, and disease), river stage and flow velocity (which affect habitat connectivity, bioenergetics, food availability, and predation), entrainment and stranding risk, and potentially affects cues that stimulate outmigration (Windell et al. 2017, Moyle 2002).

Fall-run/Late Fall-run Chinook Salmon juveniles rear in and emigrate from the upper Sacramento (Keswick to Red Bluff) year-round, with a peak rearing period during January through April and, for Late Fall-run Chinook Salmon only, a secondary peak in August through November (Table 5.14-1; Table 5.14-2). Flows during summer, fall and winter of dry and critically dry years generally have the greatest potential to negatively impact the juvenile life stage in the upper Sacramento River because reservoir storage and cold water pool in these seasons and water year types may be insufficient to provide suitable flow and water temperature conditions in the rearing habitats.

Many of the factors that affect rearing and emigrating Fall-run/Late Fall-run Chinook Salmon juveniles in the middle Sacramento River are similar to those described above for the upper Sacramento River. As indicated by the SAIL conceptual model (Figure 5.6-3), flows from the upper Sacramento River and tributaries of the middle Sacramento, combined with other environmental drivers such as floodplain connectivity, food production and retention, and water diversions, affect water temperature, DO, food availability, stranding, outmigration cues and other habitat attributes that influence the timing, condition and survival of rearing juvenile Fall-run/Late Fall-run Chinook Salmon. The proportion of juveniles surviving to emigrate from the middle Sacramento River depends largely on growth and predation, which are greatly affected by habitat conditions, including instream flow (Windell et al. 2017).

Juvenile Fall-run/Late Fall-run Chinook Salmon spend varying amounts of time rearing in the upper Sacramento River following emergence before migrating to the middle River. They use the middle Sacramento River as rearing habitat and a migratory corridor to the Delta. Fall-run/Late Fall-run Chinook Salmon-sized juveniles occur in the middle Sacramento River at Knights Landing primarily from November through May (Table 5.14-1), with two separate peak occurrences for Late Fall-run Chinook Salmon: November through February and April and May (Table 5.14-2). The two peaks may reflect differences in the timing of emigration from different Sacramento River tributaries.

Inundated floodplains of the middle Sacramento River, such as the Yolo and Sutter Bypasses, have proven successful habitats for juvenile salmon growth (Katz, 2017). This success has been attributed to optimum water temperature, lower water velocity, and higher food quality and food density relative to the main channel. Reduced predator and competitor density also likely contribute to high growth rates observed for juvenile salmon rearing in floodplains (Windell et al. 2017).

Continuing their upstream migration from the Delta, Fall-run Chinook Salmon adults migrate through the middle and upper Sacramento River between July and December and Late Fall-run enter the middle Sacramento River between October and April. The adults typically spawn soon after reaching their spawning habitats, but some hold for a month or two in the upper river before spawning (Satterthwaite et al. 2017; California Natural Resources Agency 2016. Appendix 5E Essential Fish Habitat Assessment). The holding period for Fall-run Chinook Salmon in the Sacramento River is August to October (California Natural Resources Agency 2016. Appendix 5E Essential Fish Habitat Assessment). No information has been found regarding the period that Late Fall-run Chinook Salmon hold, but it is assumed that they hold during October and November (Satterthwaite et al. 2017).

As indicated by the SAIL conceptual model (Figure 5.6-6), flows from Keswick Dam releases affect water temperature, DO, and other habitat attributes that influence the timing, condition, distribution and survival of adult Fall-run/Late Fall-run Chinook Salmon during their upstream migration, holding and spawning in the upper Sacramento River.

5.14.5.3 Effects of Operation

5.14.5.3.1 <u>Seasonal Operations</u>

Under the WOA conditions, there would be no Shasta and Keswick reservoir operations to control storage or releases and no transfer of water from the Trinity River Basin. Therefore, there would be no control of flow or water temperature in the upper Sacramento River (other than upstream hydropower operations not under Reclamation control), where Fall-run spawn. Reservoir gates and river valves would be kept open, resulting in minimal storage (Figure 5.6-7). The seasonal flows modeled under the WOA scenario in the Sacramento River at Keswick Dam, show low summer and fall flows and high winter and spring flows (Figures 5-15 through 5-18 in the HEC5Q Temperatures section of Appendix D, *Modeling*). Other locations in the Sacramento River would show similar seasonal flow patterns (See figures in the HEC-5Q Temperatures section of Appendix D, and Figures 5.14-1 and 5.14-2).

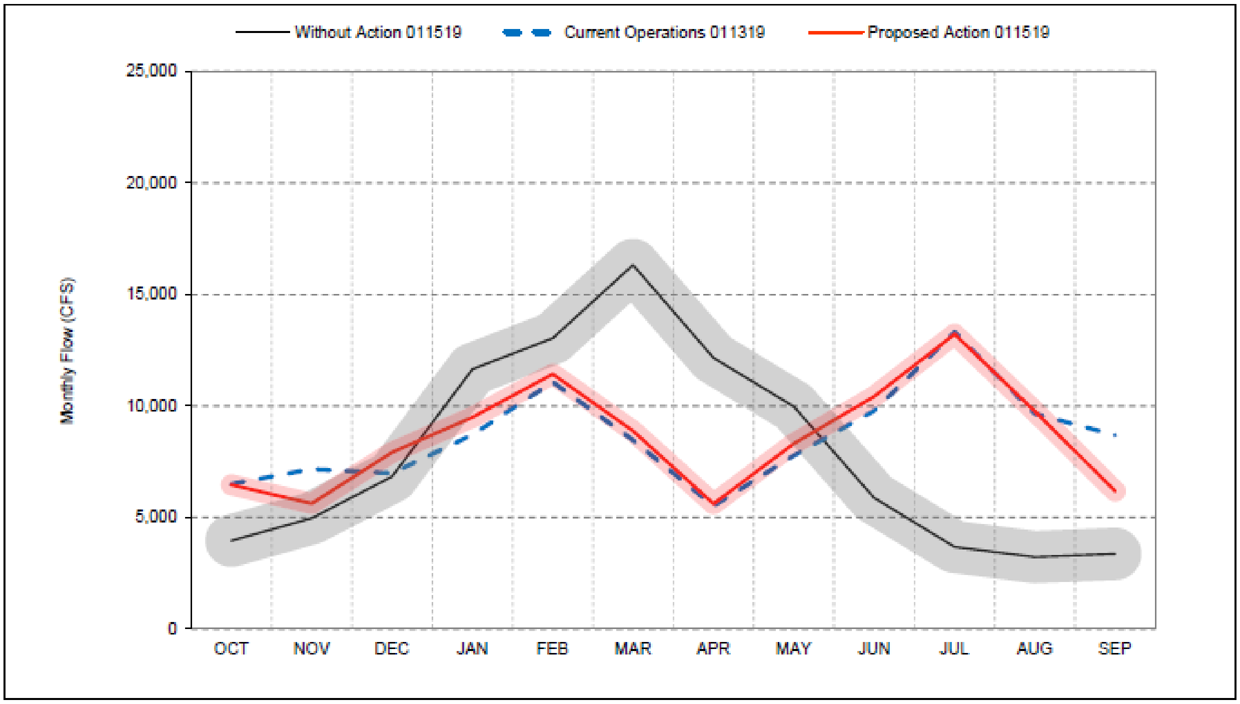


Figure 5.14-1. Mean Modeled Flows in the Sacramento River Below Keswick Dam

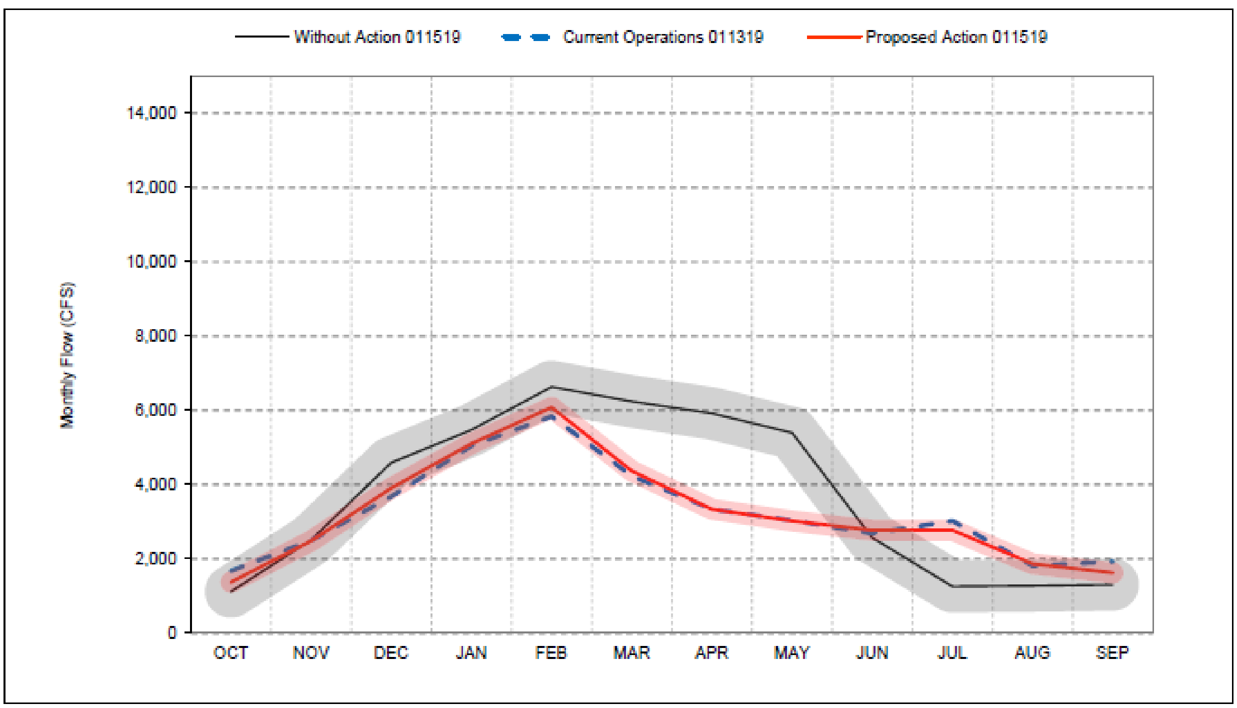


Figure 5.14-2. Mean Modeled Flows in the American River Below Nimbus Dam

Higher flows may negatively impact spawning and egg/alevin incubation. If flows are sufficiently high, they result in excessive depths and flow velocities for constructing redds, and redds that were previously built are at risk of being scoured from the bed (NMFS 2017 – CWF BO). In addition, under high flows, adults may build redds in areas that are later dewatered or isolated from the main river channel when the flows decline. High flow events with rapid flow fluctuations are likely to occur more frequently in rivers with uncontrolled flows, like the Sacramento River under the WOA conditions.

In the spawning reaches of Fall-run/Late Fall-run Chinook Salmon in the upper Sacramento River, flows under WOA during the October through April (Fall-run) and December through July (Late Fall-run) spawning, egg incubation, and alevin periods are highly variable. Flows under WOA are modeled as approximately 4,000 cfs from July through October in most water year types. The low flows would have a number of negative effects on spawning, egg incubation, and alevins of both Fall-run and Late Fall-run Chinook Salmon. As described by Windell et al. 2017, potential adverse effects of the low flows on eggs and alevins include:

- An insufficient area of river bed with suitable attributes to accommodate redds for all spawning-ready Fall-run/Late Fall-run adults.
- Inadequate flow velocities to flush sediments from the redds.
- Insufficient flow to maintain adequate levels of DO in contact with eggs and alevins in the redds and to flush metabolic wastes from the redd.
- Insufficient water depths for redds, such that minor reductions in flow result in redd stranding and dewatering.

5.14.5.3.2 <u>Sacramento River Cold Water Pool Management</u>

5.14.5.3.2.1 Eggs to Fry Emergence

5.14.5.3.2.1.1 <u>Flow</u>

Under the WOA, flows are approximately 4,000 cfs from July through October in the Sacramento River in most water year types, as inflow to Shasta Reservoir is minimal after snowmelt runoff in the late spring and summer and flows are maintained by constant spring fed sources of around 3,000 cfs upstream of Shasta in the Pit and McCloud rivers. Lower flows could limit spawning habitat, result in higher water temperatures, and dissolved oxygen for Fall-run Chinook Salmon eggs and alevin. Under COS flows during the October through February egg incubation period are usually above 6,000 cfs. The proposed action flows are similar to the COS flows at the lower end of the flow range where spawning habitat generally is most plentiful.

Differences in flows between COS and the proposed action are small in most months, but flows are moderately higher for the proposed action in June and substantially higher for the COS scenario in September and November (15-14 and 15-in the CalSim II Flows section of Appendix D). In these three months, the flow differences are expected for years with relatively wet hydrologies and, therefore, are not expected to have a meaningful effect on most Fall-run/Late Fall-run growth and survival factors. However, the Weighted Usable Area (WUA) of fall-run spawning habitat declines substantially over this range of flows (~6,000 cfs to 12,000 cfs [proposed action] or 17,000 [COS]) (Figure 15.4-3; USFWS 2003).

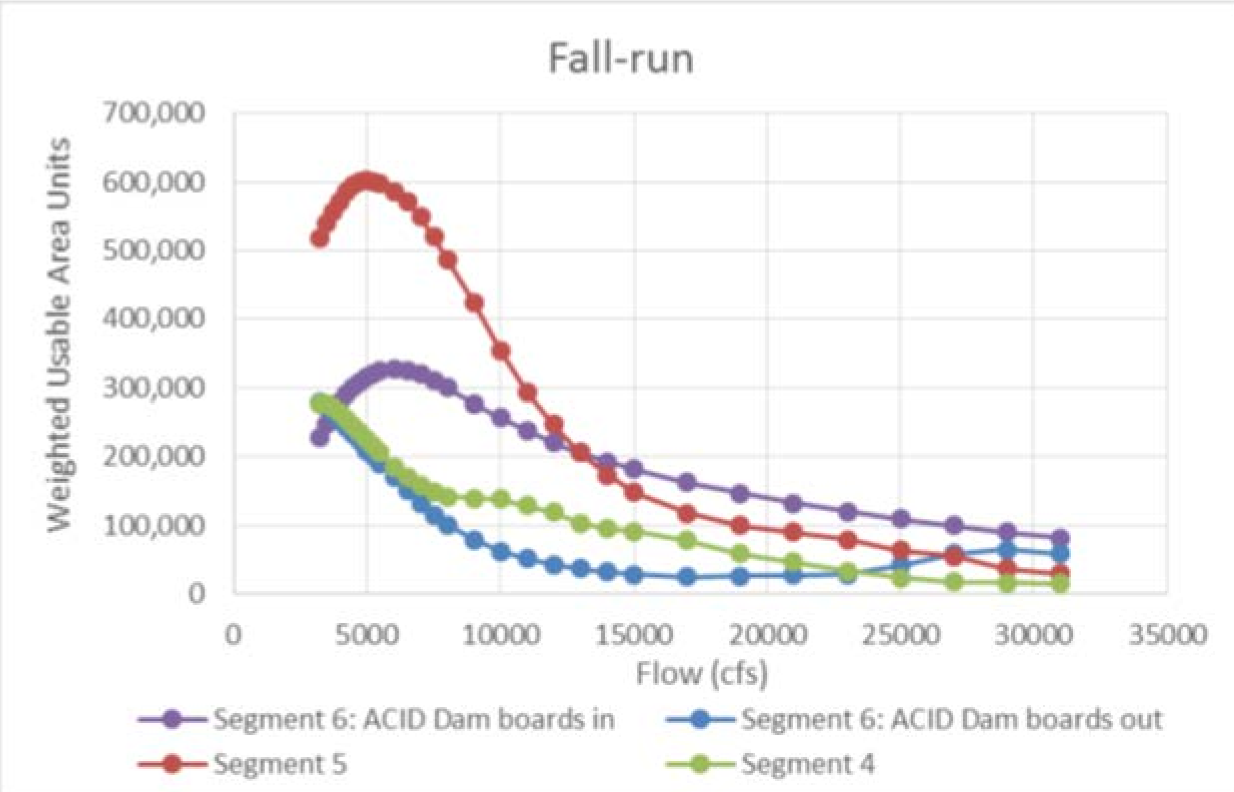


Figure 5.14-3. Spawning Habitat WUA Curves for Fall-run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

Flows under the proposed action and COS scenarios are consistently well above the WOA flows in June through October, but not during November through April (Figures 15-3through 15-18 in the CalSim II Flows section of Appendix D). In November, there is little difference in flow between the WOA and proposed action scenarios, except in the highest flow years, when the proposed action flows tend to be higher, but the COS flows are well above the WOA flows under most of the flow range. In December and February, proposed action and COS flows are generally below WOA flows for years with dry hydrologies, and are generally higher in wet years, except for the wettest Decembers. In January, proposed action and COS flows are moderately lower than the WOA flows in almost all years and during March and April, they are consistently well below the WOA flows. In May, proposed action and COS flows are below WOA flows during the wettest 50 percent of years, and similar to or slightly higher than the WOA flows in the driest 50 percent of years (Figure 15-14 in the CalSim II Flows section of Appendix D). Therefore, during the first two months of the fall-run spawning and incubation period (September through October), all the potential negative effects of low flows on Fall-run/Late Fall-run spawning and incubation listed above are expected to be less under the proposed action scenarios than under the WOA scenario. But during January through April, the potential negative effects of low flows are expected to be greater under the proposed action.

5.14.5.3.2.1.2 Water Temperature

Critical water temperatures thresholds for Fall-run/Late Fall-run Chinook Salmon vary by life stage, with eggs and alevins the most sensitive to elevated temperatures. Under the proposed action, Reclamation would operate to new water temperature management measures that include a water temperature maximum of 53.5 degrees Fahrenheit in the Sacramento River above the Clear Creek confluence.

In the upper Sacramento River, where most Fall-run/Late Fall-run spawning occurs, the WOA monthly mean water temperatures (HEC-5Q WOA scenario) during the September through April (Fall-run) and December through July (Late Fall-run) spawning and egg/alevin incubation periods would be variable. Between November and March, water temperatures would be consistently under the 53.5 and 56 degree Fahrenheit thresholds (see Appendix D, *Modeling*). Approximately 20 percent of Aprils would be above 53.5 degrees Fahrenheit but all would be below 56 degrees Fahrenheit (Figure 5.6-30). Between May and October, aside from the coldest ~5 percent of Mays and ~35 percent of Octobers, water temperatures under the WOA scenario would always be higher than 53.5 degrees Fahrenheit and 56 degrees Fahrenheit, reaching as high as 73 degrees Fahrenheit in the warmest years (Figures 5-14 through 5-18 in the HEC-5Q Temperatures section of Appendix D). Such warm summer conditions would adversely affect survival of early incubating Fall-run and later incubating Late Fall-run eggs and alevins under the WOA scenario in the upper Sacramento River during those months.

The presence of a large cold water pool and the flexibility afforded by the TCD make possible the provision of much colder water under the proposed action in the upper Sacramento River during May through October than would be possible under the WOA conditions. Under the proposed action, monthly mean water temperature outputs from HEC 5Q at Keswick range from about 46 to 66 degrees Fahrenheit during May through October (Figures 5-14 through 5-19 in the HEC-5Q Temperatures section of Appendix D). During November through April, water temperatures range from about 43 to 58 degrees Fahrenheit (Figures 5-8 through 5-13 in the HEC5Q Temperatures section of Appendix D)(). While the HEC-5Q model provides 6-hour data, the results presented here are monthly averages, which should reasonably estimate daily average water temperatures near the dam because operations at Shasta and Keswick dams create relatively stable summer flow and water temperature conditions. Variable weather conditions and travel time of water result in greater fluctuations around the mean further downstream of the dam.

There is little difference in water temperatures at Keswick Dam between the proposed action and COS scenarios during the Fall-run/Late Fall-run spawning and egg/alevin incubation period, except for in October, when the proposed action is two degrees Fahrenheit colder than the COS in the middle of the exceedance plot range (90% to 20% exceedance; Figures 5-10 through 5-12, 5-13, and 5-14 through 5-18 in the HEC-5Q Temperature section of Appendix D). It is expected that the Proposed Action would be more protective of Fall-run/Late Fall-run than Current Operations.

With the proposed improvements in water temperature management, adverse impacts on Fall-run/Late Fall-run individuals are expected to lessen under the proposed action. Therefore, benefits of the CVP include fall temperature management for Fall-run and Late Fall-run Chinook Salmon.

5.14.5.3.2.2 Rearing to Outmigrating Juveniles

5.14.5.3.2.2.1 Flows

The low fall flows under the WOA conditions would likely result in degraded conditions in juvenile rearing habitats in the upper Sacramento River for any juvenile Late Fall-run that remain in the river in the fall, as Shasta Dam is still a passage barrier under WOA. The low flows under WOA conditions during June through October would have adverse impacts on rearing habitat of Late Fall-run juveniles. These degraded habitat conditions would lead to reduced growth rate and higher mortality of the individual juveniles and a potentially reduced population abundance.

CalSim modeling indicates that upper Sacramento River flows during the year-round Fall-run/Late Fall-run juvenile rearing and emigration period in the upper Sacramento River are generally similar between the proposed action and COS (Figures 15-7 through 15-18 in the CalSim II Flows section of Appendix D) except, as described previously, for higher flows under the proposed action during December and January and higher flows during September and November under the COS scenario. These differences in flow between proposed action and COS scenarios could potentially affect juvenile habitat attributes of Fall-run and Late Fall-run juveniles both positively and negatively depending on the underlying habitat attribute (Figure 5.6-2).

From January through April, WOA flows would often be nearly twice as high as the proposed action and COS flows during years with dry hydrologies. The proposed action and COS flows in such years would generally be at the required minimum of 3,250 cfs per WRO 90-5. The WUA for rearing habitat of both Fall-run and Late Fall-run Chinook Salmon juveniles is at or near its maximum at 3,250 cfs (e.g., Figure 5.14-4) (USFWS 2005). This flow was the lowest flow included in the USFWS study. Depending on the reach sampled in the study, flow of approximately 6,000 cfs, which is the most frequent flow level for dry hydrologies under the WOA scenario, was estimated to have similar to much lower juvenile rearing habitat WUA than the 3,250 cfs flow (USFWS 2005). Although the WUA analyses indicate potentially greater juvenile rearing habitat WUA in dry years under the proposed action and COS scenarios than under the WOA scenario, the reductions in flow predicted for these scenarios would potentially affect other rearing habitat attributes of Fall-run/Late Fall-run juveniles than those measured for the WUA analyses.

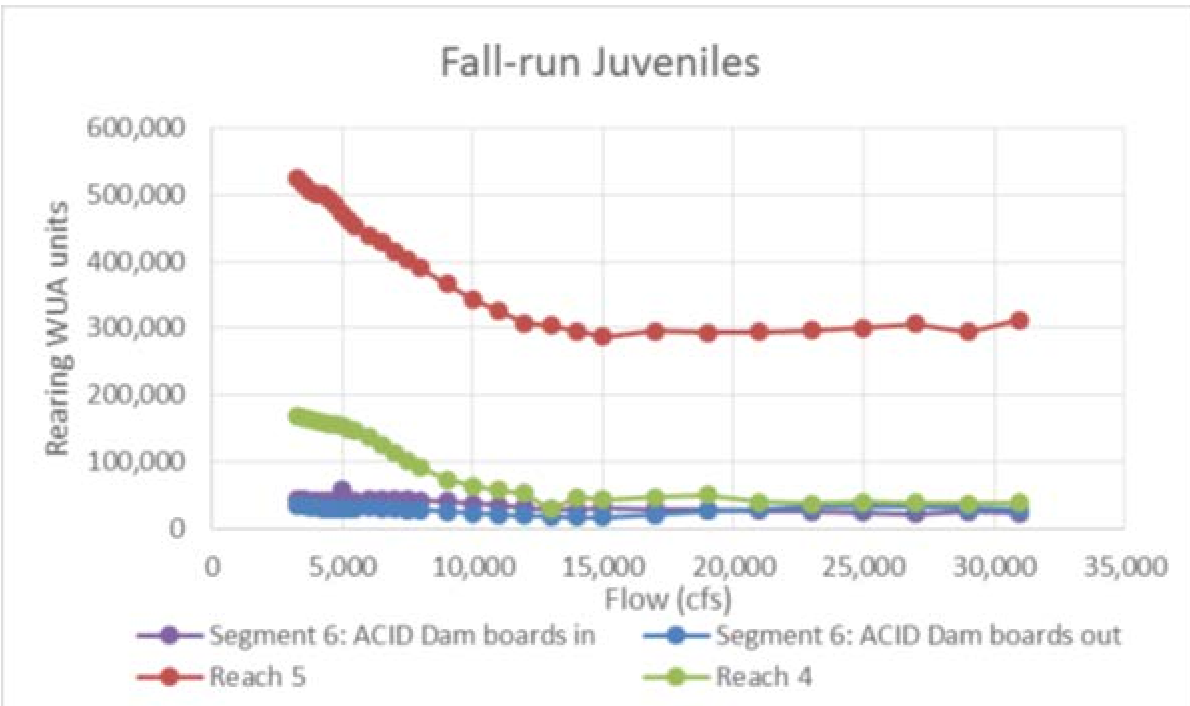


Figure 5.14-4. Rearing Habitat WUA Curves for Fall-run Chinook Salmon in the Sacramento River, Segments 4 to 6. ACID = Anderson-Cottonwood Irrigation District.

Lower winter and spring flows under the proposed action and COS relative to WOA could have both negative and positive effects on rearing juvenile Fall-run/Late-Fall run Chinook Salmon. Potential impacts include less inundation of floodplain and side-channel habitat, degraded feeding conditions, increased competition and predation, higher water temperatures and lower DO, and reduced emigration flows, while benefits include lower stranding risk because of decreased use of flood plains and lower flow fluctuations. On balance, given the USFWS (2005) results, the effect of lower winter and spring flows during most years under the proposed action relative to the WOA scenario on Fall-run/Late Fall-run Chinook Salmon juveniles and their rearing habitat is uncertain.

5.14.5.3.2.2.2 Water Temperature

In the upper Sacramento River, the WOA scenario monthly meanwater temperatures at Keswick Dam during October through April would be below the 61 degree Fahrenheit rearing juvenile threshold (USEPA, 2003) in 99-100 percent of years (Figures 5-7 to 5-9, 5-10-5-12, and 5-13 in the HEC-5Q Temperatures section of Appendix D), but would frequently be above 61 degrees Fahrenheit from May to September. The frequent exceedances of the 61 degrees Fahrenheit threshold that would occur during May through September in the upper Sacramento River would impact rearing Fall-run/Late Fall-run Chinook Salmon juveniles with greater effect to Late Fall-run.

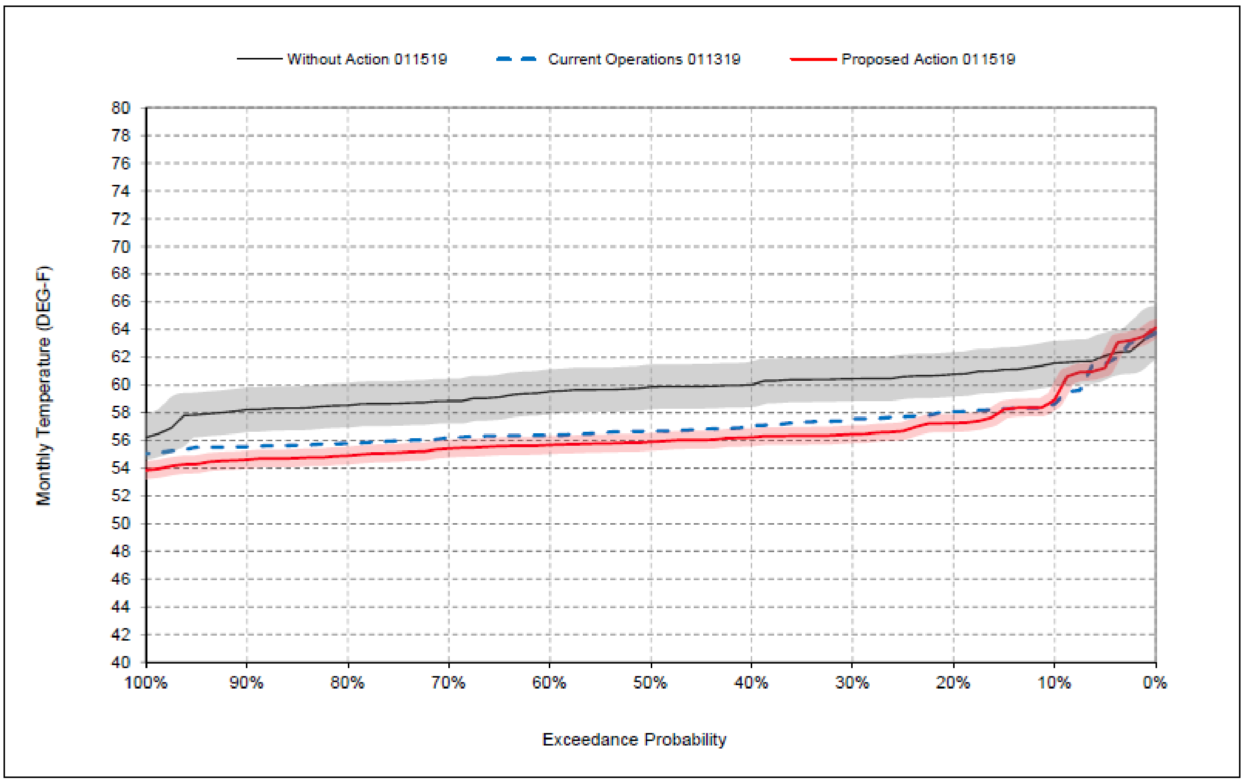


Figure 5.14-5. HEC-5Q Sacramento River Water Temperatures at Red Bluff under the WOA, proposed action and COS scenarios, October

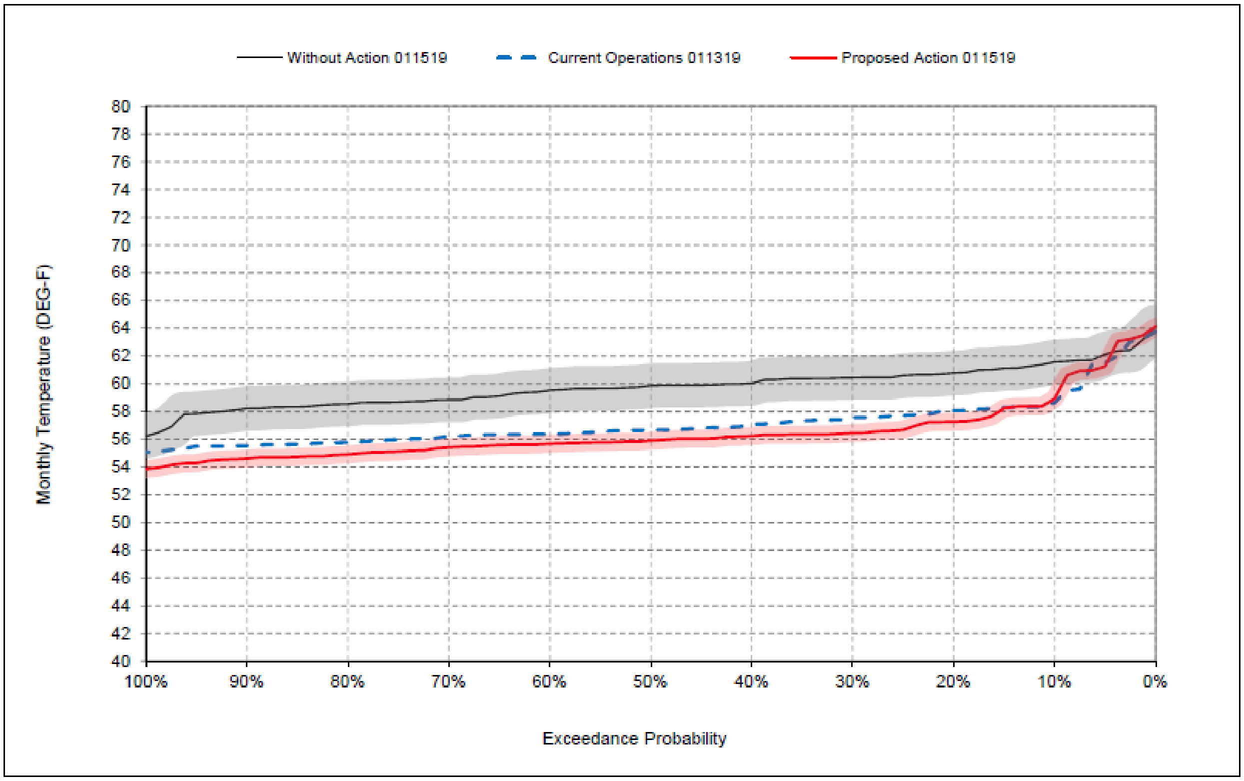


Figure 5.14-6. HEC-5Q Sacramento River Water Temperatures at Red Bluff under the WOA, proposed action and COS scenarios, May

Water temperatures at Keswick under the proposed action and COS scenarios are higher than those under the WOA scenario during November through February, are similar in March, and are lower than those under the WOA scenario in April through September (Figures 5-12 to 5-12, 5-13, and 5-14 through 5-18 in the HEC-5Q Temperatures section of Appendix D). In October, temperatures under proposed action and COS are lower than those under the WOA except in the warmest 10 percent of years (see Figure 5-7 in the HEC-5Q Temperatures section of Appendix D). A similar pattern is observed for Red Bluff, although March water temperatures under proposed action and COS would be higher than those under the WOA and April water temperatures t would be similar among the three scenarios (e.g., Figure 5.14-6, Figure 10-16, and Figure 10-6 in the HEC-5Q Temperatures section of Appendix D). All water temperatures under proposed action and COS scenarios during the Fall-run/Late Fall-run juvenile rearing period are consistently below the 61 degrees Fahrenheit threshold, except for June through October. However, during June through October, water temperatures under the WOA in almost every year would be substantially higher (~10 to 20 degrees Fahrenheit) than those under the proposed action and COS. Therefore, water temperature conditions under proposed action would provide benefits relative to the WOA conditions to juvenile Fall-run/Late Fall-run Chinook Salmon rearing in the upper Sacramento River.

5.14.5.3.2.3 Rearing to Outmigrating Juveniles in the Middle Sacramento River

5.14.5.3.2.3.1 Flow

CalSim modeling indicates that middle Sacramento River flows during November through May are generally similar between the proposed action and COS, except during November of above normal and wet years, for which the mean flows under the COS scenario are higher (Tables 17-3 in the CalSim II Flows section of Appendix D). The November reductions in flow under the proposed action scenario are predicted for the middle ranges of the exceedance curves (roughly 6,000 cfs to 13,000 cfs) (Figure WRF_LS3_Wsnov): flows in this range would provide generally comparable rearing habitat Weighted Usable Area (WUA) for Fall-run and Late Fall-run Chinook Salmon juveniles (USFWS 2005), although this study is not applicable to the middle and lower river.

As was true for the upper Sacramento River, the CalSim modeling shows large seasonal changes in the differences in middle Sacramento River flow between the WOA scenario and the proposed action and COS scenarios. In November, there are small to moderate differences in flow between the WOA and proposed action scenarios, with higher flows under the WOA scenario in the middle-high range of flow years, and lower flows under the WOA scenario in the lower flow years, but the COS flows are consistently above the WOA flows in all but the highest flow years (Figure 19-8; Tables 17-1, 18-1, and 19-1 in the Flows section of Appendix D). In December through February, the WOA flows are generally similar to or slightly higher than the proposed action and COS flows for most years (Figures 19-9 through 19-11; Tables 17-1, 18-1, and 19-1 in the Flows section of Appendix D), and in March and April, the WOA flows are consistently higher than the proposed action and COS flows (Figures 19-12 and 19-13 in the Flows section of Appendix D). In May, the WOA flows are substantially higher than the proposed action and COS flows for the 60 percent of highest flow years and are substantially lower for the 25 percent of lowest flow years (Figure 19-14 in the Flows section of Appendix D).

The higher November and May flows under the COS relative to WOA during years with drier hydrologies would likely result in enhanced conditions in juvenile rearing habitats, including more habitat complexity, side channel habitat structure and refuge habitat, and reduced disease potential. The lower proposed action flows in December through April could have both negative and positive effects on rearing juvenile Fall-run/Late Fall-run Chinook Salmon. Potential impacts include less floodplain and side-channel habitat, worse feeding conditions, increased competition and predation, higher water temperatures and lower DO, and degraded emigration flows, while potential benefits include lower stranding risk because of decreased use of flood plains and lower flow fluctuations, and lower contaminants loading from stormwater runoff. The potential impacts of lower winter and early spring flows under the proposed action are presumed provide an overall impact to the population through lesser juvenile productivityThe proposed action addresses the impact to juvenile productivity of the change in flows and water temperatures through conservation measures.

5.14.5.3.2.3.2 Water Temperature

The USEPA (2003) gives 64 degrees Fahrenheit as the critical 7 day average daily maximum (7DADM) water temperature for Chinook Salmon juveniles rearing, although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of 7DADM. In the middle Sacramento River below the Colusa Basin Drain, which is close to Knights Landing. The WOA scenario monthly mean water temperatures remain below the 64 degrees Fahrenheit threshold from November through March (14-8, 14-9, 14-10 through 14-13in the HEC 5Q Temperatures section of Appendix D), but exceed the threshold during the warmest 5 percent of years in April and the warmest 85 percent of years in May, with a maximum water temperature of 75 degrees Fahrenheit (Figures 14-13 and 14-14 in the HEC 5Q Temperatures section of Appendix D).

Water temperatures under the proposed action and COS scenarios are substantially or moderately above the WOA scenario water temperatures during most years in November through April (Figures 14-8, 14-914-12, 14-13 in the HEC 5Q Temperatures section of Appendix D), and are moderately below the WOA scenario water temperatures during most years in May (Figure 14-14 in the HEC 5Q Temperatures section of Appendix D). Water temperatures during most years in the November through April period are suitable for juvenile Fall-run/Late Fall-run Chinook Salmon that rear in and emigrate from the middle Sacramento River under the WOA and the proposed action and COS scenarios, therefore, adverse impacts on the Fall-run/Late Fall-run Chinook Salmon juveniles are not expected for these months. Under all three scenarios during May, however, the 64 degrees Fahrenheit threshold would be exceeded in most years, with the WOA scenario having greater exceedances than the proposed action and COS scenarios, especially in warmer years (Figure 14-14 in the HEC 5Q Temperatures section of Appendix D). These results indicate that water temperature conditions would too warm for juvenile Fall-run/Late Fall-run rearing and emigrating in the middle Sacramento River during May under WOA conditions, the proposed action and COS and that conditions would be worse under the WOA conditions. It should be noted that May is the last month during spring or summer that Fall-run/Late Fall-run juveniles are abundant in the middle river (Table 5.14-1), and it is likely that when water temperatures are too high they emigrate to the ocean before May. Water temperatures in the middle and lower river cannot be efficiently managed with Shasta Reservoir releases so are predominantly dependent on ambient conditions.

5.14.5.3.2.4 Adult Migration from Ocean to Rivers

5.14.5.3.2.4.1 Flow

Under WOA, CalSim modeling indicates that during the July through December fall-run Chinook salmon immigration period, the lowest flows at Keswick Dam during July through October are low enough to create potential passage problems for immigrating fall-run Chinook salmon adults, and this is even more true at Wilkins Slough, where flows reach 0 cfs in some years. The low flows under WOA would have major adverse impacts on adults migrating upstream in the middle Sacramento River and for adults holding in the upper river.

During the July through December Fall-run Chinook salmon immigration period and the October through April Late Fall-run immigration period, flows are similar between the proposed action and COS scenarios at Wilkins Slough and at Keswick, except for much higher flows during September under the COS scenario (up to ~7,000 cfs higher) at Wilkins Slough and Keswick for flows in the range from about 8,000 cfs to 16,000 cfs (Figures 19-18 and 15-18 in in the Flows section of Appendix D) and higher flows during November under the COS scenario (~3,500 cfs higher at Keswick and ~4,000 cfs higher at Wilkins Slough) for flows from about 6,000 cfs to 13,000 cfs (Figure 19-8 and 15-8 in the Flows section of Appendix D). These flow differences occur primarily for flows greater than 5,000 cfs, which are likely high enough to present no passage problems for upstream migrating adults.

The CalSim modeling shows large seasonal changes in the differences in middle and upper Sacramento River flow between the WOA scenario and the proposed action and COS scenarios. In November through February, the WOA flows are generally similar to or slightly higher than the proposed action and COS flows for most years at both Wilkins Slough and Keswick Dam. The main exception is November, when there is little difference in flow between the WOA and proposed action scenarios, except for higher proposed action flows in the highest flow years at Keswick, but the COS flows are well above the WOA flows under most of the flow range (Figures 19-8 and 15-8 in the Flows section of Appendix D). In

March and April, the WOA flows are generally higher than the proposed action and COS flows at both locations (Figures 19-12 and 19-13 and 15-12 and 15-13 in the Flows section of Appendix D). For the remainder of the months included in the Fall-run and Late Fall-run Chinook Salmon adult immigration periods (July through October), the proposed action and COS flows are generally higher or much higher than the WOA flows at both locations (Figures 19-16 through 19-18 and 19-7; 15-16 through 15-18 and 15-7 in the Flows section of Appendix D. The higher flows during July through October in years with dry hydrologies at Wilkins Slough and Keswick under the proposed action relative to the WOA scenario would likely benefit Fall-run/Late Fall-run adults migrating in the middle and upper Sacramento River by enhancing water quality and upstream passage, and reducing stranding, straying, poaching, and disease risks (Windell et al. 2017).

5.14.5.3.2.4.2 Water Temperature

Under WOA conditions there would be no control of flow or water temperature in the Sacramento River, Shasta storage levels would be very low (see Shasta Lake Storage figures in the CalSim Storage section of Appendix D) and, assuming stratification developed, the cold water pool would be small and would not be managed.

The USEPA (2003) gives 68 degrees Fahrenheit as the critical 7DADM water temperature for Chinook Salmon adults migrating and 61 degrees Fahrenheit as the critical 7DADM for holding adults, although this is based on Pacific Northwest fish and hydrology and does not consider the operational feasibility of 7DADM. In the middle Sacramento River below the Colusa Basin Drain, WOA water temperatures exceed the water temperature threshold for migrating adults in summer, but not in the winter. During almost all years in July and August, the WOA water temperatures exceed the threshold by at least 10 degrees Fahrenheit. Therefore, water temperatures would be highly stressful to Fall-run Chinook Salmon adults migrating upstream during the first months of their July through December immigration period, whereas they would be moderately stressful in some years to Late Fall-run migrating upstream during October.

In the upper Sacramento River at Keswick, the WOA scenario monthly average water temperatures are consistently below the 61 degrees Fahrenheit threshold for holding Fall-run/Late Fall-run adults from October through December, when the Late Fall-run adults are expected to hold, but exceed the threshold by over 15 degrees Fahrenheit in every year during the July and August holding period of fall-run adults (Figures 5-16 and 5-17 in the HEC 5Q Temperatures section of Appendix D). Therefore, water temperatures under the WOA conditions would be suitable for holding Late Fall-run adults, but would negatively impact holding Fall-run Chinook Salmon females and their unspawned eggs.

Under the proposed action and COS scenarios, the monthly mean water temperatures in the middle Sacramento River below the Colusa Basin Drain would be below the 68 degrees Fahrenheit threshold for immigrating adults from November through April and in almost all years during October (Figures 14-7, 14-8, 14-9 through 14-14, 14-13 in the HEC 5Q Temperatures section of Appendix D), but would exceed the threshold during July and August in all or almost all years (Figures 14-16 and 14-17 in the HEC 5Q Temperatures section of Appendix D). The much higher percentage of years exceeding the threshold under the proposed action than the COS scenario, indicates that conditions in the middle Sacramento River would be more stressful for the upstream migrating fall-run Chinook salmon adults under the proposed action than under COS. The reason for this difference in water temperatures under the two scenarios is that river flow is much higher under the COS scenario (see Figure 5-18 in the HEC 5Q Temperatures section of Appendix D) because of Fall X2 releases for Delta smelt protection. Upstream migrating fall-run Chinook salmon adults would also be exposed to water temperatures exceeding the 68 degrees Fahrenheit threshold during July and August, but Late Fall-run Chinook salmon would not be exposed to water temperatures exceeding the threshold in any month during their October through April migration period, except for a few years (less than 5 percent) in October.

In the upper Sacramento River at Keswick, under the proposed action and COS scenarios, the average water temperatures would stay below the 61 degrees Fahrenheit threshold for holding adults during November through July of all years (Figures 5-8, 5-9, 5-19 through 5-12, 5-13, 5-14 through 5-16 in the HEC 5Q Temperatures section of Appendix D) and from August through October in, at most, 4 percent of years (Figures 5-17 and 5-7 in the HEC 5Q Temperatures section of Appendix D).

In the middle Sacramento River downstream of the Colusa Basin Drain, water temperatures under the proposed action and COS scenarios are generally similar to the WOA scenario water temperatures during November and December (Figures 14-8 and 14-9 in the HEC 5Q Temperatures section of Appendix D), above the WOA scenario water temperatures from January through April (Figure 14-10 through 14-12, 14-13 in the HEC 5Q Temperatures section of Appendix D), below the WOA scenario water temperatures during July through October (Figures 14-16 through 14-18, and Figure 14-7 in the HEC 5Q Temperatures section of Appendix D). In the upper Sacramento River at Keswick, water temperatures under the proposed action and COS scenarios are similar to WOA water temperatures during March (Figure 5-12 in the HEC 5Q Temperatures section of Appendix D), well above the WOA scenario water temperatures during November through February (Figures 5-8 through 5-11 in the HEC 5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in all years during April through September, and all but 7 percent of years in October (Figures 5-13, 5-14 through 5-7 in the HEC 5Q Temperatures section of Appendix D).

Water temperatures are suitable for Late Fall-run Chinook salmon immigration during their October through April migration period under all three scenarios in the middle Sacramento River as well as for holding in the upper rive. However, water temperatures during July through September, the first three months of the fall-run Chinook salmon immigration and holding period, exceed the 68 degrees Fahrenheit threshold below the Colusa Basin Drain during every year under the WOA scenario and in most years under the proposed action and COS scenarios, but the exceedances are typically much greater under the WOA scenario (Figures 14-16 through 14-18 in the HEC 5Q Temperatures section of Appendix D). In October, the threshold is exceeded in much lower percentages of years, but the water temperatures are consistently higher for the WOA scenario (Figure 14-7 in the HEC 5Q Temperatures section of Appendix D).

At Keswick, the 61 degrees Fahrenheit threshold for holding adults is not exceeded in any years during November through April under any of the scenarios (Figures 5-8, 5-9, 5-10 through 5-12, 5-13 in the HEC 5Q Temperatures section of Appendix D). In July through September, the threshold is exceeded in every year under the WOA scenario, but in only a few years under the proposed action and COS scenarios (5-16 through 5-18 in the HEC 5Q Temperatures section of Appendix D). In October, the threshold is exceeded in no years under the WOA scenario and in 4 percent of years under the proposed action and COS scenarios, although water temperatures under the proposed action and COS scenarios are lower than those under the WOA scenario, except in the warmest 7 percent of years (Figure 5-7 in the HEC 5Q Temperatures section of Appendix D). Water temperatures would be suitable for Late Fall-run Chinook salmon holding adults, except under the proposed action and COS scenarios in the warmest five percent of Octobers. During the summer months (July through September), when water temperatures are generally stressful for adult salmon in the Sacramento River, the water temperatures under the WOA conditions in both the middle and upper Sacramento River are almost always much higher than those under The proposed action or COS. It is unlikely that migrating adult fall-run Chinook salmon could survive the elevated water temperatures in the middle Sacramento River predicted for the summer months under tWOA or that eggs of the adult fall-run Chinook salmon holding in the upper Sacramento River could survive the predicted high summer water temperatures. Water temperature conditions under the proposed action and COS are also unfavorable for fall-run adults migrating during July through September, but the temperatures are less than 5 degrees Fahrenheit above the 68 degree Fahrenheit threshold in at least 50 percent of years, while water temperatures under the WOA scenario are more than 10 degrees Fahrenheit above the threshold in almost every year during July and August, and are more than 5 degrees Fahrenheit above the threshold in most years during September. Water temperature conditions under the proposed action would be favorable for fall-run Chinook salmon adults holding in the upper Sacramento River in almost every year.

5.14.5.3.2.5 Adult Holding in Rivers

5.14.5.3.2.5.1 Flows

WOA's low flows in July and August would potentially increase exposure of holding fall-run Chinook salmon adults to poor water quality, pathogens and anglers. WOA flows are roughly similar to proposed action and COS flows during November and December, except for the higher COS flows during November noted above (Figures 15-8 and 15-9 in the Flows section of Appendix D), and are much lower than proposed action and COS flows during July, August and most years in October (Figures 15-16 and 15-17, and 15-7 in the Flows section of Appendix D 15-Kaug, and WSF_LS1_KWKoct). In general, higher flows are likely to benefit holding Fall-run/Late Fall-run adults by affording better water quality (including cooler water temperatures and higher DO), reduced exposure to pathogens, and lower risk from anglers (Windell et al. 2017). The proposed action and COS scenarios would have much higher flows than the WOA scenario during summer, when flow is often low Therefore, the proposed action is expected to be more protective of Fall-run/Late Fall-run Chinook Salmon than the Without Action conditions.

5.14.5.3.2.5.2 Water Temperatures

In the upper Sacramento River at Keswick, water temperatures under the proposed action and COS scenarios are higher than WOA water temperatures during November and December (Figures 5-8 and 5-9 in the HEC 5Q Temperatures section of Appendix D), and well below the WOA scenario water temperatures in July, August and October, except for the warmest Octobers (Figures 5-16, 5-17 and 5-7 in the HEC 5Q Temperatures section of Appendix D). Water temperatures under the WOA scenario are predicted to exceed the 61 degrees Fahrenheit holding threshold in all years during July and August, and are predicted to exceed the 61 degrees Fahrenheit holding threshold under the proposed action and COS scenarios less than 5% percent of years in August and October. These results indicate that proposed action, relative to WOA, provide a clear benefit to adult Fall-run/Late Fall-run Chinook Salmon holding in the upper Sacramento River.

5.14.5.3.3 Spring Pulse Flows

5.14.5.3.3.1 Eggs to Fry Emergence

As described in the proposed action, Reclamation will release pulse flows in the spring if projected storage on May 1 in Shasta Reservoir is above 4 MAF. If Shasta Reservoir total storage on May 1 is projected to be greater than 4 MAF, Reclamation would make a Spring pulse release as long as the release would not cause Reclamation to drop into a lower Tier of the Shasta summer temperature management or interfere with the ability to meet other anticipated demands on the reservoir.

Spring pulse releases are not at the time of year of egg incubation, and rather would be timed to attract juvenile Fall-run Chinook salmon to move downstream. Spring pulses could benefit late redds by increasing dissolved oxygen in the water for eggs. Late eggs emerging from the gravel could be exposed to redd dewatering on the ramp-down side of a spring pulse.

5.14.5.3.3.2 Rearing to Outmigrating Juveniles

Spring pulse flows would benefit juvenile salmonids by triggering their outmigration (Kjelson et al.,1981), and possibly by increasing survival and reducing predation. Please see the Spring-run Chinook salmon effects analysis for more detail on mechanisms and benefits.

5.14.5.3.4 Fall/Winter Refill and Redd Maintenance

Under WOA, fall flows are low. Under the proposed action, Reclamation proposes to adjust fall flows based on Shasta Reservoir storage to avoid dewatering Winter-run and Fall-run Chinook salmon redds and cold water pool impacts. Higher flows than the WOA during this September – November period could benefit fall-run Chinook salmon redds. Currently, Reclamation lowers flows in the early fall period in order to conserve water for spring cold water pool. This can result in dewatering Fall-run Chinook salmon redds that were laid at higher flows when Reclamation was keeping flows high to avoid dewatering Winter-run Chinook salmon redds. Therefore, this action could potentially benefit Fall-run Chinook salmon in years where Reclamation ends the year with high storage in the reservoir.

5.14.5.3.5 Clear Creek Flows

5.14.5.3.5.1 Eggs to Fry Emergence

Fall-run/Late Fall-run Chinook salmon eggs and emerging fry would be exposed to the effects of Clear Creek geomorphic flows, and potentially spring attraction flows based on the proposed timing of these releases (after January 1 for geomorphic flows; April-June for spring attraction flows [Clear Creek Technical Team 2018]), and the seasonal occurrence of this life stage in Clear Creek (October – February; Table 5.14-1). Potential effects of these flows include increased gravel scour which could displace incubating eggs from redds, resulting in exposure to increased predation, mechanical shock and abrasion, and increased water temperature if transported out of suitable incubation habitat. Geomorphic flows could also temporarily increase suspended solids and turbidity, causing sediment deposition in redds that can reduce hydraulic conductivity through the redd and result in reduced oxygen delivery to eggs, reduced flushing of metabolic waste, and entombment of alevins via a sediment “cap” that prevents or impedes emergence (Everest et al. 1987, Lisle et al. 1989).

Studies on Clear Creek have shown that the sediment transport threshold generally occurs between 3000–3500 cfs (McBain and Trush 2001, Pittman and Matthews 2004). Events of this magnitude occurred in 50% (26 of 52) of years since Whiskeytown Dam was constructed, while daily average flows > 3000 cfs occur on 0.2% of days since WY 1965 (37 days total). Proposed geomorphic and attraction flows up to the safe release capacity (approximately 900 cfs) under the proposed action represent approximately 30% of the flow needed to transport sediment in the absence of flows from downstream tributaries. As a result, adverse impacts associated with these releases are expected to be of low magnitude, compared to conditions created by existing storm peak discharges, and occur with low frequency.. If geomorphic flows under the proposed action were to achieve their intended effect (gravel mobilization), the total area and overall quality of egg incubation habitat would be increased.

Fall-run/Late Fall-run Chinook Salmon eggs and emerging fry would not be exposed to the effects of Whiskeytown water temperature controls in Clear Creek, based on the timing of these controls (60°F at IGO gage June 1-September 15; 56°F at IGO gage September 15-October 31), and the seasonal occurrence of this life stage in Clear Creek (December-April; Table 5.14-1). Therefore, temperature controls are anticipated to have no effect on this life stage.

5.14.5.3.5.2 Rearing to Outmigrating Juveniles

Rearing and outmigrating juvenile Fall-run/Late Fall-run Chinook samon would be exposed to the effects of geomorphic and spring attraction flows under the proposed action relative to WOA given the likely timing of spring attraction flows (May-June [Clear Creek Technical Team 2018]), geomorphic flows (contemporaneous with peak storm flows after January 1), and the peak timing of this life stage in Clear Creek (year-round; Table 5.14-1).

These flow releases have the potential to degrade water quality via increased suspended solids and turbidity, leading to direct physiological impacts on rearing and outmigrating juvenile health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility. The effects of this exposure could also include displacement of rearing fish from suitable habitat, leading to increased predation and exposure to increased water temperatures.

Studies on Clear Creek have shown that the sediment transport threshold generally occurs between 3000–3500 cfs (McBain and Trush 2001, Pittman and Matthews 2004). Events of this magnitude occurred in 50% (26 of 52) of years since Whiskeytown Dam was constructed, while daily average flows > 3000 cfs occur on 0.2% of days since WY 1965 (37 days total). Proposed geomorphic and spring attraction flows up to the safe release capacity (approximately 900 cfs) under the proposed action represent approximately 30% of the flow needed to transport sediment in the absence of flows from downstream tributaries. As a result, adverse effects associated with geomorphic flow releases are expected to be of low magnitude, compared to conditions created by existing storm peak discharges, and occur with low frequency. Therefore, the potential for geomorphic and spring attraction flow releases to result in negative population-level effects on rearing and outmigrating Fall-run/Late Fall-run Chinook is anticipated to be low.

Some rearing and outmigrating Fall-run/Late Fall-run Chinook salmon juveniles would be exposed to the effects of Whiskeytown water temperature controls in Clear Creek given the timing of these controls (June 1-September 15 & September 15-October 31), and the peak timing of this life stage in Clear Creek (year-round; Table 5.14-1). However, this life stage of Fall-run/Late Fall-run Chinook typically utilizes rearing habitat during cooler winter and spring months, so a low number of individuals would be affected by water temperature controls from June-October. The oversummering Fall-run/Late Fall-run juveniles would benefit from the temperature management.

5.14.5.3.5.3 Adult Migration from Ocean to Rivers

Few, if any, migrating adults would be exposed to the effects of geomorphic and spring attraction flows under the proposed action given the likely timing of these flows (geomorphic flows contemporaneous with peak storm flows after January 1; spring attraction flows May-June [Clear Creek Technical Team 2018]) and the peak timing of this life stage in Clear Creek (October-December; Table 5.14-1). Therefore, this action is anticipated to have no effect on this life stage.

Under the proposed action relative to WOA, low numbers of migrating adults could be exposed to Whiskeytown Dam water temperature controls in Clear Creek, based on the timing of these controls (June 1-September 15 & September 15-October 31) and the seasonal timing of this life stage in Clear Creek

(October-December; Table 5.14-1). Water temperature objectives during this period (56°F-60°F) are well within the acceptable range (38°F -56°F; Bell 1991) for this life stage of Fall-run/Late Fall-run Chinook and well below the levels that cause acute to chronic stress (≥ 70°F; Lindley et al. 2004). In addition, effects of exposure to Whiskeytown Dam temperature controls in Clear Creek would result in a reduction in water temperatures in Clear Creek compared to the WOA, both at IGO and the creek mouth, by 5-13°F in the months of September and October at 50% exceedance probability.

5.14.5.3.5.4 Adult Holding in Rivers

Few, if any, holding adults would be exposed under the proposed action to the effects of geomorphic and spring attraction flows given the likely timing of these flows (geomorphic flows contemporaneous with peak storm flows after January 1; spring attraction flows May-June [Clear Creek Technical Team 2018]) and the peak timing of this life stage in Clear Creek (July-December; Table 5.14-1). Therefore, this action is anticipated to have no effect on this life stage.

Holding adults would be exposed to Whiskeytown Dam temperature controls in Clear Creek, based on the timing of these controls (June 1-September 15 & September 15-October 31) and the seasonal timing of this life stage in Clear Creek (July-December; Table 5.14-1). Water temperature objectives during this period (56°F-60°F) are well within the acceptable range (38°F -56°F; Bell 1991) for this life stage of Fall-run/Late Fall-run Chinook and well below the levels that cause acute to chronic stress (≥ 70°F; Lindley et al. 2004). In addition, effects of exposure to Whiskeytown Dam temperature controls in Clear Creek would be a reduction in water temperatures in Clear Creek compared to the WOA, both at IGO and the creek mouth, by 5-13°F (HEC 5Q Temperature Results) in the months of September and October at 50% exceedance probability.

5.14.5.3.6 Feather River

5.14.5.3.6.1 Eggs to Fry Emergence

5.14.5.3.6.1.1 Flow Effects

Eggs and emerging fry of Fall-run/Late Fall-run Chinook salmon would be exposed to the effects of Oroville Dam releases and resulting flows in the High Flow Channel (HFC) of the Feather River downstream of the Oroville Complex FERC Project boundary, based on the seasonal occurrence of this life stage in the Feather River (January–April; Table 5.14-1 and Table 5.14-2, NMFS 2016), minimum instream flow requirements in the HFC (Table 5.14-3), and compliance with Water Rights Decision 1641 (D-1641).

As indicated by the Salmon and Sturgeon Assessment of Indicators by Life-stage (SAIL) Upper River conceptual model (CM1), these flows, combined with other environmental drivers, affect water temperature, DO levels, sedimentation, substrate composition, and other habitat attributes that influence redd quality, which in turn determines egg-to-fry survival (Johnson et. Al., 2016, Windell et. Al., 2017). Insufficient flow during this life stage may result in higher water temperatures, lower DO in redds, and redd dewatering, each of which may lead to elevated egg mortality. Insufficient flow may also limit the habitat area available for redd construction, thereby limiting available habitat for this life stage. Excessive flow during this life stage may scour redds, and higher flows upstream of the HFC may attract spawning adults further upstream into the Low Flow Channel (LFC), where spawning habitat is less abundant, and the effects of superimposition are greater (Sommer et. Al., 2001).

Table 5.14-3. Feather River High Flow Channel minimum instream flow requirements included in the NMFS BO and USFWS BO

	High Flow Channel Minimum Instream Flow (cfs)		
Preceding April – July runoff (Percent of Normal)	**Oct-Feb**	**March**	**April-Sept**
55% or greater	1,700	1,700	1,000
Less than 55%	1,200	1,000	1,000

Under WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Reservoir gates and diversion tunnels would be kept open, resulting in annual storage volumes less than 1,000 TAF (Figure 5.14-7). As a result, there would be limited control of flow or water temperature in the Feather River HFC, which provides habitat for this life stage. Oroville Dam under the WOA releases lower summer and fall flows and higher winter and spring flows compared to the proposed action and current operations (Figures 5.14-8 and 5.14-9).

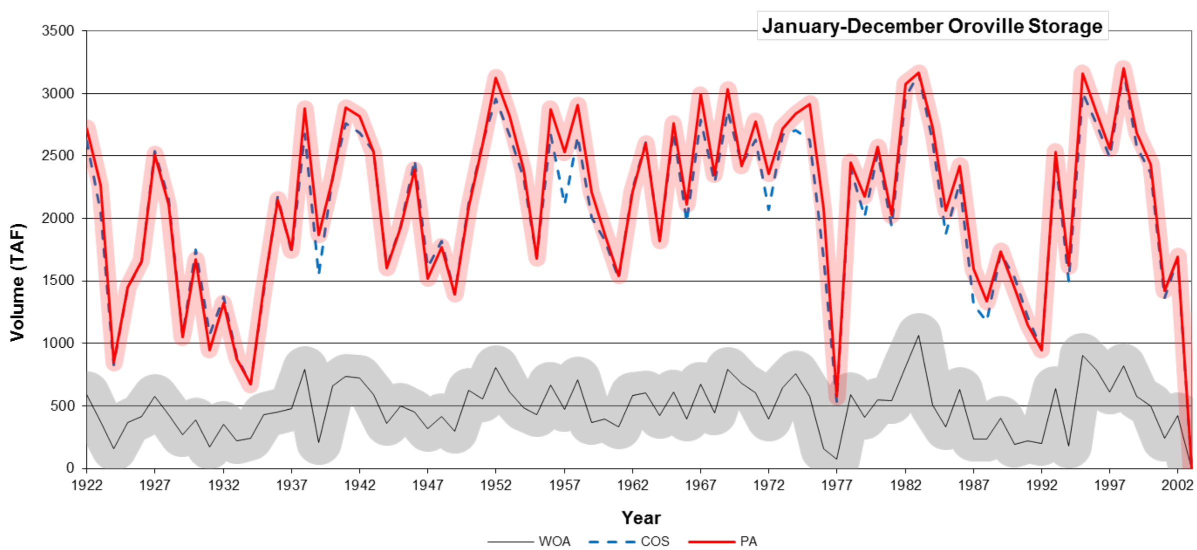


Figure 5.14-7. CalSim II estimates of mean Oroville storage (Thousand Acre-Feet [TAF]) for the period 1923–2002 under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action).

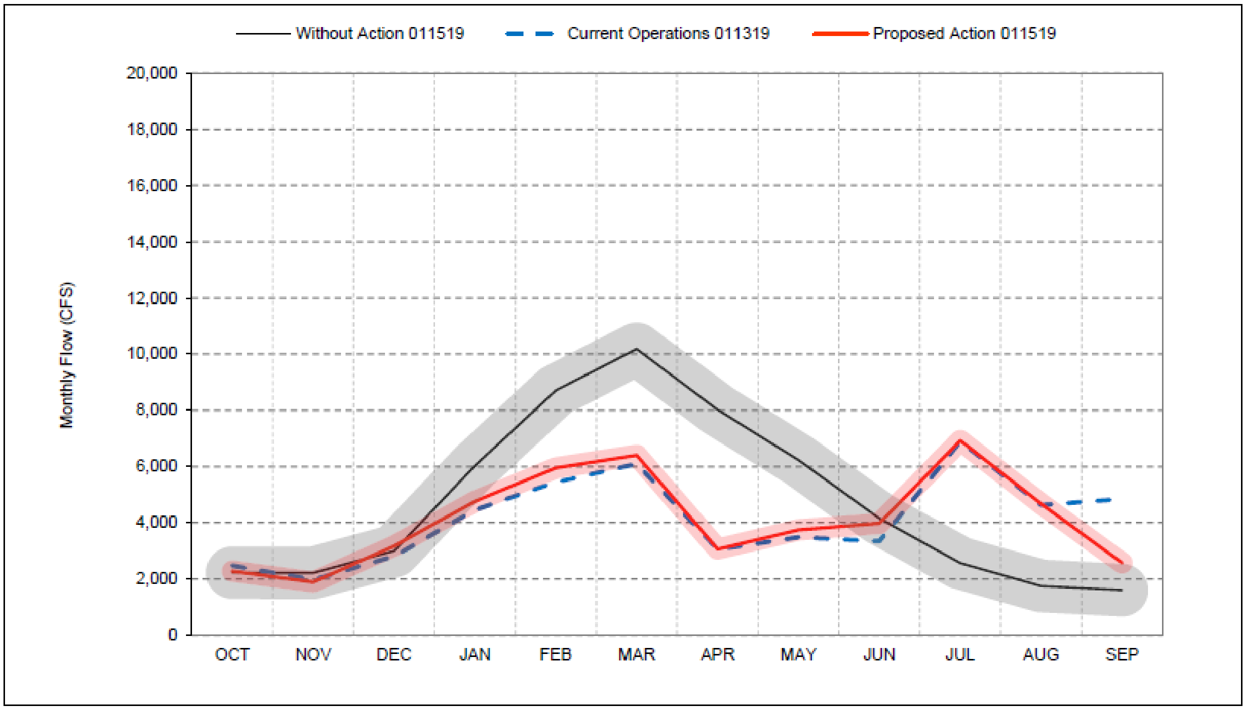


Figure 5.14-8. CalSim II estimates of Feather River long-term average streamflow below Thermalito Afterbay under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action).

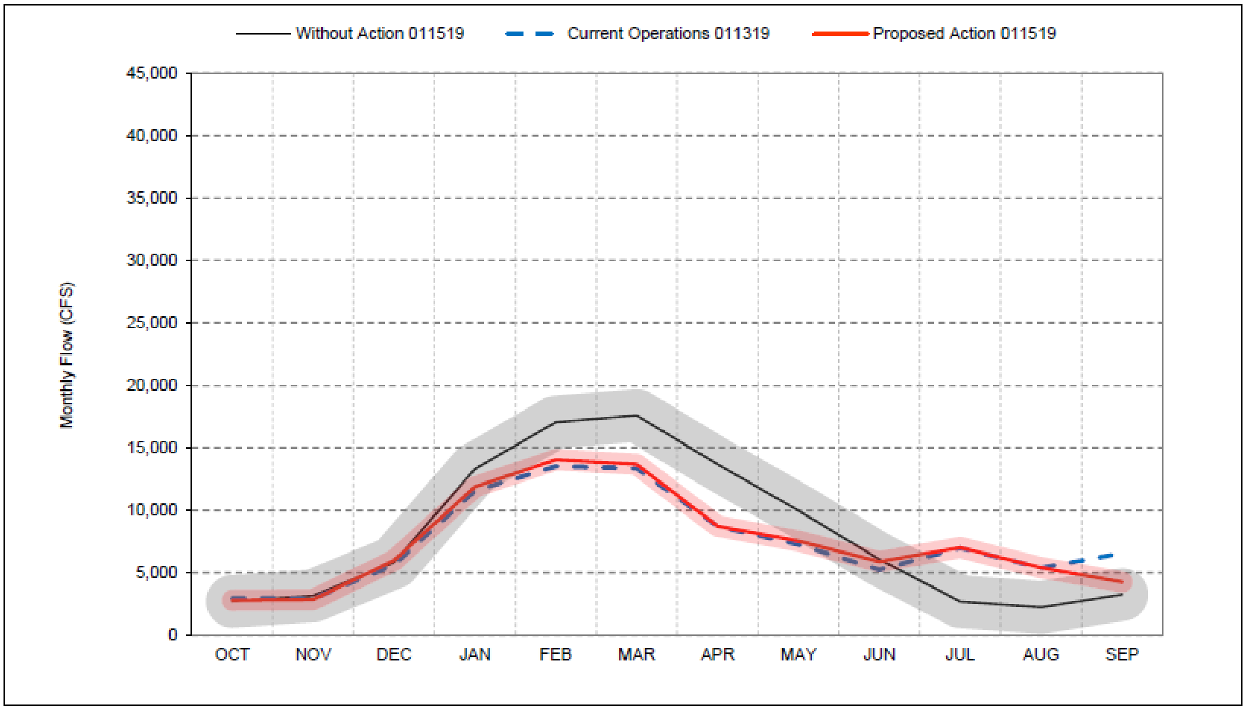
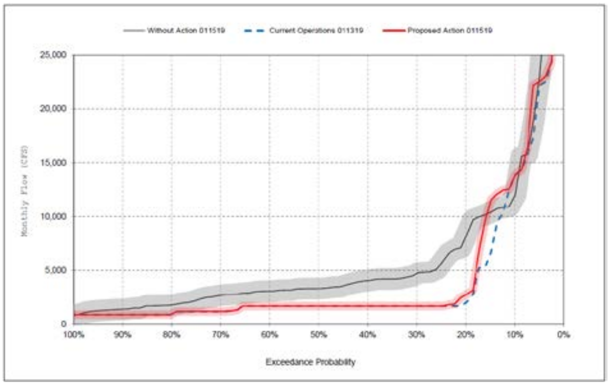


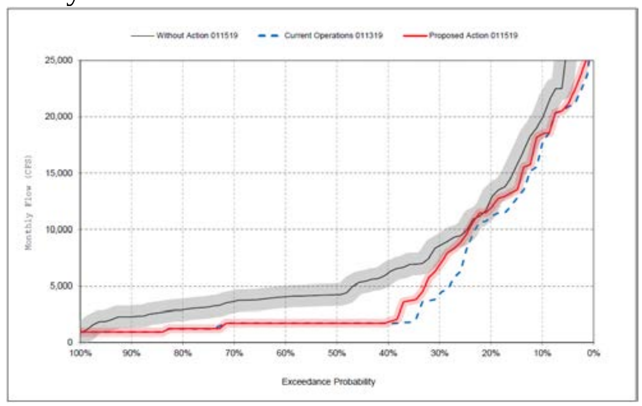
Figure 5.14-9. CalSim II estimates of Feather River mouth long-term average flow under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action).

Feather River flows below Thermalito Afterbay under the WOA would be similar to or higher than flows under the proposed action and COS during the peak seasonal timing of Fall-run/Late Fall-run Chinook salmon egg incubation and fry emergence (January–April) (Figure 5..14-10). Although flows under the proposed action and COS are lower, there is little to no risk falling below the required minimum flow for January and February (1,200–1,700 cfs, depending on preceding April–July runoff) and March and April (1,000–1,700 cfs, depending on preceding April–July runoff).

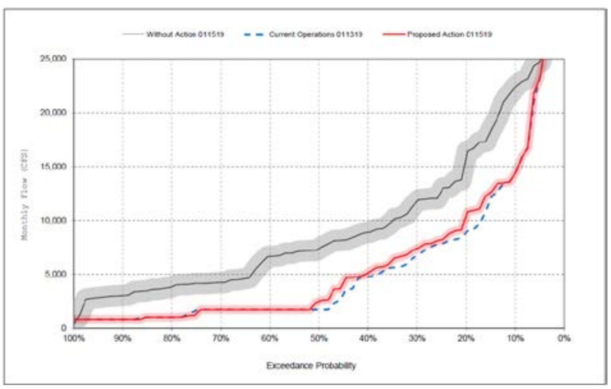
January



February



March



April

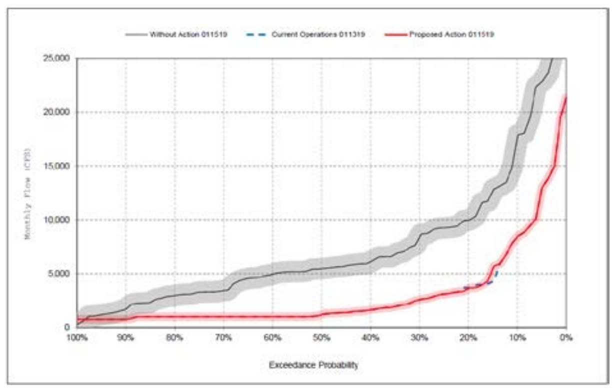


Figure 5.14-10. CalSim II estimates of Feather River flow below the Thermalito Afterbay in January–April under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action).

Flows in the Feather River HFC during the egg incubation to fry emergence period under the proposed action and COS would be lower than under WOA in below normal, dry, and critically dry year types (Figure 5.14-11). Importantly, CalSim II model output indicates projected flows under the proposed action and COS would increase the likelihood that flows in January–March would not meet the minimum instream flow criteria of 1,700 cfs for preceding April–July runoff of 55% or greater; an exception is February and March in below normal years. In years where the preceding April–July runoff is less than 55%, the minimum instream flow criteria would not be met in January of critically dry years (Figure 5.14-11).

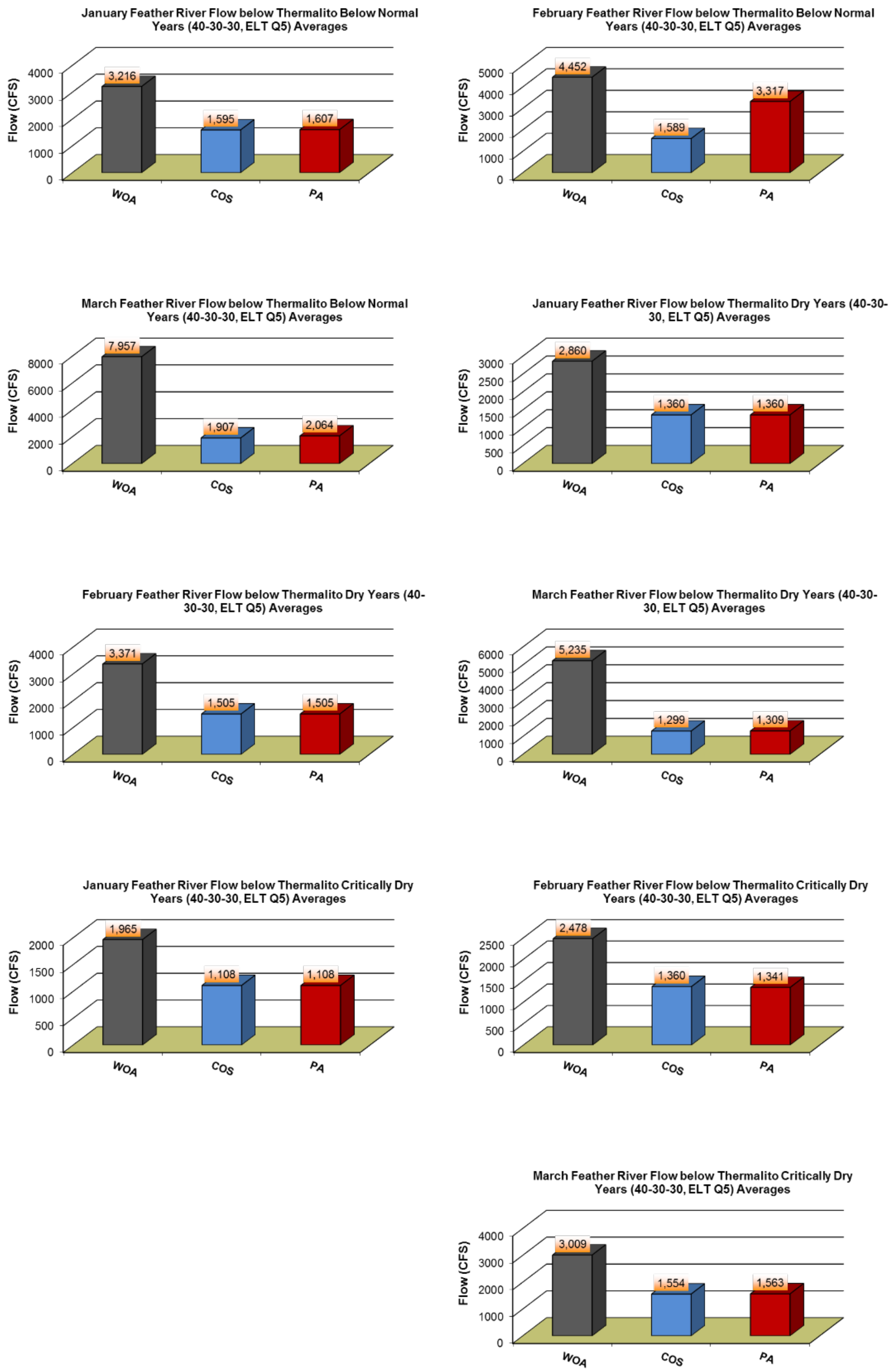


Figure 5.14-11. CalSim II estimates of Feather River flow below Thermalito Afterbay, January through February, for below normal, dry, and critically dry water years under the WOA (Without Action), COS (Current Operations), and PA (Proposed Action) scenarios.

5.14.5.3.6.1.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of Fall-run/Late Fall-run Chinook salmon eggs. Exposure to the effects of elevated water temperatures include an inability to satisfy metabolic demand, and acute to chronic physiological stress, eventually leading to egg mortality (Stillwater Sciences 2006, Anderson 2017, Martin et al. 2017). The highest survival rates for Fall-run/Late Fall-run Chinook eggs occur at < 54 °F; water temperatures are stressful to eggs above 56 °F, are lethal above 60 °F, and the upper lethal limit is 62 °F (Stillwater Sciences 2006).

Eggs and emerging fry of Fall-run/Late Fall-run Chinook salmon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (January–April; NMFS 2016), and the timing of the water temperature objectives (year-round objectives; Table 5.14-4). Under WOA, Lake Oroville would not be operated to control storage or flow releases and no conveyance of water to San Luis Reservoir via the Banks Pumping Plant would be made. Therefore, there would be no control of flow or water temperature in the Feather River HFC where Fall-run/Late Fall-run Chinook salmon egg incubation could occur. Resulting water temperatures under the WOA in the Feather River HFC at Gridley Bridge as modeled by the RecTemp temperature model are generally lower during the winter months, and higher during the summer and fall with peak annual water temperatures of approximately 78°F occurring in July and August (Figure 5.14-12).

Table 5.14-4. Maximum Daily Mean Water Temperature for the HFC.

Period	**Temperature**
January 1 – March 31	56
April 1 – 30	61
May 1 – 15	64
May 16 – 31	64
June 1 – August 31	64
September 1 – 8	61
September 9 – 30	61
October 1 – 31	60
November 1 – December 31	56

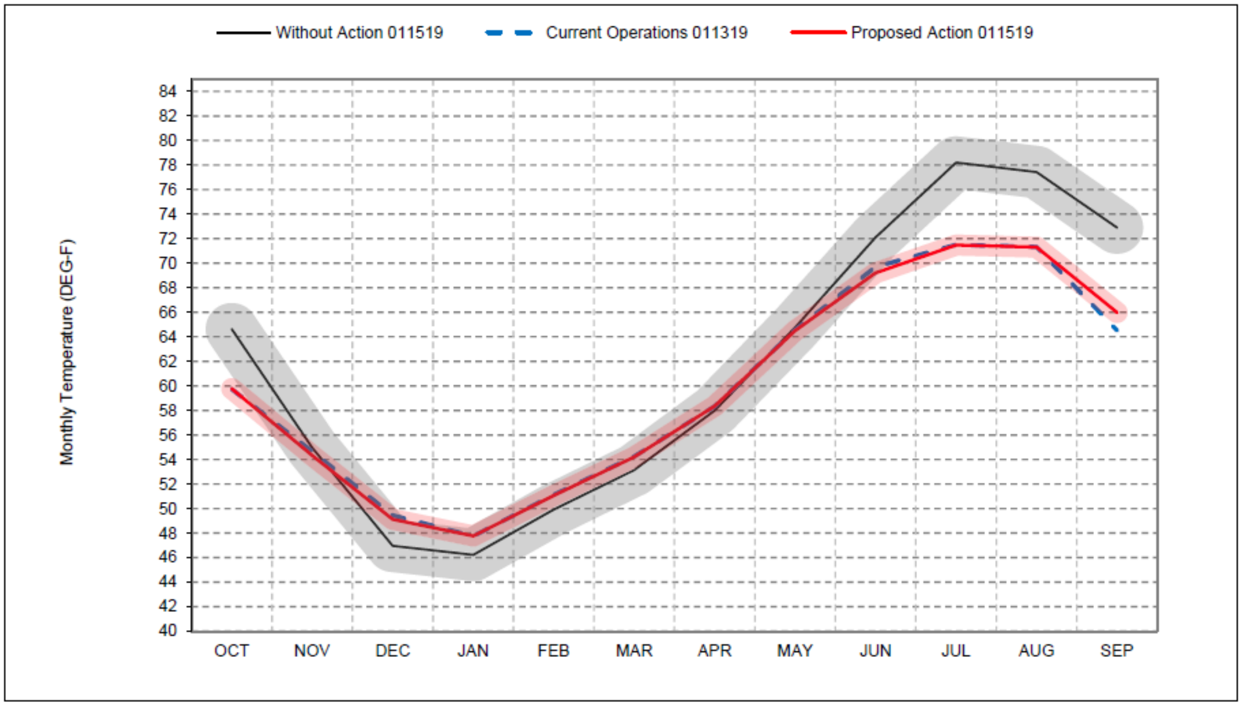


Figure 5.14-12. Long-term average RecTemp estimates of Feather River water temperature at Gridley Bridge under the WOA, COS, and proposed action.

Under the proposed action and COS operations and flow releases would be managed to achieve Feather River HFC water temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May. Temperatures at Gridley Bridge under the WOA are slightly lower than water temperatures under the proposed action and COS during January through March, and are roughly equivalent during the month of April (Figure 5.14-13).

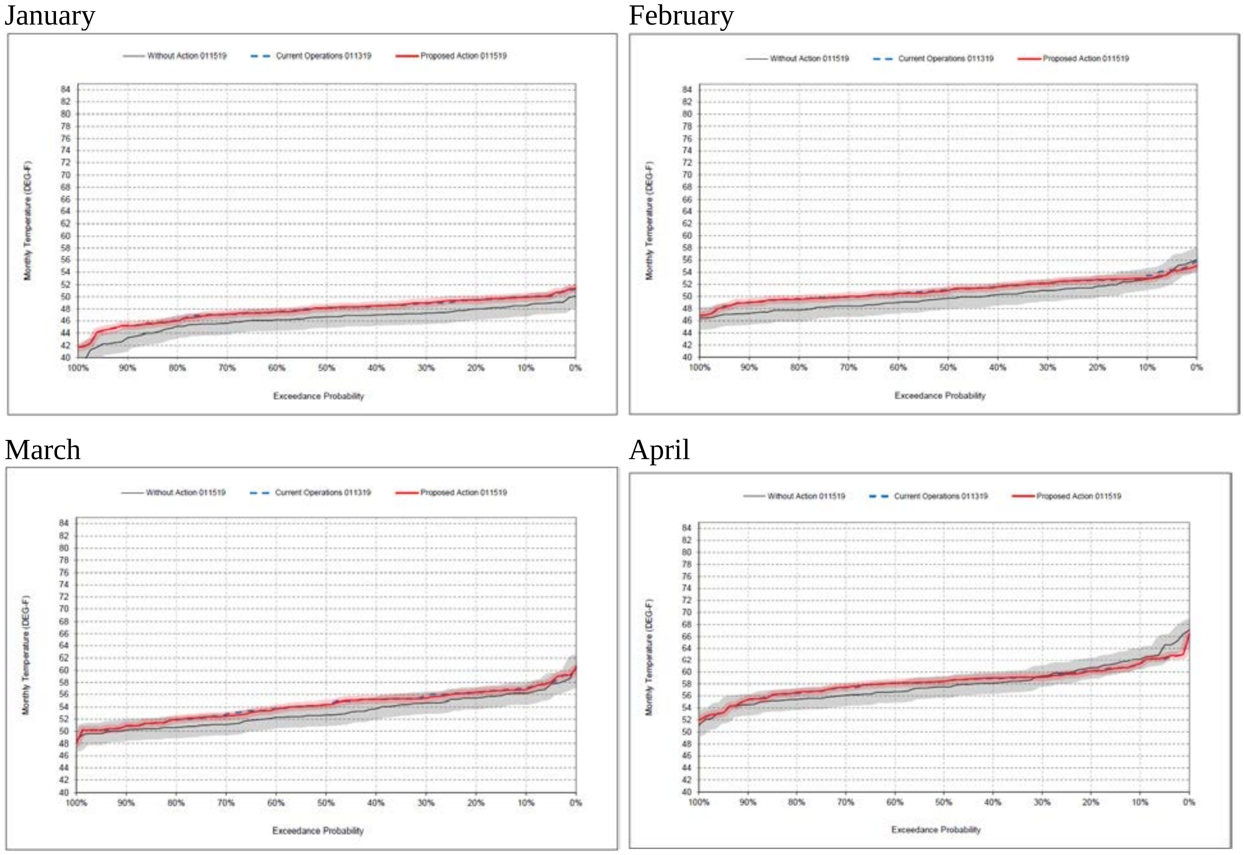


Figure 5.14-13. RecTemp estimates of Feather River water temperature at Gridley Bridge under the WOA, COS, and proposed action for January to April.

Water temperatures at Gridley Bridge under the WOA, COS, and proposed action could fall below 56 °F during the months of January–March, which is within the range of optimal egg development and survival. Water temperatures in April under all three scenarios would range from 56 °F to 60 °F, which is within the chronic to acute stress range. Water temperatures exceeding the objectives and the biological thresholds for this life stage of Fall-run/Late Fall-run Chinook would have adverse impacts on individuals, including acute to chronic physiological stress and increased likelihood of egg mortality. However, RecTemp model output indicates water temperatures projected under the proposed action and COS will increase the likelihood that the April water temperatures would remain below the lethal limit (62 °F) at low exceedance probabilities and that April water temperature objectives are met. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be minimized under the proposed action.

5.14.5.3.6.2 Rearing to Outmigrating Juveniles

5.14.5.3.6.2.1 <u>Flow Effects</u>

Rearing to outmigrating juvenile Fall-run/Late Fall-run Chinook salmon would be affected by Oroville Dam releases and resulting flows in the HFC of the Feather River downstream of the Oroville Complex FERC boundary, based on the seasonal occurrence of this life stage in the Feather River (year-round possible with peak abundance January–April and August–November; Table 5.14-1 and Table 5.14-2, NMFS 2016), minimum instream flow requirements in the High Flow Channel of the Feather River (year-round requirements; Table 5.14 -1), and compliance with Water Rights Decision 1641 (D-1641).

Feather River flows below Thermalito Afterbay under – WOA generally approximate or are significantly higher than flows under the proposed action and COS during the peak seasonal timing of Fall-run/Late Fall-run Chinook juvenile rearing (January–April, Figure 5.14-10; August–November, Figure 5.14-11). In particular, flows are reliably higher under the WOA from January to May and in November (Figures 5.14-10 and 5.14-11), lower in August–October, a trend especially pronounced in wetter water year types. The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios. Differences in flows between the proposed action and COS are less pronounced than differences between the proposed action and WOA during the January to April and August to November periods.

Lower proposed action flows could have both negative and positive effects on rearing juvenile Fall-run/Late Fall-run Chinook Salmon. Flows can modulate water temperature and DO concentration leading to changes in contaminant toxicity, pathogen virulence, food availability, bioenergetics and disease susceptibility. In addition, river stage and flow velocity may affect habitat connectivity, and availability which in turn may influence food availability, predation, crowding, entrainment and stranding risk, and can potentially affect cues that stimulate outmigration (Windell et al. 2017, Moyle 2002). There can be positive effects of lower flows including lower stranding risk resulting from decreased use of floodplain habitat and lower flow fluctuations, and lower contaminant loading from stormwater runoff. The comparative magnitude of positive and negative effects of lower flows under the proposed action and COS compared to the WOA are difficult to quantify, however, potential adverse effects of the proposed action lower flows from January–April are anticipated to be minimal since projected flows during this period remain well in excess of all applicable minimum instream flows for the Feather River HFC.

5.14.5.3.6.2.2 Water Temperature Effects

Rearing Fall-run/Late Fall-run Chinook salmon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (year-round possible with peak abundance January–April and August–November; Table 5.14-1 and Table 5.14-2, NMFS 2016), and the timing of the water temperature objectives (year-round objectives; Table 5.14-8)..

Water temperatures under WOA in the Feather River HFC at Gridley Bridge are similar to the proposed action and COS water temperatures during the January–April period and significantly higher during the August–November period (Figure 5..14-12). Under the proposed action and COS, operations and flow releases would be managed to achieve Feather River HFC water temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May (Figure 5.14-12). Water temperatures at Gridley Bridge under the WOA are the same or lower than water temperatures under the proposed action and COS from January to April, and higher than the proposed action and COS from August to November, which coincides with the peak seasonal timing of rearing Fall-run/Late Fall-run Chinook. The risk of water temperature-related stress and mortality are not present during the January–April period as water temperatures remain well within the optimal range (< 61°F) for this life stage and under the Feather River HFC temperature objectives for these months. The risk of water temperature-related stress under the proposed action and COS are present during the month of August, however water temperatures are significantly lower than under the WOA, which approach lethal levels in August. As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be less severe under the proposed action, especially during below normal, dry, and critically dry water year types (Figure 5.14-13).

5.14.5.3.6.3 Migrating Adults

5.14.5.3.6.3.1 Flow Effects

Feather River flows below Thermalito Afterbay under the WOA are generally somewhat lower than the proposed action and COS during October and are approximate or are significantly higher than flows under the proposed action and COS during November–March, the peak seasonal timing of Fall-run/Late Fall-run Chinook adult migration (Figure 5.14-10). The likelihood of flows occurring that are less than the minimum instream flow requirements during these months is very low under all scenarios, although some risk exists under the three scenarios in October, November, and January of critically dry years, when flows are less than or are approaching the minimum instream flow requirements (Figure 5.14-11).

Proposed action and COS flows during this period are lower than WOA flows, however, flows are not anticipated to decline below minimum instream flow standards or to a level that results in any increased passage or barrier issues in the Feather River HFC. These adverse impacts of lower flows are generally mitigated by flow increases, but there can be adverse effects of high flows including higher stranding risk resulting from increased use of flood plain habitat and greater flow fluctuations, and higher contaminant loading from stormwater runoff.

Significantly lower proposed action flows in February and March could result in both negative and positive effects on migrating adult Fall-run/Late Fall-run Chinook. Negative effects include a decrease in floodplain and side-channel habitat, degraded foraging conditions, increased competition and predation, higher water temperatures and lower DO, and reduced immigration flows. Positive effects are anticipated to be a lower stranding risk resulting from decrease use of flood plain habitat and less flow fluctuations, and contaminant loading from storm water runoff. The comparative magnitude of positive and negative effects of lower flows under the proposed action and COS to the WOA are difficult to quantify, however, potential adverse effects of lower flows are anticipated to be minimal since projected flows during this period remain well in excess of all applicable minimum instream flows for the Feather River HFC.

5.14.5.3.6.3.2 Water Temperature Effects

Water temperatures, combined with other environmental drivers, have the potential to heavily influence condition and survival of migrating adults. Exposure to the effects of elevated water temperatures can include an increased susceptibility to disease, and physiological stress potentially leading to mortality and altered migration timing and speed. Migrating adult Fall-run/Late Fall-run Chinook require temperatures < 57°F for optimal survival (Marine 1992 as cited in Stillwater Sciences 2006).

Migrating adult Fall-run/Late Fall-run Chinook salmon would be exposed to the effects of water temperature objectives for the Feather River HFC, based on the seasonal occurrence of this life stage in the Feather River (July–April, peak abundance October–March; Table 5.14-1, Table 5.14-2, and NMFS 2016), and the timing of the water temperature objectives (year-round objectives; Table 5.14-3 -2).

Water temperatures in the Feather River from October to March are relatively less influenced by flow releases from Lake Oroville than in summer, given the larger flow volumes, and colder air temperatures during these months. Under the WOA water temperatures in the Feather River HFC at Gridley Bridge l are approximately similar to the proposed action and COS water temperatures from February and March, with small differences projected in November to January and slightly larger differences projected in October (Figure 5.14-12).

Under the proposed action and COS operations and flow releases would be managed to achieve Feather River HFC water temperature objectives, resulting in water temperatures that are generally lower than those modeled under the WOA from June to October, and water temperatures that are roughly equivalent from November to May. Water Temperatures at Gridley Bridge under the proposed action and COS are the same or slightly higher than water temperatures under the WOA from November to March and lower than the WOA in October, which coincides with the peak seasonal timing of migrating adult Fall-run/Late Fall-run Chinook salmon. The risk of water temperature-related stress and mortality are low during this period as water temperatures are projected to be within the optimal range (<57 °F) for this life stage from November to March; water temperatures under the proposed action and COS are slightly above the optimal range in October, however, are significantly less than under the WOA (Figure 5.14-12). As a result, potential adverse effects of water temperature objectives on this life stage are anticipated to be less severe under the proposed action relative to WOA, especially during below normal, dry, and critically dry water year types (Figure 5.14-13).

5.14.5.3.7 American River Seasonal Operations (includes 2017 FMS and "planning minimum")

5.14.5.3.7.1 Egg to Fry Emergence

For lower American River flows (below Nimbus Dam), Reclamation proposes to adopt the minimum flow schedule and approach proposed by the Water Forum in the 2017 Flow Management Standard (FMS) as part of the proposed action. The 2017 FMS includes a Minimum Release Requirement (MRR) with flows that range from 500 to 2000 cfs based on time of year and annual hydrology. The objective of the planned minimum is to preserve storage to protect against future drought conditions and to facilitate the development of the cold water pool when possible and improve habitat conditions for steelhead and fall-run Chinook Salmon in the lower American River. In addition, redd dewatering protective adjustments were included in the 2017 FMS to limit potential redd dewatering due to reductions in the MRR during the January through May period coincident with the embryo incubation period for Fall-run/Late Fall-run Chinook Salmon.

The embryo incubation and alevin development period for Fall-run/Late Fall-run Chinook Salmon follows the October through March spawning period (peaking in Nov through September) (Table 5.14-1 and Table 5.14-2), with fry emerging from the gravel from late December to March. This period coincides with the timing of this proposed action, and would likely directly benefit this life stage. The implementation of the proposed 2017 FMS measures under the proposed action would provide suitable habitat conditions in the lower American River tailored for Chinook Salmon and Steelhead, particularly during drought conditions and improve conditions for this life stage relative to WOA.

5.14.5.3.7.2 Rearing to Outmigrating Juveniles

The 2017 FMS under the proposed action also includes the provision for spring pulse flows, with the purpose to provide a juvenile salmonid (fall-run Chinook Salmon and steelhead) emigration cue before relatively low flow conditions and associated unsuitable thermal conditions later in the spring in the river, and downstream in the lower Sacramento River. The 2017 FMS should provide a pulse flow event at some time during the period extending from March 15 to April 15 by supplementing normal operational releases from Folsom Dam under certain conditions when no such flow event has occurred between the preceding February 1 and March 1 time frame. Fall-run/Late Fall-run Chinook Salmon exhibit a stream-type life history where excessively high water temperatures have been identified as one of the factors threatening Fall-run/Late Fall-run Chinook Salmon in the Central Valley and a factor for listing of the species (NMFS 2014). The 2017 FMS under the proposed action also includes water temperature objectives that would provide suitable temperatures for juveniles by maintaining water temperatures below 65°F from mid-May to mid-October. The implementation of the proposed 2017 FMS measures would provide suitable habitat conditions in the lower American River and for Fall-run/Late Fall-run Chinook Salmon, particularly during drought conditions and improve conditions for this life stage.

5.14.5.3.7.3 Adult Migration from Ocean to Rivers

Adult Fall-run/Late Fall-run Chinook Salmon enter freshwater beginning in July, peak in October through December, and are present until about February 1 (Table 5.14-1 and 5.14-2). Adults hold primarily in deep cold pools in proximity to spawning areas or below the dam or weir until they are sexually mature and ready to spawn (CDFG 1998; NMFS 2009). Excessively high water temperatures has been identified as one the factors threatening Fall-run/Late Fall-run Chinook Salmon and a factor for considering listing of the species, particularly in the adult immigration and holding life stage (NMFS 2014). In addition to the MRR flows, the 2017 FMS under the proposed action also includes the following water temperature objectives to provide suitable temperatures for salmonids:

- 60°F or less by October 1 to provide suitable conditions for fall-run Chinook holding and early spawning,

Although the Folsom coldwater pool is generally insufficient to meet water temperature objectives, the implementation of the 2017 FMS under the proposed action would provide more suitable habitat conditions in the lower American River for Fall-run/Late Fall-run Chinook Salmon relative to WOA, particularly during drought conditions.

5.14.5.3.7.4 Adult Holding in Rivers

Fall-run Chinook Salmon experience egg retention or pre-spawning mortality in the American River in most years when water temperatures in the fall holding period are sub-optimal. During 1993 to 2017 the proportion of unspawned adults ranged from 3% to 67% and averaged 20% and the proportion that retained some eggs (greater than 30% egg retention) ranged from 6% to 80% with and average of 33% (Figure 5.14-14). The American River has the highest level of pre-spawning mortality for Fall-run/Late Fall-run Chinook Salmon measured for any river in the Central Valley. Effects for adult holding would be the same as for migrating adults, discussed above. The proposed action strives to provide conditions more conducive to successful spawning and would benefit adults holding in the American River.

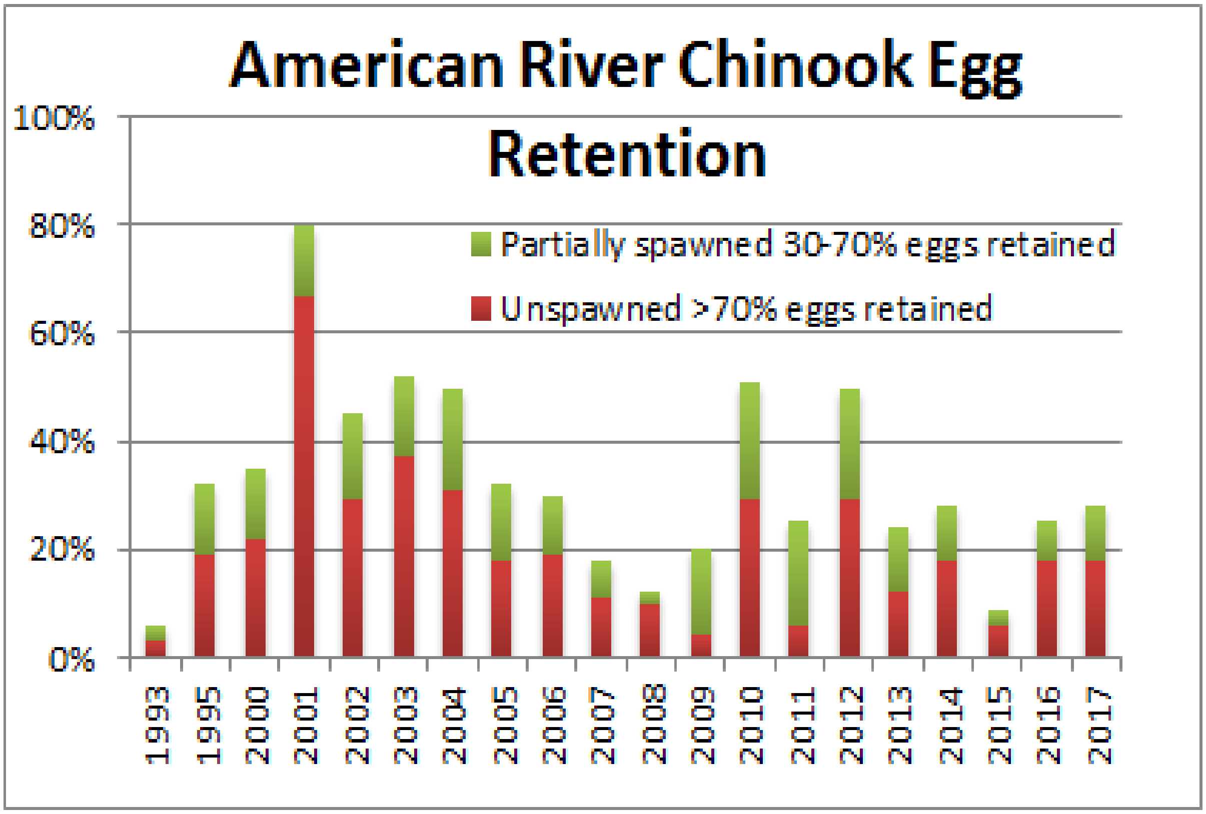


Figure 5.14-14. American River Chinook Salmon egg retention. Egg retention refers to eggs left unspawned in female carcasses.

5.14.5.3.8 <u>Stanislaus River Stepped Release Plan</u>

5.14.5.3.8.1 Eggs to Fry Emergence

Fall-run Chinook Salmon eggs, alevin and/or fry are found throughout most of the Stanislaus River from Goodwin Dam downstream to Oakdale. Under WOA conditions, the lower level river outlets of New Melones would be closed to preserve the integrity of the gate structure and the Flood Control and Industrial gate would be set fully open and assumed to pass a flow of approximately 8,000 cfs. Inflow exceeding this capacity would be stored in New Melones until the releases capacity could physically evacuate the water. If necessary, the spillway would be used to prevent overtopping of the New Melones Dam and protecting the structural integrity of the New Melones Dam and related facilities. This spillway is not gated and would naturally flow should the reservoir reach that height. This would result in Fall-run/Late Fall-run Chinook Salmon distribution being similar to current conditions as Goodwin Dam would still represent a total barrier to further upstream migration. Water temperatures under the WOA scenario within the Stanislaus River would represent those of uncontrolled flows coming off the western Sierra Nevada that travel through the CVP storage and conveyance facilities on the Stanislaus River that would be operated only to the extent necessary to fulfill non-discretionary duty to ensure their continued existence. Operations of non-CVP facilities would still occur as they are occurring today. Modeled flows associated with this scenario below Goodwin Dam are depicted below.

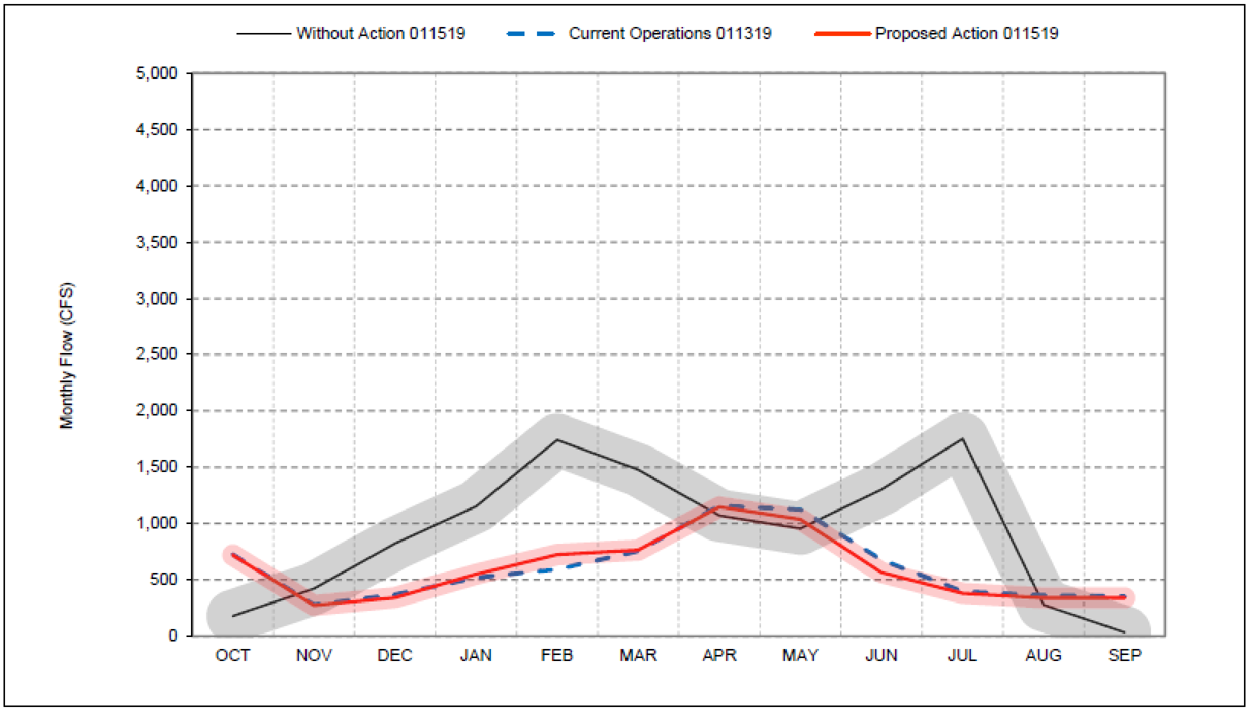


Figure 5.14-15. Stanislaus Modeled Flows. Long-Term-Average Modeled flows under WOA, COS and proposed action Scenario in the Stanislaus River Below Goodwin Dam

Current operations within the Stanislaus River are managed according to the 2008 USFWS BO, the 2009 NMFS BO, COA, and the New Melones Interim Plan of Operations (IPO).

Current operations of New Melones Dam under the IPO, which has been in effect since 1997, were developed prior to completion of current tools to understand hydrology in the Stanislaus River Basin, and the water delivered from New Melones was overallocated in many years and was not able to consistently meet requirements for fish flows, water temperature, water quality, dissolved oxygen, and water deliveries.

Under the proposed action, Reclamation proposes to implement the New Melones Stepped Release Plan to create a sustainable operation on the Stanislaus River that strives to meet requirements for fish flows, temperature, water quality, dissolved oxygen, and water deliveries. The Draft Stepped Release Plan incorporates up-to-date information about hydrology in the basin and is based on recent versions of CalSim modeling.

An attraction flow in October would be provided each year and assist in upstream migration of Fall-run Chinook Salmon. Attraction flows would be maintained at 200 cfs through the November-December spawning period. This is slightly less than the optimal 300 cfs spawning flow but would maintain Fall-run Chinook Salmon populations. Egg incubation during November to February would occur under suitable water temperature and flow conditions at most times. During dryer years water temperature in October and November would be above suitable at times but proposed action water temperatures would be cooler than WOA and COS so the proposed action would generally improve incubation success.

5.14.5.3.8.2 Rearing to Outmigrating Juveniles

The NMFS' *Recovery Plan for Central Valley Chinook Salmon and Steelhead* (NMFS 2014) identifies recovery actions on the Stanislaus River. These actions include managing flow releases to provide suitable water temperatures and flows for all steelhead life stages, and the Stepped Release Plan would improve the ability to manage water temperatures in droughts. The plan also identifies the need to evaluate whether pulse flows are beneficial to adult steelhead immigration and juvenile steelhead emigration.

The stepped operation plan under the proposed action includes spring flows during April and May intended to improve juvenile rearing and outmigration survival. These flows occur earlier than the natural flows under WOA. The earlier flows are beneficial in providing a way for juveniles to get out through the lower San Joaquin River and Delta before water temperatures become unsuitable later in the spring to summer.

5.14.5.3.8.3 Adult Migration from Ocean to Rivers

The attraction flows under the stepped release plan are timed to assist with Fall-run/Late Fall-run Chinook immigration. Flows of about 750 cfs or higher attract high numbers of Fall-run Chinook Salmon into the Stanislaus River, including many strays from other rivers. A partial barrier to Fall-run Chinook Salmon exists in Goodwin Canyon where early migrating Chinook hold over the summer. When the fall attraction flows occur Chinook are able to pass this area more quickly and reach habitats near Goodwin Dam. The area near Goodwin Dam provides cooler water earlier in the fall, conducive to successful spawning.

5.14.5.3.8.4 Adult Holding

Fall-run Chinook Salmon Adults hold in the Stanislaus River from summer for early running Chinook up until spawning in October. Generally water temperatures would be suitable most years in the upper portions of the river at Knights Ferry and above for the proposed action scenarios and the COS and unsuitable under WOA. A key holding location is in the Goodwin Canyon area for the early running Fall-run Chinook salmon and as noted above the fall pulse flow provides a cue and ability for the fish to distribute to suitable spawning areas. The proposed action is generally cooler than COS which as a benefit to adult survival during holding prior to spawning.

5.14.5.3.9 Alteration of Stanislaus River Dissolved Oxygen Requirement

5.14.5.3.9.1 Eggs to Fry Emergence

Fall-run Chinook Salmon eggs, alevin and/or fry are found throughout most of the Stanislaus River from Goodwin Dam downstream to Oakdale. Under WOA, flow would be uncontrolled through the CVP project facilities and fish distribution would be similar to current operations as Goodwin Dam would represent a significant barrier to further upstream migration but the warm fall water temperatures would not be conducive to high survival. Current operations are required to meet a year-round dissolved oxygen minimum of 7 mg/L, which was introduced in an effort to protect salmon, steelhead, and trout in the river (CDFW 2018). However, maintaining dissolved oxygen concentrations above 7 mg/L in the Stanislaus River at Ripon is challenging during drought conditions, and, based on studies of juvenile distribution and abundance, does not appear to be warranted to protect salmonids in the Stanislaus River (Kennedy and Cannon 2005, Kennedy 2008).

Reclamation currently operates to a 7.0 mg/L dissolved oxygen requirement at Ripon from June 1 to September 30. Reclamation proposes to move the compliance location to Orange Blossom Bridge, where the species (steelhead) are primarily located at that time of year. Based on multi-year observations of salmonid abundance in the River Kennedy and Cannon (2005) and Kennedy (2008) found that over-summering juvenile salmonids are primarily found upstream of Orange Blossom Bridge, which is approximately 31 miles upstream from Ripon. Dissolved oxygen monitoring at the Stanislaus River Weir (approximately 15 miles upstream from Ripon) indicates that dissolved oxygen concentrations can be 0.5-1 mg/L higher at this location than those measured at Ripon (Cramer Fish Sciences 2006a-d). Because the fish are located primarily at least twice this distance upstream from Ripon, the dissolved oxygen concentration is likely to be at this level or higher where the majority of these fish occur. The majority of Fall-run Chinook Salmon eggs, alevin and/or fry are found in locations where summer dissolved oxygen levels would be expected to be maintained at or near 7 mg/L, although no eggs, alevin, or fry are present in the river in the summer.

5.14.5.3.9.2 Rearing to Outmigrating Juveniles

As discussed above, as the majority of juvenile Fall-run Chinook Salmon are found in locations where summer dissolved oxygen levels would be expected to be maintained at or above 7 mg/L.

Additionally, as juvenile fall run Chinook are outmigrating from January through the end of June (Zerg et al, 2014), there would be no individual- or population-level effects from this element on this life stage.

5.14.5.3.9.3 Adult Migration from Ocean to Rivers

Based on the typical seasonal occurrence of this life stage in the River (July to October), adult migrating Chinook Salmon would be expected to be exposed to the effects of the relaxation of dissolved oxygen requirements at Ripon. During low flow periods in the Stanislaus River there could be delay of adults migrating up the Stanislaus River if dissolved oxygen is too low.

5.14.5.3.10 <u>Delta Seasonal Operations including OMR Management</u>

Hydrodynamic changes associated with river inflows and South Delta exports under the proposed action have been suggested to adversely affect juvenile Chinook Salmon in two distinct ways: 1) “near-field” mortality associated with entrainment to the export facilities, 2) “far-field” mortality resulting from altered hydrodynamics.

5.14.5.3.10.1 Entrainment

Zeug and Cavallo (2014) analyzed > 1000 release groups representing, more than 28 million coded wire tagged juvenile fish including winter, Fall-run/Late Fall-run Chinook Salmon. The average proportion Sacramento River-origin Fall-run Chinook salvaged over a 15-year period was 0.0001 and the proportion of mortality accounted for by entrainment averaged 0.0003 (Zeug and Cavallo 2014). Salvage increased with increasing exports but loss never exceeded 1% regardless of export rate. Late Fall-run Chinook Salmon juveniles were salvaged at a higher rate than any other race (0.02% of each release group) and entrainment related mortality accounted for almost 1% of total mortality on average (Zeug and Cavallo 2014). Proportional loss of Late-Fall Chinook salmon remained low until exports exceeded ~9,000 cfs when proportional loss could approach 8% (Zeug and Cavallo 2014). Average total exports for months when Fall-run/Late-Fall run Chinook Salmon juveniles are present in the Delta indicate zero entrainment risk for WOA. In the December through February period when Late-Fall run are most abundant, the proposed action proposes an average total export rate slightly higher than COS (366 cfs; Figure H-1 – Appendix H, *Bay-Delta Aquatics Effects Figures*) and will therefore have a similar entrainment risk. Total exports proposed for the proposed action in March-June (1,699 cfs higher than COS; Figure H-2 –

Appendix H, *Bay-Delta Aquatics Effects Figures*) when juvenile Fall-run/Late Fall-run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to COS, but entrainment losses for Fall-run/Late Fall-run Chinook Salmon will be low relative to total population. Entrainment risk will also increase for Late-Fall run and losses will likely be higher relative to Fall-run Chinook salmon.

Zeug and Cavallo (2014) analyzed salvage of 313 releases totaling more than 7,000,000 San Joaquin River-origin juvenile Fall-run juvenile Chinook Salmon. Salvage of Fall-run Chinook originating from the San Joaquin River averaged 1.4% and increased with export rate at the CVP and SWP (Zeug and Cavallo 2014). However, there were few observations at export rates greater than 3,000 cfs. Average mortality at the facilities represents < 5% total juvenile mortality for San Joaquin River-origin populations but can range as high as 17.5% (Zeug and Cavallo 2014). Average total exports for months when Fall-run Chinook Salmon juveniles are present in the Delta indicate zero entrainment risk for WOA. In the December through February period the proposed action proposes an average total export rate slightly higher than COS (366 cfs; Figure H-1 – Appendix H, *Bay-Delta Aquatics Effects Figures*) and will, therefore, have a similar to slightly higher entrainment risk. Total exports proposed for the proposed action in March-June (1,699 cfs higher than COS; Figure H-2 – Appendix H, *Bay-Delta Aquatics Effects* Figures) when juvenile Fall-run Chinook Salmon are most abundant in the Delta, will increase entrainment risk relative to COS. Recent acoustic studies of juvenile Fall-run Chinook Salmon in the San Joaquin River revealed that when the HORB is out, >60% of fish detected at Chipps Island came through CVP, indicating that salvage is a higher survival route than volitional migration.

As shown by the following figures, CVP and SWP Fish Facilities salvage between 0 and 140,000 Fall-run Chinook salmon annually, and between 0 and 450 Late Fall-run Chinook salmon annually. As indicated above, under the proposed action exports are expected to increase compared to both WOA and COS, and so salvage and entrainment would also be expected to increase. However, salvage may be a higher survival route than through the San Joaquin River.

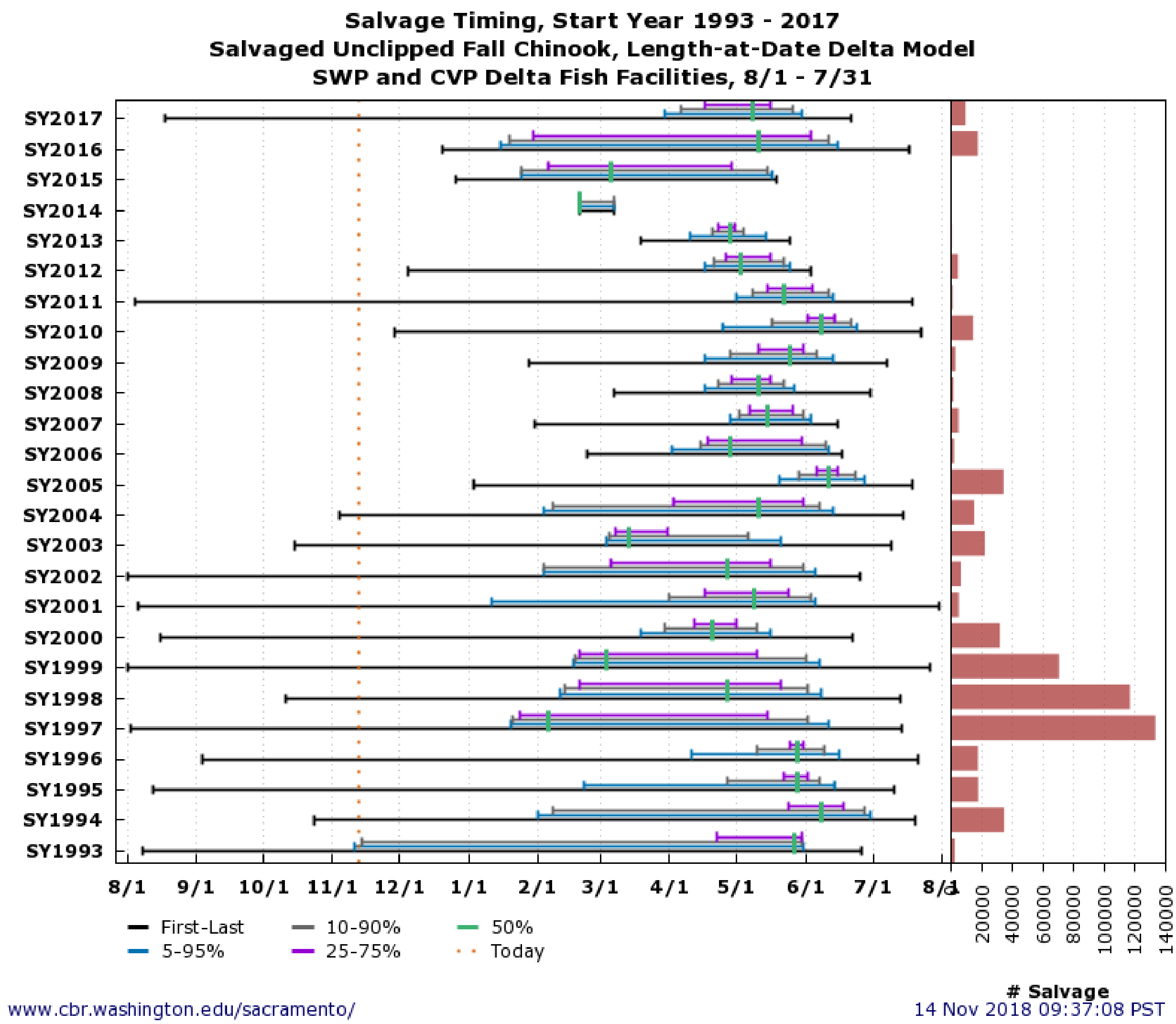


Figure 5.14-16. Fall-run Chinook Salmon Salvage, 1993-2017

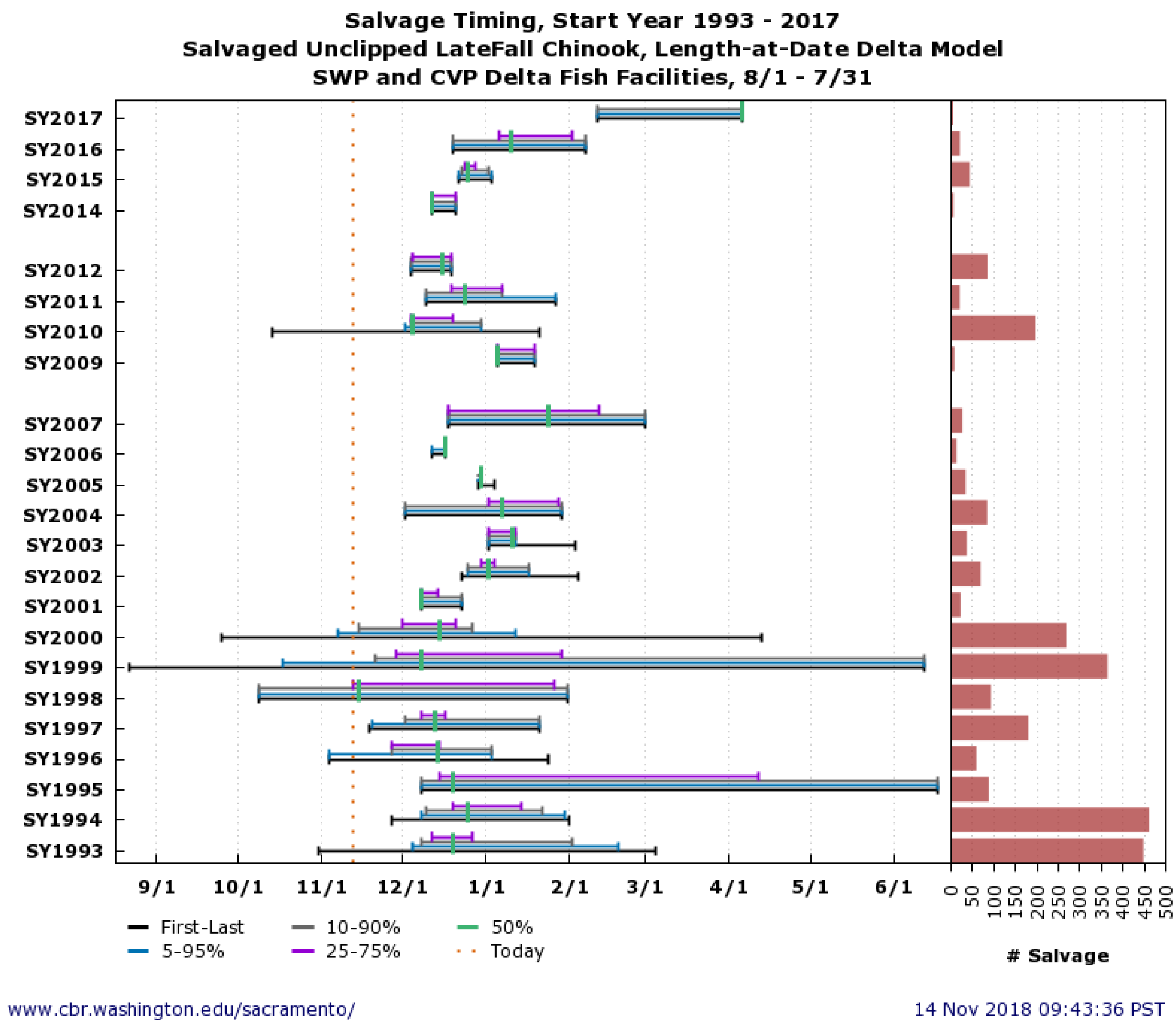


Figure 5.14-17. Late Fall-run Chinook Salmon Salvage, 1993-2017

5.14.5.3.10.2 Routing

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from the proposed action were evaluated using DSM2 as described above. Juvenile Fall-run Chinook Salmon abundance in the Delta is greatest between February and May and Late-Fall run are present in the Delta between November and July with peaks in January-February and April-May (Tables 5.14-1 and 5.14-2). In the December through February period, velocity overlap between the proposed action and COS in the Sacramento River main stem between the Sutter-Steamboat and DCC/Georgiana Slough Junctions, was >50% in all water year types (Figure H-3 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the proposed action in all water year types indicating routing into the interior Delta would be lower relative to COS (Perry et al. 2015). Comparing the proposed action to WOA in the Dec-Feb period revealed velocity overlap <50% in Dry, Above Normal and Wet years and <60% in Critical and Below Normal years (Figure H-4 – Appendix H, *Bay-Delta Aquatics Effects Figures*) with higher velocities in the WOA in all water year types. This pattern indicates routing into the interior Delta would be lower under WOA relative to the proposed action or COS (Perry et al. 2015). In the March to May period comparison of the proposed action and COS revealed similar patterns of velocity overlap as described for the December-February period (Figure H-5 – Appendix H, *Bay-Delta Aquatics Effects Figures*) indicating routing into the interior Delta would be lower under the proposed action during March-May. Comparing the proposed action with the WOA in March-May revealed low overlap in Sacramento main stem velocities between the Steamboat-Sutter Junction and the DCC-Georgiana Slough junction (Figure H-6 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA indicating routing into the interior Delta under WOA would be lower than the proposed action or COS.

Fall–run and Late-Fall run juveniles originating from the Sacramento River that enter the interior Delta via Georgiana Slough and the Delta Cross Channel can be exposed to hydrodynamic project effects that could affect routing. Once these fish arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December-February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between the proposed action and both the COS and the WOA scenarios (Figures H-7 and H-8 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Similar results were obtained when comparing the proposed action to COS and WOA in the March to May period (Figures H-9 and H-10 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

Routing of juvenile Chinook Salmon into alternative migration routes is closely related to hydrodynamics (Perry et al. 2015; Cavallo et al. 2015; Steel et al. 2012). Changes to hydrodynamics in Delta channels resulting from the proposed action were evaluated using DSM2 as described above. When Fall–run Chinook salmon juveniles originating from the Mokelumne River arrive at the junction of the Mokelumne River and the San Joaquin River, they can move south toward the export facilities or west toward the ocean. In the December-February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junction of the Mokelumne and San Joaquin Rivers between the proposed action and both the COS and the WOA scenarios (Figures H-7 and H-8 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Similar results were obtained when comparing the proposed action to COS and WOA in the March to May period (Figures H-9 and H-10 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

Juvenile Fall-run Chinook Salmon are present in the Mossdale Trawl between January and June with a peak between February and May (Table 5.14-1). Early studies using coded wire tags indicated that survival of San Joaquin River-origin juvenile Chinook Salmon was lower in the Old River Route relative to the San Joaquin main stem (Newman 2008). This finding led to strategies designed to keep larger proportions of fish in the San Joaquin River main stem including the Head of Old River rock barrier and non-physical barriers. Recent studies using acoustic technology have indicated that differences in survival among the two routes are not significant (Buchanan et al. 2013; Buchanan et al. 2018). Thus, fish that enter Head of Old River are unlikely to experience reduced survival. In the December-February period, velocity overlap between proposed action and COS at the Head of Old River was >89% in Critical, Dry, and Below Normal years, >72% in Wet years, and >53% in Above Normal years (Figure H-7 – Appendix H, *Bay-Delta Aquatics Effects Figures*). When proposed action was compared to WOA in the December-February period, velocity overlap was >50% in Critical and Dry years and >10% in all other water year types (Figure H-8 – Appendix H, *Bay-Delta Aquatics Effects Figures*). In the March-May period, velocity overlap patterns were similar to comparisons in the December-February period (Figures H-9 and H-10 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

Fall–run Chinook Salmon originating from the San Joaquin River that remain in the San Joaquin River main stem at the Head of Old River are exposed to additional junctions that lead into the interior Delta including; Turner Cut, Columbia Cut, Middle River, Old River, Fisherman's Cut and False River. In the December-February period analysis of DSM2 data indicates that there is little change to velocities in the region of the junctions with San Joaquin Rivers between the proposed action and both the COS and the WOA scenarios (Figures H-7 and H-8 – *Appendix H, Bay-Delta Aquatics Effects Figures*). Similar results were obtained when comparing the proposed action to COS and WOA in the March to May period (Figures H-9 and H-10 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

5.14.5.3.10.3 Through Delta Survival

Comparing between proposed action and WOA (Figure H-12 – Appendix H, *Bay-Delta Aquatics Effects Figures*), overlap in changes in velocity distributions were lower for each water year type (37.3 – 68.3%) with higher velocities under WOA relative to proposed action. At Steamboat Slough, when the proposed action was compared to WOA, overlap was moderate to high with values between 42.6% and 72.6 % (Fig H-14 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Velocities were higher under the WOA in all water year types (Figure H-14 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

In the March through May period at Walnut Grove, when proposed action was compared to WOA in the March through May period, velocity overlap was variable among water year types from a low of 14.1% in Wet years to 56.9% in Critical years (Figure H-16 –Appendix H, *Bay-Delta Aquatics Effects Figures*). In all water year types, velocities were greater under the WOA relative to the proposed action. At Steamboat Slough in the March through May period, velocity overlap was lower when proposed action was compared to WOA (Figure H-18 – Appendix H, *Bay-Delta Aquatics Effects Figures*). The lowest value occurred in Wet years (19.1%) and highest in Critical years (69.5%).

A recent study by 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. During the December to February period at the San Joaquin River at Highway 4, velocity distributions for proposed action relative to WOA exhibited velocity overlap decrease in all water year types, with higher velocities under WOA (Figure H-20 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Overlap values ranged from a low of 59.6% in Wet years to 83.4% in Critical years (Figure H-20 – Appendix H, *Bay-Delta Aquatics Effects Figures*). At the Head of Middle River during the December-February period, overlap was low between the proposed action and WOA in all water year types (≤34.9%) with higher velocities under WOA (Figure H-22 – Appendix H, *Bay-Delta Aquatics Effects Figures*).

Spring flow pulses descibed in the PA to achieve flows >9100 cfs at Wilkins would also provide benefits to spring run in the Delta. Spring run in the Delta would experince greater survival as flow magnitude increases from the flow pulse passing through the Delta (Perry et al. 2018). Spring run Chinook Salmon are in high and moderate abundance in the Delta during the time period when the spring flow pulses are proposed.

In the March-May period in the San Joaquin River at Highway 4, there was high overlap in Critical years (92.8%) between the proposed action and WOA. In other water year types, overlap ranged between 54.5% in Wet years to 78.6% in Dry years with higher velocities under the WOA (Figure H-24 – Appendix H, *Bay-Delta Aquatics Effects Figures*). Comparison of the proposed action with WOA in March-May at Head of Middle River revealed overlap >50% in Critical years and overlap <35% in all other water year types (Figure H-26 – Appendix H, *Bay-Delta Aquatics Effects Figures*). In all water year types, velocities were higher under the WOA relative to the proposed action.

5.14.5.3.11 Delta Cross Channel

5.14.5.3.11.1 Rearing to Outmigrating Juveniles in the Bay-Delta

The Delta Cross Channel may be closed for up to 45 days from November through January for fishery protection purposes. From February 1 through May 20, the gates are closed for fishery protection purposes. The gates may also be closed for 14 days from May 21 through June 15 for fishery protection purposes.

The peak migration of juvenile Fall-run Chinook Salmon in the Sacramento River past West Sacramento, which is near the DCC, occurs from February through May (Table 5.14-1). Therefore, the DCC is closed for the majority of the juvenile Fall-run Chinook migration period in the Sacramento River and as such, the proportion of fish exposed to an open DCC would be low. Juvenile Fall-run which are entrained into an open DCC and transported to the interior Delta have reduced survival (Perry et al. 2010). Since the proportion of juvenile Fall-run Chinook salmon exposed to an open DCC would be low the potential negative effects of DCC operation would be low.

5.14.5.3.11.2 Adult Migration

The status of the DCC gates, open or closed, affects ability of Fall-run and Late Fall-run Chinook Salmon to migrate to their river of origin. Attraction flows from the Mokelumne River are often low, resulting in an open DCC path allowing salmon to stray to the Sacramento River and spawn in Sacramento River tributaries. This is hypothesized to result in lower Mokelumne escapement than would otherwise occur and increased homogenization of Fall-run Chinook salmon. No change in DCC operations in the Fall-run or Late Fall-run Chinook salmon adult migration season (August-October) are planned so effects would be unchanged from the current condition. Reclamation proposes to improve the DCC gates to enable a more real time operation to occur. This has potential to improve conditions for migrating adults in the future.

5.14.5.3.12 Agricultural Barriers

Under the proposed action, Middle River and Old River near Tracy can begin operating as early as April 15 but the tide gates are tied open from May 16 to May 31. After May 31, the barriers in Middle River, Old River near Tracy, and Grant Line Canal are permitted to be operational until they are completely removed by November 30.

The proportion of juvenile Fall-run Chinook salmon exposed to the agricultural barriers depends on their annual timing of installation and removal. Due to their location, primarily migrants originating from the San Joaquin River would be exposed to the agricultural barriers. The peak relative abundance of juvenile Fall-run Chinook salmon in the Delta at Mossdale is February through May (Table 5.14-1). If the agricultural barriers are operating as early as April 15 then they have the potential to expose a large proportion of the juvenile Fall-run Chinook salmon migrating down the San Joaquin River. When the Head of Old River barrier is not in place, which it is not under the proposed action, acoustically tagged juvenile Chinook Salmon have demonstrated a high probability of selecting the Old River route (Buchanan 2018), which would expose them to the agricultural barriers. When the agricultural barriers are operating with tidal flap gates down, a significant decline in passage and reach survival of acoustically tagged juvenile Fall-run Chinook Salmon migrating past the barrier has been observed compared to when the barrier is not present (DWR 2018). When flap gates are tied up, Chinook Salmon passage past the agricultural barrier was improved (DWR 2018). Flap gates tied up on agricultural barriers from May 16 to May 31 would help to reduce the negative effect of the barriers during this period. However, juveniles migrating before or after this period could be exposed to the agricultural barriers with flaps down which apparently decreases passage success and survival (DWR 2018). Therefore, the potential negative effects of the agricultural barriers depends on when they are installed and whether the flap gates are down or tied up but overall would be medium to high.

5.14.5.3.13 Contra Costa Canal Rock Slough Intake

As discussed in Section 4.9.5, CCWD's operations in the proposed action are consistent with the operational criteria specified in separate biological opinions and permits that govern operations at CCWD's intakes and Los Vaqueros Reservoir (NMFS 1993; NMFS 2007; NMFS 2010; NMFS 2017; USFWS 1993a; USFWS 1993b; USFWS 2000; USFWS 2007; USFWS 2010; USFWS 2017; CDFG 1994; CDFG 2009). Therefore, the operation of the Rock Slough Intake for the Proposed Action remains unchanged from the COS.

The Contra Costa Canal Rock Slough Intake is located on a dead-end slough, far from the main migratory route for Fall-run/Late Fall-run, approximately 10 miles from the San Joaquin River and 18 miles from the Sacramento River via the shortest routes. Three life stages (fry, juveniles, and adults) of Fall-run/Late Fall-run Chinook Salmon can be present in the Delta at various times. A portion of the Fall-run Chinook salmon fry population (length-40 to 50 mm) migrates downstream soon after emergence where they rear in the lower Delta river channels and Suisun Bay during the spring. These Fall-run Chinook salmon fry enter the estuary in January and peak in abundance in February and March. Juvenile Fall-run Chinook Salmon (length-80 to 90 mm long) can be in the Delta from Apri1–early June and adult Fall-run Chinook Salmon are in the Delta during late summer and fall (approximately late June–early December). Late Fall-run juveniles can be in the Delta Rock Slough from April–June and adults migrate from October–April (Reclamation 2016).

Fish monitoring prior to the construction of the RSFS indicates the timing and magnitude of CV Fall-run/Late Fall-run presence near the Rock Slough Intake. From 1999-2009, the 11 years prior to construction of the RSFS, CCWD's Fish Monitoring Program collected a total of 18 CV Fall-run/Late Fall-run near the Rock Slough Intake (Reclamation 2016). Since construction of the RSFS, operation of the hydraulic rake cleaning system has been shown to trap and kill adult Chinook Salmon and other non-listed fish (Reclamation 2016). From 2011-2018 47 Chinook salmon were recovered at the RSFS (Reclamation 2016, Appendix A; Tenera 2018a). Approximately 60 percent were of hatchery origin; the CWTs revealed that all were Fall-run/Late Fall-run Chinook Salmon released from either Mokelumne River (53 percent), Merced River (6 percent) or Nimbus (2 percent) fish hatcheries.

5.14.5.3.13.1 Juveniles

Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, juvenile CV Fall-run/Late Fall-run are not likely to be in the vicinity of the Rock Slough Intake. However, according to NMFS (2017), juvenile salmon can be "drawn" into the south Delta under reverse flows and high CVP and SWP pumping rates. However, the water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity along the migratory path for juvenile Fall-run/Late Fall-run Chinook Salmon and are not likely to impact the movement of juvenile salmonids. Please see the Winter-run Chinook Salmon section for additional details.

5.14.5.3.13.2 Adults

Rock Slough is a relatively slow flowing, tidal waterway which ends at the Rock Slough Extension, approximately 1,700 feet upstream from the Rock Slough Intake. Rock Slough is poor habitat with relatively high water temperature and a prevalence of aquatic weeds. Due to the location of the Rock Slough Intake near the end of a dead-end slough, far from the main migratory routes, and due to the poor quality of habitat within the slough, adult Fall-run/Late Fall-run Chinook Salmon are not likely to be in the vicinity of the Rock Slough Intake. However, if some adults stray into Rock Slough, the water exiting the Contra Costa Canal on ebb tide may create a false attraction to adult salmon that are migrating upstream (NMFS 2017).

NMFS has advised Reclamation that salmonids will likely be less attracted to the area near the intake if tides can be reduced (Reclamation 2016). It is worth noting that the ebb tidal flow in Rock Slough will be substantially reduced when the Contra Costa Canal is encased in a pipeline. This ongoing, multi-phased project (the Canal Replacement Project) is being conducted as a separate action by CCWD and has undergone separate environmental review. Completion of the Canal Replacement Project will result in tidal flows being significantly reduced at the Rock Slough Intake. Modeling of the area indicates that with only the first two phases complete, ebb flows reach up to 160 cfs, but with the Contra Costa Canal fully encased, ebb flows would be greatly muted to about 10 cfs.

5.14.5.3.14 North Bay Aqueduct

Fall-run Chinook Salmon may be present in the waterways adjacent to the Barker Slough Pumping Plant, however several years of monitoring have failed to consistently capture any salmonids during the winter Delta Smelt surveys (1996 to 2004) in Lindsey Slough or Barker Slough. Captures of Chinook Salmon have usually occurred in the months of February and March and typically are only a single fish per net haul (http://www.delta.dfg.ca.goc/data/nba). Most Chinook Salmon captured have come from Miner Slough, which is a direct distributary from the Sacramento River via Steamboat and Sutter Sloughs. Few if any San Joaquin River-origin Fall-run Chinook Salmon are expected to be exposed to the North Bay aqueduct under the proposed action because it is not on the migration route of this species.

5.14.5.3.15 Water Transfers

As discussed in the Spring-run Chinook Salmon section, Reclamation’s proposed action includes expanding the water transfer window to July to November. This could result in approximately 50 TAF of additional pumping in most water year types (Figure 5.8-47). This additional pumping could increase entrainment, routing, or through-Delta mortality for Fall-run Chinook Salmon.

5.14.5.3.15.1 Rearing to Outmigrating Juvenile

Rearing to outmigrating Fall-run/Late Fall-run Chinook salmon juveniles would be exposed to increased pumping due to the water transfer window expansion in the fall associated with the proposed action, although this is not at the peak of the juvenile outmigration window. Effects are the same as those discussed under OMR management and include entrainment and predation.

5.14.5.3.15.2 Migrating Adults

Adult Fall-run Chinook Salmon would be exposed to increased pumping due to the water transfer window expansion in the fall associated with the proposed action. Effects are the same as those discussed under OMR management.

5.14.5.3.16 Clifton Court Forebay Aquatic Weed Program

Few if any juvenile Fall-run Chinook Salmon would be expected to be exposed to the Clifton Court Forebay Aquatic Weed Control Program under the Proposed Action. Juvenile Fall-run and Late Fall-run Chinook Salmon are present in the Delta between mid-November and early June with a peak in April (Table5.6-1). The application of aquatic herbicide to the waters of Clifton Court Forebay will occur during the summer months of July and August. Thus, the probability of exposing Fall-run Chinook Salmon to the herbicide is very low. Based on typical water temperatures in the vicinity of the salvage facilities during this period, the water temperatures would be incompatible with salmonid life history preferences, generally exceeding 70°F by mid-June. Mechanical harvesting would occur on an as-needed basis and therefore Fall-run Chinook Salmon could be exposed to this action, if entrained into the Forebay.

5.14.5.3.17 Suisun Marsh

5.14.5.3.17.1 Salinity Control Gates

Operation of the SMSCG from October through May coincides with downstream migration of juvenile Fall-run Chinook Salmon (Table 5.14-1). NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

5.14.5.3.17.2 Roaring River Distribution System

The RRDS' water intake (eight 60-inch-diameter culverts) under the proposed action is equipped with fish screens (3/32-inch opening, or 2.4 mm) operated to maintain screen approach velocity of 0.2 ft/s (for Delta Smelt protection) or 0.7 ft/s, so that juvenile Fall-run Chinook Salmon would be excluded from entrainment.

5.14.5.3.17.3 Morrow Island Distribution System

Although Fall-run Chinook Salmon have been entrained at this facility that is part of the proposed action, only a small proportion of total migrants are likely to encounter it.

5.14.5.3.17.4 Goodyear Slough Outfall

NMFS (2009: 438) concluded that it would be unlikely that Chinook Salmon would encounter or be negatively affected by the Goodyear Slough outfall given its location and design, which is intended to improve water circulation in Suisun Marsh and therefore was felt by NMFS (2009: 438) to likely be of benefit to juvenile salmonids by improving water quality and increasing foraging opportunities.

5.14.5.4 Effects of Maintenance

Under WOA, no maintenance would occur as the CVP and SWP are not operating. Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real-Time Water*

Operations Charter in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Green Sturgeon adults from maintenance activities.

5.14.5.4.1 Operation of a Shasta Dam Raise

Reclamation would operate a raised Shasta Dam consistent with the rest of the proposed action. Therefore, effects described elsewhere in the document would also apply to the operation of a raised Shasta Dam, and there would be no operational changes.

5.14.5.5 Effects of Conservation Measures

Conservation measures would not occur under WOA.

5.14.5.5.1 Lower Intakes Near Wilkins Slough

5.14.5.5.1.1 Eggs to Fry Emergence

The installation of fish screens near Wilkins Slough would be beneficial to Fall-run and Late Fall-run Chinook salmon egg and fry. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages. Specifically, operation of diversions with fish screens near Wilkins Slough would:

- Improve water temperatures and increase DO.
- Increase habitat complexity.
- Increase side-channel rearing habitat.
- Increase floodplain habitat and increase connectivity of floodplains with the river mainstem.
- Increase refuge habitat.
- Increase availability and quality of prey organisms.
- Reduce crowding and competition.
- Decrease predation risk.
- Decrease entrainment risk.
- Decrease potential for pathogens and diseases.
- Lower concentrations of toxic contaminants.
- Increase emigration cues.

The egg and fry life stage of Fall-run and Late Fall-run Chinook salmon, as well as the population, would benefit from this action. The survival of this life stage would directly benefit the Southern Resident Killer Whale, by increasing its available prey.

Egg and fry of Fall-run/Late Fall-run Chinook salmon would not be affected by the construction of a new diversion and screens near Wilkins Slough. Peak spawning time for Fall-run and Late Fall-run Chinook Salmon is typically in October-November, but can continue through December and into January (CDFG date unknown - https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=104280). Juveniles typically emerge from the gravel in December through March. Construction would occur during an inwater work window between June 1 and October 1; therefore, egg and fry would not be affected.

5.14.5.5.1.2 Rearing to Outmigrating Juveniles

The installation of fish screens near Wilkins Slough would be beneficial to Fall-run and Late Fall-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages.

Rearing and outmigrating Fall-run and Late Fall-run Chinook Salmon would not be affected by the construction of a new diversion and screens near Wilkins Slough, based on Fall-run/Late Fall-run Chinook Salmon rearing between one to seven months after emerging between December through March (CDFW website). Juveniles typically move downstream quickly into large rivers within a few weeks. Salmon smolts initiate migration during storm events and flow is positively correlated with migration rate (McCormick et al. 1998, Michel et al. 2013 *as cited in* CDFG website).

If rearing salmon are present in Wilkins Slough during the June 1 through October 1 in-water work window, individuals may be exposed to temporary disturbances associated with the construction of a cofferdam. Water quality may be temporarily disturbed, in addition the noise associated with construction of the cofferdam may temporarily affect juvenile Fall-run Chinook Salmon. Additionally, fish rescue operations may need be conducted during the period when water within the coffered area needs to be pumped. However, implementation of AMM's identified in Appendix E, *Avoidance and Minimization Measures* would further minimize any effects to the salmon.

Outmigrating juvenile Fall-run/Late Fall-run Chinook Salmon in the Upper Sacramento River would not be affected by the construction of a new diversion and fish screens near Wilkins Slough associated with the proposed action, based juveniles emigrating quickly downstream. Construction of diversions and fish screens near Wilkins Slough would occur during an in-water work window (June 1 and October 1), avoiding the emigration period; therefore effects of construction on emigrating Fall-run and Late Fall-run are not expected.

5.14.5.5.1.3 Rearing to Outmigrating Juveniles in the Bay Delta

The installation of fish screens near Wilkins Slough would be beneficial to Fall-run/Late Fall-run Chinook. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages.

Rearing and outmigrating Fall-run and Late Fall-run Chinook Salmon in the Bay-Delta would not be affected by the construction of a new diversion and screens near Wilkins Slough, based on Fall-run and Late Fall-run Chinook Salmon being located far downstream of construction activities. Wilkins Slough is located outside of the legal Bay-Delta – no tidal influence.

5.14.5.5.1.4 Adult Migration

The installation of fish screens near Wilkins Slough under the Proposed Action would be beneficial to Fall-run/Late Fall-run Chinook Salmon. The fish screens would prevent fish entrainment at diversions, thus increasing the survival of emigrating juveniles and immigrating adults, and in turn potentially increasing successful spawning. Additionally, the installation of new diversions and screens that would operate at lower flows, would directly benefit fish of all life stages.

Yoshiyama *et al.* (1998) identifies the migration period for Fall-run Chinook Salmon as June through December, with a peak period of September through October. The migration period for Late Fall-run Chinook Salmon is October through April, with a peak in December (Yoshiyama *et al.* 1998). Construction activities would occur during an in-water work window from June 1 through October 1. Although migrating salmon may be present during the latter portion of the window, the migrating fish would not affected by construction windows, as the construction activities would occur in an already dewatered area. Flow would not be impeded; therefore, migration of salmon to upstream spawning habitats would not be prevented. The implementation of the in-water work wind-down and other AMM's identified in Appendix E, *Avoidance and Minimization Measures* would reduce the effects of construction activities on migrating salmon.

5.14.5.5.1.5 Adult Holding

Holding Fall-run/Late Fall-run Chinook Salmon, as well as the population, would benefit from the installation of fish screens near Wilkins Slough under the proposed action.

The construction activities associated with the diversions and associated fish screens under the proposed action are not expected to affect adults holding Fall-run/Late Fall-run Chinook Salmon, due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. Additionally, per Appendix E, *Avoidance and Minimization Measures*, Reclamation will implement an in-water work window of June 1 through October 11 to reduce further effects to holding individuals. Additionally, Fall-run and Late Fall-run Chinook Salmon typically need cold water temperatures for holding; however, Wilkins Slough does not have suitable holding habitat; therefore, would not be affected by the onset of construction activities within the in-water work window.

5.14.5.5.2 Shasta Dam TCD Improvements

5.14.5.5.2.1 Eggs to Fry Emergence

Improvements to the Shasta Dam TCD would accommodate relatively small raises to Shasta Dam and reduce leakage of warm water into the structure that increases of the water temperature of the cold water that is released to maintain suitable temperatures for Fall–run/Late Fall-run Chinook Salmon that spawn in the upper Sacramento River (from Keswick Dam to the Red Bluff Diversion Dam). Because there is some overlap between winter-run and Fall-run/Late Fall-run spawning and egg/alevin incubation periods, Fall-run/Late Fall-run eggs and alevins would be somewhat similarly affected by the upper Sacramento River water temperatures, and as described previously, the proposed action would in fact be more protective of Fall-/Late Fall-run Chinook Salmon than COS and WOA. The improved flow and water temperature management associated with the Shasta Dam TCD improvements under the proposed action would be expected to provide a moderate benefit to Fall-run/Late Fall-run Chinook Salmon eggs and alevin relative to the WOA.

5.14.5.5.2.2 Rearing to Outmigrating Juveniles

All water temperatures under COS and proposed action scenarios during the Fall-run/Late Fall-run juvenile rearing period are consistently below the 61 degrees Fahrenheit threshold, except for June through September. However, during June through September, water temperatures under the WOA would be substantially higher (~10 to 20 degrees Fahrenheit) than those under the proposed action and COS.

Therefore, in general, water temperature conditions under COS and the proposed action would provide high benefits relative to the WOA conditions to juvenile Fall-run/Late Fall-run rearing in the upper Sacramento River. The ability to better manage the cold water pool and cold water releases through the Shasta TCD improvements would result in increased probability and likelihood of maintaining suitable rearing temperatures within the middle reaches of the Sacramento River. Therefore, this action would have high-level population benefits on this life stage.

5.14.5.5.2.3 Adult Migration

Under the proposed action and COS, the monthly mean water temperatures in the middle Sacramento River below the Colusa Basin Drain would be below the 68 degrees Fahrenheit threshold for immigrating Fall-run/Late Fall-run Chinook Salmon (Figures 14-9, 14-10, 14-12, 14-13 in the HEC 5Q Tempertures section in Appendix D). The ability to better manage the cold water pool and cold water releases would result in increased probability and likelihood of maintaining suitable migrating water temperatures within the Sacramento River.

5.14.5.5.2.4 Adult Holding

Under the COS and proposed action scenarios, the monthly mean water temperatures in the upper Sacramento River at Keswick, under the COS and proposed action scenarios, the average water temperatures would be well below the 61 degrees Fahrenheit threshold for holding adults from December through May (Figures 5-9, 5-12, 5-15 in the HEC-5Q Temperatures section of Appendix D). The ability to better manage the cold water pool and cold water releases would result in increased probability and likelihood of maintaining suitable migrating ad holding temperatures within the Sacramento River.

5.14.5.5.3 Sacramento River Spawning and Rearing Habitat

5.14.5.5.3.1 Egg to Fry Emergence

Habitat restoration activities under the proposed action would benefit Fall-run Chinook Salmon by increasing available spawning habitat (by placement of additional spawning gravel). The plot below shows the available spawning habitat in the Sacramento River, along with the needed habitat to support various population sizes. Also shown is the CVPIA doubling goal for Fall-run Chinook Salmon on the Sacramento River.

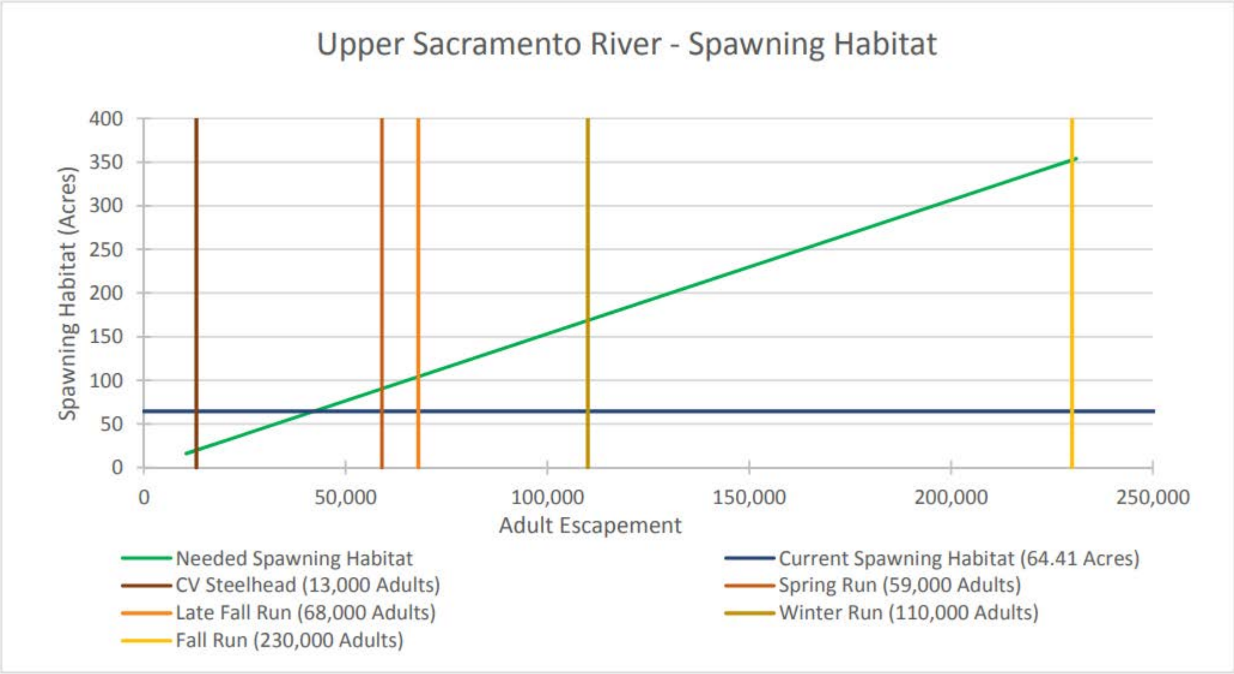


Figure 5.14-18. Estimated Salmonid habitat needed in the Sacramento River to support the range of escapement sizes (CVPIA 2018).

The construction activities associated with spawning habitat restoration under the proposed action are not expected to affect eggs and emerging fry due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures* and implementation of an in-water work window (July 15 through October 15t). The in-water work window will completely avoid the eggs and emerging fry life stage, as Fall-run/Late Fall-run Chinook Salmon typically spawn between October through November, and fry emerge between December and March (Table 5.14-2).

5.14.5.5.3.2 Rearing to Outmigrating Juveniles in the Rivers

Habitat improvement projects in the Sacramento River under the proposed action focus on increasing productivity of Fall-run Chinook Salmon and Steelhead. The in-river work occurs during low flows (less than about 5,000 cfs) in the July to October timeframe to avoid the most sensitive young juvenile and egg life stages of Steelhead and Chinook Salmon. Projects focus on rearing habitat and strive to provide spawning habitat close to the rearing habitat in the upper half of the river. Lower river projects (below River Bend) focus solely on rearing habitats and include side channel and floodplain types of habitat. Woody material is incorporated in all projects wherever possible.

Rearing and outmigrating individuals would benefit from increased side channel habitat, floodplain, gravel, and large wood resulting from habitat restoration in the Sacramento River. Effects would include an improved likelihood of rearing success due to an increase in total rearing habitat area, and rearing habitat quality. Figure 5.14-20 shows the amount of rearing habitat needed to support the range of Chinook Salmon escapement sizes in the Sacramento River along with the estimated amount of rearing habitat currently available. Rearing habitat appears particularly limited with habitat currently available to support the production of less than 500 Chinook Salmon. Rearing habitat improvements are particularly beneficial.

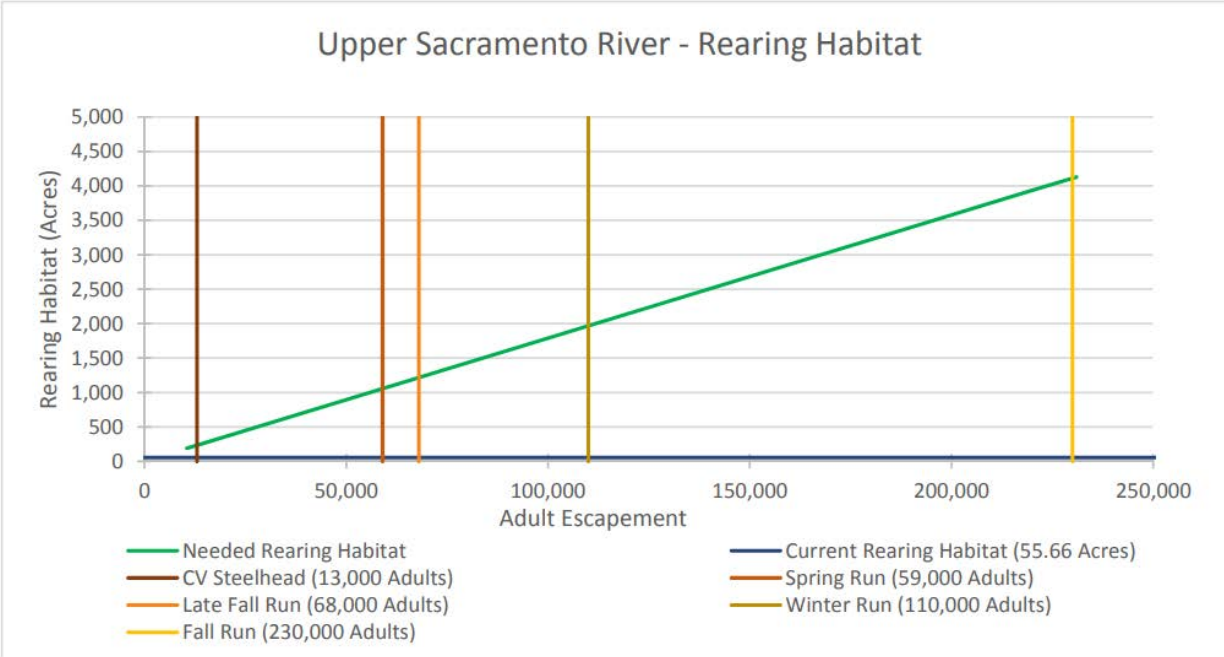


Figure 5.14-19. Estimated Salmonid rearing habitat needed in the Sacramento River to support the range of escapement sizes (CVPIA 2018).

Few rearing and outmigrating Fall-run/Late Fall-run Chinook salmon juveniles would be exposed to construction of side channel habitat, gravel augmentation, and large wood installation under the proposed action, based on the timing of the in-water work window (July 1-September 30) and seasonal occurrence of this life stage in the Sacramento River (year-round; Table 5.14-1). Most juveniles leave the river before July. Years when juvenile Chinook are present into July are wet years with high flows prohibiting in-river habitat improvement work from occurring. Construction activities in the Sacramento River could result in mortality of this life stage by crushing from heavy equipment in the stream channel, if individuals were stranded or isolated during dewatering, or if construction otherwise disturbed rearing juvenile habitat during manipulation of gravel, installation of large wood or creation of side channels. Individuals exposed to construction could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. This life stage could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, reduced foraging ability caused by decreased visibility, and impeded or delayed migration caused by elevated noise levels from machinery. Due to the juvenile life stage timing rarely overlapping with habitat work any effects would be minimal.

Any exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention, and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed construction activities under the proposed action would be minimized and affect a low number of individuals.

5.14.5.5.3.3 Adult Migration

Habitat restoration activities would benefit Fall-run/Late-Fall run Chinook Salmon by increasing available spawning habitat.

The construction activities under the proposed action associated with spawning habitat restoration are not expected to affect immigrating Fall-run/Late Fall-run Chinook Salmon because of the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. Additionally, per Appendix E, Reclamation will implement an in-water work window of July 15 through October 15 to avoid effects to immigrating Fall-run/Late Fall-run Chinook Salmon.

5.14.5.5.3.4 Adult Holding

Habitat restoration activities under the proposed action would benefit Fall-run/Late Fall-run Chinook Salmon by increasing available spawning habitat.

The construction activities associated with spawning habitat restoration under the proposed action are not expected to impact adults Fall-run/Late Fall-run Chinook Salmon holding in the Sacramento River due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. Additionally, per Appendix E, Reclamation will implement an in-water work window of July 15 through October 15 to reduce further effects to holding individuals.

5.14.5.5.4 Deer Creek Fish Passage

DWR and Reclamation's installation of a nature-like fishway at the DCID diversion dam will provide salmonids access to approximately 25 miles of spawning habitat in Deer Creek upstream from the DCID dam.

Construction effects are the same as discussed above for Sacramento River spawning and rearing habitat. Exposure to these effects would be minimized with incorporation of the avoidance and minimization measures.

5.14.5.5.5 Small Screen Program

5.14.5.5.5.1 Egg to Fry Emergence

No egg-to-emergence Fall-run/Late Fall-run Chinook Salmon in the Sacramento River would be exposed to fish screens since they remain in the gravel. Therefore, there would be no effects from fish screen operation for this life stage.

Few if any Sacramento River Fall-run/Late Fall-run Chinook Salmon in the egg-to-emergence life stage would be expected to be exposed to the effects of construction of screens on water diversion intakes under the proposed action based on the seasonal occurrence of this life stage in the Sacramento River. The egg to fry emergence stage follows the fall and winter spawning period (Table 5.14-1 and 5.14-2), which is outside of the timing of in-water construction (July 15 – October 15). Since spawning occurs in gravel substrate in relatively fast-moving, moderately shallow riffles or along banks with relatively high water velocities (Fisher 1994), there is the potential for redds to occur in the work areas or in the direct vicinity of the construction sites. However, these work areas are localized and the number of redds in these areas is expected to be low. Potential short-term adverse impacts may include temporary, localized fine sediment disturbance and deposition in spawning and embryo incubation areas directly adjacent construction sites. There could be a minor effect to a small number of individuals, although the risk from these potential effects would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*.

5.14.5.5.5.2 Rearing to Outmigrating Juveniles in Rivers

The operation of fish screens on water diversions under the proposed action would beneficially affect juvenile Fall-run/Late Fall-run Chinook Salmon rearing and migrating in the Sacramento River by reducing the entrainment of rearing and migrating fish into unscreened or poorly screened diversions. There is the potential for adverse effects to this life stage, including injury or mortality from exposure to screens that are not functioning properly due to lack of maintenance, occlusion, debris accumulation or other factors. However, the risk of this exposure will be minimized since the screens would be designed to meet NMFS and CDFW fish screen criteria and protect this life stage. Therefore, it is concluded that the operation of fish screens under the proposed action would result in beneficial effects for this life stage, due to the reduced risk of entrainment and injury.

Juvenile Fall-run/Late Fall-run Chinook Salmon rearing and migrating in the Sacramento River may be exposed to the effects of construction of screens on water diversion intakes due to their occurrence during the in-water construction season (July 15 – October 15) (Tables 5.14-1 and 5.14-21). However, the localized work area of these projects limits the potential for exposure to these projects. Potential short-term adverse effects may include temporary effects to water quality as result from in-water work, resulting in increased turbidity and suspended sediments and sediment deposition in the direct vicinity of the work area, and the temporary displacement of individual fish in the work area. If fish are present in the work area, flowing water will be isolated and fish captured and relocated to an appropriate location in an effort to minimize possible mortality. Juveniles would likely experience increased levels of stress and injury during handling, which could be exacerbated by poor water quality (increased temperatures, low dissolved oxygen saturation), and prolonged periods of holding between capture and release. There may be a minor effect to a small number of individuals, although the risk from these potential effects would be would be minimized through the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures.* In addition, the appropriate conservation measures and handling techniques will be employed to ensure that the stress resulting from handling and transport is short-lived and minor.

5.14.5.5.5.3 Rearing to Outmigrating Juveniles in the Bay-Delta

There may be moderate overlap Fall-run/Late Fall-run Chinook Salmon with the main late spring-fall irrigation period for small diversions, and small diversion screening under the proposed action could reduce entrainment of late migrating individuals.

Few if any juvenile Fall-run/Late Fall-run Chinook Salmon rearing and outmigrating in the Bay-Delta are expected to be exposed to the effects of construction of screens on water diversion intakes under the proposed action. Juvenile Sacramento River Fall-run/Late Fall-run Chinook Salmon primarily migrate from November through early May (NMFS 2014), largely outside of the timing of in-water construction (July 15 – October 15). In addition, the work area for these projects is small, limiting exposure to construction.

5.14.5.5.5.4 Adult Migration

Operational effects for adults are the same as those described above for juveniles. Adult Sacramento River Fall-run/Late Fall-run Chinook Salmon may be exposed to the effects of construction of screens on water diversion intakes based on the timing of in-water construction (August–October), the late-summer to early Fall seasonal occurrence of this life stage in the Sacramento River (Tables 5.14-1 and 5.14-2). AMMs would minimize risks.

5.14.5.5.5.5 Adult Holding

Operational effects for adults are the same as those described above for juveniles. Adult Fall-run/Late Fall-run Chinook Salmon in the holding in the Sacramento River may be exposed to the effects of construction of screens on water diversion intakes due the overlap of the timing of in-water construction (July 15 – October 15), and the July through April occurrence of this life stage (Tables 5.14-1 and 5.14-2). AMMs would minimize risks.

5.14.5.5.5.5.1 Adult Rescue

The operation of adult rescue is targeted towards adult salmonids and sturgeon, including adult Fall-run/Late Fall-run Chinook Salmon, that become trapped in the Yolo and Sutter bypasses, with the goal of increasing the number of adults returning to spawning areas; therefore, this effort could increase the number of Fall-run/Late Fall-run Chinook Salmon of all lifestages in the Sacramento River and its tributaries, and the ocean.

Exposure of this life stage to adult rescue effects would be restricted only to those adult Fall-run/Late Fall-run Chinook Salmon that become stranded in the Yolo and Sutter Bypasses and subsequently rescued and released to the Sacramento River. Adults that migrate in-river or that do not become stranded in the Yolo and Sutter bypasses would be unaffected by adult rescue activities. The number of adult Fall-run/Late Fall-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the abundance of adults that stray into the bypasses and the timing and frequency of stranding events in the bypasses. Individual adult Fall-run/Late Fall-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality, which could vary in intensity depending on the techniques used to capture individuals. Injury and increased stress associated with capture, handling and transport may affect survival of individuals after release. The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*). As such, it is concluded that the overall population-level negative effects on this life stage of Fall-run/Late Fall-run Chinook Salmon from adult rescue activities would be low relative to the without action (no rescue of stranded adult Fall-run/Late Fall-run Chinook Salmon in Yolo and Sutter bypasses).

Given that eggs are in gravel substrates and adult rescue activities would occur downstream of Fall-run/Late Fall-run Chinook Salmon spawning areas in the Sacramento River and its tributaries, there would be no direct effects on this life stage from implementing adult rescue activities.

As discussed for Winter-run and Spring-run Chinook Salmon, juvenile Fall-run/Late Fall-run Chinook Salmon occur in the Yolo and Sutter Bypasses when Sacramento River flows overtop the Fremont and/or Tisdale Weirs. Although they are unlikely to occur in the bypasses during periods when flow does not overtop the weirs, proposed modifications to the Fremont Weir to increase inundation of the Yolo bypass for floodplain rearing would provide juveniles with more consistent access to the Yolo bypass. Therefore, these juveniles could be exposed to the effects of adult rescue activities if they become stranded with adults that are targeted by adult rescue activities. The number of juvenile Fall-run/Late Fall-run Chinook Salmon that would be expected to be exposed to the effects of adult rescue activities would be based on the timing of proposed adult rescue activities, gear type used to rescue adults, and the typical seasonal occurrence of this life stage in the Yolo and Sutter bypasses. Individual juvenile Fall-run/Late Fall-run Chinook Salmon exposed to adult rescue activities would be at risk of increased stress, injury, and/or mortality during efforts to capture stranded adults, handling, and transport. Injury and increased stress associated with capture, handling, and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Fall-run/Late Fall-run Chinook Salmon would be expected to be offset by benefits associated with increased numbers of adult Fall-run/Late Fall-run Chinook Salmon returning to spawning grounds. As such, it is concluded that the overall population-level negative effects on this life stage of Fall-run/Late Fall-run Chinook Salmon from adult rescue activities would be low relative to the without action (no rescue of adult Fall-run/Late Fall-run Chinook Salmon in Yolo and Sutter bypasses).

5.14.5.5.6 Juvenile Trap and Haul

The operation of the juvenile trap and haul is targeted towards juvenile Fall-run/Late Fall-run Chinook Salmon, with the goal of increasing the survival of juveniles and, ultimately, returning adults; therefore, this effort could increase the number of Fall-run/Late Fall-run Chinook Salmon of all lifestages in the Sacramento River and its tributaries.

The number of juvenile Fall-run/Late Fall-run Chinook Salmon that would be expected to be exposed to the effects of juvenile trap and haul activities under the proposed action would be based on the timing of proposed juvenile trap and haul activities (December 1 to May 31), trapping location and efficiency, and the typical seasonal occurrence of this life stage in the Sacramento River (Tables 5.14-1 and 5.14-2). Individual juvenile Fall-run/Late Fall-run Chinook Salmon exposed to juvenile trap and haul activities would be at risk of increased stress, injury, and/or mortality. Injury and increased stress associated with handling and transport may reduce disease resistance, swimming ability, and osmoregulatory ability in juveniles, thereby adversely affecting survival of affected individuals after release. Furthermore, the risk of these effects to this life stage may be dependent on fish size (fish collected at a smaller [younger] size may be more susceptible to injury and stress) and timing of collection (fish collected later in the season when water quality conditions [e.g., water temperature] generally are more stressful for fish may make fish more susceptible to injury and stress-related effects). The risk from these potential effects would be minimized through application of AMM8 *Fish Rescue and Salvage Plan* (Appendix E, *Avoidance and Minimization Measures*), and any potential adverse effects on individual juvenile Fall-run/Late Fall–run Chinook Salmon would be expected to be offset by benefits associated with expected increased survival of the overall brood-year of Fall-run/Late Fall-run Chinook Salmon. As such, it is concluded that the overall population-level negative effects on this life stage of juvenile Fall-run/Late Fall-run Chinook Salmon from juvenile trap and haul activities would be low relative to the without action (no trapping and hauling of juvenile Fall-run/Late Fall-run Chinook Salmon during drought years) and would be potentially offset by benefits (increased juvenile survival and ultimately increased adult escapement) associated with the juvenile trap and haul program.

Given that eggs are in gravel substrates and temporary juvenile collection weirs would be placed downstream of Fall-run/Late Fall-run Chinook Salmon spawning areas in the Sacramento River and its tributaries, there would be no direct effects on this life stage from implementing juvenile trap and haul activities.

Transport may also result in earlier ocean arrival and reduced growth rates in juveniles, leading to increased mortality from predation.

Exposure of adults to trap and haul effects would be restricted only to those adult Fall-run/Late Fall-run Chinook Salmon that were trapped in the Sacramento River as juveniles and subsequently released to the lower Sacramento River and/or Bay-Delta as part of the juvenile trap and haul program. Ocean adults that had out-migrated in-river as juveniles would not be affected by juvenile trap and haul activities. Because transported juveniles are more likely to have impaired homing behavior as adults, juvenile trap and haul activities may increase the rate of straying by returning adults. Adults that stray into tributaries with unsuitable habitat may not survive or spawn successfully if habitat conditions are suitable. Adults that stray into tributaries with suitable habitat may compete with native-run adults for spawning space, excavate or superimpose their redds on the redds or native-run fish, or spawn with native-run fish, thereby introducing genes from neighboring populations that have strayed into the river.

5.14.5.5.7 Clear Creek Restoration Program

5.14.5.5.7.1 Eggs to Fry Emergence

Eggs and emerging fry of Fall-run/Late Fall-run Chinook Salmon would be exposed to the effects of increased gravel resulting from mechanical gravel mobilization under the proposed action in Clear Creek if geomorphic flows did not achieve sufficient gravel mobilization. Exposure to the effects of gravel mobilization would be beneficial, and include an increase in total incubation habitat area and reduced likelihood of redd superimposition.

A low number of eggs and emerging fry would be expected to be exposed to mechanical gravel mobilization under the proposed action, based on the timing of the in-water work window (to be determined in coordination with NMFS, USFWS, and DFW) and seasonal occurrence of this life stage in Clear Creek (December-April; Table 5.14-1). Mechanical gravel mobilization in Clear Creek could result in mortality of eggs and emerging fry by crushing if heavy equipment entered the stream channel or otherwise disturbed redds during manipulation of gravel. Individuals exposed to this activity could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. Eggs and emerging fry could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct physiological effects on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), and loss of aquatic vegetation providing physical shelter.

The likelihood and magnitude of these effects and the risk of exposure by eggs and fry would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. Including the precautions described in AMM 1–5, the temporary, adverse impacts that may result from the construction activities under the proposed action would be minimized and few individuals would be affected.

5.14.5.5.7.2 Rearing to Outmigrating Juveniles

Rearing Fall-run/Late Fall-run Chinook Salmon juveniles could be exposed to the effects of increased gravel resulting from mechanical gravel mobilization under the proposed action in Clear Creek if mechanical gravel mobilization affected existing gravels in suitable rearing habitat, including channel margins, side channels, or other shallow, slow-moving habitat with adequate cover. Assuming mechanical gravel mobilization is undertaken in areas of the channel more likely to be used for spawning nearer the mid-channel this action will have no effect on existing suitable juvenile rearing habitat.

Rearing and outmigrating juveniles would be exposed to mechanical gravel mobilization, based on the timing of the in-water work window (to be determined in coordination with NMFS, USFWS, and DFW) and peak seasonal occurrence of this life stage in Clear Creek (year-round; Table 5.14-1). Construction activities in Clear Creek could result in mortality of this life stage by crushing if heavy equipment entered the stream channel, if individuals were stranded or isolated during dewatering, or if construction otherwise disturbed rearing juvenile habitat during manipulation of gravel. Individuals exposed to construction could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. This life stage could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, reduced foraging ability caused by decreased visibility, and impeded or delayed migration caused by elevated noise levels from machinery.

Exposure to these effects under the proposed action would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention, and containment. With application of AMM 1–5, the temporary, adverse impacts that may result from the proposed construction activities would be minimized and affect a low number of individuals.

5.14.5.5.7.3 Adult Migration from Ocean to Rivers

Few, if any, migrating adults would be exposed to the effects of increased gravel resulting from mechanical gravel mobilization under the proposed action in Clear Creek. Adult migration habitat is typically situated in deeper water near mid-channel and away from shallower riffles, and pool tails where most mechanical gravel mobilization would occur.

A low number of migrating adults would be expected to be exposed to mechanical gravel mobilization under the proposed action, based on the timing of the in-water work window (to be determined in coordination with NMFS, USFWS, and DFW) and seasonal occurrence of this life stage in Clear Creek (October-December; Table 5.14-1). Construction activities in Clear Creek could result in mortality of migrating adults by crushing if heavy equipment entered the stream channel or otherwise disturbed suitable habitat during manipulation of gravel. Individuals exposed to construction could also experience loss of aquatic habitat, including loss or degradation of habitat used for resting or sheltering from predators. Migrating adults could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), loss of aquatic vegetation providing physical shelter, and impediments and delay in migration caused by elevated noise levels from machinery.

Exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed construction activities would affect few if any individuals of this life stage.

5.14.5.5.7.4 Adult Holding in Rivers

Few, if any, holding adults would be exposed to the effects of increased gravel resulting from mechanical gravel mobilization under the proposed action in Clear Creek. Holding habitat is typically situated in deep water near mid-channel and away from shallower riffles, and pool tails where most mechanical gravel mobilization would occur. Therefore, an increase in gravel would have no effect on this life stage of Fall-run/Late Fall-run Chinook Salmon.

A low number of Fall-run/Late Fall-run Chinook Salmon holding adults would be expected to be exposed to mechanical gravel mobilization under the proposed action, based on the timing of the in-water work window (to be determined in coordination with NMFS, USFWS, and DFW) and seasonal occurrence of this life stage in Clear Creek (July-December; Table 5.14-1). Construction activities in Clear Creek could result in mortality of holding adults by crushing if heavy equipment entered the stream channel or otherwise disturbed suitable habitat during manipulation of gravel. Individuals exposed to construction could also experience loss of aquatic habitat, including loss or degradation of holding pools required as hiding cover and resting areas by adult Fall-run/Late Fall-run Chinook Salmon during the gamete maturation period prior to spawning. Holding adults could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery.

Exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention, and containment, as well as AMM1 and AMM2. Including the precautions described in AMM 1-5, the temporary, adverse effects that may result from the proposed construction activities would affect a low number, if any, individuals of this life stage.

5.14.5.5.8 American River Spawning and Rearing Habitat

5.14.5.5.8.1 Eggs to Fry Emergence

Eggs and emerging fry would be exposed to the effects of increased side channel habitat, gravel, and large wood resulting from habitat restoration under the proposed action in the American River. Effects of this exposure would be beneficial and include an increase in total spawning habitat area and reduced likelihood of redd superimposition. Figure 5.14-21 shows the amount of spawning habitat needed to support the range of Chinook escapement sizes in the lower American River along with the estimated amount of spawning habitat currently available. Projects in the upper half of the lower American River under the proposed action strive to provide rearing habitat and spawning habitat adjacent to each other so that when fry emerge from the gravel they are able to move quickly into suitable habitats. Despite the plentiful spawning habitat in the upper 18 miles of the lower American River, the fish congregate in the upper three miles of the river resulting in high levels of superimposition on the riffles at Nimbus Basin, Sailor Bar, and around Sunrise Avenue. Habitat improvements in these areas under the proposed action help to distribute fish among available habitat and increase survival by reducing superimposition and providing nearby rearing habitat. These projects should be a net benefit to productivity of Fall-run/Late Fall-run Chinook Salmon and Steelhead that spawn and rear in the lower American River.

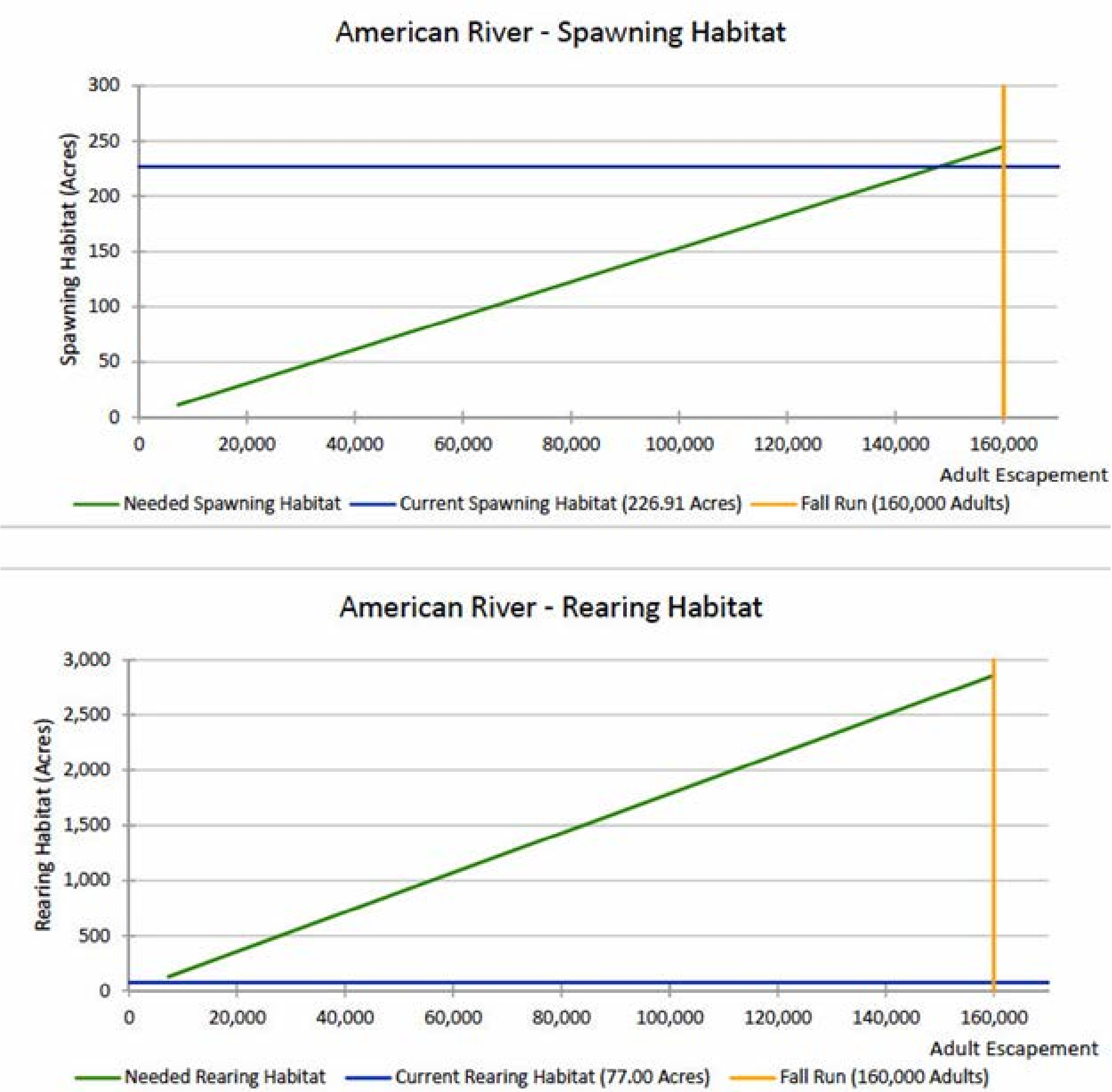


Figure 5.14-20. Estimated Chinook spawning and rearing habitat needed in the lower American River to support the range of escapement sizes (CVPIA 2018).

Construction activity occurs between July and October when no Fall-run or Late Fall-run Chinook Salmon eggs or fry are present.

5.14.5.5.8.2 Rearing to Outmigrating Juveniles

Habitat improvement projects in the lower American River under the proposed action focus on increasing productivity of Fall-run Chinook Salmon and Steelhead. The in-river work occurs during low flows (less than about 5,000 cfs) in the July to October timeframe to avoid the most sensitive young juvenile and egg life stages of Steelhead and Fall-run Chinook Salmon. Projects focus on rearing habitat and strive to provide spawning habitat close to the rearing habitat in the upper half of the lower American River. Projects on the lower part of the lower American River (below River Bend) focus solely on rearing habitats and include side channel and floodplain types of habitat. Woody material is incorporated in all projects wherever possible.

Rearing and outmigrating individuals would benefit from increased side channel habitat, floodplain, gravel, and addition of large woody material resulting from habitat restoration in the lower American River under the proposed action. Effects would include an improved likelihood of rearing success due to an increase in total rearing habitat area, and rearing habitat quality. Figure 5.14-22 shows the amount of rearing habitat needed to support the range of Chinook escapement sizes in the lower American River along with the estimated amount of rearing habitat currently available. Rearing habitat appears particularly limited with habitat currently available to support the production of less than 10,000 Chinook Salmon. Hence, rearing habitat improvements under the proposed action are particularly beneficial.

Few rearing and outmigrating Fall-run/Late Fall-run Chinook Salmon juveniles would be exposed to construction of side channel habitat, gravel augmentation, and large wood installation, based on the timing of the in-water work window (July 1-September 30) and seasonal occurrence of this life stage in the lower American River (year-round; Table 5.14-1). Most juvenile Fall-run Chinook Salmon leave the river before July. Years when juvenile Fall-run/Late Fall-run Chinook Salmon are present into July are wet years with high flows prohibiting in-river habitat improvement work from occurring. Construction activities under the proposed action in the lower American River could result in mortality of this life stage by crushing from heavy equipment in the stream channel, if individuals were stranded or isolated during dewatering, or if construction otherwise disturbed rearing juvenile habitat during manipulation of gravel, installation of large wood or creation of side channels. Individuals exposed to construction could also experience loss of aquatic habitat, leading to increased predation, increased water temperature, and reduced food availability. This life stage could also be negatively affected by degraded water quality from contaminant discharge by heavy equipment and soils and increased discharges of suspended solids and turbidity, leading to direct physiological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, reduced foraging ability caused by decreased visibility, and impeded or delayed migration caused by elevated noise levels from machinery. Due to the juvenile life stage timing rarely overlapping with habitat work, effects would be minimal.

Exposure to these effects would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention, and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed action construction activities would be minimized and affect a low number of individuals.

5.14.5.5.8.3 Adult Migration from Ocean to Rivers

Early migrating adult Fall-run Chinook Salmon would be exposed to construction of side channel and floodplain habitat, gravel augmentation, and large wood installation under the proposed action. Low numbers of Fall-run Chinook Salmon enter the lower American River through the summer with the peak immigration in October. The behavior of these fish depends on conditions in the river. During higher flow years with cooler than average water temperatures, the fish hold throughout the lower American River but wet years with high flows prohibit in-river habitat improvement work from occurring. Even if construction occurred during high flow years, during these years, fish are generally in healthy conditions and readily able to avoid in-water activities and temporary turbidity increases. During dryer years, water temperatures are warmer and flows are typically lower. These conditions are more stressful for the fish and they migrate quickly to the upstream most accessible area, either in Nimbus Basin or below the hatchery weir. The only project site that would affect these fish would be the work in Nimbus Basin.

Exposure to effects of activities under the proposed action would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. With application of AMM 1–5, the temporary, adverse effects that may result from the proposed action construction activities would affect few if any individuals to Fall-run/Late Fall-run Chinook Salmon immigrating into the lower American River.

5.14.5.5.8.4 Adult Holding in Rivers

Early arriving adult Fall-run Chinook Salmon would be exposed to construction of side channel and floodplain habitat, gravel augmentation, and large wood installation under the proposed action. Low numbers of Fall-run Chinook Salmon enter the lower American River through the summer with the peak immigration in October. The behavior of these fish depends on conditions in the river. During higher flow years with cooler than average water temperatures, the fish hold throughout the lower American River and are more likely to be holding close to activities, although construction actions are less likely to occur. During these years, Fall-run Chinook Salmon are in healthy conditions and readily able to avoid in-water activities and temporary turbidity increases. During dryer years, water temperatures are warmer and flows are typically lower. These conditions are more stressful for the fish and they migrate quickly to the upstream most accessible area, either in Nimbus Basin or below the hatchery weir. The only project site that would affect these fish would be the work in Nimbus Basin.

Exposure to effects of habitat construction under the proposed action would be minimized with incorporation of AMM1, which requires construction personnel education, and AMM2, which specifies an in-water work window and oversight by a qualified biologist. Exposure would be further minimized by implementing AMM3, 4, and 5, which stipulate best practices for stormwater pollution prevention, erosion and sediment control, and spill prevention and containment. With application of AMM 1–5 the temporary, adverse effects that may result from construction of side channel habitat, gravel augmentation, and large wood installation would affect few if any holding Fall-run Chinook Salmon adults.

5.14.5.5.9 <u>Drought Temperature Facility Improvements (American River)</u>

5.14.5.5.9.1 Eggs to Fry Emergence

Reclamation proposes to evaluate and implement alternative shutter configurations at Folsom Dam under the proposed action to allow temperature flexibility in severe droughts, thereby reducing water temperatures in the lower American River. Excessively high water temperatures has been identified as one the factors threatening Fall-run/Late Fall-run Chinook Salmon in the Central Valley (NMFS 2014). Cool water temperatures are important for embryo survival; water temperatures reportedly must be between 41°F and 55.4°F maximum survival (Moyle 2002). The implementation of the proposed drought temperature management measures under the proposed action would improve Reclamation's ability to manage water temperatures in the lower American River and meet water temperature requirements for Fall-run Chinook Salmon during drought conditions and improve conditions for this life stage. Therefore, it is concluded that this proposed action would likely beneficially affect the egg-to-emergence life stage of Fall-run Chinook Salmon in the lower American River by reducing the effects of drought conditions on water temperatures.

5.14.5.5.9.2 Rearing to Outmigrating Juveniles

Reclamation proposes to evaluate and implement alternative shutter configurations at Folsom Dam under the proposed action to allow temperature flexibility in severe droughts, thereby reducing water temperatures in the lower American River. A few Juvenile Fall-run/Late Fall-run Chinook Salmon may be present in the American River year-round since they may reside in freshwater for 12 to 16 months (Tables 5.14-1 and 5.14-2), however, some migrate to the ocean as young-of-the-year in the winter or spring months within eight months of hatching (CALFED 2000). The implementation of the proposed drought temperature management measures under the proposed action would improve Reclamation's ability to manage water temperatures in the lower American River and meet water temperature requirements for rearing Fall-run/Late Fall-run Chinook Salmon during drought conditions and improve conditions for this life stage.

5.14.5.5.9.3 Adult Migration from Ocean to Rivers

Adult Central Valley Fall-run/Late Fall-run Chinook Salmon are present in summer through winter and in relatively high abundance primarily in October through March, spawning soon after entering their natal streams (Tables 5.14-1 and 5.14-2) (Moyle 2002; Yoshiyama et al. 1998). Central Valley Fall-run/Late Fall-run Chinook Salmon require cool freshwater. In the Central Valley, fall water temperatures are reportedly suitable for Chinook Salmon only above 150 to 500-m elevations, and most of that high elevation habitat is now upstream of impassable dams (Schick et al. 2005). The implementation of the proposed drought temperature management measures under the proposed action would improve Reclamation's ability to manage temperatures in the lower American River and meet water temperature requirements for Chinook Salmon during drought conditions and improve conditions for this life stage. Therefore, it is concluded that this proposed action would likely beneficially affect this life stage of Fall-run/Late Fall-run Chinook Salmon in the lower American River by reducing the effects of drought conditions on water temperatures.

5.14.5.5.9.4 Adult Holding in Rivers

The implementation of the proposed drought temperature management measures under the proposed action would improve Reclamation's ability to manage temperatures in the lower American River and meet water temperature requirements for Fall-run/Late Fall-run Chinook Salmon holding in the lower American River during drought conditions and improve conditions for this life stage.

5.14.5.5.10 Stanislaus River Spawning and Rearing Habitat

5.14.5.5.10.1 Eggs to Fry Emergence

Habitat restoration activities under the proposed action would benefit Fall-run Chinook Salmon by increasing available spawning habitat (by placement of additional spawning gravel). The plot below shows the available spawning habitat in the Stanislaus River, along with the needed habitat to support various population sizes. Also shown is the CVPIA doubling goal for Fall-run Chinook Salmon the Stanislaus River.

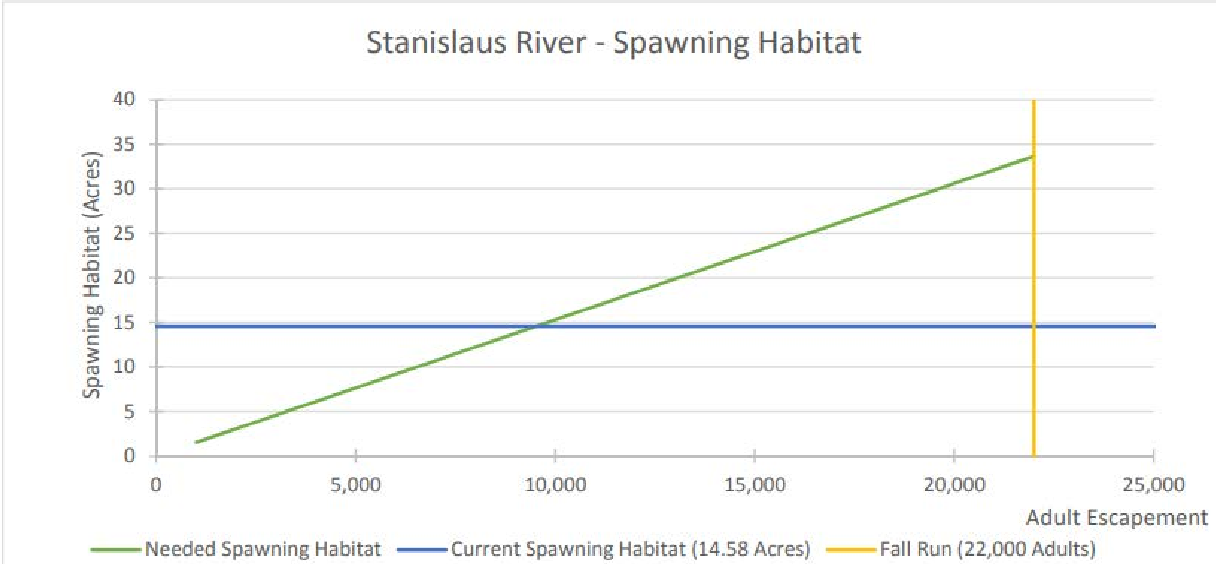


Figure 5.14-21. Estimated Chinook spawning habitat needed in the Stanislaus River to support the range of escapement sizes (CVPIA 2018).

The construction activities associated with spawning habitat restoration are not expected to affect eggs and emerging fry due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures* and implementation of an in-water work window (July 15 through October 15th). The in-water work window will completely avoid the eggs and emerging fry life stage, as Fall-run/Late Fall-run Chinook Salmon typically spawn between October through November, and fry emerge between December and March (Table 5.14-2).

5.14.5.5.10.2 Rearing to Outmigrating Juveniles

Habitat restoration activities would benefit Fall-run/Late Fall-run Chinook Salmon by increasing available rearing habitat. Reclamation expects that the additional rearing habitat would support the progeny of an additional 2,800 adult salmon. The plot below shows the available rearing habitat in the Stanislaus River, along with the needed habitat to support various population sizes. Also shown is the CVPIA doubling goal for Fall-run Chinook Salmon in the Stanislaus River. The creation of side channel and rearing habitat would increase the quality and quantity of off channel rearing (and spawning areas). The habitat restoration activities would improve the riparian habitat available for, Fall-run Chinook Salmon rearing.

The benefit of the habitat restoration activities within the Stanislaus River would yield increasing riparian vegetation, which provides:

- instream object and overhanging object cover;
- new shaded riverine habitat; and
- additional area for food source.

The creation of side-channel and floodplain rearing habitat would also increase the aquatic habitat complexity and diversity within the Stanislaus River and provide additional predator escape cover.

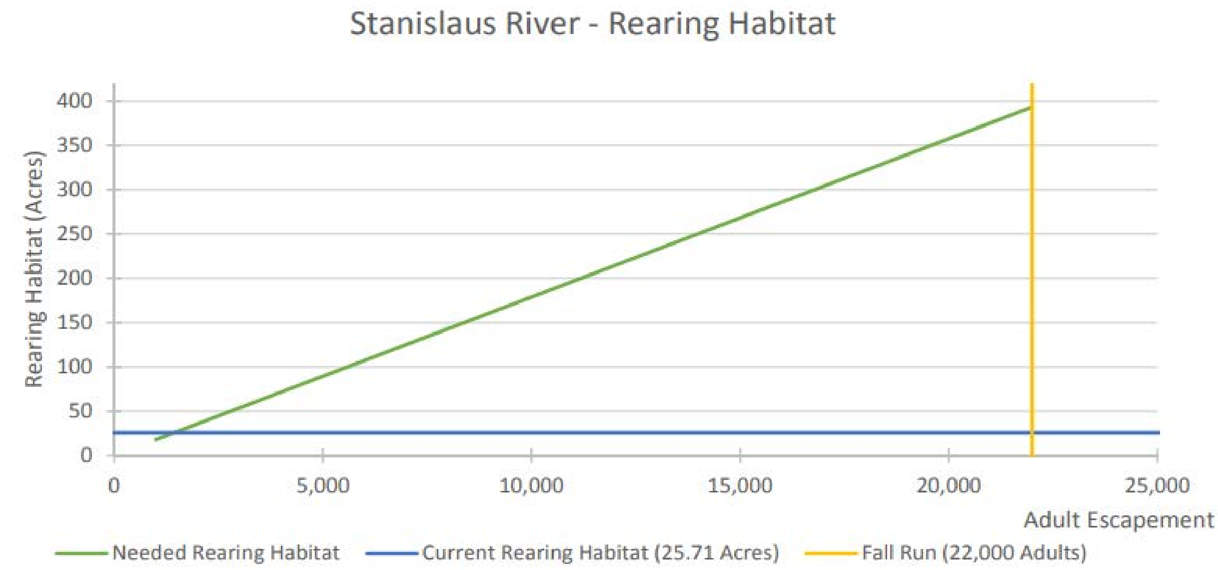


Figure 5.14-22. Estimated Chinook rearing habitat needed in the Stanislaus River to support the range of escapement sizes (CVPIA 2018).

The construction activities associated with spawning and rearing habitat restoration under the proposed action are not expected to affect rearing and outmigrating Fall-run Chinook Salmon due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures* and implementation of an in-water work window (July 15 through October 15).

5.14.5.5.10.3 Adult Migration from Ocean to Rivers

Habitat restoration activities under the proposed action would benefit Fall-run/Late Fall-run Chinook Salmon by increasing available spawning habitat.

The construction activities associated with spawning habitat restoration are not expected to affect immigrating Fall-run/Late Fall-run Chinook Salmon to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. Additionally, per Appendix E, Reclamation will implement an in-water work window of July 15 through October 15 to avoid effects to immigrating individuals.

5.14.5.5.10.4 Adult Holding in Rivers

Habitat restoration activities would benefit Fall-run/Late Fall-run Chinook Salmon by increasing available spawning habitat.

The construction activities associated with spawning habitat restoration are not expected to affect adults holding Fall-run/Late Fall-run Chinook Salmon in the Stanislaus River due to the implementation of general avoidance and minimization measures identified in Appendix E, *Avoidance and Minimization Measures*. Additionally, per Appendix E, Reclamation will implement an in-water work window of July 15 through October 15 to reduce further effects to holding individuals.

5.14.5.5.11 <u>Lower SJR Habitat</u>

Under the proposed action, restoration of lower San Joaquin River spawning and rearing habitat for salmonids, including a large extent of floodplain habitat, would have the potential to increase rearing habitat for Fall-run Chinook Salmon on the San Joaquin River. Increased rearing habitat provides cover from predators and habitat complexity as well as food. Construction impacts to Fall-run Chinook salmon due to potential outmigrating juveniles would be minimized with AMMs.

5.14.5.5.12 <u>Tracy Fish Facility Improvements</u>

5.14.5.5.12.1 Rearing to Outmigrating Juveniles in the Bay-Delta

A small proportion of juvenile Fall-run Chinook Salmon are expected to be exposed to the Tracy Fish Facility improvements (Zeug and Cavallo 2014). However, for fish that arrive at the facility, the proposed improvements are likely to increase survival through the facility.

Few juvenile Fall-run or Late-Fall run Chinook Salmon would be expected to be exposed to construction of the CO2 injection device proposed for the Tracy Fish Facility Improvements, based on lack of observed salvage during the August–October in-water work window (Figures WR_salvage_unclipped_date, WR_salvage_clipped_date, and WR_salvage_clipped_CWT_race in Appendix F, *Juvenile Salmonid Monitoring, Sampling, and Salvage Summary from SacPAS*). To the extent that the construction affects the ability of juvenile Fall-run, and Late-Fall run Chinook Salmon to be efficiently salvaged (as part of the entrainment risk habitat attribute in the SAIL conceptual model; Figure WR_CM4), there could be a minor effect to a small number of individuals, although risk would be minimized through appropriate AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.14.5.5.13 <u>Suisun Marsh Salinity Control Gates Operation</u>

5.14.5.5.13.1 Rearing to Outmigrating Juveniles in the Delta

Under the proposed action, Reclamation would operate the SMSCG to provide food for Delta Smelt in Suisun Marsh. Operation of the SMSCG from June through October under the proposed action coincides with a portion of the downstream migration of Fall-run Chinook Salmon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. However NMFS (2009) determined that operation of the SWSCG is unlikely to impede migration of juvenile salmonids or produce conditions that support unusually high numbers of predators.

5.14.5.5.13.2 Adult Migration from Ocean to Rivers

Operation of the SMSCG from June through October under the proposed action coincides with a portion of the upstream migration of Fall-run Chinook Salmon. Montezuma Slough provides an alternative route to their primary migration corridor through Suisun Bay. Due to their strong swimming ability and migratory route, the operation of the Suisun Marsh Salinity Control Gate is unlikely to impede the migration of adult salmonids or produce conditions that support unusually high numbers of predators.

5.14.5.5.14 Summer-Fall Delta Smelt Habitat

Some juvenile Fall-run Chinook Salmon are anticipated in the Delta in the summer and fall, during the time period that Reclamation would be operating for Summer-Fall Delta Smelt habitat. However, actions Reclamation would take under this are unlikely to affect Fall-run Chinook Salmon.

5.14.5.5.15 Clifton Court Predator Management

Predator control efforts in Clifton Court Forebay under the proposed action could reduce pre-screen loss of juvenile Fall-run Chinook Salmon entrained into Clifton Court Forebay. Larger proportions of Late Fall-run Chinook Salmon are lost at the facilities and this action would have a larger beneficial effect for this run.

5.14.5.5.16 Sacramento Deepwater Ship Channel

Moderate to high proportions of juvenile Fall-run Chinook Salmon are expected to be exposed to the Sacramento Deepwater Ship Channel (SDWSC) conservation measure under the proposed action. This conservation measure would hydrologically connect the Sacramento River with the SDWSC via the Stone Lock facility from mid-spring to late fall (Wood Rodgers 2018), allowing food to enter the Delta and an alternate migration pathway. Juvenile Fall-run Chinook Salmon abundance in the Delta is moderate in peaks in April and May (Table 5.14-1). Juvenile Fall-run Chinook Salmon passing the Stone Lock facility when there is a hydrologic connection between the waterways could potentially be entrained into the SDWSC. Estimates of salmonid survival in the SDWSC are not available to compare with rates in the Sacramento River route. However, fish entering the SDWSC would not be exposed to entrainment into the interior Delta through the DCC or Georgiana Slough which would provide a benefit if survival rates are similar.

No San Joaquin River-origin Fall-run are expected to be exposed to the Sacramento Deepwater Ship Channel.

5.14.5.5.17 North Delta Food Subsidies/Colusa Basin Drain

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall, and possibly could contribute food to increase food web productivity during Fall-run Chinook Salmon juvenile outmigration.

5.14.5.5.18 Suisun Marsh Roaring River Distribution System Food Subsidies Study

Under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG would occur in summer/fall and therefore would have limited effects on Spring-run Chinook Salmon, who are in the Delta between January – February for adults, and November through June for juveniles, with a peak of juvenile migration from March to April.

5.14.5.5.19 Tidal and Channel Margin Restoration

A large proportion of juvenile Fall-run and Late-Fall run Chinook Salmon are expected to be exposed to 8,000 acres of tidal habitat restoration in the Delta. Tidal habitat restoration is expected to benefit juvenile Fall-run/Late Fall-run Chinook Salmon in several aspects represented by the Winter-run conceptual model (5.6-4) including, increased food availability and quality and refuge habitat from predators. These benefits can manifest in higher growth rates and increased survival through the Delta. Migration through the Delta represents a short period in the migration of juvenile and Late Fall-run Chinook Salmon.

Few juvenile Fall-run or Late-Fall run Chinook Salmon would be expected to be exposed to the effects of construction of 8,000 acres of tidal habitat restoration, based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Tables 5.14-1 and 5.14-2). Individuals being exposed to construction could experience risk of potential effects similar to those suggested in recent restoration projects such as the Lower Yolo Restoration Project (NMFS 2014). This includes temporary loss of aquatic and riparian habitat leading to increased predation, increased water temperature, and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance (e.g., gill damage and reduced ability to take in oxygen, increasing metabolic cost), indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Many of these are elements highlighted in the SAIL conceptual model (Figure 5.6-4). The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*).

5.14.5.5.20 Predator Hot Spot Removal

Predator hot spot removal under the proposed action is primarily focused on providing positive effects to downstream-migrating juvenile salmonids including Fall-run and Late-Fall run Chinook Salmon. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated are in the primary migratory routes of juvenile Fall-run Chinook. All hotspots are limited in scale relative to overall available habitat and previous research has not found a consistent positive effect of predator removal on juvenile salmon survival (Cavallo et al. 2012, Michel et al. 2017, Sabal et al. 2017).

5.14.5.5.21 San Joaquin River Scour Hole Predation Reduction

Fall-run Chinook salmon outmigrating from the San Joaquin River are exposed to predation at the junction of the San Joaquin River and Old River. This action would reduce predation at this site, improving juvenile San Joaquin origin Fall-run Chinook salmon survival.

Few Fall-run Chinook Salmon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction to adjust bathymetry would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.14.5.5.22 Knight's Landing Outfall Gates Fish Barrier

Reclamation and DWR's fish barrier at the Knight's Landing Outfall Gates would prevent possible entrainment of salmonids into the Colusa Basin Drain. This project would reduce entrainment and therefore increase survival of Fall-run Chinook salmon adults.

Few Fall-run Chinook salmon are expected to be exposed to in-water construction impacts due to observance of species protective work windows. Impacts of construction would be minimized in accordance with Appendix E, Avoidance and Minimization Measures.

5.14.5.5.23 Delta Cross Channel Gate Improvements

Few Fall-run and Late-Fall run Chinook Salmon are expected to be exposed to improvements to the Delta Cross Channel. Seasonal closure periods would still be in place to protect migrating salmonids. Potential diurnal operation during closure periods could increase exposure of Fall-run and Late-Fall run juvenile to entrainment into the interior Delta. However, improved biological and physical monitoring associated with improvements would likely minimize potentially increased entrainment. Greater operational flexibility and increased gate reliability resulting from improvements would reduce the risk of gate failure that could result in higher rates of entrainment.

5.14.5.5.24 Tracy Fish Facility Improvements

Although these actions could positively affect juvenile Fall-run Chinook Salmon through greater salvage efficiency, only small proportions of Fall-run Chinook Salmon are lost at the CVP (Zeug and Cavallo 2014).

5.14.5.5.25 Skinner Fish Facility Improvements

Skinner fish facility improvements from predator control efforts to reduce predation following entrainment into Clifton Court Forebay could reduce pre-screen loss of Fall-run/Late Fall-run juvenile Chinook Salmon entrained into Clifton Cout Forebay. However, only small proportions of Fall-run Chinook Salmon are lost at the SWP (Zeug and Cavallo 2014). Larger proportions of Late Fall-run Chinook Salmon are lost at the facilities and this action would have a larger effect for this run.

5.14.5.5.26 Delta Fishes Conservation Hatchery

Potential effects of the Delta Fishes Conservation Hatchery include inadvertent propagation and release of nuisance species and reduced water quality resulting from hatchery discharge. Mitigation and minimization measures are detailed in the EIR/EIS for the facility (Horizon Water and Environment 2017) Potential exposure of juvenile Fall-run Chinook Salmon would be restricted to a small spatial area within the primary migration route.

As with the other proposed construction activities under the proposed action in the Bay-Delta, few juvenile Fall-run or Late-Fall run Chinook Salmon would be expected to be exposed to the effects of construction of the Delta Fishes Conservation Hatchery based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (Tables 5.14-1 and 5.14-2). The relatively few individuals occurring near the construction site could be subject to effects similar to those previously described for habitat restoration (e.g., temporary loss of habitat leading to predation, degraded water quality, reduced foraging ability caused by reduced visibility, noise-related delay in migration, and direct effects from contact with construction equipment or isolation/stranding within enclosed areas). The risk from these potential effects would be minimized through application of

AMMs (Appendix E, *Avoidance and Minimization Measures*). The application of AMMs will reduce effects, and the in-water construction is of a small scale.

5.14.5.6 Monitoring

Effects to Fall-run Chinook Salmon from monitoring would be similar to those discussed for Winter-run and Spring-run Chinook Salmon, as discussed in those sections.

5.15 Effects on Southern Resident Killer Critical Habitat

Critical habitat for the Southern Resident Killer Whale was designated in November 2006 (71CFR 229). Three specific areas are designated, (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, which comprise approximately 2,560 square miles (6,630 sq km) of marine habitat. The designation includes the following PBFs essential for conservation of the Southern Resident Killer Whale:

1. Water quality to support growth and development; and
2. Prey species of sufficient quantity, quality, and availability to support individual growth, reproduction, and development, as well as overall population growth; and
3. Passage conditions to allow for migration, resting, and foraging.

Southern Resident Killer Whales rely on 23 different species as prey, with salmon being the preferred prey (71 CFR 229). Given that critical habitat occurs within Puget Sound and the Strait of Juan de Fuca, the majority of prey consumed within critical habitat consists of populations native to rivers tributary to that habitat. The precise proportion of Central Valley-origin Chinook salmon consumed in the Southern Resident Killer Whale diet when they are feeding within critical habitat has not been determined, but fewer than 10% of Central Valley-origin Chinook salmon are collected from as far north as Tillamook Head on the northern Oregon coast (Satterthwaite et al. 2013). Southern Resident Killer Whale critical habitat is several hundred kilometers north of that area. The principal source of prey for Southern Resident Killer Whale within critical habitat is Fraser River-origin Chinook salmon, with chum salmon also important for fall foraging in Puget Sound (National Marine Fisheries Service 2014b).

In summary, the proposed action has no potential to affect water quality within Southern Resident Killer Whale critical habitat. The proposed action is unlikely to affect the production of Central Valley–origin Chinook salmon; and the proportion of Central Valley-origin Chinook salmon occurring within designated critical habitat is very low and thus has negligible potential to affect the Southern Resident Killer Whale prey base within critical habitat.

5.16 Delta Smelt

The effects of seasonal operations in the proposed action, as compared to without action, include entrainment into the central and south Delta, salvage loss in the export facilities, lower Delta outflow during the spring, and higher Delta outflow in the summer and fall. The effects of lower flows reduce food production and transport. OMR management as part of the proposed action Core Water Operation seeks to minimize and/or avoid entrainment risk and salvage loss. The proposed action includes the Summer-Fall Delta Smelt Habitat action, Suisun Marsh Salinity Control Gate Operation, and restoration of tidal marsh habitat. These conservation measures seek to provide a low salinity zone within productive

Delta Smelt habitat. Conservation measures under the proposed action also include food subsidy studies aiming to meet the needs of Delta Smelt for food production and retention that would otherwise occur in lost habitat.

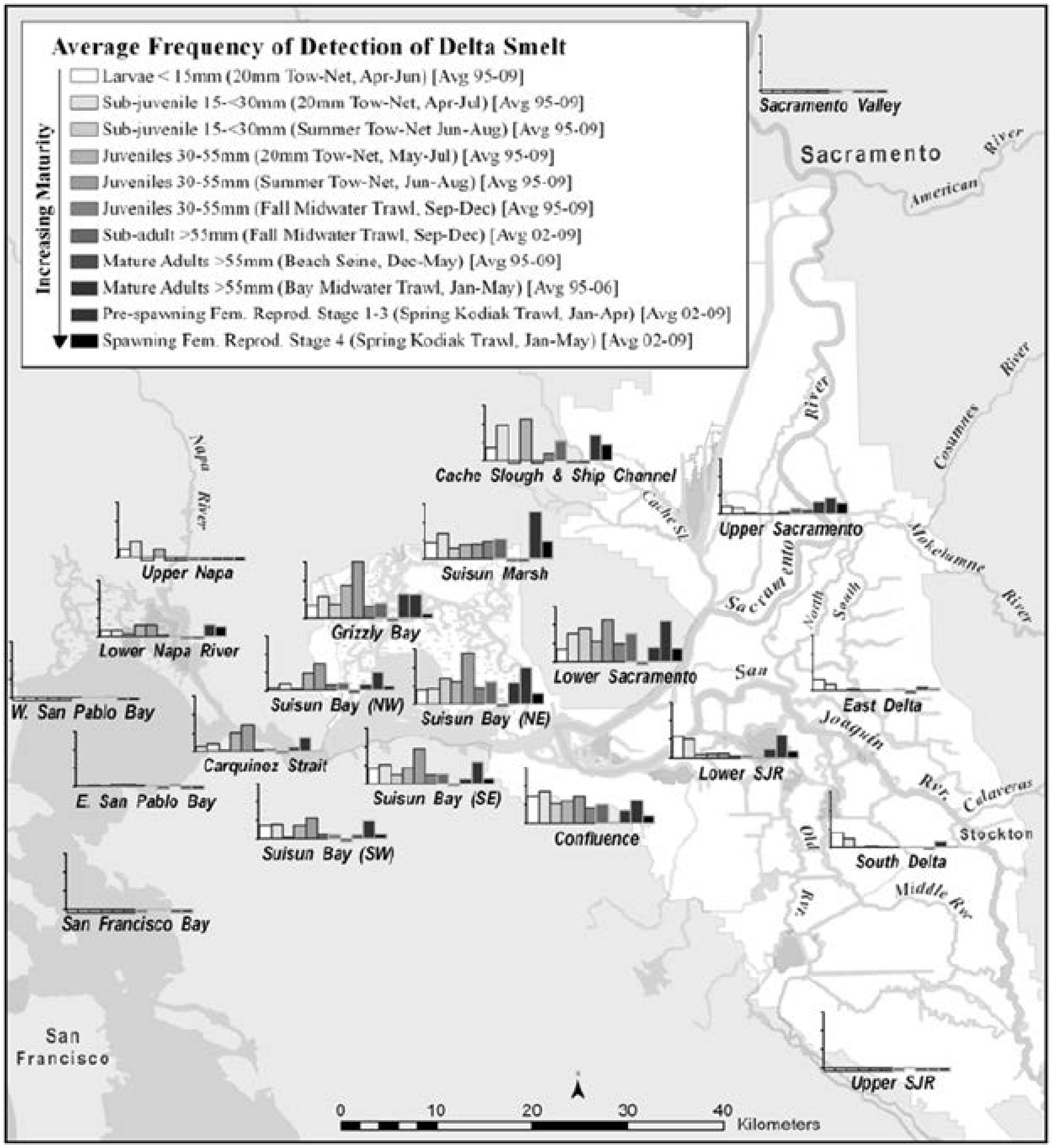
OMR management for Delta Smelt under the proposed action establishes protective criteria to avoid entrainment based on work from the Delta Smelt Scoping Team under the Collaborative Science and Adaptive Management Team. Additional protective measures occur when environmental criteria indicate that entrainment is more likely. Enhanced monitoring in real-time and predictive tools provide additional information that allows for more flexible water operations.

The legacy of levees and dredging of channels reduced the availability of high quality habitat to areas within a “north Delta arc” (habitats within the north portion of the Delta along the Sacramento River) and downstream of the confluence of the Sacramento and San Joaquin Rivers into Suisun Marsh and Suisun Bay. The absence of habitat throughout the Delta requires higher Delta outflow to maintain suitable water quality in the remaining areas that Delta Smelt can rear. The proposed action is structured to respond to this degraded environmental baseline. Management of the low salinity zone into the confluence provides low salinity water quality and food export into the remaining areas of high productivity. Operation of the Suisun Marsh Salinity Control Gate provides low salinity habitat at a lower water cost. Tidal habitat restoration increases the areas of high quality habitat. Food subsidy projects address stresses on populations due to food limited conditions in the absence of productive habitat.

Other stressors continue to impact Delta Smelt including contaminants, invasive species and warm water temperatures. These factors will continue to reduce the ability of Delta Smelt to reproduce and rebuild populations. Reintroduction from the U.C. Davis Fish Conservation and Culture Laboratory jump starts rebuilding the population to buffer against external factors. In the long-term, the Delta Fish Species Conservation Hatchery under the proposed action can support the population.

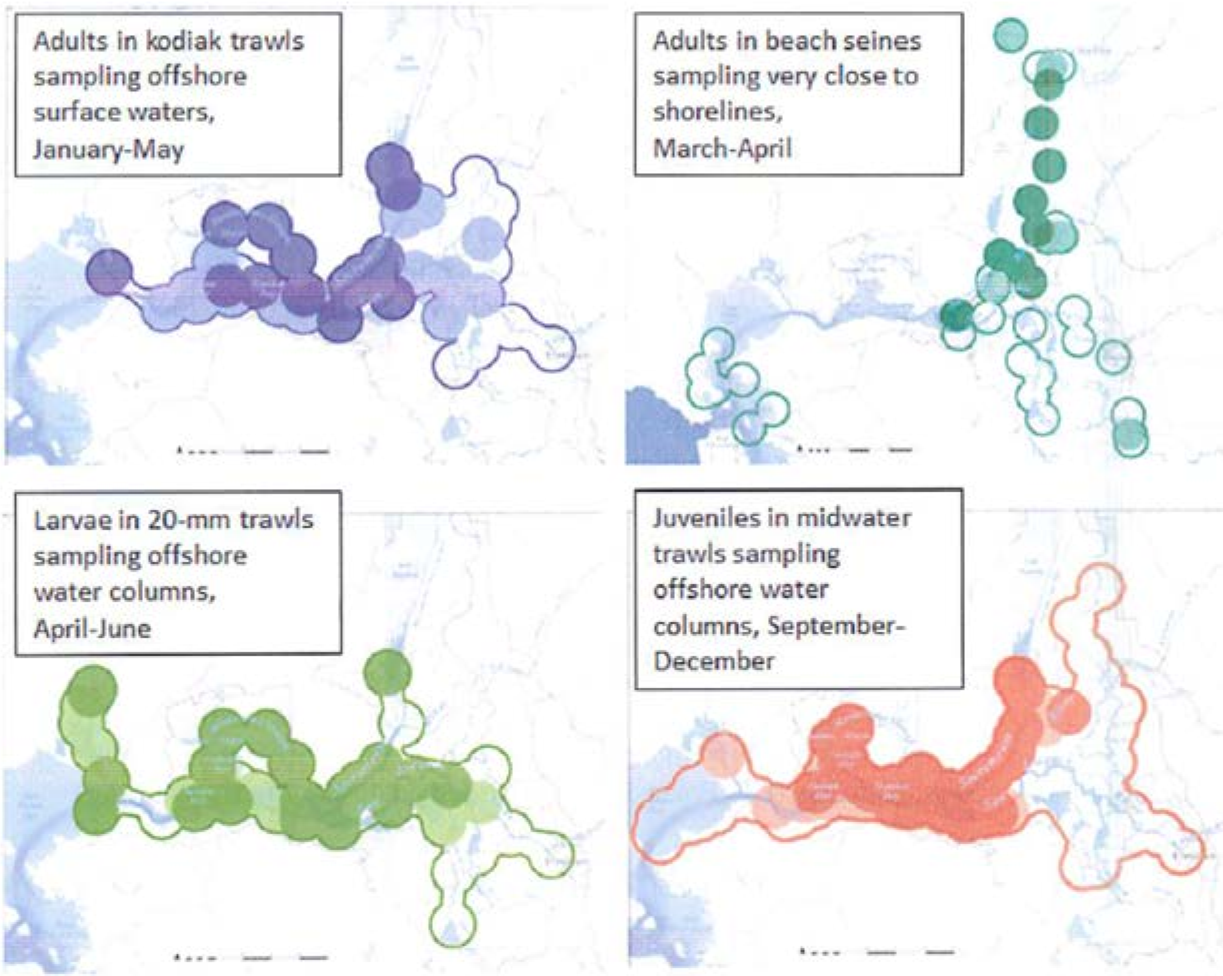
5.16.1 Lifestage Timing and Distribution

The effect analysis considers where the proposed action overlaps with the life stage timing and distribution of Delta Smelt in the action area, as illustrated in Figures 5.16-1 and 5.16-2.



Source: Merz et al. (2011, p.178). Note: Regions where the average frequency of detection for a given life stage was zero are indicated by no data column being present. Regions that were not sampled for a given life stage are indicated by a data column suspended slightly below the x-axis. Y-axis ticks indicate frequencies of 0, 25, 50, 75, 100 percent.

Figure 5.16-1. Average Annual Percentage of Sampling Events Where Delta Smelt Were Observed by Life Stage and Region for Interagency Ecological Program Surveys.



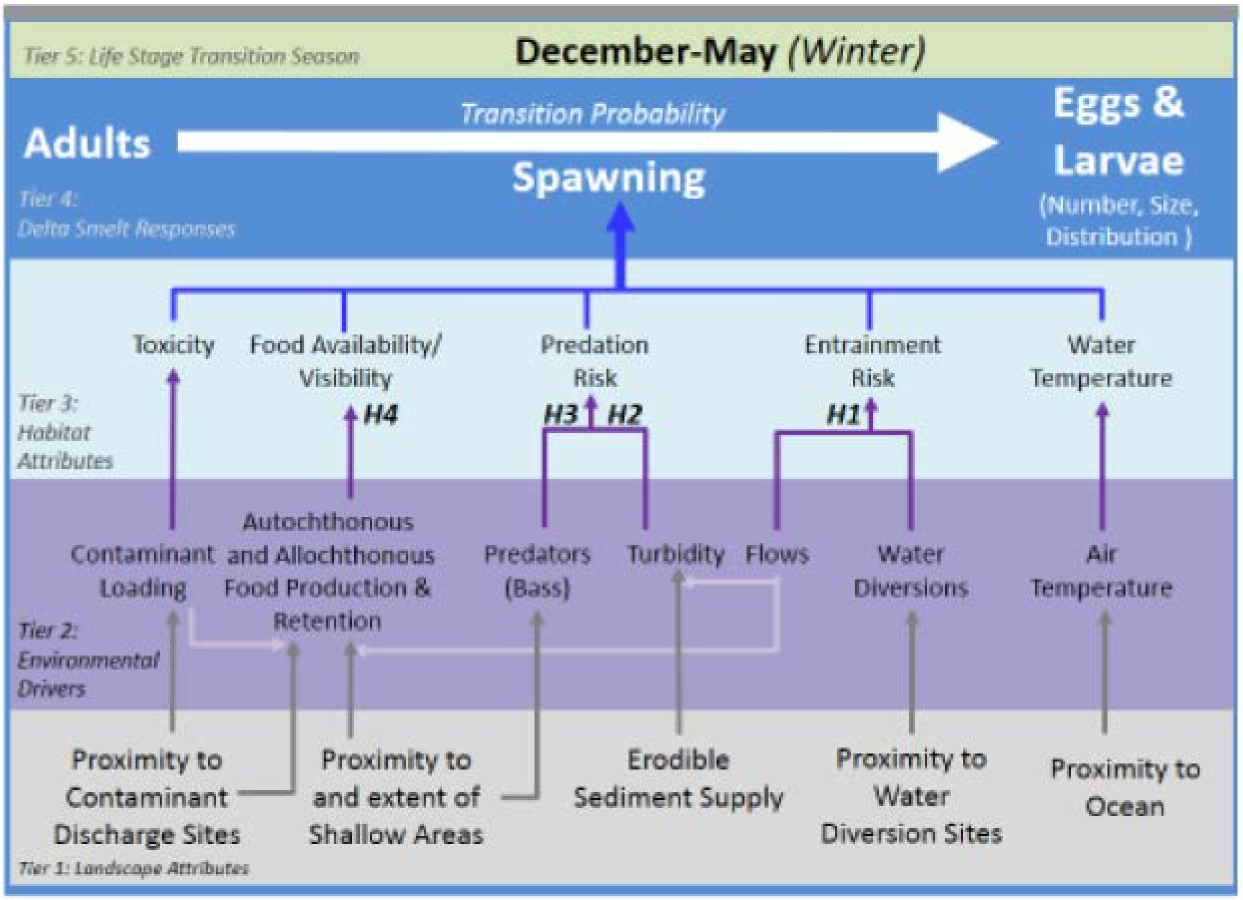
Source: USFWS (2017a, p.141). Note: The sampling regions covered by each survey are outlined. The areas with dark shading surround sampling stations in which 90 percent of the Delta Smelt collections occurred, the areas with light shading surround sampling stations in which the next 9 percent of delta smelt collections occurred.

Figure 5.16-2. Maps of Multi-Year Average Distributions of Delta Smelt Collected In Four Monitoring Programs

5.16.2 Conceptual Models

The IEP MAST (2015) developed "a general life cycle conceptual model for the four Delta Smelt life stages (adults, eggs and larvae, juveniles, and subadults) that includes stationary landscape attributes and dynamic environmental drivers, habitat attributes, and Delta Smelt responses".

A life stage transition in the December–May period addresses adults transitioning to eggs and larvae. Adults seldom if ever fully mature in December, but begin dispersing at that time. Additionally, there is limited impact to eggs/larvae until February. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.16-3.

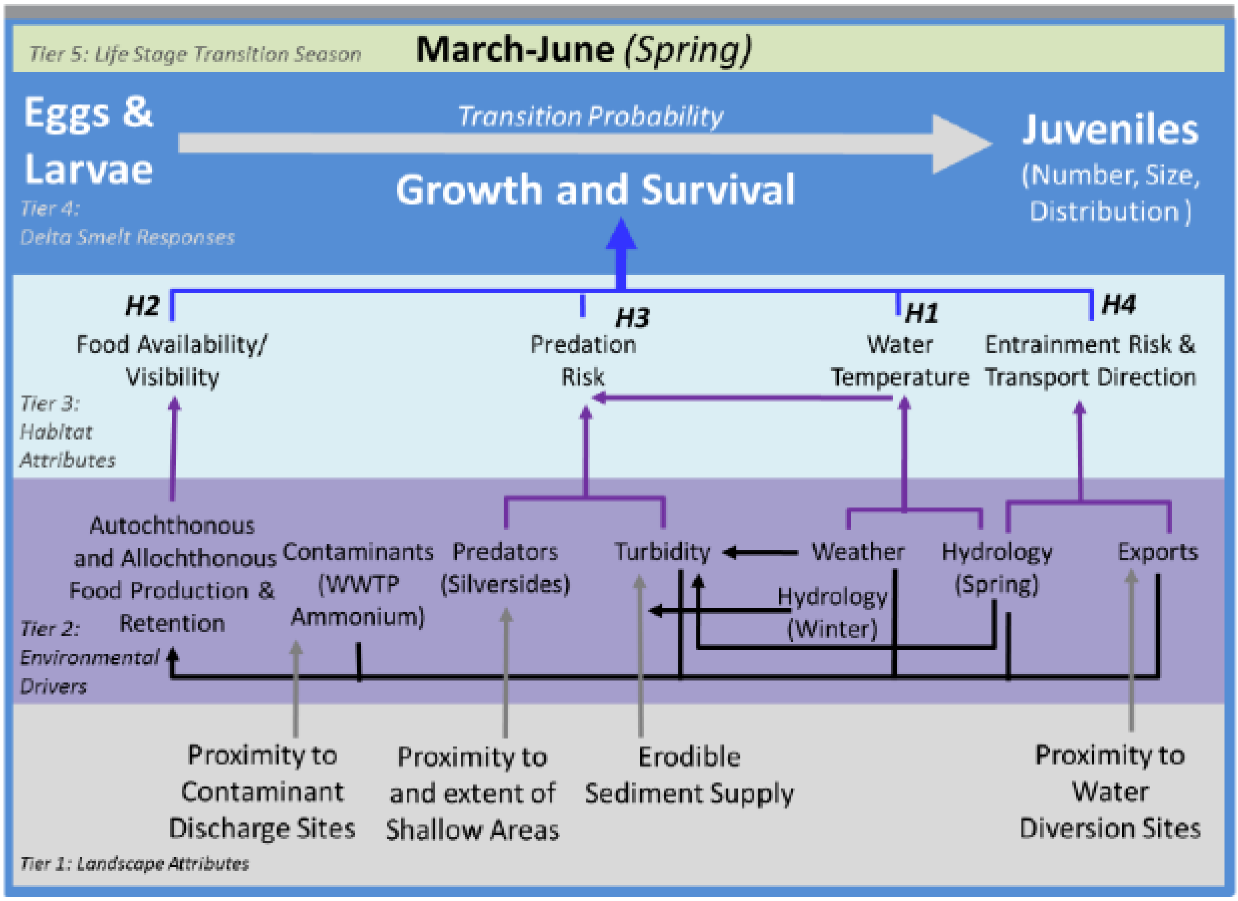


Source: IEP MAST (2015). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.16-3. Conceptual Model of Drivers Affecting the Transition of Delta Smelt Adults to Eggs/Larvae.

Adult habitat attributes and environmental drivers related to the proposed action are primarily entrainment risk due to exports and food availability.

A life stage transition in the March–June period address eggs/larvae transitioning to juveniles. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.16-4.

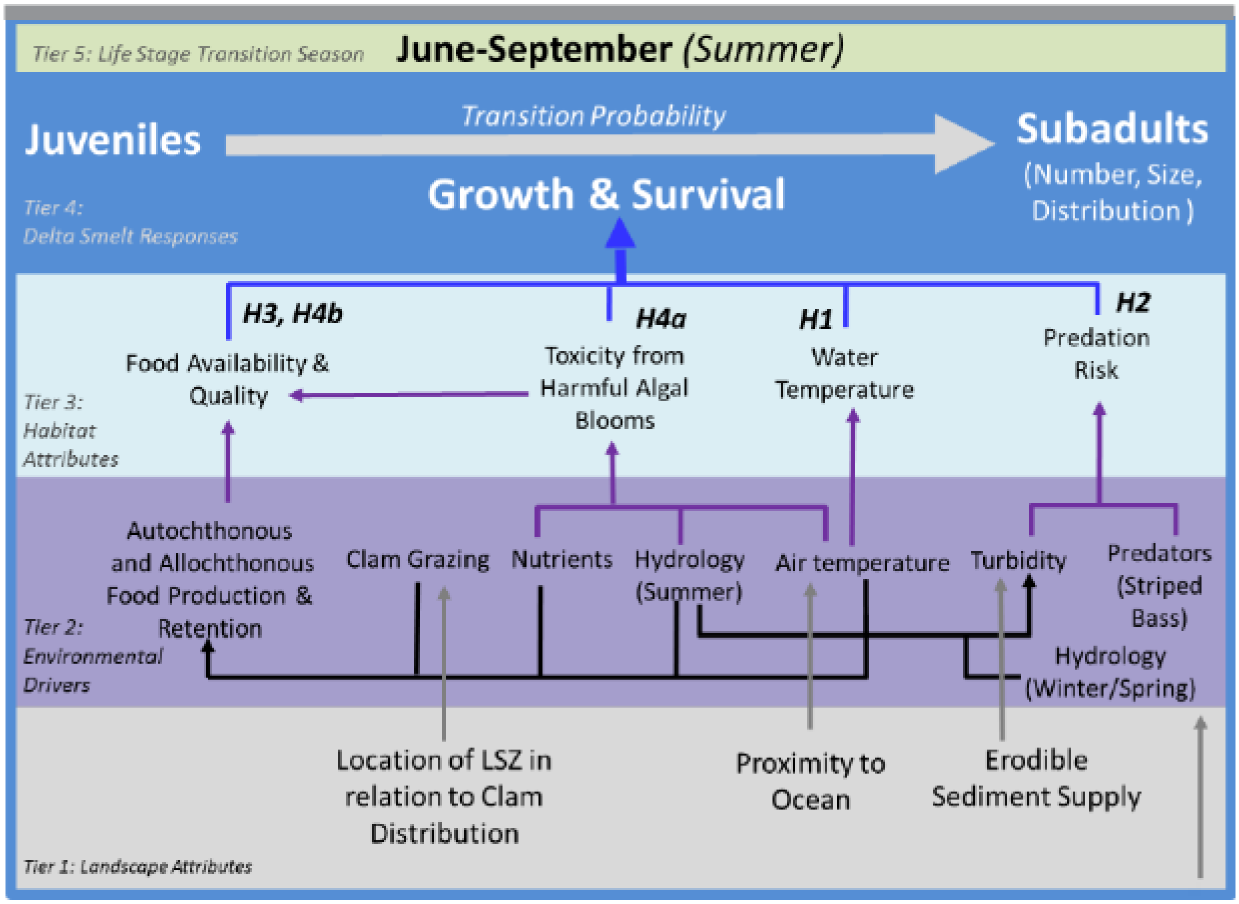


Source: IEP MAST (2015). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.16-4. Conceptual Model of Drivers Affecting the Transition of Delta Smelt Eggs/Larvae to Juveniles.

Larvae habitat attributes and environmental drivers related to the proposed action are primarily food availability from food production and retention and entrainment risk due to exports.

A life stage transition in the June–September period addresses juveniles transitioning to subadults. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.16-5.

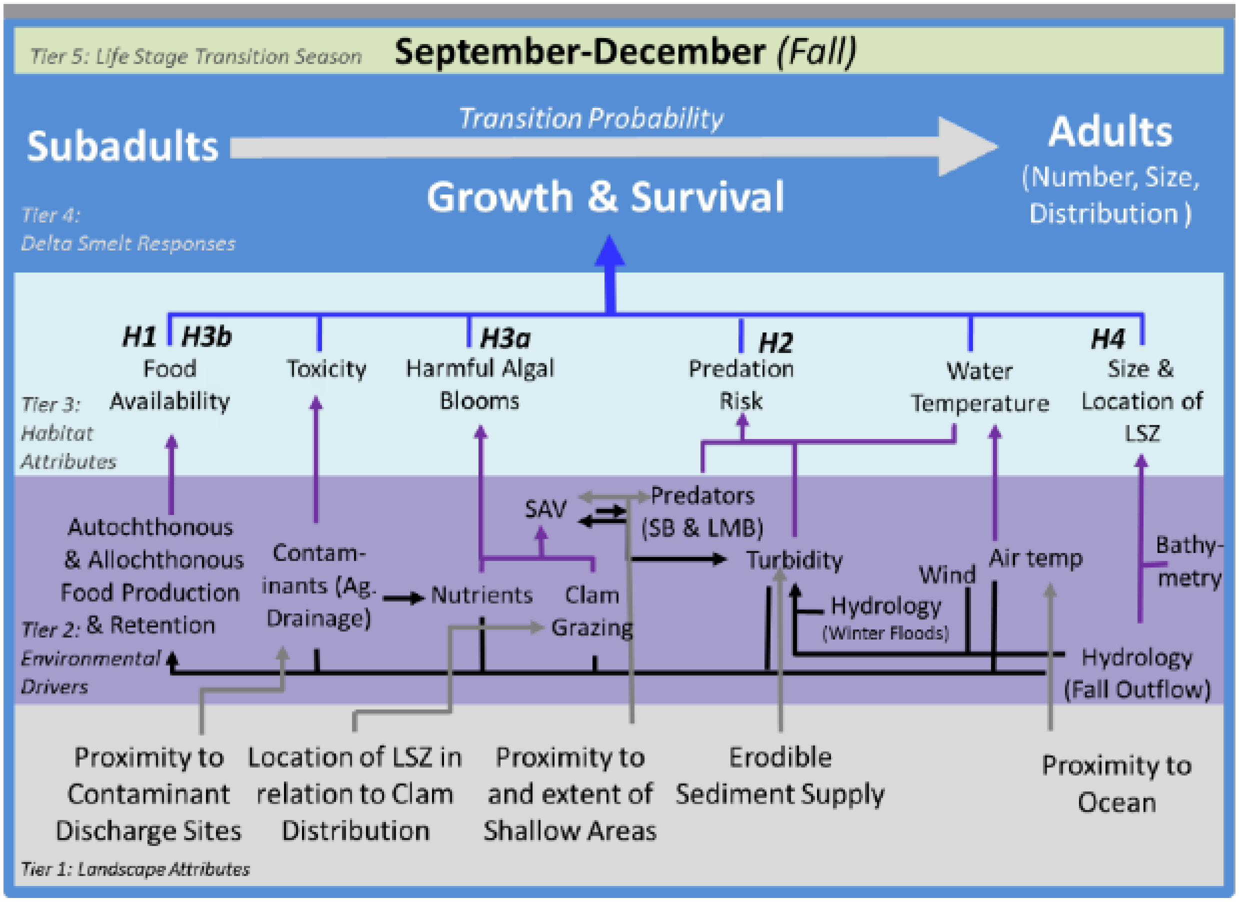


Source: IEP MAST (2015). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.16-5. Conceptual Model of Drivers Affecting the Transition of Delta Smelt Juveniles to Subadults.

Juvenile habitat attributes and environmental drivers related to the proposed action are primarily food availability from food production and retention, as well as sediment changes relating to predation, and algal blooms.

A life state transition in the September–December period addresses subadults transitioning to adults. The hypothesized landscape attributes, environmental drivers, and habitat attributes affecting this life stage transition are illustrated in Figure 5.16-6.



Source: IEP MAST (2015). Note: Hypotheses are referenced by the H-number for habitat attributes.

Figure 5.16-6. Conceptual Model of Drivers Affecting the Transition of Delta Smelt Subadults to Adults.

Subadult habitat attributes and environmental drivers relates to the proposed action are primarily food availability from food production and retention.

5.16.3 Effects of Operations and Maintenance

5.16.3.1 Seasonal Operations

The storage and diversion of water under the proposed action results in changes to the low salinity zone as represented in the position of X2. The position of X2 for the proposed action is further upstream than without action on average (Figure 5.16-7).

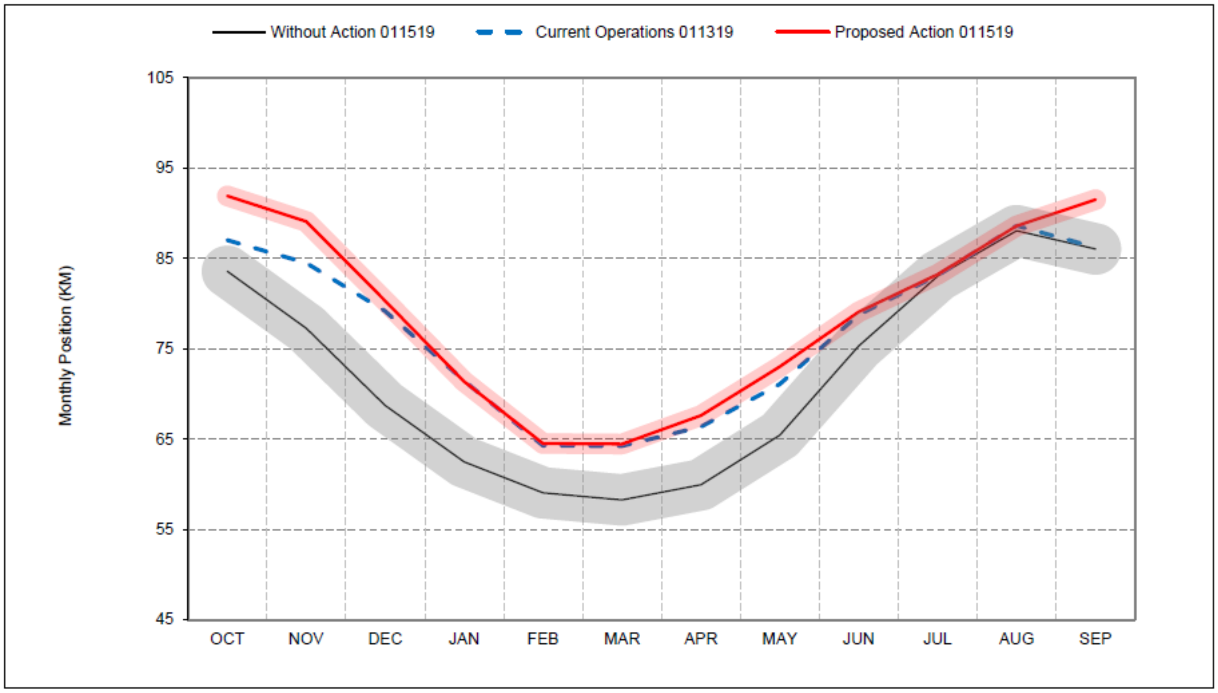


Figure 5.16-7. X2 Long-term Average Position by Month

The differences between the proposed action and without action depend upon the water year type and season (Figure 5.16-8 and 5.16-9).

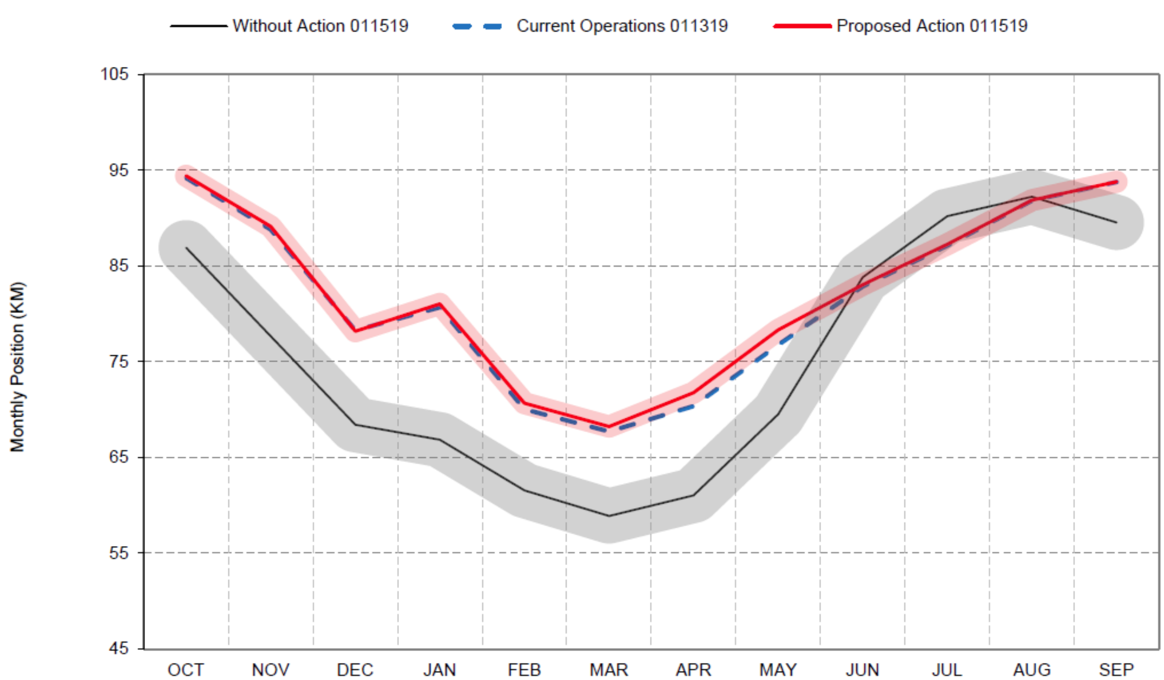


Figure 5.16-8. X2 Dry Year Position by Month

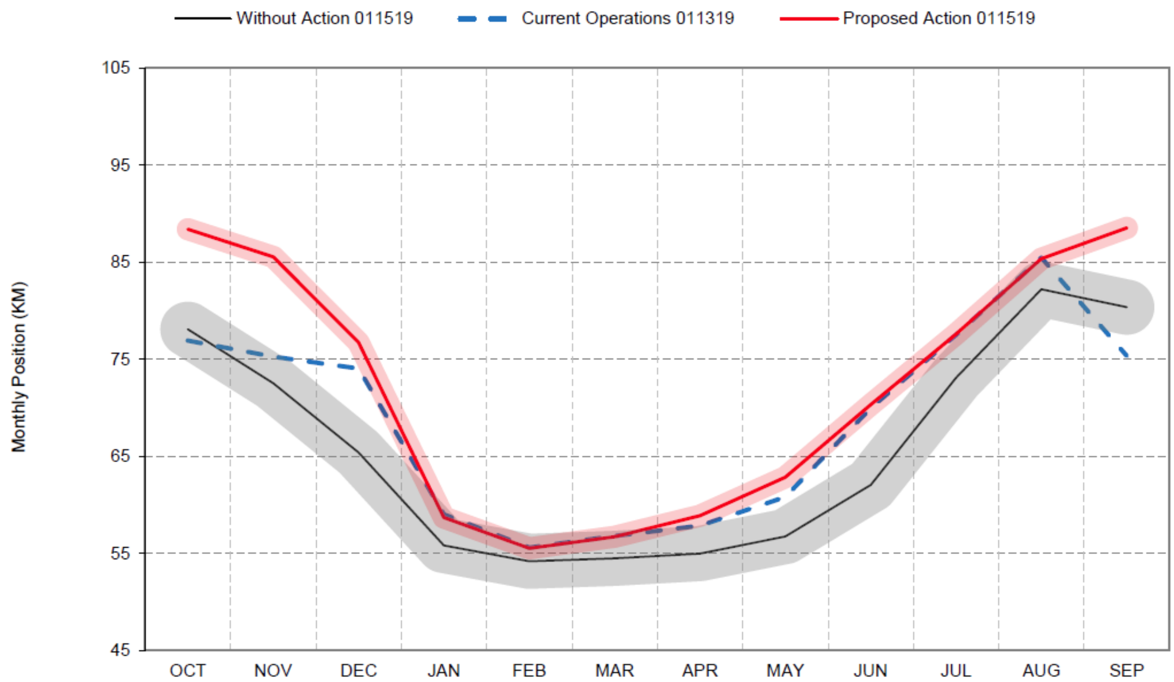


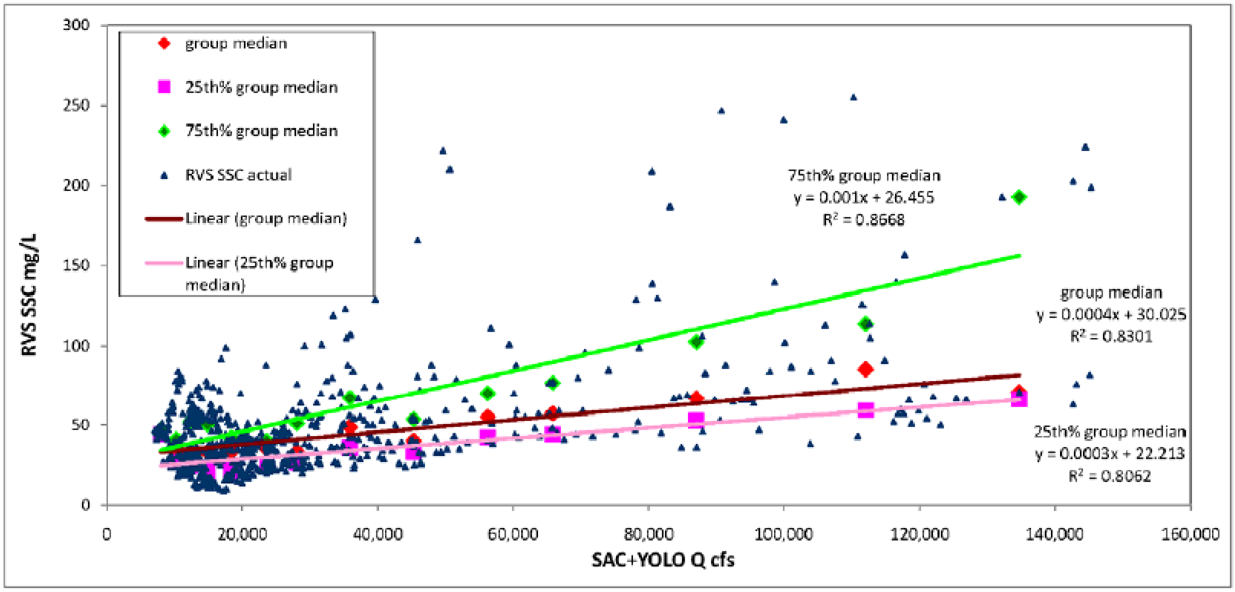
Figure 5.16-9. X2 Wet Year Position by Month

The effect of seasonal operations in the proposed action as compared to without action is to reduce the frequency of the low salinity zone being located within the productive habitat of Suisun Marsh and bay during some seasons and hydrologic year types, and increase the frequency in others.

5.16.3.1.1 Adults to Eggs and Larvae

5.16.3.1.1.1 Predation Risk

The IEP MAST (2015) conceptual model identifies predation risk as a habitat attribute affecting Delta Smelt egg survival (Figure 5.16-3). Flows interact with erodible sediment supply to affect turbidity. In general, greater turbidity is thought to lower the risk of predation on delta smelt. Large amounts of sediment enter the Delta from winter and spring storm runoff, with resuspension by tidal and wind action. A conceptual model of sedimentation in the Delta includes a submodel for river supply, which notes that dams and reservoirs have contributed to decreased sediment supply to the Delta (Schoellhamer et al. 2012, their Figure 4). Under the without action scenario, the dams and reservoirs continue to block sediment supply. Greater flow passing through reservoirs may pass greater amounts of sediment supply than under current operations and the proposed action. Cloern et al. (2011, their Figure S1) developed a rating curve of Sacramento River at Rio Vista suspended sediment concentration as a function of Sacramento River at Freeport + Yolo Bypass flows to the Delta (reproduced as Figure 5.16-10, below). Based on this curve, differences between the proposed action and without action scenarios in suspended sediment concentration as a function of mean winter-spring Rio Vista flows (Figures 32-9, 32-10, 32-11, 32-12, 32-13, and 32-14 in Appendix D, *Modeling*) are suggested to potentially be low during the high flow winter months (December–February), whereas differences in spring (April-May) could be greater.



Source: Cloern et al. (2011, their Figure S1).

Figure 5.16-10. Sediment Rating Curve for the Sacramento River at Rio Vista, 1998-2002

Available estimates of sediment removal by the south Delta export facilities are low, i.e., ~2% of sediment entering the Delta at Freeport in 1999–2002 (Wright and Schoellhamer 2005). These estimates were made at similar ratios of south Delta exports to Sacramento River + Yolo Bypass inflow as were modeled for the proposed action scenario suggesting that south Delta exports under the proposed action would remove only a small percentage of sediment entering the Delta. Given the limited expected difference in suspended sediment entering the Delta under the proposed action relative to without action, as well as the small percentage of sediment that would be expected to be removed by the south Delta export facilities, the potential negative effect of the proposed action on turbidity generally would be expected to be low. Per the MAST conceptual model, high turbidity relates to low predation risk for Delta Smelt. There is uncertainty in this conclusion given the complexity of sedimentation mechanisms in the Delta (Schoellhamer et al. 2012, their Figure 7), and the fact that quantitative analyses of the effects of exports on predation risk and turbidity have not been conducted (IEP MAST 2015, p.52).

5.16.3.1.1.2 Food Availability

Although food availability during other life stages has been suggested to be important from various statistical and modeling analyses (e.g., Miller et al. 2012; Kimmerer and Rose 2018), food availability is also posited by the IEP MAST (2015) conceptual model to affect the probability of adults spawning and transitioning to egg/larval production (Figure 5.16-3). The draft Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project EIS/EIR suggests that implementation of the Fremont Weir notch could increase food web productivity and therefore benefit growth and survival of Delta Smelt adults occurring downstream of the Yolo Bypass during the winter (DWR and Reclamation 2017, p.8-111 to p.8-112). This potential positive effect could improve the likelihood of adult Delta Smelt successfully spawning, per the mechanism described by the IEP MAST (2015) conceptual model (Figure 5.16-3). Flow is needed in the Yolo Bypass to create this food effect. The Yolo Bypass was assumed to be operational in this biological assessment, therefore all modeling scenarios show flow through Yolo Bypass, providing for this potential positive effect on Delta Smelt spawning (see Appendix D, *Modeling* for the mean modeled flow through Yolo Bypass in various months).

5.16.3.1.2 Eggs and Larvae to Juveniles (March – June)

5.16.3.1.2.1 Food Availability

The IEP MAST (2015) conceptual model suggests that south Delta exports could affect food availability for larval Delta Smelt (Figure 5.16-4), due to entrainment of food (Jassby and Cloern 2000; Kimmerer and Rose (2018 Trans Am Fish Soc)). There is a positive correlation between the density of the important Delta Smelt larval/juvenile zooplankton prey *Eurytemora affinis* in the low salinity zone and Delta outflow (as indexed by X2) during the spring (March–May; Kimmerer 2002, Greenwood 2018). Also, outflow is required to continuously flush *P. forbesi*, a relatively recent important Delta Smelt food source, from freshwater areas where it grows (Kimmerer et al. 2018 SFEWS) into Delta Smelt habitat, where it is eaten by larval Delta Smelt once it is abundant in May–June (Nobriga 2002; Slater and Baxter 2014). Therefore, the mechanism suggested by the conceptual model for the effects of south Delta exports on food availability could be related to hydrodynamic effects of Delta outflow. As shown in Figure X2_marmay, Delta outflow would be lower under the PA than the WOA scenario, and therefore X2 would be greater (i.e., further upstream). Based on the negative relationship between *Eurytemora affinis* density and X2, the modeling results suggest that food density for *Eurytemora affinis* under the proposed action could be negatively affected, which could potentially affect individual Delta Smelt growth and survival per the MAST conceptual model assuming other interactions in the relationship are fixed. As noted by Greenwood (2018, p.4-5), there is appreciable uncertainty in the predictions of *Eurytemora affinis* density as a function of X2, with 95% prediction intervals typically spanning several orders of magnitude. This correlation may be reflecting a water temperature influence of high flow conditions and the loss of mysids which were a historical predator whose abundance was high when flow was high.

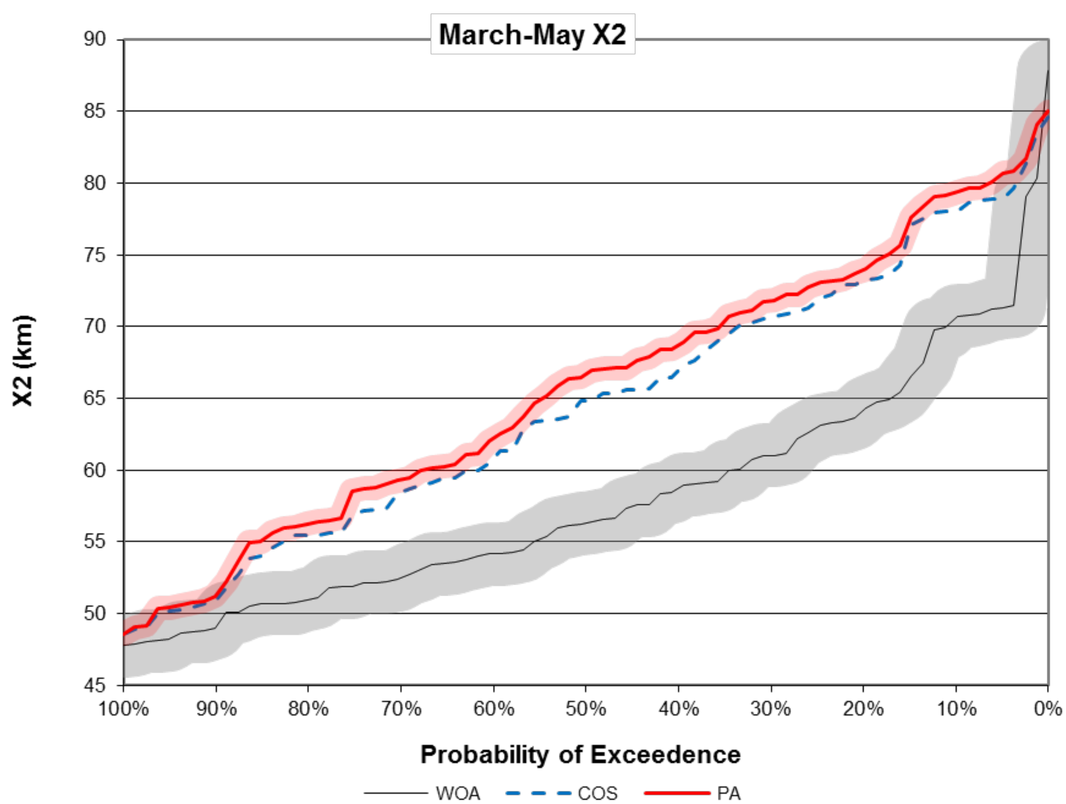


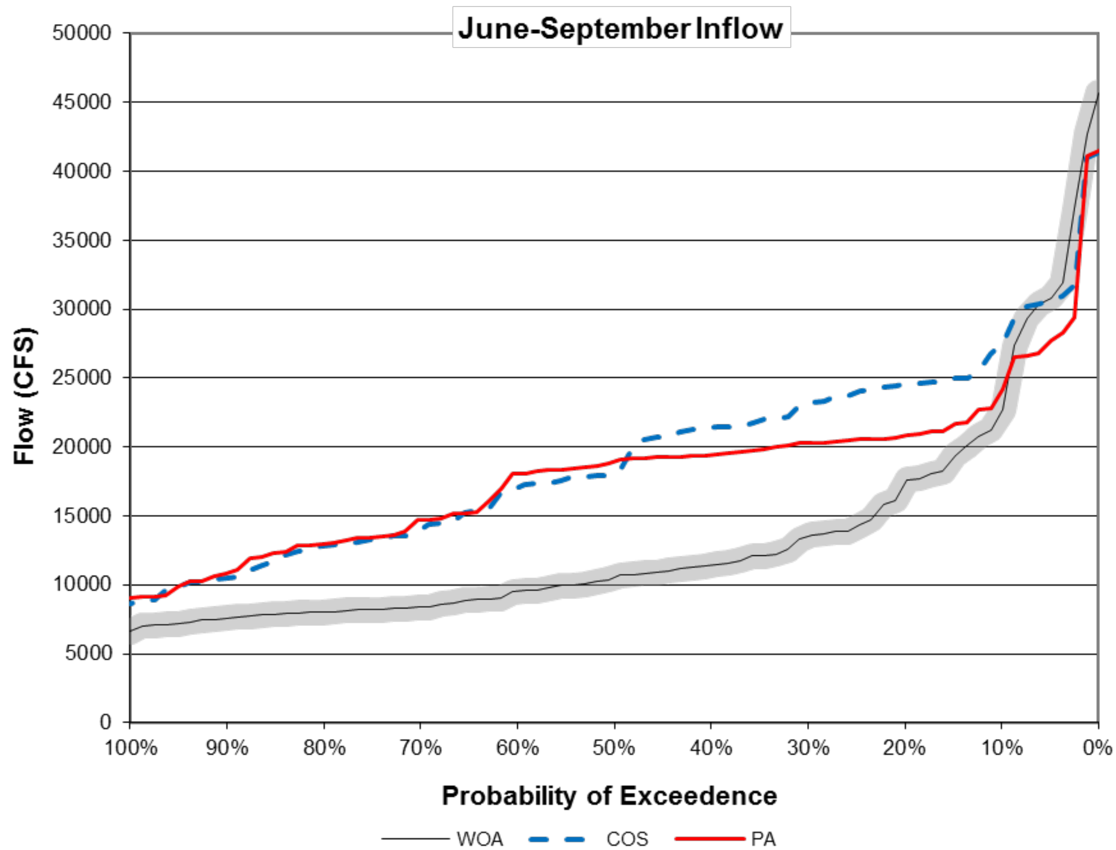
Figure 5.16-11. Mean Modeled X2 from CalSim, March–May

The proposed action includes construction of the rest of the 8,000 acres of tidal habitat restoration to offset potential negative effects on food availability based on the hydrodynamic influence of the south Delta export facilities during the spring larval and early juvenile Delta Smelt period (Kratville 2010); these factors could reduce the potential negative effects from the proposed action on larval/early juvenile Delta Smelt food availability. Under WOA, habitat restoration would not occur.

5.16.3.1.2.2 Predation Risk

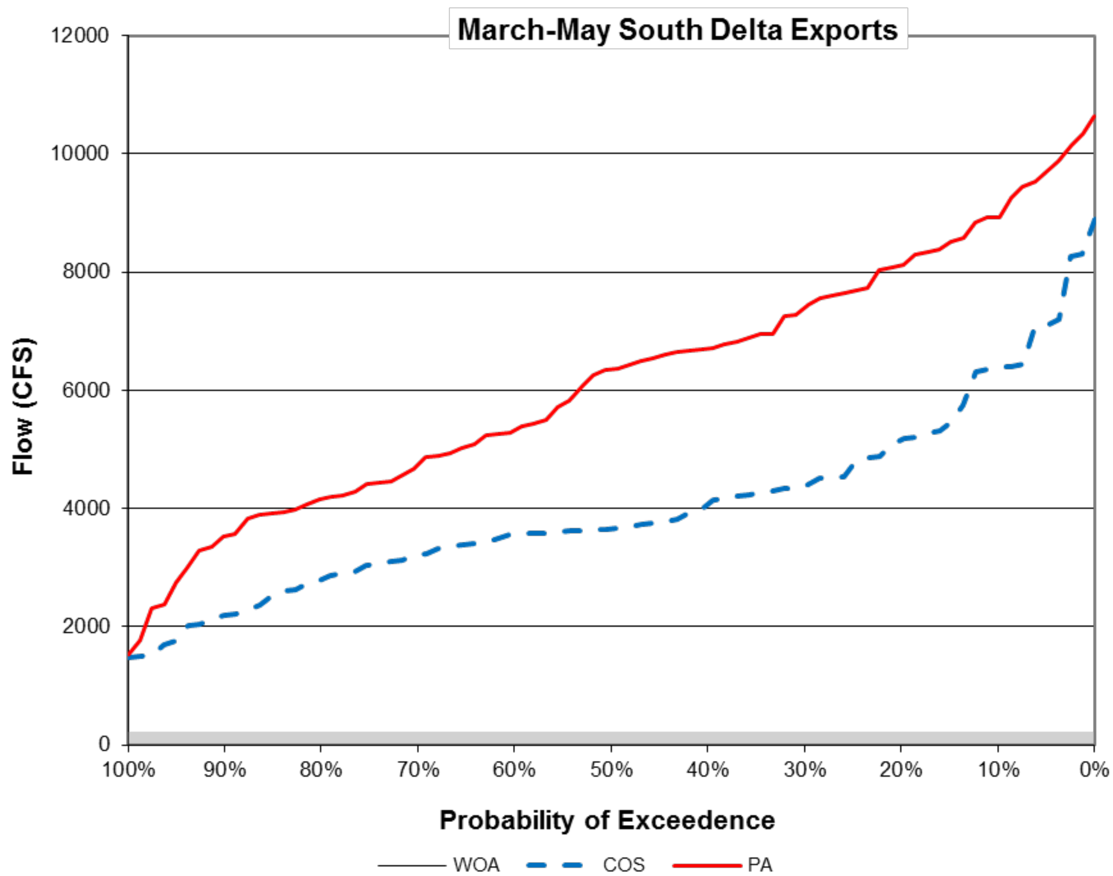
The IEP MAST conceptual model (2015) suggests that the probability of egg/larval Delta Smelt surviving to juveniles is influenced by predation risk, which may involve different factors such as turbidity, water temperature, and predators (silversides) (Figure 5.16-4). As previously described for adult Delta Smelt, potential effects of the proposed action on turbidity as a result of reduced upstream supply and removal by south Delta exports are concluded to be low, although this is uncertain. Wild detection of embryos and larvae are sparse, which reduces the certainty of any conclusions, although silversides have been found with Delta Smelt in their guts during the larval period (Schreier et al. 2016). As discussed by USFWS (2017a, p.274), water temperature in the San Francisco Estuary is driven mainly by air temperature and even in the Delta the water temperature is only slightly affected by freshwater inflow; flow-related effects on Delta water temperature are expected to be minor (Wagner et al. 2011).

With respect to silversides, Mahardja et al. (2016) found in a multivariate model that summer (June–September) Delta inflow and spring (March–May) south Delta exports had the strongest correlations with cohort strength; both relationships were negative. Mahardja et al. (2016, p.12) cautioned that the relationships are not meant to imply causality, given that the mechanisms could not be identified, and that further investigation is merited. In addition, beach seines (used in the study) only sample upstream of the confluence, so if high flow moves silversides downstream, then the inverse correlation of flow and abundance is misleading. Recognizing this uncertainty, the proposed action would not be expected to result in greater silverside cohort strength than without action, given that both spring south Delta exports and summer inflow to the Delta generally are greater under the PA compared to WOA , as shown in Figure 5.16-13 and Figure 5.16-14. A similar situation exists for the comparison of COS to the WOA.



Note: Delta inflow is represented by Freeport + Yolo + Mokelumne + Vernalis flow.

Figure 5.16-12. Mean Modeled Delta Inflow, June–September



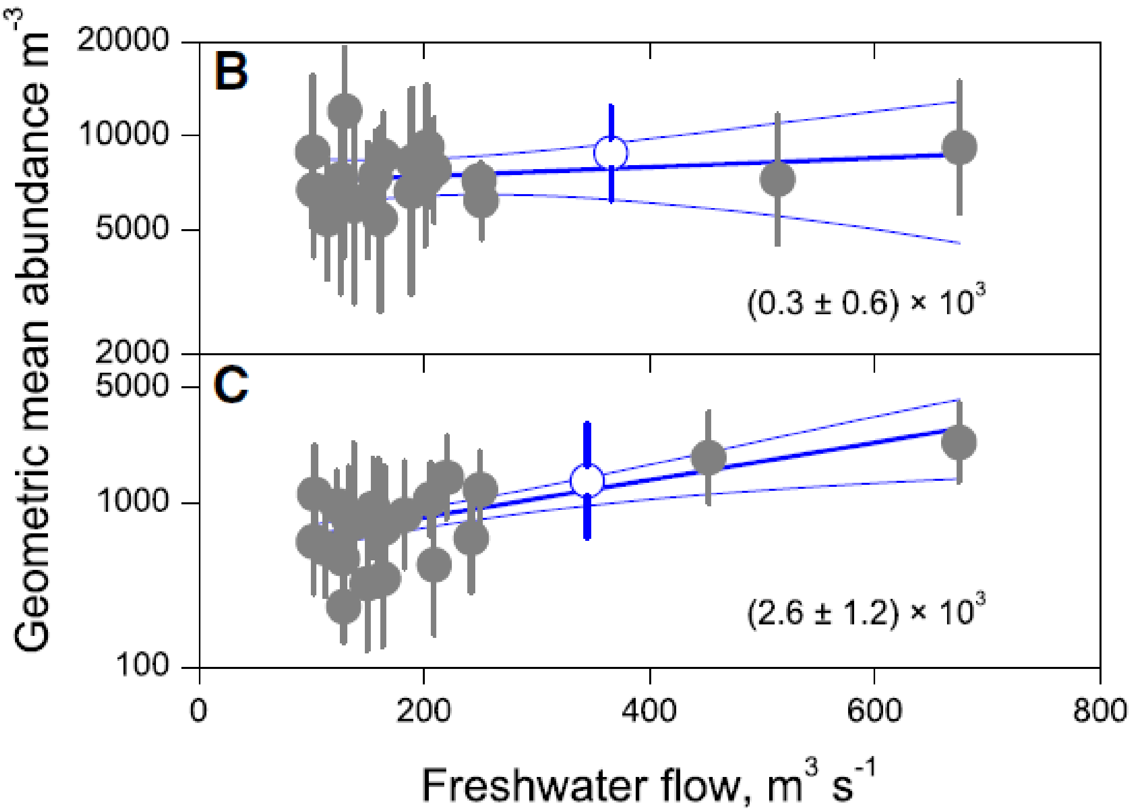
Note: South Delta exports under the WOA scenario are zero.

Figure 5.16-13. Mean Modeled South Delta Exports, March–May

5.16.3.1.3 Juveniles to Subadults (June – September)

5.16.3.1.3.1 Food Availability

As described in the IEP MAST (2015) conceptual model, food availability and quality is a key component of the June–September transition probability of juvenile Delta Smelt to subadulthood through growth and survival of individuals (Figure 5.16-5). The south Delta exports influence the subsidy of the Delta Smelt zooplankton prey *Pseudodiaptomus forbesi* to the low salinity zone from the freshwater Delta (Kimmerer et al. 2018a), with these potential negative effects probably being of particular importance on the San Joaquin River side of the Delta given the high density of *P. forbesi* there (Kimmerer et al. 2018b). South Delta exports may entrain *P. forbesi* (USFWS 2008, p.228; Kimmerer et al. 2018b), resulting in a positive correlation between July–September Delta outflow and *P. forbesi* density in the low salinity zone (Kimmerer et al. 2018a; Figure pforbes1). Given the suggested importance of the San Joaquin River side of the Delta for spatial subsidy of *P. forbesi* to the low salinity zone and modeled losses of *P. forbesi* to entrainment by the south Delta export facilities (Kimmerer et al. 2018b), modeled flows in the lower San Joaquin River (DSM2 outputs RSAN018 + SLTRM004 + SLDUT007, which is a representation of QWEST) may offer some perspective on relative differences in this potential negative effect between operational scenarios. QWEST is defined as the average daily flow traveling past Jersey Point. As shown in the figures below (Figures 5.16-16 to 5.16-18), July–September QWEST flows generally would be positive under WOA, whereas the PA would have positive QWEST flows in a small percentage of years (similar to COS), possibly indicating a lower potential for spatial subsidy of *P. forbesi* to the low salinity zone under the proposed action relative to without action.



Source: Kimmerer et al. (2018b). Note: Error bars are 95% confidence limits based on all samples from the selected stations, and points for 2011 are shown as open circles. Lines with error bounds are from least-squares models of log of abundance versus flow, weighted by the inverse of variance. Values are slopes with 95% confidence intervals; only the slope for the low salinity zone stations was statistically significant.

Figure 5.16-14. July-–September Geometric Mean Abundance of *Pseudodiaptomus forbesi* Copepodites and Adults for 1994–2016 in (B) Freshwater Stations (Salinity < 0.5) and (C) Low Salinity Zone Stations (Salinity 0.5–5), Excluding Suisun Marsh and the Central to Eastern Delta.

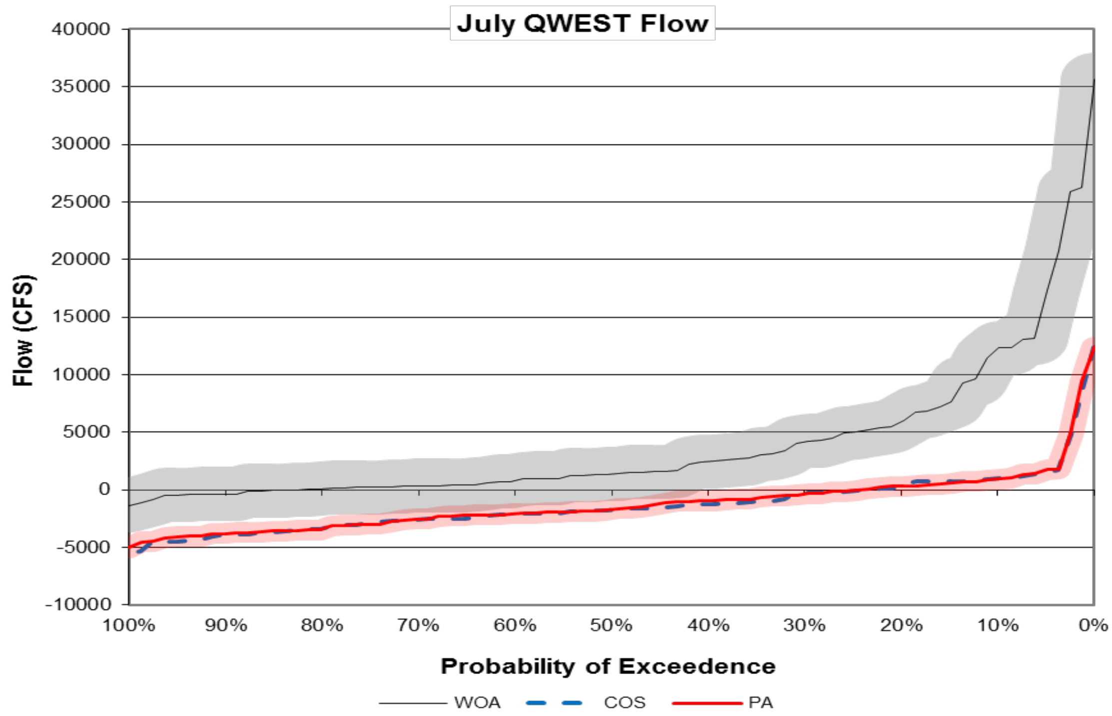


Figure 5.16-15. Mean Modeled QWEST Flow, July

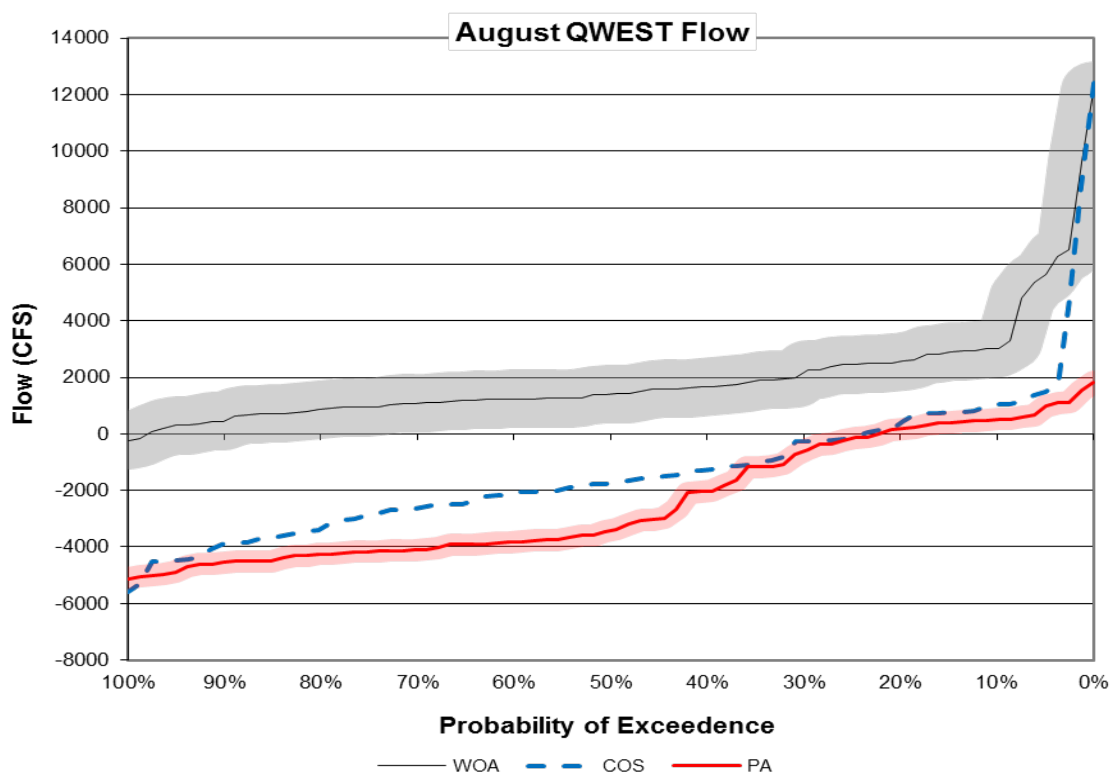


Figure 5.16-16. Mean Modeled QWEST Flow, August

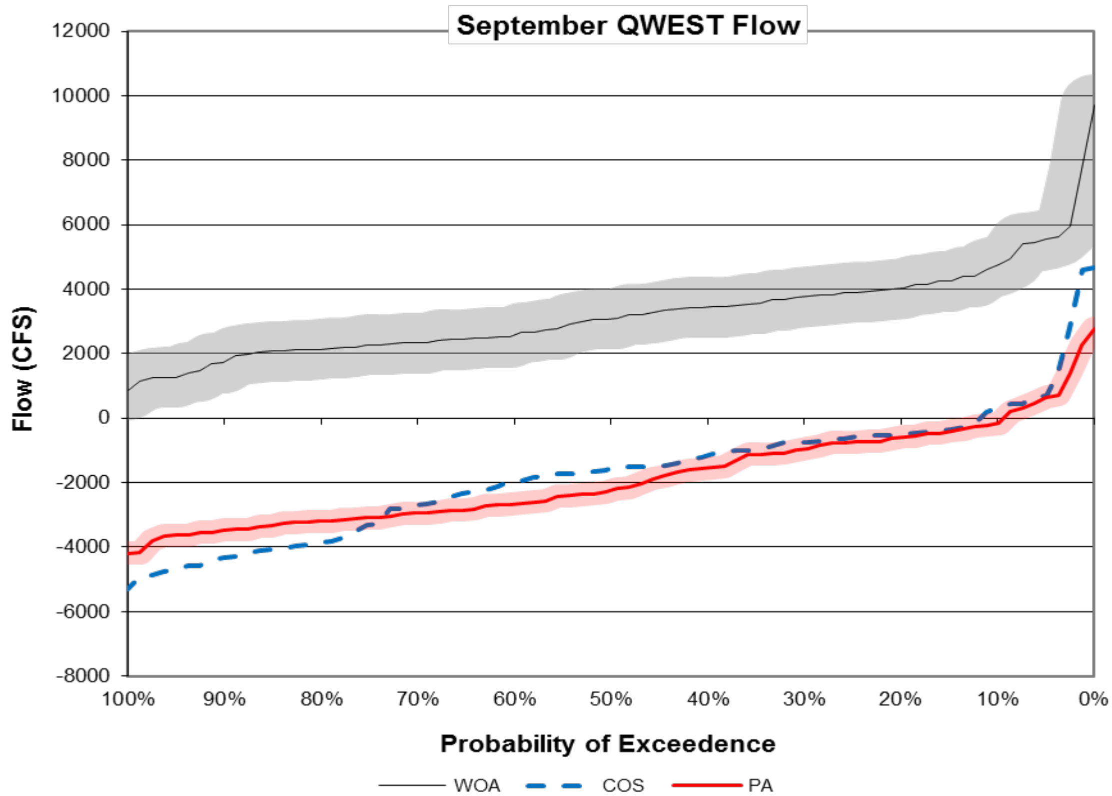


Figure 5.16-17. Mean Modeled QWEST Flow, September

P. forbesi suffers from high mortality rates on its nauplii (larvae) when it resides in the low salinity zone. This mortality is not caused by salinity, but by predation on the nauplii (larvae) (Kayfetz et al. 2017). This means that *P. forbesi* abundance in the low-salinity zone would crash similarly to *E. affinis* if it were not for an upstream subsidy from the Delta where *P. forbesi* densities are higher (Kimmerer et al. 2018; E&C). Delta outflow appears to provide this subsidy by facilitating the transport of *P. forbesi* from the Delta into Suisun Bay; Kimmerer et al. (2018; Hydrobiologia) demonstrated that although system-wide, *P. forbesi* density does not correlate with Delta outflow, its density in the low-salinity zone does. Therefore, there is some evidence for potential OMR management effects on *P. forbesi* transport to the low salinity zone, but not for overall calanoid copepod density in the low salinity zone.

Potential effects from the proposed action related to both the SMSCG action (beneficial effects, discussed below) and the south Delta export facilities on food availability would be expected to have the potential to affect a sizable portion of the Delta Smelt population. Bush (2017) demonstrated that on average 77 percent of adult Delta Smelt either migrate to the low salinity zone as early juveniles or are resident in the low salinity zone throughout their lives. In contrast, an average of 23 percent of Delta Smelt surviving to adulthood are resident in the Cache Slough Complex/Sacramento Deepwater Ship Channel region throughout their lives. Those Delta Smelt resident in the Cache Slough Complex/Sacramento Deepwater Ship Channel region would not be expected to be affected by seasonal flows of the proposed action in terms of SMSCG operations and the south Delta export facilities. During and just after the August 2018 pilot implementation of the SMSCG action, EDSM data from surveys between August 6 and September 7 suggest an average of 20 percent (range 0–100%) of juvenile Delta Smelt were in Suisun Marsh, although there is appreciable uncertainty in the estimates given low numbers of fish caught (USFWS 2018_EDSM). The IEP MAST (2015) conceptual model posited link between summer hydrology and clam grazing (Figure 5.16-5) was not supported by an examination of *P. amurensis* biomass and grazing rate during the fall (Brown et al. 2014, p.50-56), so it is unclear what effect differences in hydrology might have on clam grazing.

Overall, it is concluded with some uncertainty that OMR management under the proposed action would have negative effects on transport of *P. forbesi* to the low salinity zone relative to without action. However, operations of the SMSCG under the proposed action would provide greater access to the relatively food-rich Suisun Marsh habitat in above normal and below normal water years (further discussed below). Moreover, tidal habitat restoration (an additional approximately 6,000 acres) would be undertaken as part of the proposed action, and has the potential to reduce some of the negative effects from OMR management on food availability.

5.16.3.1.3.2 Harmful Algal Blooms

The IEP MAST (2015) conceptual model posits a linkage between various factors (nutrients, summer hydrology, and air temperature) and toxicity from harmful algal blooms to Delta Smelt and their prey (Figure 5.16-5). Based on this conceptual model (see also additional discussion in IEP MAST 2015, p.85-86), differences in flows could influence harmful algal blooms. Lehman et al. (2013) reported on *Microcystis* blooms observed from 2004-2008. During these years, median QWEST flows differed by only 6 m^3/s between the two wetter years and the two drier years and *Microcystis* density showed no response to this flow variable. Lehman et al. (2013) described the range of QWEST flow at which *Microcystis* occurred in their study (-8,500 to 1,800 cfs). It is uncertain if QWEST greater than this range would result in lower likelihood of *Microcystis* blooms, but if so, there may be greater potential for blooms under the PA than WOA given that flows above the range noted by Lehman et al. (2013) occur less frequently under the PA during the main *Microcystis* summer/early fall months (Figures 5.16-16 to 5.16-18). The pattern is essentially the same for the COS compared to WOA. However, consideration only of flow does not account for other factors that could be affected by water operations that may be important in affecting *Microcystis*, such as channel velocity (RBI 2017). Note also that this analysis does not account for other factors shown to correlate with occurrence of *Microcystis* blooms that are not greatly affected by water operations such as water temperature and nutrients (RBI 2017).

A previous analysis by RBI (2017) examined DSM2-HYDRO-modeled maximum daily absolute velocity during June–November at various locations in the south Delta which are susceptible to *Microcystis* blooms, in relation to a critical velocity of threshold of 1 ft/s, above which turbulent mixing may disrupt *Microcystis* blooms. Note that there is uncertainty in this threshold given that it was developed for a different system and velocity below this threshold has been shown to disrupt blooms in other systems (RBI 2017). Applying a similar analysis for the present effects analysis suggested that along the mainstem San Joaquin River from Antioch to Brandt Bridge, current operations and the proposed action would differ little from without action in terms of having channel velocity that potentially could disrupt *Microcystis* blooms (Figure 5.16-19, Figure 5.16-20, Figure 5.16-21). In Old River at Tracy Road and Middle River at Bacon Island, maximum velocity under the PA and COS would be lower than WOA, although all scenarios generally would have maximum velocity below 1 ft/s and, therefore, may not differ in terms of potentially providing conditions unlikely to disrupt *Microcystis* blooms (Figure 5.16-22 and Figure 5.16-23). In contrast, maximum velocity at Grant Line Canal downstream of the temporary barrier, Old River at Bacon Island, and Old River at Highway 4 generally was below 1 ft/s under PA and COS, but close to or above 1 ft/s under WOA (Figure 5.16-24, Figure 5.16-25, Figure 5.16-26). Greater maximum velocity under WOA reflects the absence of agricultural barriers, which reduce tidal flows under current operations and the proposed action. A greater frequency of maximum velocity below 1 ft/s may indicate greater potential for *Microcystis* blooms not to be disrupted in Old River and Grant Line Canal close to the agricultural barriers under the proposed action compared to without action. However, even if *Microcystis* blooms were disrupted less under the proposed action, these blooms would not necessarily directly or indirectly (through effects on prey) affect juvenile Delta Smelt in the low salinity zone given that the prevailing direction of movement would be upstream because of south Delta export pumping (e.g., Figures 5.16-16 through 5.16-18). The IEP MAST conceptual model also notes that relatively clear water is a factor thought to cause more intensive *Microcystis* blooms (IEP MAST 2015, p.85). The proposed action has less sediment supply and, therefore, potentially less sediment for resuspension in the Bay-Delta during the summer/fall period when *Microcystis* blooms occur.

There is a difference in flows between the proposed action and without action scenarios, as well as possibly greater potential for lower velocity to limit *Microcystis* bloom disruption, and the potential for higher water clarity as a result of reduced sediment supply.

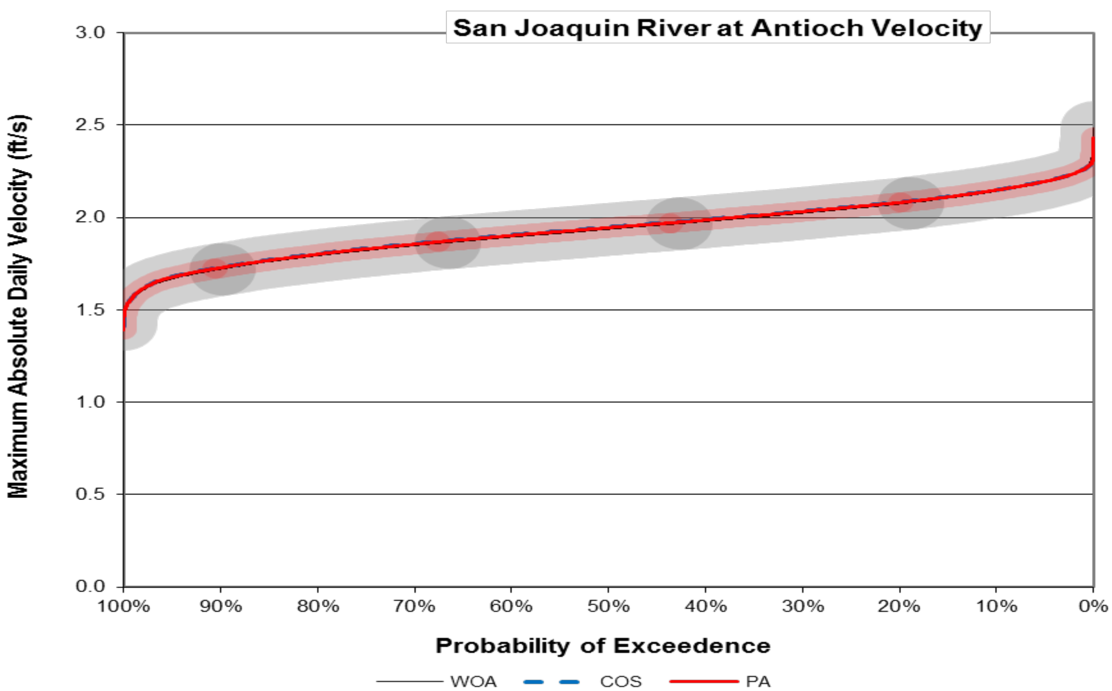


Figure 5.16-18. Modeled Maximum Absolute Daily Velocity in the San Joaquin River at Antioch, June–November

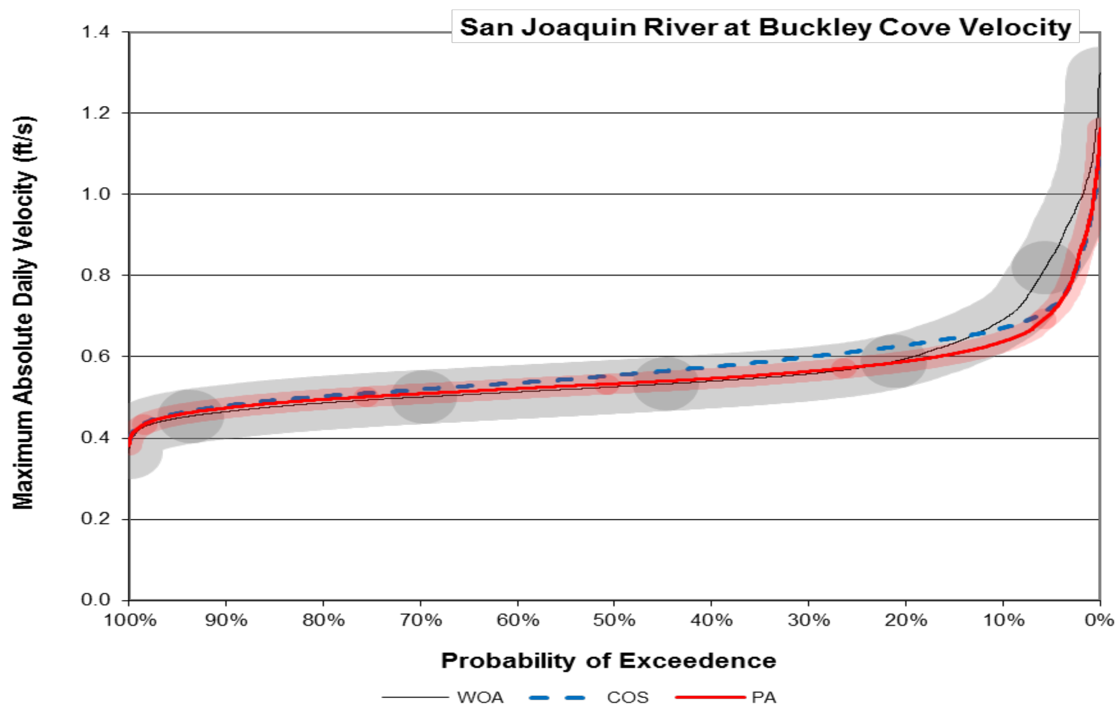


Figure 5.16-19. Modeled Maximum Absolute Daily Velocity in the San Joaquin River at Buckley Cove, June–November

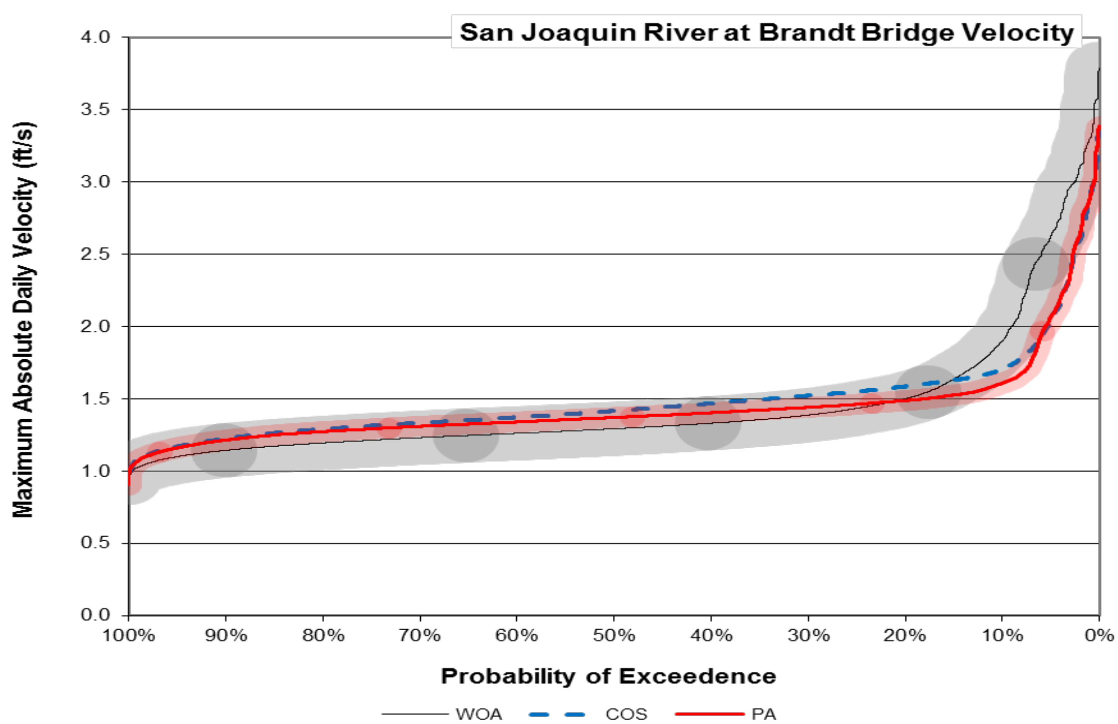


Figure 5.16-20. Modeled Maximum Absolute Daily Velocity in the San Joaquin River at Brandt Bridge, June–November

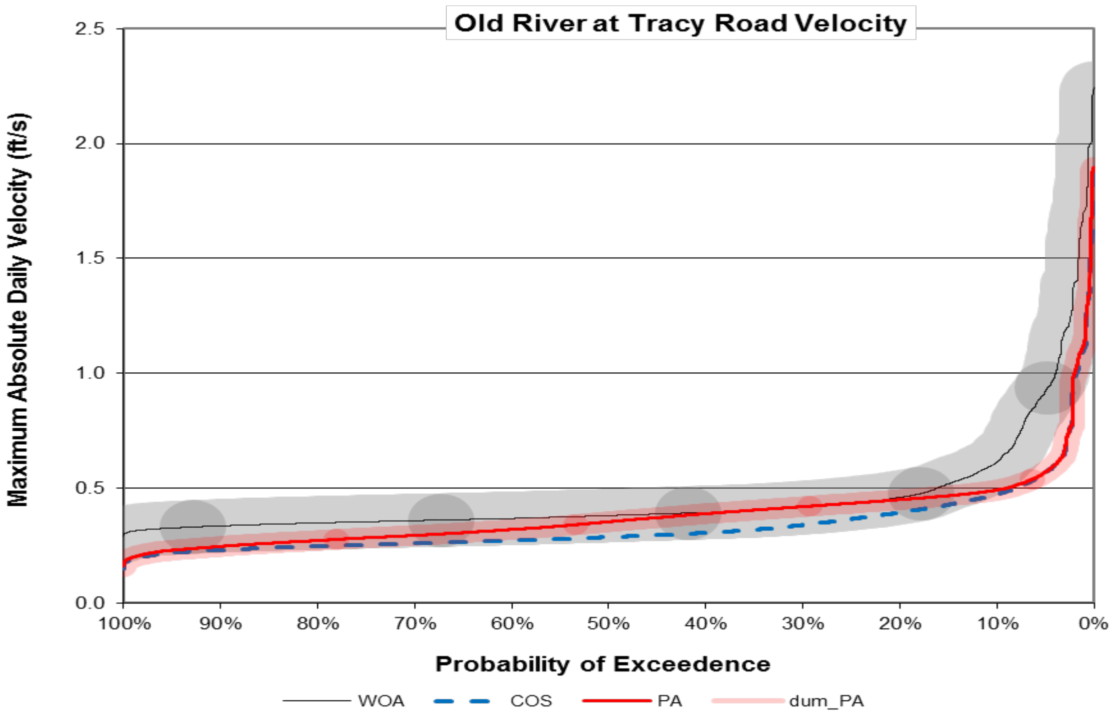


Figure 5.16-21. Modeled Maximum Absolute Daily Velocity in Old River at Tracy Road, June–November

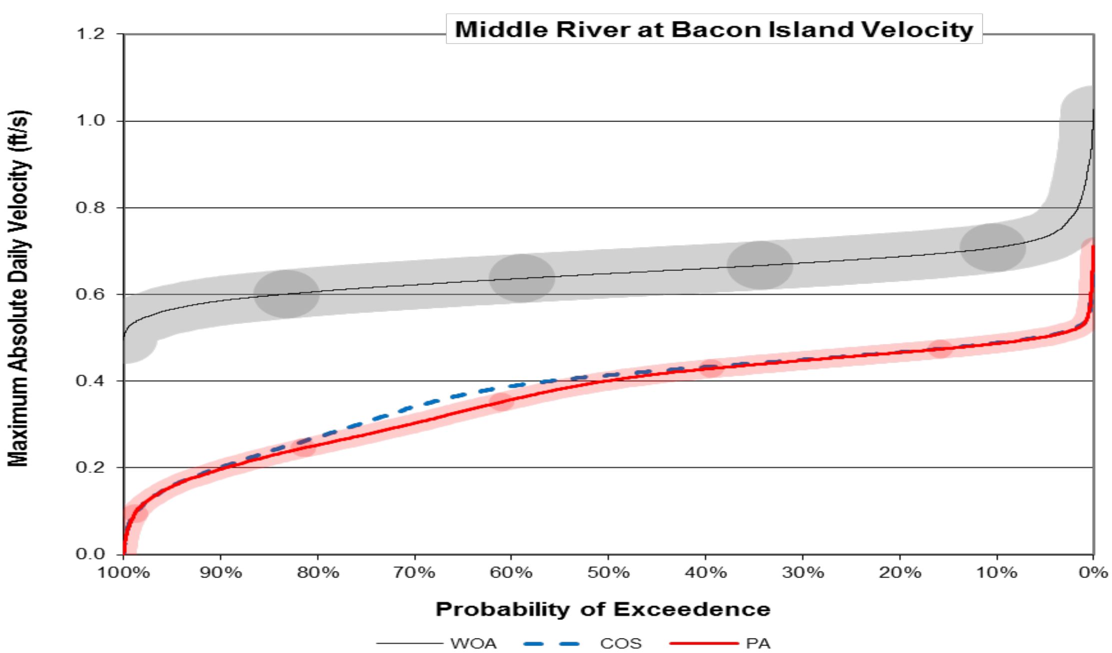


Figure 5.16-22. Modeled Maximum Absolute Daily Velocity in Middle River at Bacon Island, June–November

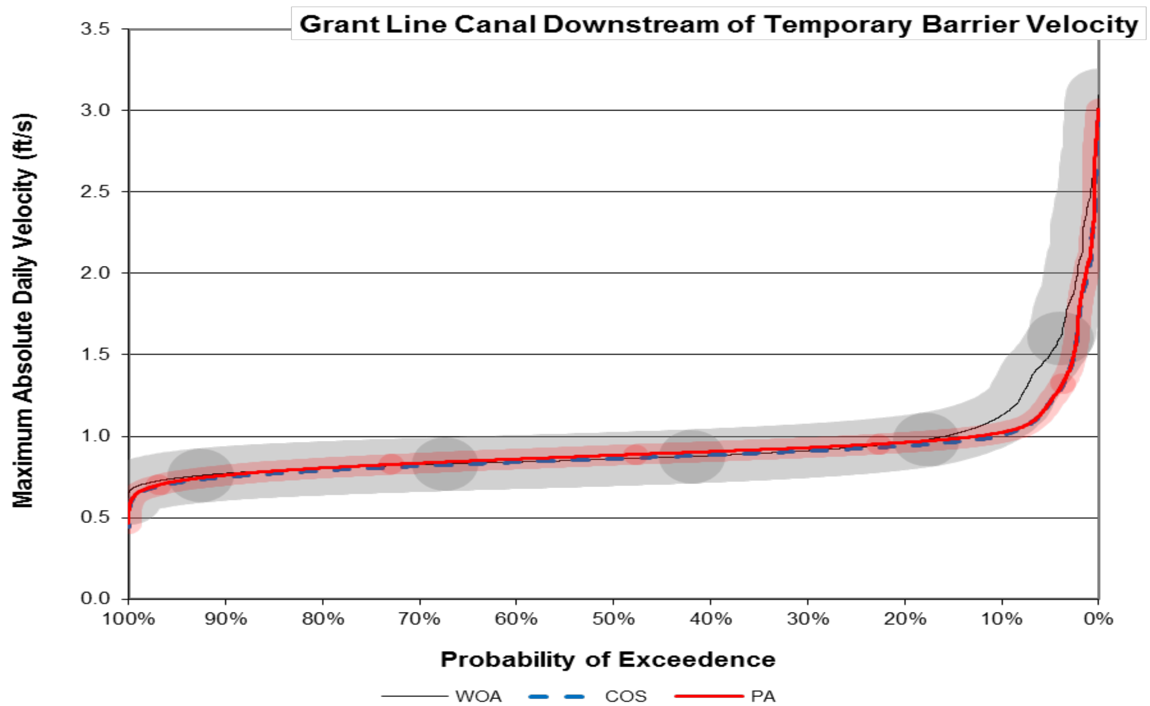


Figure 5.16-23. Modeled Maximum Absolute Daily Velocity in Grant Line Canal Downstream of the Temporary Barrier, June–November

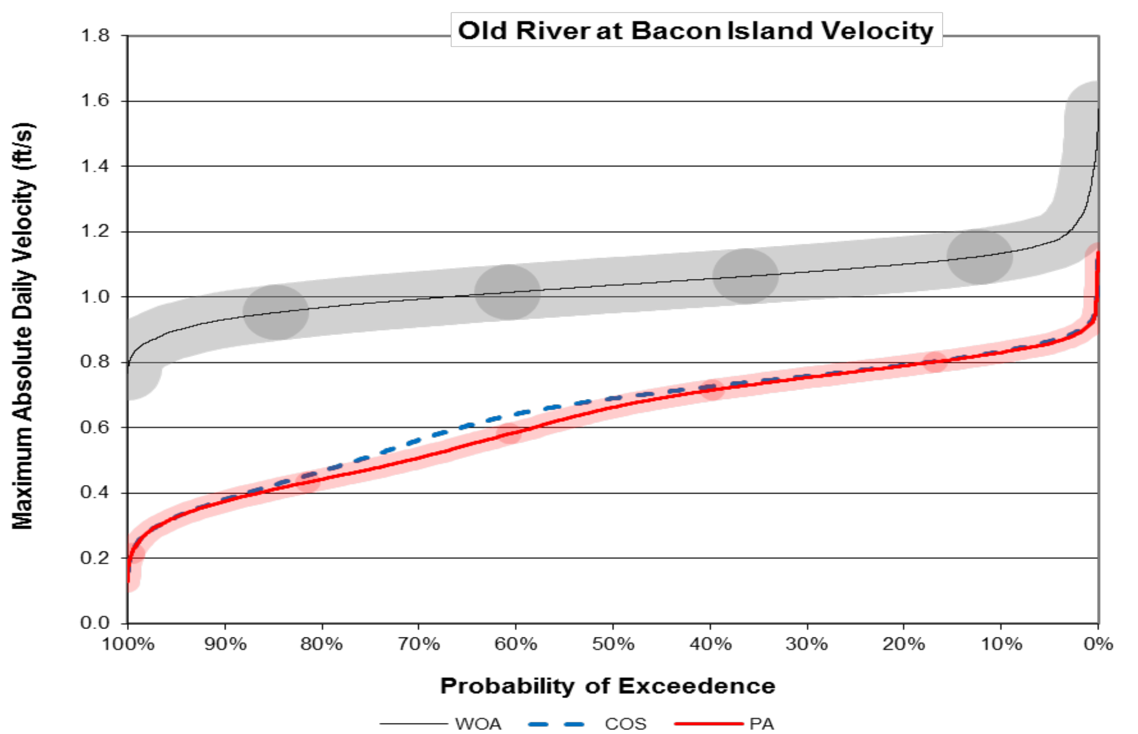


Figure 5.16-24. Modeled Maximum Absolute Daily Velocity in Old River at Bacon Island, June–November

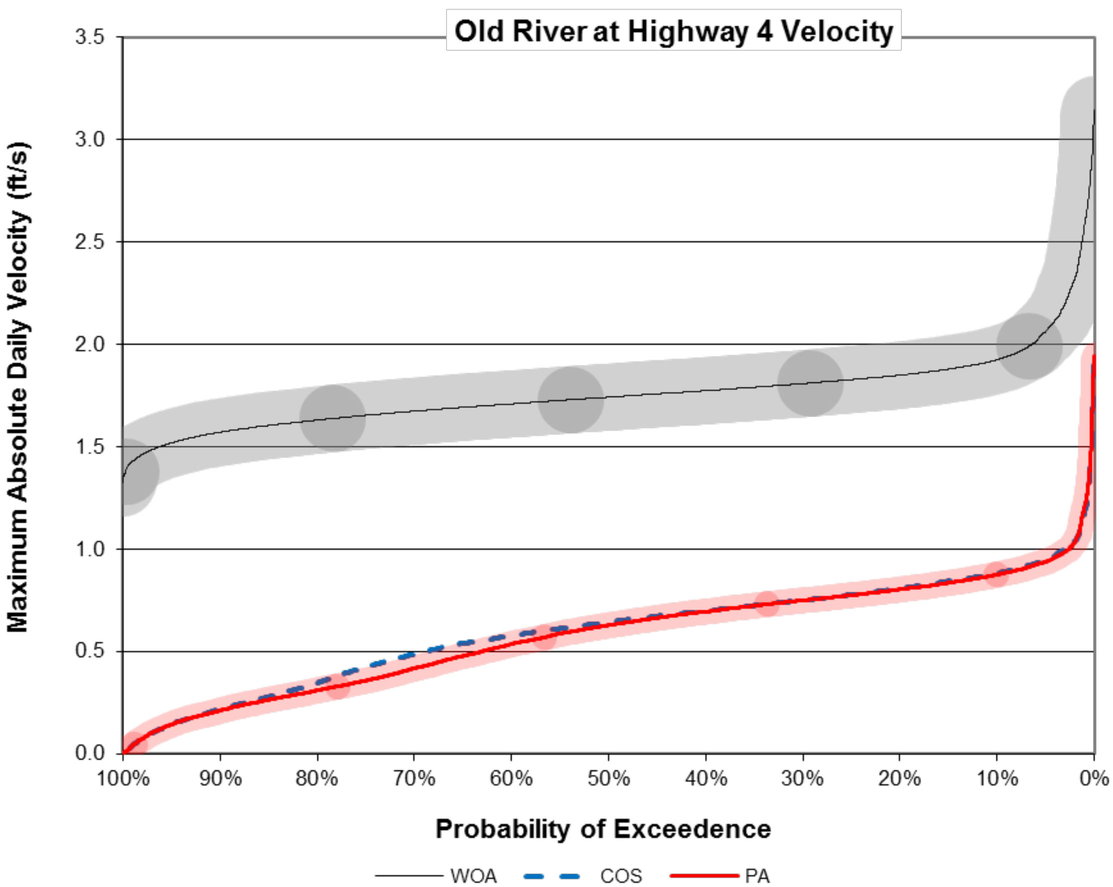


Figure 5.16-25. Modeled Maximum Absolute Daily Velocity in Old River at Highway 4, June–November

5.16.3.1.3.3 Predation Risk

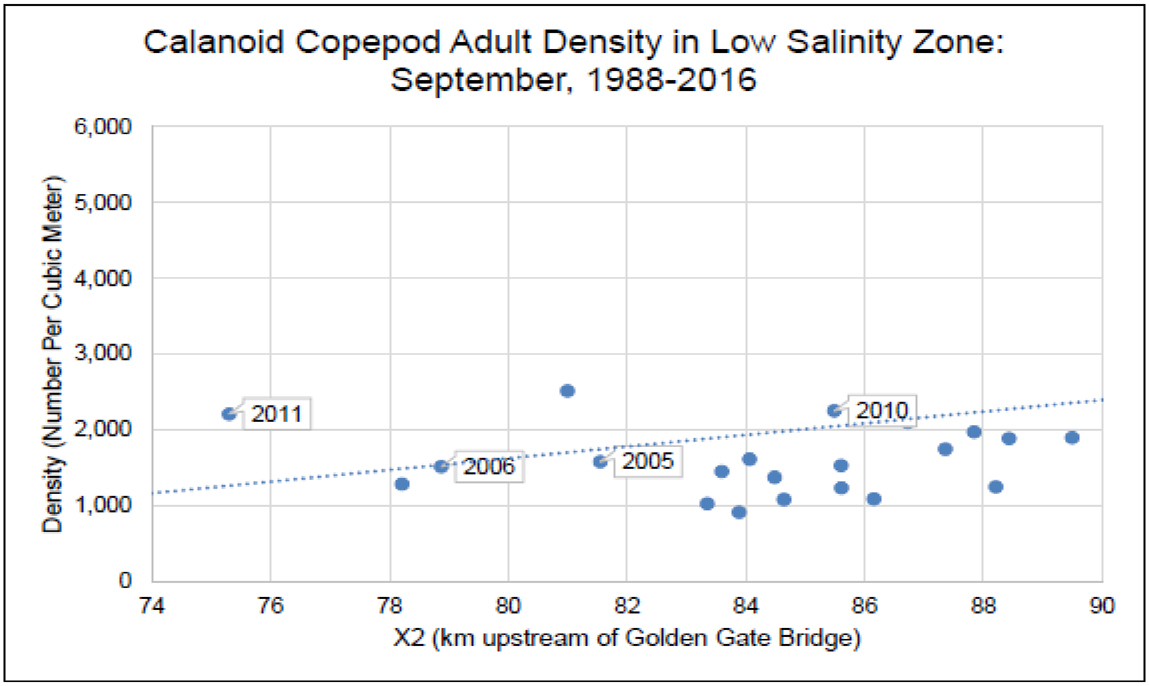
The IEP MAST (2015) conceptual model posits that predation risk for juvenile Delta Smelt is a function of predators (in particular Striped Bass), turbidity, and water temperature (Figure 5.16-5). As previously discussed for larval Delta Smelt, effects on water temperature from the proposed action relative to without action would be negligible. Turbidity during the low-flow summer and fall periods is partly a function of sediment delivery during the high-flow winter/spring periods, for it influences the amount of sediment for available (see summary by IEP MAST 2015, p.50). As discussed previously for adult Delta Smelt, differences in winter/spring flows and sediment delivery may result in a negative effect as a result of the proposed action potentially providing less sediment for resuspension in the summer/fall compared to without action. The IEP MAST (2015) conceptual model does not include factors affecting the abundance of predators (Striped Bass). Recent studies suggest that greater fall Delta outflow (represented by X2) and lower water clarity are positively linked to age-0 abundance (Mac Nally et al. 2010; Thomson et al. 2010), although there is uncertainty in the extent to which such effects would translate to changes in abundance of Striped Bass ages 1 to 3 (i.e., the subadults suggested to prey on Delta Smelt by IEP MAST 2015, p.132) given relatively low correspondence in abundance trends for age 0 and age 1 (Sommer et al. 2011) and apparent density dependence between ages 1 and 2 (Kimmerer et al. 2000).

5.16.3.1.4 Subadults to Adults (September – December)

The proposed action's OMR management during the Delta Smelt subadult to adult transition period (September–December) has the potential to influence several habitat attributes posited to be affected by Delta outflow in the IEP MAST (2015) conceptual model. These include food availability, size and location of the low salinity zone, and turbidity affecting predation risk (Figure 5.16-6).

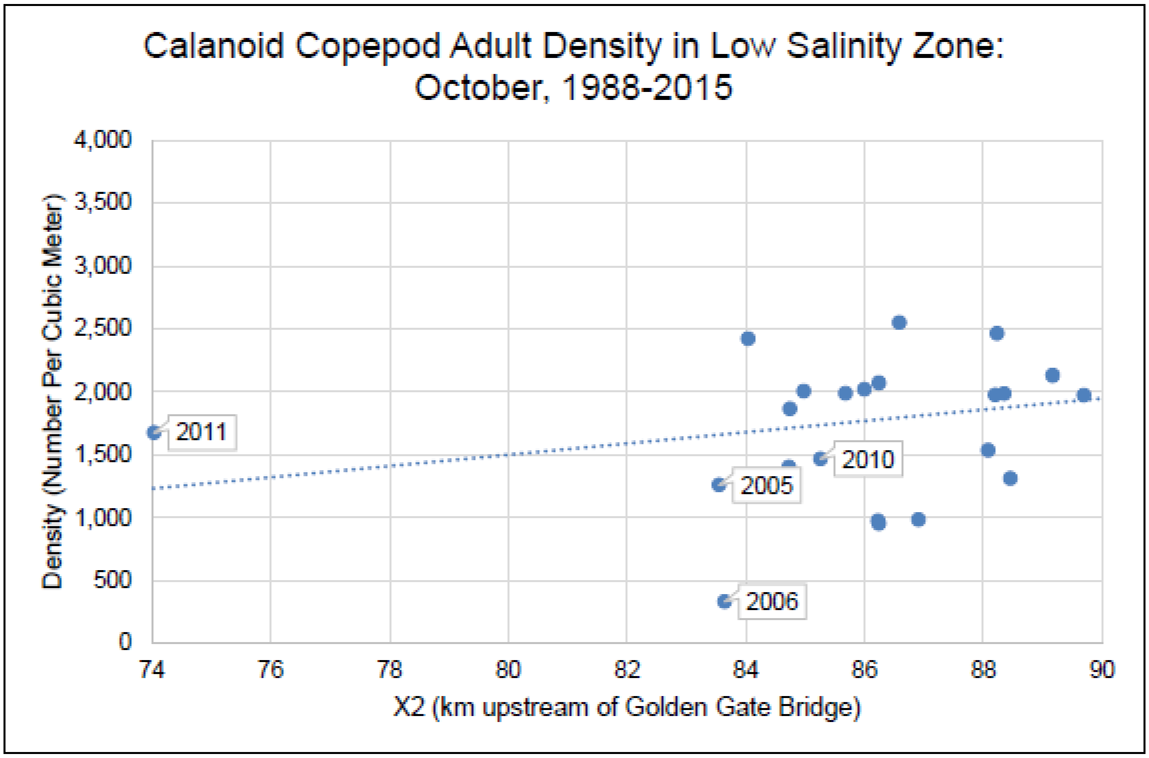
5.16.3.1.4.1 Food Availability

As also discussed for juvenile Delta Smelt, seasonal south Delta export operations have the potential to negatively affect Delta Smelt food availability through reduced *P. forbesi* subsidy to the low salinity zone rearing habitat occupied by most Delta Smelt reaching adulthood. Although the FLaSH investigations predicted that Delta Smelt food availability (as represented by calanoid copepods) in the fall low salinity zone would be greater with lower X2 (i.e., higher outflow) (Brown et al. 2014, p.25), this was not found to be the case either for the post--*Potamocorbula amurensis* invasion period (1988–2015/2016; Figure 5.16-27; Figure 5.16-28; Figure 5.16-29; Figure 5.16-30; Figure 5.16-31; Figure 5.16-32) or for the period following onset of the Pelagic Organism Decline (2003-–2015/2016; ICF 2017, p.78–82). Therefore, as noted for juvenile Delta Smelt, there is some evidence for potential negative OMR management-related effects on *P. forbesi* transport to the low salinity zone, but not for overall calanoid copepod density in the low salinity zone.



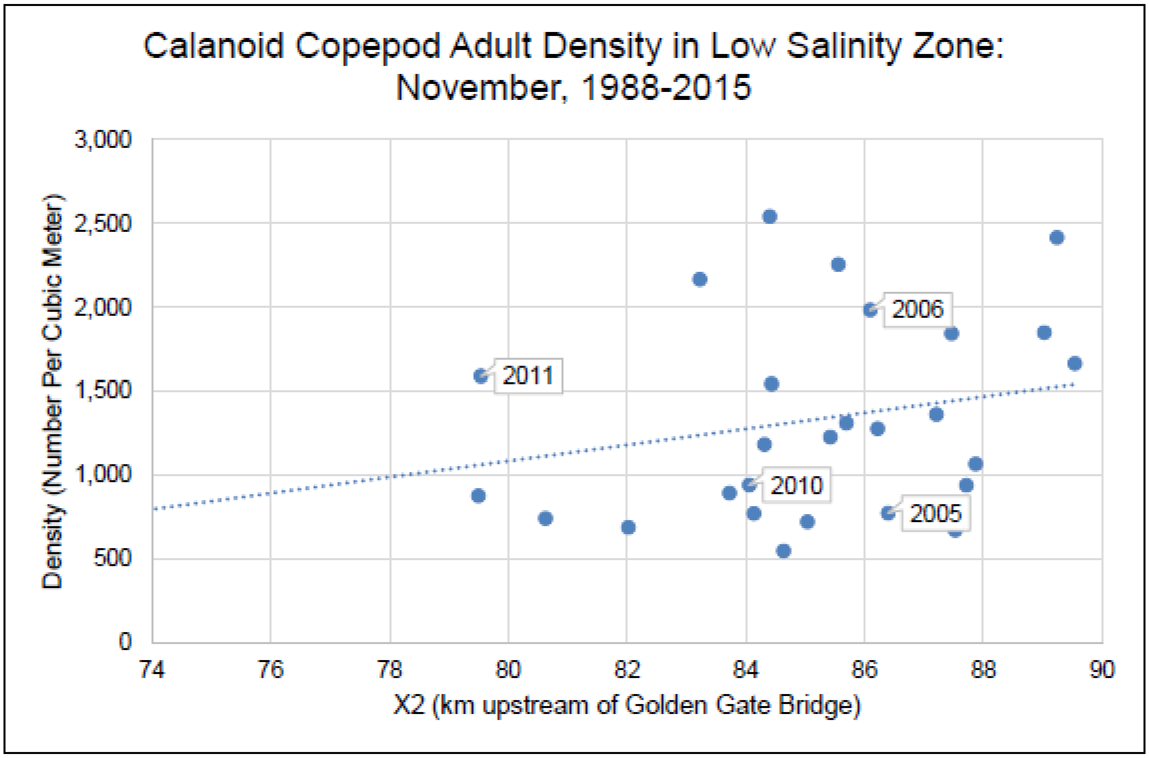
Source: ICF (2017, p.74). Note: Trend line shows non-significant linear regression.

Figure 5.16-26. Mean September Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.



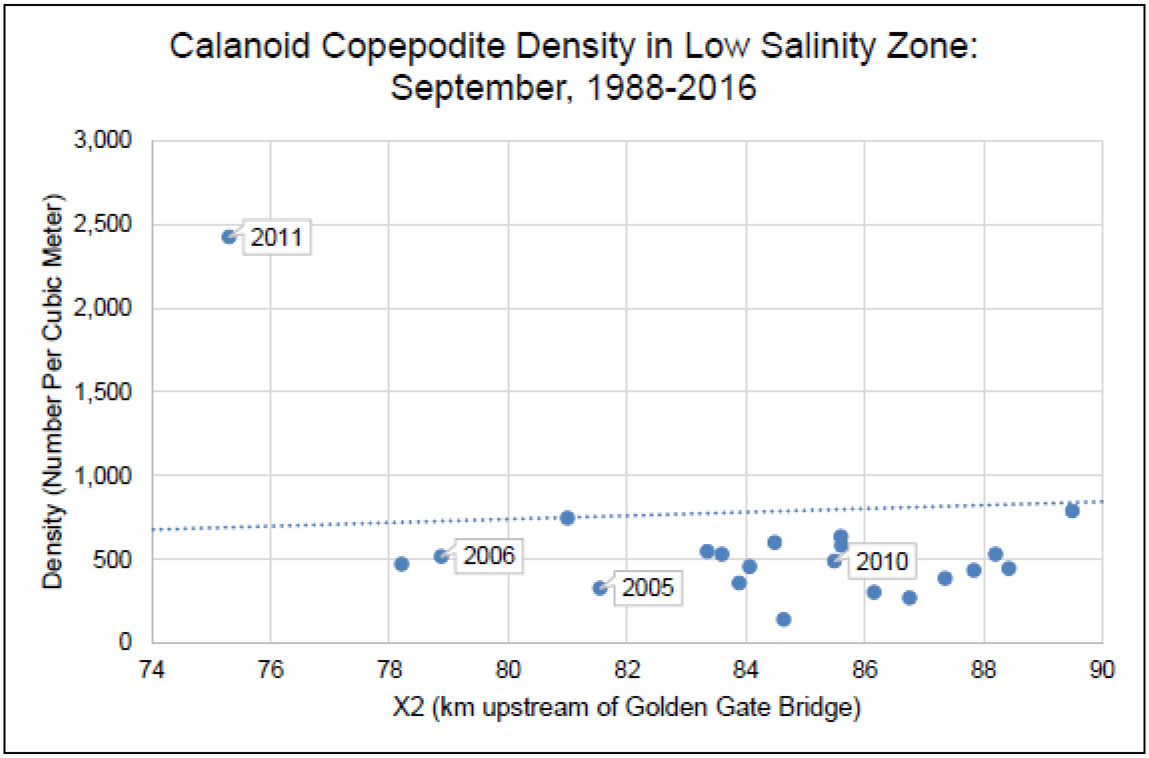
Source: ICF (2017, p.74). Note: Trend line shows non-significant linear regression.

Figure 5.16-27. Mean October Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.



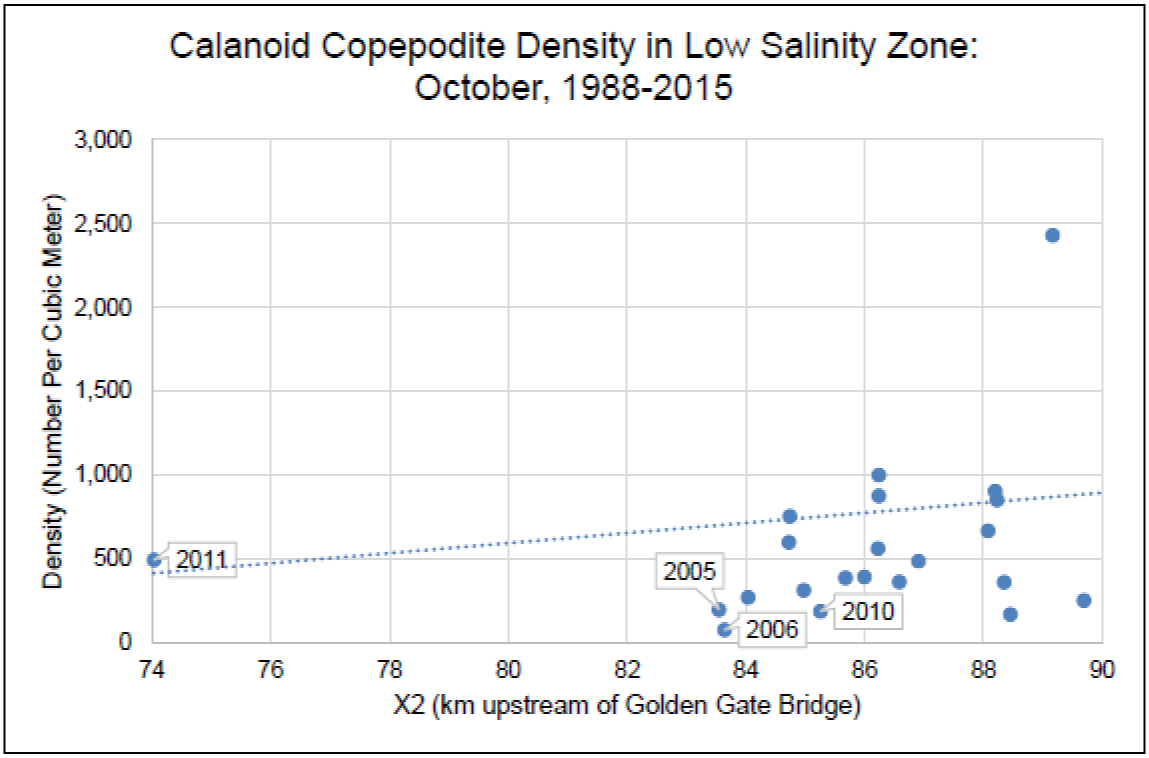
Source: ICF (2017, p.75). Note: Trend line shows non-significant linear regression.

Figure 5.16-28. Mean November Calanoid Copepod Adult Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.



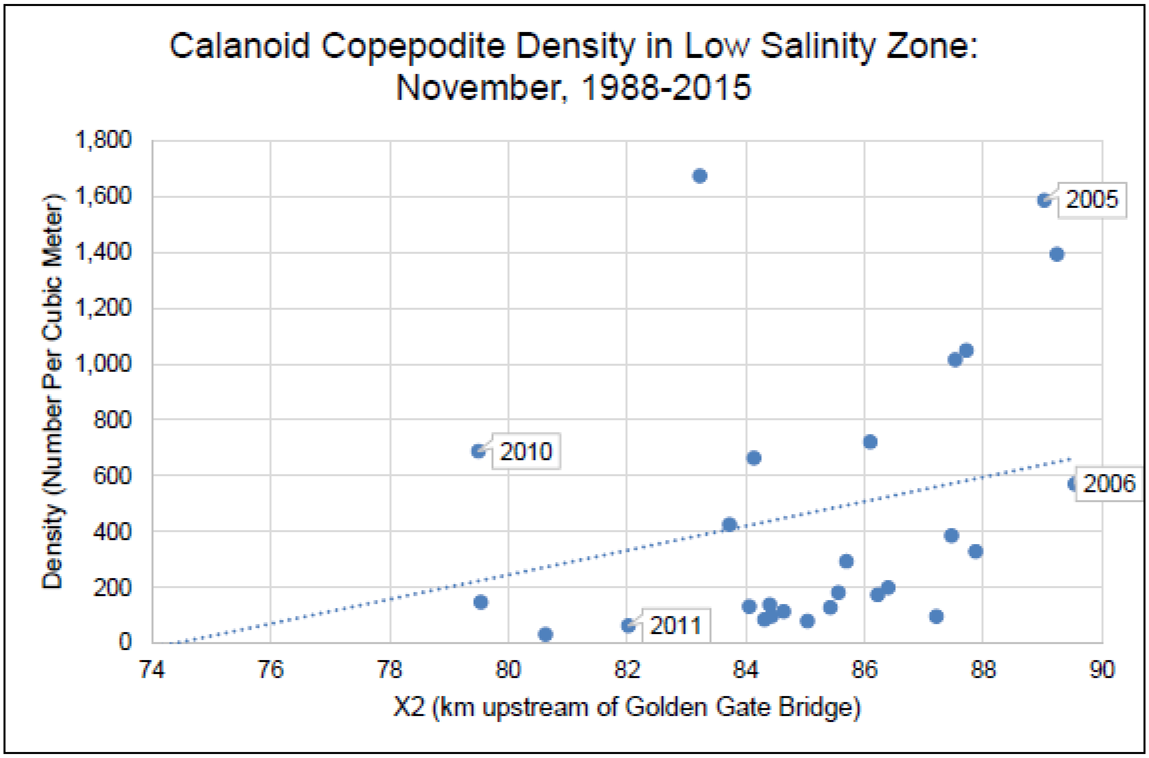
Source: ICF (2017, p.75). Note: Trend line shows non-significant linear regression.

Figure 5.16-29. Mean September Calanoid Copepod Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.



Source: ICF (2017, p.76). Note: Trend line shows non-significant linear regression.

Figure 5.16-30. Mean October Calanoid Copepod Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.



Source: ICF (2017, p.76). Note: Trend line shows non-significant linear regression.

Figure 5.16-31. Mean November Calanoid Copepod Copepodite Density in the Low Salinity Zone (Salinity = 1 to 6) from Environmental Monitoring Program Zooplankton Survey Data (Clarke-Bumpus Net) versus Mean X2 from 1988-2016.

5.16.3.1.4.2 Size and Location of the Low Salinity Zone

Pertaining to the indication that subadult Delta Smelt abundance, survival and growth are affected by the size and position of the low salinity during fall, as posited by the IEP MAST conceptual model, IEP MAST (2015, p.142) concluded: “The limited amount of available data provides some evidence in support of this hypothesis, but additional years of data and investigations are needed.” Others have found that low salinity zone habitat may not be a predictor of Delta Smelt survival (Reclamation, 2017).

The proposed action does not include the fall X2 action from the 2008 biological opinion, which results in X2 under the PA being essentially the same as COS in drier years, but greater (more upstream) than WOA and COS in wet and above normal years. Given these caveats, the model shows September X2 would tend to be ≥ 85 km in around 95% or more of years, which would give a predicted low salinity zone area of around 11,000 acres (4,480 hectares; Figure 5.16-36, as developed from the X2-low salinity zone area look-up table from Brown et al. 2014, p.79) or less. X2 greater than or equal to 85 km results in the low salinity zone generally not occurring in the broader, shallower habitat in Suisun Bay (specifically Honker Bay) that provides an increase in the area of the lower salinity zone (DMA 2014, p.38). By way of comparison, September X2 under WOA would be around 75–83 km at 50–95% exceedance, giving a predicted low salinity zone area of 12,500–20,800 acres (5,100–8,400 hectares; Figure 5.16-36), and the low salinity zone occurring in Suisun Bay in around two thirds of years (Figure 5.16-33). Similar patterns (i.e., appreciably lower predicted low salinity zone area in wetter years under the PA relative to WOA) would also generally be evident in October (Figure 5.16-37), whereas larger differences between the PA and WOA would tend to occur in 60% of years in November (Figure 5.36-38). Operation of the SMSCG and additional Delta outflow to ensure no net upstream movement of X2 during proposed SMSCG operation in June–October of wet, above normal and below normal years was not modeled in CalSim; it is not expected that these factors would have a large influence on X2 relative to the modeling results from CalSim.

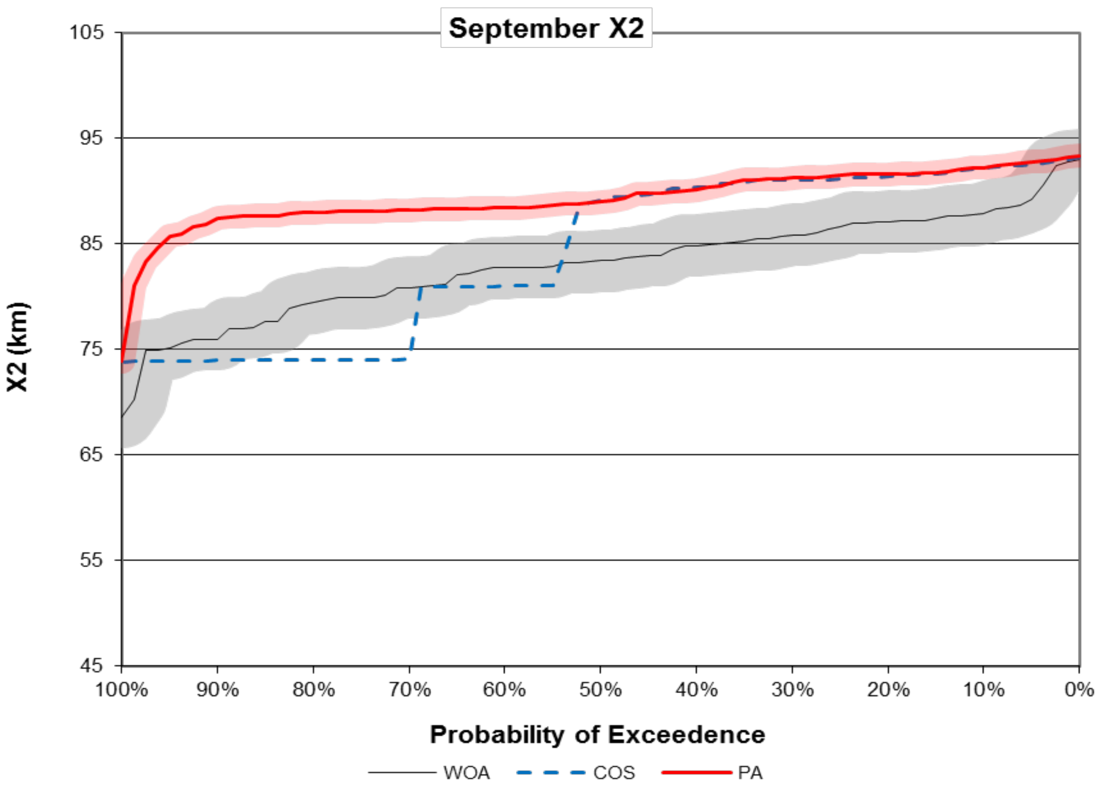


Figure 5.16-32. Mean Modeled X2 from CalSim, September.

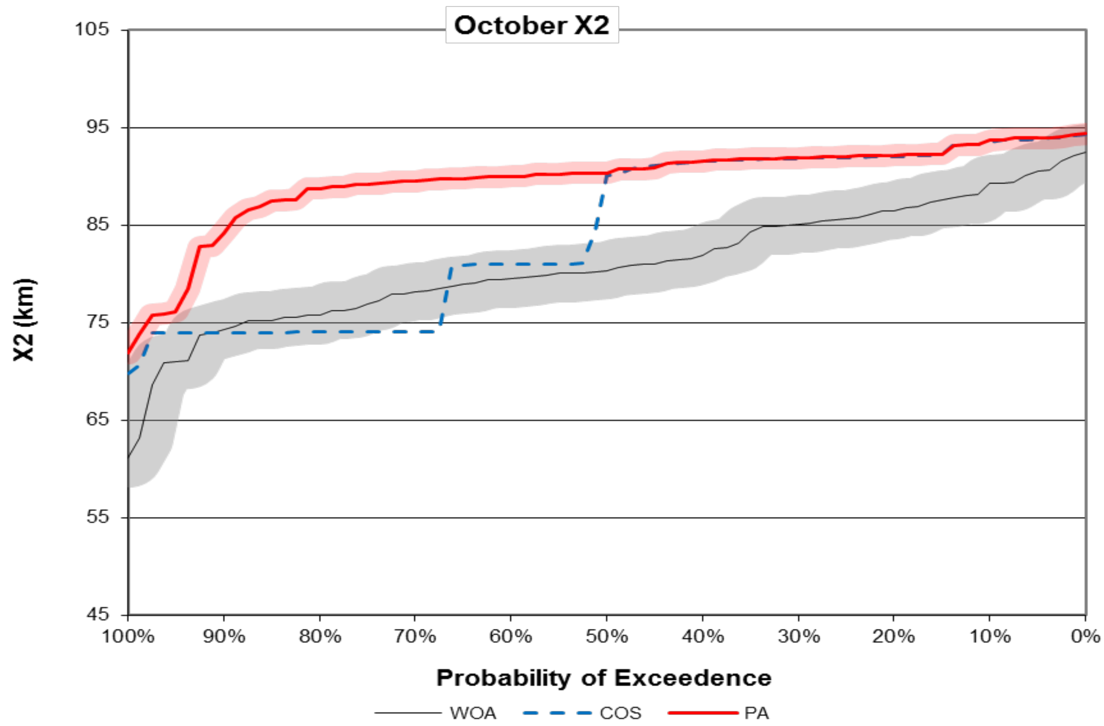


Figure 5.16-33. Mean Modeled X2 from CalSim, October.

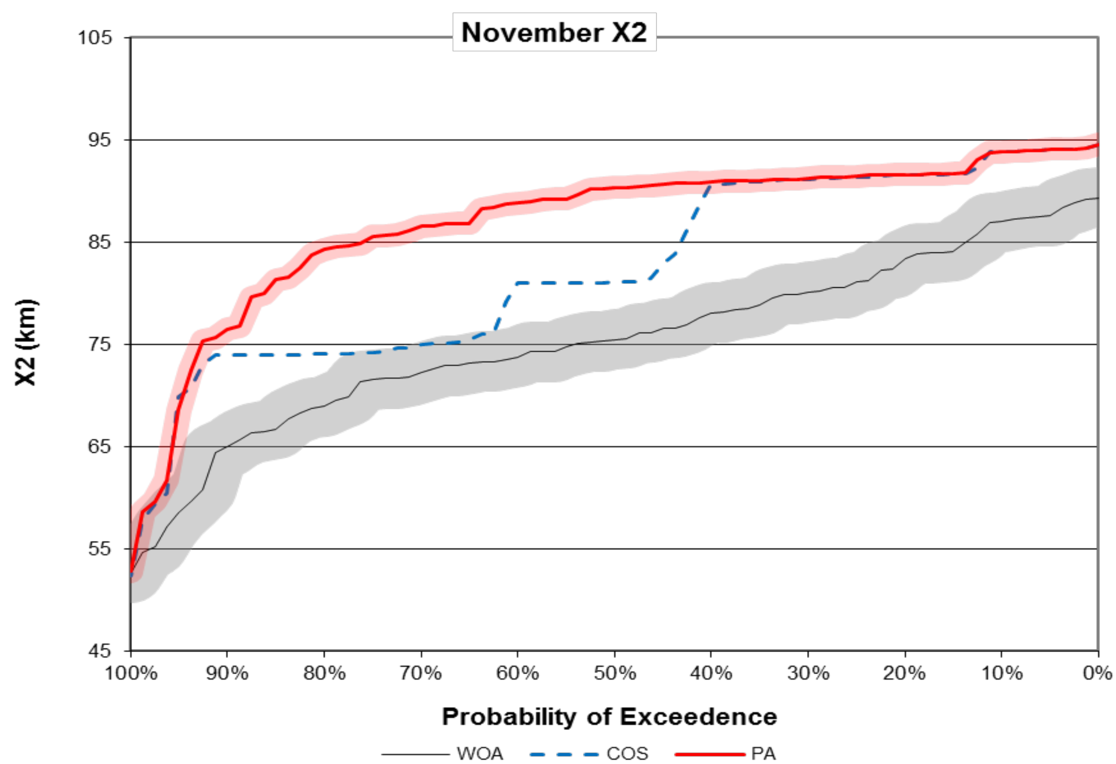


Figure 5.16-34. Mean Modeled X2 from CalSim, November.

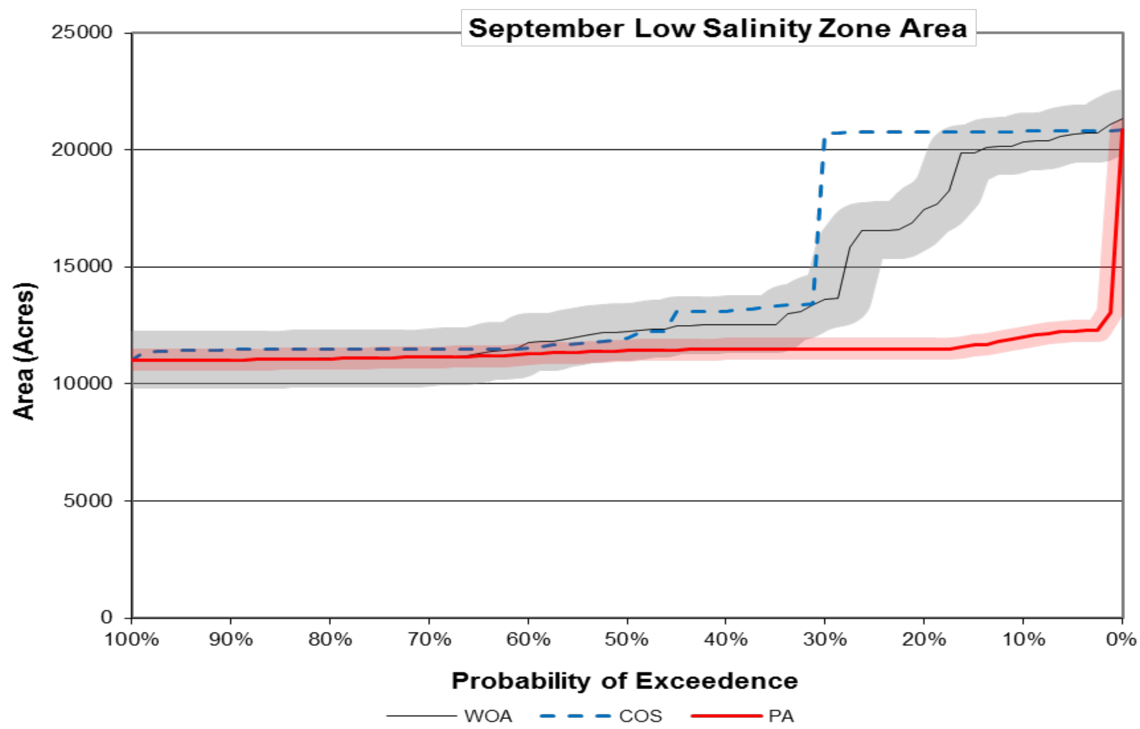


Figure 5.16-35. Mean Modeled Low Salinity Zone Area, September.

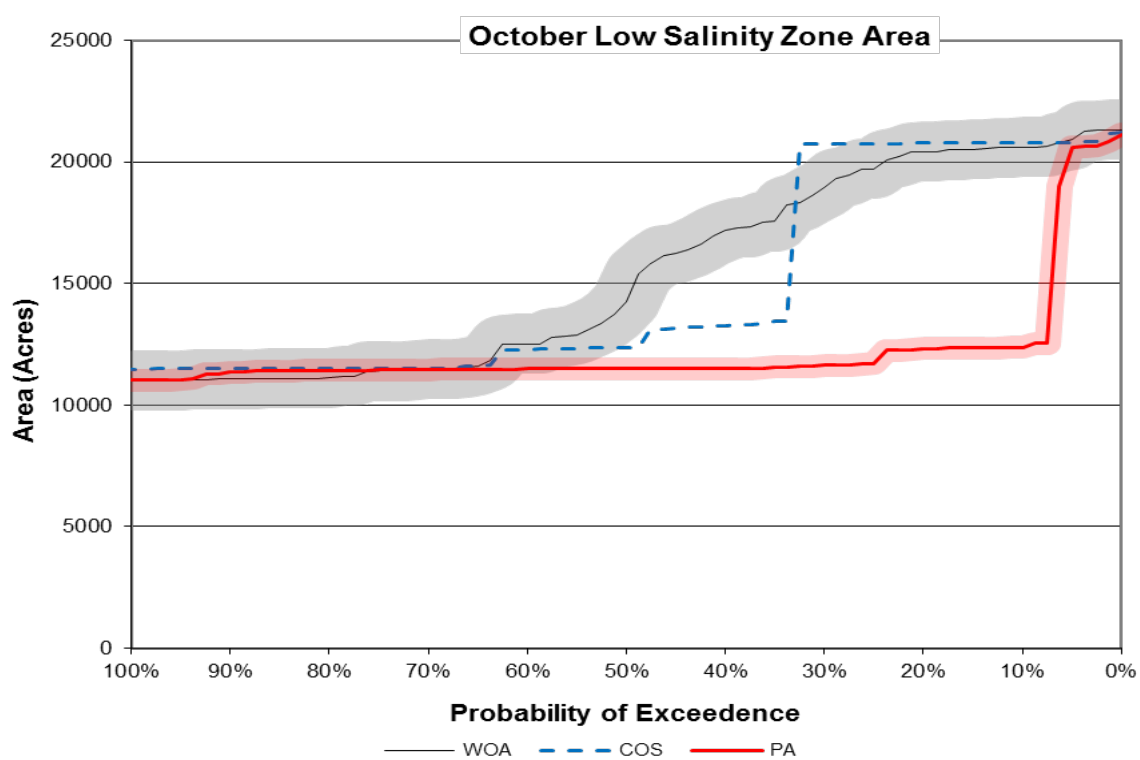


Figure 5.16-36. Mean Modeled Low Salinity Zone Area, October.

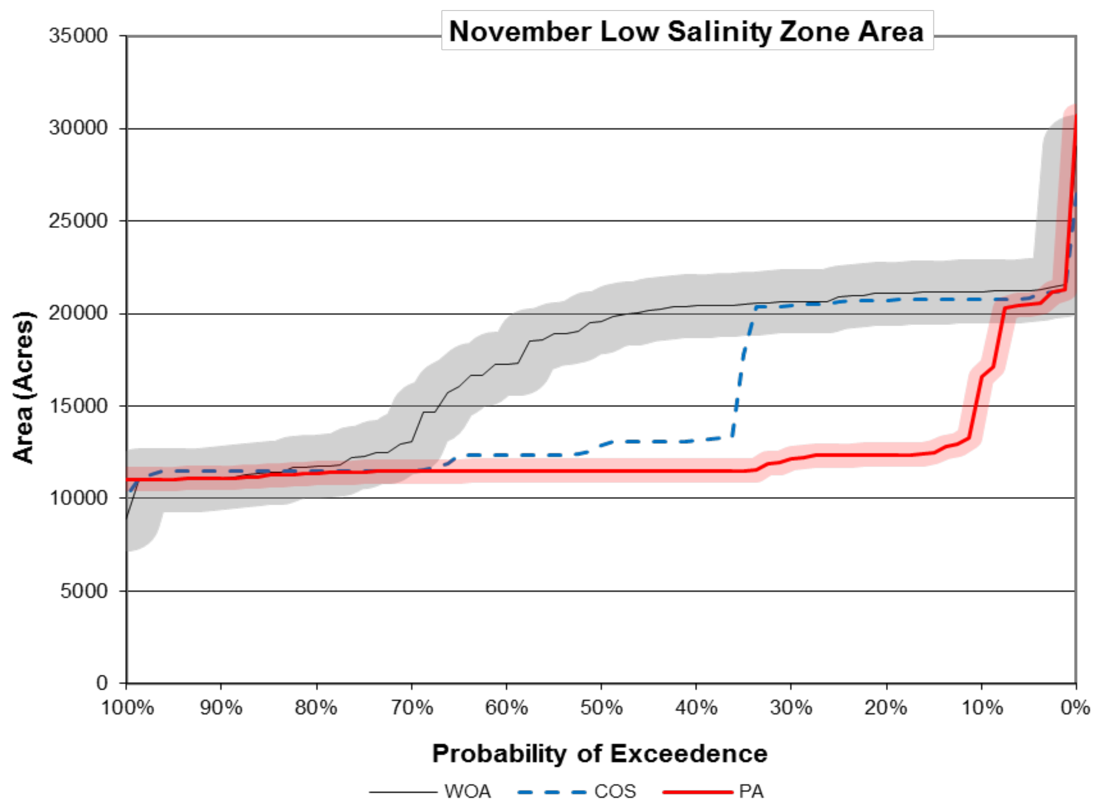


Figure 5.16-37. Mean Modeled Low Salinity Zone Area, November.

The overall potential reduction in the size of the low salinity zone and its general placement outside of Suisun Bay under the proposed action as summarized above from CalSim modeling has the potential to result in adverse impacts to Delta Smelt, per the hypothesis from the IEP MAST (2015) conceptual model (Figure 5.16-6).

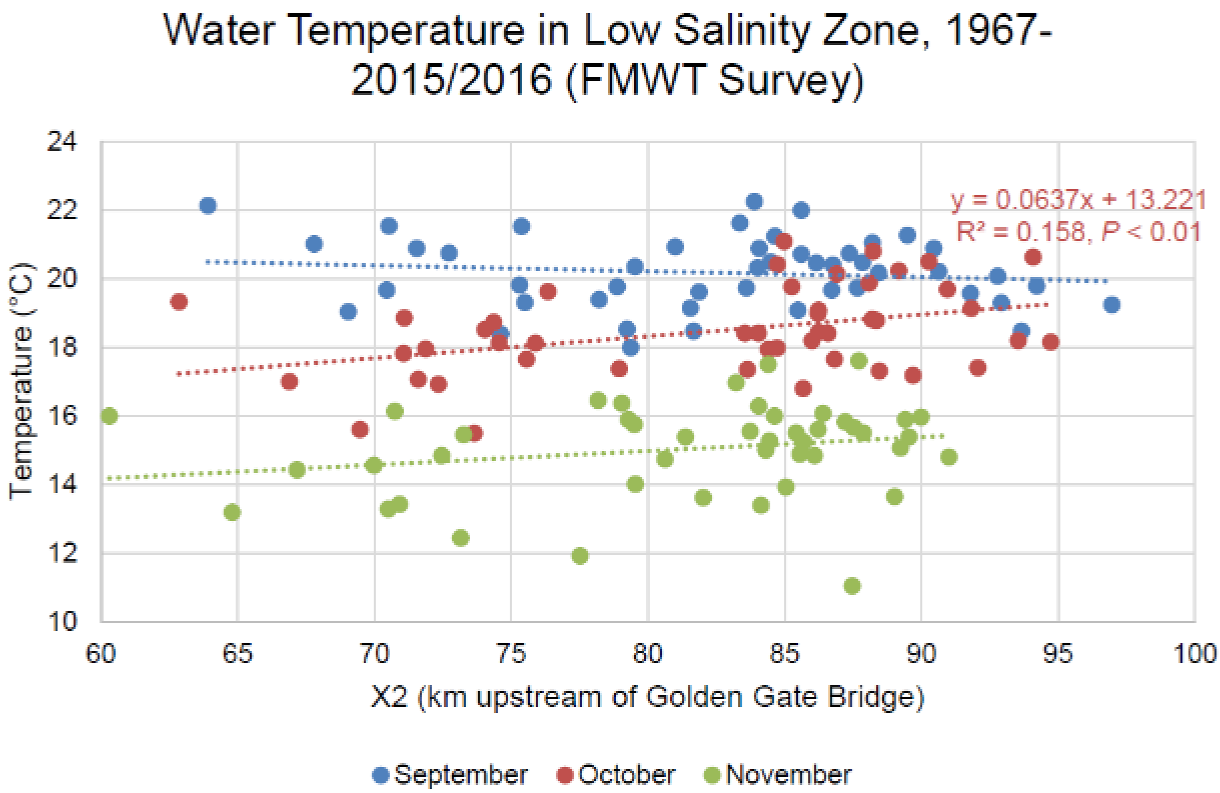
5.16.3.1.4.3 Harmful Algal Blooms

As described in more detail for juvenile Delta Smelt, differences in Delta flows, velocity, and water clarity could affect the occurrence of *Microcystis* blooms. Increases in harmful algal blooms resulting from the proposed action relative to without action could potentially result in negative impacts to subadult Delta Smelt, although this is uncertain.

5.16.3.1.4.4 Predation Risk

Turbidity could be affected by the proposed action relative to without action. Thus, potentially less sediment supply during the winter/spring could give less sediment for resuspension during the fall subadult period. With greater (more upstream) X2 under the PA (see Figure 5.16-33, 5.16-34, 5.16-35), the low salinity zone potentially could overlap areas with greater water clarity (i.e., lower turbidity) that are more likely to have wind-wave sediment resuspension (IEP MAST 2015, p.50), which could then translate into greater predation risk. The extent to which observed negative correlations between fall X2 and water clarity in the low salinity zone are the result of antecedent conditions (i.e., sediment supply during high-flow months) is uncertain (ICF 2017, p.106), although recent science indicates that wind may control turbidity (Bever et al., 2018).

As previously described for other life stages, water temperature would not be expected to be greatly affected by the proposed action, as illustrated by the low to no correlation between water temperature in the low salinity zone and X2 (Figure 5.16-39). Any effects would be well within the tolerance of subadult Delta Smelt (Komorske et al. 2014).

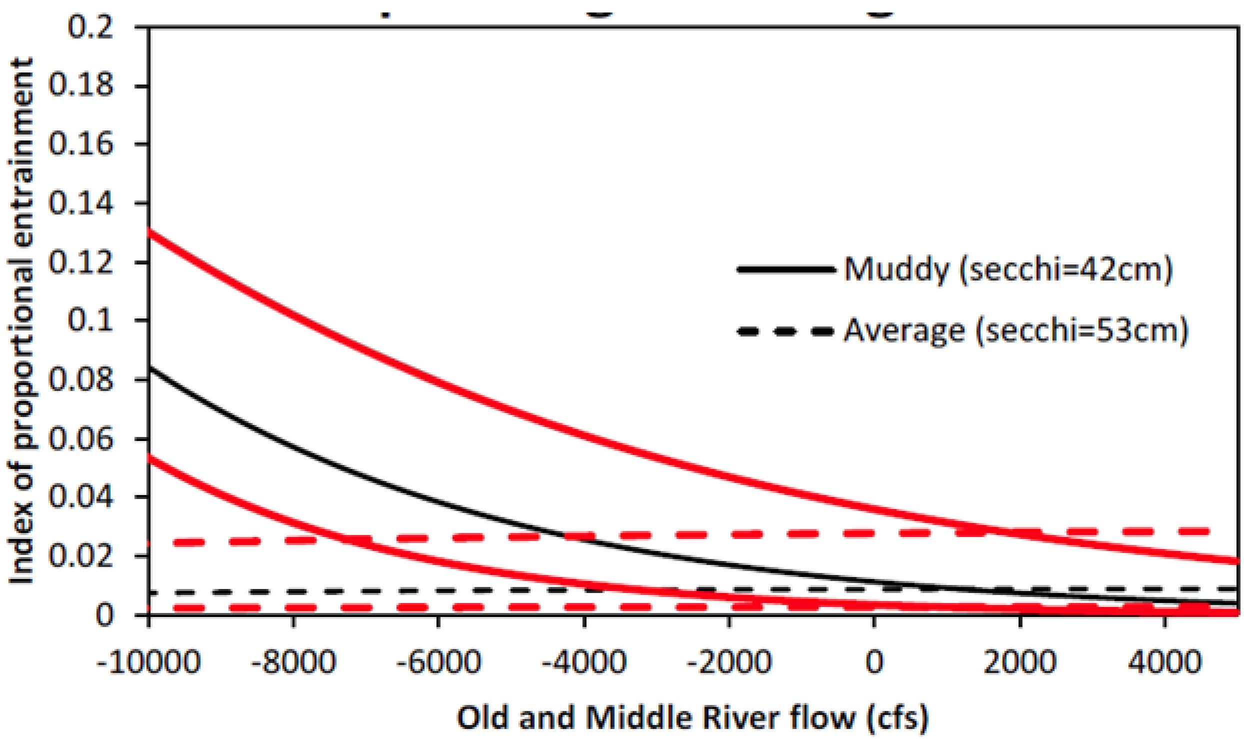


Source: ICF (2017, p.118). Note: Lines show regressions, but only October was statistically significant.

Figure 5.16-38. Mean Water Temperature in the Low Salinity Zone (Salinity = 1 to 6) from Fall Midwater Trawl Survey Data versus Mean X2, 1967 to 2015/2016

5.16.3.2 OMR Management

For adult Delta Smelt moving to spawn and transition to the egg/larval life stage, water diversions and flows (hydrology) together act to affect entrainment risk (Figure 5.16-3). In general, Delta Smelt salvage increases as increasing net OMR flow reversal (i.e., more negative net OMR flows) interacts with turbidity exceeding 10–12 NTU during December–March (USFWS 2008, Grimaldo et al. 2009). Analyses by Grimaldo et al. (2017) confirmed previous observations of relationships with OMR flows, and provided refined understanding of other factors influencing entrainment risk (expressed as number of adult Delta Smelt salvaged). Increased entrainment risk (defined as 50% of salvage) can occur following winter first flush events when precipitation increases flow and turbidity in the Delta and adult Delta Smelt move upstream into the Delta to spawn (Grimaldo et al. 2009; 2017). When water of higher turbidity (≥12 NTU) entering the Delta from the Sacramento River forms a continuous “bridge” between the central Delta (lower San Joaquin River) and Old and Middle Rivers, and negative OMR flows are relatively high, the risk of entrainment can increase. OMR flows alone do not predict entrainment risk; turbidity is also a key consideration, along with precipitation, exports and population size. For predictions of proportional loss of adult Delta Smelt during the post-2008 biological opinion period, using data for 2009–2015, proportional entrainment is predicted to be fairly insensitive to OMR flows at an average turbidity (Secchi depth), but steeply increases as OMR becomes more negative when turbidity is elevated (Figure 5.16-40).



Source: USFWS (2018). Note: Red lines indicate 95% Confidence Intervals.

Figure 5.16-39. Model Predictions of Adult Delta Smelt December–March Proportional Entrainment Index as a Function of Mean December–February Old and Middle River Flows and Secchi Depth During Delta Fish Surveys.

5.16.3.2.1 Adults to Eggs and Larvae (December – May)

5.16.3.2.1.1 Entrainment Risk

The without action conditions of no south Delta export would not entrain adult Delta Smelt. The lack of south Delta export pumping is reflected in OMR flows under the WOA scenario generally being positive (Figures 5.16-41, 5.16-42, 5.16-43, 5.16-44).

Based on the typical distribution of Delta Smelt, few individuals would be expected to occur in the south Delta (Figures 5.16-1 and 5.16-22). CalSim modeling suggests that OMR flows under the proposed action generally would be similar to current operations, reflecting the onset of OMR management after December 1 during which OMR generally would be ≥ -5,000 cfs. As reflected in Figures OMR_Jan and OMR_Feb, OMR flows under the PA have the potential to be slightly more negative than COS, but additional exports would only occur within the scope of protective criteria, which are described in the *OMR Management* section of the *Proposed Action* description. The monthly CalSim modeling does not reflect real-time criteria that are included in the proposed action, but does make assumptions to account for turbidity bridge avoidance actions in the overall monthly results. Overlapping protections also exist for NMFS-managed species, which could be triggered even when triggers have not occurred for Delta

Smelt, and would offer incidental protection to Delta Smelt. Operation to the OMR flow criteria included in the proposed action would be expected to limit the risk of entrainment loss.

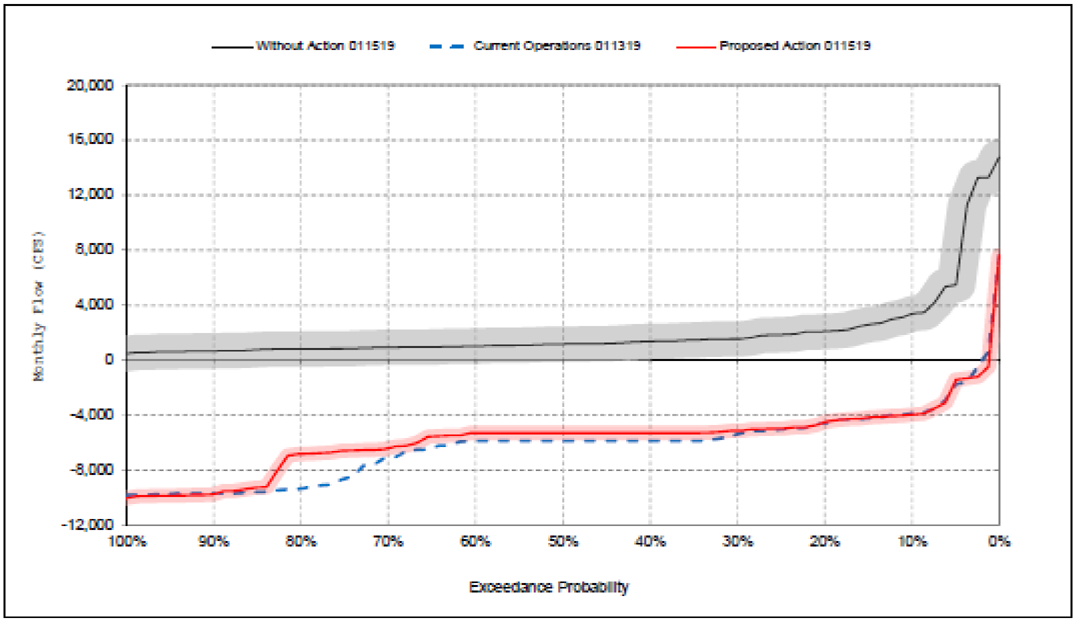


Figure 5.16-40. Mean Modeled Old and Middle River Flows, December

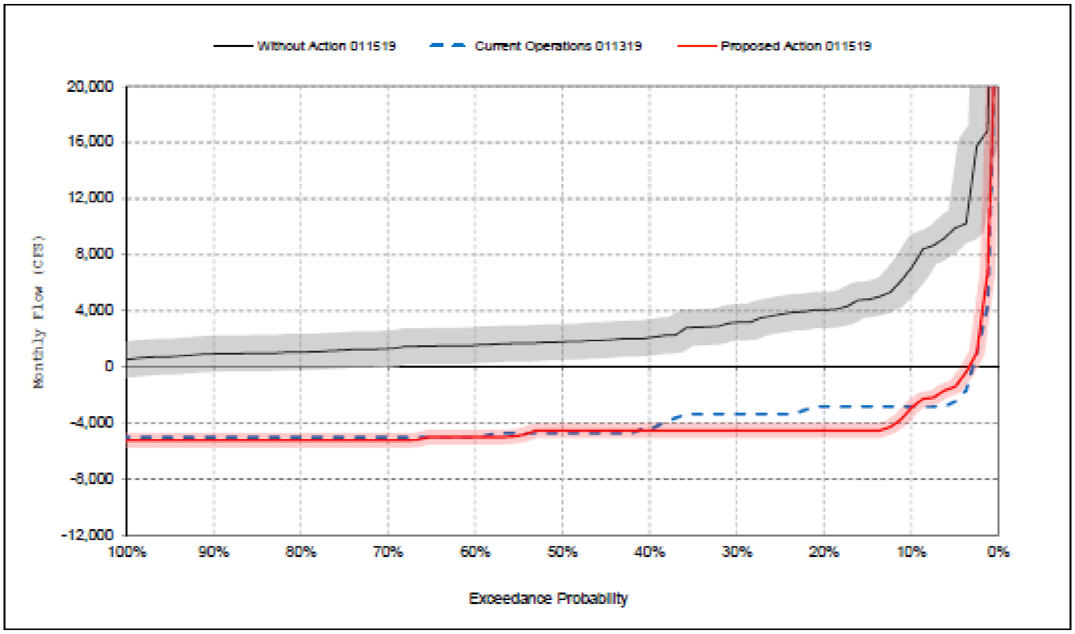


Figure 5.16-41. Mean Modeled Old and Middle River Flows, January.

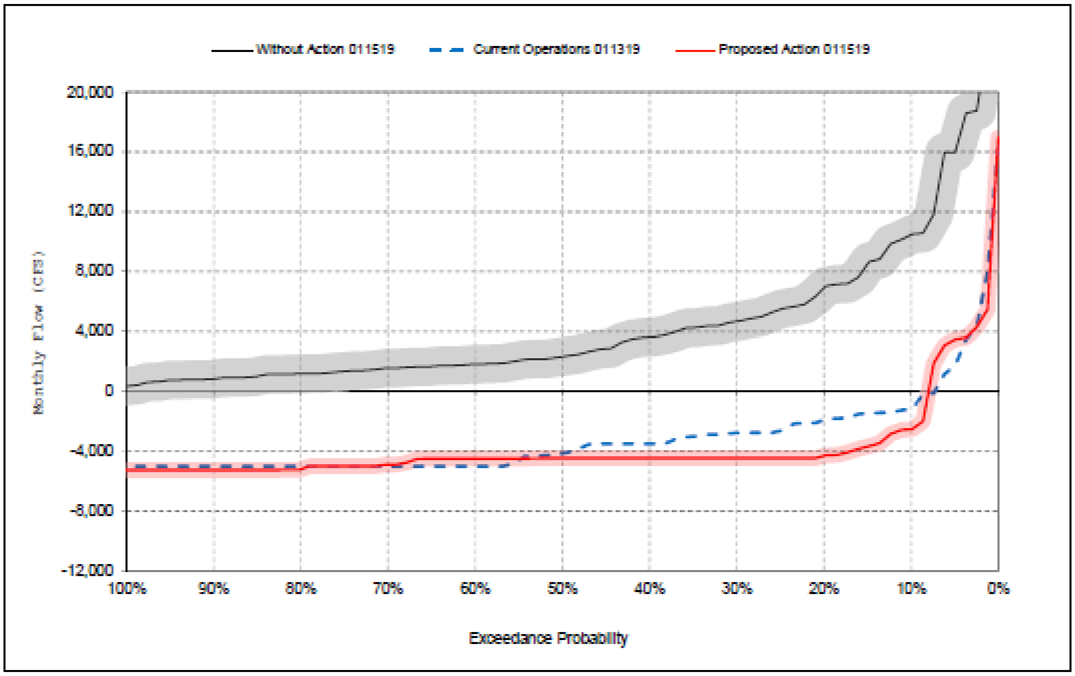


Figure 5.16-42. Mean Modeled Old and Middle River Flows, February.

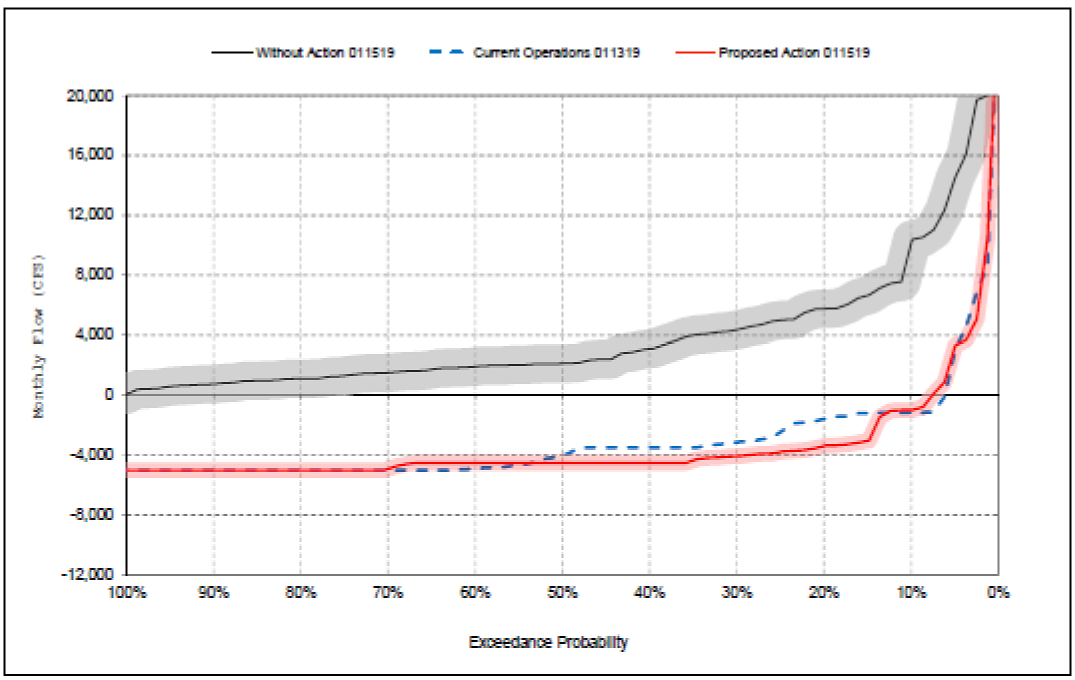


Figure 5.16-43. Mean Modeled Old and Middle River Flows, March.

5.16.3.2.2 Eggs and Larvae to Juveniles (March – June)

5.16.3.2.2.1 Entrainment Risk

The IEP MAST (2015) conceptual model suggests that larval and early juvenile Delta Smelt entrainment risk is related to exports and spring hydrology (Figure 5.16-4). Under without action conditions of no south Delta export pumping, there would be no entrainment of larval/early juvenile Delta Smelt at the south Delta exports for the CVP and SWP. The lack of south Delta export pumping is reflected in OMR flows under the WOA scenario generally being positive during March–June (Figures 5.16-44, 5.16-45, 5.16-46, 5.16-47). Current operations limit entrainment risk per the requirements of the 2008 biological opinion RPA Action 3. OMR flows are limited to protective levels ≥ -5,000 cfs during the main period of larval/early-juvenile entrainment risk (March-–June), as shown in the long-term modeling for the COS (Figures 5.16-44, 5.16-45, 5.16-46, 5.16-47).

Current operations management has kept salvage (take) of early juvenile Delta Smelt below the protective low limits prescribed in the 2008 biological opinion. However, salvage is inefficient for fish smaller than 30 millimeters in length. Therefore, larval juveniles less than 30 mm in size may not be accounted for accurately. As with adult Delta Smelt, CalSim modeling suggests that OMR flows under the PA generally would be similar to the OMR flows under COS in March (Figure 5.16-44), or generally be lower in April–June (Figures 5.16-45, 5.16-46, 5.16-47). As described further in the *OMR Management* section of the *Proposed Action by Basin* description, when larval or juvenile smelt are within the entrainment zone of the pumps based on monitoring group assessment and net flow in the lower San Joaquin River (QWEST) is negative, it is proposed that hydrodynamic models informed by survey data (e.g., EDSM or 20-mm Survey) would be run to estimate the percentage of larval and juvenile smelt that could be entrained, and operations would be adjusted such that modeling indicates that no greater than 10% loss of modeled larval and juvenile cohort Delta Smelt would be entrained. Similar to current operations, the proposed action would cease OMR management by the earlier of a) June 30, or b) when daily mean water temperature at Clifton Court Forebay reaches 25°C for three consecutive days—an indicator of poor habitat conditions and low likelihood of Delta Smelt presence in the south Delta (USFWS 2008, p.365)—and more than 95% of juvenile salmonids have migrated past Chipps Island (or Mossdale water temperatures have exceeded 72 degrees Fahrenheit for 7 days in June). Inclusion of these measures in the proposed action suggests that relatively few larval and juvenile Delta Smelt individuals would be lost to entrainment at the south Delta export facilities.

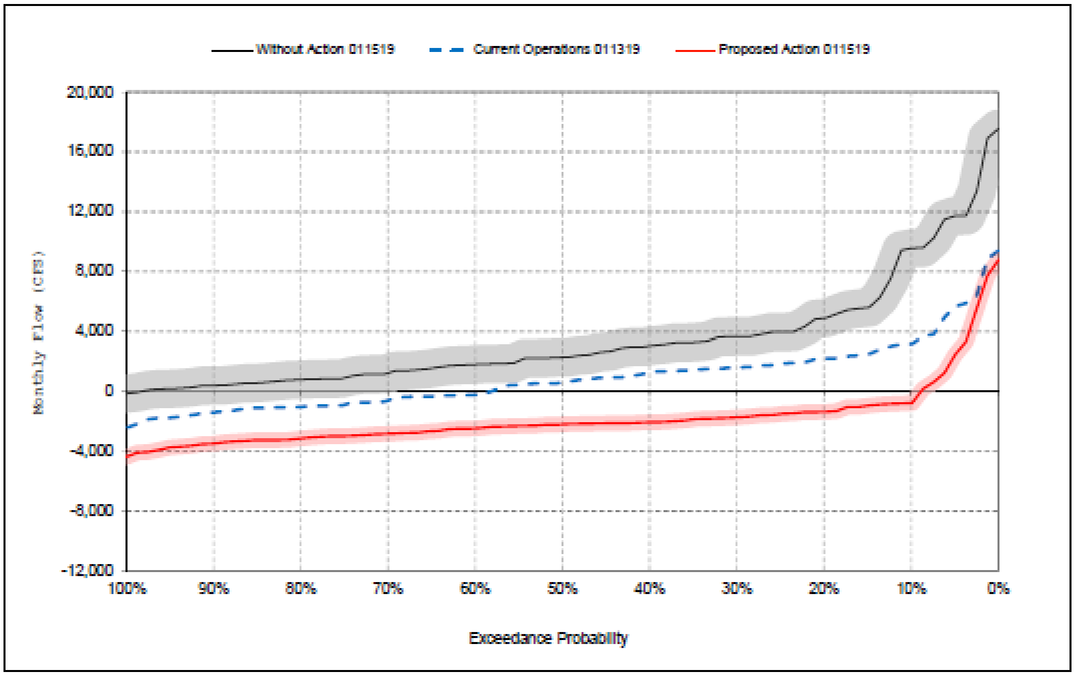


Figure 5.16-44. Mean Modeled Old and Middle River Flows, April.

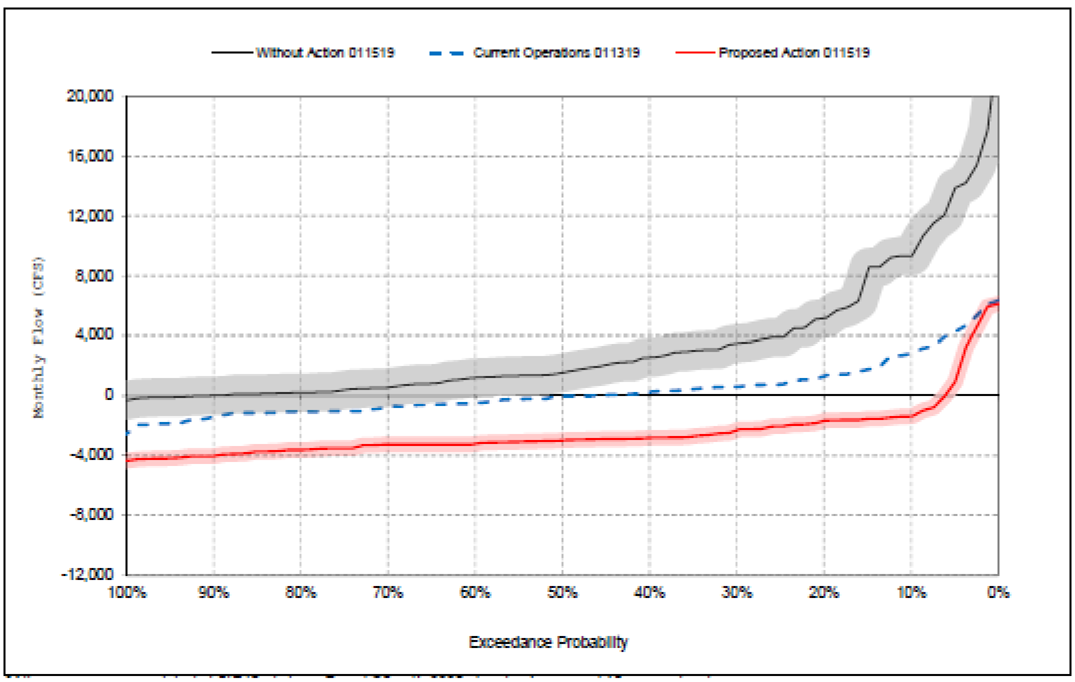


Figure 5.16-45. Mean Modeled Old and Middle River Flows, May.

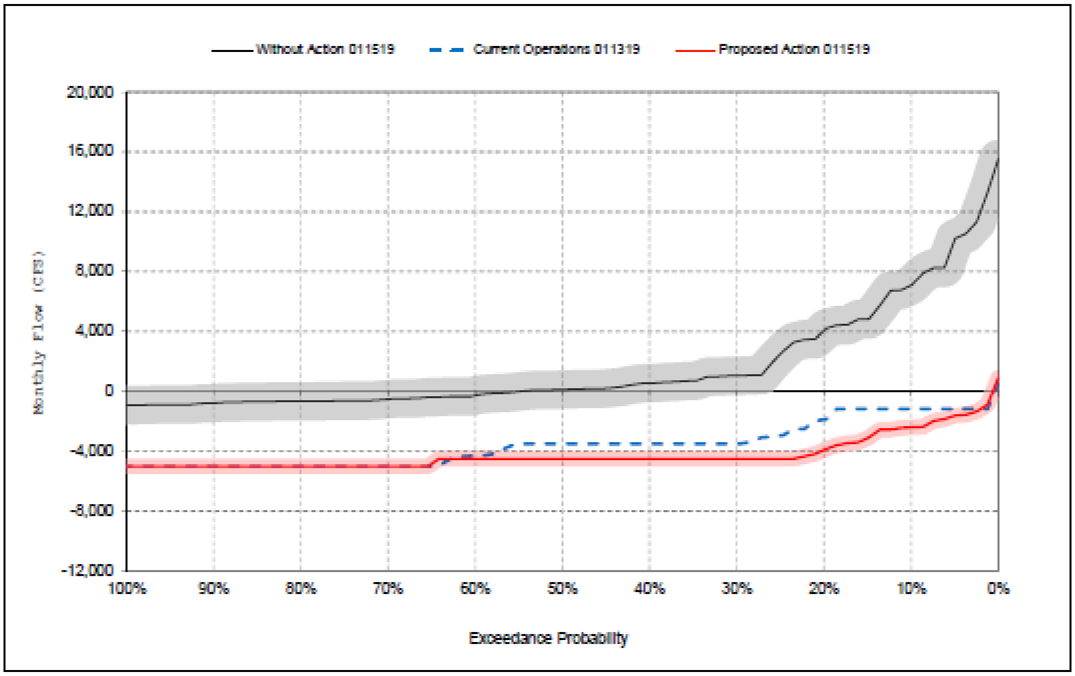


Figure 5.16-46. Mean Modeled Old and Middle River Flows, June.

5.16.3.3 Delta Cross Channel

5.16.3.3.1 Adults to Eggs and Larvae (December – May)

As discussed by USFWS (2017a, p.265), it is unknown what, if any, direct impacts occur to Delta Smelt as a result of opening or closing the DCC gates. USFWS (2017a, p.265) considered the region near the DCC gates to only be transiently used during movement of some adult Delta Smelt upstream. USFWS (2017a, p.265) suggested that it may be possible that opening or closing the DCC gates changes the migration path of some Delta Smelt, but noted that it is unknown if there may be a change in predation risk or likelihood of successful spawning, for example. During the adult Delta Smelt upstream migration period (principally December–March; USFWS 2017a, p.265), the DCC gates under the proposed action would largely be closed as a result of adherence to D-1641 criteria as well as real-time operations as a function of juvenile salmonid catch indices and projected water quality in the central/south Delta. Under without action conditions, DCC gates are permanently closed. USFWS (2017a, p.265) suggested that closure of the DCC would create more natural hydrology for migrating adult Delta Smelt by keeping flow in the Sacramento River and Georgiana Slough. Under the proposed action, the DCC gates are open for periods, possibly impacting Delta Smelt; however, there is limited occurrence of adult Delta Smelt near the DCC.

5.16.3.3.2 Eggs and Larvae to Juveniles (March – June)

Under the proposed action, the DCC would be expected to be largely closed during the March–June egg/larval transition period to juveniles. As described in more detail for adults, it is not known what effect the gates have on migration paths of Delta Smelt, but any effects would be expected to be limited given the low occurrence near the DCC (Figures 5.16-1 and 5.16-2; see also USFWS 2017a, p.159). Potential hydraulic effects on flows toward the south Delta export facilities would be taken into consideration when assessing south Delta entrainment risk, for example.

5.16.3.3.3 Juveniles to Subadults (June – September)

The distribution of juvenile Delta Smelt is downstream of the DCC (Figures 5.16-1 and 5.16-2) and so any near-field effects of the DCC would not occur. Under the proposed action and consistent with current operations, the DCC would largely be open during the June–September transition from juveniles to subadults. The IEP MAST (2015) conceptual model does not specifically address habitat attributes that would be affected by this difference, which is a change in flow distribution rather than a change in overall summer hydrology, an environmental driver included in the conceptual model. More flow entering the lower San Joaquin River through the DCC presumably could lead to greater potential for flux of *P. forbesi* to the low salinity zone, given the important of the San Joaquin River side of the Delta as a source of *P. forbesi* (Kimmerer et al. 2018c). However, the effect of south Delta exports on the flux of *P. forbesi* to the low salinity zone may be more important than any effect of the DCC, as suggested by QWEST flows (Figures 5.16-16 through 5.16-18).

5.16.3.3.4 Subadults to Adults (September – December)

As described for juvenile Delta Smelt, the distribution of subadult Delta Smelt is downstream of the DCC (Figures DS-1 and DS-2) and so any near-field effects of the DCC would not occur. Under the proposed action and consistent with current operation, the DCC would largely be open during the September–December transition from subadults to adults, prior to upstream migration as adults. It could be argued that an open DCC would provide more flow to the lower San Joaquin River and, therefore, increase the potential for flux of *P. forbesi* to the low salinity zone (Kimmerer et al. 2018c). However, as described for juvenile Delta Smelt, south Delta exports appear to be a more important effect than the effect of the DCC given the generally negative QWEST flows (Figure 5.16-18).

5.16.3.4 Temporary Barriers Program

5.16.3.4.1 Adults to Eggs and Larvae (December – May)

As discussed by USFWS (2008, p.225-226), the TBP under the proposed action has the potential to influence south Delta hydraulics by blocking flow entering the Delta from the San Joaquin River. Blocking this flow has the potential to increase entrainment risk of adult Delta Smelt during the later spring months after the barriers are installed. However, the Head of Old River barrier would not be installed under the proposed action. Adult Delta Smelt occurring in the vicinity of the barriers could be subjected to predation (USFWS 2008, p.226), although based on the typical distribution, few individuals would be expected to occur in the south Delta (Figures 5.16-1 and 5.16-2).

5.16.3.4.2 Eggs and Larvae to Juveniles (March – June)

As described for adult Delta Smelt, entrainment risk of larval Delta could be affected by the TBP, although the Head of Old River barrier would not be installed under the proposed action, thereby avoiding potential effects of that facility (USFWS 2008, p.225-226). The other barriers could also have effects such as trapping Delta Smelt upstream where they could be susceptible to entrainment, but effects would be limited given the low occurrence in the area (Figures 5.16-1 and 5.16-2).

5.16.3.4.3 Juveniles to Subadults (June – September)

Given occurrence outside of the south Delta, the TBP under the proposed action would not have direct effects on juvenile Delta Smelt, although USFWS (2008, p.226) suggested that there could be an effect on the flux of *P. forbesi* to the low salinity zone. Any such effect presumably would be small relative to the effect of south Delta exports on this flux, which was previously discussed in relation to seasonal operations.

5.16.3.4.4 Subadults to Adults (September – December)

As described for juvenile Delta Smelt, given occurrence outside of the south Delta, the TBP under the proposed action would not have direct effects on subadult Delta Smelt, although USFWS (2008, p.226) suggested that there could be an effect on the flux of *P. forbesi* to the low salinity zone. Any such effect presumably would be small relative to the effect of south Delta exports on this flux, which was previously discussed in relation to seasonal operations.

5.16.3.5 Contra Costa Water District Rock Slough Intake

Rock Slough is a relatively slow flowing, tidal waterway which ends at the Rock Slough Extension, approximately 1,700 feet upstream from the Rock Slough Intake. Rock Slough is generally poor habitat with relatively high water temperature and a prevalence of aquatic weeds (USFWS 2008; Reclamation 2016). Fish monitoring at the Rock Slough facilities, including the Rock Slough Headworks, RSFS, and Pumping Plant 1, from 1999 through 2018 has collected very few smelts of any life stage: two larval smelts, one delta smelt (8.3 mm TL collected May 2012) and one longfin smelt (7.3 mm TL collected March 2008); no juvenile smelts; and one adult smelt (66 mm FL delta smelt on February 2005) (Reclamation 2016; Tenera 2018b; ICF 2018). No smelts have been collected at the Rock Slough facilities since 2012.

Based upon poor habitat quality, the limited number delta smelt collected near the Rock Slough Intake, and the design criteria for the RSFS (approach velocity of 0.2 ft/sec), it is concluded that any near-field effect on hydrodynamics (i.e., near the Rock Slough Intake) and any entrainment of delta smelt at the Rock Slough Intake would be negligible. The following sub-sections address “far-field” effects resulting from altered Delta hydrodynamics for each life stage.

5.16.3.5.1 Adults to Eggs and Larvae (December – May)

Rock Slough Intake is located on Rock Slough, approximately 3.5 miles west of the junction of Rock Slough and Old River, which is over 12 river miles north of the gates to the SWP Clifton Court Forebay. Given its location, the Rock Slough Intake does not affect net reverse flow in Old and Middle Rivers (OMR), and any effect that diversions at Rock Slough Intake would have in the Old and Middle River corridor would be to increase the northerly (positive) flow away from the Banks and Jones Pumping Plants.

However, diversions at the Rock Slough Intake could affect flows in the San Joaquin River at Jersey Point, which is approximately 14 river miles from the Rock Slough Intake (via the shortest route through Franks Tract). The following analysis quantifies the maximum effect of Rock Slough diversions on velocity in the San Joaquin River at Jersey Point. The maximum effect of Rock Slough diversions on the channel velocity would be the maximum diversion rate (350 cfs) divided by the minimum cross-sectional area of the channel. This calculation assumes that all water diverted at Rock Slough comes from the San Joaquin River at Jersey Point, which is a conservative assumption (i.e., overestimates the effect on velocity).

The cross-sectional area of the San Joaquin River at Jersey Point is approximately 60,500 square feet (sf), but varies depending on the tidal stage from approximately 56,000 sf to 68,000 sf as calculated from USGS measurements of flow and velocity at Jersey Point (Station: 11337190) every 15 minutes for Water Years 2014 through 2018 (see Winter-run section). The maximum effect of water diversions at Rock

Slough Intake on velocity in the San Joaquin River at Jersey Point is calculated as 350 cfs divided by 56,000 sf, resulting in 0.00625 feet per second (ft/sec). For comparison, the most stringent fish screening requirement in the Delta (i.e., USFWS screening criteria for Delta Smelt) is 0.2 ft/sec, which is 32 times the maximum possible contribution from Rock Slough diversions. Furthermore, the actual effect is likely to be much lower than 0.00625 ft/sec because the water diverted at the Rock Slough Intake does not all come from the San Joaquin River west of Jersey Point.

Recognizing that CCWD owns and operates two additional intakes in the south Delta, this analysis examines the combined effect of all three intakes. CCWD's Old River Intake and Middle River Intake have a physical capacity of 250 cfs at each intake. If CCWD were to divert at all three intakes at the maximum capacity at the same time, total CCWD diversions would be 850 cfs. The corresponding effect on velocity in the San Joaquin River at Jersey Point would be 0.015 ft/sec. The velocity threshold used to protect Delta Smelt from diversions in the vicinity of fish screens (0.2 ft/sec) is over 13 times greater than the maximum possible contribution from CCWD's combined physical capacity. The water diversions at the Rock Slough Intake when combined with diversions at CCWD's Old River Intake and Middle River Intake have a negligible effect on velocity in the San Joaquin River at Jersey Point.

Nonetheless, even extremely small changes in velocity can affect the movement of neutrally buoyant particles such as phytoplankton. To examine the effect on neutrally buoyant particles, Reclamation calculated the distance that a particle would travel due to the maximum permitted Rock Slough diversions over the course of a day. A change in velocity of 0.00625 ft/sec could move a neutrally buoyant particle approximately 540 ft over the course of the day (0.00625 ft/sec * 86,400 sec/day). For comparison, the tidal excursion on the San Joaquin River at Jersey Point during a flood tide (i.e., the distance a particle will travel tidally upstream during a flood tide) is about 34,000 ft on average (or 6.4 miles), which is about 63 times the distance that diversions at Rock Slough could move a particle at the same location over the course of a full day. Therefore, the maximum possible contribution of diversions at Rock Slough on movement of neutrally buoyant particles such as phytoplankton is insignificant in comparison to the tidal excursion and mixing at this location.

Although the diversions at the Rock Slough Intake under the proposed action are not likely to impact adult Delta Smelt, the aggregate effects of all water diversion in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

5.16.3.5.2 <u>Eggs and Larvae to Juveniles (March – June)</u>

As described for adult Delta Smelt above, the maximum diversion rate at Rock Slough would have an insignificant effect on Delta hydrodynamics. Although the diversions at the Rock Slough Intake under the proposed action are not likely to impact larvae and juvenile Delta smelt, the aggregate effects of all water diversion in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

5.16.3.5.3 <u>Juveniles to Subadults (June – September)</u>

Juvenile Delta Smelt would not be expected to occur near the Rock Slough Intake in the south Delta (Figures 5.16-1 and 5.16-2) and so there would be no near-field individual or population-level effects from this diversion on this life stage. Furthermore, as described for adult Delta Smelt above, the maximum diversion rate at Rock Slough would have an insignificant effect on far-field Delta hydrodynamics. Although the diversions at the Rock Slough Intake under the proposed action are not likely to impact juvenile and subadults Delta smelt, the aggregate effects of all water diversion in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

5.16.3.5.4 Subadults to Adults (September – December)

Subadult Delta Smelt would not be expected to occur near the Rock Slough Intake in the south Delta (Figures 5.16-1 and 5.16-2) and so there would be no near-field individual or population-level effects from this diversion on this life stage. Although the diversions at the Rock Slough Intake under the proposed action are not likely to impact subadults and adult Delta smelt, the aggregate effects of all water diversion in the Delta, including exports at Jones and Banks Pumping Plants can affect channel velocity.

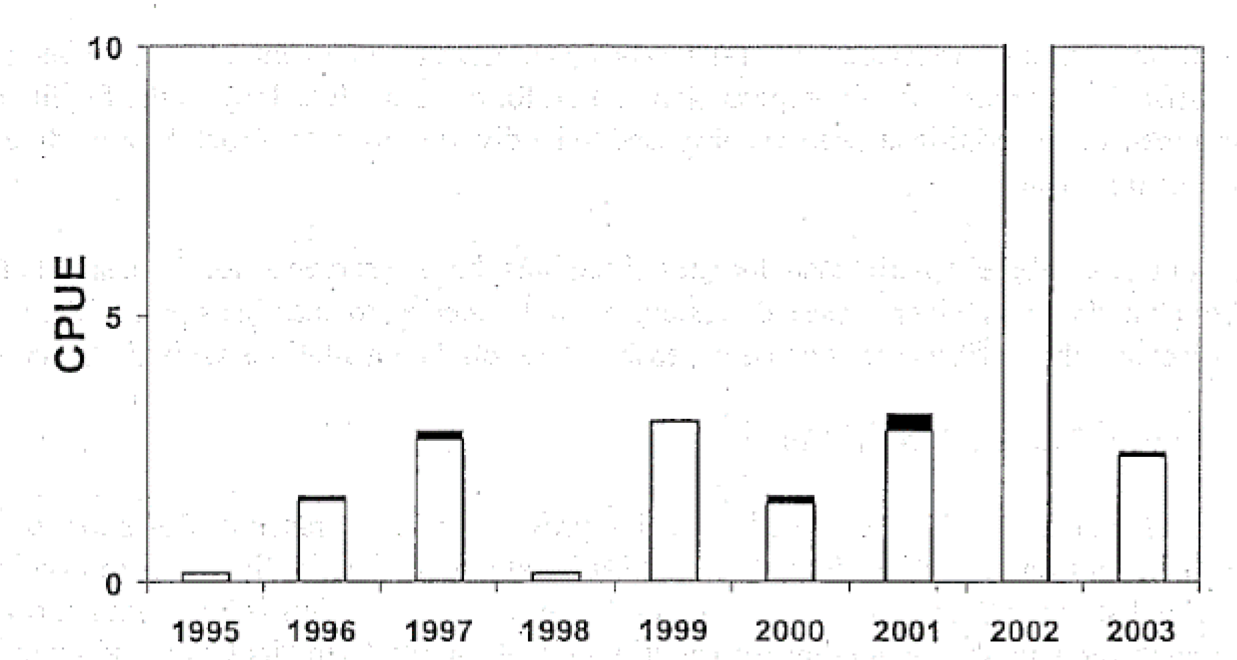
5.16.3.6 North Bay Aqueduct

5.16.3.6.1 Adults to Eggs and Larvae (December – May)

Under without action conditions, there would be no pumping at the Barker Slough Pumping Plant (BSPP). Under the proposed action, operational criteria at the BSPP would be the same as under current operation. Consistent with modeling assessed in the 2008 biological opinion, the CalSim modeling this biological assessment assumes that the current operations and the proposed action divert approximately 71,000 acre-feet of water per year as part of SWP operations, based on contracted amounts. Actual diversions during 2009-–2016 were lower (~33,000–50,000 acre-feet per year from the DAYFLOW database). As summarized by USFWS (2017a, p.269), the Cache Slough Complex from which the BSPP diverts water is an area of high adult Delta Smelt density (see also Figures 5.16-1 and 5.16-2). However, that does not mean catches are high everywhere in the complex. For instance, historical catch rates of Delta Smelt larvae in Barker Slough were consistently low during surveys undertaken following the issuance of the 1995 SWP/CVP biological opinion (USFWS 2005; Figure NBA_ds), indicating that a relatively small portion of the Delta Smelt population in the Cache Slough Complex is susceptible to entrainment/impingement from NBA diversions (USFWS 2017a, p.270). The BSPP intakes are screened to 3/32-inch opening, which excludes Delta Smelt >25 mm and therefore would be expected to preclude the potential for adult entrainment (USFWS 2017a, p.269). Approach velocity of ~0.2 ft/s at two of the ten units minimizes impingement potential on the screens (USFWS 2017a, p.269-270), whereas impingement potential presumably is greater at the eight larger units with approach velocity of ~0.44 ft/s (California Department of Fish and Game 2009, p.3). As a result of the California Department of Fish and Game (2009) ITP for operations of the SWP, diversion rates are limited to 50 cfs from January 15 to March 15 of dry and critically dry years (per the current forecast based on D-1641) if Longfin Smelt are detected at Station 716 during the annual Smelt Larval Survey. These restrictions reduce NBA diversions during the period of potential adult Delta Smelt occurrence and the early part of the delta smelt spawning season as well. However, the North Bay Aqueduct may have effects on predation (e.g., near the fish screens) and food availability (entrainment of plankton) in addition to direct entrainment.

5.16.3.6.2 Eggs and Larvae to Juveniles (March – June)

Historical catch rates of larval and early juvenile Delta Smelt in Barker Slough were low (USFWS 2005; Figure 5.16-48), suggesting limited exposure to potential effects of the proposed action from the BSPP. The 3/32-inch openings of the BSPP intakes mean that individual larval and early juvenile Delta Smelt are susceptible to entrainment, but there would be relatively low occurrence in the area.



Source: USFWS (2005, p.181). Note: The NBA values are the mean annual CPUE for stations 720, 721, and 727. The nearby North Delta sites are the mean annual CPUE for stations 718, 722, 723, 724, and 726 (https://www.wildlife.ca.gov/Portals/0/Images/Conservation/Delta/nbabase.gif)

Figure 5.16-47. Delta Smelt Catch Per Unit Effort (CPUE; Fish Per Trawl) for North Bay Aqueduct Monitoring in Barker Slough (Dark Bars) Compared to Nearby North Delta Sites (Lindsay, Cache, and Miner Sloughs; White Bars).

5.16.3.6.3 Juveniles to Subadults (June – September)

Available monitoring suggests infrequent occurrence in Barker Slough (Figure NBA_ds), and the majority of juveniles reaching adulthood would tend to rear in the low salinity zone in most years (Bush 2017), suggesting limited exposure to potential effects of the proposed action from the BSPP. The 3/32-inch openings of the BSPP intakes would be expected to exclude most juvenile Delta Smelt from entrainment.

5.16.3.6.4 Subadults to Adults (September – December)

The majority of subadults reaching adulthood would tend to rear in the low salinity zone in most years (Bush 2017), suggesting limited exposure to potential effects of the proposed action from the BSPP, and the 3/32-inch openings of the BSPP intakes would exclude subadult Delta Smelt from entrainment.

5.16.3.7 Water Transfers

As discussed in Spring-run Chinook Salmon section, Reclamation’s proposed action to expand the transfer window to July to November could result in additional pumping of approximately 50 TAF per year in most water year types. As shown in Figures 5.16-1 and 5.16-2, larvae and sub-adults are the main lifestages of Delta Smelt found in the south Delta, and both of these lifestages would occur in the South Delta mostly in the spring. The water transfer window therefore does not overlap with anticipated Delta Smelt presence in the South Delta. However, an occasional Delta Smelt could potentially be exposed to increased pumping as result of water transfers, which could cause entrainment, or predation risk. Effects would be the same as those discussed for OMR management above.

5.16.3.8 Clifton Court Forebay Aquatic Weed Program

In the without action scenario, Clifton Court Forebay (CCF) gates are not operated and Banks Pumping Plant is not run, and therefore there would be no removal of aquatic weeds from CCF. This program does occur under current operations as removal of aquatic weeds is necessary for operation of the CVP and SWP to allow for drawing water into the pumping plants and avoiding physical blockage at the trashracks, reducing pumping rates to prevent pump cavitation.

5.16.3.8.1 Adults to Eggs and Larvae (December – May)

For control of aquatic weeds (predominantly *Egeria densa*) in CCF, the proposed action includes application of herbicides (see proposed action for more details) after water temperatures within CCF are above 25°C or after June 28 and prior to the activation of Delta Smelt and salmonid protective measures following the first flush rainfall event in fall/winter, and mechanical harvesting as needed. Given the timing of the action, individual adult Delta Smelt would not be exposed to any toxic effects of the herbicides, as adult Delta Smelt would not be in CCF after water temperatures are above 25°C or after June 28 and before activation of Delta Smelt protection measures. Mechanical removal of aquatic weeds in CCF would occur on an as needed basis and therefore could coincide with occurrence of migrating adult Delta Smelt. Delta Smelt generally would not be expected to found near aquatic weeds (Ferrari et al. 2014), but could occur near the weeds if both fish and weeds are concentrated into particular areas by prevailing water movement in the CCF. Any potential adverse effects to individual Delta Smelt from mechanical removal of water hyacinth or other aquatic weeds (e.g., injury from contact with cutting blades) possibly would be offset to some extent by the reduced probability of predation by weed-associated predatory fishes and increases in salvage efficiency at the Skinner Fish Delta Fish Protective Facility because of reduced smothering by weeds. However, as noted by USFWS (2017a, p.271), mortality in CCF is very high for adults (Castillo et al. 2012), so that any effects of weed control would be limited as Delta Smelt in CCF would already have deceased. In addition, as previously described in the *Entrainment Risk* section, south Delta exports would be managed to limit the occurrence and therefore entrainment risk of Delta Smelt at the south Delta export facilities, thus limiting the number of individuals entering CCF that could be exposed to the weed control program.

5.16.3.8.2 Eggs and Larvae to Juveniles (March – June)

Control of aquatic weeds in CCF with herbicides under the proposed action (i.e., after water temperatures within CCF are above 25°C or after June 28 and prior to the activation of Delta Smelt and salmonid protective measures following the first flush rainfall event in fall/winter) would not affect larval Delta Smelt, given their life stage timing (March–June). Although mechanical removal activities under the proposed action could in theory affect larval Delta Smelt in CCF, they already have poor chances of survival in CCF (as discussed previously in the *Entrainment Risk* section) as salvage is only effective for larger fish.

5.16.3.8.3 Juveniles to Subadults (June – September)

Juvenile Delta Smelt occur in the low salinity zone or in the north Delta and not in the south Delta (Figures 5.16-1 and 5.16-2); there would not be effects on juvenile Delta Smelt from the CCF aquatic weed control program under the proposed action.

5.16.3.8.4 <u>Subadults to Adults (September – December)</u>

Subadult Delta Smelt occur in the low salinity zone or in the north Delta and not in the south Delta (Figures 5.16-1 and 5.16-2); there would not be effects on juvenile Delta Smelt from the CCF aquatic weed control program under the proposed action.

5.16.3.9 Suisun Marsh Facilities

Under the without action scenario, DWR would not operate the Suisun Marsh Salinity Control Gate, Roaring River Distribution System, Morrow Island Distribution System, or Goodyear Slough Outfall leading to a saltier Suisun Marsh and decreased Delta Smelt habitat. However, depending on the time of year, the without action scenario would result in much higher Delta outflow than the proposed action and current operations; thereby resulting in overall increases in Delta Smelt habitat.

5.16.3.9.1 <u>Adults to Eggs and Larvae (December – May)</u>

5.16.3.9.1.1 Suisun Marsh Salinity Control Gates

Operations of the SMSCG under the proposed action includes current operations (i.e., 0 - 253 days per year from October through May) plus an additional 60 days in June–October of wet, above normal and below normal water years to benefit juvenile and subadult Delta Smelt. In Wet year types, the average number of gate operation days between October and May is 50. In Below Normal years 72 days, in Dry water year types 52 days is the average number of days of gate operation, and in Critical water year types, DWR operates the SMSCG on average 156 days between October and May. In 2011, DWR did not need to operate the SMSCG at all. In 2015, DWR operated the gates for 253 days between October and May to help meet water quality criteria during that drought year. As such, the recent analysis of potential effects by USFWS (2017a, p.266-267) is relevant. Potential blockages of the migration of adult Delta Smelt individuals by SMSCG operations, previously the primary concern of USFWS (2008), were found to be of lesser concern by USFWS (2017a, p.267), given that Delta Smelt can spawn in Montezuma Slough (see adult distribution and frequency of occurrence in Figures 5.16-1 and 5.16-2). USFWS (2017a, p.267) also suggested that aggregation of predators such as Striped Bass near the SMSCG could increase predation rates, and operation of the SMSCG could increase risk of entrainment in diversions. There is limited risk of entrainment as the Roaring River Distribution System is screened, and little evidence for small diversions resulting in considerable entrainment of juvenile Delta Smelt (Nobriga et al. 2004).

5.16.3.9.1.2 Roaring River Distribution System

Water diversion operations of the RRDS under the proposed action would not change relative to current operations (although draining of the RRDS to Grizzly Bay/Suisun Bay would change in summer/fall, in coordination with the SMSCG action). As noted by USFWS (2017a, p.267-268), the RRDS is screened (3/32-inch opening), therefore excluding Delta Smelt of ~30 mm and larger and operated to maintain an approach velocity of 0.7 or 0.2 ft/s to minimize effects to Delta Smelt from entrainment, impingement, and screen contact.

Other effects of the Roaring River Distribution System could include increased predation near the fish screen and entrainment of plankton affecting food availability, as discussed above under North Bay Aqueduct. However, due to the relatively small capacity of the Roaring River Distribution System, these effects are anticipated to be small.

5.16.3.9.1.3 Morrow Island Distribution System

No changes in current MIDS operations are included in the proposed action. As discussed by USFWS (2017a, p.268-269), entrainment of individual adult Delta Smelt by the three MIDS unscreened 48-inch intakes could occur, but the effects would be expected to be limited to wet years (Enos et al. 2007), per spawner distributions found by Hobbs et al. (2005). No Delta Smelt were collected during entrainment sampling at MIDS in 2004-2006 (Enos et al. 2007). MIDS is often closed or diversions are small during the spring spawning period of adult Delta Smelt, which may offer protection given that Delta Smelt microhabitat occupancy tends to be in open water away from structures. Beach seine data has shown some Delta Smelt along the shore, which could be affected by MIDS.

Other effects of the Morrow Island Distribution System could include increased predation and negative effects on food availability through entrainment of plankton, as discussed above for the Roaring River Distribution System. However, due to the relatively small capacity of the Morrow Island Distribution System, these effects are anticipated to be small.

5.16.3.9.1.4 Goodyear Slough Outfall

Operation of the flap gates at the Goodyear Slough outfall under the proposed action would continue as under current operations. As discussed by USFWS (2017a, p.269), individual adult Delta Smelt could be entrained into Goodyear Slough by the flap gates' creation of a small southerly net flow, but the Goodyear Slough area is generally too saline for Delta Smelt and occurrence would only be likely in wet years (Enos et al. 2007, p.17).

The small southerly net flow could create other effects including such as increased predation near the flap gates. However, due to the relatively small capacity of the Goodyear Slough Outfall, these effects are anticipated to be small.

5.16.3.9.2 Eggs and Larvae to Juveniles (March – June)

5.16.3.9.2.1 Suisun Marsh Salinity Control Gates

As described for adult Delta Smelt, operations of the SMSCG under the proposed action would be unchanged from current operations during March–June. Gate operations could change movement patterns of larval Delta Smelt, potentially increasing risk of entrainment by diversions within Suisun Marsh, although existing modeling for RRDS suggests this risk to be limited as discussed in the life stage above.

5.16.3.9.2.2 Roaring River Distribution System

Effects to larval and young juvenile Delta Smelt from the RRDS under the proposed action would be limited and unchanged from current operations. Delta Smelt smaller than 30 mm could be susceptible to entrainment, whereas slightly larger fish could be susceptible to impingement (USFWS 2017a, p.268). Available particle tracking modeling suggests that entrainment risk would be low (USFWS 2017a, p.268).

5.16.3.9.2.3 Morrow Island Distribution System

As noted for adult Delta Smelt, there would be no changes to current MIDS operations under the proposed action, and any potential effects (in particular entrainment) would be expected to be limited given that conditions are generally too saline for Delta Smelt (limiting exposure to wet years) and the MIDS intakes are often closed or diversions are small during the spring larval period (USFWS 2017a, p.268-269).

5.16.3.9.2.4 Goodyear Slough Outfall

As described for adult Delta Smelt, operation of the Goodyear Slough outfall under the proposed action would continue as under current operations. Larval Delta Smelt individuals could be entrained into Goodyear Slough by the flap gates' creation of a small southerly net flow. However, the Goodyear Slough area is generally too saline for Delta Smelt and occurrence would only be likely in wet years (Enos et al. 2007, p.17).

5.16.3.9.3 Juveniles to Subadults (June – September)

5.16.3.9.3.1 Suisun Marsh Salinity Control Gates

As summarized for adult Delta Smelt, operation of the SMSCG under the proposed action could affect individual juvenile Delta Smelt through increased entrainment at local diversions or predation near the gates. There is limited risk of entrainment as the Roaring River Distribution System is screened, and little evidence for small diversions resulting in considerable entrainment of juvenile Delta Smelt (Nobriga et al. 2004).

5.16.3.9.3.2 Roaring River Distribution System

As discussed for adult Delta Smelt, juvenile Delta Smelt of ~30 mm and greater would be expected to be excluded from entrainment at RRDS under the proposed action, and the 0.7 or 0.2-ft/s approach velocity is protective of Delta Smelt.

5.16.3.9.3.3 Morrow Island Distribution System

No juvenile Delta Smelt were collected during entrainment monitoring at MIDS in 2004-–2006 by Enos et al. (2007), and juvenile Delta Smelt of ~30 mm and greater would be excluded from entrainment associated with the MIDS under the proposed action.

5.16.3.9.3.4 Goodyear Slough Outfall

As described for adult Delta Smelt, only in wet years would the Goodyear Slough outfall under the proposed action be expected to have potential effects to individual juvenile Delta Smelt as a result of entrainment into Goodyear Slough.

5.16.3.9.4 Subadults to Adults (September – December)

5.16.3.9.4.1 Suisun Marsh Salinity Control Gates

Operation of the SMSCG could result in increased entrainment at local diversions of individual subadult Delta Smelt or predation near the gates. However, the RRDS will be screened under the proposed action and there is little evidence that small diversions result in considerable entrainment of juvenile Delta Smelt (Nobriga et al. 2004).

5.16.3.9.4.2 Roaring River Distribution System

As discussed for other life stages, Delta Smelt of ~30 mm and greater and therefore all subadults would be expected to be excluded from entrainment at RRDS associated with the proposed action, and the 0.7 or 0.2-ft/s approach velocity is protective of Delta Smelt.

5.16.3.9.4.3 Morrow Island Distribution System

No subadult Delta Smelt were collected during entrainment monitoring at MIDS in 2004-–2006 by Enos et al. (2007) and those authors concluded that conditions are generally too saline, except for spawners (i.e., during the wet season) of wetter years. Therefore, effects of operation under the proposed action are expected to be negligible.

5.16.3.9.4.4 Goodyear Slough Outfall

As described for other life stages, only in wet years would the Goodyear Slough outfall under the proposed action be expected to have potential effects to individual Delta Smelt as a result of entrainment into Goodyear Slough. Given the seasonality of subadult occurrence during what is a low-flow portion of the year, exposure to the effects of Goodyear Slough outfall would be expected to be negligible.

5.16.3.10 Effects of Maintenance

Maintenance effects include crushing, impingement, noise, and harassment from in-water work to repair facilities. Implementation of the species avoidance and take minimization steps described in Appendix E, *Avoidance and Minimization Measures* would be anticipated to minimize potential negative effects to Delta Smelt from maintenance activities.

5.16.4 Effects of Conservation Measures

The following are proposed conservation measures that are intended to offset or reduce the effects of operations and maintenance under the proposed action. These conservation measures would only occur due to the implementation of the proposed action and are beneficial in nature. The following analysis examines the construction related effects of the measures but also the benefits to the population once completed. Conservation measures would not occur under the without action scenario.

While conservation measures are beneficial, they may involve construction, which may have temporary impacts to Delta Smelt. Actions involving construction (i.e., Delta habitat restoration, Yolo Bypass project, the small screen program, predator hot spot removal, habitat restoration, improvements to the Delta Cross Channel, Tracy Fish Facility, Skinner Fish facility, reconstruction of the lock at the upstream end of the Sacramento Deepwater Ship Channel, restoration of lower San Joaquin River spawning and rearing habitat, and construction of the Delta Smelt Conservation Hatchery) would not be expected to overlap the occurrence of adult Delta Smelt given the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (December–May; Figure 5.16-3). Therefore, construction-related effects under the proposed action are not expected to impact adult Delta Smelt.

In addition, larval Delta Smelt would not be expected to be exposed to the effects of construction associated with the proposed action, based on the timing of in-water construction (August–October) and the typical seasonal occurrence of this life stage in the Delta (March–June; Figure 5.16-4).

Juvenile and subadult Delta Smelt have the potential to be exposed to the effects of construction under the proposed action, based on the timing of in-water construction (August–October) and the occurrence of this life stage in the lower Sacramento River where some construction of conservation measures would occur. Effects to individual Delta Smelt could include temporary or permanent loss of habitat; exposure to increased suspended sediment and turbidity leading to changes in habitat quality and foraging ability; potential harm from accidental release of construction-related hazardous materials, chemicals, and waste; and effects from inadvertent spread of invasive or nuisance species. Such effects include some of the habitat attributes hypothesized to be of importance to this life stage (Figure 5.16-5). The risk from these potential effects would be minimized through application of measures such as those described in Appendix E, *Avoidance and Minimization Measures*.

5.16.4.1 Suisun Marsh Salinity Control Gates

5.16.4.1.1 Adults to Eggs and Larvae (December – May)

Adult Delta Smelt are not affected by the SMSGC operation under the proposed action as they are not generally in Suisun Marsh during June through September when the action would occur (see Figures 5.16-1 and 5.16-2).

5.16.4.1.2 Eggs and Larvae to Juveniles (March – June)

Larvae Delta Smelt are not affected by the SMSCG operation under the proposed action as they are not generally in Suisun Marsh during June through September when the action would occur (see Figures 5.16-1 and 5.16-2).

5.16.4.1.3 Juveniles to Subadults (June – September)

As described in the IEP MAST (2015) conceptual model, food availability and quality is a key component of the June–September transition probability of juvenile Delta Smelt to subadulthood through growth and survival of individuals (Figure 5.16-5). The proposed action includes SMSCG operations in 60 days during June–October of wet, above normal and below normal water year types in order to increase Delta Smelt food availability and quality through increased access to, and provision of low salinity Delta Smelt juvenile habitat in, the relatively food-rich Suisun Marsh habitat. The operation of the SMSCG would be combined with operation of the RRDS in order to allow productivity from the RRDS to be exported to the Grizzly Bay/Suisun Bay area (as described for the Delta Smelt Resiliency Strategy; California Natural Resources Agency 2016). As described further below, this action can also provide benefit to the subsequent, subadult life stage.

Evidence from a pilot 2018 application of the SMSCG action provides support for predicted habitat benefits. The SMSCG were operated during August 2018 and it was found that Delta Smelt entered the marsh and, therefore, had access to more productive habitat, better water quality conditions (lower salinity and higher turbidity) occurred, and the benefits extended well beyond the period of gate operations (Sommer et al. 2018). Thus, the proposed SMSCG action potentially increases Delta Smelt habitat suitability in an area with relatively high food availability and growth potential, as reflected by Delta Smelt individual-level responses such as stomach fullness (Hammock et al. 2015). The 2018 pilot implementation of the SMSCG action illustrated that the action could provide salinity conditions in Suisun Marsh during below normal years that, from the perspective of Delta Smelt juveniles, were similar to or better than in wet years (Sommer et al. 2018). This may be of particular importance during periods of several drier years in a row.

Seasonal operations of the SMSCG as part of the proposed action potentially provide a positive effect to Delta Smelt juveniles through increased food availability that would provide some offsetting of potential negative effects from seasonal water operations. The south Delta exports influence the subsidy of the Delta Smelt zooplankton prey *Pseudodiaptomus forbesi* to the low salinity zone from the freshwater Delta (Kimmerer et al. 2018a), with these potential negative effects probably being of particular importance on the San Joaquin River side of the Delta given the high density of *P. forbesi* there (Kimmerer et al. 2018b).

Potential effects from the proposed action related to the SMSCG action would be expected to have the potential to affect a sizable portion of the Delta Smelt population. Bush (2017) demonstrated that on average 77 percent of adult Delta Smelt either migrate to the low salinity zone as early juveniles or are resident in the low salinity zone throughout their lives. During and just after the August 2018 pilot implementation of the SMSCG action, EDSM data from surveys between August 6 and September 7 suggest an average of 20 percent (range 0–100%) of juvenile Delta Smelt were in Suisun Marsh, although there is appreciable uncertainty in the estimates given low numbers of fish caught (USFWS 2018_EDSM).

5.16.4.1.4 Subadults to Adults (September – December)

As described in more detail for Delta Smelt juveniles, the proposed SMSCG operation in June–October of wet, above normal and below normal years has the potential to increase Delta Smelt habitat suitability through lower salinity in the relatively food-rich Suisun Marsh, in conjunction with export of food to Grizzly Bay/Suisun Bay through operation of the RRDS. As described for juvenile Delta Smelt, the IEP MAST (2015) conceptual model posited link between fall hydrology and clam grazing (Figure 5.16-6) was not supported by an examination of *P. amurensis* biomass and grazing rate during the fall (Brown et al. 2014, p.50-56), so it is unclear what effect differences in hydrology might have on clam grazing and food availability.

As applied during the pilot 2018 implementation of the proposed SMSCG action discussed previously, additional Delta outflow is required to ensure that Delta salinity is maintained within D-1641 required levels, and that there is no net effect on X2. It is expected that this requires a few tens of thousands of acre-feet of additional Delta outflow (Zhou 2018); the required amount in 2018 was 37,000 acre-feet (Sommer et al. 2018). As illustrated with modeling for representative above normal (2005) and below normal (2012) years, operation of the SMSCG in August coupled with outflow augmentation to prevent no net X2 effect leads to a small increase in the overall Delta Smelt abiotic habitat Station Index (Table 5.16-1), a metric that includes salinity, turbidity, and current velocity (Bever et al. 2016).

Table 5.16-1. Monthly-Averaged Delta Smelt Station Index for with and without Suisun Marsh Salinity Control Gates Reoperation With Outflow Augmentation Scenarios.

Month	Year	Delta Smelt Station Index without SMSCG Reoperation	Incremental Change with SMSCG Reoperation With Outflow Augmentation
August	2005	0.54	0.03
August	2012	0.24	0.03
September	2005	0.48	0.04
September	2012	0.20	0.01
October	2005	0.39	0.01
October	2012	0.18	0.01

Source: Anchor QEA (2018, p.98-99). Notes: SMSCG Reoperation With Outflow Augmentation scenario shown in the table is the ‘Reoperation + Variable Outflow’ scenario from Anchor QEA (2018, p.8). Index shown is for entire area. SMSCG assumed to be operated in August.

5.16.4.2 Summer-Fall Delta Smelt Habitat

Reclamation proposes to conduct actions as described in the proposed action to target creation of summer and fall Delta Smelt habitat.

The plots below in Figure 5.16-49 show raw daily electrical conductivity and chlorophyll from the sensors at False River (FAL), Antioch (ANH), and Mallard Island (MAL) from 2007 to the present. These physical parameters would be used to determine whether Reclamation has created Delta Smelt Summer-Fall Habitat under this action. Delta Outflow relates best to salinity, as expected, with slight relationships for the other variables. Chlorophyll is rarely above 10 ug/L at any of these stations, which per Mueller-Solger et al. (2002) is an indicator of conditions for good zooplankton growth.

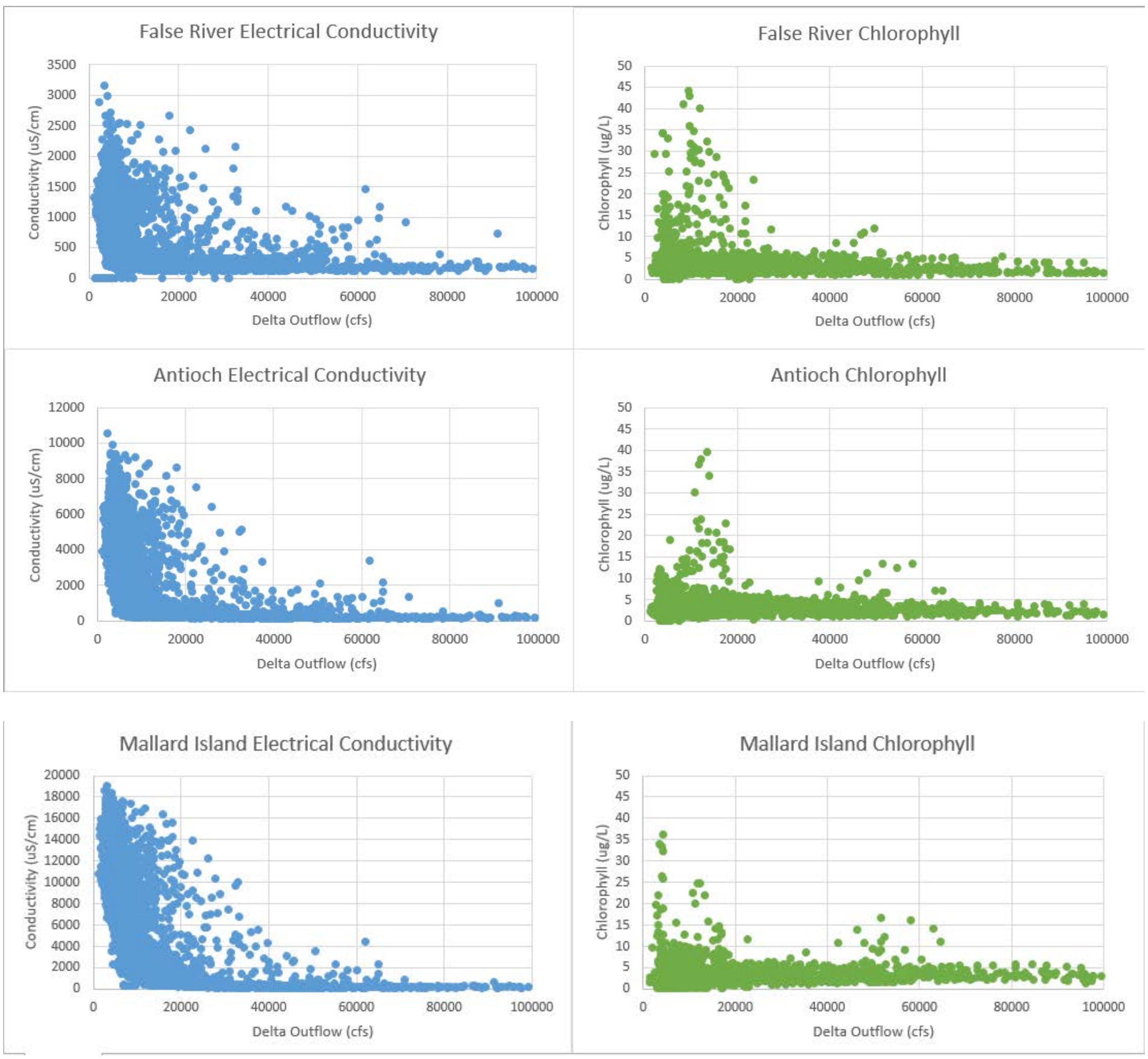
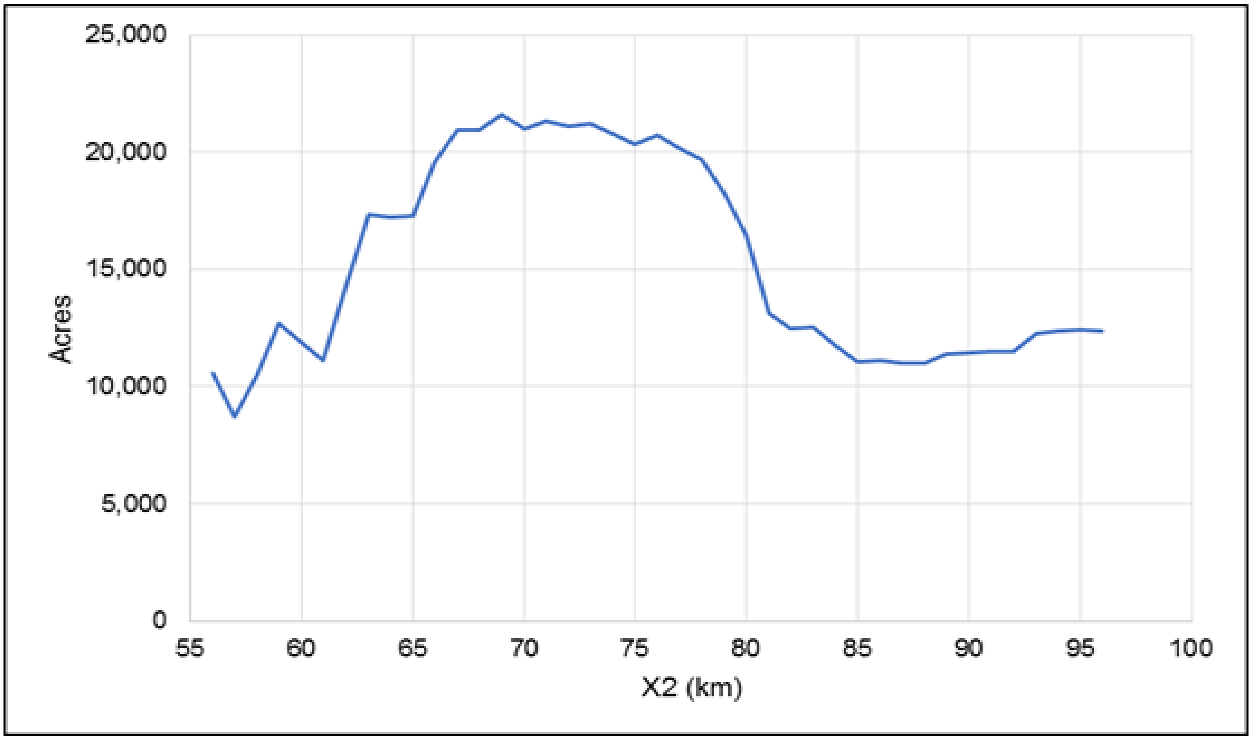


Figure 5.16-48. Raw daily electrical conductivity and chlorophyll from the sensors at False River, Antioch, and Mallard Island from 2007 onwards.

In the Without Action, X2 is at 86 km on average in September and 84 km on average in October. Under the proposed action, X2 is at 92 km on average in September and October; however, the modeling does not include the Delta Smelt Habitat action, so under the proposed action in wetter year types it is expected that X2 would be further downstream. As can be seen from Figure 5.16-52, there is very little difference in the acres of the low salinity zone between 84 and 92 km X2. Under the current operations scenario, X2 is at 86 km on average in September and 87 km on average in October, and is also within the same range of approximately 11,000 acres of low-salinity zone habitat as the proposed action and the without action. At X2 below 81 km, acres of low salinity zone increases, with a substantial water supply impact. Meeting Delta Smelt Summer-Fall Habitat physical and biological features using alternate mechanisms may allow smelt benefits not modeled in the proposed action.



Source: Brown et al. (2014, p.79).

Figure 5.16-49. Acres of low salinity zone (1-6ppt) versus X2 in kilometers from the Golden Gate Bridge

Summer-Fall Delta Smelt Habitat has no effect on Delta Smelt adults, eggs, larvae or juveniles. Summer-Fall Delta Smelt Habitat could benefit subadult to adult Delta Smelt by improving turbidity, food, low salinity zone area, or temperatures, depending on the actions Reclamation and DWR take to implement the action.

5.16.4.3 Clifton Court Predator Removal

Predator control efforts under the proposed action to reduce predation on listed fishes following entrainment into Clifton Court Forebay could reduce salvage-related loss of adult Delta Smelt. Entrainment risk under the proposed action would be managed to limit the potential for adult Delta Smelt to occur in the south Delta and be entrained. Depending on the gear type of Clifton Court predator control efforts, predator control efforts may also catch Delta Smelt (that would likely have been salvaged or lost).

5.16.4.3.1 Eggs and Larvae to Juveniles (March – June)

Depending on the geartype of Clifton Court predator control efforts, predator control efforts under the proposed action may also catch Delta Smelt that would likely have been salvaged or lost.

5.16.4.3.2 Juveniles to Subadults (June – September); Subadults to Adults (September – December)

Juvenile and subadult Delta Smelt do not occur in the south Delta (Figure 5.16-1).

5.16.4.4 San Joaquin Steelhead Telemetry Study

The San Joaquin Steelhead telemetry study does not affect Delta Smelt as it would be primarily in the San Joaquin River upstream, and also does not involve trapping or other mechanisms to affect Delta Smelt of any lifestage.

5.16.4.5 Food Subsidies (Sacramento Deepwater Ship Channel, Colusa Basin Drain, and Roaring River Distribution System)

These beneficial conservation measures would not occur under the without action scenario. The Colusa Basin Drain action was undertaken as a pilot implementation in 2016.

5.16.4.5.1 Adults to Eggs and Larvae (December – May)

Under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG has the potential to positively affect the food availability attribute posited to be of importance for adult Delta Smelt, thereby improving growth and survival (Figure 5.16-3). The timing of this action may be largely outside the adult Delta Smelt December–May time period given that increased SMSCG operations under the proposed action would occur in June–September of above normal and below normal years, although the Delta Smelt Resiliency Strategy notes that coordinated draining operations could benefit all Delta Smelt life stages (California Natural Resources Agency 2016, p.9).

Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have limited effects on adult Delta Smelt during December–May. Any adults that survive the spawning season could be affected.

Hydraulic reconnection of the Sacramento Deepwater Ship Channel with the Sacramento River through modification of the West Sacramento lock system would allow downstream transport of foodweb materials from the Ship Channel during the summer and therefore would have no effects on adult Delta Smelt during December-–May. Any adults that survive the spawning season could be exposed to the action, but would not be affected by the increasing food. This action could also increase the mobilization of accumulated sediment in the channel, which could have historical pesticides in it, possibly affecting Delta Smelt.

5.16.4.5.2 Eggs and Larvae to Juveniles (March – June)

As described for adult Delta Smelt, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS draining to Grizzly Bay in conjunction with reoperation of the SMSCG under the proposed action has the potential to positively affect growth and survival of Delta Smelt larvae through increased food availability (Figure 5.16-4). The timing of this action may be largely outside the larval Delta Smelt March–June time period given that increased SMSCG operations under the proposed action would occur in June–September of above normal and below normal years, although the Delta Smelt Resiliency Strategy notes that coordinated draining operations could benefit all Delta Smelt life stages (California Natural Resources Agency 2016, p.9).

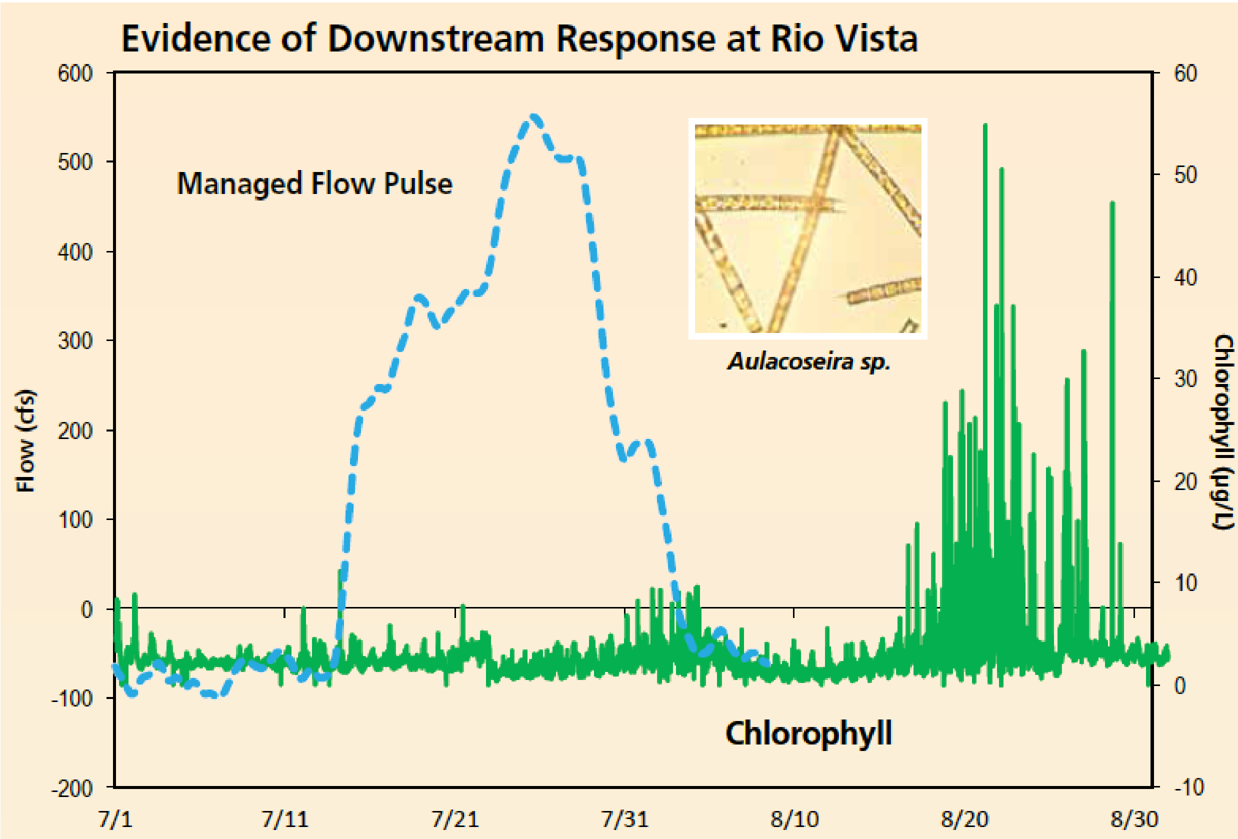
Provision of north Delta food subsidies by routing Colusa Basin drain water to the Cache Slough area through the Yolo Bypass would occur in summer/fall and therefore would have no effects on larval Delta Smelt during March–June.

Hydraulic reconnection of the Sacramento Deepwater Ship Channel with the Sacramento River through modification of the West Sacramento lock system would allow downstream transport of foodweb materials from the Ship Channel during the summer and, therefore, would have no effects on larval Delta Smelt during spring (March–June).

5.16.4.5.3 Juveniles to Subadults (June – September)

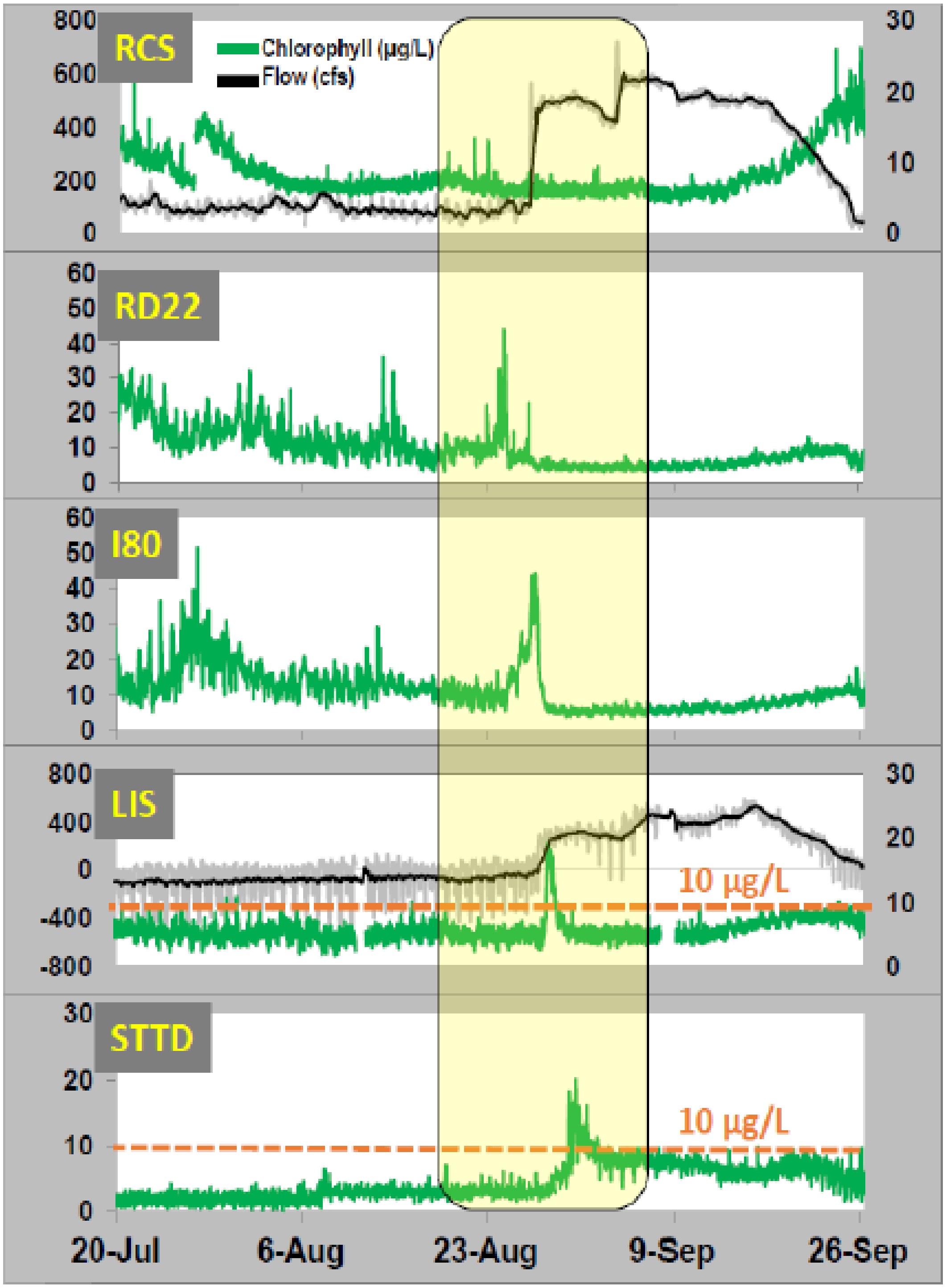
As noted for adult Delta Smelt, under the proposed action, provision of Suisun Marsh food subsidies through coordination of managed wetland flood and drain operations in Suisun Marsh and draining of RRDS to Grizzly Bay/Suisun Bay in conjunction with reoperation of the SMSCG has the potential to positively affect the food availability attribute posited to be of importance for juvenile Delta Smelt, thereby improving growth and survival (Figure 5.16-5). Increased SMSCG operations would occur in June–September of above normal and below normal years, and coordinated draining operations could benefit all Delta Smelt life stages, including juveniles (California Natural Resources Agency 2016, p.9). As described further in the analysis of conservation measure effects, during and just after the August 2018 pilot implementation of the SMSCG action, EDSM data from surveys between August 6 and September 7 suggest an average of 20% (range 0–100%) of juvenile Delta Smelt were in Suisun Marsh, although there is appreciable uncertainty in the estimates given low numbers of fish caught (USFWS 2018_EDSM).

Augmentation of flow from the Colusa Basin drain during summer/early fall could increase transfer of food web materials to the north Delta, thereby potentially increasing the food availability habitat attribute suggested hypothesized to be important for juvenile Delta Smelt (Figure 5.16-5). As previously described, an average of 23% of Delta Smelt surviving to adulthood are resident in the Cache Slough Complex/Sacramento Deepwater Ship Channel region throughout their lives, whereas the remainder either migrate to the low salinity zone or are resident there (Bush 2017). The proportion of the population resident in the north Delta would be most likely to benefit from the north Delta food subsidies action. A pilot implementation of this action in 2016 found that primary production in the north Delta increased as a result of the action (Figure 5.16-53; as had been observed in previous years without pilot implementation; Frantzich et al. 2018), with enhanced zooplankton growth and egg production (California Natural Resources Agency 2017). Reclamation (2018, p.2) suggested that a chlorophyll concentration of 10 μg/l of chlorophyll, as achieved in 2016 for a number of days during the action (Figure 5.16-53), could support relatively high zooplankton production (Mueller-Solger et al. 2002) without adversely affecting water quality (e.g., dissolved oxygen concentration). Analyses are underway to determine the potential effectiveness of a 2018 pilot implementation of the action, but preliminary information suggests that chlorophyll concentration above 10 µg/l was limited in duration in the Yolo Bypass (Figure 5.16-54) and there was no increase at Rio Vista (Figure 5.16-55).



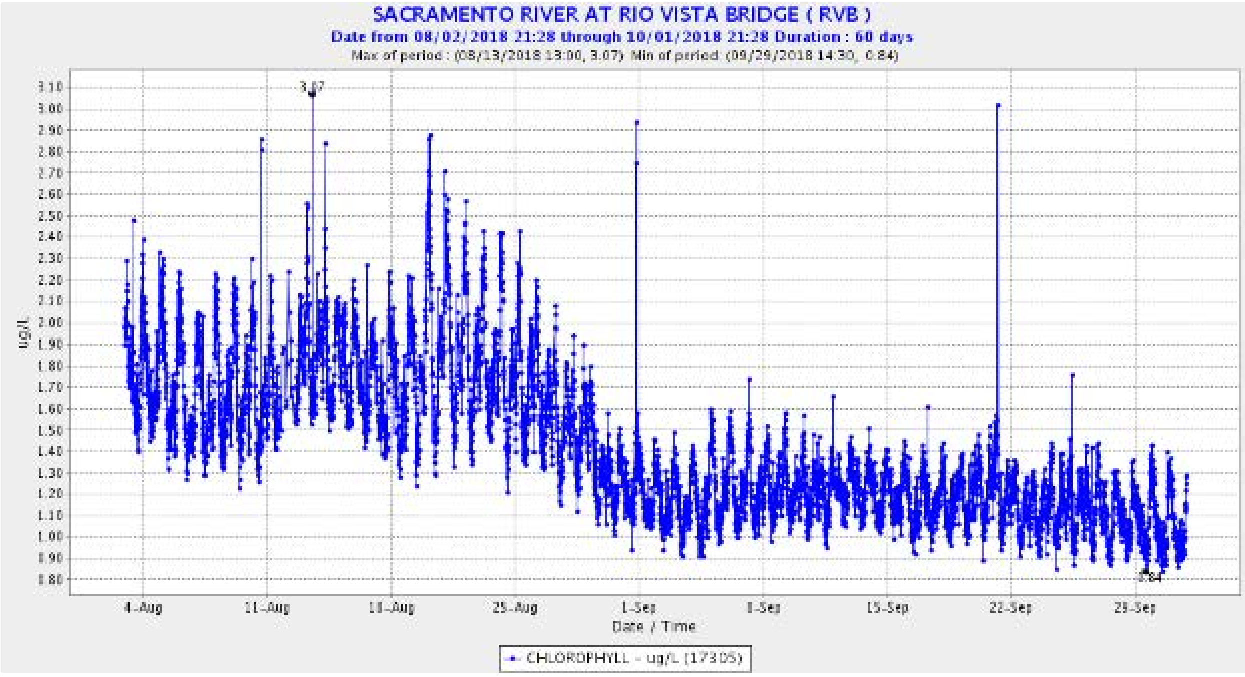
Source: California Natural Resources Agency (2017).

Figure 5.16-50. Managed Flow Pulse in the Yolo Bypass Toe Drain at Lisbon Weir and Chlorophyll Concentration at Rio Vista During 2016 Pilot North Delta Food Subsidies Action.



Source: NCWA (2018). Note: Yellow box indicates flow pulse into Yolo Bypass from Colusa Basin Drain.

Figure 5.16-51. Managed Flow Pulse in the Yolo Bypass Toe Drain at Lisbon Weir and Chlorophyll Concentration from North (RCS) to South (STTD) in the Yolo Bypass During 2018 Pilot North Delta Food Subsidies Action.



Source: California Data Exchange Center, http://cdec.water.ca.gov/jspplot/jspPlotServlet.jsp?sensor_no=17305&end=10%2F01%2F2018+21%3A28&geom=huge&interval=60&cookies=cdec01, accessed January 2, 2019.

Figure 5.16-52. Chlorophyll Concentration at Rio Vista Before, During, and After 2018 Pilot North Delta Food Subsidies Action.

Hydraulic reconnection of the Sacramento Deepwater Ship Channel with the Sacramento River through modification of the West Sacramento lock system, together with nutrient additions, potentially would allow downstream transport of foodweb materials from the Ship Channel during the summer. This could provide a benefit to individual Delta Smelt juveniles through increased growth and survival per the food availability attribute suggested hypothesized to be important in the IEP MAST (2015) conceptual model (Figure 5.16-5). The efficacy of the proposed action has yet to be tested with pilot studies (Reclamation 2018).

5.16.4.5.4 Subadults to Adults (September – December)

As described for Delta Smelt juveniles, this action could positively affect an appreciable portion of Delta Smelt subadults given operation of the SMSCG potentially in September, in conjunction with RRDS draining to Grizzly Bay/Suisun Bay. The extent of the potential positive effect would be dependent on the scale of managed wetland operations that could be coordinated for draining to habitats occupied by subadult Delta Smelt.

Hydraulic reconnection of the Sacramento Deepwater Ship Channel with the Sacramento River through modification of the West Sacramento lock system would allow downstream transport of foodweb materials from the Ship Channel during the summer. Therefore, the proposed action could result in positive effects on subadult Delta Smelt during early fall, if, as suggested by Reclamation (2018, p.2), any resulting phytoplankton/zooplankton bloom is self-sustaining for up to a month. The efficacy of the proposed action has yet to be tested with pilot studies.

5.16.4.6 Habitat Restoration

Completion of the 8,000 acres of habitat restoration would not occur under WOA. This action is currently underway, and the proposed action proposes to continue this ongoing work.

5.16.4.6.1 Adults to Eggs and Larvae (December – May)

Tidal habitat restoration associated with the proposed action has the potential to positively affect Delta Smelt adults through increased food availability, as well as also resulting in potential negative effects from contaminants, although the latter would be expected to be less than in areas previously used for agriculture. As previously noted, net export of food from restored areas may be limited (Lehman et al. 2010; Kimmerer et al. 2018c) and the greatest density of food export will be to areas within one tidal excursion of restored areas (Hartman et al. 2017, p.95).

5.16.4.6.2 Food Availability

The proposed action includes tidal habitat restoration of approximately an additional 6,000 acres. This tidal habitat restoration has the potential to increase food availability for Delta Smelt. For adult Delta Smelt, this relates directly to the food availability habitat attribute linked to the probability of spawning in the IEP MAST (2015) conceptual model (Figure 5.16-3). Recent studies indicate that net export of food from restored lands may be limited (Lehman et al. 2010; Kimmerer et al. 2018c), and the conceptual model indicates that the greatest density of food export will be to areas within one tidal excursion of restored areas (Hartman et al. 2017, p.95). Restored habitat may be occupied by adult Delta Smelt given suitable habitat features (Sommer and Mejia 2013).

5.16.4.6.3 Contaminants

Tidal habitat restoration under the proposed action has the potential to produce negative effects to Delta Smelt related to contaminants from the initial construction, although it also may reduce contaminant loading in the long term. As described in the recent biological opinion for the Yolo Flyway Farms restoration project, habitat restoration may result in an initial export of on-site contaminants (e.g., agricultural pesticides, organic pollutants and mercury) to downstream areas (USFWS 2017b). Contaminants would have the potential to negatively affect individual Delta Smelt or their prey (e.g., by reducing swimming ability (see brief review by IEP MAST 2015, p.66-67)). The potential for other contaminant issues (methylmercury) will be addressed through AMM10 *Methylmercury Management* (Appendix E, *Avoidance and Minimization Measures*). As mentioned above, pesticides like organophosphates and pyrethroids are likely to have a net loss after habitat restoration due to biomediation and sequestration of the pesticide in the restored habitat.

5.16.4.6.4 Eggs and Larvae to Juveniles (March – June)

As previously described for adult Delta Smelt, the additional approximately 6,000 acres of tidal habitat restoration in the north Delta under the proposed action has the potential to increase food availability for Delta Smelt. For larval/early-juvenile Delta Smelt, this relates directly to the food availability habitat attribute linked to the probability of growth and survival in the IEP MAST (2015) conceptual model (Figure 5.16-4). Recent studies indicate that net export of food from restored lands may be limited (Lehman et al. 2010; Kimmerer et al. 2018c), but the restored habitat may be occupied by larval/early juvenile Delta Smelt given suitable habitat features (Sommer and Mejia 2013) in which food could be accessed.

Contaminant related impacts are discussed above in the Adults to Eggs and Larvae section.

5.16.4.6.5 Juveniles to Subadults (June – September)

As previously described for the adult and larval/early juvenile Delta Smelt life stages, the additional approximately 6,000 acres of tidal habitat restoration under the proposed action could potentially increase food availability, which is also an important factor noted for juvenile Delta Smelt in the IEP MAST (2015) conceptual model (Figure 5.16-5). Export of food from restored areas may be limited.

5.16.4.6.6 Subadults to Adults (September – December)

As with the other life stages, habitat restoration under the proposed action has the potential to increase food availability, which is an important factor noted in the IEP MAST (2015) conceptual model. However, food export from restored areas may be limited.

5.16.4.7 Predator Hot Spot Removal

5.16.4.7.1 Adults to Eggs and Larvae (December – May)

Predator hot spot removal under the proposed action is primarily focused on providing positive effects to downstream-migrating juvenile salmonids but could also reduce predation of individual adult Delta Smelt. Although the action would not be limited to existing identified hot spots (e.g., those identified by Grossman et al. 2013), the existing hotspots that may be representative of where removal efforts may be most concentrated tend to mostly be at the periphery of Delta Smelt habitat; and all hotspots are limited in scale relative to overall available habitat. However, in these periphery areas it is possible that predation control could affect competitors of Delta Smelt, benefiting Delta Smelt.

5.16.4.7.2 Eggs and Larvae to Juveniles (March – June)

Although predator hot spot removal under the proposed action is expected to result in some benefits to Delta Smelt eggs and larvae, these benefits would be limited. The predator hot spot removal action would be most likely to reduce habitat for larger predators that are a threat to juvenile salmonids as opposed to smaller predators of Delta Smelt eggs/larvae such as silversides.

5.16.4.7.3 Juveniles to Subadults (June – September)

As discussed further for adult Delta Smelt, predation hot spots have limited spatial extent. Moreover, existing identified predation hot spots generally are on the margins of habitat that would be occupied by juvenile Delta Smelt.

5.16.4.7.4 Subadults to Adults (September – December)

As discussed further for adult Delta Smelt, existing identified predation hot spots generally are on the margins of habitat that would be occupied by subadult Delta Smelt. Also, predator hotspots have a limited spatial extent.

5.16.4.8 Delta Cross Channel Operations and Improvements

Under the proposed action, Reclamation would operate the DCC for improving central Delta salinity, and would close the DCC when fish may be impacted as described in the proposed action. Reclamation would also use modeling to predict when D-1641 salinity standards would be exceeded, and open the DCC to avoid the exceedances. This would result in increased instances when the DCC is open under the proposed action as compared to current operations. However, as part of DCC improvements, Reclamation would construct a project to allow for diurnal or more frequent operation of the DCC than currently possible due to infrastructure limitations. This improved operational flexibility may allow future adjustments to DCC operations to benefit fish species in the Delta.

5.16.4.8.1 Adults to Eggs and Larvae (December – May)

As discussed by USFWS (2017a, p.265), it is unknown what, if any, impacts occur to Delta Smelt as a result of opening or closing the DCC gates. USFWS (2017a, p.265) considered the region near the DCC gates to only be transiently used during movement of some adult Delta Smelt upstream. USFWS (2017a, p.265) suggested that it may be possible that opening or closing the DCC gates changes the migration path of some Delta Smelt, but noted that it is unknown if there may be a change in predation risk or likelihood of successful spawning, for example. During the adult Delta Smelt upstream migration period (principally December–March; USFWS 2017a, p.265), the DCC gates would largely be closed as a result of adherence to D-1641 criteria as well as real-time operations as a function of juvenile salmonid catch indices and projected water quality in the central/south Delta. USFWS (2017a, p.265) suggested that closure of the DCC would create more natural hydrology for migrating adult Delta Smelt by keeping flow in the Sacramento River and Georgiana Slough. Potential far-field effects of the DCC on Delta hydraulics and how these could affect adult Delta Smelt entrainment risk would be considered when managing south Delta exports.

5.16.4.8.2 Eggs and Larvae to Juveniles (March – June)

Under the proposed action, the DCC would be expected to be largely closed during the March–June egg/larval transition period to juveniles. As described in more detail for adults, it is not known what effect the gates have on migration paths of Delta Smelt, but any effects would be expected to be limited given the low occurrence near the DCC (Figures 5.16-1 and 5.16-2; see also USFWS 2017a, p.159). Potential hydraulic effects on flows toward the south Delta export facilities would be taken into consideration when assessing south Delta entrainment risk, for example.

5.16.4.8.3 Juveniles to Subadults (June – September)

The distribution of juvenile Delta Smelt is downstream of the DCC (Figures 5.16-1 and 5.16-2), so any near-field effects of the DCC would not occur. Under the proposed action and consistent with current operations, the DCC would largely be open during the June–September transition from juveniles to subadults. The IEP MAST (2015) conceptual model does not specifically address habitat attributes that would be affected by this difference, which is a change in flow distribution rather than a change in overall summer hydrology, an environmental driver included in the conceptual model. More flow entering the lower San Joaquin River through the DCC presumably could lead to greater potential for flux of *P. forbesi* to the low salinity zone, given the important of the San Joaquin River side of the Delta as a source of *P. forbesi* (Kimmerer et al. 2018c). However, the effect of south Delta exports on the flux of *P. forbesi* to the low salinity zone may be more important than any effect of the DCC, as suggested by QWEST flows (Figures 5.16-16 through 5.16-18).

5.16.4.8.4 Subadults to Adults (September – December)

The distribution of subadult Delta Smelt is downstream of the DCC (Figures 5.16-1 and 5.16-2) and so any near-field effects of the DCC would not occur. Under the proposed action and consistent with current operations, the DCC would largely be open during the September–December transition from subadults to adults, prior to upstream migration as adults. As noted for juvenile Delta Smelt, the IEP MAST (2015) conceptual model does not specifically address habitat attributes that would be affected by DCC gates being opened vs. closed, but it could be argued that an open DCC would provide more flow to the lower San Joaquin River and therefore increase the potential for flux of *P. forbesi* to the low salinity zone (Kimmerer et al. 2018c). However, as described for juvenile Delta Smelt, south Delta exports appear to be a more important effect than the effect of the DCC given the generally negative QWEST flows (Figure 5.16-18).

5.16.4.9 Tracy Fish Facility Operations and Improvements

5.16.4.9.1 Adults to Eggs and Larvae (December – May)

The proposed action includes operating the TFCF, as well as TFCF improvements to reduce entrainment loss for salmonids through predator removal with carbon dioxide or angling. As summarized by USFWS (2017a, p.259), prescreen loss of adult Delta Smelt at the TFCF has not been quantified and whole facility salvage efficiency is low (Table 5.16-2; see also Sutphin and Svoboda 2016). Reduction in prescreen loss could improve salvage efficiency by reducing predation of adult Delta Smelt individuals.

Table 5.16-2. Factors Affecting Delta Smelt Entrainment and Salvage at the South Delta Export Facilities (Source: USFWS 2017a, p.259).

Factor	Adults	Larvae < 20 mm	Larvae >20 mm and Juveniles	Source
Pre-screen loss (predation prior to encountering fish salvage facilities)	CVP: unquantified; SWP: 89.9–100%	Unquantified	CVP: unquantified; SWP: 99.9% (based on only one juvenile release)	SWP: Castillo et al. (2012)
Fish facility efficiency	CVP: 13%; SWP: 43–89%	~0%	CVP: likely < 13% at all sizes, << 13% below 30 mm (based on adult data); SWP: 24–30%	CVP (Kimmerer 2008; adults only); SWP: Castillo et al. (2012)
Collection screens efficiency	~100%	~0%	<100% until at least 30 mm	USFWS (2011)
Identification protocols	Identified from subsamples, then expanded in salvage estimates	Not identified	Identified from subsamples, then expanded in salvage estimates	USFWS (2011)
Collection and handling	48-hour experimental mean survival of 93.5% (not statistically different from control) in 2005; 88.3% in 2006 (significantly less than 99.8% of control)	Unquantified	48-hour experimental mean survival of 61.3% in 2005 and 50.9% in 2006 (both significantly less than mean control survival of 82.0–85.9%)	Morinaka (2013)

Factor	Adults	Larvae < 20 mm	Larvae >20 mm and Juveniles	Source
Trucking and release (excluding post-release predation)	No significant additional mortality beyond collection and handling (above)	Unquantified	No significant additional mortality than collection and handling (above), although mean survival was 37.4% in 2005	Morinaka (2013)

Under the proposed action, a number of programmatic actions are proposed to improve salvage efficiency of TFCF. These actions could positively affect adult Delta Smelt through greater salvage efficiency. The entrainment risk under the proposed action would be managed to limit the potential for adult Delta Smelt to occur in the south Delta and be entrained.

5.16.4.9.2 Eggs and Larvae to Juveniles (March – June)

Larval Delta Smelt are unlikely to be salvaged and therefore the Tracy Fish Facility improvements under the proposed action would have no effects on this life stage.

5.16.4.9.3 Juveniles to Subadults (June – September)

Few if any juvenile and no subadult Delta Smelt would be expected to be exposed to the effects of operation of the carbon dioxide injection device or other Tracy Fish Facility improvements associated with the proposed action, given that these life stages are largely downstream of Tracy Fish Facility and juvenile entrainment risk during June would be managed to limit exposure to the facility.

5.16.4.9.4 Subadults to Adults (September – December)

Subadult Delta Smelt would not occur in the south Delta (Figure 5.16-1) and therefore there would be no effects from Skinner Fish Facility improvements under the proposed action on this life stage.

5.16.4.10 Skinner Fish Facility Operations and Improvements

5.16.4.10.1 Adults to Eggs and Larvae (December – May)

Skinner fish facility improvements from predator control efforts under the proposed action to reduce predation on listed fishes following entrainment into CCF could reduce salvage-related loss of adult Delta Smelt. However, entrainment risk under the proposed action would be managed to limit the potential for adult Delta Smelt to occur in the south Delta and be entrained. Depending on the gear type of Clifton Court predator control efforts, predator control efforts may also catch Delta Smelt that would likely have been salvaged or lost).

5.16.4.10.2 Eggs and Larvae to Juveniles (March – June)

Larval Delta Smelt are unlikely to be salvaged and therefore the Skinner Fish Facility improvements under the proposed action would have no effects on this life stage. Depending on the gear type of Clifton Court predator control efforts, predator control efforts may also catch Delta Smelt that would likely have been salvaged or lost.

5.16.4.10.3 Juveniles to Subadults (June – September); Subadults to Adults (September – December)

Juvenile and subadult Delta Smelt do not occur in the south Delta (Figure 5.16-1) and therefore there would be no effects from Skinner Fish Facility improvements under the proposed action on this life stage. Depending on the gear type of Clifton Court predator control efforts, predator control efforts may also catch Delta Smelt that would likely have been salvaged or lost.

5.16.4.11 Small Screen Program

Screening of small diversions (< 150 cfs) under the proposed action would be anticipated to have limited positive effects on individual adult Delta Smelt through reductions in entrainment. This life stage largely occurs outside of the main late spring-fall season when diversions typically occur (Siegfried et al. 2014), although there are a large number of small diversions. Based on factors such as observed limited entrainment of Delta Smelt at a small diversion in a field study (Nobriga et al. 2004) and the small hydrodynamic effect of such diversions, the DRERIP Delta Smelt conceptual model considered small diversions to be of minimal or no importance to Delta Smelt (Nobriga and Herbold 2009).

There may be some overlap of larval Delta Smelt with the main late spring-fall irrigation period for small diversions. Small diversion screening could reduce entrainment of sufficiently large (>20 mm or so) Delta Smelt larvae/early juvenile individuals. Similarly small diversion screening could reduce entrainment of Delta Smelt juveniles and subadults. However, entrainment by small diversions is posited to be of minimal importance to Delta Smelt (Nobriga and Herbold 2009).

5.16.4.12 Increased Production and Release from UC Davis Fish Culture and Conservation Laboratory (FCCL)

Under the proposed action, the existing UC Davis Fish Culture and Conservation Laboratory (FCCL) would be used to produce and release up to 50,000 adult Delta Smelt annually into the Sacramento-San Joaquin Delta to supplement the existing population. Release of cultured Delta Smelt to supplement the wild population would only be done following implementation of a number of risk reduction strategies (Table 5.16-3) and regulatory decisions made by USFWS and with genetic diversity in released cultured fish equivalent to that of the native stock. Supplementation of the wild population with hatchery-reared individuals could benefit individual adult Delta Smelt by making finding mates easier and, thereby, reducing the potential for Allee effects, which are declines in growth rate per fish at low population size (IEP MAST 2015, p.98). Given that wild Delta Smelt abundance may be of a similar magnitude—i.e., adult abundance in 2016–2018 as low as 16,000–48,000, with 95% confidence intervals of ~3,400–92,000 (see Figure 2.14-1 in Chapter 2)—as the abundance of adult fish that could be reared in the FCCL, the potential for benefits to the Delta Smelt are significant.

Potential negative effects of increased production at the FCCL include propagation and spread of invasive or nuisance species, which could affect Delta Smelt individuals through changes in food web structure. Increased production would be managed to avoid risks.

5.16.4.13 Delta Smelt Conservation Hatchery

Under the proposed action, Reclamation proposes to partner with DWR to construct and operate a conservation hatchery for Delta smelt in Rio Vista. The conservation hatchery would breed and propagate a stock of fish with equivalent genetic resources of the native stock and at sufficient quantities to effectively augment the existing wild population, so that they can be returned to the wild to reproduce naturally in their native habitat.

5.16.4.13.1 Adults to Eggs and Larvae (December – May)

Operation of the Delta Fish Species Conservation Hatchery has the potential to affect adult Delta Smelt in positive and negative ways, which are discussed here. By 2030, the likelihood of negative effects could be negligible.

5.16.4.13.1.1 Potential Positive Effects

The existing FCCL has a maximum capacity of just over 50,000 adult Delta Smelt. Operation of the Delta Fish Species Conservation Hatchery under the proposed action would substantially increase this capacity, although specific details are to be developed. Release of cultured Delta Smelt to supplement the wild population would only be done following implementation of a number of risk reduction strategies (Table 5.16-3) and regulatory decisions made by USFWS and with genetic diversity in released cultured fish equivalent to that of the native stock. Of particular importance will be the need to minimize hatchery domestication. Supplementation of the wild population with hatchery-reared individuals could benefit individual adult Delta Smelt by making finding mates easier and thereby reducing the potential for Allee effects, which are declines in growth rate per fish at low population size (IEP MAST 2015, p.98). Given that wild Delta Smelt abundance may be of a similar magnitude—i.e., adult abundance in 2016–2018 as low as 16,000–48,000, with 95% confidence intervals of ~3,400–92,000 (see Figure 2.14-1 in Chapter 2)—as the abundance of adult fish that could be reared in the Delta Fish Species Conservation Hatchery, the potential positive effect on adult Delta Smelt from release of Delta Smelt from the hatchery is high. Uncertainty in the potential positive effect stems from risks that would be reduced by a number of different strategies (Table 5.16-3).

Table 5.16-3. Risk Reduction Strategies for Implementation of Delta Smelt Culture at the Delta Fish Species Conservation Hatchery (Source: Lessard et al. 2018, p.9).

Risk type	Risk factor	Risk reduction strategies
Ecological	Interspecific interactions	Scale and adjust (via adaptive management program) release numbers to optimize production while avoiding significant, density-related, intraspecific effects or interspecific ecological risks. Requires monitoring program and adaptive management decision loop on an annual basis.
	Intraspecific interactions	
	Pathogen transfer	Use best management practices to minimize or eliminate pathogen transfer; implement rigorous fish health screening and maintenance program.
	Lack of suitable habitat for reintroduction	Don't release hatchery-reared Delta smelt in areas where habitat conditions or capacity are insufficient (this is still an unknown for Delta Smelt spawning habitat).
	Lack of suitable spawning or early life habitat conditions	Experimentally release a range of life stages and use a monitoring and adaptive management program to guide decision-making on life stage releases to increase post-release survival for demographic enhancement of recipient wild population.
	Behavioral changes	Develop, refine, and employ best management practices that integrate hatchery-produced Delta Smelt with the natural genetic and life history diversity of wild Delta Smelt to minimize possible behavioral changes in progeny.
Demographic	Broodstock mining	Because the effect of broodstock mining depends on the likelihood that fish would reproduce successfully if left in the wild, consider reducing broodstock take during high water years. There is no risk if there is no natural production.
	Broodstock selection	Collect 100 wild broodstock annually (based on current take limit) across greatest available temporal and spatial ranges to maximize diversity of broodstock and resulting phenotypes, genotypes and adaptive plasticity among progeny groups. Broodstock requirement could change with scale of the hatchery and genetic diversity in the wild.
	Spawner disruption	Refine and implement most efficient means of wild broodstock collection to minimize disturbance to wild spawners/spawning in the river.
Genetic	Loss of diversity	If feasible, continue to annually supplement captive refuge population with 100 new wild-origin broodstock annually (based on current take limit). Broodstock requirement could change with scale of propagation and genetic diversity in the wild. Continue to define and implement breeding matrices annually, using empirical genetic data to minimize kinship in broodstock crosses and resulting progeny groups, and to minimize risk of selection.
	Inbreeding depression	
	Selection	
Uncertainty	Measurement error	Conduct hatchery supplementation in an experimental framework that includes a robust monitoring and evaluation program, relevant measurable benchmarks to evaluate benefits and risks, and a clear decision structure for future adaptive management.
	Process error	
	Implementation error	Promote and evaluate tools and techniques that facilitate improved evaluation of the contribution and survival of cultured fish in the wild. Review practices with expert hatchery evaluation team to ensure use of best available information, operations, and protocols to minimize implementation error.

5.16.4.13.1.1.1 Potential Negative Effects

Potential negative effects of the Delta Fish Species Conservation Hatchery under the proposed action include propagation and spread of invasive or nuisance species, which could affect Delta Smelt individuals through changes in food web structure. Hatchery operations would require implementation of a Hazard Analysis and Critical Control Points plan, or similar control mechanism, which would include methods to prevent the introduction of invasive or nuisance species into the hatchery and operational practices that prevent the spread of these species within and outside of the facility, should prevention efforts fail. Hatchery operations would include actions to minimize the spread of invasive or nuisance species by sampling to determine whether such species are present and, if so, taking extra precautions to prevent spread. Sampling would be conducted on a quarterly basis at locations such as intake structures, raceway head boxes, settling ponds, and any other areas of concern. If suspect or questionable snails or mussels are found, specimens would be sent to the regional invasive-species scientist for identification (California Department of Fish and Game 2015), so that hatchery operations are not anticipated to result in the spread of invasive or nuisance species.

Discharges of water from the Delta Fish Species Conservation Hatchery could affect adult Delta Smelt individuals through changes in water quality, including increased water temperature, decreased dissolved oxygen, changes in water chemistry (pH and salinity), increased nutrient inputs, increased suspended solids, and release of other undesirable constituents such as parasites, disease microorganisms, and related treatment chemicals, but all of these factors would be managed to minimize effects. Water for the hatchery would mostly be sourced from a groundwater well and is anticipated to be consistent with Sacramento River water temperature adjacent to the hatchery. Dissolved oxygen levels of discharge water would be monitored and kept above applicable criteria (5 mg/l), with filtration to reduced biological oxygen demand. Salinity and pH would not be expected to be greatly affected, as analysis of larger scale salmonid hatchery facilities in California found limited evidence for increases (ICF Jones and Stokes 2010). Nutrient inputs and other constituents would be limited because effluent would pass through a water treatment facility for filtration and disinfection. Discharge of suspended solids such as uneaten feed and biological waste would be limited through treatment at an onsite treatment system consisting of drum filters, an underground holding tank between rearing tanks and drum filters, and settling ponds. Should it be necessary, a portable system to treat effluent could also be installed for specific individual rearing tanks, or a centralized holding tank and activated carbon filtration system. Overall, groundwater and surface water quality used at the hatchery would be monitored to protect the health of the fish being reared, and discharged water would be treated in accordance with required permits and protocols. This, coupled with the very small size of the discharge (5.5–11 cfs) in relation to tidal flows in the Sacramento River near the hatchery location (peak tidal flows of ± 100,000 cfs; http://cdec.water.ca.gov/dynamicapp/QueryF?s=SRV), suggests minimal effects.

Construction of the Delta Fish Species Conservation Hatchery in Rio Vista could benefit Delta Smelt through removal of creosote-treated wood pilings, that would remove a source of contaminants, as well as in-water structure that could provide habitat for predatory fishes. Potential negative effects would occur from operation of the marina and docks for research vessels, which could provide habitat for predatory fishes and increase predation on adult Delta Smelt. Loss of shallow-water habitat from construction of the facility could affect adult Delta Smelt spawning habitat availability, but would be compensated offsite at an appropriate mitigation ratio for the project footprint.

5.16.4.13.2 Eggs and Larvae to Juveniles (March – June)

Given appropriate application of risk reduction strategies (Table 5.16-3), potential negative effects from the Delta Fish Species Conservation Hatchery under the proposed action such as pathogen transfer from cultured to wild individuals would be minimized. Following application of these risk reduction strategies, release of cultured larval Delta Smelt presumably would have little effect on wild individuals (in contrast to adults, for example, for which increased numbers of individuals could lead to increased spawning opportunities, for example). As discussed for adults, potential negative effects on individual Delta Smelt such as propagation and spread of invasive/nuisance species leading to food web changes, and discharge of hatchery effluent resulting in water quality effects, could occur but would be limited.

5.16.4.13.3 Juveniles to Subadults (June – September)

As discussed for other life stages of Delta Smelt, given appropriate application of risk reduction strategies (Table 5.16-3), potential negative effects from the Delta Fish Species Conservation Hatchery under the proposed action such as pathogen transfer from cultured to wild juvenile Delta Smelt would be minimized. Following application of these risk reduction strategies, release of cultured juvenile Delta Smelt presumably would have little effect on wild individuals, given that interspecific associations appear to not be strong: Bennett (2005, p.22) suggested that "[j]uveniles and adults may occur in loose aggregations rather than tight schools, judging from the patchiness of fish catch in the monitoring surveys". As discussed for adults, potential negative effects on individual Delta Smelt such as propagation and spread of invasive/nuisance species leading to food web changes and discharge of hatchery effluent resulting in water quality effects, could occur but would be limited.

In-water construction work for the hatchery intake and outfall could result in effects to individual Delta Smelt such as temporary or permanent loss of habitat; exposure to increased suspended sediment and turbidity leading to changes in habitat quality and foraging ability; potential harm from accidental release of construction-related hazardous materials, chemicals, and waste; and effects from inadvertent spread of invasive or nuisance species. Such effects include some of the habitat attributes hypothesized to be of importance to this life stage (Figure 5.16-5). The risk from these potential effects would be minimized through application of AMMs (Appendix E, *Avoidance and Minimization Measures*). There is low potential exposure because of the in-water work window, minimized by application of AMMs, and the small scale of the in-water construction.

5.16.4.13.4 Subadults to Adults (September – December)

As discussed for other life stages, given appropriate application of risk reduction strategies (Table 5.16-3), potential negative effects from the Delta Fish Species Conservation Hatchery under the proposed action such as pathogen transfer from cultured to wild Delta Smelt would be minimized. Following application of these risk reduction strategies, release of cultured subadult Delta Smelt presumably would have little effect on wild individuals, given the loose aggregations rather than tight schooling behavior suggested by Bennett (2005, p.22). As discussed for adults, potential negative effects on individual Delta Smelt such as propagation and spread of invasive/nuisance species leading to food web changes, and discharge of hatchery effluent resulting in water quality effects, could occur but would be limited.

5.16.4.14 Lower SJR Habitat Restoration

5.16.4.14.1 Adults to Eggs and Larvae (December – May)

Under the proposed action, restoration of lower San Joaquin River spawning and rearing habitat for salmonids, including a large extent of floodplain habitat, would have the potential to produce food web materials that could be exported downstream to areas where Delta Smelt adults would occur, thereby positively affecting growth and survival per the IEP MAST (2015) conceptual model (Figure 5.16-3). However, transport downstream of productivity from this restoration to areas where Delta Smelt adults are likely to occur in greater numbers (See Figures 5.16-1 and 5.16-2) may be limited for two reasons. First, food web materials transported in flow entering the interior Delta through junctions such as Old River would be unlikely to move far downstream because of the prevailing hydrodynamics created by the south Delta export facilities (as shown by OMR reverse flows). In addition, river flows sufficiently large to inundate the floodplains frequently would tend to be somewhat limited in occurrence (ESA PWA 2012).

There would be no construction impacts of the Lower SJR habitat restoration under the proposed action on Delta Smelt, as Delta Smelt do not occur upstream in the San Joaquin River.

5.16.4.14.2 Eggs and Larvae to Juveniles (March – June)

As discussed in more detail for adult Delta Smelt, potential food availability effects on Delta Smelt may be low from Lower San Joaquin River spawning and rearing habitat restoration under the proposed action because enhanced productivity from inundated floodplains may occur relatively infrequently and export downstream may be limited by the hydrodynamic effects of the south Delta export facilities.

5.16.4.14.3 Juveniles to Subadults (June – September)

There would be no effects from food material production and export as a result of lower San Joaquin River spawning and rearing habitat restoration under the proposed action because the winter/spring inundation period of this habitat would not overlap the Delta Smelt juvenile period (June-–September).

5.16.4.14.4 Subadults to Adults (September – December)

As noted for juvenile Delta Smelt, there would be effects from food material production and export as a result of lower San Joaquin River spawning and rearing habitat restoration including floodplain habitat under the proposed action because the winter/spring inundation period of this habitat would not overlap the Delta Smelt subadult period (September–December, prior to transition to adulthood and movement triggered by the initial first flush of precipitation and flow).

5.16.4.15 Effects of Monitoring

5.16.4.15.1 Adults to Eggs and Larvae (December – May)

A number of monitoring activities described in Appenidx E – ROC Real Time Water Operations Charter, in the section *Monitoring Program for Core CVP and SWP Operation* would have the potential to capture adult Delta Smelt. USFWS (2017, p.186) suggested that historically, take of Delta Smelt in survey collections was low compared to estimated population abundance, but that given the combination of recent population decline and substantial increase in survey effort, scientific take of Delta Smelt may be reaching a relevant fraction of Delta Smelt in some seasons. A summary by USFWS (2017, p.195) showed, for example, that the total number of juvenile and adult Delta Smelt captured in IEP studies (which form much of the basis for the monitoring program) per year ranged from 447 in 2016 to 4,713 in 2005 (Table 5.16-4). Corresponding estimates of adult population size in these years were 477,775 in 2005 and 16,159 in 2016, which, accounting for the fact that not all individuals shown in Table 5.16-4 were adults, that the percentage collected was < 1% in 2005 and < 2.8% in 2016. As noted by USFWS (2017, p.186), some surveys have been modified to limit incidental catches of Delta Smelt. Although Table 5.16-4 does not account for other surveys that would capture individual adult Delta Smelt, in particular EDSM (take for EDSM is about 0.5% to 1% per year), it is anticipated that through consideration of overall potential take, sampling effort in monitoring activities would be limited. Importantly, monitoring would enable effects of the proposed action to be limited, e.g., by informing real-time operations for OMR adjustment.

Table 5.16-4. Number of Juvenile and Adult Delta Smelt Individuals (≥20-mm Fork Length) Captured from 2005 to 2016 for Interagency Ecological Program Studies (Source: USFWS 2017, p.195).

Survey	Year											
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fall Midwater Trawl	28	39	27	21	32	54	344	47	21	11	7	7
Townet Survey	120	83	45	0	0	2	318	28	0	1	23	6
SF Bay Study	85	21	64	45	20	49	181	95	77	43	51	6
20-mm	15	0	2	1	2	5	8	63	9	1	0	2
Yolo Bypass	4	17	4	26	88	19	31	133	134	46	50	18
Broodstock Collections (FCCL)	2297	2418		70	23	80		2	198			
Delta Juvenile Fish Monitoring	761	954	245	119	136	445	956	710	464	301	245	103
New Technologies and Release Sites, Element 2 (Electrofishing)				2								
Indicators to Predict Adverse Effects to Salvaged Delta Smelt	64											
Fish Predation in the CHTR Phase	19											
Acute Mortality Associated with CHTR		28										
Directed Fish Collections	5	371	4									
Upper estuary zooplankton						1	2	2	0	1	0	0
Investigation of Antioch and Pittsburg Power Plants				2	14		0					
Spring Kodiak Trawl	1311	473	708	339	671	659	445	1204	339	356	107	260
Morrow Island Distribution	2	1										
UCD Suisun Marsh	2	1	3	1	4	2	22	10	6	7	3	0
Smelt Larva Survey		1	0	0	2	0	2	10	4	0	2	0
Mossdale Spring Trawl						1			0	0	0	0
Fish Community Monitoring			3	3	8		9					
Effects of Largemouth Bass on Delta Ecosystem						5						
Pilot Mark-recap to Estimate Pre-screen Loss and Salvage Efficiency				189	10							
Smelt Migration Study (AKA First Flush)**						659		822				
Gear Efficiency Evaluation in Support of Delta Smelt Modeling								721	863	890	185	0
FRP Tidal Wetland Monitoring Study											0	2
USGS Early Warning											0	42
USGS Physical and Biological Drivers												1
TOTAL	4713	4407	1105	818	1010	1981	2318	3847	2115	1657	673	447

*Smelt Migration sampling in year 2010 includes one day of sampling in 2011

5.16.4.15.2 Eggs and Larvae to Juveniles (March – June)

A number of monitoring activities under the proposed action described in Appendix C, *ROC Real Time Water Operations Charter*, in section *Routine Operations and Maintenance on CVP Activities* would have the potential to capture larval Delta Smelt. A summary by USFWS (2017, p.195) showed, for example, that the total number of larval Delta Smelt captured in IEP studies (which form much of the basis for the monitoring program) per year ranged from 108 in 2015 to 1,564 in 2012 (Table 5.16-5). There are no estimates of overall larval population size in these years, but given that a) estimates of adult Delta Smelt captured were < 1–3% of the adult population, b) the total number of individual larvae captured was of similar or lower order magnitude as the number of adults captured per year (i.e., hundreds to thousands of individuals per year), and c) the population size of larvae would logically be appreciably greater than that of adults (Bennett 2005, p.12), then the overall population-level loss of larval Delta Smelt would be expected to be much lower than that of adults. Additional monitoring activities such as EDSM may increase the population-level capture above that suggested by the above analysis, but it would not be anticipated that this would be a substantial increase. Importantly, and as noted for adult Delta Smelt, monitoring would enable effects of the under the proposed action to be limited by informing real-time operations for OMR adjustment.

Table 5.16-5. Number of Larval Delta Smelt Individuals (<20-mm Fork Length) Captured from 2005 to 2016 for Interagency Ecological Program Studies (Source: USFWS 2017, p.194).

Survey	Year											
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
Fall Midwater Trawl	0	0	0	0	10	0	0	0	0	0	0	0
Townet Survey			10	82	49	198	470	246	171	75	0	0
SF Bay Study	0	0	0	0	0	0	0	0	0	0	0	1
South Delta fish investigations	8		277									
20-mm*	644	978	135	274	435	633	1162	1076	1125	256	99	126
Yolo Bypass	0	0	0	0	0	0	0	0	0	0	0	0
Delta Juvenile Fish Monitoring	14										0	0
Directed Fish Collections			2									
Upper estuary zooplankton			2	17		10	3	3	5	1	0	0
Investigation of Antioch and Pittsburg Power Plants				17	10	1	1					
Spring Kodiak Trawl	26					1		1	2	53	3	26
Morrow Island Distribution			1									
UCD Suisun Marsh										2	0	0
Smelt Larva Survey		79	274	0	0	6	3	238	118	24	6	8
Mossdale Spring Trawl											0	0
Fish Community Monitoring				22								
Pilot Mark-recap to Estimate Pre-screen Loss and Salvage Efficiency					111							
Gear Efficiency Evaluation in Support of Delta Smelt Modeling									85	147	0	0
FRP Tidal Wetland Monitoring Study											0	0
USGS Early Warning											0	0
USGS Physical and Biological Drivers												0
TOTAL	692	1057	701	412	615	1049	1639	1564	1506	558	108	161

*20mm Study reports larvae and juveniles together (age-0). Age-1+ reported as adults.

5.16.4.15.3 <u>Juveniles to Subadults (June – September)</u>

As described for adult Delta Smelt, capture of Delta Smelt in recent years may be a greater percentage of the population than historically occurred as a result of lower population size and greater survey effort. However, as concluded for adult Delta Smelt, impacts across all surveys would be considered when determining sampling effort in order to limit potential negative effects.

5.16.4.15.4 <u>Subadults to Adults (September – December)</u>

As described for adult Delta Smelt, capture of Delta Smelt in recent years may be a greater percentage of the population than historically occurred as a result of lower population size and greater survey effort. However, as concluded for adult Delta Smelt, impacts across all surveys would be considered when determining sampling effort in order to limit potential negative effects.

5.17 Delta Smelt Critical Habitat

USFWS (2017a, p.298-299) summarized the primary constituent elements (PCEs) as defined in the critical habitat rule. These include physical habitat (i.e., spawning substrate and possibly depth variation in relation to pelagic habitat), water (i.e., water of suitable quality, including certain conditions of temperature, turbidity, and food availability, which can be degraded by high entrainment risk and contaminant exposure, for example), river flow (transport flow to facilitate spawning migrations and transport of offspring to low salinity zone rearing habitats), and salinity (the low salinity zone nursery habitat, which generally increases as Delta outflow increases and X2 decreases). Volume of low salinity zone does not necessarily translate to increased survival as habitat may not be the limiting factor on Delta Smelt. Multiple other abiotic and biotic factors also affect Delta Smelt at all times. The analysis below considers potential positive and negative effects to these PCEs by various life stage habitat functions used by USFWS (2017a, p.304-323), i.e., spawning habitat (physical habitat), larval and juvenile transport habitat (river flow), rearing habitat (salinity), and adult migration habitat (physical habitat and river flow).

5.17.1 PCE 1 – Physical Habitat

With respect to the physical habitat PCE of Delta Smelt critical habitat, the proposed action could potentially reduce the supply of sand for spawning substrate during the high-flow winter/spring period relative to the without action. As suggested by a sedimentation conceptual model provided by Schoellhamer et al. (2012, p.4), lower Sacramento River sediment samples have a greater percentage of sand than lower San Joaquin River sediment, probably because of larger river floods and greater sand supply from the Sacramento River watershed. As Schoellhamer et al. (2012, p.4) went on to note: “At Rio Vista, Thompson and others (2000) observed that large floods increased the percent of sand on the bed (up to nearly 100% from nearly 0%)…During the intervals between floods, finer sediment deposited, the bed sediment became finer...At two other sites in the Sacramento and San Joaquin rivers, however, the fraction of sand varied over a similar range but appeared unrelated to flow, perhaps because of spatial heterogeneity.” Thus, while there is the potential for a negative effect of the proposed action on supply of sand spawning substrate, the extent of this potential effect is uncertain given likely site-specific differences and the lack of relationships predicting sandy substrate spawning habitat as a function of flow. Implementation of tidal and channel margin restoration may provide additional Delta Smelt spawning habitat (USFWS 2017, p.111), which would contribute to reducing the potential negative effect of the proposed action.

Construction of proposed facilities and other actions—principally the Delta Fish Species Conservation Hatchery, as well as some of the programmatic actions— under the proposed action has the potential to reduce the extent of physical habitat in terms of spawning substrate. The extent of this loss is dependent on site-specific conditions. It is anticipated that construction of tidal habitat restoration would more than address any loss of physical habitat from the proposed action, given the need to include areas meeting likely Delta Smelt spawning habitat characteristics in the restored areas (USFWS 2017, p.111).

5.17.2 PCE 2 – Water

Potential positive effects to food availability may occur from SMSCG operations under the proposed action during June–September of above normal and below normal water years (reducing salinity to improve habitat conditions in the relatively food-rich Suisun Marsh) and tidal restoration (an additional approximately 6,000 acres.

Relative to the without action scenario, reduced winter-spring inflow to the Delta under the proposed action has the potential to reduce sediment supply and therefore turbidity during winter-spring, as well as during summer/fall when resuspension of sediment supplied in the winter/spring is important. Under the proposed action, greater South Delta exports, less spring Delta outflow, and possibly agricultural barriers have the potential to negatively affect food availability in the low salinity zone by reducing *E. affinis* in spring and reducing the subsidy of *P. forbesi* from the lower San Joaquin River to the low salinity zone in summer/fall.

During summer/fall, there is the potential for effects to flow, velocity, and water clarity under the proposed action to negatively affect the water quality PCE relative to the without action scenario by increasing the potential for harmful algal blooms, although this is uncertain.

Effluent from the Delta Fish Species Conservation Hatchery under the proposed action could have a negative effect on water quality, although such effects would be minimized through factors such as filtration, and the effluent discharge rate would be small. Water temperature effects from operations of the proposed action are expected to be minor.

Tidal habitat restoration will benefit other PCEs, but could result in increased exposure to contaminants and noise and vibration from in-water work. Tracy Fish Facility improvements, the Delta Fish Species Conservation Hatchery, and programmatic actions under the proposed action have benefits to the species, but include increased exposure to contaminants and noise and vibration from in-water work. These temporary potential negative effects would be avoided, minimized, and mitigated using project-specific measures including those described in Appendix E, *Avoidance and Minimization Measures*.

5.17.3 PCE 3 – River Flow

The proposed action directly influences the river flow PCE for adult migration and larval and juvenile transport of Delta Smelt as a result of south Delta exports. As described previously, OMR reverse flows would be managed to minimize impacts to Delta Smelt by avoiding turbidity bridges, and allowing more positive OMR flows during integrated early winter pulse protection. Limited negative effects on river flow for adult migration and larval and juvenile transport which could result in entrainment also would stem from proposed action operations of the Suisun Marsh Facilities and Ag Barriers. The proposed action operations of the Rock Slough Intake and the North Bay Aqueduct will not affect OMR as these facilities are located outside of the OMR region. Rock Slough Intake and the North Bay Aqueduct could have minimal effects on river flow in the vicinity of each intake (near-field effects), but such effects are mitigated by operations that meet low approach velocity at the fish screens. Finally, Rock Slough Intake and the North Bay Aqueduct have negligible effect on far-field Delta hydrodynamics. Potential negative effects on river flow could occur as a result of tidal restoration effects on channel hydrodynamics, although modeling and design of restoration would be done so as to minimize such effects.

It is not anticipated that construction components of the proposed action would affect river flow.

5.17.4 PCE 4 – Salinity

The proposed action has the potential to positively and negatively affect the salinity PCE related to the low salinity zone nursery habitat for Delta Smelt. As described previously, operations of the SMSCG in June–October of above normal and below normal years have the potential to provide lower salinity and therefore positively affect habitat conditions for juvenile and subadult Delta Smelt in the Suisun Marsh, with additional Delta outflow provided to avoid movement of X2 upstream as a result of SMSCG operation. In addition, the addition of Delta outflow in Above Normal and Wet years has the potential to provide lower salinity and therefore positively affect habitat conditions.

South Delta exports and water flow into the Delta under the proposed action have the potential to affect the low salinity zone rearing habitat. USFWS (2017a, p.307–316) assessed this in terms of the proportion of CalSim-modeled months (June–December) that the low salinity zone (i.e., salinity at or below 6) would be outside of Suisun Bay, as indicated by X2 ≥ 85 km (DMA 2014, p.38). Performing this analysis in the context of the proposed action suggests that relative to the WOA, there could be positive effects to low salinity zone rearing habitat during June–September (lower percentage of years with X2 ≥ 85 km), no effect in October, and negative effects in November-–December (higher percentage of years with X2 ≥ 85 km; Figure 5.17-1). To the extent that tidal restoration (i.e., the additional approximately 6,000 acres as part of tidal habitat restoration) provides new low salinity zone habitat that is occupied by rearing Delta Smelt, this could provide some offsetting of potential reductions resulting from operations.

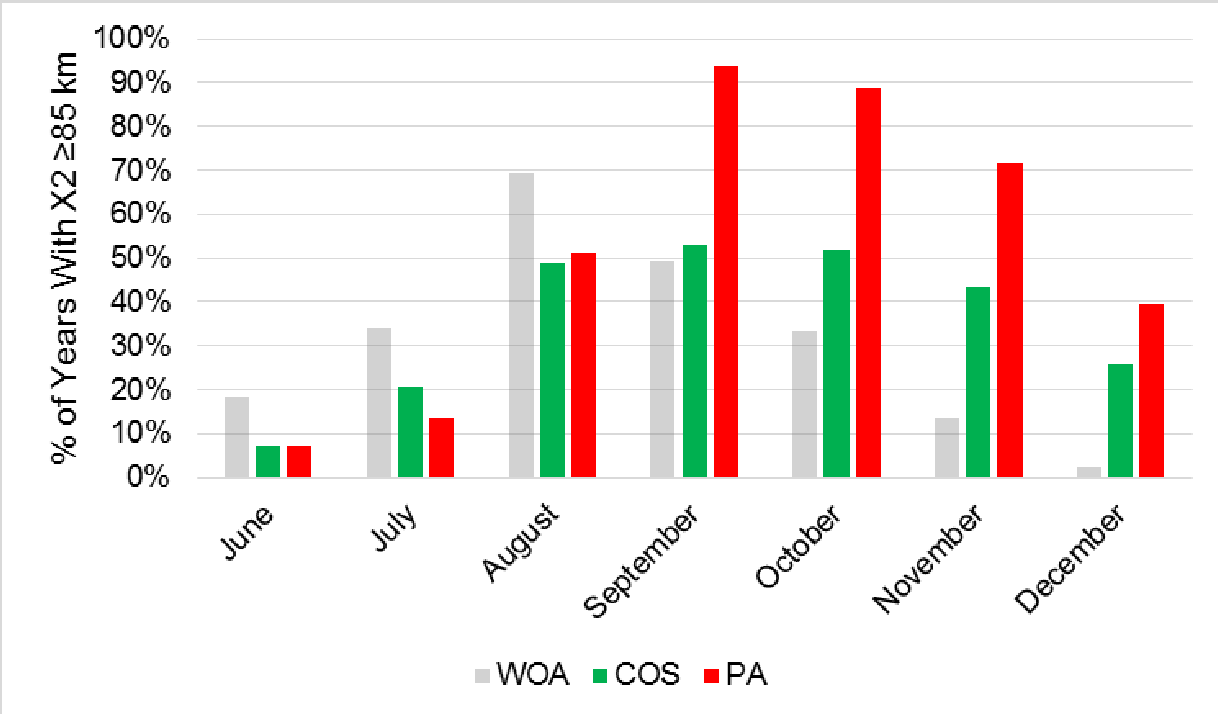


Figure 5.17-1. Percentage of Years with Mean X2 ≥ 85 km, June–September.

It is not anticipated that construction components of the proposed action would affect salinity.

5.17.5 Effects of Maintenance

Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Delta Smelt critical habitat.

5.17.6 Effects of Monitoring Activities

The activities under the proposed action described in Appendix C, *ROC Real Time Water Operations Charter* in section *Monitoring Program for Core CVP and SWP Operation* would be expected to have limited effects on Delta Smelt critical habitat. The physical habitat PCE could be affected by placement of equipment such as anchors holding the acoustic receiver network or by benthic sampling as part of the Environmental Monitoring Program, but the effects would be very small relative to the extent of critical habitat. The water quality PCE could be minimally affected, for example, by trawling or benthic gear contacting the substrate and disturbing sediment, although again these effects would be expected to be limited. As described in the section discussing effects of monitoring on Delta Smelt, capture of individual Delta Smelt would occur but would be limited by consideration of take limits in relation to population status.

5.18 Coho Salmon, Southern Oregon/Northern California Coastal ESU

The proposed action provides beneficial effects to Coho Salmon due to higher flows and lower temperatures in the summer and fall, as compared to WOA. The proposed action affects Coho Salmon in the spring as compared to WOA, by reducing flows during egg incubation, fry emergence, and decreasing available habitat for juvenile rearing through less inundated area in natal habitats on the Trinity River.

The ongoing implementation of the Trinity River Restoration Program ROD, included in the proposed action but previouxsly consulted on, helps to address these effects.

5.18.1 Lifestage Timing

Coho Salmon enter the Klamath/Trinity River Basin as sexually mature adults and disperse into the various tributaries to spawn. In the Trinity River, adults return from September to December (Figure 5.18-1) and spawn from November to January (Leidy and Leidy 1984; USFWS and Hoopa Valley Tribe 1999). Juvenile Coho Salmon spend up to one year in the Trinity system prior to emigration to the ocean. Spawning generally occurs in low gradient tributaries rather than the mainstem of the Trinity River (NMFS 2014). Coho Salmon fry emerge from the gravel the following spring from February to May. Juveniles rear in the Trinity system through the summer and winter (age 0). Coho smolts emigrate from the system in their second spring (age 1). Their extended freshwater residency prior to emigration (compared to Chinook salmon) makes them vulnerable to adverse summer water temperature and scarcity of low water velocity, off-channel habitat during winter (NMFS 2014).

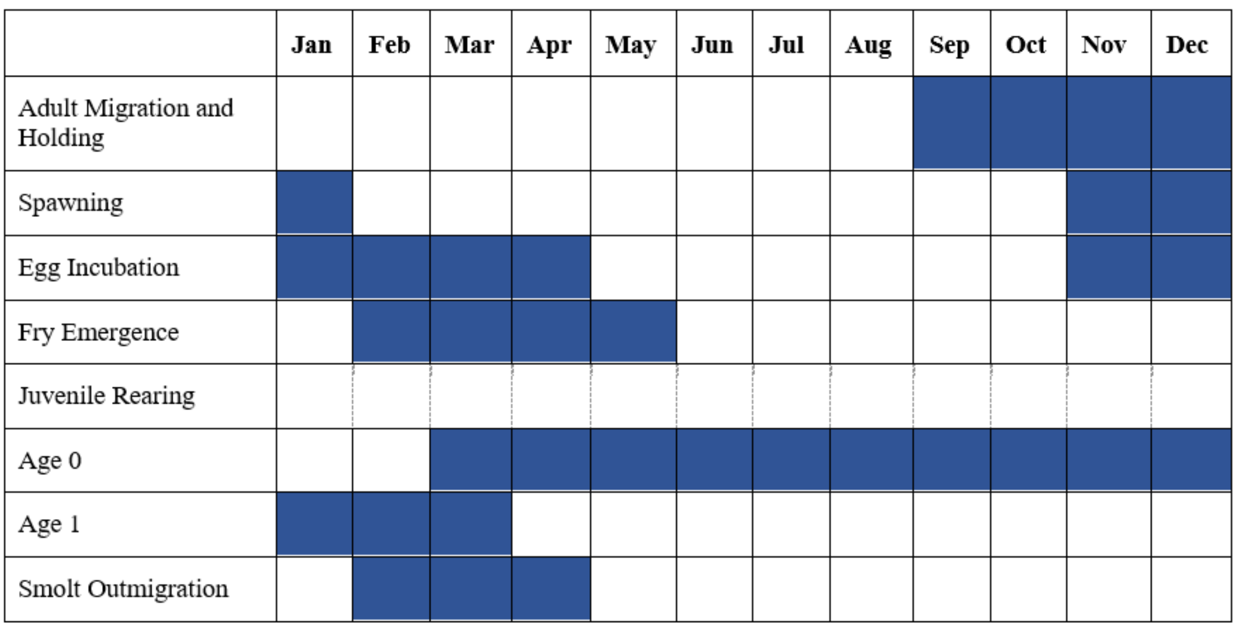


Figure 5.18-1. Life History Schedule of Trinity River Salmonids based on Leidy and Leidy (1984)

5.18.2 Conceptual Model Linkages

There is no conceptual model for Coho Salmon which describes in detail the hypothetical mechanistic pathways that underlie the relationships between environmental stressors and salmonid survival comparable to the "Salmon and Sturgeon Assessment of Indicators by Life stage" as has been developed for Winter-run Chinook salmon in the Sacramento River (Windell et al 2017). But, adapting a general conceptual model based on Windell et al. (2017) (Figure5.18-2) provides a framework for assessing the effects of the proposed action on SONCC Coho.

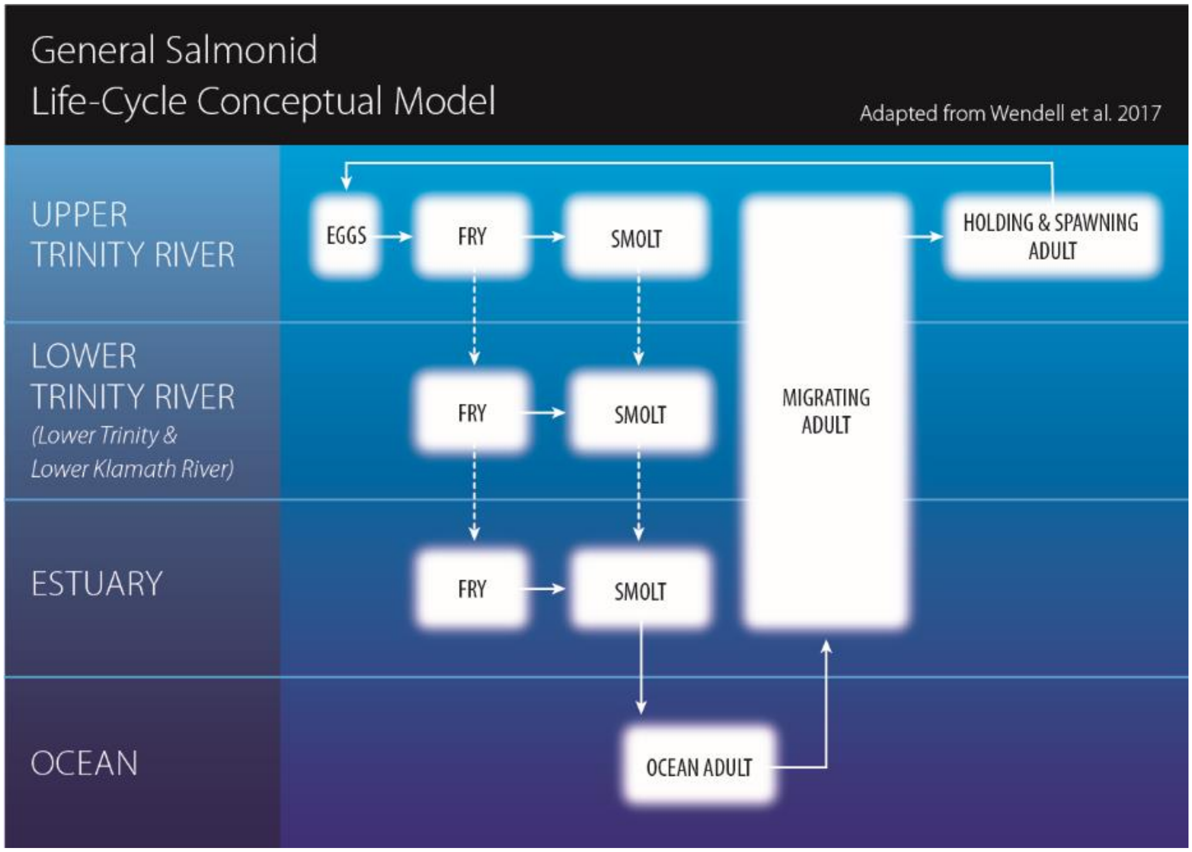


Figure 5.18-2. Conceptual Model of Habitat use by Life Stage

According to NMFS (2014), adverse hatchery effects are a very high stressor on SONCC Coho in the Trinity River. Altered hydrologic function and lack of channel and floodplain structure are also very high or high stressors in the lower and upper Trinity River. One of the most important ecological requirements of Coho Salmon is cold, clean, well oxygenated water. Increased water temperature, changes in pH above or below optimum levels, reduced dissolved oxygen, increased nutrient loading, and increased extent or duration of turbidity all may affect Coho Salmon. Water temperature influences Coho Salmon growth and feeding rates (partly through increased metabolism) and development of embryos and alevins (McCullough 1999), as well as timing of life-history events such as freshwater rearing, seaward migration (Holtby and Scrivener 1989), and upstream migration and spawning (Spence et al. 1996). Increased water temperature can be detrimental to the survival of most life stages of Coho Salmon, but summer-rearing juveniles are the most likely to be affected by elevated water temperatures. Elevated water temperature can result in increased levels of stress hormones in Coho Salmon, often resulting in mortality (Ligon et al. 1999). Increased water temperature, even at sub-lethal levels, can inhibit migration, reduce growth, stress fish, reduce reproductive success, inhibit smoltification, contribute to outbreaks of disease, and alter competitive dominance (Elliott 1981). Environmental changes include altered timing and magnitude of high and low flows, alteration of temperature and dissolved oxygen levels, and changed cues for seasonal migration. EPA (2003) recommends 13 degrees Celsius or 55 degrees Fahrenheit for salmonid spawning and egg incubation (November to April for Coho), 61 degrees Fahrenheit for juvenile rearing (year-round), 64 degrees for non-core juvenile rearing, and 68 degrees for adult migration (September – December).

The juvenile life stage of the lower Klamath population of Coho Salmon is limited by the lack of quality rearing habitat, Juvenile summer rearing habitat is impaired mostly from subsurface flow conditions in the tributaries caused by heavy sediment loads and winter rearing habitat is severely lacking because of channel simplification, disconnection from the floodplain, degraded riparian conditions, poor large wood availability, and an estuary which has been altered and reduced in size due to development, channelization, and diking. Poor water quality of the mainstem Klamath River (e.g., high water temperatures resulting from degraded riparian conditions and water withdrawals upstream) affects both juveniles and adult Coho Salmon.

5.18.3 Effects of Operations and Maintenance

Under WOA Trinity and Lewiston dams would remain in place but would not be operated to store water and diversion of Trinity Basin water into the Sacramento River system would not occur. This scenario would restore much of the pre-dam hydrograph dominated by late spring snow melt hydrology. Lewiston Dam would remain in place and continue to impound sediment behind the dam as well as block upstream passage.

Under WOA, temperatures would be above juvenile holding temperature thresholds in the mainstem Trinity River. Much of the refugia habitat was blocked by Lewiston Dam or degraded by land use practices and sedimentation (USFWS and HVT 1999). Thus, under WOA juvenile Coho would need to find refuge habitat downstream in the Lower Klamath reach or in tributary streams. High water temperatures in September could also create barriers to upstream migrating adults and or reduce the amount of suitable holding habitat available for use prior to spawning.

5.18.3.1 Seasonal Operations

Environmental changes of altered hydrology include altered timing and magnitude of high and low flows, alteration of temperature and dissolved oxygen levels, and changed cues for seasonal migration. In terms of the timing and magnitude of high and low flows, the proposed action is the same as COS. The proposed action would result in much lower flows from October through April, and higher flows from May through September relative to WOA. As Coho Salmon spawn from February to April, this reduction in flow would reduce the amount of available spawning habitat and increase competition, with detrimental effects on Coho Salmon. Competition with hatchery fish released from Trinity River Hatchery limits rearing and spawning capacity in the Upper Trinity River for naturally produced Coho (NMFS 2014). For those redds that are laid, higher survival of Coho Salmon eggs and emerging alevins is expected under the proposed action relative to WOA due to reduced fine sediment in the channel substrate, and an increased food base for these fish due to increased macroinvertebrate production. See Figures 5.18-3 and Figure 5.18-4.

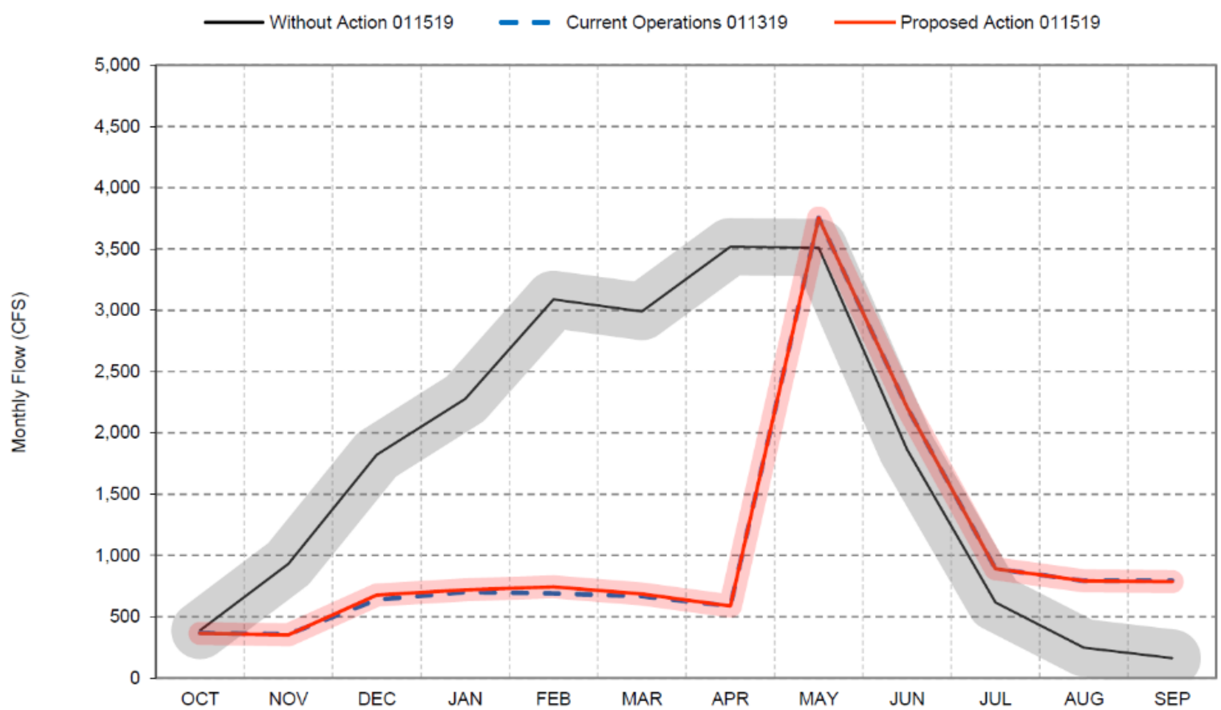


Figure 5.18-3. Average Monthly Flow below Lewiston for the Proposed Action, without Action, and Current Operations

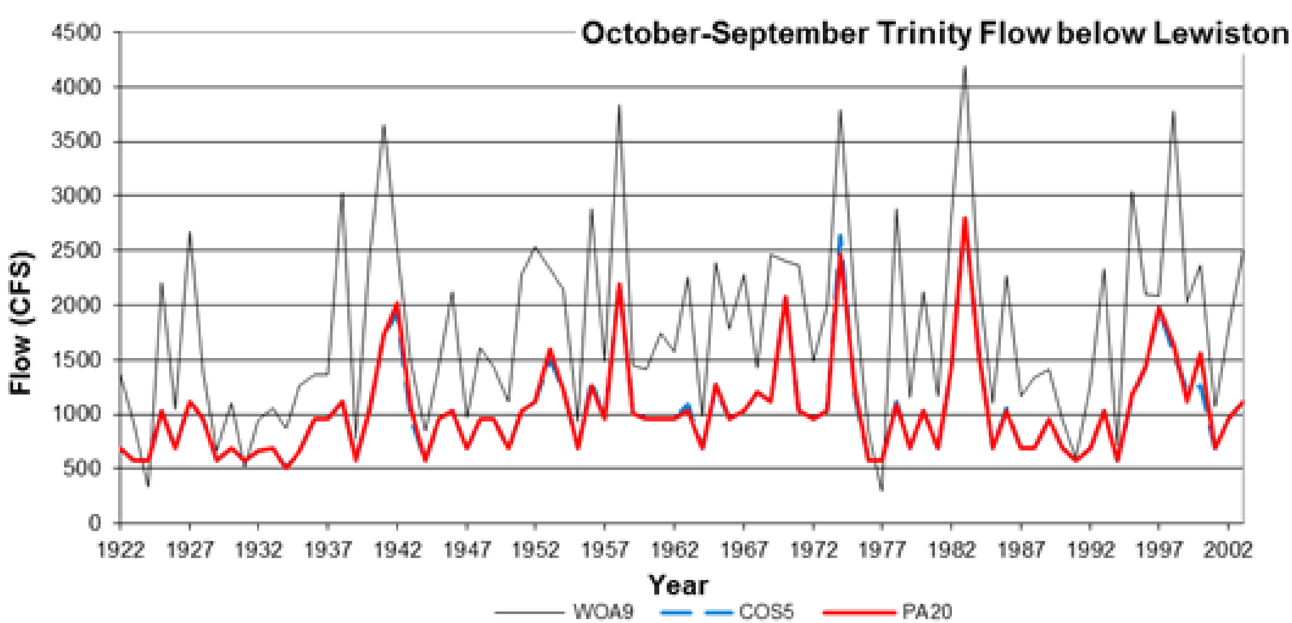


Figure 5.18-4. CalSim II Simulated Annual Flow in the Trinity River below Lewiston Dam under the Without Action (WOA9), Current Operations (COS5) and Proposed Action (PA20) Scenarios

As discussed in the conceptual model section above, increased water temperature can be detrimental to the survival of most life stages of Coho Salmon, but in the SONCC Coho Salmon ESU summer-rearing juveniles are the most likely to be affected by elevated water temperatures. Increased water temperature, even at sub-lethal levels can inhibit migration, reduce growth, stress fish, reduce reproductive success, inhibit smoltification, contribute to outbreaks of disease, and alter competitive dominance (Elliott 1981). EPA (2003) recommends 13 degrees Celcius or 55 degrees Fahrenheit for salmonid spawning and egg incubation (November to April for Coho), 61 degrees Fahrenheit for juvenile rearing (year-round), 64 degrees for non-core juvenile rearing, and 68 degrees for adult migration (September – December).

Compared to WOA, the proposed action would result in higher water temperatures during November - April, and much lower water temperatures from May through October. Higher water temperatures during the winter are not expected to negatively impact Coho Salmon life stages, since water temperatures are expected to stay within the suitable range for these life stages (below 55 degrees, see figures below). Conversely, significantly lower water temperatures during the summer and fall months should provide a benefit to over summering juvenile Coho Salmon rearing. Under the proposed action, temperatures are below 55 degrees year-round nearly all of the time, except for in some Critical years. This is a substantial benefit of the proposed action as compared to WOA.

See Figures 5.18-5 and 5.18-6.

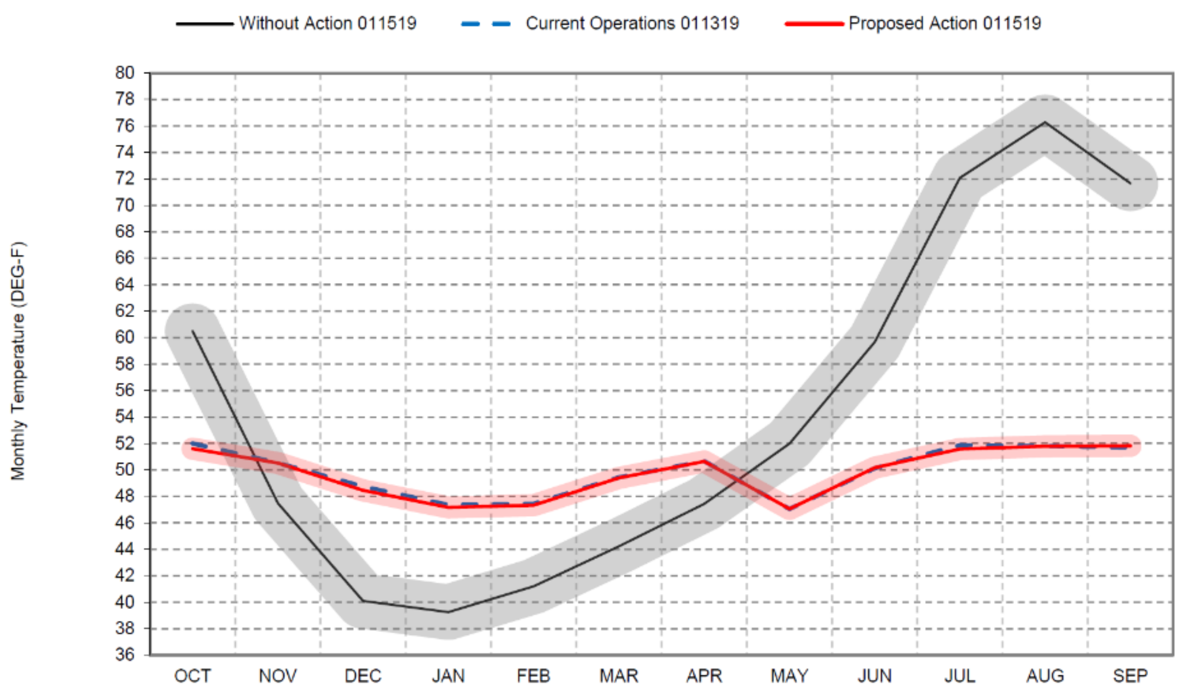


Figure 5.18-5. Monthly Mean Temperatures in the Trinity River below Lewiston Dam under the Proposed Action, without Action, and Current Operations

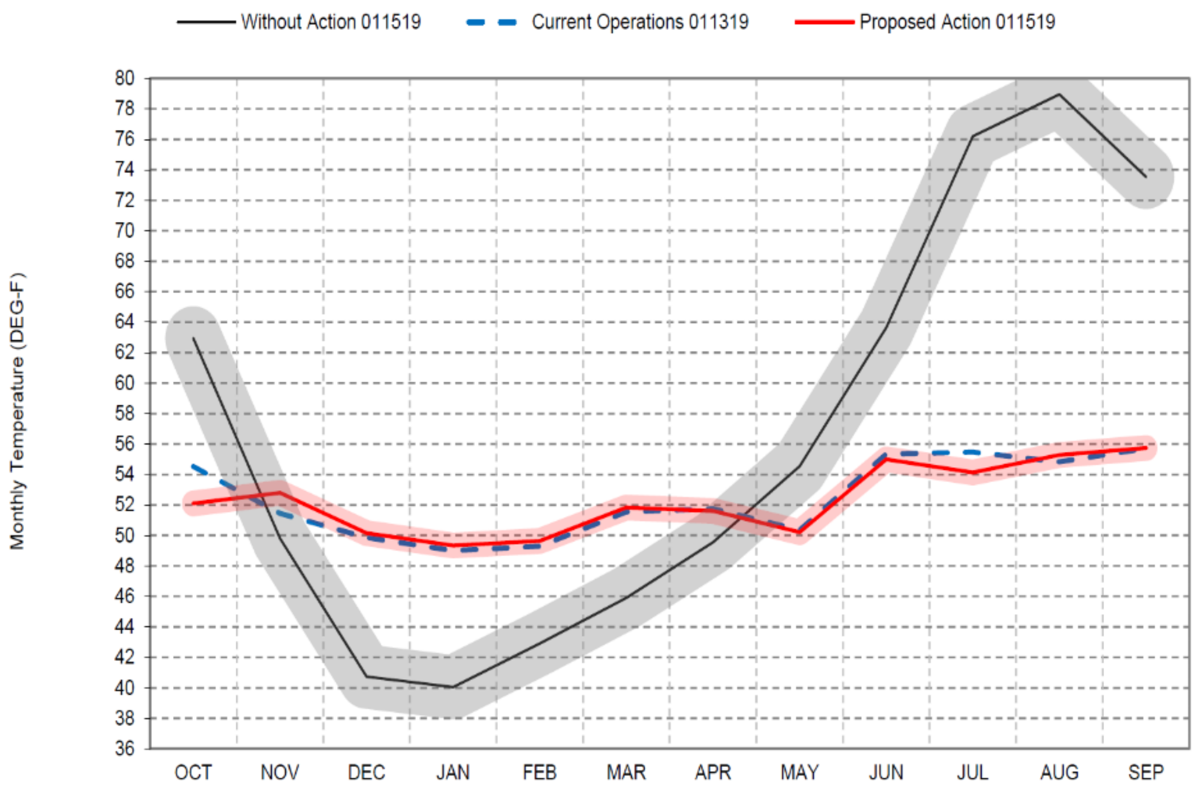


Figure 5.18-6. Critical Water-year Type Mean Temperatures in the Trinity River below Lewiston Dam under the Proposed Action, without Action, and Current Operations

5.18.4 Conservation Measures

Conservation measures under the proposed action described in the Winter-run Chinook Salmon section would not overlap with the Coho Salmon spatial distribution and, therefore, are not expected to affect Coho Salmon.

5.19 Coho Critical Habitat, Southern Oregon/Northern California Coastal ESU Critical Habitat

Prior to the construction of the TRD, the Trinity River was an unregulated, meandering, dynamic alluvial river within floodplain habitat. High flows periodically changed the size, shape, and location of river bars. Flow regulation by the TRD removed nearly all high flows that were responsible for forming and maintaining dynamic alternate bar sequences that supported development of rearing habitat in the mainstem trinity. No longer scoured by winter floods downstream of the TRD, streambank (riparian) vegetation encroached into the river channel and formed riparian berms along the channel margins. Reduced flows, loss of coarse sediment impounded by the dam, and riparian encroachment caused the mainstem of the river downstream from the TRD to change from a series of alternating riffles and deep pools that provided high-quality salmonid habitat to a largely monotypic run habitat confined between riparian berms (a trapezoid-shaped channel). The loss of alluvial features and diverse riverine habitats reduced the quantity and quality of salmonid habitats and the populations that relied upon them (USFWS and HVT 1999).

5.19.1 Seasonal Operations

Under the WOA, uncontrolled flows would be released to the Trinity River, however the dam would continue to impound sediment. Without sediment to rebuild the bar, pool, and riffle habitat that supports coho spawning and rearing, the uncontrolled flow would likely continue to degrade habitat that has been designated as critical for the conservation of SONCC Coho.

Compared to WOA, the proposed action would improve habitat by continuing implementation of a normal (reduced) hydrograph, and restoration of functioning alluvial river and connected floodplain habitat. Because the expected outcome of implementation of the proposed action is improved fish habitat conditions (including necessary Coho Salmon habitat), the value of critical habitat for both the survival and recovery of SONCC Coho Salmon will not be appreciably diminished.

5.20 Eulachon, Southern DPS

Eulachon occur in the Klamath River watershed and, therefore, could be subjected to effects from seasonal operations of Lewiston Dam; there would be no effects from any other components of the proposed action. Adult Eulachon typically spawn at age 2-5 in the lower portions of rivers. As described in Chapter 2, Eulachon spawning generally occurs between December and June, with larvae being transported to the estuary and ocean by spring freshets.

Climate change is ranked as the highest threat to Eulachon, with dams and diversions the second most important threat to the Klamath River population of Eulachon. Operation of Trinity Reservoir, as well as associated changes in the Klamath River, have shifted the spring peak flow of the lower Klamath River from its historical peak in April to its current peak in March, one full month earlier (NRC 2004, as cited in Gustafson et al. 2010). Habitat–related effects to Eulachon as a result of the continued operations of Trinity Reservoir has the potential to affect Eulachon spawning behavior; egg viability; and larvae and juvenile growth, development, and survival. However, the principal habitat-related effects to Eulachon as a result of the continued operations of the dams are the hydrological effects on the estuary–plume environment, which is utilized by Eulachon larvae and juveniles for rearing and maturation. The April through July period coincides with Eulachon larval ocean entry and residence timing, and changes in flows during this period are likely to affect the chemical and physical processes of the estuary– plume environment (NMFS 2008a). Studies highlight the connection between river-derived nutrients, coastal upwelling, chemical and physical process in the estuary–plume environment, primary productivity, and the importance of the estuary–plume environment to Eulachon, especially Eulachon larvae and juveniles. However, there is no direct data on the link between decreases in freshwater inputs into the estuary-plume environment and effects on Eulachon larvae and juveniles to assess the significance of effects.

In general, Eulachon would spawn at low water levels before spring freshets (Lewis et al. 2002, as cited in Willson et al. 2006). In many rivers, the spawning reach is more or less limited to the part of the river that is influenced by tides (Lewis et al. 2002, as cited in Willson et al. 2006). However, Eulachon are reported to go as far as 80 km up the Susitna River (Barrett et al. 1984, Vincent-Lang and Queral 1984; as cited in Willson et al. 2006), possibly because of a low gradient (Lewis et al. 2002, Ref. 269). Eulachon once ascended more than 160 km in the Columbia River system. There is some evidence that water velocity greater than 0.4 m/s begins to limit upstream movements, at least for a segment of the Eulachon population (Lewis et al. 2002, as cited in Willson et al. 2006).

Entry into the spawning rivers appears to be related to water temperature and the occurrence of high tides (Ricker et al. 1954, Eulachon Research Council 2000, Prince Rupert Forest Region 1998, Bishop et al. 1989b, Lewis et al. 2002, WDFW/ODFW 2001, Spangler 2002; as cited in Willson et al. 2006).

Spawning is reported to occur at temperatures from 4° to 10°C; colder temperatures may stop migration (WDFW/ODFW 2001), at least in some rivers. run timing (as estimated from harvest rates) in the Fraser River tended to be earlier in years with somewhat warmer temperatures (r = −0.47; Ricker et al. 1954, as cited in Willson et al. 2006). Incubation is temperature-dependent, and so incubation times can differ among rivers and years. Egg survival is greatly influenced by salinity: exposure to salt water, especially salinity greater than 16 ppt, can be lethal (Farara 1996 cited in Lewis et al. 2002, as cited as cited in Willson et al. 2006). Major temperature changes also affect survival (e.g., a change from 5° to 11°C; Lewis et al. 2002, as cited in Willson et al. 2006). Peaks in larval outmigration are thought to occur during periods of relatively stable water temperatures and at low light intensities (Spangler 2002, as cited in Willson et al. 2006).

Thus, the proposed action could affect the transitions between adults and egg/larvae, and between egg/larvae and juveniles[1]. Seasonal operations of Lewiston Dam in winter and spring are of relevance for potential effects on Eulachon. Under WOA, based on observed data in the Klamath River from 1962-2003 and CalSim modeled results for WOA, Trinity River flow provides between 6% (September) to 19% (May) of the flow in the Klamath River (Figure 5.20-1). For the period from 1962–2003, under WOA, flow in the Trinity River at Lewiston as a percentage of observed flow in the Klamath River near Klamath has ranged from 0–15% in January to 11% to 47% in May (Table 5.20-1). Therefore, under WOA, flow from the Trinity River at Lewiston forms a small percentage (mean of 10%) of flow entering the lower Klamath River during December–April and a larger percentage in May and June (17%).

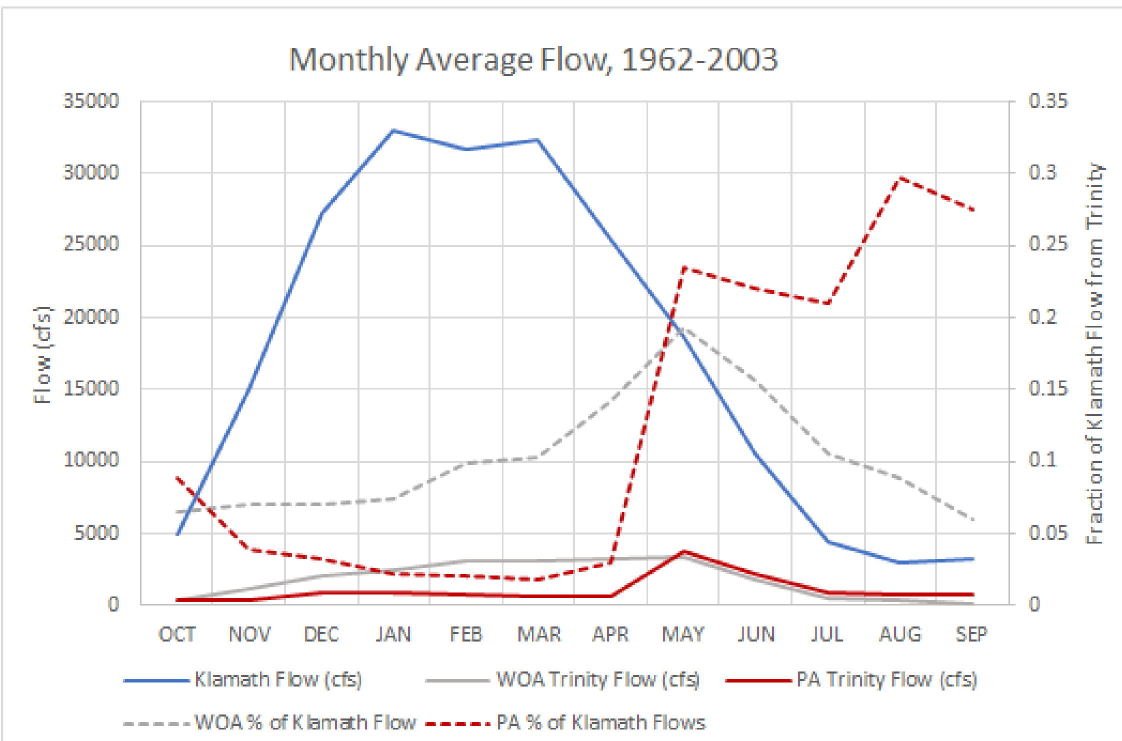


Figure 5.20-1. Monthly Average Klamath Flow (Observed) and Trinity Flow (Modeled).

Table 5.20-1. Modeled Flow in the Trinity River at Lewiston as a Percentage of Observed Flow in the Klamath River near Klamath, 1962-2003. (WOA/PA)

	DEC	JAN	FEB	MAR	APR	MAY	JUN
Max	0.18/0.18	0.15/0.07	0.2/0.11	0.26/0.09	0.34/0.11	0.43/0.47	0.41/0.5
95%	0.18/0.18	0.15/0.07	0.2/0.11	0.26/0.09	0.34/0.11	0.43/0.47	0.41/0.5
75%	0.08/0.04	0.1/0.03	0.14/0.02	0.12/0.02	0.19/0.04	0.22/0.3	0.21/0.32
50%	0.07/0.02	0.08/0.01	0.09/0.01	0.11/0.01	0.14/0.02	0.19/0.24	0.14/0.21
25%	0.05/0.01	0.06/0.01	0.07/0.01	0.08/0.01	0.11/0.01	0.17/0.16	0.12/0.14
5%	0.03/0.01	0.03/0	0.05/0.01	0.06/0.01	0.08/0.01	0.13/0.13	0.09/0.09
Min	0.01/0	0.01/0	0.04/0	0.05/0	0.07/0.01	0.12/0.11	0.07/0.05
Mean	0.07/0.03	0.07/0.02	0.1/0.02	0.1/0.02	0.14/0.03	0.19/0.23	0.16/0.22

For the December–June period of concern for Eulachon, CalSim modeling suggests that the proposed action scenario would reduce flows in December to April, but actually would increase flows in May and June. This pattern is essentially identical for the current operations COS scenario in relation to the WOA scenario. The patterns suggest that Trinity River flow changes would occur during the spawning migration period (December–April, with the main historical period being March–April; NRC 2004, p.275), with little or no effect to flow in the Trinity River expected during the later egg incubation and larval downstream migration period, which occurs around one month after spawning (NRC 2004, p.275). The extent to which the limited December-–April flows may negatively affect Eulachon is uncertain, given the lack of quantitative relationships between biological performance and flow. However, as discussed above, studies have shown effects on food in the estuary-plume environment, shifts in timing of spring freshets, and temperature affect Eulachon. Incubation is temperature-dependent, and major temperature changes affect survival (e.g., a change from 5° to 11°C; Lewis et al. 2002, as cited in Willson et al. 2006).

The most recent status review update noted that there have been catches of Eulachon in the Klamath River during surveys in recent years, whereas prior to that, runs were rare or sporadic for several decades (Gustafson 2016, p.13). The Klamath subpopulation appears to be much smaller than the Columbia, Fraser, and British Columbia subpopulations, some of which can number in the tens to hundreds of millions (NMFS 2017 Eulachon, p.73). See Figures 5.20-2 through 5.20-6.

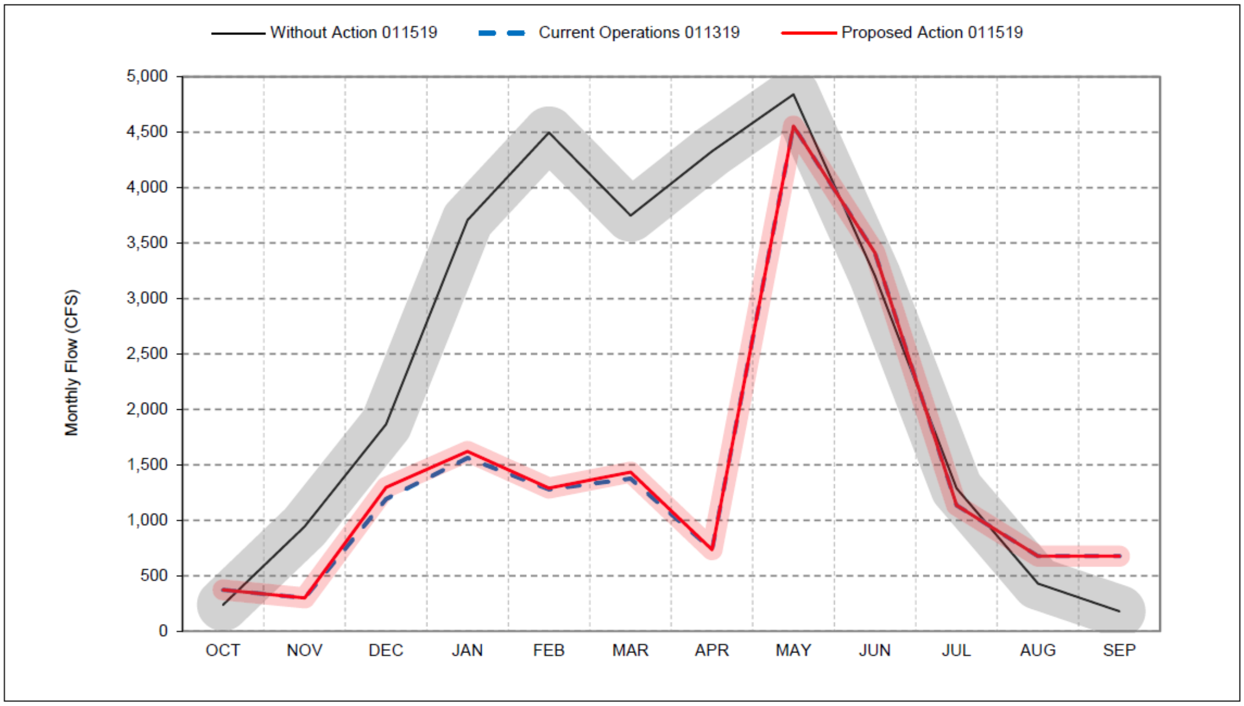


Figure 5.20-1. Mean Modeled Flow in the Trinity River Below Lewiston, Wet Years.

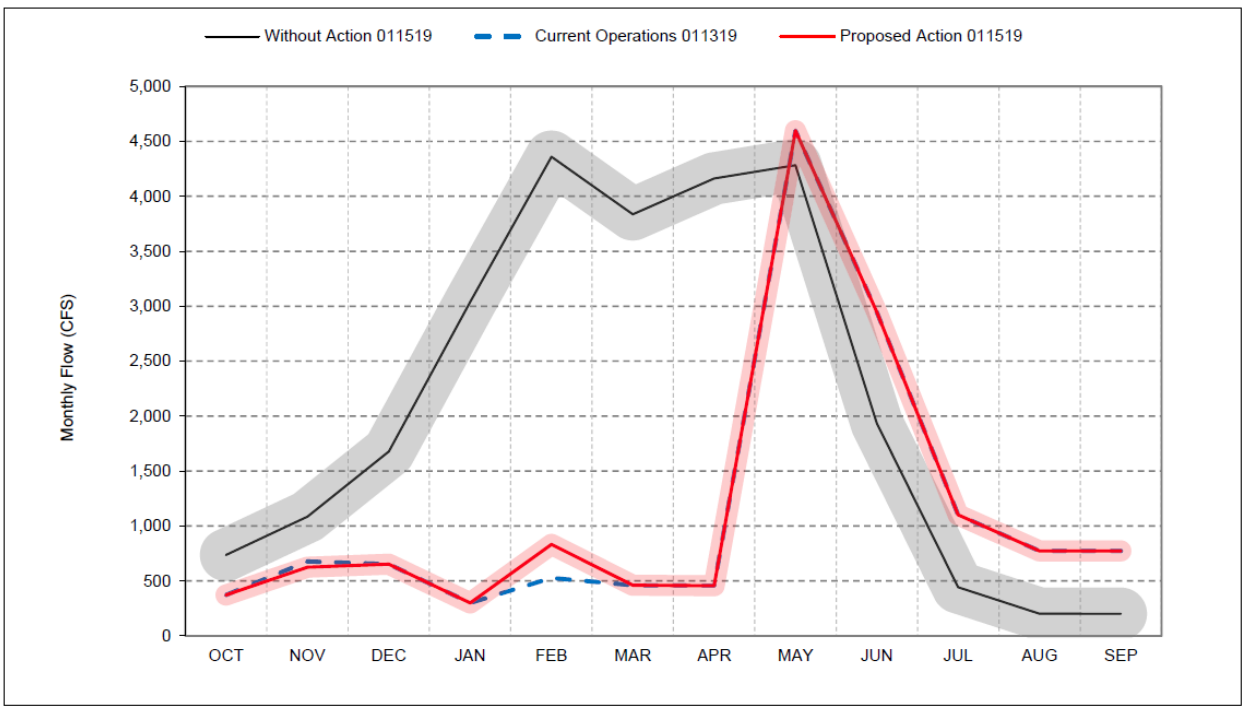


Figure 5.20-2. Mean Modeled Flow in the Trinity River Below Lewiston, Above Normal Years.

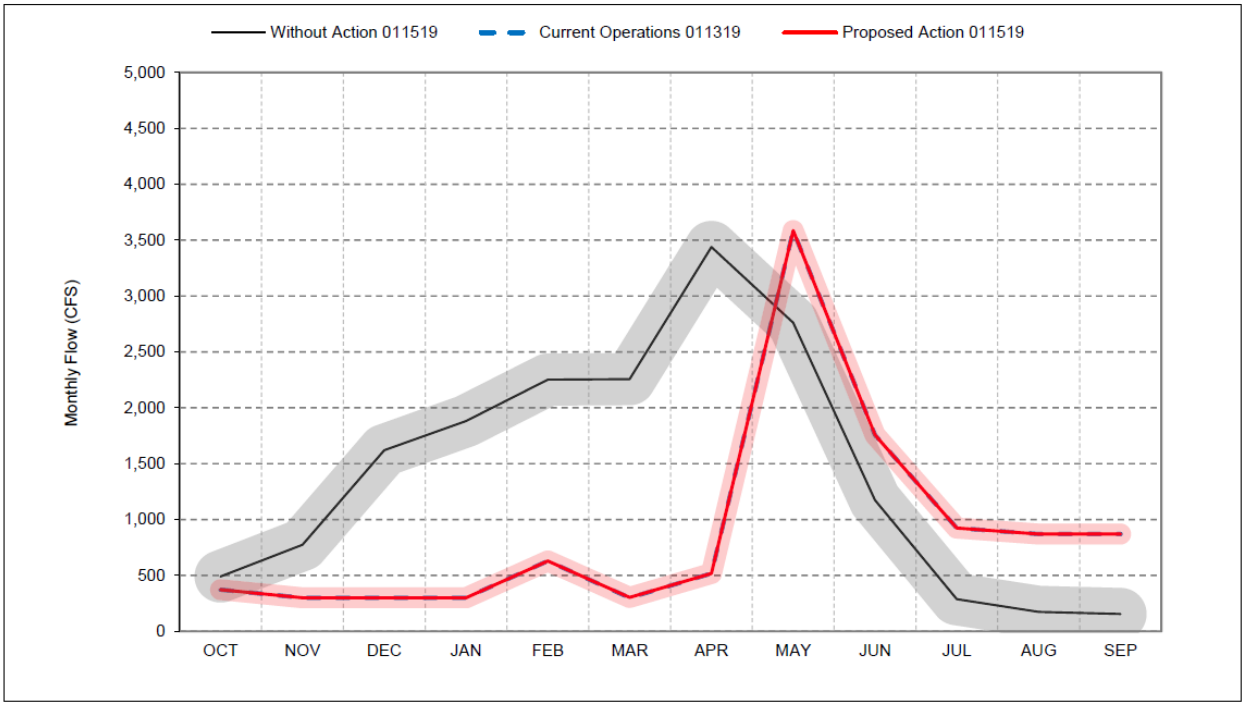


Figure 5.20-3. Mean Modeled Flow in the Trinity River Below Lewiston, Below Normal Years.

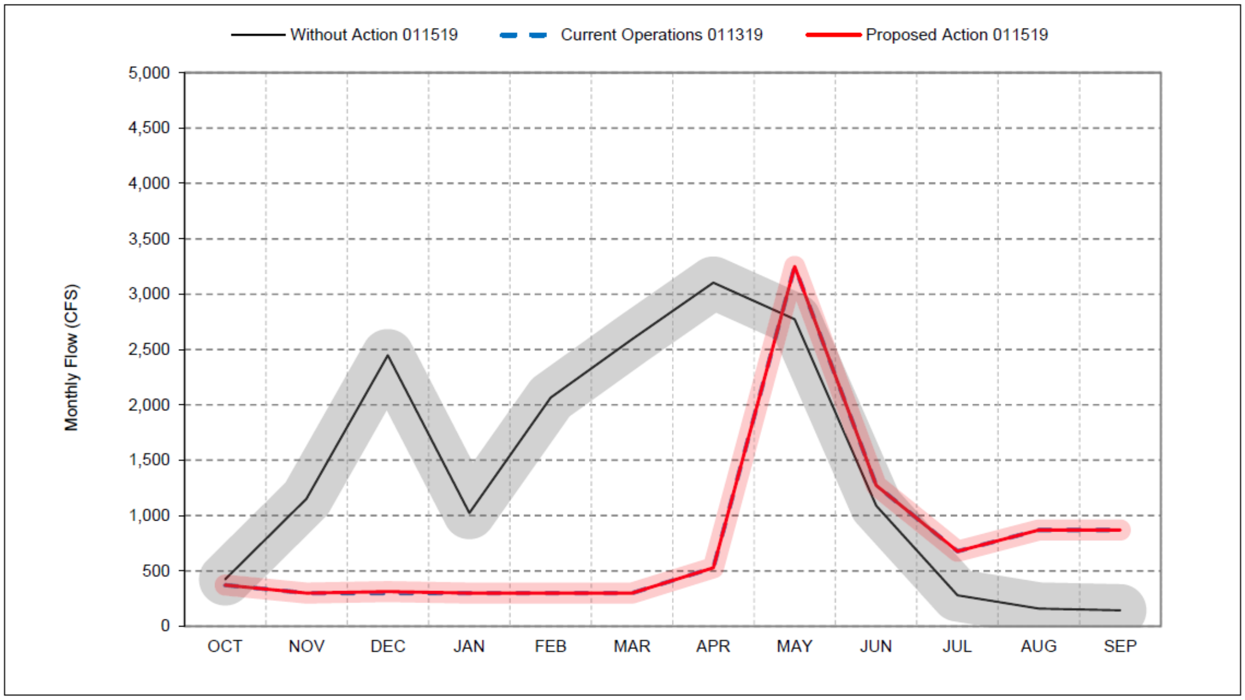


Figure 5.20-4. Mean Modeled Flow in the Trinity River Below Lewiston, Dry Years.

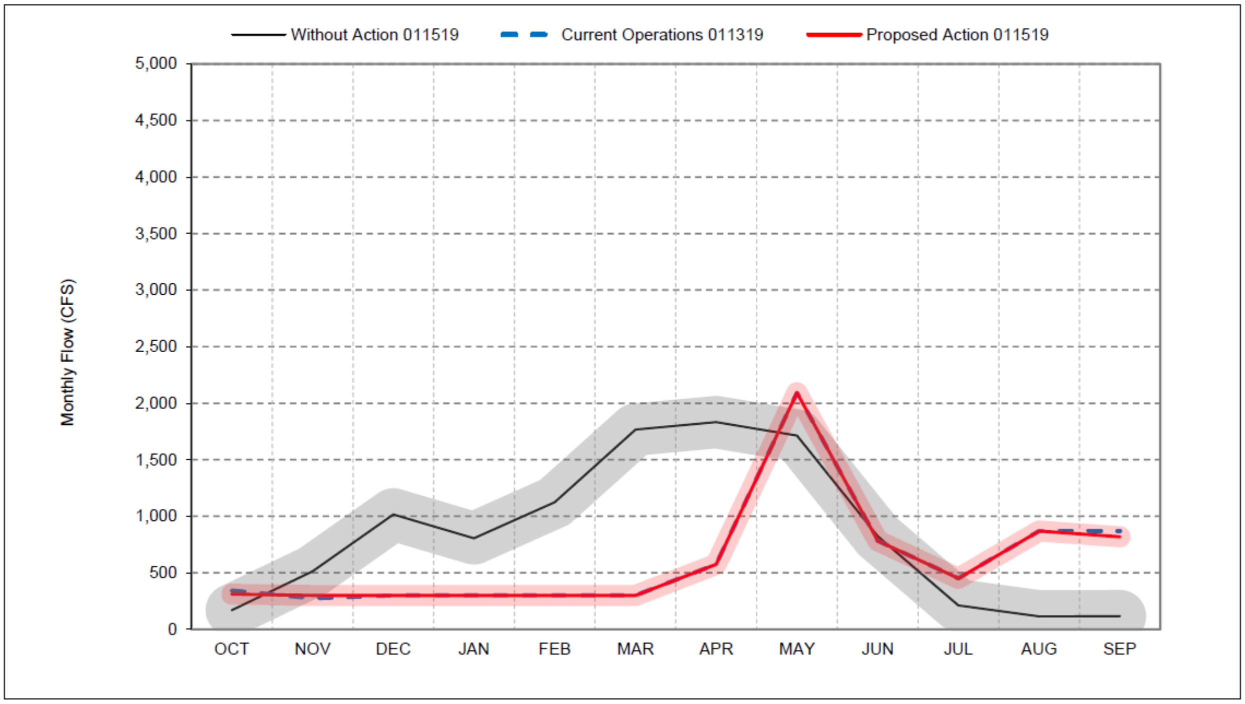


Figure 5.20-5. Mean Modeled Flow in the Trinity River Below Lewiston, Critically Dry Years.

Under the proposed action, Trinity River at Lewiston flows would contribute between 1,000 to 4,000 cfs less to flow entering the lower Klamath River than WOA during December-–April, reducing flows to approximately 300 cfs in most years. The timing coincides with Eulachon spawning and larvae being transported to the estuary and ocean. Under WOA, flows from the Trinity River provide, on average, 10% of the flow of the Klamath River, with the greatest percentage in May. Flows under the proposed action in the lower Klamath River could be reduced from 0% to nearly 23% compared to WOA in December - April of some years, with the average less than 10%. While the proposed action substantially reduces flow in December - April, and the proposed action slightly reduces flows in May of Wet water year types, the proposed action overall slightly increases flows from the Trinity River in May as compared to WOA, which is the month when the Trinity River provides the largest portion of the Klamath River flows. As previously noted, it is uncertain the extent to which there may be negative effects because of these differences, given the lack of quantitative relationships between biological performance and flow, but mechanisms include food transport and temperature.

Eulachon in the Klamath River generally spawn March–April (NRC 2004, p.275). Adult Eulachon require rapid changes in temperature of 6-8 C to experience mortality (Blahm and McConnell, 1971). Temperature modeling data for the proposed action are not available for the lower Klamath River where Eulachon spawn, but temperature averages in the Trinity River below Lewiston between December-April under the proposed action are not appreciably different than the WOA in the months of March and April (see Figure 5.20-7 and Figures 1-1 to 1-6 in the HEC-5Q modeling summary in Appendix D, *Modeling*), which, given that spawning sites for Eulachon have been found up to 52 F/11 C (see review by Willson et al. 2006), and the modest contribution of Trinity River water to the lower Klamath River (i.e., perhaps 20% under WOA; see discussion above) suggests that effects on spawning temperature would be limited.

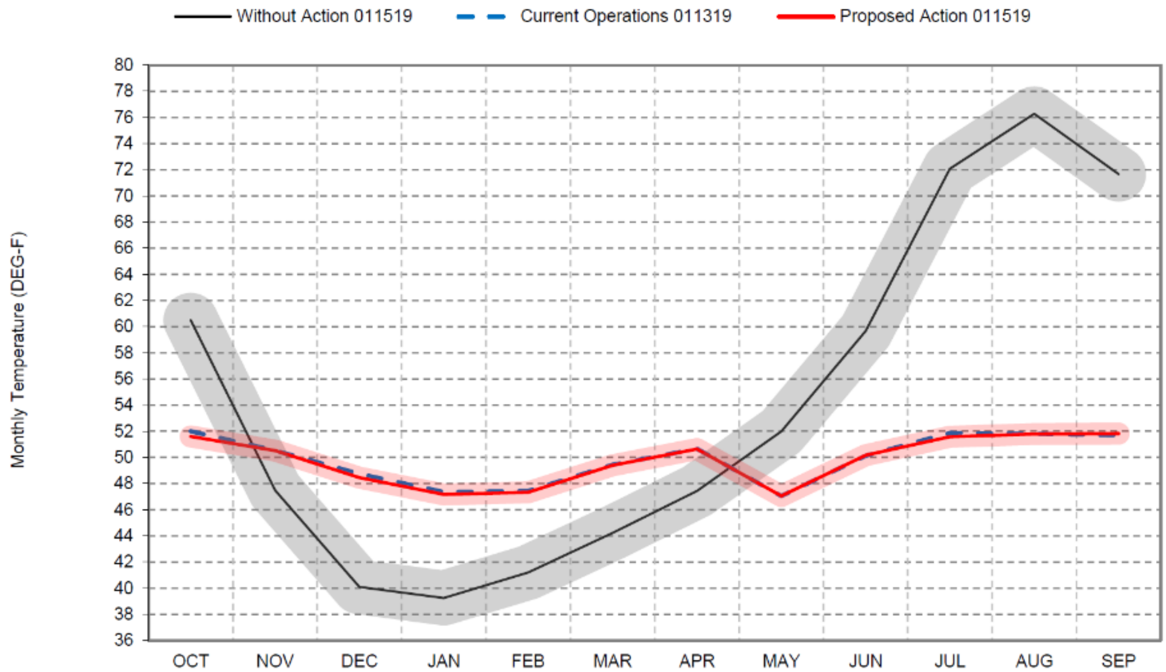


Figure 5.20-6. Mean Modeled Temperature in the Trinity River Below Lewiston

5.21 Eulachon, Southern DPS Critical Habitat

5.21.1 Freshwater Spawning and Incubation Sites

As described in the *Aquatic Status of the Species and Designated Critical Habitat* for *Eulachon, Southern DPS*, the physical or biological features (PBFs) include water flow, quality and water temperature conditions and substrate supporting spawning and incubation. As previously noted, flow during December-–April under the proposed action is lower than under the WOA scenario; Figures 5.20-2 through 5.20-6). As previously stated, there is a lack of quantitative relationships between flow and Eulachon biological performance.

5.21.2 Freshwater and Estuarine Migration Corridors

As described in the *Aquatic Status of the Species and Designated Critical Habitat* for *Eulachon*, *Southern DPS*, the PBFs include freshwater and estuarine migration corridors free of obstruction and with water flow, quality and water temperature conditions supporting larval and adult mobility, and with abundant prey items supporting larval feeding after the yolk sac is depleted. The proposed action does not physically obstruct migration corridors—Eulachon only occur in the lower 8 miles or so of the tidal Klamath River (NRC 2004, p.275)—but could reduce water flow during December-–April, which includes the main historical period of spawning migration (March–April; NRC 2004, p.275). As previously noted, larval downstream migration occurs around one month after spawning, and, therefore, their exposure to reduced flows would be limited.

5.21.3 Nearshore and Offshore Marine Foraging Habitat

The proposed action would not be expected to have negative effects on the nearshore and offshore marine foraging habitat PBFs of Eulachon critical habitat.

5.22 Analytical Approach – Terrestrial Species

This section analyzes potential effects from the proposed action on terrestrial listed species, including riparian brush rabbit, riparian woodrat, salt marsh harvest mouse, California Rigway's rail, least Bell's vireo, western yellow-billed cuckoo, giant garter snake, valley elderberry longhorn beetle, soft bird's-beak, Suisun thistle, vernal pool fairy shrimp, vernal pool tadpole shrimp, California tiger salamander, and California least tern. This section also analyzes effects of the proposed action on listed species' designated critical habitat.

5.22.1 Wildlife and Plant Species

5.22.1.1 Range Maps and Species Occurrences

To determine which project components could affect federally listed terrestrial species, reclamation reviewed species range maps to assess which project components overlap the species' ranges as depicted in Chapter 2 range map figures. All the range maps originated from the following data sources.

- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. California Tiger Salamander Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 24, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Clapper Rail Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Giant Garter Snake Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Least Tern Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 24, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Salt-Marsh Harvest Mouse Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2, 2019.
- California Department of Fish and Wildlife California Interagency Wildlife Task Group. 2016. Yellow-Billed Cuckoo Range. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: January 2,2019.
- U.S. Geological Survey Gap Analysis Project. 2018. San Joaquin Valley Wood Rat Range. Available: https://gapanalysis.usgs.gov/species/data/download. Accessed: January 15, 2019.
- Carol W. Witham, Robert F. Holland and John Vollmar. 2014. Changes in the Distribution of Great Valley Vernal Pool Habitats from 2005 to 2012. Available: https://vernalpools.org/2012CVPIA/2012RemapVernalPoolsFINAL.zip. Accessed: August 27, 2017.

- U.S. Fish and Wildlife. 2005. Vernal Pool Core Areas.

Where the species' range overlaps the general area of effect for a proposed project component, Reclamation then assessed whether the species' current range includes the area. For all species except giant garter snake and California red-legged frog, Reclamation assumed the range maps reflect the current species' range for all except California red-legged frog and giant garter snake: for these species, the range maps include the historic range and Reclamation based species potential on more recent occurrences and information on locations where the species are believed to be extirpated.

5.22.1.2 Land Cover Data and Species Models

Reclamation used existing land cover data and, where available, species habitat models to assess which habitat components would affect federally listed species' habitat. Reclamation used the following data sources to make these determinations:

- Aerial Information Systems, Inc. 2011. Delta Vegetation and Land Use. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets/200_299/ds292.zip. Accessed: December 10, 2018.
- U.S. Geological Survey. 2017. NHD Flowline. Available: http://prd-tnm.s3-website-us-west-2.amazonaws.com/?prefix=StagedProducts/Hydrography/NHD/State/HighResolution/GDB. Accessed: May 4, 2017.
- U.S. Geological Survey. 2017. NHD Area. Available: http://prd-tnm.s3-website-us-west-2.amazonaws.com/?prefix=StagedProducts/Hydrography/NHD/State/HighResolution/GDB. Accessed: May 4, 2017.
- Geographic Information Center, Chico Research Foundation. 2016. Vegetation - Great Valley Ecoregion. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets/2600_2699/ds2632.zip. Accessed: November 11, 2017.
- Chico State University and California DWR. 2001. Legal Delta Boundary. Available: ftp://ftp.dfg.ca.gov/BDB/GIS/BIOS/Public_Datasets. Accessed: December 11, 2018. BDCP species models.

Table 5.23-1 lists each of the project components and indicates the federally listed species that may be affected by each, based on the analysis described above.

5.22.1.3 Avoidance and Minimization Measures, Effects Estimates

Reclamation developed avoidance and minimization measures with the first goal being to avoid effects on federally listed species, and the second goal being to minimize unavoidable effects. Reclamation analyzed each project component to determine whether it could fully avoid effects on federally listed species. If effects were determined to be unavoidable, or potentially unavoidable, Reclamation estimated the potential effects on each species.

The approach Reclamation used to estimate potential effects differed by project component, since the amount and source of information differed by project component. Project footprints were available for most of the spawning and rearing habitat restoration projects. For other habitat restoration projects, hypothetical footprints were used to estimate effects. These hypothetical footprints had been developed for BDCP, California WaterFix, and California Ecorestore. Reclamation also used information from existing environmental documents where available.

Precise, site-specific project information was unavailable for most of the project components. As such, the impact acres provided are intended to place upper limits on species effects to assist USFWS in making no-jeopardy determinations for each of the species.

5.22.2 Wildlife and Plant Critical Habitat

The analyses of potential effects on species' designated critical habitat follow the species analyses. Potential effects to primary constituent elements (PCEs)/physical and biological features (PBFs) of critical habitat are analyzed for western yellow-billed cuckoo and valley elderberry longhorn beetle. These analyses often draw on the foundation provided in the species analyses. Analysis of effects to critical habitat is guided by consideration of recent analyses by USFWS (2017a) and NMFS (2017), which included refined interpretation of critical habitat PCEs/PBFs relative to the original descriptions at the time critical habitat was designated.

In general, riparian vegetation would establish and grow more successfully during winter under the WOA scenario, but the low summer WOA flow could result in the loss of this vegetation. Therefore, the effect of the proposed action relative to the WOA on riparian habitat is uncertain.

5.23 Effects on Covered Wildlife and Plant Species

This section provides the results of the effects analysis for covered wildlife and plant species. Section 5.22, Analytical Approach, describes the methods used for this analysis. The project components that may affect each species are indicated in Table 5.23-1. The maximum allowable habitat loss for each species is provided in Table 5-Terrestrial.

Construction actions affecting terrestrial species are covered programmatically in this BA. As part of the subsequent site-specific consultation, Reclamation will provide a memo describing the action in detail, including where, when and how.

5.23.1 Riparian Brush Rabbit

The riparian brush rabbit occurs in the Stanislaus River and San Joaquin River watershed, and project components within these watersheds may affect this species as follows.

5.23.1.1 Stanislaus River Watershed

5.23.1.1.1 <u>Proposed Flow Changes</u>

For the purposes of the wildlife and plant species analyses, "proposed flow changes" constitute the expected effects of implementing the proposed action compared to WOA. Differences in flow management between the proposed action and WOA would have the potential to affect a covered wildlife or plant species if flow changes were to directly affect the species, directly alter habitat availability or quality, or result in vegetation changes that would alter habitat availability or quality. The great majority of stream channels within the action area are linear channels confined by levees or other engineered works that provide negligible habitat for covered wildlife or plant species. However, there is potential to affect such species at those sites where habitat has not been removed by channel alteration, or where habitat has been restored, or where habitat is expected to be restored during the proposed term of the proposed action. In the first two of these cases, existing habitat shows evidence of adaptation to anthropogenic modifications to the ecosystem that date back decades, and in many cases over a century.

These modifications include hydrologic changes associated with water manipulation; topographic changes associated with flood control, agriculture, restoration site construction, and other causes; and biological changes associated with the introduction of non-native species. Implementation of the proposed action generally results in higher flows in the fall and lower flows in the spring than WOA, and very minor potential changes relative to COS and are small relative to normal month-to-month and year-to-year variability in the system. Lower flows in the spring under the proposed action compared to WOA could potentially result in less riparian vegetation recruitment, such as cottonwood seed dispersal. However, flows under the proposed action would generally be more stable compared to WOA and would not alter the timing and magnitude of hydrologic vegetation and peak flow incidents such that erosion and potential loss of riparian vegetation occurs.

For example, CalSim results show average maximum flows in the Sacramento River below Keswick in April under the proposed action would be 30,893 cfs, compared to 56,209 cfs under WOA (see Appendix D, *Modeling*). With average maximum spring flows such as these the proposed action is more likely to negatively affect riparian vegetation recruitment compared to WOA. These maximum spring flows under WOA are not likely to destabilize the existing ecosystem or cause substantial disturbances to riparian vegetation as they are similar to average maximum flows during different times of the year compared to the proposed action and COS. Higher flows in the fall under the proposed action compared to WOA could result in reduced drought stress in riparian or wetland vegetation.

Table 5.23-1. Terrestrial: Terrestrial Project Components

Watershed	Title[1]	Riparian Brush Rabbit	Riparian Woodrat	Salt Marsh Harvest Mouse	CA Ridgway's Rail	Western Yellow-Billed Cuckoo	Least Bell's Vireo	Giant Garter Snake	Valley Elderberry Longhorn Beetle	Suisun Thistle	Soft Bird's-Beak	Vernal pool fairy shirmp	Vernal pool tadpole shrimp	California tiger salamander	California red-legged frog	California least tern
Upper Sacramento	Spawning and Rearing Habitat Restoration					X	X	X	X						X	
Upper Sacramento	Battle Creek Salmon and Steelhead Restoration Project								X							
Upper Sacramento	Colusa Basin Drain Food Web Routing					X	X	X	X							
Upper Sacramento	Seasonal Operations					X	X	X	X							
Feather River	FERC Flows					X			X							
American River	Spawning and Rearing Habitat Restoration					X			X							
American River	2017 FMS and “Planning Minimum”					X			X							
Bay-Delta	Delta Fishes Conservation Hatchery													X		

[1] Only project components with potential to affect federally listed terrestrial species are listed.

Watershed	Title[1]	Riparian Brush Rabbit	Riparian Woodrat	Salt Marsh Harvest Mouse	CA Ridgway's Rail	Western Yellow-Billed Cuckoo	Least Bell's Vireo	Giant Garter Snake	Valley Elderberry Longhorn Beetle	Suisun Thistle	Soft Bird's-Beak	Vernal pool fairy shirmp	Vernal pool tadpole shrimp	California tiger salamander	California red-legged frog	California least tern
Bay-Delta	Delta Cross Channel Improvements							X								
Bay-Delta	Tidal Habitat Restoration			X	X			X	X	X	X	X	X	X		X
Bay-Delta	Suisun Marsh Salinity Control Gates			X	X					X	X					
Bay-Delta	OMR Management			X	X			X	X	X	X					
Stanislaus	Spawning and Rearing Habitat Restoration					X	X		X							
Stanislaus	Stepped Release Plan	X	X			X	X		X							
San Joaquin River Lower	Spawning and Rearing Habitat Restoration	X	X			X	X		X							

5.23.1.1.1.1 Effects of Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Stanislaus watershed, differences between the proposed action and COS are negligible, on the order of a few percent decrease in flow in February and a few percent increase in May and June. These changes are unlikely to produce any measurable change in quantity or quality of riparian brush rabbit habitat in the Stanislaus watershed, and there is no apparent mechanism by which these changes could result in harm to individual riparian brush rabbits. Conversely, differences between the proposed action and WOA are large, with substantial reductions in flows in Februrary, March, June and July, potentially causing drought stress in riparian or wetland vegetation, and increases in flows from August to October, which should allow for greater riparian growth than under WOA. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.1.1.1.2 Spawning and Rearing Habitat

Gravel will be placed in-stream, therefore will not result in loss or disturbance of riparian brush rabbit habitat. Access to the enhancement site by vehicles, workers, and equipment may disturb habitat or disrupt normal behavioral patterns of riparian brush rabbits in the vicinity of the activity, in the absence of avoidance and minimization measures. BOR will implement AMM-RBR/RWR to avoid adverse effects on riparian brush rabbit from spawning habitat restoration.

Enhancement of salmonid rearing habitat along the lower Stanislaus River may involve modification of river banks or creation of side channels in or near riparian habitat. This could result in loss of riparian brush rabbit habitat. In the absence of AMMs, this could also result in disruption of normal riparian brush rabbit behavioral patterns and injury or mortality of individuals through use of heavy equipment in occupied habitat. Reclamation will implement AMM-RBR/RWR however, to avoid occupied riparian brush rabbit habitat. Reclamation will remove no more than 10 acres of suitable but unoccupied riparian brush rabbit habitat.

5.23.1.2 Lower San Joaquin River Watershed

5.23.1.2.1 <u>Proposed Flow Changes</u>

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the lower San Joaquin watershed, differences between the proposed action and COS are almost nonexistent and have no potential to produce any change in quantity or quality of riparian brush rabbit habitat in the lower San Joaquin watershed. There is also no risk that these changes could result in harm to individual riparian brush rabbits. Conversely, differences between the proposed action and WOA are large, with flows in Februrary and May-June in particular much lower than under WOA. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.1.3 Lower San Joaquin Spawning and Rearing Habitat

5.23.1.3.1 <u>Habitat Loss or Conversion</u>

5.23.1.3.1.1 Permanent Habitat Loss

This proposed action component will involve a large-scale floodplain habitat restoration effort in the Lower San Joaquin River. Levee construction could result in removal or conversion of riparian brush rabbit habitat. Levee construction may result in the permanent removal of approximately 45 acres of riparian habitat and 25 acres of associated grassland habitat for the riparian brush rabbit along the lower San Joaquin River. Reclamation will ensure that riparian brush rabbit habitat permanently removed does not exceed the maximum allowable habitat loss for this species.

AMM-RBR/RWR requires avoidance of habitat occupied or assumed to be occupied by riparian brush rabbit.

5.23.1.3.1.2 Temporary Habitat Loss

Based on the hypothetical floodplain restoration footprint, the construction of setback levees to restore seasonally inundated floodplain is expected to temporarily remove up to 35 acres of suitable riparian habitat and 20 acres of adjacent grassland habitat. Temporarily disturbed areas will be restored as riparian and grassland habitat within 1 year following completion of construction activities. Although the effects are considered temporary, several years may be required for ecological succession to occur and for restored riparian habitat to functionally replace habitat that has been affected. Most of the riparian vegetation within the species' range is early- to midsuccessional, and this species prefers riparian scrub that is early successional; therefore, the replaced riparian vegetation is expected to meet habitat requirements for the riparian brush rabbit within the first few years after the initial restoration activities are complete.

5.23.1.3.1.3 Periodic Inundation

Existing levees will be breached for floodplain restoration and the newly constructed setback levees will allow inundation through seasonal flooding. The potentially inundated areas may consist of suitable riparian brush rabbit habitat. Based on a hypothetical footprint of floodplain restoration used for BDCP, floodplain restoration will result in periodic inundation of approximately 265 acres of riparian habitat and 425 acres of associated grassland habitat for the riparian brush rabbit ([to be developed]). Although they consist of small patches and narrow bands of riparian vegetation, many of the areas potentially affected are in proximity to, or contiguous with, habitat with recorded occurrences of riparian brush rabbits. The restored floodplain will include a range of elevations from low-lying areas that flood frequently (i.e., every 1 to 2 years) to high-elevation areas that flood infrequently (i.e., every 10 years or more). Seasonal flooding in restored floodplains can result in injury or mortality of individuals if riparian brush rabbits occupy these areas and cannot escape flood waters.

AMM-RBR/RWR requires avoidance of habitat occupied or assumed to be occupied by riparian brush rabbit. This includes avoiding flooding in areas known to be occupied by riparian brush rabbit. The adverse effects of periodic inundation on the riparian brush rabbit in suitable habitat that may become occupied in the future will be further minimized through construction and maintenance of flood refugia to allow riparian brush rabbits to escape flood conditionsthrough the creation of flood refugia mounds with thick cover vegetation and on the landward sides of the newly constructed levees (Kelly et al. 2011).

5.23.1.3.1.4 Construction-Related Effects

Construction-related effects on the riparian brush rabbit include construction-related injury or mortality and indirect noise and visual disturbance to habitat in the vicinity of construction. Effects on the species are described below for each effect category. Effects are described collectively for all covered activities, and are also described for specific covered activities to the extent that this information is pertinent for assessing the value of affected habitat or the specific nature of the effect.

5.23.1.3.1.5 Construction-Related Injury or Mortality

Reclamation will avoid disturbance of occupied riparian brush rabbit habitat and therefore will avoid construction-related injury or mortality of this species.

5.23.1.3.1.6 Construction-Related Effects on Adjacent Habitat

Construction of setback levees for floodplain restoration may result in noise and visual disturbance to the riparian brush rabbit. This effect will be avoided or minimized through establishment of nondisturbance buffers as described in AMM-RBR/RWR.

The use of mechanical equipment during construction might cause the accidental release of petroleum or other contaminants that will affect the riparian brush rabbit in adjacent habitat, if the species is present. The potential for this adverse effect will be avoided and minimized through best management practices (BMPs) under *AMM2 Construction Best Management Practices and Monitoring*.

5.23.2 Riparian Woodrat

The riparian woodrat occurs in the Stanislaus River and San Joaquin River watershed, and project components within these watersheds may affect this species as follows.

5.23.2.1 Stanislaus River Watershed

5.23.2.1.1 <u>Spawning Habitat Restoration</u>

Gravel will be placed in-stream, therefore will not result in loss or disturbance of riparian woodrat habitat. Access to the enhancement site by vehicles, workers, and equipment may, however, disturb habitat or disrupt normal behavioral patterns of riparian woodrats in the vicinity of the activity, in the absence of avoidance and minimization measures. Reclamation will implement AMM-RBR/RWR, to completely avoid adverse effects on riparian woodrat from spawning adaptive management.

5.23.2.1.2 <u>Rearing Habitat Restoration</u>

Enhancement of salmonid rearing habitat along the lower Stanislaus River may involve modification of river banks or creation of side channels in or near riparian habitat. This could result in loss of riparian woodrat habitat. In the absence of AMMs, this could also result in disruption of normal riparian woodrat behavioral patterns and injury or mortality of individuals through use of heavy equipment in occupied habitat. Reclamation will implement AMM-RBR/RWR, however, to avoid occupied riparian woodrat habitat. Reclamation will remove no more than 10 acres of suitable but unoccupied riparian woodrat habitat, and will offset this loss through restoration of suitable habitat or preservation of occupied habitat.

5.23.2.1.3 Proposed flow changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Stanislaus watershed, differences between the proposed action and COS are negligible, on the order of a few percent increase in flow in February and a few percent decrease in May and June. These changes are unlikely to produce any measurable change in quantity or quality of riparian woodrat habitat in the Stanislaus watershed, and there is no apparent mechanism by which these changes could result in harm to individual riparian woodrats. Conversely, differences between the proposed action and WOA, with flows in Februrary, March, June and July much lower than flows under the WOA, and higher flows from August to October. However, existing vegetation has established in response to COS flows, and so while WOA would have increased riparian vegetation than today, the proposed action would not impact it as it does not exist. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.2.2 Lower San Joaquin River Watershed

5.23.2.2.1 Lower San Joaquin Spawning and Rearing Habitat (Steady Finance)

5.23.2.2.1.1 Habitat Loss or Conversion

5.23.2.2.1.1.1 Permanent Habitat Loss

This proposed action component will involve a large-scale floodplain habitat restoration effort in the Lower San Joaquin River. Levee construction could result in removal or conversion of riparian woodrat habitat. Based on a hypothetical footprint developed for BDCP, levee construction may result in the permanent removal of approximately 41 acres of riparian woodrat habitat along the lower San Joaquin River. Reclamation will ensure that riparian woodrat habitat permanently removed does not exceed the maximum allowable habitat loss for this species.

AMM-RBR-RWR requires avoidance of habitat occupied or assumed to be occupied by riparian woodrat.

5.23.2.2.1.1.2 Temporary Habitat Loss

Based on the hypothetical floodplain restoration footprint, the construction of setback levees to restore seasonally inundated floodplain is expected to temporarily remove up to 35 acres of suitable riparian woodrat habitat. Temporarily disturbed areas will be restored as riparian habitat within 1 year following completion of construction activities. Although the effects are considered temporary, several years (10 - 20) may be required for ecological succession to occur and for restored riparian habitat to functionally replace habitat that has been affected.

5.23.2.2.1.2 Periodic Inundation

Existing levees will be breached for floodplain restoration and the newly constructed setback levees will allow inundation through seasonal flooding. The potentially inundated areas may consist of suitable riparian woodrat habitat. Based on a hypothetical footprint of floodplain restoration used for BDCP, floodplain restoration will result in periodic inundation of approximately 200 acres of riparian woodrat habitat (Table 5-Terrestrial). The restored floodplain will include a range of elevations from low-lying areas that flood frequently (i.e., every 1 to 2 years) to high-elevation areas that flood infrequently (i.e., every 10 years or more). Seasonal flooding in restored floodplains can result in injury or mortality of individuals if riparian woodrats occupy these areas and cannot escape flood waters.

AMM-RBR/RWR requires avoidance of habitat occupied or assumed to be occupied by riparian woodrat. This includes avoiding flooding in areas known to be occupied by riparian woodrat. The adverse effects of periodic inundation on the riparian woodrat in suitable habitat that may become occupied in the future will be further minimized through construction and maintenance of flood refugia to allow riparian woodrats to escape flood conditions, with patches of riparian trees, as described in the Draft Habitat Assessment Guidelines & Survey Protocol for the Riparian Brush Rabbit and the Riparian Woodrat (USFWS, available at https://www.fws.gov/sacramento/es/Survey-Protocols-Guidelines/).

5.23.2.2.1.3 Construction-Related Effects

Construction-related effects on the riparian woodrat include construction-related injury or mortality and indirect noise and visual disturbance to habitat in the vicinity of construction. Effects on the species are described below for each effect category. Effects are described collectively for all covered activities, and are also described for specific covered activities to the extent that this information is pertinent for assessing the value of affected habitat or the specific nature of the effect.

5.23.2.2.1.3.1 Construction-Related Injury or Mortality

Reclamation will avoid disturbance of occupied riparian woodrat habitat and therefore will avoid construction-related injury or mortality of this species.

5.23.2.2.1.3.2 Construction-Related Effects on Adjacent Habitat

Construction of setback levees for floodplain restoration may result in noise and visual disturbance to the riparian woodrat. This effect will be avoided or minimized through establishment of nondisturbance buffers as described in AMM-RBR-RWR.

The use of mechanical equipment during construction might cause the accidental release of petroleum or other contaminants that will affect the riparian woodrat in adjacent habitat, if the species is present. The potential for this adverse effect will be avoided and minimized through best management practices (BMPs) under *AMM2 Construction Best Management Practices and Monitoring*.

5.23.2.2.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the lower San Joaquin watershed, differences between the proposed action and COS are almost nonexistent and have no potential to produce any change in quantity or quality of riparian woodrat habitat in the lower San Joaquin watershed. There is also no risk that these changes could result in harm to individual riparian woodrats. Conversely, differences between the proposed action and WOA are large, with much lower flows in February and May-June than WOA, and higher flows in the fall than WOA. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.3 Salt Marsh Harvest Mouse

The salt marsh harvest mouse occurs in Suisun Marsh, and the components of the proposed action that may affect this species are in the Bay-Delta watershed only.

5.23.3.1 Bay-Delta Watershed

Project components within the Bay-Delta watershed that could affect salt marsh harvest mouse are those occurring in Suisun Marsh. These include Suisun Marsh salinity control gates and Chipps Island restoration. Potential effects of each of these components on the salt marsh harvest mouse and the measures to avoid, minimize, or offset these effects are described below.

5.23.3.1.1 <u>Suisun Marsh Salinity Control Gates</u>

Under the proposed action the Suisun Marsh Salinity Control Gates (SMSCG) will be operated between June and October for no more than 60 days in wet, above-normal and below-normal Sacramento Valley Index year types. The gates would be operated to minimize seawater intrusion into Montezuma Slough and decrease salinities overall to expand the extent of suitable habitat for Delta smelt. Other than this proposed change in SMSCG operations, gate operations would be unchanged from current conditions and salinities will not be substantially changed.

UnTRIM modeling of the proposed operation of the SMSCG found salinity decreases up to 2 PSU in Montezuma Slough in August and September in dry and below-normal water years (GEI 2018). Because of the limited temporal scale of the proposed action (60 days), the limited temporal overlap between the proposed action and the typical flooding regime for diked wetlands, the variability of existing salinities as well as the variability created between years when the proposed action is implemented and years when it is not; the salinity variability in the winter and spring (when there are no effects from the proposed action but when diked wetland flooding occurs), and the requirements to maintain adherence with RWQCB water quality requirements, the effects from SMSCG operations are presumed insignificant to the vegetation community. Thus, effects on the salt marsh harvest mouse are also considered insignificant. That is, effects to the vegetation community as a result of reduced salinities by no more than 2% in above-normal and below normal water years are not expected to affect salt marsh harvest mouse habitat to the extent that take would occur.

5.23.3.1.1.1 Tidal Habitat Restoration

The USFWS, in their 2008 biological opinion, required Reclamation to “to create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh” to address adverse impacts on Delta smelt and its habitat. DWR has since been performing this action at a variety of restoration sites (Table 5.23-2). None of these projects has yet been certified by USFWS as meeting any portion of the 8,000 acre requirement, but the total acreage of the projects shown in Table 5-DSHR is 12,309 acres, and DWR staff, based on site-specific consultations with USFWS completed to date, consider it likely that completion of these restoration projects will provide mitigation acreages sufficient to fulfill the USFWS habitat creation requirement. As shown in Table 5.23-2, only a subset of these projects are included in the proposed action; the remainder have either completed ESA consultation and are being implemented pursuant to the terms and conditions of a project-specific biological opinion, or are being separately consulted under a lead agency other than Reclamation, and will be transferred to DWR ownership following completion of the restoration work.

Table 5.23-2. DWR Tidal Restoration Projects to secure Compliance with the 2008 USFWS Requirement for 8,000 Acres of Delta Smelt Habitat

Project	Status	Approx. Acres[d]	In Proposed Action
Decker Island	Done	140	No[a]
Lindsey Slough	Done	0	No[c]
Yolo Flyway Farms	Done	300	No[a]
Dutch Slough	In construction	660	Yes[f]
Tule Red	In construction	610	No[a]
Winter Island	2019 construction	553	Yes
Hill Slough	2019 construction	750	Yes[e]
Arnold Slough/Bradmoor Island	2019 construction	659	Yes
Chipps Island	2021 construction	807	Yes
Lookout Slough	2022 construction	3000	No[b]
Lower Yolo Ranch	Planning	1600	Yes
Prospect Island	2020 construction	1360	No[a]
Wings Landing	2020 construction	190	No[b]
Unnamed private project	2020 construction	1680	No[b]
TOTAL ACRES	--	12309	--
TOTAL ACRES UNDER proposed action	--	[waiting on Reclamation]	--

Sources for this table: EcoRestore fact sheets (DWR 2019), email from Gardner Jones (DWR), emails from Catherine McCalvin (DWR).

Notes

[a] A biological opinion has been issued for this project.

[b] This project is being undertaken by a private party, and lead agency is note Reclamation (DWR will assume ownership after site is constructed).

[c] Project presumably re ceived a biological opinion, but primarily restored freshwater and alkali wetlands, although it did include a tidal slough. Acreage of slough not stated in documentation at http://resources.ca.gov/docs/ecorestore/projects/Lindsey_Slough.pdf

[d] None of these projects have yet been certified by USFWS as counting towards the 8,000-acre requirement; acres shown are therefore approximate, representing a DWR estimate of what will be qualifying acreages.

[e] A biological assessment has been submitted but a biological opinion has not yet been received.

[f] Project is in construction, therefore ESA compliance is assumed, but not confirmed.

5.23.3.1.1.2 Habitat Conversion

The component projects and approach used in Tidal Habitat Restoration have been described previously. Tidal Habitat Restoration at sites named in Table 5.23-2 that are part of the proposed action could affect salt marsh harvest mouse via direct effects of construction, or through conversion of habitat, as described below. Take of salt marsh harvest mouse resulting from restoration at these sites will not be authorized through the biological opinion for this project, and will require separate consultation. Acreages of impact to modeled salt marsh harvest mouse habitat at these three sites are shown in Table 5.23-3. Models used to identify habitat for the salt marsh harvest mouse are described in the Draft BDCP (DWR and Reclamation 2013, Appendix 2.A).

Table 5.23-3. Expected Impacts on modeled Salt Marsh Harvest Mouse Habitat from Tidal Habitat Restoration

	Restoration Site (acres)			
Habitat Type	**Arnold Slough/ Bradmoor Island**	**Chipps Island**	**Hill Slough**	**Total**
Managed Wetland – Upland	3	0	15	18
Managed Wetland – Primary	68	41	98	207
Managed Wetland – Secondary	133	171	53	357
Tidal Brackish Emergent Wetland – Primary	25	123	524	672
Tidal Brackish Emergent Wetland – Secondary	26	307	14	346.49
Upland Secondary	24	0	141	165
TOTAL	276	642	830	1,748

The effects on habitat will include the conversion of primary mid- and high-marsh habitat types to secondary low-marsh types; the conversion of secondary, low-marsh habitat to subtidal habitat; and the conversion of upland refugia habitat to tidal habitat. While it is expected that primary and secondary salt marsh harvest mouse habitat will persist after restoration of tidal action, the extent of primary habitat types (mid- and high-marsh) is expected to decrease in the near-term. In the longer-term, and with the implementation of conservation measures , the extent of primary habitat is expected to expand. The extent of primary habitat may not expand to pre-restoration conditions, although the habitat will be more resilient to climate change because tidal habitat has potential to accrete sediment to keep up with sea level rise whereas diked wetlands do not. Sea level rise is one of the primary threats to the Suisun Marsh salt marsh harvest mouse (USFWS 2013b). Most occupied habitat in Suisun Marsh is diked and subsided and therefore vulnerable to catastrophic loss as a result of levee failure; and levees are more likely to fail as sea levels rise (USFWS 2013b). Consistent with the Suisun Marsh Plan Biological Opinion (USFWS 2013a), the creation of more resilient tidal wetland salt marsh harvest mouse habitat will compensate for the loss of diked wetland habitat.

5.23.3.1.1.3 Construction-Related Effects

Tidal Habitat Restoration may include excavation of levees, construction of tidal control gates, movement and staging of large construction equipment, piling and storage of soils, dredging, and filling and grading of vegetated areas. The operation of equipment for construction could result in injury or mortality of salt marsh harvest mice, if present. Only nonmechanized equipment will be used to remove vegetation in salt marsh harvest mouse habitat. Restrictions on the use of mechanized equipment, biological construction monitoring, and other measures will be implemented to ensure that salt marsh harvest mice occupying the construction area will be able to leave and escape to suitable adjacent habitat. Any vegetation removed will be done under supervision of a CDFW- and USFWS-approved biological monitor familiar with salt marsh harvest mouse. Temporary exclusion fences will be installed to ensure that mice do not reenter work areas during construction.

5.23.3.1.2 <u>Proposed Flow Changes</u>

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Bay-Delta watershed, the methodology must be altered somewhat to reflect the complex effects of flow manipulation in the Delta and Suisun Marsh. In Suisun Marsh, the proposed action would maintain conditions similar to current, while under the WOA scenario DWR would cease operations of the Suisun Marsh Salinity Control Gates. The proposed action maintains a more constant salinity regime within the Marsh than would exist under WOA. Changes under the PA scenario would be negligible relative to COS, with little potential for the PA to modify habitat or otherwise harm the salt marsh harvest mouse.

In the Bay and in the lower Delta (the only portion of the Delta occupied by salt marsh harvest mouse), differences between proposed action and COS are negligible, on the order of a few percent change in flows at various times of the year. Changes at this scale are unlikely to produce any measurable change in quantity or quality of salt marsh harvest mouse habitat in the Delta, and there is no apparent mechanism by which these changes could result in harm to individual salt marsh harvest mice. Conversely, differences between the proposed action and WOA are large, with decreased flows in all months except September, and January through March flows under WOA exceeding flows in any month under PA or COS. The flow increases under WOA could result in flooding and erosion at any restoration sites or residual habitat for salt marsh harvest mice in the Bay-Delta, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action would provide benefits as compared to the Without Action by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.4 California Ridgway's Rail

The components of the proposed action that may affect this species are only in the Bay-Delta watershed.

5.23.4.1 Bay-Delta Watershed

Project components within the Bay-Delta watershed that could affect California Ridgway's rail are those occurring in Suisun Marsh. These include Suisun Marsh salinity control gates, and potentially tidal restoration. Potential effects of each of these components on California Ridgway's rail and the measures to avoid, minimize, or offset these effects are described below.

5.23.4.1.1 Suisun Marsh Salinity Control Gates

As described above for salt marsh harvest mouse, SMSCG operation is not expected to modify the vegetation communities in Suisun Marsh, therefore this project component is not expected to adversely affect California Ridgway's rail habitat to the extent that take would occur.

5.23.4.1.2 Tidal Habitat Restoration

The component projects and approach have been described previously. The sites named in Table 5.23-2 that are part of the proposed action are outside the range of California Ridgeway's rail, but it is near the range boundary for the species. Delta Smelt habitat could provide habitat where the species' range could expand, which would be a beneficial effect.

5.23.4.1.3 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Bay-Delta watershed, the methodology must be altered somewhat to reflect the complex effects of flow manipulation in the Delta and Suisun Marsh. In Suisun Marsh, the WOA scenario would cease operations of the Suisun Marsh Salinity Control Gates. This would lead to a more varied salinity regime within the Marsh, resulting in changes in marsh vegetation that would persist until the vegetation adapted to the new salinity and flow regime. This would likely render some areas of Ridgway's rail habitat unsuitable, while creating new areas of suitable habitat. To the extent that the Ridgway's rail could not migrate to accommodate these habitat changes, or was adversely affected by short-term losses in suitable habitat, mortality would result. Conversely, as described above in Section 5.24.3.1.1 *Suisun Marsh Salinity Control Gates*, changes under the PA scenario would be negligible relative to COS, with little potential for the PA to modify habitat or otherwise harm the Ridgway's rail.

In the Bay, differences between the proposed action and COS are negligible, on the order of a few percent change in flows at various times of the year. Changes at this sale are unlikely to produce any measurable change in quantity or quality of Ridgway's rail habitat in the Bay, and there is no apparent mechanism by which these changes could result in harm to individual Ridgway's rail. Conversely, differences between WOA and the PA are large, with increased flows in all months except September, and January through March exceeding flows in any month under PA or COS. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for Ridgway's rail in the Bay, resulting in degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.5 Least Bell's Vireo

Watersheds with project components that may affect suitable least Bell's vireo habitat within the species' range include Upper Sacramento River watershed, Stanislaus River watershed, Lower San Joaquin River watershed, as well as Delta watershed with migratory stopover habitat. Applicable components are described below for each watershed.

5.23.5.1 Upper Sacramento River Watershed

The only Upper Sacramento River Watershed project components within the range of least Bell's vireo that may affect the species are *Colusa Basin Drain.* Effects of these components on least Bell's vireo are described below.

5.23.5.1.1 Colusa Basin Drain Food Web Routing

High water levels (flows of 200 to 500 cfs) are proposed to pass through the Yolo Bypass which is in a disjunct portion of the current range for this species. The proposed flows will not exceed local flooding levels. Flows are proposed in July, August and/or September for approximately 4 weeks, which would coincide with June through mid-September nesting although no adverse effects to individuals or habitat are anticipated.

5.23.5.1.2 Proposed flow changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the upper Sacramento watershed, differences between the proposed action and COS are negligible, on the order of a few percent decrease in flow in November and a few percent increase in May and June. These changes are unlikely to produce any measurable change in quantity or quality of least Bell's vireo habitat in the upper Sacramento watershed, and there is no apparent mechanism by which these changes could result in harm to individual least Bell's vireos. Conversely, differences between the proposed action and WOA are large, with flows in February and March in WOA exceeding flows in any month under PA or COS, and very low flows in WOA from July to September, which could very likely cause drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for least Bell's vireos in the upper Sacramento watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.5.2 Stanislaus River Watershed

Stanislaus River Watershed project components within the small disjunct mapped range of least Bell's vireo include Spawning and Rearing Habitat Named Projects, Spawning Habitat Restoration and Rearing Habitat Restoration. Although no current occurrences of this species are known in the watershed the effects of these components on least Bell's vireo are described below.

5.23.5.2.1 Spawning and Rearing Habitat

Gravel will be placed in-stream, therefore will not result in loss or disturbance of least Bell's vireo habitat. Access to the enhancement site by vehicles, workers, and equipment may, however, disturb habitat or disrupt normal behavioral patterns of least Bell's vireo in the vicinity of the activity, in the absence of project component specific avoidance and minimization measures. Reclamation will implement AMM-LBV to completely avoid adverse effects on least Bell's vireo from spawning and rearing habitat restoration. Rearing habitat creation will be outside the range of least Bell's vireo.

5.23.5.2.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Stanislaus watershed, differences between proposed action and COS are negligible, on the order of a few percent increase in flow in February and a few percent decrease in May and June. These changes are unlikely to produce any measurable change in quantity or quality of least Bell's vireo habitat in the Stanislaus watershed, and there is no apparent mechanism by which these changes could result in harm to individual least Bell's vireos. Conversely, differences between the proposed action and WOA are large, with flows in Februrary, March, June and July under WOA exceeding flows in any month under PA or COS, and very low flows from August to October, potentially causing drought stress in riparian or wetland vegetation. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for least Bell's vireo in the Stanislaus watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.5.3 Lower San Joaquin River Watershed

Lower San Joaquin River Watershed project components within the small disjunct mapped range of least Bell's vireo include Lower San Joaquin Spawning and Rearing Habitat. Effects of this component on least Bell's vireo are described below.

5.23.5.3.1 Lower San Joaquin Spawning and Rearing Habitat

5.23.5.3.1.1 Habitat Loss or Conversion

Levee construction could result in removal or conversion of least Bell's vireo habitat. Based on a hypothetical footprint developed for BDCP, levee construction may result in the permanent removal of approximately 28 acres of least Bell's vireo habitat along the lower San Joaquin River. Although habitat consists primarily of small patches, these patches are in proximity to other habitat along the San Joaquin River. Although much of this component would occur north of San Joaquin River portion of mapped range of least Bell's vireo, the southern extent could be as close as 5 miles from least Bell's vireo breeding occurrences from 2005-2007. Reclamation will ensure that least Bell's vireo habitat permanently removed does not exceed the maximum allowable habitat loss for this species.

Under AMM-LBV, injury or mortality to nesting least Bell's vireos will be avoided through preconstruction surveys and establishment of 500-foot no-disturbance buffers around active nests.

5.23.5.3.1.2 Construction-Related Effects

Although least Bell's vireo nesting has not been observed in recent years in the disjunct San Joaquin River portion of mapped range, occurrences suggest that the reestablishment of a breeding population is a possibility in this area. If the least Bell's vireo nests where covered activities are to occur, equipment operation for construction activities could result in injury or mortality of individuals. Risk will be greatest to eggs and nestlings that could be injured or killed through crushing by heavy equipment, nest abandonment, or increased exposure to the elements or to predators. Injury to adults and fledged juveniles is unlikely, as these individuals are expected to avoid contact with construction equipment. Under AMM-LBV, injury or mortality to nesting least Bell's vireos will be avoided through preconstruction surveys and establishment of 500-foot no-disturbance buffers around active nests, as described in AMM-LBV. Construction activities may create noise up to 60 dBA at no more than 1,200 feet from the edge of the noise generating activity. While 60 dBA is the standard noise threshold for birds (Dooling and Popper 2007), this standard is generally applied during the nesting season, when birds are more vulnerable to behavioral modifications that can cause nest failure. There is evidence, however, that migrating birds will avoid noisy areas during migration (McClure et al. 2013). To minimize this effect, BOR will reduce noise in the vicinity of least Bell's vireo habitat as described in AMM-LBV. This will include surveying for least Bell's vireos within the 60 dBA noise contour around the construction footprint, and if a least Bell's vireo is found, limiting noise to less than 60 dBA where the bird occurs until it has left the area.

Night lighting may also have the potential to affect least Bell's vireos. While there is no data on effects of night lighting on this species, studies show that other bird species are attracted to artificial lights and this may disrupt their behavioral patterns or cause collision-related fatalities (Gauthreaux and Belser 2006). To minimize this effect, BOR will screen all lights and direct them away from habitat as described in AMM-LBV. With this measure in effect, and given that least Bell's vireos are expected to occur in the vicinity of project activities seldom if at all, residual lighting effects on the species are expected to be negligible and is not expected to result in take of the species.

5.23.5.3.1.3 Inundation

Based on the hypothetical floodplain restoration footprint, the construction of setback levees to restore seasonally inundated floodplain is expected to inundate an estimated 148 acres of least Bell's vireo habitat. The floodplains will transition from areas that flood frequently (i.e., every 1 to 2 years) to areas that flood infrequently (i.e., every 10 years or more). Periodic inundation as a result of floodplain restoration is not expected to adversely affect the least Bell's vireo because flooding is unlikely to occur during the breeding season when the vireo could be present, and the potential effects of inundation on existing riparian vegetation are expected to be minimal. While frequent flooding in the lower elevation portions of the floodplain may result in scouring of riparian vegetation, this is expected to have a beneficial rather than an adverse effect on the species.

5.23.5.3.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the lower San Joaquin watershed, differences between the proposed action and COS are almost nonexistent and have no potential to produce any change in quantity or quality of least Bell's vireo habitat in the lower San Joaquin watershed. There is also no risk that these changes could result in harm to individual least Bell's vireos. Conversely, differences between proposed action and WOA are large, with flows in February and May-June under WOA that exceed flows in any month under PA or COS. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for least Bell's vireo in the lower San Joaquin watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.6 Western Yellow-Billed Cuckoo

Western yellow-billed cuckoo surveys, monitoring, and adaptive management conducted in accordance with Chapter 4, Section 4.10.1.5.2, *Conservation Measures*, will ensure project effects do not exceed those analyzed in this biological assessment and the programmatic biological opinion.

5.23.6.1 Upper Sacramento River Watershed

Upper Sacramento River Watershed project components within the mapped range of western yellow-billed cuckoo include Spawning and Rearing Named Projects and Colusa Basin Drain Food Web Routing. Implementation of AMM24 will result in minimization and avoidance of effects on western yellow-billed cuckoo. Effects from the project components are described below.

5.23.6.1.1 Spawning and Rearing Named Projects

5.23.6.1.1.1 Permanent Habitat Loss or Conversion

Creation of side channels will require removal of riparian habitat within the range of western yellow-billed cuckoo. The majority of the proposed projects are north of Red Bluff, California, where no occurrences of this species have been reported. However, the southernmost two proposed projects (La Barranca and Woodson Bridge Bank Rearing Improvement) are south of Red Bluff and overlap with a 2013 occurrence and 1988 occurrence, respectively. Although Reclamation will minimize removal of riparian habitat to the extent feasible through implementation of AMM22, up to 58 acres of western yellow-billed cuckoo habitat may be removed.

5.23.6.1.1.2 Construction-Related Effects

Although the majority of sites are far from known western yellow-billed cuckoo occurrences, the recent observation identified above suggest that western yellow-billed cuckoos may nest in the area. If the western yellow-billed cuckoo nests where covered activities are to occur, equipment operation for construction activities could result in injury or mortality of individuals. Risk will be greatest to eggs and nestlings that could be injured or killed through crushing by heavy equipment, nest abandonment, or increased exposure to the elements or to predators. Injury to adults and fledged juveniles is unlikely, as these individuals are expected to avoid contact with construction equipment. Under AMM-WYBC, injury or mortality to nesting western yellow-billed cuckoos will be avoided through preconstruction surveys and establishment of a 500-foot no-disturbance buffers around active nests, as described in AMM-WYBC. Construction activities may create noise up to 60 dBA at no more than 1,200 feet from the edge of the noise generating activity. While 60 dBA is the standard noise threshold for birds (Dooling and Popper 2007), this standard is generally applied during the nesting season, when birds are more vulnerable to behavioral modifications that can cause nest failure. There is evidence, however, that migrating birds will avoid noisy areas during migration (McClure et al. 2013). To minimize this effect, Reclamation will reduce noise in the vicinity of western yellow-billed cuckoo habitat as described in AMM-WYBC. This will include surveying for western yellow-billed cuckoos within the 60 dBA noise contour around the construction footprint, and if a western yellow-billed cuckoo is found, limiting noise to less than 60 dBA where the bird occurs until it has left the area.

Night lighting may also have the potential to affect western yellow-billed cuckoos. While there is no data on effects of night lighting on this species, studies show that other bird species are attracted to artificial lights and this may disrupt their behavioral patterns or cause collision-related fatalities (Gauthreaux and Belser 2006). To minimize this effect, Reclamation will screen all lights and direct them away from habitat as described in AMM-WYBC. With this measure in effect, and given that western yellow-billed cuckoos are expected to occur in the vicinity of project activities seldom if at all, residual lighting effects on the species are expected to be negligible and is not expected to result in take of the species.

5.23.6.1.1.3 Colusa Basin Drain Food Web Routing

5.23.6.1.1.3.1 Inundation Effects

High water levels (flows of 200 to 500 cfs) are proposed to pass through the Yolo Bypass which includes a disjunct portion of the current range for this species. The proposed flows will not exceed local flooding levels and are unlikely to reach 3 feet above the ground where effects on cuckoo are possible. Flows are proposed in July, August and/or September for approximately 4 weeks, which would coincide with June through mid-September nesting although no adverse effects to individuals or habitat are anticipated.

5.23.6.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the upper Sacramento watershed, differences between the proposed action and COS are negligible, on the order of a few percent decrease in flow in November and a few percent increase in May and June. These changes are unlikely to produce any measurable change in quantity or quality of western yellow-billed cuckoo habitat in the upper Sacramento watershed, and there is no apparent mechanism by which these changes could result in harm to individual western yellow-billed cuckoos. Conversely, differences between the proposed action and WOA are large, with flows in February and March under WOA exceeding flows in any month under PA or COS, and very low flows from July to September in WOA, which could very likely cause drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for western yellow-billed cuckoos in the upper Sacramento watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, as it has higher flows in the fall and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.6.3 American River Watershed

Project components in the American River Watershed that may affect western yellow-billed cuckoo include Spawning and Rearing Habitat Restoration . Nimbus Hatchery Physical and Operational Improvements will avoid disturbance of western yellow-billed cuckoo habitat as described in AMM-WYBCC.

5.23.6.3.1 Spawning and Rearing Habitat

5.23.6.3.1.1 Permanent Habitat Loss or Conversion

Creation of spawning habitat will avoid disturbance of western yellow-billed cuckoo habitat, consistent with AMM-WYBC. Creation of side channels will require removal of riparian habitat within the range of western yellow-billed cuckoo. Although Reclamation will minimize removal of riparian habitat to the extent feasible through implementation of AMM-WBYC, up to four acres of riparian habitat may be removed.

5.23.6.3.1.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the American River watershed, differences between the proposed action and COS are negligible, on the order of a few percent decrease in flow in December, February and March, a few percent increase in July and September. These changes are unlikely to produce any measurable change in quantity or quality of western yellow-billed cuckoo habitat in the American River watershed, and there is no apparent mechanism by which these changes could result in harm to individual western yellow-billed cuckoos. Conversely, differences between the proposed action and WOA are large, with flows in February, March, and April under WOA exceeding flows in any month under PA or COS, and very low flows from July to October under WOA, potentially causing drought stress in riparian or wetland vegetation. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for western yellow-billed cuckoos in the American River watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, as it has higher flows in the fall and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.6.4 Stanislaus River Watershed

5.23.6.4.1 <u>Spawning and Rearing Habitat Named Projects</u>

Creation of spawning habitat will avoid disturbance of western yellow-billed cuckoo habitat, consistent with AMM-WYBC. Creation of side channels will require removal of riparian habitat within the range of western yellow-billed cuckoo. Although Reclamation will minimize removal of riparian habitat to the extent feasible through implementation of AMM-WYBC, up to 43 acres of riparian habitat may be removed.

5.23.6.4.2 <u>Proposed flow changes</u>

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Stanislaus watershed, differences between proposed action and COS are negligible, on the order of a few percent decrease in flow in February and a few percent increase in May and June. These changes are unlikely to produce any measurable change in quantity or quality of western yellow-billed cuckoo habitat in the Stanislaus watershed, and there is no apparent mechanism by which these changes could result in harm to individual western yellow-billed cuckoos. Conversely, differences between the proposed action and WOA are large, with flows in February, March, June and July under WOA exceeding flows in any month under PA or COS, and very low flows from August to October in WOA, potentially causing drought stress in riparian or wetland vegetation. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for western yellow-billed cuckoo in the Stanislaus watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, as it has higher flows in the fall and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.6.5 Lower San Joaquin River Watershed

Lower San Joaquin River Watershed project components within the range of western yellow-billed cuckoo include Lower San Joaquin Spawning and Rearing Habitat . Effects of this component on western yellow-billed cuckoo are described below.

5.23.6.5.1 Lower San Joaquin Spawning and Rearing Habitat

5.23.6.5.1.1 Habitat Loss or Conversion

Levee construction associated with floodplain restoration will result in the permanent removal of up to an estimated 11 acres of western yellow-billed cuckoo habitat. This habitat is of moderate value: although it consists primarily of small patches, these patches are in proximity to other habitat along the San Joaquin River, and some of the patches are adjacent to existing conservation lands. Because the estimates of habitat loss resulting from floodplain restoration are based on projections of where restoration may occur, actual habitat loss is expected to be lower because sites will be selected to minimize effects on western yellow-billed cuckoo habitat.

5.23.6.5.1.1.1 Construction-Related Effects

If the western yellow-billed cuckoo nests where covered activities are to occur, equipment operation for construction activities could result in injury or mortality of individuals. Risk will be greatest to eggs and nestlings that could be injured or killed through crushing by heavy equipment, nest abandonment, or increased exposure to the elements or to predators. Injury to adults and fledged juveniles is unlikely, as these individuals are expected to avoid contact with construction equipment. Under AMM-WYBC, injury or mortality to nesting western yellow-billed cuckoos will be avoided.

5.23.6.5.1.2 Inundation

Based on a hypothetical floodplain restoration, this activity will periodically inundate an estimated 70 acres of habitat for the western yellow-billed cuckoo. The floodplains will transition from areas that flood frequently (i.e., every 1 to 2 years) to areas that flood infrequently (i.e., every 10 years or more). Periodic inundation as a result of Yolo Bypass operations and floodplain restoration is not expected to adversely affect the yellow-billed cuckoo because flooding is unlikely to occur during the breeding season when the cuckoo could be present, and the potential effects of inundation on existing riparian vegetation are expected to be minimal. While frequent flooding in the lower elevation portions of the floodplain may result in scouring of riparian vegetation, this is expected to have a beneficial rather than an adverse effect on the species.

5.23.6.5.2 Proposed Flow Changes

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the lower San Joaquin watershed, differences between the proposed action and COS are almost nonexistent and have no potential to produce any change in quantity or quality of western yellow-billed cuckoo habitat in the lower San Joaquin watershed. There is also no risk that these changes could result in harm to individual western yellow-billed cuckoos. Conversely, differences between the proposed action and WOA are large, with flows in February and May-June under WOA that exceed flows in any month under PA or COS. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for western yellow-billed cuckoo in the lower San Joaquin watershed, resulting in degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, as it has lower flows in the spring and maintains current general flow regimes.

5.23.7 Giant Garter Snake

Based on the 2017 Recovery Plan (USFWS 2017) the current range of the giant garter snake encompasses nine separate populations associated with distinct watershed basins. Known giant garter snake populations and corresponding recovery units that overlap with proposed action components include the Butte Basin, Sutter Basin, Colusa Basin, Yolo Basin, and Delta Basin populations. Components of the proposed action that may affect this species are in the Upper Sacramento River watershed and the Bay-Delta watershed only.

5.23.7.1 Upper Sacramento River Watershed

Upper Sacramento River Watershed project components within the range of giant garter snake include Spawning and Rearing Named Projects, Colusa Basin Drain Food Web Routing. Projects within Sacramento River and on its banks, however, are not expected to affect giant garter snake habitat. This species does not typically occupy large rivers. Therefore, project components described below do not include Spawning and Rearing Named Projects or Sacramento Weir, as these components occur along the Sacramento River.

Effects from each of these components are described below.

5.23.7.1.1 <u>Colusa Basin Drain Food Web Routing</u>

5.23.7.1.1.1 Permanent Habitat Loss or Conversion

The diversion of approximately 24,000 AF of agricultural water over a 4-week period (during July, August, and/or September) from Colusa Basin into Yolo Bypass rather than outfalling into the Sacramento River would not result in adverse effects on giant garter snake because the Sacramento River does not support suitable aquatic habitat for this species. Increasing flows into the Yolo Bypass during late summer would be expected to increase surface water and improve habitat conditions for giant garter snake in the Yolo Bypass. Therefore, Food Web Routing would have a beneficial effect on giant garter snake.

5.23.7.1.2 <u>Proposed flow changes</u>

See the discussion of flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the upper Sacramento watershed, differences between the proposed action and COS are negligible, on the order of a few percent increase in flow in November and a few percent decrease in May and June. These changes are unlikely to produce any measurable change in quantity or quality of giant garter snake habitat in the upper Sacramento watershed, and there is no apparent mechanism by which these changes could result in harm to individual giant garter snakes. Conversely, differences between WOA and the PA are large, with flows in February and March exceeding flows in any month under PA or COS, and very low flows from July to September, which could very likely cause drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for giant garter snakes in the upper Sacramento watershed, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action does not have these impacts, as it has higher flows in the fall and maintains current vegetation. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.7.2 Bay-Delta Watershed

5.23.7.2.1 Delta Cross Channel Improvements

Delta Cross Channel Improvements involves modernizing Delta Cross Channel gates. Potentially suitable giant garter snake habitat is present in the vicinity of these gates. Assuming disturbance will occur within a 25-foot radius around the existing gates, Delta Cross Channel Improvements could result in loss of up to 0.2 acre of upland and .4 acre of aquatic habitat for giant garter snake.

5.23.7.2.2 Tidal Habitat Restoration

5.23.7.2.2.1 Habitat Conversion

The component projects and approach were described previously. Habitat Restoration at two of the sites named in Table 5-.23-2 that are part of the proposed action could affect giant garter snake via direct effects of construction, or through conversion of habitat, as described below. Take of giant garter snake resulting from restoration at these sites will not be authorized through the biological opinion for this project, and will require separate consultation. Acreages of impact to modeled giant garter snake habitat at these three sites are shown in Table 5-5.23-4. Models used to identify habitat for the giant garter snake are described in the Draft BDCP (DWR and Reclamation 2013, Appendix 2.A).

Table 5.23-4. Expected Impacts on Modeled Giant Garter Snake Habitat from Tidal Habitat Restoration

	Restoration Site (acres)		
Habitat Type	**Dutch Slough**	**Lower Yolo Ranch**	**Total**
Aquatic – Nontidal	37	8	45
Aquatic – Tidal	17	45	62
Upland	279	368	647
TOTAL	333	421	754

Tidal Habitat Restoration at each site would be achieved by conversion of currently leveed, cultivated land through breaching or setback of levees, thereby restoring tidal fluctuation to land parcels currently isolated behind those levees. Where appropriate, portions of restoration sites will be raised to elevations that will support tidal marsh vegetation following levee breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation. Surface grading will create a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces.

Permanent effects on giant garter snake aquatic habitat are likely to occur when agricultural ditches are modified and flooded as part of the tidal habitat restoration process, or as part of the channel margin restoration process in projects that entail levee setback. The conversion of rice to tidal habitat would be a permanent loss, however, rice is not common in the areas where tidal restoration and channel margin restoration would likely be sited. Other aquatic features that have potential to occur on restoration sites include natural channels and topographic depressions. Tidal aquatic edge habitat where open water meets the levee edge will also be permanently lost in those reaches where the levee is breached. Temporary effects on aquatic edge habitat are also likely to occur during the time of construction, though these effects would not be expected to last more than 2 years. Permanent effects on upland habitat will primarily occur where upland habitat is removed to create tidal connectivity.

5.23.7.2.2.2 Construction Related Effects

The operation of equipment for land clearing and restoration could result in injury or mortality of giant garter snakes. This risk is highest from late fall through early spring, when the snakes are dormant. Increased vehicular traffic associated with construction activities could contribute to a higher incidence of road kill. However, construction monitoring and other measures will be implemented to avoid and minimize injury or mortality of this species during construction, as described in AMM-GSS. Noise and visual disturbance outside the project footprint but within 200 feet of construction activities could temporarily affect the use adjacent habitat. These effects will be minimized by siting construction 200 feet away from the banks of giant garter snake aquatic habitat, where feasible, as described in AMM-GSS.

5.23.7.2.3 Proposed Flow Changes

See Section 5.24.1.1.3.1 *General Discussion of Flow Change Effects* for a statement of the methods and approach used to assess proposed flow change effects on covered species. In the Bay-Delta watershed, the methodology must be altered somewhat to reflect the complex effects of flow manipulation in the Delta and Suisun Marsh. In Suisun Marsh, the WOA scenario would cease operations of the Suisun Marsh Salinity Control Gates. This would lead to a more varied salinity regime within the Marsh, resulting in changes in marsh vegetation that would persist until the vegetation adapted to the new salinity and flow regime. This would likely render some areas of giant garter snake habitat unsuitable, while creating new areas of suitable habitat. To the extent that the giant garter snake could not migrate to accommodate these habitat changes, or was adversely affected by short-term losses in suitable habitat, mortality would result, possibly with long-term effects on genetic diversity and population structure. Conversely, as described previously, changes under the proposed action scenario would be negligible relative to COS, with little potential for the proposed action to modify habitat or otherwise harm the giant garter snake.

In the Delta, differences between COS and the proposed action are negligible, on the order of a few percent change in flows at various times of the year. Changes at this sale are unlikely to produce any measurable change in quantity or quality of giant garter snake habitat in the Delta, and there is no apparent mechanism by which these changes could result in harm to individual giant garter snake . Conversely, differences between WOA and the PA are large, with increased flows in all months except September, and January through March exceeding flows in any month under the proposed action or COS. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for giant garter snakes in the Delta, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.8 Valley Elderberry Longhorn Beetle

5.23.8.1 Upper Sacramento River Watershed

All Upper Sacramento River watershed project components that result in habitat disturbance are within the range of valley elderberry longhorn beetle. Effects of the remaining components are described for each relevant component below.

5.23.8.1.1 <u>Colusa Basin Drain Food Web Routing</u>

High water levels (flows of 200 to 500 cubic cfs) are proposed to pass through the Yolo Bypass which is in a disjunct portion of the current range for this species. The proposed flows will not exceed local flooding levels. Flows are proposed in July, August and/or September for approximately 4 weeks, which would potentially adversely affect valley elderberry shrubs, although the extent to which these effects might occur is uncertain.

5.23.8.1.1.1 Spawning and Rearing Habitat Restoration

5.23.8.1.1.1.1 <u>Permanent Habitat Loss or Conversion</u>

During placement of gravel and other measures to enhance spawning habitat, Reclamation will avoid disturbance of elderberry shrubs consistent with AMM-VELB. Creation of side channels will require removal of riparian habitat within the range of valley elderberry longhorn beetle, and although Reclamation will minimize disturbance associated with this activity, they may remove up to an estimated 58 acres of riparian habitat that could include elderberry shrubs supporting valley elderberry longhorn beetle. Assuming an estimated average of 0.9 shrubs per acre (from BDCP, Appendix 6B), rearing habitat restoration could result in removal of up to 52 elderberry shrubs. Reclamation will offset adverse effects on elderberry shrubs through transplantation of affected shrubs and planting of new shrubs and associated riparian vegetation consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017).

5.23.8.1.1.1.2 <u>Construction-Related Effects</u>

Habitat restoration may include use of heavy equipment for ground clearing, grading, excavation, and placement of gravel or habitat structures. Construction related actions could injure or kill valley elderberry longhorn beetles if individuals are present in shrubs to be transplanted, but the potential for this effect will be minimized as described AMM-VELB.

The operation of equipment during construction in the vicinity of occupied elderberry shrubs could also result in injury or mortality of valley elderberry longhorn beetles if they are actively dispersing between shrubs, which is generally between March 15th to June 15th; or if occupied shrubs are inadvertently damaged by construction activities. These effects will be avoided and minimized as described in AMM-VELB.

Temporary construction-related ground disturbances could generate dust that could adversely affect adjacent valley elderberry longhorn beetle habitat. Dust is listed in the valley elderberry longhorn beetle recovery plan as a threat to the species (U.S. Fish and Wildlife Service 1984). However, one study indicated that dust deposition was not correlated with valley elderberry longhorn beetle presence (Talley et al. 2006), although dust was weakly correlated with elderberry stress symptoms (water stress, dead stems, smaller leaves). During times of drought, when elderberry shrubs are under stress, dust deposition could further stress the shrubs, potentially leading to their death. Such a loss of shrubs could adversely affect valley elderberry longhorn beetle (Talley and Hollyoak 2009). The potential effects of dust on valley elderberry longhorn beetle will be minimized by applying water during construction activities or by presoaking work areas that will occur within 100 feet of any potential elderberry shrub habitat.

Exhaust from construction and maintenance vehicles may result in deposition of particulates, heavy metals, and mineral nutrients that could influence the quality and quantity of elderberry shrubs and thereby affect beetle presence and abundance. The results of a study by Talley and Hollyoak (2009) showed no relationship, however, between the distance of the shrubs from highways and the presence or abundance of the beetle.

Temporary lighting from construction activities could adversely affect valley elderberry longhorn beetle. The effects of lighting on valley elderberry longhorn beetle are unknown, although insects are known to be subject to heavy predation when they are attracted to night lighting (Eisenbeis 2006). No restoration activity will occur during nighttime hours in the vicinity of habitat for federally listed species.

5.23.8.2 Proposed flow changes

See the previous discussion regarding flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. Differences between the proposed action and COS are negligible, on the order of a few percent decrease in flow in November and a few percent increase in May and June. These changes are unlikely to produce any measurable change in quantity or quality of valley elderberry longhorn beetle habitat in the upper Sacramento watershed, and there is no apparent mechanism by which these changes could result in harm to individual valley elderberry longhorn beetles. Conversely, differences between WOA and the PA are large, with flows in spring exceeding flows under PA or COS, and very low flows in the summer, which could very likely cause drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability. The flow increases could result in flooding and erosion at any restoration sites or residual habitat for valley elderberry longhorn beetles, resulting in a substantial degradation in quality and possible loss of existing habitat, with potential for mortality of individual animals in response to flooding or loss of foraging resources. The proposed action would provide benefits as compared to the Without Action by increasing fall flows, avoiding drought stress in riparian or wetland vegetation that depended upon flow to maintain soil water availability, and by keeping more constant spring flows, avoiding erosion at restoration sites.

5.23.8.3 American River Watershed

All American River watershed project components that result in habitat disturbance are within the range of valley elderberry longhorn beetle. Effects from other components are described below.

5.23.8.3.1 Spawning and Rearing Habitat Restoration

5.23.8.3.1.1 Permanent Habitat Loss or Conversion

Creation of spawning habitat will avoid disturbance of valley elderberry longhorn beetle habitat, consistent with AMM-VELB. Creation of side channels will require removal of riparian habitat within the range of valley elderberry longhorn beetle. Although Reclamation will minimize removal of riparian habitat to the extent feasible through implementation of AMM-VELB, up to four acres of riparian habitat may be removed (approximately 3 to 4 elderberry shrubs). Reclamation will offset adverse effects on elderberry shrubs through transplantation of affected shrubs and planting of new shrubs and associated riparian vegetation consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017), or through mitigation.

5.23.8.3.1.2 Construction-Related Effects

Construction-related effects associated with Spawning and Rearing Named Projects in the American River Watershed are as described above for Spawning and Rearing Named Projects in the Upper Sacramento River Watershed.

5.23.8.4 Stanislaus River Watershed

5.23.8.4.1 Spawning and Rearing Habitat Named Projects

5.23.8.4.1.1 Permanent Habitat Loss or Conversion

Creation of spawning habitat will avoid disturbance of valley elderberry longhorn beetle habitat, consistent with AMM-VELB. Creation of side channels will require removal of riparian habitat within the range of valley elderberry longhorn beetle. Although Reclamation will minimize removal of riparian habitat to the extent feasible through implementation of AMM-VELB, up to 43 acres of riparian habitat may be removed. Reclamation will offset adverse effects on elderberry shrubs through transplantation of affected shrubs and planting of new shrubs and associated riparian vegetation, consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017), or through mitigation.

5.23.8.4.1.2 Construction-Related Effects

Construction-related effects associated with Spawning and Rearing Named Projects in the Stanislaus River Watershed are as described above for Spawning and Rearing Named Projects in the Upper Sacramento River Watershed.

5.23.8.5 Lower San Joaquin River Watershed

Lower San Joaquin River Watershed project components within the range of valley elderberry longhorn beetle include Lower San Joaquin Spawning and Rearing Habitat Restoration. Effects of this component on valley elderberry longhorn beetle are described below.

5.23.8.5.1 Lower San Joaquin Spawning and Rearing Habitat

5.23.8.5.1.1 Habitat Loss or Conversion

Levee construction associated with floodplain restoration will result in the permanent removal of up to an estimated 52 acres of valley elderberry longhorn beetle habitat (an estimated 47 shrubs). Reclamation will offset adverse effects on elderberry shrubs through transplantation of affected shrubs and planting of new shrubs and associated riparian vegetation consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017).

5.23.8.5.1.2 Construction-Related Effects

Construction-related effects associated with *Lower San Joaquin Rearing Habitat Restoration* are as described above for *Spawning and Rearing Habitat Restoration* in the Upper Sacramento River Watershed.

5.23.8.5.1.3 Inundation

Based on a hypothetical floodplain restoration, this activity will periodically inundate an estimated 226 acres of riparian habitat for the valley elderberry longhorn beetle. The area to be inundated will transition from areas that flood frequently (i.e., every 1 to 2 years) to areas that flood infrequently (i.e., every 10 years or more). While elderberry shrubs are not expected to be sustained in the lower elevation areas that frequently flood, the higher floodplain is expected to remain as high-value habitat for the species.

5.23.8.6 Bay-Delta Watershed

5.23.8.6.1 Tidal Habitat Restoration

5.23.8.6.1.1 Habitat Conversion

The component projects and approach used in Tidal Habitat Restoration have been described previously. Tidal Habitat Restoration at four of the sites named in Table 5.23-2 that are part of the proposed action could affect Valley elderberry longhorn beetle via direct effects of construction, or through conversion of habitat, as described below. Take of Valley elderberry longhorn beetle resulting from restoration at these sites will not be authorized through the biological opinion for this project, and will require separate consultation. Acreages of impact to modeled Valley elderberry longhorn beetle habitat at these three sites are shown in Table 5.23-5. Models used to identify habitat for the valley elderberry longhorn beetle are described in the Draft BDCP (DWR and Reclamation 2013, Appendix 2.A).

Table 5.23-5. Expected Impacts on Modeled Valley Elderberry Longhorn Beetle Habitat from Tidal Habitat Restoration

Habitat Type	Restoration Site				
	Dutch Slough	Hill Slough	Lower Yolo Ranch	Winter Island	Total
Habitat (acres)	29	0	56	3	88
Estimated number of shrubs	26	0	50	3	79

Levee breaches performed during tidal wetland restoration will require removal of riparian and contiguous grassland habitat within the range of valley elderberry longhorn beetle. The number of shrubs and stems that would be affected would be determined during preconstruction surveys in suitable habitat as outlined in AMM-VELB. Reclamation will offset adverse effects on elderberry shrubs through transplantation of affected shrubs and planting of new shrubs and associated riparian vegetation consistent with *Framework for Assessing Impacts to the Valley Elderberry Longhorn Beetle* (USFWS 2017c).

5.23.8.6.1.2 Construction Related Effects

Tidal Habitat Restoration may include use of heavy equipment for ground clearing, grading, excavation, and placement of large wood. Construction related actions could injure or kill valley elderberry longhorn beetles if individuals are present in shrubs to be transplanted, but the potential for this effect will be minimized as described in AMM-VELB.

The operation of equipment during construction in the vicinity of occupied elderberry shrubs could also result in injury or mortality of valley elderberry longhorn beetles if they are actively dispersing between shrubs, which is generally between March 15th and June 15th; or if occupied shrubs are inadvertently damaged by construction activities. These effects will be avoided and minimized as described in AMM-VELB.

Temporary construction-related ground disturbances could generate dust that could adversely affect adjacent valley elderberry longhorn beetle habitat. Dust is listed in the valley elderberry longhorn beetle recovery plan as a threat to the species (U.S. Fish and Wildlife Service 1984). Dust deposition is not correlated with valley elderberry longhorn beetle presence (Talley et al. 2006), but it is weakly correlated with signs of stress in elderberry plants (water stress, dead stems, smaller leaves). During times of drought, when elderberry shrubs are under stress, dust deposition could further stress the shrubs, potentially leading to their death. Such a loss of shrubs could adversely affect valley elderberry longhorn beetle (Talley and Hollyoak 2009). The potential effects of dust on valley elderberry longhorn beetle will be minimized by applying water during construction activities or by presoaking work areas within 100 feet of any potential elderberry shrub habitat.

Exhaust from construction and maintenance vehicles might deposit particulates, heavy metals, and mineral nutrients that could influence the quality and quantity of elderberry shrubs and thereby affect beetle presence and abundance. A study by Talley and Hollyoak (2009) showed no relationship, however, between the distance of the shrubs from highways and the presence or abundance of the beetle.

Temporary lighting from construction activities could adversely affect valley elderberry longhorn beetle. The effects of lighting on valley elderberry longhorn beetle are unknown, although insects are known to be subject to heavy predation when they are attracted to night lighting (Eisenbeis 2006). No restoration activity will occur during nighttime hours in the vicinity of habitat for federally listed species.

5.23.9 Soft Bird's-Beak and Suisun Thistle

5.23.9.1 Bay-Delta

5.23.9.1.1 <u>Bay-Delta Watershed</u>

Project components that could affect these species include Suisun Marsh salinity control gates and Chipps Island restoration. Potential effects of each of these components on soft bird's-beak and Suisun thistle and the measures to avoid, minimize, or offset these effects are described below.

5.23.9.1.2 <u>Suisun Marsh Salinity Control Gates</u>

Under the proposed action the Suisun Marsh Salinity Control Gates (SMSCG) will be operated between June and October for no more than 60 days in wet, above-normal and below-normal Sacramento Valley Index year types. The gates would be operated to minimize seawater intrusion into Montezuma Slough and decrease salinities overall to expand the extent of suitable habitat for Delta smelt. Other than this proposed change in SMSCG operations, gate operations would be unchanged from current conditions and salinities will not be substantially changed.

UnTRIM modeling of the proposed operation of the SMSCG found salinity decreases up to 2 PSU in Montezuma Slough in August and September in dry and below-normal water years (GEI 2018). Because of the limited temporal scale of the proposed action (60 days), the limited temporal overlap between the proposed action and the typical flooding regime for diked wetlands, the variability of existing salinities as well as the variability created between years when the proposed action is implemented and years when it is not; the salinity variability in the winter and spring (when there are no effects from the proposed action but when diked wetland flooding occurs), and the requirements to maintain adherence with RWQCB water quality requirements, the effects from SMSCG operations would reduce salinities by no more than 2% in above-normal and below normal water years. Because salinity levels of the habitat in which soft bird's-beak or Suisun thistle would not be substantially altered, the proposed operation of the SMSCG would not be likely to affect either species.

5.23.9.1.3 Tidal Habitat Restoration

The proposed action will convert the 450-acres of nontidal wetlands in the northern property to tidal action and may implement enhancement actions on the 250-acre southeastern parcel that is currently exposed to muted tidal action. Chipps Island occurs within the range of soft bird's-beak. However, neither soft bird's-beak nor Suisun thistle occur on Chipps Island. Therefore, habitat restoration at Chipps Island would not affect either soft bird's-beak or Suisun thistle. Restoration of tidal habitat at this site potentially could provide habitat where soft bird's-beak or Suisun thistle could be introduced, which would be a beneficial effect.

5.23.9.1.4 Bradmoor Island Habitat Restoration

The proposed action will restore tidal inundation to approximately 500 acres of managed wetlands and enhance and protect another 115 acres of existing tidal habitat. Bradmoor Island occurs within the range of soft bird's-beak. However, neither soft bird's-beak nor Suisun thistle occur on Bradmoor Island. Therefore, habitat restoration at Bradmoor Island would not affect either soft bird's-beak or Suisun thistle. Restoration of tidal habitat at this site potentially could provide habitat where soft bird's-beak or Suisun thistle could be introduced, which would be a beneficial effect.

5.23.9.1.5 Dutch Slough Habitat Restoration

The proposed action will restore 1,187 acres of Delta habitats on three leveed parcels adjacent to Dutch Slough. This area is outside of the ranges for Soft bird's-beak and Suisun thistle, and the proposed action would not affect either soft bird's-beak or Suisun thistle.

5.23.9.1.6 Hill Slough Habitat Restoration

The proposed action will restore tidal marsh on 750 acres of managed wetlands and enhance 200 acres of upland managed wildlife habitat. This area is within the range of both Soft bird's-beak and Suisun thistle, although neither species is known to occur within the action area. The proposed action is not likely to directly affect either species. However, restoration of tidal habitat at this site potentially could provide habitat into which soft bird's-beak or Suisun thistle could spread or where the species could be introduced, which would be a beneficial effect.

5.23.9.1.7 Lower Yolo Ranch Habitat Restoration

The proposed action will restore about 1,670 acres of tidal wetlands on a site which has historically been used for cattle grazing. This area is outside of the ranges for Soft bird's-beak and Suisun thistle, and the proposed action would not affect either soft bird's-beak or Suisun thistle.

5.23.9.1.8 Winter Island Habitat Restoration

The proposed action will restore tidal action on 589 acres of habitat on Winter Island. Winter Island occurs within the range of soft bird's-beak. However, neither soft bird's-beak nor Suisun thistle occur on Winter Island. Therefore, habitat restoration at Winter Island would not affect either soft bird's-beak or Suisun thistle. Restoration of tidal habitat at this site potentially could provide habitat where soft bird's-beak or Suisun thistle could be introduced, which would be a beneficial effect.

5.23.9.1.9 Proposed Flow Changes

See the previous discussion regarding flow change effects for a statement of the methods and approach used to assess proposed flow change effects on covered species. In Suisun Marsh, the methodology must be altered somewhat to reflect the complex effects of flow manipulation in the Delta and Suisun Marsh. In Suisun Marsh, the WOA scenario would cease operations of the Suisun Marsh Salinity Control Gates. This would lead to a more varied salinity regime within the Marsh, resulting in changes in marsh vegetation that would persist until the vegetation adapted to the new salinity and flow regime. This would likely render some areas of soft bird's-beak nor Suisun thistle habitat unsuitable, potentially extirpating occurrences of these plants, while also creating new areas of suitable habitat. To the extent that soft bird's-beak or Suisun thistle could not disperse to accommodate these habitat changes, or were adversely affected by short-term losses in suitable habitat, mortality would result, possibly with long-term effects on genetic diversity and population structure. Conversely, as described above in Section 5.24.3.1.1 *Suisun Marsh Salinity Control Gates*, changes under the PA scenario would be negligible relative to COS, with little potential for the PA to modify habitat or otherwise harm soft bird's-beak or Suisun thistle.

5.23.10 Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp

Project components with the potential to affect vernal pool fairy shrimp and vernal pool tadpole shrimp are associated with *Tidal Habitat Restoration.* Reclamation will, however, avoid disturbance of vernal pools that are occupied or assumed to be occupied, including a 250-foot buffer of upland around the pools, for the restoration projects.

5.23.11 California Tiger Salamander

Project components with the potential to affect California tiger salamander are associated with Tidal Habitat Restoration and Conservation Fish Hatchery. Reclamation will, however, avoid disturbance of potentially occupied California tiger salamander habitat for this restoration.

5.23.12 California Least Tern

Project components with the potential to affect California least tern are associated with Tidal Habitat Restoration. Although most of the project components could affect aquatic areas that provide California least tern foraging habitat, these activities are not expected to adversely affect the species, since foraging habitat is readily available and the restoration and enhancement projects are expected to increase food supply. Proposed flow changes under the proposed action likewise have little potential to alter extent or quality of habitat available to the California least tern. Reclamation will avoid disturbance of any

California least tern nesting colony sites. The proposed action is therefore expected to have a net beneficial effect on the species.

5.23.13 California Red-Legged Frog

Project components with potential to affect California red-legged frog are associated with *Spawning and Rearing Named Projects* in the Upper Sacramento River Watershed. Although these components occur within the historic range of the species, there are no known populations within these areas and Reclamation has conducted surveys for California red-legged frog to support past spawning and rearing projects along the Sacramento River, south of Shasta Dam, and have not observed the species. Therefore, the likelihood of species occupancy of habitats along the Sacramento River downstream of Shasta Dam is discountable.

5.24 Effects on Terrestrial Species Critical Habitat

Federally listed species with critical habitat in the Action Area include western yellow-billed cuckoo, California red-legged frog, California tiger salamander, valley elderberry longhorn beetle, vernal pool fairy shrimp, vernal pool tadpole, soft bird's-beak, and Suisun thistle. Effects on critical habitat will be avoided for all these species except western yellow-billed cuckoo. Effects are described below.

5.24.1 Western Yellow-Billed Cuckoo Proposed Critical Habitat

Western yellow-billed cuckoo proposed critical habitat is present in Tisdale Bypass and Sutter Bypass. However, Reclamation's proposed action does not modify flows in the Tisdale or Sutter Bypasses. Changes in frequency of inundation in the Sacramento River would be minor, and within the current minimum and maximum flows. The proposed action could provide for some different riparian species that require year-round flows, as compared to WOA, where low flows in the fall would stress invasive plants and encourage drought tolerant native species to persist.

The average monthly flows under adjusted CP4A were similar (5% or less difference) to the proposed action in June-August. The average flows generally increase in September (by 44%) and November (by 30%) and decrease in December-May (by at most 19%) with a raised Shasta Dam (adjusted CP4A) compared to the proposed action model results. The operation of a Shasta Dam raise is not anticipated to change the minimum or maximum flows in the Sacramento River.

5.24.2 Valley Elderberry Longhorn Beetle

Critical habitat for valley elderberry longhorn beetle is present along the American River. However, Reclamation will avoid valley elderberry longhorn critical habitat. Therefore, there is no effect to valley elderberry longhorn beetle critical habitat.

5.24.3 Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp

Critical habitat for vernal pool fairy shrimp and vernal pool tadpole shrimp is present in areas that Reclamation could potentially use for Tidal Habitat Restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for these species in the critical habitat units. Therefore, the proposed action has no effect on critical habitat for these species.

5.24.4 California Tiger Salamander

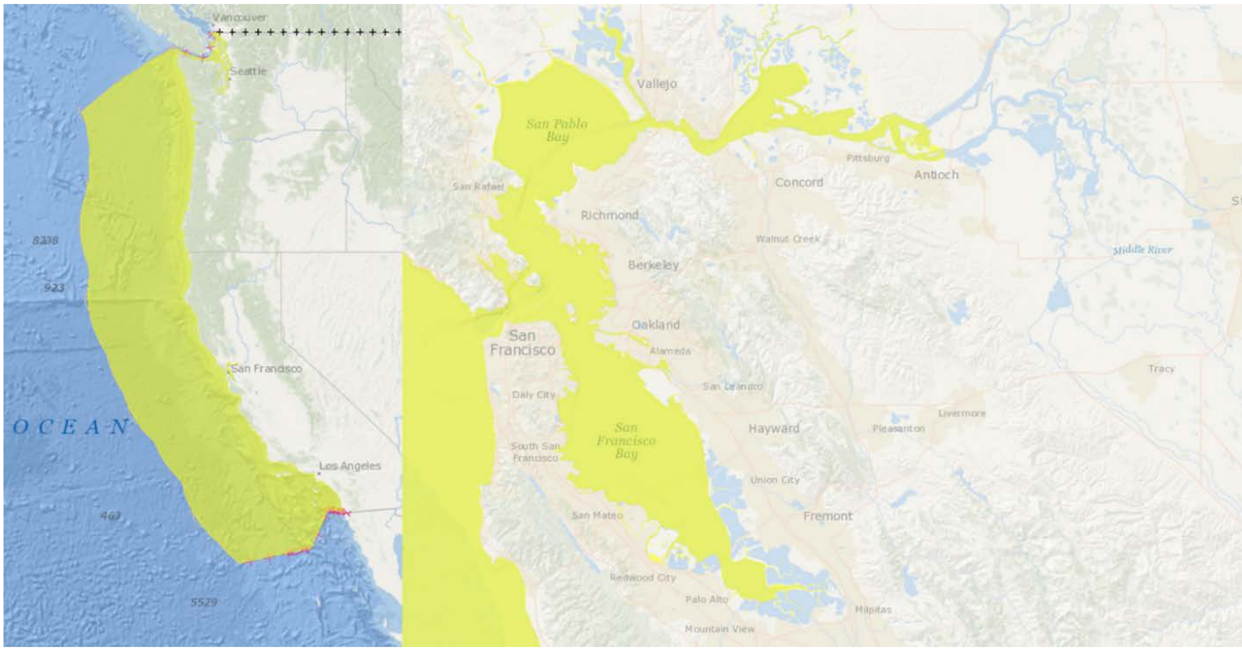
Critical habitat for California tiger salamander is present in areas that Reclamation could potentially use for Tidal Habitat Restoration. Reclamation will, however, avoid areas that would affect the primary constituent habitat elements for this species in the critical habitat units.

5.25 Essential Fish Habitat

The action area encompasses designated EFH for Pacific Coast Salmon (Figure 5.25-1), Coastal Pelagic Species (Figure 5.25-2), and Pacific Coast Groundfish (Figures 5.25-3 and 5.25-4). There is a number of species included in these groups that could be present in the action area (Table 5.25-1). The analyses below generally focus on species that are likely to be abundant (relative to other species within each group) in the main portion of the action area that could be affected by the proposed action, i.e., Pacific Coast Salmon: Sacramento River Winter-run Chinook Salmon, Central Valley Spring-run and Fall-run/Late Fall-run Chinook Salmon, Upper Klamath-Trinity Rivers Fall-run and Spring-run Chinook Salmon, Southern Oregon-Northern California Coastal Chinook Salmon, and Southern Oregon-Northern California Coast Coho Salmon; Coastal Pelagic Species: Northern Anchovy; and Pacific Coast Groundfish: Starry Flounder.

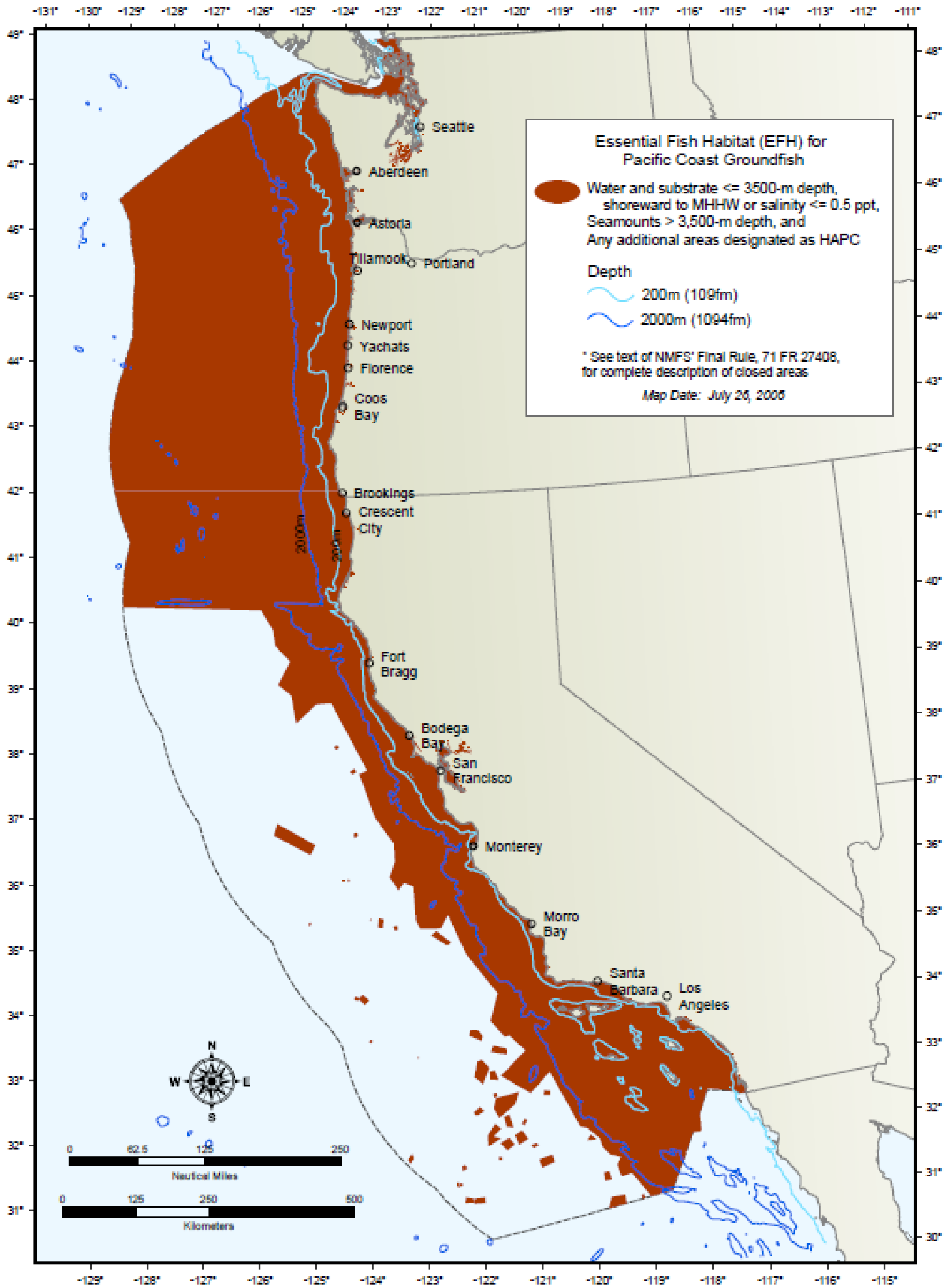
Source:
https://www.westcoast.fisheries.noaa.gov/publications/habitat/essential_fish_habitat/west_coast_salmon_efh_2014__1_.pdf . Accessed: December 20, 2018.

Figure 5.25-1. Essential Fish Habitat for Pacific Coast Salmon



Source: https://www.habitat.noaa.gov/protection/efh/efhmapper/ Accessed: December 20, 2018. Note: Left map shows full extent of Coastal Pelagic Species EFH; right map includes main portion of EFH in the San Francisco Bay-Delta (there is no EFH in the Lower Klamath River, so that area is not included).

Figure 5.25-2. Essential Fish Habitat for Coastal Pelagic Species in the Vicinity of the Action Area



Source: https://www.westcoast.fisheries.noaa.gov/publications/gis_maps/maps/groundfish/map-gfish-efh.pdf
Accessed: December 19, 2018.

Figure 5.25-3. Essential Fish Habitat for Pacific Coast Groundfish

Table 5.25-1. Essential Fish Habitat Species Potentially Present in the Action Area, with Focal Species in Bold

Species or FMP	**Common Name**	**Scientific Name**	**Comment**
Coastal Pelagic Species	Jack Mackerel	*Trachurus symmetricus*	Present; eggs & larvae
Coastal Pelagic Species	Northern Anchovy	*Engraulis mordax*	Abundant; eggs, larvae, juveniles & adults
Coastal Pelagic Species	Pacific Sardine	*Sardinops sagax*	Rare; juveniles & adults
Pacific Coast Groundfish FMP	Big Skate	*Raja binoculata*	Present; juveniles & adults
Pacific Coast Groundfish FMP	Bocaccio	*Sebastes paucispinis*	Rare; juveniles
Pacific Coast Groundfish FMP	Brown Rockfish	*Sebastes auriculatus*	Abundant; juveniles & adults
Pacific Coast Groundfish FMP	Cabezon	*Scorpaenichthys* spp.	Rare; juveniles & adults
Pacific Coast Groundfish FMP	Curlfin Sole	*Pleuronichthys decurrens*	Present; juveniles
Pacific Coast Groundfish FMP	English Sole	*Pleuronectes vetulus*	Abundant; juveniles & adults
Pacific Coast Groundfish FMP	Kelp Greenling	*Hexagrammos* spp.	Present; juveniles & adults
Pacific Coast Groundfish FMP	Leopard Shark	*Triakis semifasciata*	Present; juveniles & adults
Pacific Coast Groundfish FMP	Lingcod	*Ophiodon elongatus*	Present; juveniles & adults
Pacific Coast Groundfish FMP	Pacific Sanddab	*Citharichthys sordidus*	Present; eggs, larvae, juveniles & adults
Pacific Coast Groundfish FMP	Pacific Whiting (Hake)	*Merluccius productus*	Present; eggs & larvae
Pacific Coast Groundfish FMP	Sand Sole	*Psettichthys melanostictus*	Present; larvae, juveniles & adults
Pacific Coast Groundfish FMP	Soupfin Shark	*Galeorhinus zyopterus*	Present; juveniles & adults

Species or FMP	Common Name	Scientific Name	Comment
Pacific Coast Groundfish FMP	Spiny Dogfish	*Squalus acanthias*	Present; juveniles & adults
Pacific Coast Groundfish FMP	Starry Flounder	*Platichthys stellatus*	Abundant; eggs, larvae, juveniles & adults
Pacific Coast Salmon FMP	Chinook Salmon	*Oncorhynchus tshawytscha*	Abundant; eggs, larvae, juveniles & adults
Pacific Coast Salmon FMP	Coho Salmon	*Oncorhychus kisutch*	Present; eggs, larvae, juveniles & adults

Source: Adapted from NMFS (2017, p.1211).

5.25.1 Pacific Coast Salmon

Pacific Coast Salmon EFH includes the entire action area (Figure 5.25-1).

5.25.1.1 Effects of Operation

Operations of the proposed action have the potential to positively and negatively affect Pacific Coast Salmon EFH. Detailed analyses for *Flow-Dependent Actions* were previously described for Central Valley Chinook Salmon stocks, i.e., Winter-run, Spring-run, and Fall-run/Late Fall-run. Potential positive effects of the proposed action relative to the without action generally would occur as a result of reservoir storage allowing summer/fall releases to maintain favorable temperature conditions for early life stages, as exemplified for Winter-run Chinook Salmon in the Sacramento River below Keswick Dam (see Section 5.2.1.2.1 *Flow-Dependent Actions*). Potential negative effects of the Core Water Operation generally could occur during winter and spring, particularly the latter, which coincides with the main period of juvenile downstream migration and is when flow is often appreciably lower under the proposed action compared to the without action. These factors could affect juvenile salmon travel time and survival, for example.

Non-flow-dependent actions' operational effects generally would be expected to have positive effects on Chinook Salmon stocks from the Central Valley, although some negative effects are also possible, as discussed in species sections above.

5.25.1.2 Effects of Conservation Measures

As discussed in species sections above, the various proposed construction activities potentially could result in direct or indirect alteration in the quantity and quality of Pacific Coast Salmon EFH, but generally would provide beneficial long-term effects. Effects include temporary loss of aquatic and riparian habitat leading to increased predation and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity, leading to direct toxicological impacts on fish health/performance, indirect impairment of aquatic ecosystem productivity (e.g., reduction in benthic macroinvertebrate production and availability), loss of aquatic vegetation providing physical shelter, and reduced foraging ability caused by decreased visibility; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. These potential effects would be minimized through restriction of in-water work to windows limiting exposure by reducing potential for spatiotemporal overlap, and implementation of other AMMs to minimize the potential for effects when species do overlap with in-water work. In the long-term, the conservation measures proposed in this document should improve the extent and quality of EFH by increasing spawning and rearing habitat in the Sacrament, American, and Stanislaus Rivers.

5.25.1.3 Effects of Maintenance

Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Pacific Coast Salmon EFH from maintenance activities.

5.25.1.4 Effects of Monitoring Activities

It is anticipated that there would be minimal negative effects of monitoring activities on Pacific Coast Salmon EFH, given the limited spatial extent of habitat that would be affected by activities such as trawling, seining, or operating video weirs, for example. Monitoring activities are summarized in Appendix C, *ROC Real Time Water Operations Charter* in section *Monitoring Program for Core CVP and SWP Operation*.

5.25.2 Coastal Pelagic Species

Coastal Pelagic Species EFH in the action area includes the action area upstream to the western Delta (lower Sacramento and San Joaquin Rivers), but not the Lower Klamath River (Figure 5.25-2).

5.25.2.1 Effects of Operation

Coastal Pelagic Species EFH could be subject to operational effects of the proposed action’s Core Water Operation 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. There is a large amount of Coastal Pegalic Species EFH relative to the action area (Figure 5.25-3).

5.25.2.2 Effects of Conservation Measures

Construction of proposed action components generally would be upstream of Coastal Pelagic Species EFH. Depending on the location of tidal marsh habitat restoration, there may be some construction effects from this component of the proposed action, for example if restoration sites border Suisun Bay or are on the lower Sacramento and San Joaquin Rivers. Depending on the specifics of the work, and as previously described for Pacific Coast Salmon, effects to Coastal Pelagic Species EFH could include factors such as temporary loss of aquatic habitat leading to increased predation and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Implementation of AMMs (see Appendix E, *Avoidance and Minimization Measures*) would avoid and minimize potential effects to Coastal Pelagic Species EFH.

5.25.2.3 Effects of Maintenance

Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Coastal Pelagic Species EFH from maintenance activities.

5.25.2.3.1 Effects of Monitoring Activities

It is anticipated that there would be minimal negative effects of monitoring activities on Coastal Pelagic Species EFH, given the limited spatial extent of habitat that would be affected by sampling in the Bay-Delta (in particular the Fall Midwater Trawl, 20-mm Survey, Spring Kodiak Trawl, Bay Study, Smelt Larva Survey, Summer Townet Survey, Chipps Island Trawl, Enhanced Delta Smelt Monitoring, and Environmental Monitoring Program; see Appendix E relative to the overall extent of EFH.

5.25.3 Pacific Coast Groundfish

Pacific Coast Groundfish EFH in the action area includes San Francisco Bay and Suisun Bay, but not the legal Delta (Figure 5.25-3).

5.25.3.1 Effects of Operation

As with Coastal Pelagic Species EFH, the proposed action's Core Water Operation could affect the Pacific Coast Groundfish EFH 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 Pacific Coast Groundfish EFH such as Starry Flounder (Baxter et al. 1999), and indices of habitat availability of Starry Flounder are not related to Delta outflow (expressed as X2; Kimmerer et al. 2009). Kimmerer et al. (2009) found a significant negative relationship between annual mean March–June X2 (an index of Delta outflow) and annual mean Starry Flounder bay otter trawl abundance indices, which they suggested could be related to an increase in residual circulation in the San Francisco Estuary with increasing Delta outflow; if such an increase translates to more rapid or more complete entrainment of Starry Flounder early life stages into the estuary, or more rapid transport to their rearing grounds, then presumably survival from hatching to settlement would be higher under high-flow conditions (Kimmerer et al. 2009: 385). Relative to the without action WOA scenario, the proposed action scenario has lower March–June Delta outflow and therefore higher X2 (Figure 5.25-4), potentially resulting in a negative effect to Pacific Coast Groundfish EFH as reflected by Starry Flounder abundance. There is appreciable uncertainty in this predictive relationship, however (ICF International 2016: p.5.E-34.

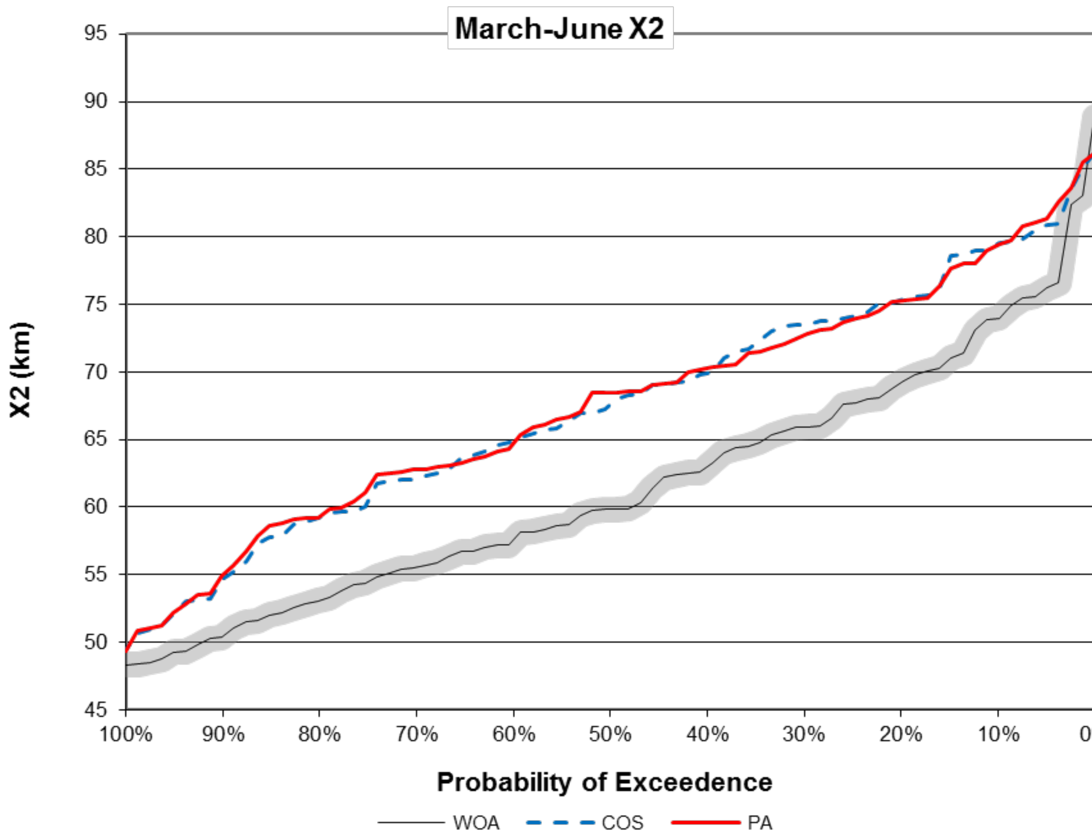


Figure 5.25-4. Mean Modeled X2, March–June

5.25.3.2 Effects of Conservation Measures

Construction of proposed action components generally would be upstream of Pacific Coast Groundfish EFH. As described for Coastal Pelagic Species EFH, there may be some construction effects from the tidal marsh habitat restoration component of the proposed action, for example if restoration sites border Suisun Bay. Depending on the specifics of the work, and as previously described for Pacific Coast Salmon, effects to Pacific Coast Groundfish EFH could include potential negative effects such as temporary loss of aquatic habitat leading to increased predation and reduced food availability; degraded water quality from contaminant discharge by heavy equipment and soils, and increased discharges of suspended solids and turbidity; impediments and delay in migration caused by elevated noise levels from machinery; and direct injury or mortality from in-water equipment strikes or isolation/stranding within dewatered cofferdams. Implementation of AMMs (see Appendix E, *Avoidance and Minimization Measures*) would avoid and minimize potential effects to Pacific Coast Groundfish EFH.

5.25.3.3 Effects of Maintenance

Implementation of the species avoidance and take minimization steps described in Appendix C, *ROC Real Time Water Operations Charter* in section *Routine Operations and Maintenance on CVP Activities* would be anticipated to minimize potential negative effects to Pacific Coast Groundfish EFH from maintenance activities.

5.25.3.4 Effects of Monitoring Activities

It is anticipated that there would be minimal negative effects of monitoring activities on Pacific Coast Groundfish EFH, given the limited spatial extent of habitat that would be affected by sampling in the Bay-Delta (in particular the Fall Midwater Trawl, 20-mm Survey, Spring Kodiak Trawl, Bay Study, Smelt Larva Survey, Summer Townet Survey, Chipps Island Trawl, Enhanced Delta Smelt Monitoring, and Environmental Monitoring Program; see Appendix C, *ROC Real Time Water Operations Charter* in section *Monitoring Program for Core CVP and SWP Operation*).