BUREAU OF RECLAMATION

Final Biological Assessment

The Effects of the Proposed Action to Operate the Klamath Project from April 1, 2020 through March 31, 2024 on Federally Listed Threatened and Endangered Species

Klamath Project, Oregon/California
Interior Region 10 California Great Basin

U.S. Department of the Interior

February 2020

Mission Statements

The mission of the Department of the Interior is to protect and manage the Nation's natural resources and cultural heritage; provide scientific and other information about those resources; and honor its trust responsibilities or special commitments to American Indians, Alaska Natives, and affiliated island communities.

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Acronyms and Abbreviations

AF	acre-feet
ACT	Agency Coordination Team
ACFFOD	Amended and Corrected Findings of Fact and Order of Determination
AFA	*Aphanizomenon flos-aquae*
ASR	Aquatic Scientific Resources
BA	Biological Assessment
BIA	Bureau of Indian Affairs
Bio	Biology
BiOp	Biological Opinion
BLM	Bureau of Land Management
BOD	biochemical oxygen demand
°C	degrees Celsius
CDFW	California Department of Fish and Wildlife
C.F.R.	Code of Federal Regulations
cfs	cubic feet per second
cm	centimeter
Copco	California Oregon Power Company
DDT	dichlorodiphenyltrichloroethane
Department	Department of the Interior
DPS	Distinct Population Segment
DO	dissolved oxygen
EFH	Essential Fish Habitat
EOM	end of month
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
EWA	Environmental Water Account
°F	degrees Fahrenheit
feet/s	feet per second
FASTA	Flow Account Scheduling Technical Advisory
FERC	Federal Energy Regulatory Commission
FR	Federal Register
FRAM	Fishery Regulation Assessment Model
GCID	Glenn-Colusa Irrigation District
Hydro	Hydrology
HCP	Habitat Conservation Plan
HID	Horsefly Irrigation District
IGD	Iron Gate Dam
IGH	Iron Gate Hatchery
KBAO	Klamath Basin Area Office
KBRA	Klamath Basin Restoration Agreement

KBPM	Kamath Basin Planning Model
KDD	Klamath Drainage District
kg	kilogram(s)
KHSA	Klamath Hydroelectric Settlement Agreement
KID	Klamath Irrigation District
KLS	Klamath largescale sucker
KPFA	Klamath Power and Facilities Agreement
KRRC	Klamath River Renewal Corporation
KSD	Klamath Straits Drain
KWUA	Klamath Water Users Association
LKNWR	Lower Klamath National Wildlife Refuge
LRD	Link River Dam
LRDC	Lost River Diversion Channel
LRS	Lost River Sucker(s)
LVID	Langell Valley Irrigation District
m/s	meters per second
mg/L	milligrams per Liter
mg O_2/L	milligrams of oxygen per Liter
µg/L	micrograms per Liter
mm	millimeter
N	nitrogen
NFWF	National Fish and Wildlife Foundation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NTP	Notice to Proceed
NWFSC	Northwest Fisheries Science Center
NWR	National Wildlife Refuge
ODEQ	Oregon Department of Environmental Quality
O&M	Operation and Maintenance
OM	organic matter
OSF	Oregon Spotted Frog
OWRD	Oregon Water Resources Department
pHOS	proportion of hatchery fish on spawning grounds
pNOB	natural origin fish used in hatchery broodstock
P	phosphorus
PA	Proposed Action
PAH	polynuclear aromatic hydrocarbons
PBF	physical or biological features
PCB	polychlorinated biphenyl
PIT	Passive Integrated Transponder
POI	prevalence of infection
POR	Period of Record
PP	particulate phosphorus
Project	Klamath Project

PVID	Poe Valley Improvement District
QA/QC	quality assurance/quality control
Reclamation	U.S. Bureau of Reclamation
rkm	river kilometer
RBM	River Basin Model-10
RM	river mile
ROC	reinitiation of consultation
RPA	reasonable and prudent alternative
SAR	Smolt-to-adult return
Secretary	Secretary of the United States Department of the Interior
Services	United States Fish and Wildlife Service as well as the National Marine Fisheries Service
SNS	Shortnose Sucker(s)
SONCC	Southern Oregon/Northern California Coast
SRCD	Siskiyou Resource Conservation District
SRKW	Southern Resident Killer Whale
SRP	soluble reactive phosphorus
Stat.	Statute
TAF	thousand acre-feet
TID	Tulelake Irrigation District
TIN	total inorganic nitrogen
TL	total length
TLS1A	Tule Lake Sump 1A
TMDL	total maximum daily load
TP	Total phosphorus
UKL	Upper Klamath Lake
U.S.	United States
U.S.C.	United States Code
USFS	United States Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
WDFS	Washington State Department of Fish and Wildlife
WRIMS	Water Resource Integrated Modeling System
WUA	weighted usable area
WY	water year
YOY	Young-of-the-Year

Executive Summary

This Biological Assessment (BA) has been prepared pursuant to section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended, (1973, 16 U.S.C. 1531 et seq), to evaluate the potential effects of the continued operation of the Bureau of Reclamation's (Reclamation) Klamath Project (Project) on species listed as threatened or endangered under the ESA. The Project is located in south-central Oregon and northeastern California and contains approximately 230,000 acres of irrigable land. Reclamation stores, diverts, and conveys waters of the Klamath and Lost Rivers to meet authorized Project purposes and contractual obligations in compliance with state and federal laws and carries out the activities necessary to maintain the Project and ensure its proper long-term functioning and operation.

Federally-listed species that occur within the Action Area and are considered as part of this consultation are the endangered Lost River sucker (LRS; *Deltistes luxatus*), endangered shortnose sucker (SNS; *Chasmistes brevirostris*), threatened Southern Oregon/Northern California Coast (SONCC) coho salmon *(Oncorhynchus kisutch)* Evolutionarily Significant Unit (ESU), threatened Southern Distinct Population Segment (DPS) of the North American green sturgeon (*Acipenser medirostris),* endangered Southern Resident killer whale (SRKW; *Orcinus orca*) DPS, and threatened DPS of Pacific eulachon (*Thaleichthys pacificus*).

Reclamation currently meets its obligations under the ESA by operating the Project in accordance with the U.S. Fish and Wildlife Service (USFWS) March 29, 2019, *Biological Opinion on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2024, on the Lost River Sucker and the Shortnose Sucker* (USFWS 2019 BiOp) and the March 29, 2019, National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) *Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Klamath Project Operations from April 1, 2019 through March 31, 2024* (NMFS 2019 BiOp). Reclamation has reinitiated consultation with both USFWS and NMFS (collectively, the Services) on the operation of the Project and has prepared this BA to assist with the reinitiated consultation. Reclamation's Proposed Action (PA) for this BA is the operation of the Project from April 1, 2020, through March 31, 2024. Reclamation proposes to continue to store waters of the Klamath and Lost rivers, operate the Project for the delivery of water to meet authorized Project purposes and contractual obligations inclusive of deliveries to national wildlife refuges in compliance with applicable state and federal law. Reclamation also proposes to conduct routine maintenance activities on Project facilities that are not only limited in duration, but necessary to maintain Project facilities and ensure the proper long-term viability, functioning, and operation of the Project.

Reclamation has considered the best scientific and commercial information available and determined the potential effects of the PA on federally ESA-listed species. This analysis shows that the PA may affect and is likely to adversely affect LRS and SNS and SONCC coho salmon. This analysis also indicates that designated critical habitat for both LRS and SNS as well as coho

salmon is likely to be adversely affected. The analysis further demonstrates that the PA may affect, but is not likely to adversely affect the Southern DPS of the North American green sturgeon, the SRKW DPS, and the Southern DPS of Pacific eulachon, and may affect, but is not likely to adversely affect proposed critical habitat for the SRKW DPS and designated critical habitat for the Southern DPS of Pacific eulachon, Bull Trout, and Oregon spotted frog.

Based on these conclusions, Reclamation is requesting formal consultation under section 7(a)(2) of the ESA with the USFWS on the LRS and SNS and their designated critical habitat, and with NMFS on the coho salmon and their designated critical habitat, the Southern DPS of North American green sturgeon, the SRKW DPS and its proposed critical habitat, and the Southern DPS of Pacific eulachon and its designated critical habitat.

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1 Introduction

1.1 Purpose of the Biological Assessment

The United States (U.S.) Bureau of Reclamation (Reclamation) currently meets its obligations under the Endangered Species Act (ESA) by operating the Klamath Project (Project) in accordance with two March 29, 2019, biological opinions: the U.S. Fish and Wildlife Service (USFWS *Biological Opinion on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2024, on the Lost River Sucker and the Shortnose Sucker* (USFWS 2019a) and the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NMFS) *Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Klamath Project Operations from April 1, 2019 through March 31, 2024* (NMFS 2019 BiOp).

Reclamation reinitiated consultation with both the USFWS and NMFS (collectively, the Services) (USFWS 2018, 50 CFR 402.16) on November 13, 2019, because new information identified in Fall 2019 revealed effects on Southern Oregon Northern California Coast (SONCC) coho that had not been considered in Reclamation's Modified Biological Assessment nor the 2019 NMFS BiOp. The current reinitiated consultation will analyze Reclamation's proposal to modify the water management approach for Project operations to address this new information as related to the effects of Project operations on listed species and/or their designated critical habitat. In particular, Reclamation proposes to continue to store waters of the Klamath and Lost rivers, operate the Project, for the delivery of water to meet authorized Project purposes and contractual obligations inclusive of deliveries to national wildlife refuges (NWRs) in compliance with applicable state and federal law. Reclamation also proposes to conduct routine operation and maintenance (O&M) activities on Project facilities that are not only limited in duration, but necessary to maintain Project facilities and ensure the proper long-term viability, functioning, and operation of the Project. Additionally, Reclamation proposes to carry out various conservation measures meet its obligations under the ESA regarding the effects of its Proposed Action (PA) on ESA-listed species and/or their critical habitat.

Reclamation has prepared this Biological Assessment (BA) pursuant to section 7(a)(2) of the ESA of 1973, as amended (1973, 16 U.S.C. 1531 et seq) to evaluate the potential effects to federally-listed species that could result from the continued O&M of the Project.

This BA provides information on the anticipated effects of the PA that cover the period from April 1, 2020 through March 31, 2024[1], on federally-listed species for use by the Services in

[1] Reclamation's PA has a term of 4 years (2020 to 2024) or until such time that reinitiation of formal consultation is required as outlined in Section 50 CFR § 402.16. Reclamation determined that the term of the 2020 PA is consistent with the intent of the previous PA (e.g., 2018), and is appropriate due to uncertainties that may occur within the Klamath River Basin (e.g., dam removal on the Klamath River). and the inability to describe the PA over a period longer than 4 years.

preparation of their respective 2020 BiOps. Reclamation has collaborated extensively with each of the Services in the development of the PA and BA. As a result, Reclamation has prepared a single BA for the purposes of its reinitiated section 7(a)(2) consultation with the Services.

1.2 Klamath Project Description

Authorized in 1905, the purpose of the Project is to provide water for irrigation, domestic, and related purposes (e.g., stock watering) to approximately 230,000 acres of farmland in southern Oregon and northern California. The Project's service area encompasses lands in Klamath County, Oregon and Siskiyou and Modoc counties, California. Communities within the Project include Klamath Falls, Bonanza, Merrill, and Malin in Oregon, and Tulelake and Newell in California.

The Project consists of a complex network of storage and conveyance features including reservoirs, lakes, dams, diversion dams, canals, and drains. Major Project facilities in Oregon include the A, B, C, D, E, F and G canals; Link River Dam (LRD); Gerber Dam; Malone Diversion Dam; Miller Creek Diversion Dam; the Lost River Diversion Dam and Channel; Anderson-Rose Diversion Dam; and the Klamath Straits Drain (KSD). Major Project facilities in California include, the D, J, M, N, R, Q, and P canals; Clear Lake Dam; and the Tule Lake Tunnel (*see* Figure 1-1 and Appendix 1A). Water made available through these facilities is delivered to Project lands through approximately 675 miles of canals and laterals. Irrigation return flows and local runoff is collected from irrigated lands through approximately 545 miles of drains. Approximately 50 separate pumps are used to convey irrigation and drainage water to different portions of the Project.

In addition to Project facilities, in which title is vested in the U.S., locally and privately-owned irrigation works, such as Harpold Dam on the Lost River and the Ady and North canals in the Lower Klamath Lake area, are also are used to divert and convey Project water to its place of use. In certain cases, Reclamation has agreements with the owners of these facilities, concerning their construction and continued operation.

The waters of the Upper Klamath and Lost River watersheds are used for irrigation and related purposes within the Project and are considered "Project water" whether stored in Upper Klamath Lake (UKL), Clear Lake Reservoir, or Gerber Reservoir, or diverted from natural flow in both the Klamath and Lost rivers. Total active storage capacity of the Project's three reservoirs is approximately 1,066,000 acre-feet (AF).

Stored water in Clear Lake and Gerber reservoirs is generally used for irrigation purposes in Langell and Yonna valleys, although it can be and occasionally has been used for irrigation in the portion of the Project between Klamath Falls, Oregon and Tulelake, California. Project water stored in UKL is used for irrigation on lands between Klamath Falls and Tulelake, the Lower Klamath Lake area, and along the Klamath River between Lake Ewauna and the town of Keno, Oregon. Natural flow in the Lost River above Harpold Dam is primarily used in Langell and Yonna valleys, although all water in the Lost River below Harpold Dam is generally diverted and used within the Project during the irrigation season. Natural flow in the Klamath River, resulting from natural runoff and other discharges into the river below LRD, is primarily used in

the Lower Klamath Lake area. (*See* Chapter 1.3.3., Reclamation Water Supply Contracts, for further information on the Project's service area.)

Project water is also delivered from various sources to two USFWS NWRs. *See* Chapter 1.3.6, National Wildlife Refuges, regarding how water is delivered and used within the refuges.

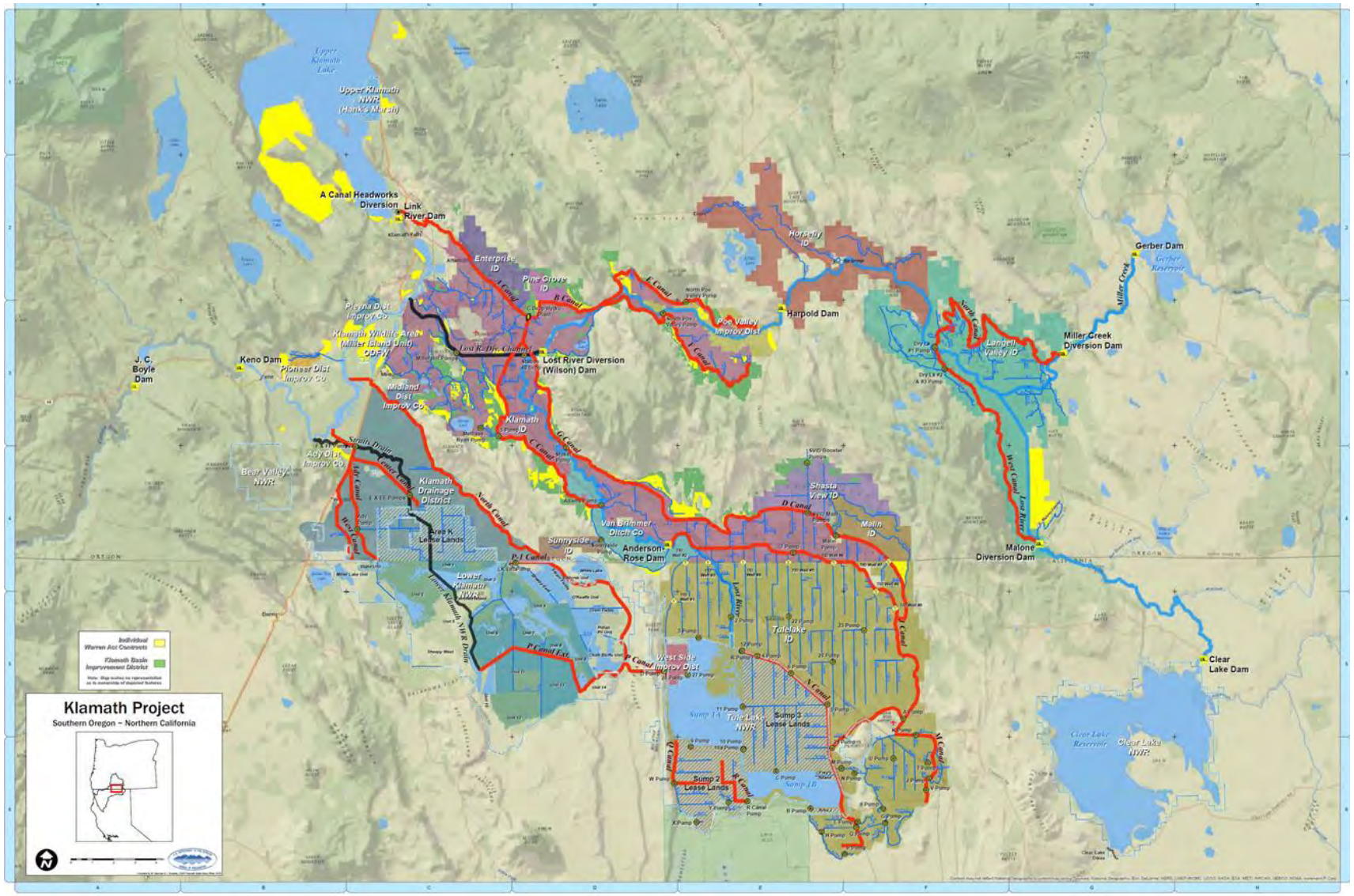

Figure 1-1. Klamath Project Map

1.3 Overview of Klamath Project Operations

Legal and statutory authorities and obligations, water rights, and contractual obligations have informed and shaped Reclamation's PA. This section of the BA elaborates on those authorities, responsibilities, and obligations.

1.3.1 Project Authorization and Purpose

The Project is one of the earliest federal Reclamation projects. The Act of February 9, 1905, (Reclamation Act; 33 Stat. 714), authorized the Secretary of the U.S. Department of the Interior (Secretary; Department) to change the level of several lakes and to dispose of certain lands that were later included in the Project. The Oregon and California legislatures, on January 20 and February 3, 1905, respectively, passed legislation ceding certain lands to the U.S. for use as Project lands[2]. The Project was authorized by the Secretary in May 1905, in accordance with the Reclamation Act of 1902 (Public Law No. 57-161, 32 Stat. 388 (codified as 43 U.S.C. 371 et seq, 1902), and approved by President William Howard Taft on January 5, 1911, pursuant to the Advances to the Reclamation Fund Act of 1910 (36 Stat. 835).

The Secretary's authorization provided for the construction of Project works with the purpose to drain portions of Lower Klamath and Tule lakes; reclaim and homestead the uncovered lakebeds (including providing protection against flooding); and to appropriate water for irrigation of public and private lands within the Project area.

1.3.2 Project Water Rights

The Project diverts stored water for irrigation, and related purposes from streams and natural lakes in both Oregon and California. Section 8 of the Reclamation Act of 1902 requires that Reclamation obtain water rights for water used for Project purposes and administer those water rights in accordance to state law relating to the appropriation of water for beneficial uses, unless the applicable state laws are inconsistent with express or clearly implied congressional directives (Reclamation Act of 1902, 43 U.S.C. 383; Cal. v. U.S., 438 U.S. 645, 678 (1978); appeal on remand, 694 F.2d 117 (1982)).

On May 19, 1905, pursuant to Oregon state law, Reclamation filed a notice with the State Engineer of Oregon claiming, on behalf of the Project, "all the waters of the Klamath Basin in Oregon consisting of the entire drainage basins of the Klamath River and Lost River … and their tributaries." Notices of water rights were filed in California, pursuant to California law, for water from the Lost River and its tributaries. Reclamation's initial plans for the Project, on which these notices were based, contemplated providing water for irrigation purposes to generally the same area currently served by the Project.

In addition to Reclamation's 1905 notices and related filings, Reclamation acquired several canals and related companies that existed prior to the Project's authorization. Reclamation used portions of these existing canals, like the Henley-Ankeny Canal and the Adams Canal, in constructing the Project. Associated water rights were generally included in these purchases, and

[2] *See* 1905 Or. Laws, p. 63; 1905 Cal. Stat., p. 4.

in some cases (e.g., the Henley-Ankeny Canal), Reclamation was obligated to provide water to lands then already being irrigated.

Since 1975, the State of Oregon has been in the process of adjudicating all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon, including the rights associated with Reclamation's 1905 notices and the various canal systems Reclamation acquired at the time. This process, generally known as the Klamath Basin General Stream Adjudication, will eventually result in a final determination of the nature and relative priority of water rights for the Project to water from the Klamath River and its tributaries, including UKL.

As part of Klamath Basin General Stream Adjudication, in 2013 the State of Oregon issued a Findings of Fact and Order of Determination, which has since been amended and corrected. Under Oregon law, this Amended and Corrected Findings of Fact and Order of Determination (ACFFOD) is enforceable unless judicially stayed. Enforcement of the ACFFOD occurs through the Oregon Water Resources Department (OWRD), based on a "call" by a water user that there is a deficiency in the water available to meet their water rights. In that event, in accordance with the legal doctrine of prior appropriation, OWRD may curtail diversions from the same source under water rights with later ("junior") priority dates, in order to make water available for water rights with earlier ("senior") priority dates.

According to the ACFFOD, the priority date of the water rights for the Project based on Reclamation's 1905 notices is May 19, 1905. Since issuance of the ACFFOD in 2013, Reclamation, along with districts and other water users within the Project, have made a "call" for the Project water rights in 2013, 2014, and 2015, which have resulted in the OWRD temporarily curtailing diversions from UKL and its various tributaries under junior water rights.

As it currently stands, the ACFFOD identifies 203,500 acres that may be irrigated within the Project with water from UKL and the Klamath River, including lands within Lower Klamath and Tule Lake NWRs and the service area for Van Brimmer Ditch Company. The ACFFOD imposes various conditions on the way these water rights may be exercised (e.g., rate of diversion, volume of water used, time of use).

The ACFFOD also recognizes separate, federally-reserved water rights appurtenant to various portions of Tule Lake and Lower Klamath NWRs, for the water necessary to satisfy the primary purposes of the refuges. These federally-reserved water rights for the refuges currently have priority dates later than the water rights for the Project based on Reclamation's 1905 notices.

The ACFFOD is subject to ongoing judicial review before the Klamath County Circuit Court. Parties claiming water rights in the Adjudication, including the U.S., have filed various exceptions to the ACFFOD. The resolution of those exceptions is still ongoing, and the schedule for completing the adjudication is uncertain. The ACFFOD may be modified when this legal process is complete. Parties may also petition the court to judicially stay enforcement on all or portions of the ACFFOD while the exceptions are being resolved.

The Klamath Basin General Stream Adjudication does not encompass water rights to water from the Lost River or its tributaries. Project water rights to water from the Lost River and its tributaries are not subject to the Lost River decree issued in 1918 and have never been adjudicated. Until such a process is completed in a manner that binds the U.S., these water rights are unenforceable in the State of Oregon, in terms of curtailing water users with junior rights.

In general terms, a water right constitutes a legal right to appropriate water (i.e., divert from a natural waterbody and apply it to beneficial use), in accordance with applicable state law. A water right does not guarantee or assure that water will physically be there to satisfy any given water right, regardless of priority, or that other conditions or requirements do not preclude being able to divert the water that is physically available.

With respect to the Project, in certain circumstances, Reclamation may be unable to deliver water due to shortages or other legal or physical reasons. *See* Chapter 1.3.7., Endangered Species Act, and 1.3.8., Tribal Water Rights and Trust Resources. *See* also, for example, Klamath Water Users Assoc. v. Patterson, 204 F. 3d 1206 (9th Cir. 2000) and Kandra v. U.S., 145 F. Supp. 2d 1192 (D. Or. 2001).

1.3.3 Reclamation Water Supply Contracts

Between 1908 and 1972, Reclamation, acting through and on behalf of the Secretary, entered into over 150 perpetual contracts with district entities and individual landowners to provide water from the Project for irrigation and related purposes, in exchange for payment of Project costs and other conditions. In total, Reclamation's perpetual contracts for water from the Project (UKL, Klamath and Lost rivers, Clear Lake and Gerber reservoirs) cover 204,239 irrigable acres, including portions of Lower Klamath and Tule Lake NWRs. Note that there are portions of the Project that are not served under a perpetual water contract (see Chapter 1.3.4. Temporary Water Contracts).

Water supply contracts on the Project fall into one of three categories. In some cases, these contracts encompass lands for which the owners claimed non-federal water rights that predated the Project. Those types of contracts are generally called "settlement contracts." In other situations, Reclamation only agreed to deliver water to a specified point, and the contracting entity or individual was then responsible for constructing and operating the non-federal facilities necessary to convey the water to its intended place of use. Those types of contracts are generally called "Warren Act contracts." Lastly, in some cases Reclamation constructed all the works necessary to deliver the water to its intended place of use, in which case the contracts are called "repayment contracts." All three types of contracts are included in the general term "water supply contracts."

Some of Reclamation's water supply contracts specify a maximum volume of water to be provided on an annual basis (e.g., 2.0 or 2.5 AF per irrigable acre), whereas other contracts only limit the volume to be provided to the requirements of beneficial irrigation use (which in some cases is defined by state law, such as the 3.5 AF per irrigable acre on-field duty established in the ACFFOD).

Some water supply contracts do not specify or otherwise limit the sources of water Reclamation is obligated to provide water from. Most notably, Reclamation has at certain times in the past

made water available from Clear Lake and Gerber reservoirs to satisfy irrigation needs within Tulelake Irrigation District (TID) and Klamath Irrigation District (KID).

Some water supply contracts establish different contractual priorities to Project water. In these cases, Project water may be available to one contractor when it is not otherwise available to another. Reclamation generally notifies Project contractors by letter and phone if water is temporarily unavailable due to a shortage in the available supply.

In some cases, in addition to providing for a water supply, Reclamation's contracts provide for district entities to operate and maintain specified Project facilities. Districts with such contracts include KID, TID, and Langell Valley Irrigation District (LVID). In operating Project facilities, these districts are obligated to perform delivery and drainage services to lands outside their respective district service areas. For example, KID operates Project facilities that provide irrigation and drainage service to eight other district entities and hundreds of individual landowners under separate contracts with Reclamation for water from UKL and the Klamath River.

1.3.4 Temporary Water Contracts

On a year to year basis, Reclamation and two districts within the Project (KID and TID) enter into contracts or agreements to temporarily provide water to lands not covered by perpetual repayment contracts. Water is generally only available under such temporary water contracts to the extent there is water in excess of the needs of water users served under perpetual water supply contracts. Project water is delivered to lands covered under temporary contracts through the existing Project facilities.

In recent years, Reclamation has limited the availability of temporary water contracts to private lands capable of receiving water from the P Canal system, which conveys excess water from the Tule Lake Sumps that is pumped from Tule Lake Sump 1A (TLS1A) to the Lower Klamath Lake area via Pumping Plant D. There are currently approximately 2,900 acres of privately-owned land that can receive water from the P Canal system. In addition to private lands, turnouts on the P Canal system also deliver water to lands within or administered as part of Lower Klamath NWR. If not delivered through a turnout, water in the P Canal system is discharged into units of Lower Klamath NWR.

The acreage served by KID and TID under temporary water contracts varies but is approximately 2,000 acres combined. Note that in addition to a contract or agreement for water with either Reclamation, KID, or TID, lands using Project water from UKL and the Klamath River must be within the current place of use identified in the ACFFOD, except in the case of a temporary water right transfer approved by the State of Oregon in accordance with Oregon Senate Bill 206 (2015).

1.3.5 Project - Power Contracts

In 1917, the U.S. entered into a contract with California Oregon Power Company (Copco) for the construction and operation of the LRD, at the outlet of UKL. Pursuant to the 1917 contract, the U.S. holds title (ownership) to the LRD. In 1956, the Federal Energy Regulatory Commission (FERC) licensed Copco's "Project 2082" subject to the condition of extension of the 1917 contract for an additional 50 years, to 2006. Project 2082 consisted of Copco's construction and

operation of seven hydroelectric developments on the Klamath River, totaling 169 megawatts: (1) East Side and (2) West Side hydroelectric facilities on the Link River, (3) Keno Dam (non-generating), (4) J.C. Boyle Dam, (5) Copco No. 1 Dam, (6) Copco No. 2 Dam, (7) and Iron Gate Dam (IGD). Under the 1956 contract, Copco operated and maintained LRD and sold power at low fixed rates to designated irrigation loads within and above the Project. Copco also, pursuant to the 1956 contract and subject to the irrigation needs of the Project, set and maintained the level of UKL and Klamath River flows to facilitate power generation at Copco hydroelectric facilities.

From 1921 until 1997, Copco (now PacifiCorp) controlled UKL elevations and Klamath River flows downstream for power generation purposes subject to Project irrigation needs. In 1997, a letter agreement was signed, amending the 1956 contract to allow PacifiCorp to continue to be responsible for the daily operations and maintenance procedures at LRD and to provide power to irrigation lands, but recognizing Reclamation's responsibility for specifying Klamath River flows and UKL elevations through LRD, as it is Reclamation's primary point of control for Klamath River flows.

The 1956 contract expired in 2006. As a result, irrigation and drainage power rates paid by Project irrigators have increased up to twenty-fold to full retail tariffs. Reclamation and PacifiCorp amended the 1956 contract to continue PacifiCorp's O&M of LRD.

Currently, PacifiCorp's February 16, 2012, Interim Operations Habitat Conservation Plan (HCP) and subsequent Incidental Take Statement issued by NMFS requires PacifiCorp to operate IGD, located 63 miles below LRD, in accordance with any required flow releases identified in a BiOp resulting from Reclamation's current or future ESA section 7 consultations.

In March 2014, PacifiCorp stopped operating East Side and West Side power plants on the Link River for power generation. Water continues to be routed through these power plant facilities to comply with water delivery contracts and to slow the deterioration of the historic wooden flume on the East Side diversion at LRD.

1.3.6 National Wildlife Refuges

The Upper Klamath, Lower Klamath, Tule Lake, and Clear Lake NWRs are adjacent to or within the Project service area and are affected by Project operations. These refuges were established by various executive orders starting in 1908. The USFWS manages the refuges, as part of the Klamath Basin Refuge Complex, under the Migratory Bird Treaty Act (codified as 16 U.S.C. 703-712, 1918), NWR System Administration Act of 1966 (16 U.S.C. 668dd-668ee, 1966), NWR System Improvement Act (Pub. L. 105-57, 111 Stat. 1252-1260), the 1964 Kuchel Act (Pub. L. 88-567) (Kuchel Act; described below), and other laws pertaining to the NWR System.

These refuges support numerous fish and wildlife species and provide habitat and resources for migratory birds of the Pacific Flyway. Approximately 80 percent of the migrating waterfowl on the Pacific Flyway come through the Klamath Basin on both spring and fall migrations. During the peak of the migration, there are up to one million birds in the Klamath Basin Refuge Complex, primarily in Lower Klamath and Tule Lake NWRs.

Project operations make water available for use on the refuges, and water within the refuges is commonly used for both irrigation and fish and wildlife purposes. *See* Chapter 1.3.2., Project Water Rights, regarding the various water rights appurtenant to lands in Lower Klamath and Tule Lake NWRs.

Operationally, Lower Klamath NWR can receive Project water from UKL and the Klamath River, as well as water from the Tule Lake sumps, which is conveyed through Sheepy Ridge via the Tule Lake Tunnel. Tule Lake NWR can receive Project water from irrigation return flows, which are stored in the Tule Lake sumps; however, when irrigation demand is high, stored water from UKL (diverted at the Lost River Diversion Channel (LRDC) and released through Station 48) may be used to meet associated demands within the refuge. Tule Lake NWR can also utilize water from natural flow in the Lost River. In some instances, stored water from Clear Lake Reservoir has been released to support irrigation operations within TID, including Tule Lake NWR.

Note that all of Tule Lake NWR is served under Reclamation's water supply contract with TID (Contract No. 14-06-200-5954, dated September 10, 1956), which provides for the district to provide delivery and drainage services to these lands through Project facilities for which the O&M is transferred to TID. The portion of Lower Klamath NWR in Oregon, comprising approximately 5,600 acres, is served under the water supply contract between Reclamation and Klamath Drainage District (KDD) (Contract No. Ilr-402c, dated April 28, 1943). In addition, the USFWS has a separate agreement with KDD, dated May 25, 1940, for use of the Ady Canal to deliver water to the portion of Lower Klamath NWR in California.

In connection with Upper Klamath NWR, the USFWS manages two federally-acquired parcels adjacent to the NWR (Agency Lake and Barnes Ranch) with associated water rights. In 2017, USFWS applied to OWRD to temporarily transfer the water rights from the Agency Lake and Barnes Ranch properties to Lower Klamath NWR through the 2021 irrigation season. OWRD approved this application, designated as number T-12642, by order dated August 2, 2017. Following 2021, Reclamation anticipates that USFWS will likely apply to extend the temporary transfer or to make it permanent. The USFWS temporary water right transfer from the Agency Lake and Barnes Ranch properties is not part of Reclamation's PA, though it is considered within the environmental baseline and accounted for in anticipated operations as described in the PA.

1.3.6.1 Refuge Agricultural Lands

Portions of Lower Klamath and Tule Lake NWRs are also used for agricultural purposes and are administered through either Reclamation's agricultural leasing program or the USFWS cooperative farming program. In Lower Klamath NWR, approximately 26,000 acres are used for the production of small grains, grass hay, and grazing (though only 10,000 acres can be irrigated in any year under the ACFFOD). In Tule Lake NWR, approximately 17,000 acres are utilized for the production of small grains, alfalfa, potatoes and onions.

When the Project was authorized in 1905, lands uncovered by draining Lower Klamath and Tule lakes were intended to be homesteaded and receive irrigation water from the Project pursuant to Reclamation laws. From 1910 to the early 1950s, Reclamation planned and constructed Project facilities for this objective. In the 1960s, Congress and interested stakeholders debated whether

lands within Lower Klamath and Tule Lake NWRs should be homesteaded or instead set aside for refuge purposes. This controversy ultimately led to passage of the Kuchel Act (Pub. L. 88-567) in 1964.

The Kuchel Act provided that all lands within Tule Lake, Lower Klamath, Upper Klamath, and Clear Lake NWRs "are hereby dedicated to wildlife conservation," and that homesteading of these lands was discontinued, and these lands were to be administered by the Secretary "for the major purpose of waterfowl management, but with full consideration to optimum agricultural use that is consistent therewith." Further Congress directed that the Secretary was to "continue the present pattern of leasing" refuge lands, "consistent with proper waterfowl management." In 1977, Congress amended the NWR System Administration Act of 1966 (Pub. L. 94-223) to provide, in part, that "all lands, waters, and interests therein administered by the Secretary [of the Interior] as wildlife refuges … shall be administered by the Secretary through [USFWS]…." Pursuant to these two laws, Reclamation and USFWS entered in a cooperative agreement in 1977 (USFWS and Reclamation 1977) relating to the administration of Tule Lake, Lower Klamath, and Clear Lake NWRs. This agreement provided for Reclamation to continue administering the leasing program for refuge lands, in consultation and subject to the approval of the USFWS.

In accordance with the Cooperative Agreement of 1977, Reclamation currently administers 15,000 acres in Tule Lake NWR and 5,600 acres in Lower Klamath NWR under annual lease contracts. Current lease contracts commonly give the lessee the option to renew the lease for up to five years. The terms of these contracts vary based on location and are regularly updated to reflect current conditions and refuge needs. The remainder of the agricultural lands within the refuges, namely 2,500 acres in Tule Lake and 20,000 acres Lower Klamath NWR, are managed by the USFWS as part of its cooperative farming program.

1.3.7 Endangered Species Act

The ESA requires every federal agency to ensure that any discretionary action it authorizes, funds, or carries out is not likely to jeopardize the continued existence of any endangered or threatened species or destroy or adversely modify its critical habitat (*see* Endangered Species Act of 1973, 16 U.S.C. 1536(a)(2); USFWS and NMFS 2018, 50 CFR 402.03). To ensure compliance with those mandates, the ESA's implementing regulations outline a detailed process that requires federal agencies to consult with USFWS or NMFS, or both, depending on the species involved, on such actions if they "may affect" listed species and/or critical habitat. Among other things, the consultation analyzes the potential impacts of a PA on ESA-listed species and their critical habitat. A federal agency prepares a BA to determine whether formal consultation or a conference is necessary. A BA evaluates the potential effects of the action on listed and proposed species and designated and proposed critical habitat and determines whether any such species or habitat are likely to be adversely affected by the action (USFWS 2018, 50 CFR 402.12). Reclamation has prepared this BA accordingly.

For the purposes of this BA, impacts to listed species are analyzed with respect to: (1) storage and release or the delivery of water; and (2) the O&M activities necessary to maintain Project facilities to ensure long-term functioning and operation.

1.3.8 Tribal Water Rights and Trust Resources

There are seven federally recognized Indian Tribes in the Klamath Basin including The Klamath Tribes in Oregon (which include the Klamath, Modoc, and Yahooskin Tribes; collectively The Klamath Tribes), and the Yurok Tribe, the Karuk Tribe, the Hoopa Valley Tribe, and the Quartz Valley Tribe, and the Resighini Rancheria in California. Reclamation has a trust responsibility, as a federal agency, to protect tribal trust resources of three of the seven federally recognized tribes: The Yurok, Hoopa Valley, and The Klamath Tribes.

Based on the treaty between the U.S. and The Klamath Tribes, dated October 14, 1864, the Klamath Tribes and the U.S. Bureau of Indian Affairs (BIA) have claimed federally-reserved water rights to support hunting, fishing, and gathering by The Klamath Tribes within their former reservation boundaries. In 2013, the State of Oregon issued the ACFFOD, which identifies specific instream flows in tributaries to UKL within the boundaries of the former Klamath Indian Reservation. The ACFFOD also recognizes a water right in UKL, to maintain water surface at various elevations during different times of the year. Under the ACFFOD, these water rights are held by the BIA, on behalf of The Klamath Tribes, and have a priority date of "time immemorial," making them prior ("senior") to all other water rights recognized in the ACFFOD.

A stipulated agreement between the U.S., The Klamath Tribes, and Project water users provides that the water right for minimum water surface levels in UKL will not be exercised against any water rights prior to August 9, 1908. The stipulated agreement is valid until the judicial review of the Klamath Basin General Stream Adjudication within the Klamath County Circuit Court is complete. As discussed further in Chapter 1.3.2., the ACFFOD is subject to ongoing judicial review, but is still currently enforceable absent a petition to a court to stay enforcement of all or portions of the ACFFOD during this legal process. The Klamath Tribes, through the BIA, have made a call to enforce some or all of the water rights for instream flows in tributaries to UKL, at varying levels, every year since issuance of the ACFFOD in 2013.

The Yurok and Hoopa Valley Tribes have Federal Indian reserved fishing rights to take anadromous fish within their reservations in California. These rights were secured to the Yurok and Hoopa Valley Indians by a series of nineteenth century executive orders. These executive orders also reserved rights to an instream flow of water sufficient to protect the Yurok and Hoopa Valley tribes' rights to take fish within their reservations. These rights were vested at the latest in 1891 and perhaps as early as 1855. (*See* U.S. v. Adair, supra; Arizona v. California, 373 U.S. 546, 600 [1963]; U.S. v. Winans, 198 U.S. 371 [1905].)

1.4 Action Area

The Action Area is generally defined by the PA and those areas directly and indirectly affected by that PA (USFWS 2018, 50 CFR 402.02), relative to any federally-listed species and/or critical habitat or those species proposed for listing. For suckers, the action area includes UKL, the Lost River Basin from Clear Lake and Gerber reservoirs downstream to Tule Lake, all other areas within the boundaries of the Project, and the Klamath River between Link River and Keno Dam. For coho salmon, the action area includes the area within the boundaries of the Project and the Klamath River from UKL to the mouth of the river at Klamath, California. The Action Area specific to the Southern Resident killer whale (SRKW) extends from the mouth of the Klamath

River out into the Pacific Ocean where SRKW feed on concentrations of adult Chinook salmon (*see* p 9 for more detail).

1.5 Species Considered

The federally-listed species that may be affected by the PA and therefore considered in this document were identified in coordination with the Services. The species considered were confirmed through correspondence Reclamation conducted with the Services in February 2020. As shown in Appendix 1B, Reclamation sent and received concurrence on specific species within the Action Area and critical habitat under the jurisdiction of either the USFWS or NMFS.

Table 1-1 lists the endangered and threatened species that are known to, or, are suspected to occur within the Action Area that may be affected by the PA and which are considered in this document. Table 1-2 lists the endangered and threatened species that are known to, or, are suspected to occur within the Action Area for which Reclamation has determined the Project has no effect upon. As such, the species identified in Table 1-2 will not be discussed further in this document.

Table 1-1. Endangered and threatened species that are known to, or are suspected to occur within the Action Area that may be affected by the Proposed Action and which are considered in this document in Chapter 7 (Lost River and shortnose suckers), Chapter 8 (Southern Oregon Northern California Coast coho salmon), Chapter 9 (Southern Resident killer whale Distinct Population Segment), and Chapter 10 (North American green sturgeon Southern Distinct Population Segment and Pacific eulachon Southern Distinct Population Segment).

Phylum	Species Common Name	Species Scientific Name	ESA Status	Critical Habitat Designation
Fish	Lost River sucker	*Deltistes luxatus*	Endangered	Designated
Fish	Shortnose sucker	*Chasmistes brevirostris*	Endangered	Designated
Fish	Southern Oregon Northern California Coast coho salmon	*Oncorhynchus kisutch*	Threatened	Designated
Fish	North American green sturgeon (Southern Distinct Population Segment)	*Acipenser medirostris*	Threatened	Designated
Fish	Pacific eulachon (Southern Distinct Population Segment)	*Thaleichthys pacificus*	Threatened	Designated
Mammal	Southern Resident killer whale (Distinct Population Segment)	*Orcinus orca*	Endangered	Designated

Table 1-2. Endangered, threatened, and proposed species that are known or are suspected to occur within the Action Area for which the Bureau of Reclamation has determined the Klamath Project has no effect upon. The species denoted with an asterisk (*) will be analyzed while the remainder of the species will NOT be analyzed in this document[3].

Phylum	Species Common Name	Species Scientific Name	ESA Status	Critical Habitat Designation
Mammal	Gray wolf	*Canis lupus*	Endangered	None
Mammal	North American Wolverine	*Gulo gulo luscus*	Proposed	n/a
Mammal	Fisher	*Pekiana pennant*	Proposed	n/a
Plant	Applegate's milk-vetch*	*Astragalus applegatei*	Endangered	None
Plant	Greene's tuctoria	*Tuctoria greenei*	Endangered	Designated
Bird	Northern spotted owl	*Strix occidentalis caurina*	Threatened	Designated
Bird	Yellow-billed cuckoo (Western Distinct Population Segment)	*Coccyzus americanus occidentalis*	Threatened	Proposed
Fish	Bull trout*	*Salvelinus confluentus*	Threatened	Designated
Amphibian	Oregon spotted frog*	*Rana pretiosa*	Threatened	Designated
Plant	Slender Orcutt grass	*Orcuttia tenuis*	Threatened	Designated
Invertebrate	Shasta crayfish	*Pacifastacus fortis*	Endangered	None
Plant	Yreka phlox	*Phlox hirsuta*	Endangered	None
Plant	Gentner's fritillary	*Fritillaria gentneri*	Endangered	Designated
Amphibian	California red-legged frog	*Rana aurora draytonii*	Threatened	Designated

[3] Note: Further discussion on Reclamation's determination to omit these species from further consideration in this BA is provided in Part 10.

2 Consultation History

On July 18, 1988, the USFWS published a final rule designating LRS and SNS as endangered species, which implemented protection provided by the ESA of 1973, as amended. Reclamation began consultations the next year on the effects of aquatic herbicide use within the Project on these species. On August 14, 1991, Reclamation completed the first consultation on the effects of Project operations on all federally-listed species. On January 6, 1992, Reclamation finished another consultation, specific to LRS and SNS. On December 11, 2012, the USFWS published a final rule designating critical habitat for both suckers. The designation included two critical habitat units for each species. Additional consultations have occurred since then, the most recent being in March 2019 (Table 2-1).

On May 6, 1997, NMFS listed the SONCC coho salmon Evolutionarily Significant Unit (ESU) as threatened. NMFS designated critical habitat for the SONCC coho population on May 5, 1999. On March 9, 1999, Reclamation requested formal section 7 consultation under the ESA on the effects of Project operations on SONCC coho salmon. On July 12, 1999, NMFS issued a final BiOp (effective through March 2000) which concluded that the proposed one-year operation of the Project was not likely to jeopardize the continued existence of SONCC coho salmon or adversely modify designated critical habitat. Since 1999, NMFS and Reclamation have conducted six section 7 consultations regarding the potential effects of Reclamation's proposed Project operations on SONCC coho salmon and its designated critical habitat (1999, 2001, 2002, and 2010, 2013, 2019). In 2001 and early 2002, a series of consultations were completed with NMFS and USFWS, which resulted in the curtailment of Project deliveries in 2001. In May 2002, consultations with the Services covering Project operations into 2012 were completed.

In October 2007, Reclamation initiated consultations with both Services, related to Project operations between 2008 and 2018. On April 2, 2008, USFWS issued a final BiOp addressing Project operations through 2018. USFWS' 2008 BiOp concluded that the Project was not likely to jeopardize the continued existence of the endangered suckers or to adversely modify their critical habitat. On March 15, 2010, NMFS issued a final BiOp, covering the time period 2010 to 2018, which concluded Reclamation's PA was likely to jeopardize the continued existence of SONCC coho salmon and likely to result in the destruction or adverse modification of its designated critical habitat.

In December 2012, Reclamation formally reinitiated consultation with the Services, pursuant to section 7(a)(2) of the ESA, related to the potential effects of proposed Project operations between April 1, 2013 and March 31, 2023 on federally-listed threatened and endangered species. Reclamation's BA concluded that the PA was likely to adversely affect the LRS and SNS and SONCC coho salmon and their critical habitat. The Services final joint BiOp was issued in May 2013 and concluded that the continued operation of the Project for a 10-year term was not likely to jeopardize the continued existence of suckers or the SONCC coho salmon ESU, nor result in the destruction or adverse modification of their critical habitat.

In December 2018, Reclamation formally reinitated consultation with both Services for operation of the Project between 2019 and 2029. The term of the 2018 PA was later amended on February 15, 2019, to water years 2019 through 2024. On March 29, 2019, the Services provided separate, but coordinated 2019 BiOps. The USFWS 2019 BiOp concluded that Reclamation's 2018 PA was not likely to jeopardize the continued existence of the LRS and SNS and is not likely to result in the destruction or adverse modification of their critical habitat. The NMFS 2019 BiOp concluded that Reclamation's 2018 PA was not likely to jeopardize the continued existence of the SONCC coho salmon ESU, or the SRKW Distinct Population Segment (DPS), or destroy or adversely modify designated critical habitat for the SONCC coho salmon ESU. NMFS also concluded that the 2018 PA was not likely to adversely affect green sturgeon, eulachon, or designated critical habitat for eulachon.

In compliance with section 305(b) of the Magnuson-Stevens Fishery Conservation and Management Act, Reclamation conducted an essential fish habitat (EFH) assessment which analyzed Chinook salmon (*Oncorhynchus tshawytscha*) and SONCC coho salmon. Upon review, NMFS concluded that Reclamation's 2018 PA would adversely affect SONCC coho and Chinook salmon EFH. NMFS provided conservation recommendations that would protect, by avoiding or minimizing the adverse effects described above, the mainstem Klamath River and tributaries designated as EFH for Pacific Coast salmon. Reclamation reviewed NMFS's EFH assessment response document and associated conservation recommendations and provided a written response to NMFS (pursuant to 50 CFR S 600.920(k)(l)) on April 25, 2019.

As described in Chapter 1.1, Reclamation reinitiated consultation with both Services (50 CFR 402.16) on November 13, 2019, because new information identified in Fall 2019 revealed effects on Southern Oregon Northern California Coast (SONCC) coho that had not been considered in Reclamation's Modified Biological Assessment nor the 2019 NMFS BiOp. The current reinitiated consultation and focus on this BA will analyze Reclamation's proposal to modify the water management approach for Project operations to address this new information as related to the effects of Project operations on listed species and/or their designated critical habitat. The table below summarizes the history of ESA consultations undertaken by Reclamation since 1988.

Table 2-1. History of Endangered Species Act Consultations Undertaken by the Bureau of Reclamation since 1988.

Date	USFWS	NMFS	Subject of Consultation	Determination
7/18/1988	X		Endangered and Threatened Wildlife and Plants; Determination of Endangered Status for the Lost River Sucker and Shortnose Sucker.	Endangered status was determined for the Lost River sucker and shortnose sucker. This rule implemented listing and protection provided by Endangered Species Act.
6/14/1989 (superseded by 1995 BiOp)	X		Formal Endangered Species Consultation on the Use of Acrolein (Magnicide H) in Canals and Drainage Ditches Within the Project Service Area in Klamath County, Oregon, and Siskiyou County, California.	The continued use of acrolein in Klamath Project canals and drainage ditches, as traditionally applied, is likely to jeopardize the continued existence of the shortnose sucker and Lost River sucker.

Date	USFWS	NMFS	Subject of Consultation	Determination
8/14/1991 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the 1991 Operation of the Project on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The proposed 1991 drought operation of the Klamath Project was likely to jeopardize the continued existence of Lost River sucker and shortnose sucker but would not jeopardize the continued existence of the bald eagle. The American peregrine falcon was not likely to be affected and was not addressed in the consultation.
1/6/1992 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the 1992 Operation of the Klamath Project on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The operation of the Project was not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker or the bald eagle. The American peregrine falcon was not likely to be affected and was not addressed in the consultation.
3/27/1992 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Effects of the 1992 Operation of the Klamath Project on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The proposed 1992 operation of the Klamath Project was likely to jeopardize the continued existence of the Lost River sucker and shortnose, but not likely to jeopardize the continued existence of the bald eagles. The American peregrine falcon was not likely to be affected and was not addressed in the consultation.
5/1/1992 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Effects of the 1992 Operation of the Klamath Project at Clear Lake Reservoir on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The proposed 1992 operation of the Klamath Project at Clear Lake Reservoir was likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker, but not likely to jeopardize bald eagles. The American peregrine falcon was not likely to be affected and was not addressed in the consultation.
7/22/1992 (superseded by 2008 BiOp)	X		Formal Consultation on the Effects of the Long-Term Operation of the Klamath Project on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The long-term operation of the Project was likely to jeopardize the continued existence of the LRS and SNS, but not likely to jeopardize the continued existence of the bald eagle. The American peregrine falcon was not likely to be affected and was not addressed in the consultation.

Date	USFWS	NMFS	Subject of Consultation	Determination
2/22/1993 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the BiOp for the Long-Term Operation of the Project – Upper Klamath Lake Operations.	One-year modification of lake elevation. The Bureau of Reclamation was released from the March 1, 1993 requirement of a maintaining a 4,141-foot surface elevation for 1993 only.
8/11/1994 (superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Long-Term Operation of the Project, with Special Reference to Operations at Clear Lake Reservoir on the Lost River Sucker and Shortnose Sucker, Bald Eagle, and American Peregrine Falcon.	The proposed long-term operation of the Klamath Project was likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker, but not likely to jeopardize the continued existence of the bald eagle. The American peregrine falcon was not likely to be affected and was not addressed in the consultation. Reasonable and Prudent Alternatives were specified in the Biological Opinion for Clear Lake and a new minimum elevation for Clear Lake Reservoir was established.
2/9/1995	X		Final Biological Opinion on the Use of Pesticides and Fertilizers on Federal Lease Lands and Acrolein and Herbicide Use on the Klamath Project Rights-of-Way (Reinitiation of Consultation on the Use of Acrolein for Aquatic Weed Control in Reclamation Canals and Drains).	The use of pesticides and fertilizers on federal lease lands and acrolein and herbicide use on the Klamath Project rights-of way was not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and may affect, but not likely to adversely affect the bald eagle, or Applegate's milk-vetch, and not likely to affect the American peregrine falcon.
2/2/1996 (not superseded by 2008 BiOp)	X		Reinitiation of Formal Consultation on the Use of Pesticides and Fertilizers on Federal Lease Lands and Acrolein and Herbicide Use on the Klamath Project Rights-of-Way Located on the Klamath Project.	Use of Metam-Sodium, Lorsban, Pounce, and Disyston on Klamath Project lands as described under the description of the Proposed Action was not likely to jeopardize the continued existence of the bald eagle, American peregrine falcon, Lost River sucker and shortnose sucker, or adversely modify the Lost River sucker and shortnose sucker proposed critical habitat.

Date	USFWS	NMFS	Subject of Consultation	Determination
7/15/1996 (superseded by 2008 BiOp)	X		Formal Consultation on PacifiCorp and The New Earth Corporation Operations, as Permitted by Reclamation, for the Lost River Sucker and Shortnose Sucker.	The Proposed Action was not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and was not likely to adversely modify or destroy proposed critical habitat.
5/6/1997		X	Endangered and Threatened Species; Threatened Status for Southern Oregon Northern California Coast Evolutionarily Significant Unite of Coho Salmon.	The Southern Oregon Northern California Coast Evolutionarily Significant Unit of coho salmon was determined to be a “species” under the Endangered Species Act of 1973, as amended, and was listed as threatened. Critical habitat was not designated.
4/2/1998 (superseded by 2008 BiOp)	X		Amendment to the 1992 Biological Opinion Dealing with A-Canal Sucker Entrainment Reduction.	The Bureau of Reclamation was granted a 5-year extension (to 2002) to implement entrainment reduction measures for all life stages of Lost River sucker and shortnose sucker into A-canal. The date for completion of A Canal screen was extended until 2002. Not likely to jeopardize species.
4/20/1998	X		Amendment to the 1992 Biological Opinion to Cover Operation of Agency Lake Ranch Impoundment.	The action was not likely to jeopardize the continued existence of Lost Ricer sucker and shortnose sucker.
4/21/1998 (superseded by 2008 BiOp)	X		Amendments to the August 27, 1996, Biological Opinion on PacifiCorp and New Earth Operations, as Permitted by Reclamation, for the Lost River Sucker and Shortnose Sucker.	Five amendments regarding sampling dates, report consolidation and due date extension, extension of incidental take coverage, and monitoring fulfillment. Not likely to jeopardize species.
6/2/1998		X	The Bureau of Reclamation transmitted a Biological Assessment to the National Marine Fisheries Services on 1998 Klamath Project operations and Requested Formal Consultation.	The National Marine Fisheries Service deferred consultation until the following year (1999).
7/13/1998 (superseded by 2008 BiOp)	X		An Amendment to the Revised July 22, 1992 Project Long-Term Operations Biological Opinion, Dealing with Anderson-Rose Releases. The purpose of this amendment is to adjust requirements for	The United States Fish and Wildlife Service concurred with The Bureau of Reclamations recommended Reasonable and Prudent Alternative changes. Not likely to jeopardize species.

Date	USFWS	NMFS	Subject of Consultation	Determination
			release of spawning flows from Anderson-Rose Dam on the Lost River.	
3/9/1999		X	Project operations 1999 Biological Opinion. Reclamation provided the Draft Project 1999 Annual Operations Plan Environmental Assessment and requested the National Marine Fisheries Service use the 1998 Biological Assessment as the basis for preparing the 1999 Biological Assessment.	The Bureau of Reclamation requested formal consultation with the National Marine Fisheries Service regarding the 1999 Annual Operations Plan.
4/15/1999	X		Amendment to the 1996 Biological Opinion. Incidental Take of Lost River Sucker and Shortnose Sucker Owing to Lowered Water Levels in Upper Klamath Lake by a Change in Operation of Link River Dam to Reduce Risk of Flooding During the Spring 1999 Runoff Period.	The Service concurred with Reclamation's determinations of "may affect, likely to adversely affect," and it was determined that the action was not likely to jeopardize the continued existence of Lost River suckers and shortnose suckers.
5/5/1999		X	Designated Critical Habitat; Central California Coast and Southern Oregon Northern California Coast Coho Salmon.	Critical habitat was designated for two Evolutionarily Significant Units of coho salmon pursuant to the Endangered Species Act.
6/18/1999		X	Reclamation letter regarding Draft Biological Opinion for Project operations 1999 (Dated April 22,1999).	Reclamation reviewed draft Biological Opinion and proposed to modify Klamath Project operations described in the 3/9/1999 draft Environmental Assessment.
7/12/1999		X	National Marine Fisheries Service Biological Opinion on Klamath Project operations through March 2000.	Not likely to jeopardize Southern Oregon Northern California Coast coho salmon or adversely modify designated critical habitat.
8/18/1999	X		One-year, Emergency Amendment to the 1995 Biological Opinion, Use of Pesticides and Fertilizers on Leased Lands and Use of Acrolein in Project Canals and Drains.	The Langell Valley Irrigation District-operated canal system was exempt from the prohibitions of Section 9 of the Endangered Species Act. Incidental take covered by amendment for shortnose suckers in Langell Valley Irrigation District-operated irrigation canal system. The amendment included Reasonable and Prudent Measures to be implemented

Date	USFWS	NMFS	Subject of Consultation	Determination
				by Langell Valley Irrigation District to minimize take.
9/10/1999 (superseded by 2008 BiOp)	X		Revised Amendment to the 1992 Biological Opinion to Cover Operations and Maintenance of Agency Lake Ranch Impoundment.	Service concurred with Bureau of Reclamation's determination of "may affect, likely to adversely affect" and determined the action was not likely to jeopardize the continued existence of Lost River suckers and shortnose suckers.
4/4/2000		X	National Marine Fisheries Service letter advised the Bureau of Reclamation to request initiation of consultation pursuant to section 7(a)(2) of the Endangered Species Act on Klamath Project operations.	1999 Biological Opinion and associated Incidental Take Statement expired on 3/31/2000.
4/26/2000		X	Klamath River Flows Below Iron Gate Dam- 2000 Operation Plan-Project.	Proposed flows were both sufficient and necessary to avoid possible 7(d) foreclosures and fulfill obligation to protect Tribal trust resources.
1/22/2001		X	The Bureau of Reclamation's Biological Assessment of the Project's Continuing Operations on Southern Oregon Northern California Coast Evolutionarily Significant Unit of Coho Salmon and their Critical Habitat.	Requested initiation of formal Endangered Species Act section 7 consultation. Biological Assessment provided description of the effects on federally listed species and its designated critical habitat from on-going operation of the Klamath Project based on historic operations.
4/5/2001	X		Biological Opinion Regarding the Effects of Operation of the Bureau of Reclamation's Klamath Project on the Endangered Lost River Sucker and Shortnose Sucker, Threatened Bald Eagle, and Proposed Critical Habitat for the Lost River Sucker and Shortnose Sucker.	Likely to jeopardize the Lost River sucker and shortnose sucker and adversely modify proposed critical habitat. Not likely to jeopardize the continued existence of the bald eagle.
4/6/2001		X	2001 Biological Opinion on Ongoing Klamath Project operations.	Likely to jeopardize Southern Oregon Northern California Coast coho salmon and likely to adversely modify designated critical habitat.
4/13/2001 (superseded by 2008 BiOp)	X		Concurrence Memorandum Responding to the Bureau of Reclamation's Request to Postpone Spawning Releases	Not likely to jeopardize sucker species; United States Fish and Wildlife Service concurred with drought year assessment.

Date	USFWS	NMFS	Subject of Consultation	Determination
			at Anderson Rose Dam for 2001.	
8/22/2001 (superseded by 2008 BiOp)	X		Amendment to the April 5, 2001 Biological Opinion on Klamath Project operations to Cover Safety of Dams Modification of the Clear Lake Dam.	Not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and will not likely adversely modify proposed critical habitat.
9/12/2001 (superseded by 2008 BiOp)	X		Amendment to the April 5, 2001 Biological Opinion on Klamath Project operations to Cover Link River Topographic Survey Fish Passage Assessment.	Not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and will not likely adversely modify their proposed critical habitat.
9/19/2001	X		Amendment to the November 27, 2000 Biological Opinion for the Airport Runway Extension Project and the April 5, 2001 Biological Opinion on Klamath Project operations to Cover Salvage in the Lost River Diversion Channel and for the Station 48 Maintenance Project.	Not likely to jeopardize the continued existence of Lost River sucker and shortnose sucker and will not likely adversely modify their proposed critical habitat.
9/28/2001		X	Amendment to the April 6, 2001 Biological Opinion and Reasonable and Prudent Alternatives for Reclamation's Project operations.	Provided minimum Iron Gate Dam flows for Oct to Dec 2001.
12/28/2001		X	Amendment to the April 6, 2001 Biological Opinion and Reasonable and Prudent Alternatives for the Bureau of Reclamation’s Klamath Project operations.	Provided minimum Iron Gate Dam flows for Jan to Feb 2002.
2/27/2002	X	X	Reclamation’s Final Biological Assessment on Effects of Proposed Actions Related to Klamath Project operations (April 1, 2002-March 31, 2012).	Requested initiation of formal Endangered Species Act Section 7 consultation.
3/28/2002 (superseded by 2008 BiOp)	X		Biological/Conference Opinion Regarding the Effects of Operation of Reclamation’s Project During the Period April 1, 2002, Through May 31, 2002 on the Endangered Lost River Sucker and Shortnose Sucker, Threatened Bald Eagle, and Proposed Critical Habitat for the Lost River Sucker and Shortnose Sucker.	Not likely to jeopardize the continued existence of the Lost River Sucker and shortnose sucker or bald eagle.

Date	USFWS	NMFS	Subject of Consultation	Determination
5/16/2002		X	National Marine Fisheries Service Draft Biological Opinion on Klamath Project operations between April 1, 2002, and March 31, 2012.	Likely to jeopardize the continued existence of Southern Oregon Northern California Coast coho salmon and adversely modify critical habitat.
5/31/2002		X	Biological Opinion on Klamath Project operations and the Klamath Project's effects on the Southern Oregon Northern California Coast coho salmon.	Likely to jeopardize the continued existence of Southern Oregon Northern California Coast coho salmon and likely to adversely modify critical habitat.
5/31/2002 (superseded by 2008 BiOp)	X		Biological Opinion on the 10-year (June 1, 2002, through March 31, 2012) Operation Plan for the Klamath Project.	Likely to jeopardize the continued existence of the Lost Ricer sucker and shortnose sucker, and in part, the adverse modification of their proposed critical habitat. Not likely to jeopardize the continued existence of the bald eagle.
7/24/2002 (not superseded by 2008 BiOp)	X		Biological/Conference Opinion Regarding the Effects of Construction of the A-Canal Fish Screen and Link River Fish Ladder, Reclamation – Project and its Effect on the Endangered Lost River Sucker and Shortnose Sucker and Proposed Critical Habitat for Lost River Sucker and Shortnose Sucker.	Not likely to jeopardize the continued existence of shortnose sucker and Lost River sucker.
3/4/2003 (superseded by 2008 BiOp)	X		Amendment to the 2002 Biological Opinion on the Effects of the 10-Year Operations Plan for the Klamath Project as it Relates to Operation of Clear Lake and Gerber Reservoir.	No effects to Lost River sucker and shortnose sucker different from those analyzed in the 2002 Biological Opinion.
5/31/2007 (not superseded by 2008 BiOp)	X		Biological Opinion Regarding the Effects on Listed Species from Implementation of the Pesticide Use Program on Federal Leased lands, Tule Lake and Lower Klamath National Wildlife Refuges, Klamath County, Oregon, and Siskiyou and Modoc Counties, California.	Not likely to adversely affect the bald eagle, Lost River sucker and shortnose sucker, and therefore will not likely jeopardize their continued existence.
10/1/2007	X		The Bureau of Reclamation's Biological Assessment on The Effects of the Proposed Action to Operate the Klamath Project	May affect, and is likely to adversely affect coho salmon, Lost River sucker and shortnose sucker, and may adversely modify critical

Date	USFWS	NMFS	Subject of Consultation	Determination
			from April 1, 2008 to March 31, 2018.	habitat for coho salmon, Lost River sucker and shortnose sucker. No effect on Applegate's milk-vetch.
4/2/2008	X		Biological/Conference Opinion Regarding the Effects of the Bureau of Reclamation's Proposed 10-Year Operation Plan (April 1, 2008- March 21, 2018) for the Project and its Effects on Lost River sucker and shortnose sucker.	Not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and is not likely to destroy or adversely modify proposed critical habitat for these species.
3/15/2010		X	National Marine Fisheries Service Biological Opinion on Operation of the Klamath Project Between 2010 and 2018.	Likely to jeopardize the continued existence of Southern Oregon Northern California Coast coho salmon and is likely to destroy or adversely modify Southern Oregon Northern California Coast coho salmon designated critical habitat.
12/11/2012	X		Endangered and Threatened Wildlife and Plants; Designation of Critical Habitat for Lost River Sucker and Shortnose Sucker.	Two units of critical habitat for the Lost River sucker and shortnose sucker were designated under Endangered Species Act.
5/31/2013	X	X	Joint Biological Opinion on the Effects of Proposed Klamath Project operations from May 31, 2013, through March 31, 2023, on Five Federally Listed Threatened and Endangered Species.	May affect but is not likely to adversely affect the southern Distinct Population Segment of green sturgeon, the southern Distinct Population Segment of Pacific eulachon, or both their critical habitat. Not likely to jeopardize the continued existence of the Southern Oregon Northern California Coast coho salmon evolutionarily significant unit, the Lost River sucker and shortnose sucker, nor likely to result in the destruction or adverse modification of their critical habitat.

Date	USFWS	NMFS	Subject of Consultation	Determination
3/29/2019		X	Endangered Species Act Section 7(a)(2) Biological Opinion, and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Response for Klamath Project Operations from April 1, 2019 through March 31, 2024	Not likely to jeopardize the continued existence of the Southern Oregon Northern California Coast coho salmon Evolutionarily Significant Unit, or the Southern Resident killer whale Distinct Population Segment, or destroy or adversely modify designated critical habitat for the Southern Oregon Northern California Coast coho salmon Evolutionarily Significant Unit. Not likely to adversely affect green sturgeon, eulachon, or designated critical habitat for eulachon. Regarding MSA, the National Marine Fisheries Service concluded the Proposed Action would adversely affect coho salmon and Chinook salmon Essential Fish Habitat and provided conservation recommendations that would protect, by avoiding or minimizing the adverse effects described above, the mainstem Klamath River and tributaries designated as Essential Fish Habitat for Pacific Coast salmon.
3/29/2019	X		Biological Opinion on the Effects of Proposed Klamath Project Operations from April 1, 2019, through March 31, 2024, on the Lost River Sucker and the Shortnose Sucker	Not likely to jeopardize the continued existence of the Lost River sucker and shortnose sucker and is not likely to result in the destruction or adverse modification of their critical habitat.

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3 Analytical Approach

3.1 Analytical Approach

Project operations have been continually adjusted to comply with ESA requirements since 1988, when the first consultations (for SNS and LRS) occurred. Extensive coordination has occurred in development of the PA and this BA. The coordination has included Agency Coordination Team meetings, Tri-agency[4] Hydrology Team meetings, Tri-agency Biology Team meetings, and other meetings between Reclamation and the Services scheduled since October 2019. The general analytical approach used by Reclamation in the development of this BA has been framed by this collaboration and by the factors discussed below.

3.2 Legal, Analytical, and Ecological Framework

Pursuant to section 7(a)(2) of the ESA, federal agencies must ensure that their activities are not likely to jeopardize the continued existence of any listed species or result in the destruction or adverse modification of critical habitat. The analytical framework associated with this BA is outlined below. The ecological framework within the Effects Analysis for suckers is based on lake elevations and habitat, whereas the Effects Analysis for coho salmon are based upon river flows below IGD. Therefore, the analyses have been conducted differently and the ecological approach is detailed in Chapters 7 and 8. Additionally, the effects analysis for SRKW is based on a suite of population modeling and other analytic tools and is detailed in Chapter 9.

Section 7(a)(2) of the ESA and implementing regulation 50 CFR 402.14(c) detail the following to be described in BAs:

1. The purpose of the action;
2. The duration and timing of the action;
3. The location of the action;
4. The specific components of the action and how they will be carried out;
5. Maps, drawings, blueprints, or similar schematics of the action; and
6. Any other available information related to the nature and scope of the PA relevant to its effects on listed species or designated critical habitat.

The Project has a unique mix of factors that are considered in operational decisions, even if not directly related to a section 7 consultation, including:

Limited Carry-Over Water Storage Capacity.

[4] Where the term Tri-agency is used it refers to Reclamation and the Services.

UKL, the largest Project water source, is relatively shallow and has limited storage capacity (approximately 562 thousand acre-feet; (TAF). As a result, it cannot store large quantities of spring runoff and lacks storage capabilities in wet years to carryover volumes that could help meet all water needs in subsequent dry years, unlike Clear Lake and Gerber reservoirs in the Lost River Basin.

Dependency upon Forecasted Streamflows for Water Management Decisions.
As a consequence of limited storage in UKL, Reclamation must base its various water management decisions each year on stream inflow forecasts issued by the Natural Resources Conservation Service (NRCS) between January and June. Reclamation makes water management decisions and the March 1 initial allocations between the Project, and the Klamath River (Environmental Water Account [EWA] supply) and UKL (UKL reserve) based on the March – September NRCS inflow forecast. The final forecast (generally the most accurate, but still subject to error) is released in June and can result in adjustments to the allocations made on April 1; the EWA supply and UKL reserve can be both increased or decreased with the June 1 inflow forecast, whereas Project Supply cannot decrease below the April 1 allocation with the issuance of the May and June inflow forecasts. The final determination for Project Supply is made in June and is then fixed through the end of September. It is important to note that *delivery* of the "fixed" Project Supply is not guaranteed; Reclamation retains discretion to curtail deliveries from UKL to comply with unforeseeable legal requirements and hydrologic conditions as necessary.

Multiple Legal Responsibilities. The Secretary, through Reclamation, must manage and operate the Project pursuant to various legal responsibilities, including the Reclamation Act, the Kuchel Act, ESA, and the federal trust responsibility to Indian tribes. These independent acts and mandates can have differing requirements.

A Highly Variable Natural Hydrologic System.
The Klamath Basin has demonstrated a wide range of variable water conditions, from extreme drought conditions to extreme flood flow, sometimes within the span of a couple years. Recent precipitation and stream flow trends (within the last 20 years) have been drier than the median for the Period of Record (POR; Water Years [WY] 1981 (starting on October 1, 1980 to 2019) used in this analysis, but such fairly short-term trends can, and have, reversed within the Basin making any long-term forecasting difficult. For example, Klamath Falls rain gage data from WYs 1911 to 2018 shows that the ten driest years on record were, in order, 1926, 1924, 2010, 1955, 2012, 1992, 1920, 1931,1994, and 1920. The ten wettest years, in order, were 1956, 1958, 1993, 1996, 1982, 1965, 1927, 1940, 1984, and 1952. (Most years have some missing data points, but the years 1998 to 2001, in particular, were excluded due to numerous missing data points.) The 1980's were a wetter than average decade, making the last two decades appear even drier by comparison. Reclamation believes that the POR used in this analysis contains a reasonable range of hydrologic conditions likely to be experienced over the next 4 years. If the trend in recent declining inflows continues, it could reduce available water for all resource needs in the Klamath Basin, in the manner defined by the PA.

3.3 Use of Best Available Science

The ESA requires that the action agency, in any request of formal consultation, provide "the Service with the best available scientific and commercial data available, or that can be obtained during the consultation for an adequate review of the effects that an action may have upon listed species or critical habitat" (USFWS and NMFS 2018, 50 CFR 402.14(d)). Additionally, Department Policy (305 Department Manual 3) states that "Scientific and scholarly information considered in Departmental decision making must be robust, of the highest quality, and the result of as rigorous scientific and scholarly processes as can be achieved." Finally, Reclamation has an agency-specific scientific integrity policy (CMP-P13; Reclamation 2012c) further defining required practices relating to the use of scholarly and scientific information.

Reclamation has prepared this BA using the best available scientific and commercial data available as required by law and policy. Reclamation has included references to all documentation and information that was reviewed and/or referenced in preparation of this BA.

3.4 Water Resource Integrated Modeling System

Reclamation used results generated by the Water Resource Integrated Modeling System (WRIMS) to identify the Klamath River and UKL hydrographs that are likely to occur as a result of implementing the PA. WRIMS is a generalized water resources modeling system, broadly accepted by the hydrologic community, for evaluating operational alternatives of large, complex river basins. WRIMS integrates a simulation language for flexible operational criteria specification, a linear programming solver for efficient water management decisions, and graphics capabilities for ease of use. These combined capabilities provide a comprehensive and powerful modeling tool for water resource systems simulation. Reclamation has worked closely with the Services' hydrologists to develop a WRIMS model specific to the Klamath Basin for this consultation, referred to as the Klamath Basin Planning Model (KBPM) hereafter.

Data files generated by the WRIMS model include daily modeled output. The daily modeled outputs can be summarized by week, month, or WY. For ongoing analysis, Reclamation will also use exceedance tables created by WRIMS results. Exceedance tables are developed through data analysis of historical hydrological conditions. Exceedance tables depict the probability that specific hydrologic conditions will be met or exceeded during a given time. For example, a 95 percent exceedance value would represent relatively dry conditions, because actual hydrological conditions can be expected to meet or exceed that value in 95 out of 100 years. Conversely, a 5 percent exceedance value would represent a period of unusually high precipitation, given that conditions can only be expected to meet or exceed that value in 5 years out of 100. A 50 percent exceedance value represents median hydrological conditions. It is important to note that within a WY hydrologic conditions, as represented by the exceedance value, are likely to vary between and within months.

3.5 Period of Record Hydrograph

For UKL and the area within the Project served from that source (excluding Tule Lake), the ACT recommended using October 1, 1980 to November 30, 2019 for the POR from which to run the daily time step WRIMS model. This time period, October 1, 1980 to November 30, 2019, incorporates daily inflows into UKL; including years (2013 through 2019) when the Project was being operated under the criteria identified in the 2013 BiOp and subsequent 2019 BiOps; and contains a reasonable, adequate distribution of dry, average, and wet years, including the two driest years for which complete, quality assurance/quality controlled (QA/QC'ed) data exists, 1992 and 1994. With this range of data, the WRIMS model can evaluate a particular water operation strategy across the full range of reasonably foreseeable annual precipitation and hydrologic patterns. Reclamation's analysis used WRIMS to estimate mainstem Klamath River flows at IGD and UKL elevations that would likely be realized through implementation of the PA during the POR. Reclamation considers the resulting model outputs to reflect the range of flows and lake elevations reasonably expected to occur during the 4-year period of the PA (April 1, 2020 through March 31, 2024). However, it is important to note that each year in the POR has unique hydrological and climatological characteristics that only occur in that year. While the hydrology observed in the POR captures the range of conditions, the unique sequencing and patterns of climatological and hydrological events that will occur in the future cannot be predicted. As such, unique climatological and hydrological events not captured in the POR may occur, resulting in conditions not simulated by the KBPM.

For Clear Lake and Gerber reservoirs, Reclamation identified a different POR as representative given the quality and availability of relevant hydrologic data, which differed for UKL. In arriving at the applicable POR for each reservoir, Reclamation examined all available hydrologic records. For both Clear Lake and Gerber reservoirs, Reclamation uses the POR of WY 1986 through to 2019.

While the 39-year POR used for UKL analysis purposes reflects a range of wet and dry WYs, actual conditions may deviate from the representative trend in future years, possibly due to climate change. However, there is currently a lack of reliable forecasting tools available to precisely quantify the influence of global climatic changes on local hydrologic conditions. Therefore, the effects of possible future climate change, and the associated impacts on species and hydrology, are not explicitly incorporated into the analyses.

3.6 Uncertainties and Unknowns

In any ecosystem, there are always unknowns and uncertainties. This fact is especially true of aquatic ecosystems. In the Klamath Basin, these uncertainties and unknowns exist for all federally-listed species. The following describes some of the key issues where uncertainties and unknowns exist:

3.6.1 General

1. Uncertainties exist in all models. Models are a simplification and a simulation of complex ecologic and/or hydrologic processes. All models are approximations of actual conditions, and include assumed values, or computed values that are based upon uncertain data or

information. As a result, lake elevation and river flow output should be considered an approximation of what would have occurred had the hydrologic conditions in the POR manifested while operating under this PA. Uncertainties associated with the WRIMS model (and submodels) are further discussed in Appendix 4.

2. Uncertainties exist within the underlying datasets contained within the KBPM, as is common for complex datasets. While most uncertainties are not specifically known, specific concerns have been raised regarding the accuracy of the UKL bathymetric layer utilized in the KBPM to model this PA. However, it is the best information currently available and it is unclear to what extent (if any) a revised bathymetric surface will have on the existing area capacity curves.

3. Uncertainties exist in all measurements. For example, U.S. Geological Survey (USGS) water measurement gages have some amount of error that can vary by specific gage, season, and flow rate. Estimated numbers of fish abundance, disease prevalence and mortality, and habitat preference contain inherent uncertainty. This analysis uses numbers to determine relative effect rather than absolute values. To address this uncertainty, at IGD, for example, Reclamation allows a maximum of a 5 percent reduction in flows below the minimum daily average flows at IGD, not to exceed 72 hours in duration.

3.6.2 Suckers

1. Specific reasons for the loss of juvenile suckers (of both species) during their first year in UKL are largely unknown. There is no available evidence linking this loss to Project operations.

2. Suckers are entrained at Project facilities. It is unknown whether entrainment within the Project is compensatory or additive mortality to sucker populations, particularly at UKL (A Canal), and Clear Lake and Gerber reservoirs. The Baseline and analysis sections discuss entrainment as both compensatory mortality (sucker mortality would occur even without entrainment) and additive mortality (mortality occurs as a result of entrainment) within a population. The analysis section considers entrainment, which may result in either compensatory or additive mortality within a population, an adverse effect to the entrained individual and to the population from which they are entrained or emigrate.

3. Taxonomic status of sucker species is uncertain, particularly SNS in the Lost River Basin such as Clear Lake and Gerber reservoirs. Researchers have consistently concluded that the shortnose-like suckers in both Clear Lake and Gerber reservoirs are federally-listed SNS (Scoppettone et al. 1995; Perkins and Scoppettone 1996; Barry et al. 2007c).

4. The recovery of passive integrated transponder (PIT) tags at fish-eating bird colonies in the Upper Klamath Basin indicates bird predation occurs at UKL and Clear Lake Reservoir. Factors influencing bird predation are currently unknown. Bird predation is considered in the baseline condition and Reclamation has no evidence linking this mortality to Project operations.

3.6.3 Coho Salmon

1. Little is known about juvenile coho salmon movement into, out of, and within the mainstem of the Klamath River. The analysis for this BA assumes similar movement patterns as nearby drainages, where data is available.

2. Salmonids in the Klamath Basin are exposed to a number of pathogens and diseases that can impact all life stages. Recent monitoring and synthesis suggest that a number of biotic (e.g., annelid infection rates) and abiotic (e.g., water temperature, managed flow events) factors influence infectious dose and mortality of fish, though the effect varies annually. The PA specifically includes flow management below IGD in an attempt to address identified disease issues.

3. Uncertainty exists concerning the interrelationship of hatchery produced fish with the naturally produced coho salmon when both are present in the natural environment (i.e., after the hatchery fish are released into the Klamath River). This includes the role of hatchery-produced salmon in the spread and proliferation of fish disease. The effects of hatchery operations are included as a baseline condition.

4. Marine salmon survival during ocean rearing is an uncertainty that depends on a number of interacting factors, including the abundance of prey, density of predators, the degree of intra-specific competition (including that from hatchery fish), and fisheries. The importance of these factors in turn depends on ocean conditions. Even relatively small changes in local and annual fluctuations in marine water temperatures can be related to changes in salmon survival rates.

3.6.4 Southern Resident Killer Whales

1. The diet of SRKWs in the southern part of their range is poorly known compared to their diet in the Salish Sea. The effects analysis assumes the preferred diet is similar throughout their range.

2. Marine survival, distribution, and the factors affecting them (including climate change and competing predators) are poorly known for Klamath River Chinook, estimated to be the preferred food for SRKW when in the vicinity of the Klamath River. These are variable from year to year, leading to uncertainty in actual prey availability based on smolt production alone. The SRKW effects analysis will focus on Chinook production as a relative indication of the PA's effects upon their primary food source and not attempt to define actual numbers of Chinook salmon due to the uncertainty and unknowns involved.

3. The importance of Klamath River Chinook to SRKW will vary to some degree with the health of Chinook populations throughout their range. Future coast-wide abundance is unknown, leading to uncertainty in the future significance of Klamath River Chinook. This uncertainty is considered a Baseline Condition for west coast chinook populations.

4. While the relative importance of prey availability, disturbance, and toxins to SRKW population dynamics has been modeled, there are uncertainties in how well models reflect the real world. This is an inherent uncertainty in all models, as mentioned above.

While this list of uncertainties and unknowns is not exhaustive, Reclamation has coordinated with the Services to identify these uncertainties and unknowns, given our current scientific understanding and how those uncertainties are resolved in this analysis.

3.7 Other Existing and Future Actions in the Action Area Not Included in the Environmental Baseline or Cumulative Effects

3.7.1 Klamath Agreements – Dam Removal

In 2010, representatives of numerous organizations within the Klamath River Basin negotiated with PacifiCorp, to arrive at the 2010 Klamath Hydroelectric Settlement Agreement (KHSA). The KHSA addressed the interim operations of the four PacifiCorp owned dams (i.e., JC Boyle, Copco 1 and 2, and IGD) downstream of the Project and established a framework for facilities removal. Activities undertaken as a precursor to dam removal have included establishment of the Klamath River Renewal Corporation (KRRC) as the designated Dam Removal Entity and separating the Klamath Hydroelectric Project's FERC license to isolate the four dams in preparation for their transfer to the KRRC.

Although efforts continue with dam removal currently slated to occur in 2022 and 2023, this activity is under the jurisdiction of FERC and FERC will consult with the appropriate fisheries agencies under section 7 of the ESA regarding effects to listed species of any action taken by FERC related to dam removal. As of this time, FERC has not taken any action and therefore the associated private action of dam removal is currently not reasonably certain to occur. As such, under 50 C.F.R. 402.02 (USFWS and NMFS 2018) it is not required to be included in the cumulative effects discussion of this BA. However, awareness of the proposed dam removal and future basin-wide settlement efforts are important to recognize as part of the overall context of this consultation.

3.7.1.1 Dam Removal – Point of Compliance

The KBPM does not currently account for the potential removal of the four mainstem Klamath River dams in the Klamath Hydroelectric Project. On September 23, 2016, PacifiCorp and the KRRC submitted an application to the FERC to amend the existing license for the Klamath Hydroelectric Project, establish an original license for the Lower Klamath Project dams, and transfer the original license for the Lower Klamath Project to the KRRC. At that time, the KRRC also applied to surrender the license for the Lower Klamath Project, including removal of the dams. On October 5, 2017, FERC issued notice of the application for amendment and transfer of the license and soliciting comments, motions to intervene, and protests. However, FERC indicated that it was not requesting comments at that time on the surrender application, and it will issue a notice requesting comments, protests and motions to intervene on the surrender application after receiving a supplemental filing regarding a decommissioning plan. FERC still has not issued such a notice on the surrender application yet.

KRRC submitted a Definite Plan to FERC on June 28, 2018, and on September 7, 2019. The Oregon Department of Environmental Quality (ODEQ) issued its final Clear Water Act (CWA) Section 401 water Quality Certification for the removal of J.C. Boyle Dam, the only dam slated

for removal in Oregon. ODEQ's certification affirms KRRC's dam removal project will comply with all quality standards, limitations, and restorations et by Oregon law and the CWA. By December 28, 2018, the California State Water Resources Control Board released a Draft Environmental Impact Report (EIR) for the removal of the three dams located in California. On July 29, 2019, KRRC filed answers to question posed by FERC on the 2018 Definite Plan. FERC will decide on the KRRC's license transfer and surrender applications with river drawdown and removal in 2022-2023. However, FERC has not yet submitted a biological assessment or requested initiation of formal consultation under ESA section 7 with the Services on any federal action that it would take to decide whether to approve decommissioning of the four dams.

Currently, the KBPM explicitly assumes Reclamation's control point at LRD and a measurement/compliance point at IGD. If FERC approves decommissioning the four dams described above and the dams are decommissioned, Keno Dam would be expected to become the new compliance point for Reclamation's ESA releases to the Klamath River and LRD would remain the control point. Reclamation did not attempt to model a compliance point at Keno Dam in this PA. This process would require iterative modeling to arrive at new release guidelines (including new river minimums) that would be appropriate for listed coho salmon. Note that this process is necessary given that Keno Dam is not currently operated strictly as a run-of-the-river dam, meaning that there is not a clear relationship between Keno Dam and IGD releases (i.e., Copco and JC Boyle reservoirs may confound the flow relationship between Keno Dam and IGD), particularly in the late spring and summer.

Given the potential that decommissioning of the four dams described above will occur within the lifespan of this PA, the location of the compliance point will need to be moved to Keno Dam. As such, upon FERC's final action authorizing removal, Reclamation will coordinate with the Services to identify a methodology to correlate flow requirements measured at IGD under the PA to what the flow requirements would need to be measured at Keno Dam to ensure consistency prior to decommissioning. This process would include close coordination with the Services to ensure that the point of compliance shift would not result in effects outside those analyzed by the Services in their forthcoming 2020 BiOps.

3.7.2 Klamath Agreements – Keno Dam Acquisition

Along with the KHSA, a Klamath Power and Facilities Agreement (KPFA) was signed in 2016 to mitigate impacts to irrigated agriculture due to increased power rates and potential impacts due to return of anadromous fish to the Upper Klamath Basin. Collectively, the two agreements commit the Department to acquire Keno Dam from PacifiCorp, operate it consistent with historic practices, and to evaluate and construct fish entrainment alleviation facilities at Project diversions along the Klamath River upstream of Keno Dam.

3.7.3 Klamath Basin General Stream Adjudication

Since 1975, the State of Oregon has been in the process of adjudicating all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon, including the rights associated with the Project. This process, generally known as the Klamath Basin General Stream Adjudication, will eventually result in a final determination of the nature and relative priority of water rights for the Project to water from the Klamath River

and its tributaries, including UKL. *See* Chapter 1.3.2 for more information on the Klamath General Stream Adjudication.

In 2013 the State of Oregon issued a Findings of Fact and Order of Determination, which has since been amended and corrected (ACFFOD). Under Oregon law, the ACFFOD is subject to judicial review, but is enforceable unless stayed by the court. These proceedings are ongoing in Klamath County Circuit Court may result in changes to the ACFFOD and the nature of the water rights determined therein.

Enforcement of water rights in the ACFFOD since 2013, particularly The Klamath Tribes instream flow water rights to tributaries to UKL, has resulted in significant changes in hydrology in the Upper Klamath Basin. At times, all irrigation diversions in certain stream reaches have been completely curtailed by calls on the water rights held by the BIA on behalf of The Klamath Tribes. Given the effect of the Klamath Basin General Stream Adjudication and enforcement of associated water rights recognized in the ACCFOD on streams in the Upper Klamath Basin, these considerations are included in the Environmental Baseline for this consultation. But the potential changes to the ACFFOD through the judicial review process in the future, and their effects on hydrology in the Upper Klamath Basin, are not reasonably foreseeable.

3.8 Key Consultation Considerations

Reclamation has participated in extensive consultation with the Services in preparation of the PA. The final content of the BA is Reclamation's responsibility and has been prepared in compliance with section 7 of the ESA and associated implementing regulations.

The PA is modeled, and the model outputs are used to define key parameters such as Project/NWR water availability, UKL elevations, and Klamath River flows. The hydrologic model includes all current hydrologic features in the Klamath River in the Environmental Baseline (e.g., PacifiCorp owned hydroelectric facilities and both federal/non-federal diversion systems, etc.). These modeled results are the simulated direct and indirect effects that result from the implementation of the PA. As defined in CFR 402.02, "A consequence [or effect of the PA] is caused by the PA if it would not occur but for the PA and is reasonably certain to occur." These consequences are added to the Environmental Baseline described in Chapter 6.

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4 Proposed Action

4.1 Action Area

The Action Area includes "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action" (NMFS 2012a, 50 C.F.R. § 402.02). Project lands are identified in Figure 4-1.

The Action Area extends from UKL, in south central Oregon, and Gerber Reservoir and Clear Lake Reservoir in the Lost River drainage in southern Oregon and northern California, to approximately 254 miles downstream to the mouth of the Klamath River at the Pacific Ocean, near Klamath, California (Figure 4-2).

Altogether, the Project provides water for irrigation purposes to approximately 230,000 acres of land, including federally-owned lands within Lower Klamath and Tule Lake NWRs (*see* Chapter 1.3.6, regarding NWRs and associated acreages within the Project). Approximately 200,000 acres are primarily served from UKL and the Klamath River. Approximately 20,000 acres are served from Clear Lake and Gerber reservoirs, although as noted elsewhere, stored water from these reservoirs can be used under certain circumstances to meet irrigation demands in portions of the area served from UKL and the Klamath River.

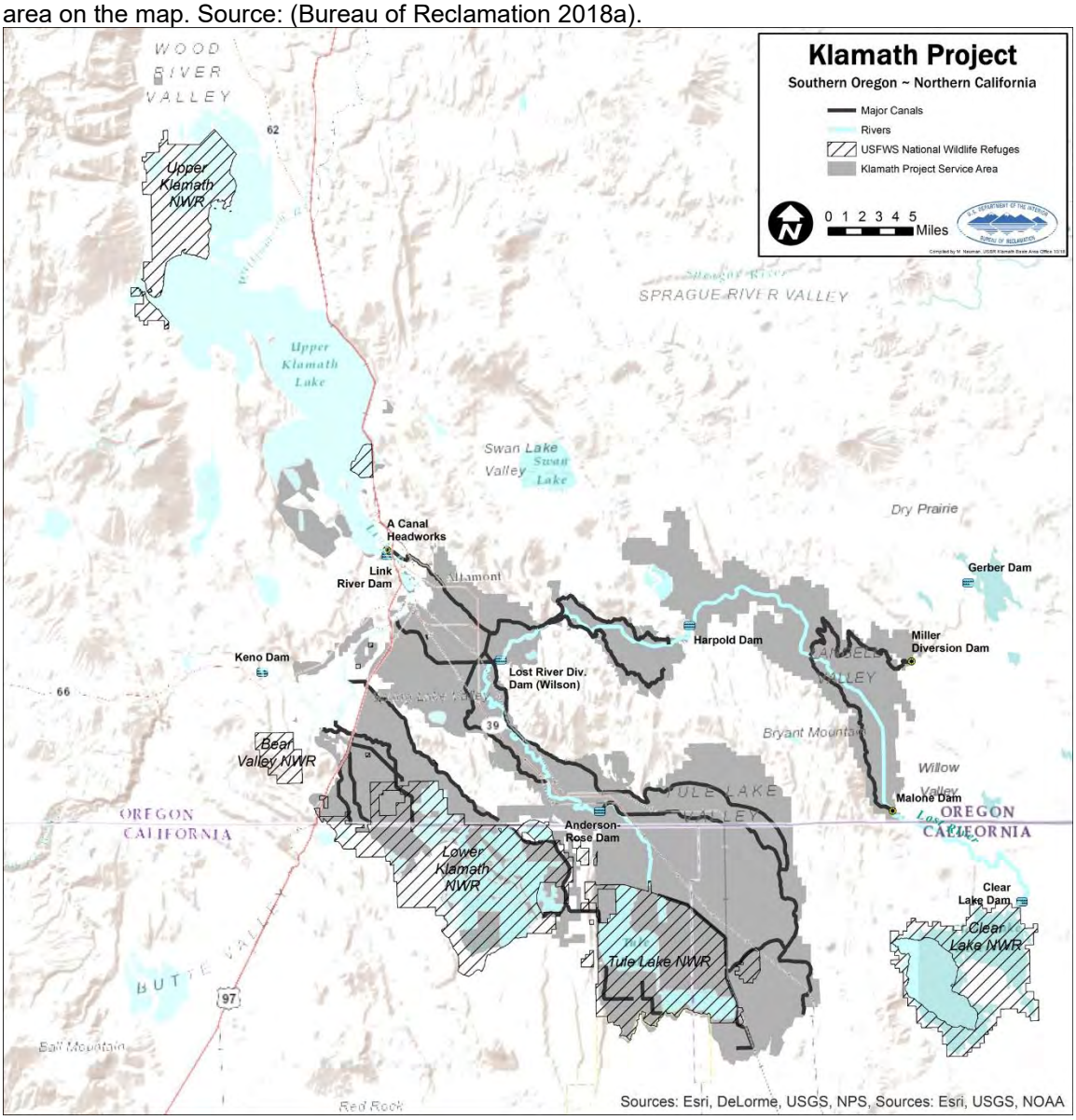
In addition to the above acreages, live flow from the Lost River is exclusively used for irrigating approximately 10,000 acres, mostly located immediately upstream and downstream of Harpold Dam (i.e., Yonna and Poe valleys). Live flow from the Lost River is also used as a supplemental irrigation source for the area of the Project served from UKL and the Klamath River.

Within the Upper Klamath Basin, the Action Area includes Agency Lake, UKL, Keno Impoundment (Lake Ewauna), Lost River including Miller Creek, and all Reclamation-owned facilities including reservoirs, diversion channels and dams, canals, laterals, and drains, including those within Tule Lake and Lower Klamath NWRs, as well as all land, water, and facilities in or providing irrigation or drainage for the service area of the Project.

Direct effects of the PA are those effects that occur as a result of implementation of the PA. Indirect effects are those effects that are caused by or will result from the PA and are later in time but are still reasonably certain to occur (NMFS 2012a, 50 C.F.R. § 402.02).. This BA considers both direct and indirect effects for the purpose of analyzing potential species impacts.

The direct effects of Project operations extend downstream from UKL to the KSD, which is the most downstream Project feature that enters the Klamath River upstream of Keno Dam, Oregon. There is a potential for direct effects on listed suckers to occur throughout the Action Area above IGD, although measures such as fish screens at the A Canal and Clear Lake Dam, and a fish ladder at the LRD reduce these effects.

Figure 4-1. Upper Klamath Basin of Oregon and California. Klamath Project lands are shown as shaded area on the map. Source: (Bureau of Reclamation 2018a).



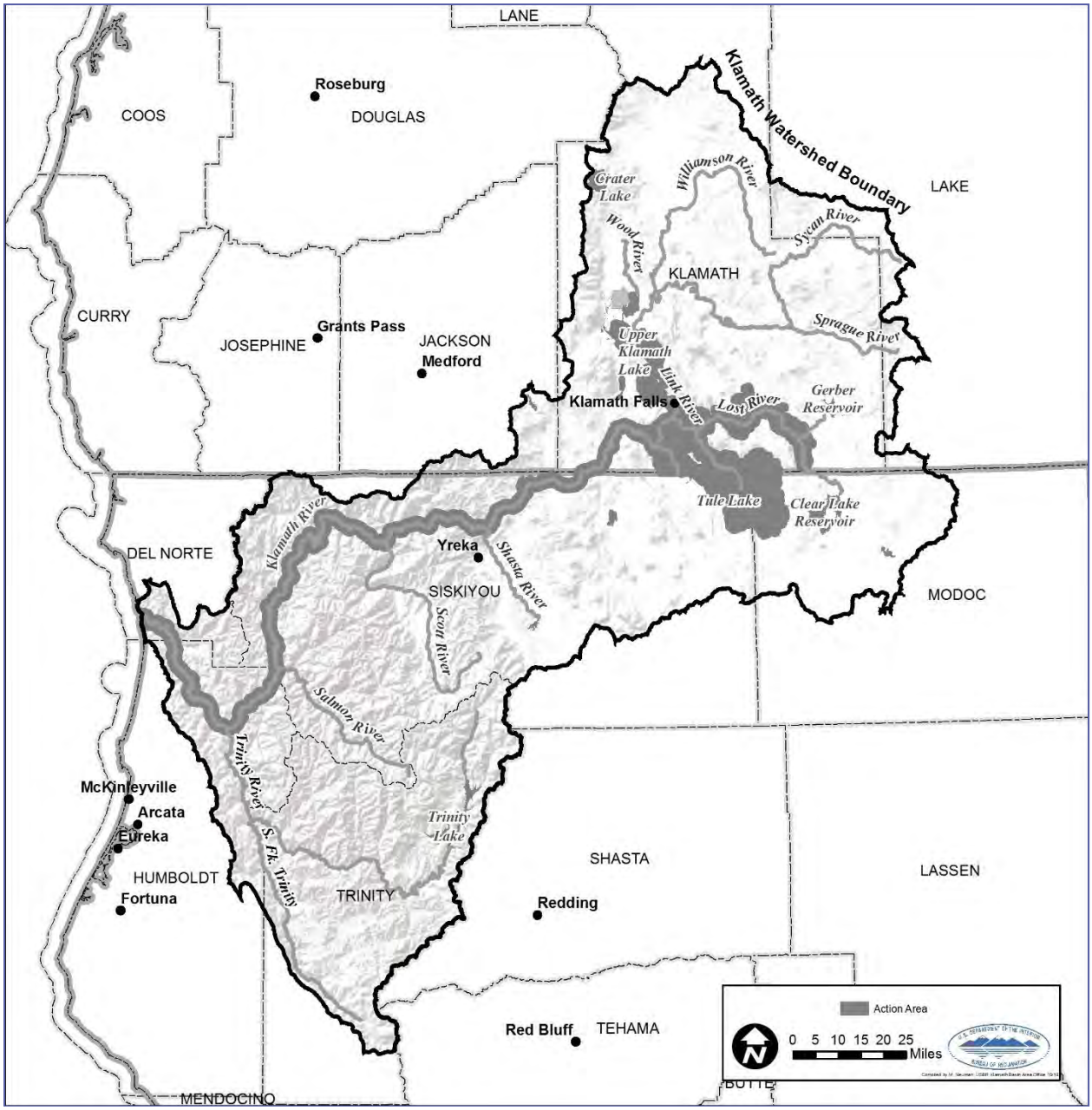


Figure 4-2. Map of the Action Area. Source: (Bureau of Reclamation 2018a).

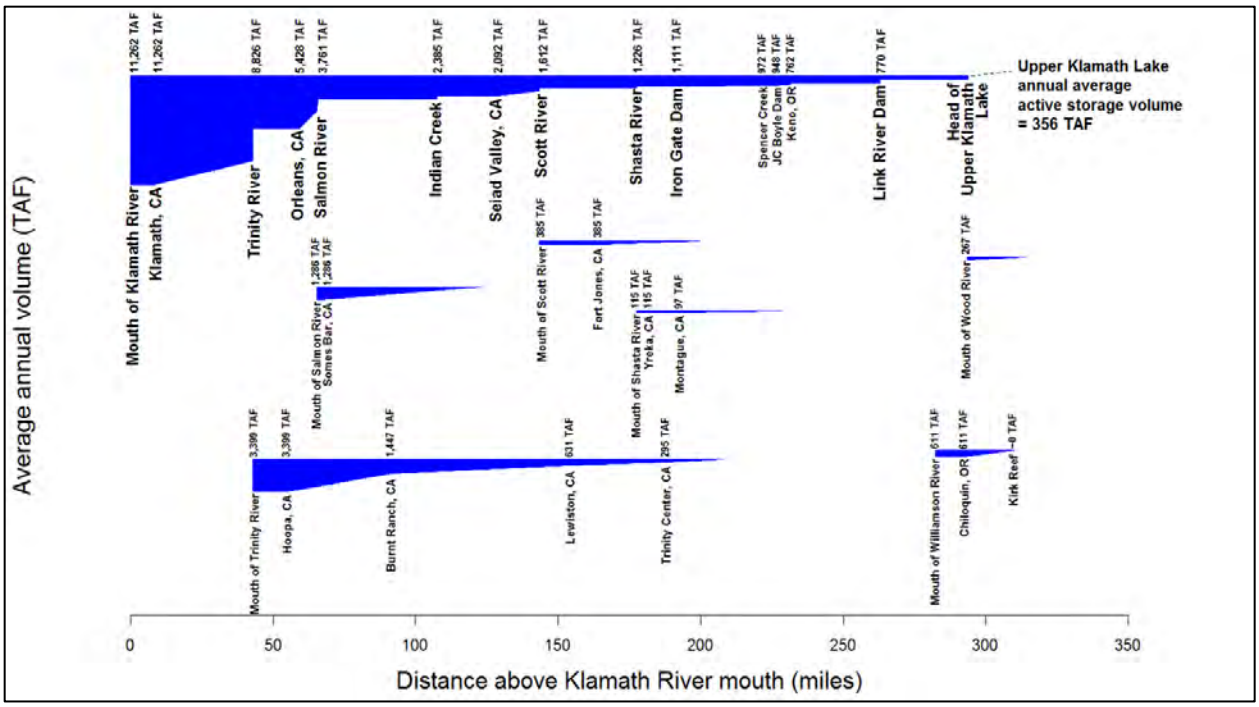


Figure 4-3. Annual volumes (thousand acre-feet [TAF]; water years 2001 to 2017) flowing through the Klamath River at major confluences and landmarks from the Project to mouth of the Klamath River. Source: Bureau of Reclamation 2017.

The Action Area specific to the SRKW extends out into the Pacific Ocean where SRKW feed on concentrations of adult Chinook salmon (*see* Chapter 9.1.2. for more detail). This Action Area extends to that section of the ocean where there is species overlap between Chinook salmon and SRKW. The exact boundaries of this area cannot be defined based upon current information.

4.2 Background

Reclamation has managed minimum UKL elevations (since 1991) and Klamath River flows at IGD (since 2001) in accordance with a series of BiOps from the Services.

For the 2018 BA, Reclamation – in consultation with USFWS and NMFS – used the 1981 through 2016 historical hydrology and revised NRCS forecasts for UKL net inflows as the most complete set of daily data available for development of the PA. As part of the consultation effort for the 2020 BiOp, Reclamation included new data to expand the POR through November 30, 2019 (i.e., 1981 through 2019), used the same UKL bathymetry as the 2019 BiOp, updated UKL net inflow estimates for the POR, and updated daily Project diversion data and return flows for the POR. The 39-year POR includes a broad range of hydrologic conditions that likely represent the range of future conditions within the timeframe covered by the PA. It is important to note that the full effects of climate change during the term of the BA are not fully understood. However, Reclamation believes that the POR includes a climate change signal to some extent, given that trends expected to continue into the future have been observed in the Pacific Northwest over the past several decades (Mote 2003).

4.2.1 Proposed Action Model Development

Reclamation incorporated the 1981 through 2019 dataset into WRIMS to assess the effects of the PA. WRIMS is a generalized water resources modeling system for evaluating operational alternatives of large, complex river basins and is essentially a mass balance model. For use in WRIMS, historical daily data for this POR was reviewed and updated with data from 2016 through 2019, and the UKL bathymetry used in the 2019 BiOp (termed "Reclamation 2017 bathymetry" and described in Neuman (2017)) was retained.

The working version of WRIMS that was used to simulate operations of the Project is referred to as the Klamath Basin Planning Model (KBPM). The KBPM encompasses the areas of the Project served by UKL and the Klamath River and extends from UKL to IGD. KBPM does not model the portion of the Project served by Clear Lake and Gerber reservoirs, although the net effects of conditions on this portion of the Project on the Klamath River are included in the model via the gains (i.e., accretions to the Klamath River) and losses (i.e., Project diversions) within the LRDC. The KBPM also does not model explicit operational details for many facilities within the Project (e.g., Pumping Plant D) and on the Klamath River such as IGD or other reservoirs owned and operated by PacifiCorp; however, reservoir storage on the Klamath River is considered in broad terms to ensure there is sufficient time to fill reservoirs to spillway elevation prior to IGD releases requiring spill. Operation of Project facilities that store and divert water from UKL and the Klamath River was simulated over a range of historical hydrologic conditions using daily input data to obtain daily, weekly, monthly, and annual results for river flows, UKL elevations, and Project diversions (including deliveries to the LKNWR). Reclamation modeled the effects of the potential management action of operation of Project facilities that store and divert water from UKL and the Klamath River on UKL elevations and Klamath River flows for the period of October 1, 1980 through November 30, 2019. The resulting simulated hydrology represents the water supply available from the Klamath River system (including UKL) at the current level of development.

The KBPM is a planning tool that assisted in the development of the PA and not all the processes built into the model can be implemented during actual operations. In addition, there are many assumptions associated with modeling efforts of this nature, and it is important to be aware of the critical assumptions that are incorporated into the KBPM. Listed below are the critical assumptions that have been identified for the KBPM. This list provides examples of how some of the processes built into the KBPM cannot be, and are not intended to be, implemented during real-time operations.

Critical KBPM assumptions include:

- The upper Klamath River basin will experience WY types within the range observed in the POR.
- UKL inflows will be within the range observed in the POR.
- NRCS inflow forecasts will be within the range and accuracy of historical inflow forecasts.

- UKL bathymetry in the model is reasonably representative of actual UKL bathymetry and therefore accurately represents UKL storage capacity.

- Water deliveries to the Project will be consistent with distribution patterns analyzed for the KBPM.

- Accretions from LRD to IGD will be consistent with accretion timing, magnitude, and volume assumed in the KBPM.

- Accretions from LRD to IGD will be routed through PacifiCorp's hydroelectric reach in a manner that is consistent with the KBPM model results for the POR.

- Facility operational constraints and limitations, and/or associated maintenance activities, will be within the historical range for the POR.

- Implementation of the PA will not exactly replicate the modeled results, and actual IGD flows and UKL elevations will differ during real-time operations.

Additionally, the KBPM is a tool and model outcomes are not prescriptive. Similarly, the occurrence of a condition that does not conform to an assumption is not necessarily inconsistent with the PA and would not necessarily trigger a duty to re-initiate consultation. The model shows the results of applying proposed operating rules to conditions over the 39-year period of record.

A detailed description of the KBPM model can be found in Appendix 4.

4.2.2 Water Supply Forecasts

Annual planning relies heavily on seasonal water supply forecasts provided by the NRCS in the form of net inflow forecasts for UKL. The water supply forecasts are developed based on antecedent streamflow conditions, precipitation, snowpack, groundwater, current hydrologic conditions, a climatological index, and historical streamflow patterns (Risley et al. 2005). NRCS updates the forecasts for the season at the start of each month from January to June, with additional unofficial forecasts provided mid-month from March through June. The official (i.e., first of the month) UKL inflow forecasts are used to estimate the seasonal net inflow to UKL through September, which is used to determine the volume of water to be reserved in UKL for the federally-listed suckers, an estimate of water supply for the Project, and an estimate of the March through September Klamath River Environmental Water Account (EWA) volume for federally-listed coho salmon (discussed further in Chapter 4.3.2.2, Operational Approach). It's important to note that the NRCS UKL inflow forecasts are seasonal volumetric estimates and actual observed inflow volumes and timing can vary substantially from the forecasted inflow, especially over shorter time periods.

Upon request in 2017, the NRCS used revised inflow data provided by Reclamation to reconstruct forecasts for 1981 to 2016, basing these reconstructed forecasts on the revised UKL net inflow data (Dunsmoor 2017a) used to develop the 2019 BiOp. The results are shown in Table 4-1. Forecast values ranged from 160,419 AF during 1991 to 1,070,129 AF during 1999.

These volumes range from 26 to 172 percent of average values for the March through September time period (average March through September inflow for the 1981 to 2016 period is 620,667 AF). Note that forecasts for 2017-2019 were derived differently (see next paragraph). Table 4-1 also shows observed annual inflows from 1981 to 2016. On average, the forecast values were 102 percent of the historical values (98 percent of median). Values for individual years ranged from 63 to 217 percent of observed inflows (as compared to 68 to 223 percent during the 2013 BiOp analysis). A detailed description of the NRCS inflow forecasting procedures is available at https://www.wcc.nrcs.usda.gov/about/forecasting.html.

When expanding the POR beyond 2016 to extend through November 2019, NRCS forecasts comparable to the reconstructed forecasts used for 1981-2016 were not available, because NRCS had continued to publish forecasts based on the UKL net inflow data set in use prior to the revisions made during development of the 2019 BiOp. As a result, to maintain consistency with the reconstructed forecasts, published forecasts for 2017-2019 were re-scaled for use in the KBPM. Procedures used are described in Appendix 4 (*see* Section A.4.3.3.9 and Section E).

Table 4-1. Reconstructed Natural Resources Conservation Service March 1st 50 percent exceedance forecasts for March through September Upper Klamath Lake (UKL) net inflow compared with observed March through September UKL net inflow from 1981-2019. Forecasts marked by * were estimated, see text for explanation. The average forecast (621,930 acre-feet (AF)) was computed across the years 1981-2019.

Year	Forecasted UKL Inflow (Acre-Feet)	Forecast Percent of Average (Avg = 620,667 AF)	Observed UKL Inflow (AF)	Observed Percent of Forecast
1981	396,563	64	366,269	92
1982	889,637	143	994,348	112
1983	1,025,671	165	1,223,989	119
1984	878,857	142	1,140,831	130
1985	795,367	128	779,262	98
1986	782,212	126	850,485	109
1987	544,961	88	519,134	95
1988	503,026	81	402,542	80
1989	743,544	120	868,712	117
1990	395,015	64	431,831	109
1991	160,419	26	348,450	217
1992	296,882	48	222,549	75
1993	945,809	152	961,351	102
1994	395,188	64	254,346	64
1995	586,569	95	712,330	121
1996	735,470	118	796,772	108
1997	900,855	145	648,847	72
1998	824,676	133	960,304	116
1999	1,070,129	172	1,027,319	96
2000	867,994	140	723,171	83
2001	407,045	66	338,805	83
2002	693,201	112	438,677	63
2003	425,598	69	474,347	111
2004	730,808	118	459,119	63
2005	456,372	74	454,378	100
2006	963,272	155	917,206	95
2007	530,635	85	526,490	99
2008	692,028	111	623,985	90
2009	514,632	83	507,524	99
2010	509,953	82	422,643	83
2011	625,019	101	808,304	129
2012	392,468	63	566,090	144
2013	519,560	84	415,096	80
2014	241,474	39	339,015	140
2015	315,982	51	293,794	93
2016	587,124	95	506,882	86
2017	879,208*	142	873,250	99
2018	350,695*	57	434,488	124
2019	726,088*	117	622,321	86

4.3 Proposed Action

The PA consists of three major elements to meet authorized Project purposes, delivering water to satisfy contractual obligations, addressing protections for listed species, and providing certainty for Project irrigators:

1. Store waters of the Upper Klamath Basin and Lost River.

2. Operate the Project, or direct the operation of Project facilities, for the delivery of water for irrigation purposes or NWR needs, or releases for flood control purposes, subject to water availability, in accordance with the Endangered Species Act as amended.

3. Perform O&M activities necessary to maintain Project facilities.

Each of the elements of the PA is described in greater detail in the following sections. The three major elements of the PA have not changed relative to the 2018 BA.

4.3.1 Element One

Store waters of the Upper Klamath Basin and Lost River.

4.3.1.1 Annual Storage of Water

Reclamation operates three reservoirs, UKL, Clear Lake and Gerber reservoirs for the purpose of storing water for delivery to the Project's service areas.

Bathymetric data compiled by Reclamation in 2017 (including nearshore areas such as Upper Klamath NWR, and Tulana and Goose Bays), indicated an "active" storage volume of 562,000 AF between the elevations of 4,136.0 and 4,143.3 feet above sea level (USBR datum), which is the historical range of water surface elevations within which UKL has been operated. *See* Chapter 6.3 for additional details regarding historical conditions in UKL.

Clear Lake Reservoir has an active storage capacity of 467,850 AF (between 4,521.0 and 4,543.0 feet above sea level, Reclamation datum).

Gerber Reservoir has an active storage capacity of 94,270 AF (between 4,780.0 and 4,835.4 feet above sea level, Reclamation datum). No storage capacity in Gerber Reservoir is exclusively reserved for flood control purposes.

Reclamation proposes to store water in UKL and Clear Lake and Gerber reservoirs year-round with a majority of the storage occurring from October through April. In some years of high net inflows or non-typical inflow patterns (i.e., significant snowfall or other unusual hydrology in late spring/early summer), contributions to the total volume stored can also be significant in May and June. Most water delivery from storage occurs during March through September, although storage releases for irrigation purposes occur year-round. Storing water through the winter raises lake elevations which usually peak between March and May. Flood control releases may occur at any time of year, as public safety, operational, storage, and inflow conditions warrant.

The Klamath Project's primary storage reservoir, UKL, is shallow with approximately 6 feet (1.8 meters [m]) of usable storage when at full pool (approximately 562,000 AF). Clear Lake and Gerber Reservoir also have limited storage capability. Thus, UKL, Clear Lake, and Gerber Reservoir do not have the capacity to carry over significant amounts of stored water from one year to the next. UKL also has limited capacity to store higher than normal inflows during spring and winter months, because the levees surrounding parts of UKL are not adequately constructed or maintained for that purpose. Therefore, the amount of water stored in any given year is highly dependent on volume and timing of inflows in that year, and to a lesser extent, preceding years.

4.3.2 Element Two

Operate the Project, or direct the operation of the Project, for the delivery of water for irrigation purposes or NWR needs, subject to water availability, and consistent with flood control purposes, while maintaining conditions in UKL and the Klamath River that are in accordance with the Endangered Species Act as amended.

Consistent with Reclamation Manual Policy "Water-Related Contracts and Charges – General Principles and Requirements" (PEC P05) and as applicable to the Klamath Project, the term "Project water" encompasses surface water, including Project seepage and return flows, that is developed by, pumped or diverted into, and/or stored based on the exercise of water rights that have been appropriated or acquired by the United States or others, or that have been decreed, permitted, certificated, licensed, or otherwise granted to the United States or others, for the Klamath Project. Consistent with state water law and as applicable to the Klamath Project, the term "live flow" encompasses surface water in natural waterways that has not otherwise been released from storage (i.e., "stored water"). Live flow can consist of tributary runoff, spring discharge, return flows, and water from other sources (e.g., municipal or industrial discharges).

Project water, both stored and from live flow, is used to meet irrigation needs within the Project service area. Live flow is diverted from UKL, the Klamath River, and the Lost River for irrigation purposes. Generally, when live flow is insufficient to meet irrigation demands, stored water is released from UKL and Clear Lake and Gerber reservoirs to meet those needs.

Water supply contracts and other agreements between Reclamation and district entities or individuals, coupled with water rights (e.g., as currently determined in the Amended and Corrected Findings of Fact and Order of Determination (ACFFOD), govern the distribution and use of Project water supplies (*see* Chapter 1.3.2, regarding Project water rights, and Chapter 1.3.3, regarding water supply contracts).

4.3.2.1 Operation and Delivery of Water from UKL and the Klamath River

The portion of the Project served by UKL and the Klamath River consists of approximately 200,000 acres of irrigable land, including areas around UKL, along the Klamath River (from Lake Ewauna to Keno), Lower Klamath Lake, and from Klamath Falls to Tulelake. Most irrigation deliveries occur between April and October, although water is diverted year-round for irrigation use within the Project.

Stored water and live flow in UKL are directly diverted from UKL, via the A Canal and smaller, privately-owned diversions. The A Canal (1,150 cubic feet per second [cfs] capacity) and the connected secondary canals it discharges into (i.e., the B, C, D, E, F, and G canals) serve

approximately 71,000 acres within the Project. In addition to the A Canal, there are approximately 8,000 acres around UKL that are irrigated by direct diversions from UKL under water supply contracts with Reclamation.

In addition to direct diversions from UKL, stored water and live flow is released from LRD, for re-diversion from the Klamath River between Klamath Falls and the town of Keno. PacifiCorp currently operates LRD under guidance from Reclamation to achieve certain flows at IGD (*see* Chapter 1.3.5, regarding Reclamation's relationship with PacifiCorp and its predecessors).

Water released from LRD flows into the Link River, a 1.5-mile waterbody that discharges into Lake Ewauna, which is the start of the Klamath River. The approximately 16-mile section of the Klamath River between the outlet of Link River and Keno Dam is commonly referred to as the Keno Impoundment or Keno Reservoir (referred to as the Keno Impoundment herein).

There are three primary points of diversion along the Keno Impoundment that are used to re-divert stored water and live flow released from UKL via the LRD. Approximately three miles below the outlet of Link River, water is diverted into the LRDC, where it can then be pumped or released for irrigation use. Pumping from the LRDC primarily occurs at the Miller Hill Pumping Plant (105 cfs capacity), which is used to supplement water in the C-4 Lateral for serving lands within KID that otherwise receive water through the A Canal. KID operates and maintains the Miller Hill Pumping Plant. In addition to the Miller Hill Pumping Plant, there are other smaller, privately-owned pumps along the LRDC that serve individual tracts within KID.

Water re-diverted into the LRDC can also be released through Station 48 (650 cfs maximum capacity), where it is then discharged into the Lost River below the Lost River Diversion Dam for re-diversion and irrigation use downstream. TID makes gate changes at Station 48 based on irrigation demands in the J Canal system, which serves approximately 62,000 acres within KID and TID. To the extent that live and return flows in the Lost River at Anderson-Rose Dam and the headworks of the J Canal (810 cfs capacity) are insufficient to meet associated irrigation demands, water is released from Station 48 to augment the available supply.

The other two primary points of diversion along the Keno Impoundment that re-divert stored water and live flow from UKL are the North and Ady canals (200 cfs and 400 cfs capacity, respectively), which are owned and operated by KDD. In addition to lands within the boundaries of KDD, the Ady Canal also delivers water to the California portion of LKNWR. Together, the North and Ady canals deliver water to approximately 45,000 acres of irrigable lands in the Lower Klamath Lake area, including lands in KDD.

In addition to the lands served by the LRDC and Ady and North canals, Reclamation has entered into water supply contracts covering approximately 4,300 acres along the Keno Reservoir, including lands on the west side of the Klamath River and on Miller Island. Privately-owned pumps are generally used to serve these lands. Refer to Figures 1-1, 4-1, and Appendix 1A for maps showing the location of the facilities referenced above.

Demands for irrigation supply over the proposed lifetime of this BA are assumed to be similar to those that have occurred in the 39-year POR for water-year 1981 through 2019. However,

continued improvements in irrigation infrastructure and equipment combined with advances in irrigation practices and technology will likely help to reduce Project irrigation demand in the future. The irrigation "demand" is the amount of water required to fully satisfy the irrigation needs of the Project. While these historical demands are retained for analysis and comparison purposes, irrigation deliveries to the Project within this PA were modeled using the Agricultural Water Delivery Sub-model (Chapter 4.3.2.2.2.2; Appendix 4, section A.4.4.4). This sub-model includes variables such as deliveries during the previous timestep, meteorological conditions, and soil moisture to predict irrigation deliveries on a 5-day timestep, scaled to Project Supply (water available to the Project from UKL; *see* definition and additional details in Chapter 4.3.2.2.2.1) and water available from the LRDC and KSD. Modeled deliveries during this 39-year POR generally fall within the range of historical Project deliveries. In addition, the POR exhibits a large range of hydrologic and meteorological conditions, and the various modeled deliveries during this period are reasonably expected to cover the range of conditions likely to occur during the proposed term of this BA.

4.3.2.2 Operational Approach

This section of the PA provides a general overview of operations; additional details regarding the fall/winter and spring/summer operational periods are discussed below in their respective sections and in Appendix 4.

For purposes of this operational approach, the portion of the Project that receives water from UKL and the Klamath River is divided into three separate areas (Area A1, Area A2, and LKNWR). Area A1 encompasses Project lands served by A Canal and the LRDC (Station 48 and Miller Hill Pumping Plant). Area A2 encompasses Project lands served by the Ady and North canals. LKNWR encompasses all lands within the designated refuge boundaries, including Area K, which is also within KDD.

Water management in the fall/winter operational period (November 1 – February 28/29 for the Project and from October 1 – February 28/29 for the Klamath River), employs a formulaic management approach focused on maintaining conditions in UKL and the Klamath River that meet the needs of the ESA-listed species as described in this BA and provide fall/winter water deliveries to the Project and LKNWR. This approach attempts to ensure appropriate water storage and sucker habitat in UKL (*see* Chapter 7 for details regarding sucker habitat) while providing Klamath River flows that mimic natural hydrologic conditions based on current conditions in the upper Klamath Basin. *See* Chapter 4.3.2.2.1 and Appendix 4, Section A.4.4.2 for in-depth details regarding the fall/winter water management approach.

Water management in the spring/summer operational period runs from March 1 through November 30 for Area A1 and LKNWR and March 1 through October 31 for Area A2, except as otherwise noted. Overlap between spring/summer operations and fall/winter operations in November remains. As in the 2018 BA and 2019 BiOp, Area A1 and LKNWR may continue diverting spring/summer water (i.e., Project Supply) after November 1, when the Project's fall/winter period begins (*see* Chapter 4.3.2.2.1 and 4.3.2.2.2 for additional details).

Generally, Reclamation proposes to determine the total available UKL Supply, accounting for sucker needs [as outlined in Chapter 7] through the spring/summer period; (*see* Chapter 4.3.2.2.2.1), and then distribute this supply between the Project (Project Supply; water available

to the Project from UKL; *see* definition and additional details in Chapter 4.3.2.2.2.1) and the Klamath River EWA (*see* Chapter 4.3.2.2.2.3 for definition and additional details). The division of the total available UKL water supply between EWA and Project Supply was determined through the iterative modeling process, relying on the expert opinion of Reclamation and through technical assistance with the Services.

The management approach employed by Reclamation in this PA attempts to to maximize the amount of water available for the Project while seeking to fill UKL during the fall/winter to increase and maximize the ecologic benefit of the volumes available for the Environmental Water Account (EWA) (including disease mitigation flows), UKL, and Project irrigation supply during the following spring/summer operational period.

In some instances, dry hydrologic conditions characterized by limited precipitation, runoff, and inflows to UKL may create shortages in the total available UKL water supply, which can result in a Project Supply that is less than the full irrigation demand. *See* Chapter 4.3.2.2.2 and Appendix 4, Section A.4.4.3 for in-depth details regarding the spring/summer operational approach.

The PA management approach has two major components:

1. UKL elevations and storage, specifically the UKL control logic and UKL Credit, to avoid destruction or adverse modification of sucker habitat and ensure adequate storage to avoid jeopardy to federally-listed species in UKL and the Klamath River and meet water supply needs of the Project; and

2. Klamath River flows, specifically EWA to avoid jeopardy to coho and destruction or adverse modification of its critical habitat including flows for disease mitigation or protection of coho habitat during the spring/summer operational period (between March 1 and September 30), and a formulaic approach for calculating IGD releases in the fall/winter (October 1 – February 28/29).

Upper Klamath Lake
This operational approach seeks to fill UKL during the fall/winter to increase the volume of water available to meet operational needs (i.e., Project Supply, EWA, and UKL Supply) during the spring/summer operational period. The PA also includes a "UKL control logic" that regulates certain releases (as described below) relative to UKL storage and recent hydrologic conditions in a manner that maintains UKL elevations for endangered suckers, and a "UKL Credit" that buffers UKL against uncertainties associated with NRCS forecast error and other factors affecting UKL inflow available for subsequent diversion.

The UKL control logic helps to manage UKL elevations for endangered suckers while ensuring adequate storage in UKL for both Klamath River and Project releases, utilizing a "central tendency." The central tendency is based on user-defined end-of-month UKL elevations which are subsequently interpolated to daily values (this is termed the generic central tendency). This results in a generic annual hydrograph that accounts for seasonal needs of suckers, seasonal water demand for the Klamath River and Project, and end-of-season elevations intended to result

in (after winter inflows) storage volumes appropriate to meet the next year's demands on UKL. This generic hydrograph is then adjusted daily, based on a normalized 60-day trailing average of raw net inflow to UKL, producing an adjusted central tendency. If UKL elevations drop below the adjusted central tendency, then releases to the Klamath River (subject to IGD minimums described in Appendix 4, Section A.4.4.2, Table A.4.4.2.2) and winter deliveries to Area A2 are reduced until UKL elevations equal or exceed the adjusted central tendency line. The adjusted central tendency is not a target to which UKL should be managed, but rather a guideline that maintains UKL elevation in line with both hydrologic conditions and the multiple demands placed upon UKL storage throughout the year. Finally, note that the generic central tendency end-of-month UKL elevations were arrived at through the iterative modeling process and are not intended to change during operations under this PA. *See* Appendix 4, Section A.4.4.1.1 for technical details regarding the UKL control logic.

The purpose of the UKL Credit is to hold water in UKL to facilitate establishing a minimum Project Supply on April 1 with no later reduction below the April 1 value, and the possibility of an increase in subsequent May 1 and June 1 allocations. Accrual of UKL Credit provides a volume of water in UKL in the case of an early season over-forecast of seasonal inflow to UKL. Any UKL Credit accrued in UKL above and beyond that necessary for full delivery of Project Supply will remain in UKL to facilitate refill of UKL in the ensuing fall/winter period. There is no carryover of accrued UKL Credit from season to season. UKL Credit can only be accrued from March 1through September 30 during controlled flow conditions (i.e., not during flood control operations), and is accumulated when LRDC flows and KSD discharges in excess of direct diversions for irrigation are utilized to meet IGD flow targets (i.e., Klamath River flows, as defined in section 4.3.2.2.2.3), resulting in a reduction in LRD releases. In other words, when Project irrigators do not divert LRDC flow or KSD return flows and these unused volumes are utilized to offset LRD releases, a volume of water (the UKL Credit, equal to the reduction in LRD releases for river flows) is stored in UKL. As with current operations, Reclamation anticipates that PacifiCorp will adjust LRD releases as appropriate to meet IGD targets, accounting for these specific accretions to the Klamath River (i.e., if LRDC and KSD accretions increase, PacifiCorp would decrease LRD releases such that IGD targets are still met, but not exceeded). Reclamation will track accretions and IGD releases to properly calculate the UKL Credit. S*ee* Chapter 4.3.2.2.2 for additional details.

For several graphical examples of the anticipated UKL elevations, *see* Appendix 4, Section B. The model output graphs provided in Appendix 4, Section B provide examples of how the annual hydrographs might look. Real-time operations will not exactly replicate the modeled results and actual flow and elevation variability will differ during real-time operations.

Klamath River

Reclamation is proposing to distribute EWA water from UKL based on the EWA allocation, UKL control logic, UKL net inflow, and NRCS-forecasted March – September net inflow (50 percent exceedance) from March 1 – September 30. From July 1 – September 30, Reclamation proposes to distribute EWA water from UKL based on the remaining EWA and UKL control logic. Reclamation also proposes to retain IGD as a compliance point for Klamath River flows (though *see* Chapter 3.7.1 for details about dam removal and associated implications for this BA). Finally, the PA conditionally supplements the EWA-based IGD release targets using the

flexible flow augmentation approach during March through June to address disease and habitat issues in years meeting specific criteria (*see* Chapter 4.3.2.2.2.4 and Appendix A, Section A.4.4.3).

As in the 2019 BiOp, IGD targets in the fall/winter and a portion of the spring/summer period are calculated using a hydrologic indicator of upper Klamath Basin conditions. Specifically, Reclamation proposes to utilize the net inflow to UKL to calculate IGD targets throughout the fall/winter period and for part of the spring/summer period (March 1 through June 30; note that from July 1 through September 30, EWA water distribution is based on EWA allocation and UKL control logic as described above and in Chapter 4.3.2.2.2.3). The intent of this method is to create a hydrograph downstream of IGD that approximates a natural flow regime reflective of actual hydrologic conditions and variability occurring in the upper Klamath Basin.

For several graphical examples of the anticipated IGD hydrograph, *see* Appendix 4, Section B. The model output graphs provided in Appendix 4, Section B provide examples of how the annual hydrographs might look. Real-time operations will not exactly replicate the modeled results and actual flow and elevation variability will differ during real-time operations. The daily IGD target flows will be implemented three days after the hydrologic conditions are observed in the upper Klamath Basin. The actual transit time may be more or less than three days depending on the magnitude of the flow rate, elevation of UKL, and the hydrologic conditions downstream of UKL. No attempt was made to calculate transit time and the three-day delay is not intended to precisely replicate flow conditions in the Klamath River. Rather, the three-day lead time is needed for IGD flow schedule planning purposes to accommodate PacifiCorp's operation of the Klamath Hydroelectric Project.

In the event of gage failure, Reclamation's professional judgment will be used in combination with all relevant hydrologic data to estimate UKL elevation and inflow, IGD releases, and/or LRD to IGD accretions. USGS gage failures occur infrequently and every attempt will be made to coordinate with USGS to appropriately estimate flow and/or elevation values whenever a gage failure occurs.

Finally, PacifiCorp's operation of the Klamath Hydroelectric Project will influence the timing and magnitude of the hydrograph downstream of IGD due to water travel time through the reservoirs and due to facilities operations. Under normal operating conditions, these influences are expected to be minimal because PacifiCorp manages hydroelectric operations to meet IGD targets.

4.3.2.2.1 Fall/Winter Operations

The fall/winter operational period extends from November 1 through February 28/29 for the Project's irrigated areas and from October 1 through February 28/29 for the Klamath River (i.e., EWA no longer applies after September 30). There is overlap between the spring/summer and fall/winter operations in October and November because the Project and the LKNWR will likely divert a portion of the spring/summer Project Supply during these months, while EWA accounting ends on October 1. Spring/summer and fall/winter diversion accounts must be kept separate during the overlap period.

The fall/winter Project operational procedure distributes the available fall/winter UKL inflows among the following:

1. UKL:
    a. Increase UKL elevation to provide endangered sucker habitat needs (as outlined in Chapter 7) throughout the fall/winter period and the following spring/summer period, as well as increase storage for spring/summer EWA releases and irrigation deliveries.
    b. This is achieved through a fall/winter UKL refill rate and the UKL control logic.
2. Klamath River:
    a. Release sufficient flow from IGD to meet ESA-listed species needs in the Klamath River downstream of IGD; this includes flows to support coho spawning from October 1 – November 15.
    b. This is achieved through the formulaic approach to calculating IGD targets.
3. Project:
    a. KDD (Area A2 – served by North Canal and Ady Canal)
    b. LKNWR (served by Ady Canal)

Additionally, sufficient flood pool capacity must be maintained as part of non-discretionary flood-related public safety.

To satisfy these objectives, Reclamation proposes to calculate IGD target flows by means of a series of context-based real-time equations using the net UKL inflow as a hydrologic indicator. Specific steps for calculating IGD target flows include:

1. Determine the LRD flow target, which is the maximum of either the minimum LRD flow target (look up table) or the LRD release target to support IGD target flows (calculated as follows)
    a. October 1 through November 15
        i. Determine the IGD target necessary for coho spawning flows
    b. November 16 through February 28/29
        i. Determine yesterday's smoothed UKL net inflow
        ii. Subtract 1.5 times the average daily UKL fill rate necessary to attain a UKL elevation of 4,143 feet on February 28/29
    c. Adjust based on the difference in UKL storage between the UKL adjusted central tendency and UKL elevation
    d. Constrain by the maximum LRD release capacity, if applicable
2. Determine the IGD flow target, which is the maximum of either the minimum IGD flow requirement (look up table; Appendix 4, Section A.4.4.2, Table A.4.4.2.2) or the IGD flow target (calculated below)

a. October 1 through November 15
    i. Determine the IGD target necessary for coho spawning flows
b. November 16 through February 28/29
    i. To the LRD flow target calculated in step 1, add LRD to Keno Dam accretions from three days prior (i.e., this step relies on the accretion that occurred in a single day three days ago)
    ii. Add the value for today's Keno Dam to IGD accretions that was forecast three days ago (i.e., this step relies on the accretion forecast for the current day that was issued three days ago)
    iii. Add KSD discharge (assumes three-day lag)
    iv. Add the maximum of either LRDC flow towards the Klamath River minus diversion of LRDC water to North and Ady canals (assumes three-day lag), or zero

Note that it is operationally possible to reduce LRD flows below the flow 'minimums' referred to above (and further described in Appendix 4, Section A.4.4.2), but this requires Reclamation to conduct a fish stranding assessment below LRD (and possibly below Keno Dam). This requires additional personnel and other resources and Reclamation will weigh the benefit of flows below LRD minimums against the personnel, resource and safety requirements necessary for completion of the stranding assessments. If a reduction below LRD "minimum" flows is desired, Reclamation retains discretion in weighing the benefits of such an action against the issues described above. Additionally, note that the LRD target flow is not adjusted to account for the fill trajectory in UKL until November 16. October 1 through November 15 is a period of transition in Klamath Basin hydrology (i.e., UKL elevation transitions from decreasing to increasing), is a biologically sensitive time downstream of IGD (e.g., Chinook spawning and egg incubation) and is subject to highly variable accretions between LRD and IGD. Therefore, no adjustments beyond those of the UKL control logic are made to enhance UKL refill during this period.

Relative to fall/winter irrigation needs, up to 28,910 and 11,000 AF of fall/winter water is made available to KDD and LKNWR, respectively, subject to the UKL control logic. Specifically, if UKL elevation is at or above the adjusted central tendency throughout the fall/winter period, the only modeled constraints to delivery would be the delivery cap (28,910 and 11,000 AF for KDD and LKNWR, respectively), conveyance capacity, and demand. However, if UKL elevation is below the adjusted central tendency, daily deliveries to KDD and LKNWR will be reduced incrementally by up to 80 percent (from the delivery rates assumed in the KBPM). Fall/winter water available for delivery to KDD and LKNWR will be assessed every 5 days, when the ratio determining the delivery adjustment (termed the "storage difference ratio") is calculated. Similarly, LRD releases can be reduced incrementally by up to 80 percent (possibly resulting in up to an 80 percent decrease at IGD, though IGD releases cannot drop below the IGD minimum flow requirements) when UKL elevation is below the adjusted central tendency; the maximum reduction occurs when UKL elevations approach the lower bound of the central tendency "envelope" as described in Appendix 4. *See* Appendix 4, Section A.4.4.1.1 for additional details.

Note that the portion of LKNWR known as Area K is also within KDD. Any portion of the water available to either KDD or LKNWR can be used within Area K.

It is possible to deviate from the fall/winter formulaic approach to calculating IGD flow targets. For instance, real-time hydrologic conditions, such as high flow events or emergency situations, or USGS rating curve adjustments may warrant the need to deviate from this formulaic approach. In addition, there may be specific ecologic objectives that water resource managers may want to address that can only be achieved by deviating from the formulaic approach to calculating IGD targets. Any time a deviation from the formulaic approach occurs, either by necessity or to address a specific ecologic objective, or if it is determined that the formulaic approach results in conditions that are not consistent with the intent of the PA, the process detailed in Chapter 4.3.2.2.3. will be followed. However, the formulaic approach for calculating IGD targets considered in this PA was designed to meet the key ecologic objectives for UKL and the Klamath River (with the exception of disease mitigation and habitat flows described in Chapter 4.3.2.2.2.4 and 4.3.2.2.2.5). Therefore, Reclamation anticipates that implementation of the formulaic approach will address these ecologic objectives, and only infrequent deviations from this approach are expected to be necessary.

Real-time hydrologic conditions will be closely monitored during the fall/winter to ensure that flood control elevations for UKL are not exceeded and adequate capacity remains in UKL to accommodate high runoff events, especially during rain on snow events. During high runoff events, deviations from the fall/winter management procedure may be required in order to protect public safety and the levees surrounding UKL. In addition, other unforeseen emergency and/or facility control issues could arise that would require deviations from the fall/winter management procedure. In such cases, Reclamation will return to the fall/winter management procedure as soon as the emergency or facility control issue is resolved, but Reclamation retains ultimate discretion regarding the timing of a return to the formulaic approach. *See* Chapter 4.3.2.2.4 for additional details regarding flood control for UKL.

4.3.2.2.2 Spring/Summer Operations

The previous section described the fall/winter operations which are the first half of each WY, while this section describes the second half of each WY, covering the irrigation season. The Project irrigation season is generally defined as March 1 through November 30 for Area A1 and LKNWR and March 1 through October 31 for Area A2, except as otherwise noted below.

The specific objectives during the spring/summer operational period include:

1. Provide irrigation deliveries to lands within the Project, including TLNWR and LKNWR, with a reasonable level of certainty; and

2. Maintain suitable habitat conditions in UKL and the Klamath River for endangered and threatened species, respectively.

The irrigation season operations are controlled by defining the available UKL Supply, which is computed from end of February storage in UKL, observed (since March 1) and forecasted monthly UKL inflows (March-September) and an end of September storage target (*see* Chapter 4.3.2.2.2.1 for additional details). Division of this supply between the Klamath River (EWA)

and Project (Project Supply; water available to the Project from UKL) is dependent on the size of UKL Supply. Any UKL inflow that is not delivered to the Project or released for Klamath River flows (EWA) will remain in UKL as storage. All water that leaves UKL through either LRD or the A Canal is accounted for against one of these two identified volumes; this includes flood control releases (but does not include spill of UKL credit, which is the first volume of water to spill during flood control operations). *See* Figure 4-4 for a schematic illustrating the division of UKL Supply.

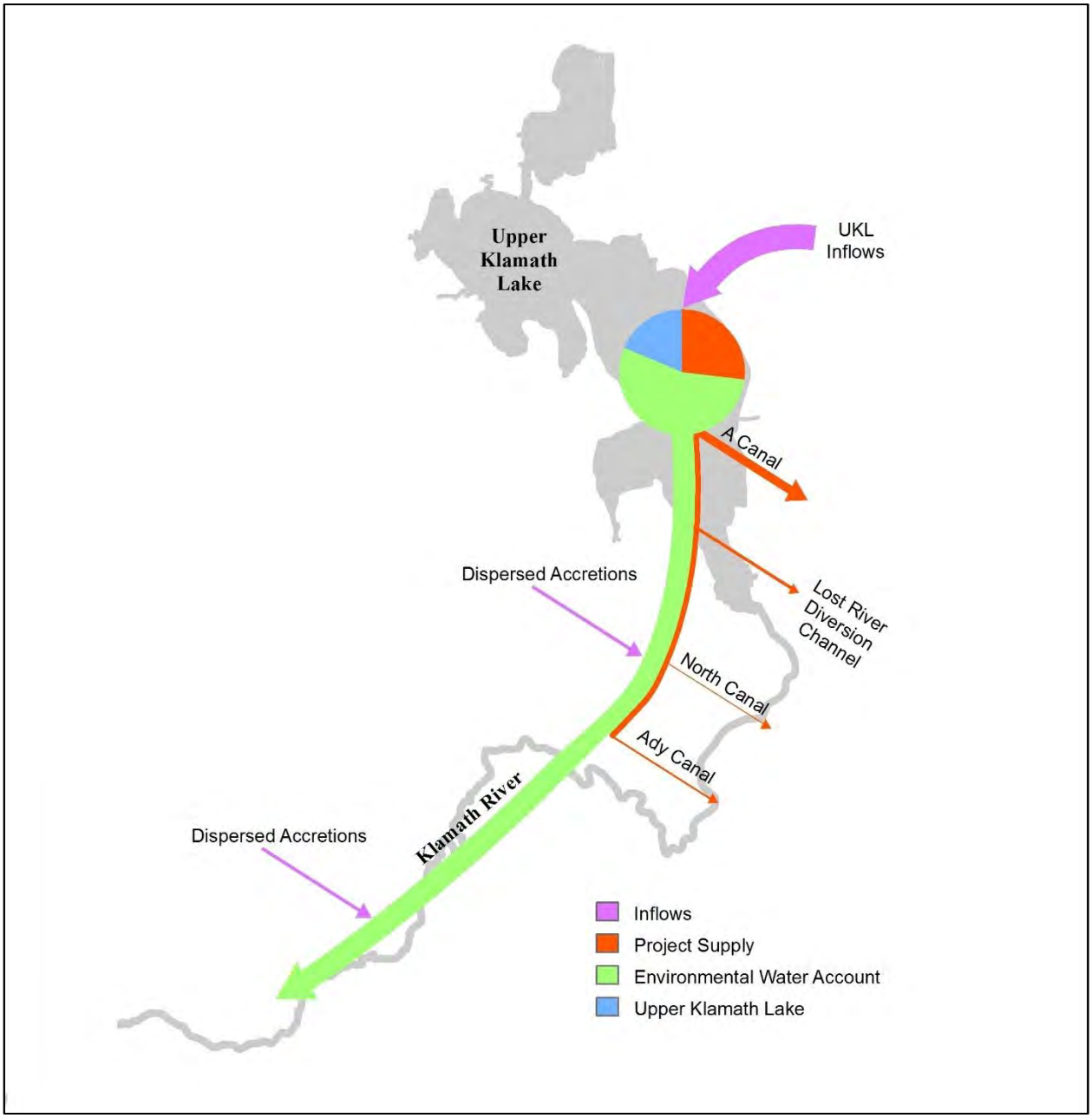


Figure 4-4. Schematic of spring/summer Environmental Water Account, Project Supply, and volume remaining in Upper Klamath Lake (UKL) (i.e., the end of September storage target). The size of the pie chart and lines are proportional to average volumes of water modeled over 1981 through 2016. Project Supply includes both irrigation supply and a supply for Lower Klamath National Wildlife Refuge deliveries;

this figure does not include Lower Klamath National Wildlife Refuge deliveries associated with transferred water rights. Source: (Bureau of Reclamation 2018a).

Throughout the spring/summer operational period, Reclamation will track EWA, Project deliveries, remaining Project Supply, UKL elevation relative to the adjusted central tendency, LKNWR deliveries, and the anticipated remaining LKNWR deliveries every 5 days (corresponding to the 5-day time step for recalculation of the storage difference ratio; *see* below for details) and adjust releases as necessary to maintain operations consistent with this PA.

See Appendix 4, Section B for examples of how the annual hydrographs might look. Actual flow and elevation variability will differ during real-time operations as a result of hydrologic conditions specific to the current period of operation. Details regarding the accounting for EWA releases, as well as Project and LKNWR deliveries, are provided below.

4.3.2.2.2.1 UKL Supply

UKL Supply is calculated on the first day of each month (or when Reclamation receives the NRCS UKL inflow forecast) from March through June. UKL Supply is calculated by adding the Mar50vol (50 percent exceedance volume) to the end of February UKL storage, and then subtracting the end of September UKL storage target. The specific steps for calculating UKL Supply and Mar50vol are detailed below.

First calculate the "Mar50vol," a combination of forecasted and observed March through September UKL inflow. For each month, Mar50vol is calculated as follows:

1. March 1
   a. Equal to the March 1 NRCS 50 percent exceedance March through September UKL inflow forecast

2. April 1
   a. April 1 NRCS 50 percent exceedance April through September UKL inflow forecast, plus
   b. Measured March net inflows

3. May 1
   a. May 1 NRCS 50 percent exceedance May through September UKL inflow forecast, plus
   b. Measured March net inflows, plus
   c. Measured April net inflows

4. June 1
   a. June 1 NRCS 50 percent exceedance June through September UKL inflow forecast, plus
   b. Measured March net inflows, plus
   c. Measured April net inflows, plus
   d. Measured May net inflows

Next, calculate the end of September UKL storage target. This target is dependent on the default end of September UKL central tendency elevation (4,139.1 feet), the end of September

"envelope" around the UKL central tendency (+/- 0.4 feet), and the Mar50vol (*see* Appendix 4, Section A.4.4.3 for specific details). The purpose of the end of September UKL storage target in determining UKL Supply is to constrain the amount of UKL storage used in a given year. Such constraint is necessary to balance near-term demand for irrigation supply or river flow with the uncertainties associated with future hydrologic conditions (e.g., the consequences of the upcoming winter being drier than normal).

The end of September UKL storage target is a mathematical term (and the name of this model variable is a legacy of the 2012 BA) and is not a management target. It is effective in "constraining" use of UKL storage since it is not mathematically allocated to EWA or Project Supply during the March 1 through June 1 spring/summer supply calculations.

4.3.2.2.2.2 Project Supply

Project Supply is calculated on the first of each month from March through June, just like EWA (*see* Chapter 4.3.2.2.2.3) and UKL Supply (*see* Chapter 4.3.2.2.2.1). To provide early-season certainty for Project irrigators, the calculated April 1 Project Supply is "locked in" such that Project Supply may go up as a result of increased NRCS UKL inflow forecasts on May 1 and June 1 but cannot drop below the April 1 calculation. In the event that the NRCS inflow forecasts are substantially lower in May and June, relative to the April forecast, UKL storage volume will be utilized to deliver the "locked-in" April 1 Project Supply. The UKL Credit as described above in Chapter 4.3.2.2 was specifically designed to help offset any negative effects to UKL storage and listed suckers (by increasing UKL elevation above what it otherwise would have been) potentially resulting from this scenario. Further, because UKL storage is utilized to offset NRCS forecast error, there is no direct effect on EWA calculations in a given WY (*see* below for additional details).

Maximum calculated Project Supply is 350,000 AF, which occurs when UKL Supply is greater than 1,035,000 AF (which occurs in 30 percent of simulated years). When UKL Supply is less than 1,035,000 AF, Project Supply is calculated as UKL Supply minus EWA (*see* below for additional details), except when UKL Supply is greater than 550,000 AF and less than 950,000 AF. In that case, the Project Supply is reduced by the Project's share of the "flexible flow augmentation" volume (determined on March 1 and April 1), which can be up to 30,000 AF (*see* Chapter 4.3.2.2.2.5 and Appendix A, Section A.4.4.3). The final determination for Project Supply is made in June and is then fixed through the end of September. Regardless of the calculated Project Supply, Reclamation retains discretion to curtail deliveries from UKL as necessary to comply with applicable legal requirements or respond to hydrologic conditions as necessary. Finally, the UKL control logic does not create any conditions upon the use of Project Supply during the spring/summer period.

Project Supply is only the supply of water to be made available from UKL to the Area A1, Area A2, and LKNWR during the spring/summer period and is separate from the water available from the LRDC and return flows from the KSD. In other words, any water from LRDC discharges or KSD return flows that is diverted by the Project does not count against the Project Supply from UKL. Project diversions of LRDC discharge and KSD return flows will be evaluated on a daily basis and subtracted from the total Project diversion to compute the daily Project Supply usage. As discussed above, any portion of LRDC or KSD return flows not diverted by the Project (that

directly support IGD targets and result in a reduction in LRD releases) accrue as UKL Credit that remains in UKL to buffer against NRCS inflow forecast error.

Reclamation has committed to water users within the Project to explore means of more efficiently managing water that would otherwise be discharged to the Klamath River from the KSD. In addition to reducing KSD operating costs, this practice could help improve water quality in the Klamath River. To the extent KSD can be operated in a manner that results in hydrologic conditions consistent with the conditions anticipated under the KBPM, Reclamation reserves the discretion to make such operational changes. Reclamation will coordinate with the Services in advance of any such operational change.

Reclamation also proposes to deliver Project Supply to LKNWR in the spring/summer operational period of March 1 through November 30. Proposed spring/summer LKNWR deliveries are likely to include a combination of water available from Project Supply and stored water from UKL available in wet years, as further described below. The PA does not put any constraints on where Project Supply available for LKNWR can be used within the refuge. USFWS retains ultimate discretion over the use of water available to LKNWR.

Reclamation proposes to coordinate with USFWS and other Project water users to determine when Project Supply during the spring/summer operational period can be made available to LKNWR consistent with Reclamation's and delivery agencies' contractual and other legal obligations. When Reclamation determines that there is Project Supply not needed to meet other Project demands, such water can be delivered to LKNWR, as the model assumes full delivery of the entire calculated Project Supply allocation in all years. *See* Chapter 4.3.2.2.8. and Appendix 4, Section A.4.4.9 for additional details regarding LKNWR operations.

In addition to a portion of Project Supply, LKNWR may also receive spring/summer deliveries in June and July if Project Supply is 350,000 AF and UKL elevations are above 4,142.5 and 4,141.5 feet, respectively, on the first of each month; daily values to be exceeded are linearly interpolated thereafter. When these conditions were met in the modeled POR (12 of the 39 years), a maximum of 3,000 AF was made available to LKNWR from this source. Note that this water is not considered Project Supply.

The KBPM utilizes perfect foresight to ensure that all of the Project Supply and all LRDC discharges and KSD return flows that are needed to meet Project demand are diverted in full. In order to realistically distribute Project Supply over the irrigation period in the KBPM, Reclamation developed an Agricultural Water Delivery sub-model. The Agricultural Water Delivery sub-model simulated delivery of irrigation water on a 5-day timestep based on variables such as meteorological conditions, soil moisture, water availability, and deliveries in the previous 5-day timestep, scaled to Project Supply. To ensure that the sub-model would adequately simulate Project deliveries under this PA, the sub-model was first tested against historical Project deliveries and performed relatively well. This sub-model is a substantial improvement over past representations of agricultural deliveries in the KBPM. *See* Appendix 4, Section A.4.4.4 for a detailed description of the sub-model, sub-model development, and statistical analysis of sub-model performance.

4.3.2.2.2.3 Environmental Water Account

Similar to IGD flow targets in the fall/winter period, EWA (the volume of water used to meet IGD flow targets in spring/summer) distribution is based on a spring/summer formulaic approach for calculating IGD flow targets. The spring/summer formulaic approach is based on the EWA allocation, UKL control logic, UKL net inflow, and NRCS-forecasted March through September net inflow (50 percent exceedance) from March 1 through June 30. From March 1 through June 30 there is also a correction applied that accelerates EWA release if there was under-release in previous days (e.g., due to UKL control) and decelerates EWA release if there was an over-release in previous days (e.g., due to flood control or disease mitigation flows). From July 1 through September 30, EWA distribution is based on remaining EWA and UKL control logic. EWA releases for disease mitigation (Chapter 4.3.2.2.2.4 and Appendix 4, Section A.4.4.6), flexible flow augmentation (*see* Chapter 4.3.2.2.2.4 and Appendix 4, Section A.4.4.7), minimum required IGD flows (Appendix 4, Section A.4.4.6, Table A.4.4.6.1), and IGD, ramping flows (Chapter 4.3.2.2.5) are not subject to reduction under the UKL control logic.

KSD return flows are not considered accretions upon which EWA releases rely. In the spring/summer period, any return flows from LRDC and KSD not used by the Project contribute to the UKL Credit during controlled flow conditions (and when LRD releases are above the minimum flow targets).

The specific steps for calculating IGD target flows in the spring/summer include:

1. Determine the LRD flow target as follows:
   a. March 1 through June 30
      i. Determine the release adjustment factor (termed "in_pct_Mar50vol") that combines observed and forecasted net inflow, NRCS forecast error, and UKL Supply.
      ii. Multiply by the calculated EWA allocation, minus the 130,000 AF EWA volume reserved for the July to September baseflow period (137,000 AF in Boat Dance years), minus the release correction that accounts for the difference between the previous day's actual and calculated LRD releases (termed "Link_release_ss_diff").
   b. July 1 through September 30
      i. Divide the volume of EWA remaining for the current month by the number of days in the current month.
   c. Adjust based on the difference in UKL storage between the UKL adjusted central tendency and UKL elevation.
   d. Constrain by the maximum LRD release capacity, if applicable.

2. Determine the IGD flow target, which is the minimum of either the maximum IGD flow (look up table) or the IGD flow target (calculated below).
   a. To the LRD flow target calculated in step 1, add LRD to Keno Dam accretions from three days prior (i.e., this step relies on the accretion that occurred in a single day three days ago).

b. Add today's forecasted Keno Dam to IGD accretions from three days prior (i.e., this step relies on the accretion forecast for the current day that was issued three days ago).
c. Increase to the minimum IGD flow requirement (Appendix 4, Section A.4.4.6, Table A.4.4.6.1), if applicable.

IGD targets during March through June may be supplemented when "flexible flow augmentation" occurs (*see* Chapter 4.3.2.2.2.5). IGD targets can be altered to implement surface flushing flows from March 1 through April 15 (*see* Chapter 4.3.2.2.2.4).

The EWA volume is calculated on the first of each month from March through June as a portion of UKL Supply. Minimum EWA is 400,000 AF, which occurs when UKL Supply is less than 670,000 AF. When UKL Supply is greater than 1,035,000 AF, EWA is calculated as UKL Supply minus the maximum calculated Project Supply (350,000 AF). When UKL Supply is between 670,000 AF and 1,035,000 AF, EWA is calculated as described in Appendix 4, Section A.4.4.3. Note that EWA is increased by 7,000 AF in even years to augment IGD releases for the Yurok Boat Dance ceremony, typically occurring in late August or early September. Additionally, the daily disaggregation of the total flexible flow augmentation volume may be added to March through June daily IGD targets in years with March 1 or April 1 UKL Supply between 550,000 and 950,000 AF (*see* Chapter 4.3.2.2.2.5 and Appendix 4, Section A.4.4.3). The EWA volume calculated from the June 1 UKL inflow forecast is the final EWA volume for the year, with the exception of years with flexible flow augmentation in which the total flexible flow augmentation volume is added to the July 1 EWA (*see* Appendix 4, Section A.4.4.3). Finally, it is possible that the spring/summer formulaic approach to calculating IGD targets described above will result in an "overspend" (i.e., formulaic approach required more volume than was calculated for EWA, particularly if the Klamath River is at minimums) or an "underspend" (i.e., formulaic approach required less volume than was calculated for EWA) between March 1 - September 30. Regardless of the calculated EWA volume, IGD releases will reflect calculated IGD targets, with the exception of implementation of surface flushing flows and flexible flow augmentation (as described above and in Chapter 4.3.2.2.2.4 and 4.3.2.2.2.5). If EWA is overspent, UKL storage will be utilized to continue meeting IGD targets through September 30. If EWA is underspent, the unused EWA volume remaining on September 30 will remain in UKL. There is no inter-annual carryover of EWA.

The EWA is accounted for through both releases for the Klamath River through LRD and releases during flood control operations. In other words, all LRD releases between March 1 and September 30 that are not diverted to the Project and/or LKNWR are counted as EWA. Conversely, all stored water and live flow that is diverted at the A Canal or released from UKL via LRD and diverted at the LRDC, North Canal, or Ady Canal during the spring/summer period will count towards use of the Project Supply. Measurements for these diversions will be obtained at the point of diversion or measured at the location identified in the ACFFOD. For the measurement of these diversions below LRD, the UKL contribution will be the overall measurement less any flows from the LRDC and KSD. Any flow released from LRD during the spring/summer period (March 1 – September 30), that is not diverted into the LRDC, North Canal, or Ady Canal, is considered an EWA release and is counted towards the EWA. Furthermore, during IGD controlled flow conditions (e.g., minimum required flows, IGD targeted flows, ramping flows), contributions to IGD flow from LRDC discharge and KSD

return flows are counted as EWA releases when they result in an equivalent reduction in LRD releases to support Klamath River flows (i.e., when UKL Credit is accrued). This does not happen when UKL is in flood control.

In order to ensure that sufficient EWA volume remains to complete formulaic IGD releases during the "baseflow" months of the spring/summer period (July through September), EWA volume may need to be reset to a higher volume to account for high expenditures during March through June. When EWA releases above those needed to meet LRD minimum flows (as defined in Chapter 4.3.2.2.1) are made, these volumes are tracked cumulatively. If the cumulative volume exceeds a percentage of total EWA, a protective increase in EWA is made to support completion of formulaic flows. This protection is considered whenever the total releases made to support river flows in excess of the minimum LRD release (termed excess releases) have exceeded 22 percent of the total EWA from July 1 to the end of September. *See* Appendix 4, Section A.4.4.8 for specific details

As with fall/winter operations, close coordination and communication between Reclamation and PacifiCorp on the operation of the Klamath Hydroelectric Project will be required to efficiently implement any EWA flow schedule. PacifiCorp will implement releases downstream of IGD based on target flows provided by Reclamation. Reclamation will calculate those target flows according to the EWA distribution formula starting on March 1 of each year, with the exception of surface flushing flows and flexible flow augmentation flows when additional volume will be added to the IGD targets. Once implementation of the formulaic approach to EWA distribution is initiated, Reclamation will monitor IGD flows to ensure that the actual observed flows are consistent with the EWA flow schedule. *See* Chapter 4.3.2.2.6. for additional information regarding coordination with PacifiCorp.

As described above, EWA distribution will follow the spring/summer formulaic approach for calculating IGD target flows. However, in addition to the opportunity for flexible implementation of surface flushing flows and flow augmentation (*see* Chapter 4.3.2.2.2.4 and 4.3.2.2.2.5), it is possible to deviate from the spring/summer formulaic approach to EWA distribution. Specifically, real-time hydrologic conditions, such as high flow events or emergency situations, may warrant the need to deviate from this formulaic approach. In addition, there may be specific ecologic objectives that water resource managers may want to address that can only be achieved by deviating from the formulaic approach to EWA distribution. Any time a deviation from the formulaic approach occurs, either by necessity or to address a specific ecologic objective, or if it is determined that the formulaic approach results in conditions that are not consistent with the intent of the PA, the process detailed in Chapter 4.3.2.2.3 will be followed. However, the formulaic approach for EWA distribution considered in this PA was designed to meet the key ecologic objectives for UKL and the Klamath River. Therefore, Reclamation anticipates that implementation of the formulaic approach will address these ecologic objectives, and frequent deviations from this approach are not expected to be necessary, aside from those anticipated for disease mitigation/habitat flows (*see* Chapter 4.3.2.2.2.4 and 4.3.2.2.2.5).

4.3.2.2.2.4 Disease Mitigation Flows

Surface Flushing Flows (SFF)
Surface flushing flows in the KBPM reflect those described as Disease Management Guidance #1 in the Disease Management Guidance document (Hillemeier et al. 2017) and constitute an average daily release of at least 6,030 cfs from IGD for at least 72 consecutive hours. The specific objective of the SFF is to disturb surface sediment along the river bottom and disrupt the life cycle of *Manayunkia speciosa* (a polychaete), which is a secondary host for the *C. shasta* parasite central to salmonid disease dynamics in the Klamath River.

The KBPM models SFF to occur from March 1 through April 15. Operationally, it may be possible to implement SFF earlier or later than this period; however, it is possible that implementing SFF after mid-April could result in effects to UKL that are different had the flow been implemented earlier. In years with SFF Status 1 or 3, as described below, Reclamation, after coordination with the Services, may implement the SFF outside of the period assumed in the KBPM. Once an SFF has been implemented in a water year, or has occurred naturally, no additional managed SFF would be implemented until the next water year at the earliest. Similarly, in years when deep flushing flows (DFF) are achieved during the December through April period, it will serve as the SFF for that given water year.
Decisions about when to trigger an SFF posed a challenge within the KBPM. Once a decision has been made that an SFF will occur, Reclamation will need to decide when to trigger it. Within the KBPM, this challenge was managed in several ways. In some years, the SFF trigger date was directly specified, something that Reclamation can clearly not replicate in real time operations. In other years, model logic was allowed to trigger an SFF when certain conditions occurred which was intended, in-part, to make efficient use of stored water by implementing the SFF when downstream accretions were relatively high. Reclamation could choose to trigger the SFF in accordance with these rules, but real-time operations will at times require consideration of potentially important factors that are not captured by the model rules. Therefore, Reclamation retains the discretion to deviate from the KBPM rules described below, and to consider appropriate information that may not be present in the KBPM rules, when making decisions regarding implementation of surface flushing flows.

More detail on how the KBPM implements surface flushing flows is given in Appendix 4, Section A.4.4.7. In the KBPM, the first step is to decide whether to implement an SFF in a specific year. This decision is made on March 1st, and then again on April 1st, based on UKL Supply, as follows:

1. On March 1:
    a. If the calculated UKL Supply is less than 815,000 AF (SFF Status 1), an SFF will be implemented.
    b. If the calculated UKL Supply is greater than or equal to 815,000 AF and less than 904,000 AF (SFF Status 2), an SFF will not be implemented.
    c. If the calculated UKL Supply is greater than or equal to 904,000 AF (SFF Status 3), an opportunistic SFF may be implemented when applicable criteria (discussed below) are met.
    d. SFF Status determined on March 1 remains unchanged through March 31.

2. On April 1, if no SFF was triggered in March then:
    a. If the calculated UKL Supply is less than 750,000 AF (SFF Status 1), an SFF will be implemented.
    b. If the calculated UKL Supply is greater than or equal to 750,000 AF and less than 904,000 AF (SFF Status 2), an SFF will not be implemented.
    c. If the calculated UKL Supply is greater than or equal to 904,000 (SFF Status 3), an opportunistic SFF may be implemented when applicable criteria (see below) are met.
    d. SFF Status determined on April 1 remains unchanged through June 30.

A UKL Supply of 904,000 AF coincides with an EWA of 575,000 AF, exceedance of which is one of the criteria necessary to implement an opportunistic SFF (described below).

After Reclamation has decided that an SFF will occur, the next step is to determine when to trigger the event. As described above, in some years the KBPM triggered the SFF on a date unique to a specific year, which is called a manual trigger operation. This was done to better simulate when operators would likely have triggered the SFF in those years based on experience gained in recent years. If a manual trigger operation was not specified for a year, then the implementation and timing of the SFF was governed by the criteria described below.

In years that are SFF Status 1, the SFF is triggered in the KBPM when the following criteria are met:

1. The date is between March 1 and April 15;
2. There is sufficient head behind LRD, and accretions between LRD and IGD, to produce 6,030 cfs for 72 hours at IGD; and
3. The previous day's UKL elevation is greater than 4,142.4 feet.
4. If all three criteria above are not met by April 15, and no surface flushing flow has occurred, then on April 15 a surface flushing flow was implemented. Under such conditions, it is possible that 6030 cfs for three days will not be attained because of insufficient head behind LRD, insufficient accretions between LRD and IGD, or both.

In years that are SFF Status 3, an opportunistic SFF is triggered in the KBPM when the following criteria are met:

1. The date is after February 28 (or February 29 in leap years) but earlier than April 16;
2. There is sufficient discharge capacity at LRD and accretions between LRD and IGD, to produce 6,030 cfs for 72 hours at IGD;
3. The previous day's UKL water surface elevation is greater than 4,142.4 feet; and
4. The previous day's IGD flow is greater than 3,999 cfs.

Reclamation will use the following guidelines to account for SFF:

1. A flow event producing an average of 6,030 cfs at IGD for 72 hours that does not

occur from March 1 through April 15, will not qualify as an SFF.

2. The volume of water used for SFF count towards use of EWA.
3. Surface flushing flows are not subject to reductions due to the UKL control logic.
4. Surface flushing flows are subject to the ramping rates identified in Chapter 4.3.2.2.5.
5. In Years when DFF are achieved during the December through April period, it will serve as the SFF for that given water year.

See Appendix 4, Part A.4.4.7 for additional information regarding implementation of surface flushing flows in the KBPM.

Deep Flushing Flows
KBPM model logic does not incorporate "forced" deep flushing flows (11,250 cfs for 24 hours), described as Disease Management Guidance #2 in the Disease Management Guidance document (Hillemeier et al. 2017). However, Reclamation will attempt to implement deep flushing flows when hydrologic conditions and public safety allow. Specifically, infrastructure limitations and public safety issues (particularly release capacity at LRD and flood concerns in the middle and lower Klamath Basin) are such that a suite of conditions must be present in order to implement a flow of sufficient magnitude to accomplish the objectives of a deep flushing flow event. These conditions include, but are not limited to, UKL storage to allow for sufficient LRD release capacity, UKL storage sufficient to protect sucker needs, substantial accretions, and Klamath River tributary discharge that does not result in risk to public safety and property. Typically, this suite of conditions occurs when UKL is at flood curve in the late winter or early spring and there is a rain-on-snow hydrologic event. Maximum LRD capacity at the maximum allowable UKL elevation under the current flood curve (4,143.3 feet) is approximately 8,600 cfs, meaning that additional accretions of up to approximately 2,650 cfs for 24 hours would be necessary to achieve 11,250 cfs from IGD at full UKL storage under this PA; accordingly, larger accretions are necessary if UKL elevation is less than 4,143.3 feet. Implementation of a deep flushing flow will require coordination with PacifiCorp and appropriate public authorities.

4.3.2.2.2.5 Flexible Flow Augmentation
In the 2019 BiOp, IGD releases during May and June were supplemented by an additional 20,000 AF in years when April 1 EWA was greater than 400,000 AF (407,000 AF in years when the Boat Dance occurs) and less than 576,000 AF. In this 2020 PA, the supplementation scheme under the 2019 BiOp was replaced by an operational approach called "flexible flow augmentation." In the flexible flow augmentation approach, when Project Supply is between 550,000 AF and 950,000 AF, a volume of water for augmenting Klamath River flow is deducted from the calculated Project Supply (PRJ_FlexAugment) and UKL (UKL_FlexAugment) and added as appropriate to IGD flow targets during March through June. The volume of flexible flow augmentation water varies according to the calculated UKL Supply (*see* Appendix A, Section A.4.4.3, Figure A.4.4.3.1).

Although real-time operations may differ on the rate at which the water is used to augment flows, for purposes of modeling the effects of flexible flow augmentation, the default rules for

implementing flexible flow augmentation are as follows (*see* Appendix A, Section A.4.4.3 for a more detailed explanation):

1. Flexible flow augmentation volumes are computed on March 1, again on April 1, and do not change thereafter. When UKL Supply is between 550,000 AF and 825,000 AF, UKL_FlexAugment is at a maximum of 10,000 AF; when UKL Supply is above 825,000 AF, UKL_FlexAugment declines linearly to zero. When UKL Supply is between 550,000 AF and 650,000 AF, PRJ_FlexAugment increases linearly from 10,000 AF to its maximum of 30,000 AF, where it remains until UKL Supply exceeds 825,000 AF, above which PRJ_FlexAugment declines linearly to zero. Both UKL_FlexAugment and PRJ_FlexAugment are zero when UKL Supply is either less than 550,000 AF or greater than 950,000 AF. EWA volume calculations do not affect the calculation or delivery of the flexible flow augmentation volume.
2. Flow augmentation can occur in the March through June window. It is not possible to reliably simulate processes and conditions that would drive the real-time decision process for releasing the flexible flow augmentation volume (*see* Appendix 4, Section A.4.4.6). As a result, the KBPM modelled this flow augmentation based on year-specific timing and duration specified in a reference table. Operationally, Reclamation will coordinate as described below to determine the starting day, duration, and daily magnitude (including potential ramping) of flexible flow augmentation, while constraining the implementation to be within the March through June window and to not exceed the total flexible flow augmentation volume.
3. In the KBPM, the daily flexible flow augmentation volume is computed as the variable named FlexFlowAdjust. As described in Chapter 4.3.2.2.2.4, in years categorized as SFF Status 2, 20,000 AF of EWA volume will be distributed in the same manner as the flexible flow augmentation volume. This is accomplished by adding 20,000 AF in the applicable year to the equations that follow:
    a. When augmentation occurs in March: FlexFlowAdjust = (PRJ_FlexAugment + UKL_FlexAugment) / duration, resulting in a uniform augmentation flow to be added to the calculated Iron Gate flow target for each day to be augmented in March.
    b. When augmentation occurs in April: FlexFlowAdjust = (PRJ_FlexAugment + UKL_FlexAugment) / (duration – days augmented in March)
    c. Water volume needed for down-ramping (if any) near the end of the augmentation period is included in the total augmentation volume.
4. FlexFlowAdjust is added to the appropriate minimum IGD flow requirement and release target.
5. Calculated Project Supply is reduced by PRJ_FlexAugment.

Because the total flexible flow augmentation volume (PRJ_FlexAugment + UKL_FlexAugment) supplements the daily IGD release targets calculated based on the EWA, it is added to the July 1 EWA to ensure proper EWA accounting for the remainder of the spring/summer season. In SFF Status 2 years, the 20,000 AF of EWA volume that is distributed in the same manner as the flexible flow augmentation volume is not added to the July 1 EWA. Additionally, the default

rules assume that when flexible flow augmentation is implemented and IGD flow targets would otherwise be at minimums, Reclamation would implement flow variability (up to +/- 75 cfs around the augmented IGD flow targets).

Reclamation anticipates that NMFS will recommend alternative distributions to default rules 2 and 3 described above, based on specific environmental conditions, forecasts, and other information, as a means to optimize the benefit to coho salmon. The Flow Account Scheduling Technical Advisory (FASTA) Team will consider and may make recommendations on deviations from the default rules used to manage the flexible flow augmentation volume, the timing of surface flushing flows, and the timing, distribution, and duration of the 20,000 AF of EWA volume for augmentation in years classified as SFF Status 2. *See* Chapter 4.3.2.2.3 for details regarding the FASTA adaptive flow management process.

4.3.2.2.3 Flow Account Scheduling Technical Advisory Team and the Flow Management Process

As discussed above, there may be opportunities to benefit coho through deviations from the formulaic approach to IGD targets in the fall/winter and EWA distribution in the spring/summer. Reclamation, in coordination with the Services, will consider input from Klamath Basin technical experts relative to these actions and opportunities. Reclamation therefore proposes that the FASTA Team be the venue in which these technical experts provide input on flow management options.

The primary purpose of the FASTA Team (made up of tribal members [Klamath, Hoopa, Yurok, Karuk], federal agencies [NMFS, USFWS, USGS], PacifiCorp, Oregon state agencies [OWRD, ODFW], California Department of Fish and Game, university researchers [Oregon State, Humboldt], and others is to share information on hydrologic, meteorological, disease, and other conditions among Klamath Basin technical experts. However, an important secondary function will be to serve as a venue for input on flow management options, including input or evaluations regarding the shaping of EWA for disease mitigation or habitat improvement/protection. Participants in the FASTA Team are technical specialists focused on meaningful participation, facilitating timely implementation of the flow input process (described below), and providing input to Reclamation and the Services. Operational or compliance decisions will not be made by the FASTA Team or during FASTA Team calls or meetings.

As operator of the Klamath Project, Reclamation retains decision-making authority relative to flow management and operations on and related to the Project, though Reclamation encourages input and feedback from the FASTA Team. Reclamation also retains discretion regarding FASTA Team participants.

Ultimately, Reclamation, as a bureau within the Department of Interior, and acting under the overall authority of the Department and Secretary of the Interior, makes flow management decisions affecting UKL and the Klamath River. The process outlined below does not relinquish any departmental or secretarial authority or responsibility. Additionally, Reclamation determines whether proposed flows are consistent with flood control, public safety, and operational constraints for UKL and the Klamath Project.

The specific process for providing flow management input via the FASTA Team is as follows:

1. A FASTA Team member (inclusive of the Services) provides input regarding flow management during a FASTA Team call, or via email or call directly to the Klamath River Manager.
   a. If the input is provided outside of a FASTA Team call, the Klamath River Manager may choose to schedule a call or otherwise discuss the input with other FASTA Team members prior to moving to step two.

2. The Klamath River Manager initiates internal Reclamation discussions to determine if the proposed flows are operationally feasible. Specifically, this will include evaluating whether:
   a. The proposed flows are feasible given Reclamation infrastructure and operations, public safety, flood control, and other operational constraints;
   b. Evaluating whether the proposed flows comply with applicable state and federal law; and
   c. Evaluating whether the proposed flows are consistent with the PA.
   d. If the proposed flows are determined by Reclamation to not be operationally feasible for the Klamath Project, no further action is necessary.

3. If Reclamation determines the proposed flows are operationally feasible, Reclamation will initiate conversations with PacifiCorp to determine if the proposed flows are operationally feasible for PacifiCorp's Klamath Hydroelectrical Project (additional information relative to coordination expectations is described in Chapter 4.3.2.2.6.)
   a. If the proposed flows are determined by Reclamation and/or PacifiCorp to not be operationally feasible, no further action is necessary.

4. If the proposed flows are operationally feasible for both Reclamation and PacifiCorp, Reclamation will initiate conversations with the Services to determine if the proposed flows provide additional ecological benefit to coho, while maintaining UKL elevations/conditions necessary for listed suckers.
   a. If the proposed flows are determined by Reclamation and/or Services to not provide additional ecological benefit, no further action is necessary.

5. If the Services' technical experts determine that the proposed flows are likely to result in benefit to coho and would not adversely affect listed suckers, then Reclamation will take steps to implement the proposed flows. Reclamation will be responsible for implementing the proposed flows, coordinating with PacifiCorp, issuing public safety notices, and any other coordination required to implement in a timely manner.

Reclamation retains discretion to deviate from the steps outlined above when considering flow management input. Additionally, Reclamation will communicate with FASTA Team members the outcome of the steps above, when possible and appropriate.

Finally, the Klamath River Manager is the individual responsible for scheduling and holding FASTA Team calls (as needed, but typically weekly or every other week) and distributing relevant information (as needed, but typically weekly, typically in the form of a slide presentation). Weekly updates will typically include information such as EWA use, Project deliveries, remaining Project Supply, UKL elevation, LKNWR deliveries, projected IGD target

flows, meteorological information, etc. Reclamation retains discretion regarding the content of the FASTA slides and any other information made available to the FASTA Team, and the timing and frequency of FASTA Team calls. Also note that Reclamation retains discretion to end FASTA calls if participants other than technical experts call in.

4.3.2.2.4 Flood Control Operations

Maximum UKL flood control elevations are utilized as a guideline in an attempt to provide adequate storage capacity in UKL to capture high runoff events, to avoid potential levee failure due to overfilling UKL, and to mitigate flood conditions that may develop in the Keno Impoundment. The general process of flood control consists of spilling water from UKL when necessary to prevent elevations from increasing above flood pool elevations, which change throughout the year in response to inflow forecasts and experienced hydrology. Flood pool elevation is calculated each day to create a smooth UKL operation, allowing UKL to fill (i.e., approach 4143.3 ft) by the end of March in drier years and by the end of April in wetter years. The UKL flood control elevations require evaluation by Reclamation, and professional judgment will be utilized in combination with hydrologic conditions, snowpack, forecasted precipitation, public safety, and other factors to determine the most appropriate action in the actual operation of UKL during flood control operations.

The flood control elevations are set at 4,141.4 feet in September and October and then increase from 4,141.4 to 4,141.8 feet from November 1 through December 31 (daily values are obtained through interpolation). In most years, there are no flood control releases during these months.

From January 1 through April 30, the UKL flood control elevations are determined based on the forecasted inflow and the day of the month. The NRCS UKL net inflow forecast is used to determine the end of month flood control elevation (Appendix 4, Section A.4.4.10, Table A.4.4.10.1) and the daily flood control elevation is linearly interpolated between the current end of month elevation and the previous month's end of month flood control elevation.

Additionally, UKL flood control elevations vary between wet and dry year types. The distinction is based on the NRCS March through September 50 percent exceedance forecast for UKL net inflow issued in January, February, and March. The forecast issued in March is used for both March and April. If the forecast March through September net UKL inflow is greater than 710,000 AF, the year is considered wet; the WY is considered dry if the forecast net inflow is equal to or less than 710,000 AF. It is important to note that the flood control curve and flood control operations are consistent with what has been implemented under the 2013 and 2019 BiOps. *See* Appendix 4, Section A.4.4.10 for details.

Reclamation retains sole discretion to determine when to initiate or cease flood control operations. No official flood operations guidance from Army Corps of Engineers is available for UKL, Clear Lake, or Gerber.

4.3.2.2.5 Flow Ramping

Ramping rates limit rapid fluctuations in streamflow downstream of dams. Reclamation proposes a ramping rate structure that varies by release rate at IGD. The ramp rates proposed below are as measured at the USGS gaging station located immediately downstream of IGD (USGS Station ID#: 11516530). IGD is owned and operated by PacifiCorp and the ramp down

rates will be implemented by PacifiCorp as part of IGD operations. Reclamation will coordinate with PacifiCorp as appropriate on the implementation of the ramp down rates.

The target ramp down rates at IGD, when possible, are as follows:

- When IGD flows are greater than 4,600 cfs: decreases in flows of no more than 2,000 cfs per 24-hour period, and no more than 500 cfs per six-hour period.

- When IGD flows are greater than 3,600 cfs but equal to or less than 4,600 cfs: decreases in flows of 1,000 cfs or less per 24-hour period, and no more than 250 cfs per six-hour period.

- When IGD flows are greater than 3,000 cfs but equal to or less than 3,600 cfs: decreases in flows of 600 cfs or less per 24-hour period, and no more than 150 cfs per six-hour period.

- When IGD flows are above 1,750 cfs but equal to or less than 3,000 cfs: decreases in flows of 300 cfs or less per 24-hour period, and no more than 125 cfs per four-hour period. (Note that ramp rates can be slower, such as 75 cfs per six-hour period, if Reclamation and PacifiCorp agree on a schedule).

- When IGD flows are 1,750 cfs or less: decreases in flows of 150 cfs or less per 24-hour period and no more than 50 cfs per two-hour period.

Upward ramping is not restricted. Additionally, NMFS concluded in their 2002 BiOp that ramp down rates below 3,000 cfs, as outlined above, adequately reduce the risk of stranding juvenile (and fry) coho salmon (NMFS 2010a).

Facility control limitations and stream gage measurement error limit the ability to accurately manage changes in releases from IGD at a fine resolution. In addition, facility control emergencies may arise that warrant the exceedance of the proposed ramp down rates. Therefore, Reclamation recognizes that minor variations in ramp rates (within 10 percent of targets) will occur for short durations and all ramping rates proposed above are targets and are not intended to be strict maximum ramp rates. Reclamation expects significant exceedance of the proposed ramp rates due to facility control limitations, stream gage error, and/or emergency situations will occur infrequently and will be corrected as soon as possible when they do occur.

Under some circumstances (based on presence and abundance of federally-listed species, life cycle stage, hydrologic conditions in the Klamath River and tributaries, and other considerations) the proposed ramp rates may be more stringent than necessary to prevent the stranding of federally-listed species downstream of IGD. Reclamation, in coordination with NMFS, may explore more flexible ramping rates to determine under what conditions those rates would be appropriate to implement.

IGD is a PacifiCorp facility and Reclamation does not have control over the implementation of ramp down rates and operations at IGD. However, Reclamation will coordinate with PacifiCorp as appropriate to ensure that implementation of the ramp down rates is consistent with those

proposed herein and required by PacifiCorp's Interim Operation Habitat Conservation Plan for Coho Salmon (HCP) (PacifiCorp 2012).

4.3.2.2.6 Coordination with PacifiCorp

PacifiCorp is required by its 2012 Biological Opinion (PacifiCorp 2012) to implement flow-related operations consistent with Reclamation's BiOp requirements. This, combined with the fact that Reclamation's PA includes IGD as a compliance point, means close coordination between Reclamation and PacifiCorp is necessary for implementation of the PA and corresponding BiOps.

All IGD target flows will be determined and coordinated with PacifiCorp three days in advance. Reclamation will also provide an IGD target forecast for an additional 11 days using projections based on NRCS UKL inflow forecasts (if available), California Nevada River Forecast Center hydrologic forecasts (namely, for accretions and some UKL tributaries), meteorological forecasts, measured flows, historical patterns, and professional judgement. If these information sources do not adequately predict flows for ongoing operations, Reclamation may ask PacifiCorp to provide accretion estimates between Keno and Iron Gate as they have since the 2013 BiOp. This additional 11 days of forecasted IGD flow targets is intended to provide additional advanced planning opportunities for resource managers and PacifiCorp. However, provisional flow targets provided for these additional 11 days are estimates and the actual IGD target flows will be determined after the upper Klamath Basin hydrologic conditions and LRD to IGD accretions are actually observed.

PacifiCorp has successfully coordinated with Reclamation to implement the requirements associated with the 2019 BiOp during the last year and 2013 BiOp prior to that. Reclamation expects this close coordination to continue for the implementation of Project operations resulting from this consultation. In addition, emergencies may arise that necessitate PacifiCorp to deviate from the IGD release target. These emergencies may include, but are not limited to, flood control, and facility and regional electrical service emergencies. Reclamation will closely coordinate with PacifiCorp should the need to deviate from the IGD flow target be identified due to an emergency. Such emergencies occur infrequently and are not expected to significantly influence flows downstream of IGD.

On a weekly basis, Reclamation will assess how the actual observed IGD flows compare to the target flows and communicate any necessary adjustments of LRD releases to PacifiCorp. During periods of rapid hydrologic change and/or during an urgent in-season flow schedule adjustment, it may be necessary to coordinate with PacifiCorp more frequently. PacifiCorp will make every attempt to follow the flow schedule provided by Reclamation (and based on the EWA distribution/IGD formulaic approach described in Chapter 4.3.2.2.1. and 4.3.2.2.2.3.) as closely as possible within the operational constraints of the Klamath Hydroelectric Project facilities and based upon their obligations under the existing HCP (PacifiCorp 2012), except when requested otherwise by Reclamation for events such as flushing flows and enhanced May/June flows. If Reclamation determines that actual mean daily flows deviate from the flow schedule above the percentages described in Chapter 3.6.1., Reclamation may need to coordinate with PacifiCorp, the FASTA Team, and Klamath Basin Area Office (KBAO) Area Manager to take corrective action, which may result in the need for a formal in-season deviation from the formulaic approach for IGD targets and EWA distribution. The relative effect of deviating from the flow

schedule depends on many hydrologic, climatologic, and ecologic factors, and the same amount of deviation from the flow schedule does not warrant the same response in all situations. For example, a deviation of 100 cfs downstream of IGD when flows are in excess of 3,000 cfs doesn't require the same consideration as a deviation of 100 cfs when IGD flows are at 900 cfs. Each instance will need to be considered on a case-by-case basis.

Relative to the process laid out in Chapter 4.3.2.2.3., Reclamation will provide PacifiCorp with adequate lead time when implementing deviations from the formulaic approach. Reclamation will make every attempt to provide two weeks advanced notice to PacifiCorp when requesting flow schedule adjustments. In some circumstances Reclamation may request PacifiCorp to respond in less than two weeks if the adjustment to the flow schedule is urgent due to the need to respond to real-time and/or emergency conditions that warrant rapid response (i.e., fish disease, fish die-off, poor water quality, unexpected hydrologic conditions, imminent flooding or other health and safety issues, etc.). Finally, this section is not inclusive of all possible Reclamation-PacifiCorp coordination needs and processes. Additional coordination details regarding specific management actions (i.e., ramping rates) are contained within sub-sections of Chapter 4.3.2.2.

4.3.2.2.7 Tule Lake Sump operations

The proposed minimum elevations for TLS 1A are described below. Tule Lake National Wildlife Refuge (TLNWR) deliveries are outlined in Chapter 4.3.2.2.8. Actual water availability and TID return flows will determine the amount of water available for TLNWR including federal lease lands. Reclamation proposes to maintain a consistent year-round minimum elevation in TLS 1A (Table 4-2).

During excessively dry periods when the UKL Supply is inadequate to meet Project demands, it may not be possible to maintain TLS 1A elevations due to decreased runoff to TLS 1A. This condition would be outside of Reclamation's control and the proposed minimum elevations would not apply. In the event that surface water supply is estimated to be unavailable or is insufficient to maintain biological minimum elevations of TLS 1A (e.g., greater than 95 percent exceedance inflow years such as 1992 and 1994), Reclamation proposes to coordinate with USFWS as early as is possible to determine if relocation of adult suckers from the sumps to more permanent bodies of water within the species range is prudent.

Table 4-2. Minimum Sump 1A Elevations (Bureau of Reclamation Datum).

Time Period	Elevation (feet)
April 1 through September 30 (each year)	4,034.0
October 1 through March 31 (each year)	4,034.0

During dry winter conditions, Reclamation will initiate discussions with USFWS to determine the best course of action, including the likelihood of a sucker relocation effort from Tule Lake. If Reclamation and USFWS deem it necessary to relocate suckers from Tule Lake during these discussions, Reclamation, in coordination with the USFWS, will develop a proposal that Reclamation will employ to relocate suckers from the Tule Lake Sumps before seasonally stressful conditions develop. The proposal will describe methods for capture and transport of fish, release sites, fish handling techniques, and the appropriate level of effort expected to relocate suckers (*See* Appendix 4 for example).

4.3.2.2.8 Other Refuge Deliveries

Federally-owned lands within TLNWR and LKNWR receive and use Project water from multiple sources, in a variety of ways as described below.

For TLNWR, irrigated agricultural lands generally obtain water for irrigation and refuge use from return flows from irrigated lands within the Project. These return flows accumulate in the Tule Lake Sumps and are diverted via the R and Q canals or are pumped into the N Canal from drains serving private lands in TID.

Generally, irrigation return flows and tributary runoff are adequate to meet irrigation and refuge demands within TLNWR, limiting the need for direct deliveries from UKL and the Klamath River. When irrigation demands are high, Project Supply during the spring/summer period (i.e., water from UKL and the Klamath River) may be needed for irrigation use within TLNWR. All deliveries to TLNWR are coordinated between TID and USFWS, Reclamation, or the individual lessee of the lands, consistent with Reclamation's water supply contract with TID.

LKNWR deliveries proposed as part of this PA are discussed in Chapters 4.3.2.2.1. and 4.3.2.2.2. above. In addition to the proposed fall/winter and spring/summer deliveries, Reclamation also anticipates that from April 1 through September 30 LKNWR *may* exercise a water right temporarily transferred from the Agency Lake and Barnes Ranch properties to irrigable lands in LKNWR (*see* Chapter 1.3.6 for further information on the current transfer order applicable to these water rights). In the State of Oregon, a valid water right, such as those appurtenant to the Agency Lake and Barnes Ranch properties, can be exercised at any time for the authorized beneficial purpose within the authorized period of use, to the extent water is physically available at the point or points of diversion and the water right is not otherwise subject to regulation based on a call by a senior water rights holder (*see* Chapter 1.3.2, for background information on the prior appropriation doctrine as applicable in the State of Oregon).

Collectively, the transferred water right from the Agency Lake and Barnes Ranch properties allows for diversions at the Ady Canal of up to approximately 31 cfs and 11,200 AF in total annually. This transferred water right has a priority date of September 13, 1920 and is potentially subject to water rights regulation in the Upper Klamath Basin based on calls by senior water rights holders, including potentially a call made on behalf of the water rights for the Project. In the event of call by the Project or other senior water rights holders, USFWS may not be able to exercise this transferred water right due to regulation by OWRD. For purposes of this PA, the KPBM assumes that diversions at the Ady Canal associated with this transferred water right will be approximately 11,000 AF.

Water diversions by the USFWS to the Ady Canal pursuant to the water right transferred from the Agency Lake and Barnes Ranch properties are not subject to UKL control logic, given that in approving this transfer, OWRD determined that this water would have historically been diverted and consumed upstream of UKL.

In addition to unused spring/summer water from the Project, water associated with the transferred water right from the Agency Lake and Barnes Ranch properties, local tributary runoff (e.g., Sheepy Creek), and groundwater sources utilized by the USFWS (all when available),

LKNWR receives water from the Tule Lake Sumps via the Tule Lake Tunnel and Pumping Plant D, which are all Project facilities.

TID operates and maintains the Tule Lake Sumps, Pumping Plant D, and the Tule Lake Tunnel. Generally, Pumping Plant D is operated as necessary to maintain water surface elevations in the Tule Lake Sumps consistent with rules and regulations issued by Reclamation (primarily for flood control purposes), levels to meet USFWS migratory bird/wildlife needs, and ESA requirements (*see* Chapter 4.3.2.2.7).

Deliveries to LKNWR via Pumping Plant D have significantly decreased in recent years due to drought, regulatory limitations on Project diversions, and increases in power costs associated with pumping. These factors have resulted in decreased pumping from Tule Lake to LKNWR through Pumping Plant D. The historical average annual volume pumped dating back to 1941 is approximately 70,000 AF. Over the last ten years the annual average volume has been under 20,000 AF. Regardless, these pumping activities are not part of Reclamation's PA and are not modeled in the KBPM, which focuses on UKL and the Klamath River.

4.3.2.2.9 Deliveries of Stored Water from Clear Lake and Gerber Reservoirs

Clear Lake and Gerber reservoirs are used to store seasonal runoff to meet irrigation needs of the Project and to prevent flooding in and around Tule Lake. Stored water from Clear Lake and Gerber reservoirs is generally used for irrigation purposes within LVID, Horsefly Irrigation District (HID), and for lands covered by individual contracts; however, Reclamation can and historically has at times released water from both reservoirs for use for irrigation purposes within KID and TID (*see* Chapter 1.3.3., regarding Reclamation's water supply contracts with KID and TID).

Stored water released from Clear Lake Reservoir is generally diverted at Malone Diversion Dam into either the West Canal or East Malone Lateral. The East Malone Lateral serves approximately 1,800 acres on the east side of the Lost River. The West Canal serves approximately 6,750 acres within LVID. The West Canal also has a spill structure at its terminus, so that water can be discharged into the Lost River for re-diversion and use within HID. Stored water from Clear Lake Reservoir can also be released through the spillway gates on Malone Diversion Dam, for use within LVID, HID, KID, and TID.

Stored water released from Gerber Reservoir is generally diverted at Miller Creek Diversion Dam into the North Canal, for irrigation use within LVID. The North Canal serves approximately 9,550 acres within LVID.

In addition to irrigation deliveries, Reclamation makes flood control releases from Clear Lake and Gerber reservoirs, when conditions necessitate.

Reclamation proposes to operate the portion of the Project served by Clear Lake and Gerber reservoirs as described below.

4.3.2.2.9.1 Clear Lake Reservoir Operations

Under the PA, Clear Lake Reservoir will provide a range of water supplies consistent with historical operations necessary to meet demand throughout the duration of the action.

Reclamation proposes to operate Clear Lake Reservoir to meet the full irrigation demand of the Project, while maintaining the end of September minimum elevation. Historical annual releases vary based on available water supply and demand, with an average release of approximately 35,000 AF, based on the POR for which adequate data is available (1986-2019). With 35,000 AF being the approximate average annual release from Clear Lake Reservoir, a volume greater than 35,000 AF will be released in approximately half of years. Historical releases from Clear Lake Reservoir have ranged from zero AF, when no irrigation water supply was available, to more than 115,000 AF when flood control operations occurred. Water supply for irrigation purposes is generally used from April 15 – September 30 of each year. The outlet at Clear Lake Dam is generally opened on April 15 and closed by October 1, although slight deviations have occurred in the POR. The typical release rate during irrigation season is approximately 120 cfs, with a typical maximum irrigation release of approximately 170 cfs. Releases can be greater during flood control operations and when irrigation demand is high. Table 4-3 summarizes monthly releases from Clear Lake Reservoir by month for the April through October time period. Some releases have also historically occurred during the months of February and March, primarily for flood control, and are not included in the table below.

Table 4-3. Summary of monthly 1986-2019 Clear Lake Reservoir releases (thousand acre-feet).

	April	May	June	July	August	September	October
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.19	5.19	6.03	7.51	7.17	5.35	0.00
Average	2.36	5.34	6.35	6.95	6.52	4.71	0.06
Maximum	31.27	29.20	16.32	15.73	18.68	27.44	0.94

Available water supply from Clear Lake Reservoir is estimated annually using a seasonal forecasting model (*see* Appendix 4, Section D). The model allows Reclamation to estimate available water supplies and provide insight on appropriate deliveries that will provide elevations greater than the end of September minimum reservoir elevation, while taking into account projected inflows, typical delivery patterns, seepage, and evaporation. Changes in releases during the irrigation season are largely dictated by irrigation demand throughout the spring/summer period. Table 4-4 lists the end of September minimum proposed elevation for Clear Lake Reservoir.

Table 4-4. Minimum Clear Lake Reservoir end of September elevation (Bureau of Reclamation Datum).

Water Body	Elevation (feet)
Clear Lake Reservoir	4,520.6

4.3.2.2.9.2 Gerber Reservoir Operations

Under the PA, Gerber Reservoir will provide a range of water supplies consistent with historical operations that are necessary to meet demand throughout the period covered by this BA. Reclamation proposes to operate Gerber Reservoir to meet the full irrigation demand of the Project, while maintaining the end of September minimum elevation. Historical annual releases vary based on available water supply and demand, with an average of approximately 35,000 AF, based on the POR for which adequate data is available (1986 through 2019). With 35,000 AF being the approximate average annual release from Gerber Reservoir, a volume greater than 35,000 AF will be released in approximately half of years. Historical releases from Gerber

Reservoir have ranged from approximately 1,000 AF, when little irrigation water supply was available, to almost 95,000 AF when flood control operations occurred. Water supply for irrigation purposes is generally used from April 15 to September 30 each year. The outlet of Gerber Dam is generally opened on April 15 and closed on October 1, although slight deviations have occurred in the POR. The typical release rate during irrigation season is approximately 120 cfs with a typical maximum irrigation release of approximately 170 cfs. Releases can be greater during flood control operations and when irrigation demand is high. Table 4-5 summarizes monthly releases from Gerber Reservoir by month for the April through October time period. Some releases have also historically occurred during the months of November through March, primarily for flood control, and are not included in the table below.

Table 4-5. Summary of monthly 1986 through 2019 Gerber Reservoir releases (thousand acre-feet).

	April	May	June	July	August	September	October
Minimum	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Median	0.09	5.46	6.69	7.81	7.39	6.00	0.00
Average	1.34	4.86	6.32	7.16	6.55	5.32	0.06
Maximum	17.03	7.85	8.63	8.94	8.35	7.34	0.80

Historically, approximately two cfs is bypassed and released into Miller Creek during the winter months to prevent a valve in the dam from freezing and improve conditions for federally-listed suckers that may be present in pools below the dam when irrigation deliveries are not occurring. This bypass has typically occurred in late October or early November until the beginning of the following irrigation season, although it has occurred as early as July. Reclamation intends to continue the two cfs bypass from Gerber Reservoir as part of operations in this PA. In the event of a mid-irrigation season shut off (as occurred in 2015), or concerns about meeting minimum lake elevations, Reclamation will coordinate with the USFWS on whether or not opening the frost valves is warranted.

Available water supply from Gerber Reservoir is estimated annually with a seasonal forecasting model (*see* Appendix 4, Section D). The model allows Reclamation to estimate available water supplies and provide appropriate deliveries that will provide elevations greater than the established end of September minimum lake elevation while taking into account projected inflows, typical delivery patterns, seepage, and evaporation. Changes in releases during the irrigation season are largely dictated by irrigation demand throughout the spring/summer period. Table 4-6 lists the end of September minimum proposed elevation for Gerber Reservoir.

Table 4-6. Minimum Gerber Reservoir end of September elevation (Bureau of Reclamation Datum).

Water Body	Elevation (feet)
Gerber Reservoir	4,798.1

4.3.2.2.10 Diversions of Live Flow from the Lost River

In addition to stored water from Clear Lake and Gerber reservoirs, live flow in the Lost River is used for irrigation within portions of HID, LVID, Poe Valley Improvement District (PVID), and for lands covered under individual contracts in the south end of Langell Valley. The live flow

from the Lost River generally consists of natural accretions and tributary runoff, particularly discharges from the Bonanza Big Springs, as well as return flows from irrigation.

Whereas LVID primarily relies upon gravity diversions of stored water, HID, PVID, and other individual landowners are primarily dependent upon pumping water (live flow and stored) from the Lost River. To facilitate its pumping operations, HID operates Harpold Dam and a series of small dams in the Lost River near Bonanza to maintain upstream water levels. Similar private dams and other structures, including private pumps, exist in the Lost River downstream of Harpold Dam.

Downstream of Poe Valley and the Olene Gap, absent significant precipitation or other operational requirements (e.g., maintenance), all flow in the Lost River is diverted at the Lost River Diversion Dam into the LRDC, where the water can be exported to the Klamath River. The LRDC has a capacity of approximately 3,000 cfs. During the irrigation season, live flow from the Lost River diverted into the LRDC (in addition to any direct storage releases from Clear Lake or Gerber reservoirs) is re-diverted for irrigation purposes prior to reaching the Klamath River (at Station 48, the Miller Hill Pumping Plant, or the various private pumps that exist along the LRDC).

Generally, there is always some water from the Lost River flowing into the LRDC, although during the spring/summer irrigation season, water from this source is relatively small compared to the amount from UKL and the Klamath River simultaneously being diverted into the LRDC for delivery through the Miller Hill Pumping Plant, Station 48, and private pumps along the LRDC.

During high flow events, the entire capacity of the LRDC (approximately 3,000 cfs) is used for diverting water from the Lost River to the Klamath River for flood control purposes. Any water in the Lost River in excess of LRDC capacity must be released through Lost River Diversion Dam and at least temporarily stored in the Tule Lake Sumps. Through Pumping Plant D, the Tule Lake Tunnel, the P Canal, and finally the KSD, such water can be exported to the Klamath River, in order to limit flooding of lands in and around Tule Lake.

4.3.2.2.11 Water Rights Regulation in the Upper Klamath Basin

The KBPM does not separately account for additional inflows to UKL that occur due to enforcement of water rights by OWRD in the Upper Klamath Basin. *See* Chapter 1.3.2., regarding the ACFFOD, the doctrine of prior appropriation as applied in the State of Oregon, and water rights enforcement by OWRD. The KBPM treats all inflow the same for purposes of the PA, regardless of whether that inflow has been altered by upstream tributary water diversions (or the lack thereof).

Consistent with the laws of the State of Oregon, live flow that is physically available at the established point or points of diversion for a water right is subject to appropriation for beneficial use, subject to any restrictions that may exist on the exercise of that water right as a matter of state and/or Federal law. Accordingly, additional inflow to UKL resulting from water rights regulation in the Upper Klamath Basin is available for appropriation and beneficial use within the Project, just like any other live flow that may exist in UKL. However, as noted above, state and Federal law, including the ESA, may nevertheless limit the extent to which this water can be

appropriated and applied to beneficial use. Accordingly, additional inflow to UKL due to water rights regulation in the Upper Klamath Basin is subject to the same operational regime as outlined in this PA, with respect to ESA requirements, as all other water in UKL.

There is one notable exception to this aspect of the PA, to maintain consistency with Oregon law. As discussed in Chapter 1.3.2., Project water rights recognized in the ACFFOD are currently enforceable, absent a judicial stay. In accordance with the doctrine of prior appropriation, when the amount of live flow available for appropriation in UKL and the Klamath River is insufficient to meet the actual beneficial irrigation demands within the Project, a call may be made for the Project water rights determined in the ACFFOD. However, OWRD's administrative rules provide that an otherwise enforceable call may be disregarded if the water made available due to enforcement is not available for use or is not otherwise being used by the senior rights holder making the call. *See* Or. Admin. R. §690-250-020. Accordingly, as part of this PA, to the extent a call is made for Project water rights, the additional inflow to UKL resulting from the call will be delivered for irrigation purposes within the Project and in addition to the Project Supply identified above in section 4.3.2.2.2.2.

In the event of a Project call, for purposes of this PA and overall compliance with the ESA, Reclamation proposes the following process to quantify and deliver for irrigation purposes available UKL inflow resulting from a Project call:

1. Reclamation will quantify inflow to UKL as a result of a Project call. Reclamation retains discretion regarding the quantification method.

2. Reclamation will review with the Services the quantification method and UKL inflow rates and volumes resulting from a Project call.

3. Reclamation will make the final determination whether and to what extent the additional water resulting from a Project call can be delivered from UKL for irrigation use within the Project consistent with Reclamation's obligations under the ESA.

4. Reclamation will continue to monitor deliveries of Project Supply, including any deliveries as a result of a Project call for consistency with the PA and BiOp, including potentially adjusting UKL central tendency to account for these inflows.

The OWRD is responsible for regulating water rights in the State of Oregon. Reclamation has no role in this process except to the extent of making a call for Project water rights when the amount of water physically available at the designated points of diversion for the Project is inadequate to meet beneficial irrigation demands within the Project. The above described process explains how and to what extent Reclamation will determine and make additional water available to the Project due to water rights regulation, consistent with ESA.

4.3.3 Element Three

Perform the O&M activities necessary to maintain Project facilities.

This section outlines the O&M activities that are performed on Reclamation's various features within the Project. These activities have been on-going throughout the history of the Project and

have been implicitly included in previous consultations with the USFWS on Project operations (*See* Chapter 2, Consultation History). No new maintenance activities are being proposed, rather these activities are only included in detail in this consultation to provide a more complete description of Project maintenance so that the potential effects of these actions on listed species can be more specifically analyzed. Reclamation has attempted to include all maintenance activities necessary to maintain Project facilities and to continue proper long-term functioning and operation. Reclamation also recognizes that this is not an exhaustive list and that there may be items that were inadvertently omitted. However, Reclamation believes that any omitted activities are similar in scope and are not outside the effects analyzed for the activities included in the following sections.

O&M activities are carried out either by Reclamation or through contract by the appropriate irrigation district according to whether the specific facility is a reserved or transferred work, respectively.

4.3.3.1 Dams and Reservoirs

4.3.3.1.1 Exercising of Dam Gates

The gates at Gerber, Clear Lake, Link River, and Lost River Diversion dams are exercised bi-annually, before and after each irrigation season to be sure they properly operate. The approximate dates the gates are exercised are March to April 15 and October 15 to November 30, and potentially in conjunction with any emergency or unscheduled repairs. The need for unscheduled repairs is identified through site visits. Once identified, the repair need is documented and scheduled. Exercising gates requires anywhere from 10 to 30 minutes depending on the facility. The gates at Gerber, Link River, and Lost River Diversion dams are opened, and water is discharged during the exercising process. Additional information that describes associated maintenance activities performed when exercising gates at specific facilities is included as follows:

1. LRD is operated by PacifiCorp who does not schedule when gate exercise occurs. The dam is operated continuously due to the flows required from UKL to the Klamath River. As such, the gates are considered exercised whenever full travel of the gates and a minimum flow of 250 cfs is achieved; PacifiCorp documents these occurrences. The stoplog gates at LRD are not exercised annually and are typically only removed under flood control operations and during infrequent stoplog replacement. A Review of O&M inspection should be performed every six years.

2. Clear Lake Dam gate exercise activities include exercising both the emergency gate and the operation gate. Depending on water conditions, some water may be allowed to discharge in order to allow for sediment flushing. Flushing requires a release of flows that must be near 200 cfs for approximately 30 minutes. This activity occurs once a year generally between March and April and is contingent on Clear Lake Reservoir surface water level elevations.

3. The frost valves at Gerber Dam are exercised annually in order to prevent freezing of dam components. Valves are opened in the fall, at the end of irrigation season, at a flow rate of approximately two cfs and closed in the spring once persistent freezing temperatures have ceased.

4.3.3.1.2 Stilling Well Maintenance

Gage maintenance is required at various project facilities to ensure accurate measurement of flows. Gage maintenance generally includes sediment removal from the stilling well, replacement of faulty equipment, modification and/or relocation of structural components, and/or full replacement of the structure, as necessary. Reclamation estimates that every 5 to 10 years, one structure is replaced. Stilling wells are cleaned once a year during the irrigation season which typically runs from April 1 through October 15.

4.3.3.1.3 Other Maintenance

To determine if repair and/or replacement of dam components is necessary, activities may include land-based observation and/or deployment of divers. Divers are deployed at Clear Lake Reservoir, Gerber Reservoir, Lost River Diversion Dam and LRD every six years prior to the Comprehensive Facilities Review for inspection of the underwater facilities. In addition, at Gerber Dam, the adjacent plunge pool is de-watered approximately every eight years for inspection of headgates, discharge works, and other components; fish salvage by Reclamation staff would be conducted for this effort. Through these inspections, if replacement is deemed necessary, Reclamation would evaluate the potential effects to federally-listed species and determine if additional ESA consultation would be required.

At LRD, the replacement of the remaining wood stop logs with concrete stop logs is proposed to occur over the next three to five years. This action may require in-water work as a floating caisson (i.e., a watertight chamber) would be placed in front of the stop log bay and then filled with water in order to submerge and seal the bay. Once sealed, the bay would be de-watered to allow for maintenance and stop log replacement. When work is completed, air would be pumped into the caisson so that it floats to the surface, and the caisson would be moved to another bay to begin work. Appropriate Reclamation staff would be on-site during the de-watering process to conduct fish salvage as needed.

At the LRDC, the removal and rebuild of the headgates is currently required. As no stop log bays exist at the channel headworks, which, if present, could isolate the gates for removal, fabrication of a bay will be necessary. This bay would be created by the installation of structural "C" channel beams in the channel walls and pier noses to allow for placement of a steel bulkhead. With a bulkhead in place, water flow can be controlled and allow for the removal of the gates. No de-watering is necessary for this activity; however, some in-water work will be required.

Design Operation Criteria, which outlines O&M guidelines for facilities maintenance is required at LRD, Clear Lake Dam, Gerber Dam, and the LRDC gates. The Design Operation Criteria is used to develop Standard Operating Procedures for Reclamation facilities. The Standard Operating Procedures outline the maintenance procedures, requirements, and schedule. The activities address the structural, mechanical, and electrical concerns at each respective facility. Some of the components of facilities that require maintenance are typically reviewed outside of the irrigation season and include, but are not limited to, the following:

- Trash racks - Maintained when necessary and are not on a set schedule. Trash racks are cleaned, and debris removed daily and is specific to each pump as individual pumps may or may not run year-round. Cleaning can take anywhere from one to eight hours.

- Fish screens (Screens at Clear Lake Reservoir are cleaned as described below).
- Concrete repair occurs frequently and as needed (not on a set time schedule). The amount of time necessary to complete repairs to concrete depends on the size and type of patch needed.
- Gate removal and repair/replacement (performed when needed, no set time schedule.) Inspections of gates occur during the dive inspection prior to the Comprehensive Facilities Review every six years. Gates are continually visually monitored.

Boat ramps and associated access areas at all reservoirs must be maintained, as necessary, in order to perform all weather boating access to carry out activities associated with O&M of the Project. If the boat ramp is gravel, it should be maintained on a five-year cycle. If the structure is concrete, it should be maintained on a 10-year cycle. Maintenance can include grading, geotextile fabric placement, and gravel augmentation/concrete placement depending on boat launch type. Reclamation does not perform maintenance of boat ramps on a time schedule, but rather as needed.

4.3.3.2 Canals, Laterals, and Drains

All canals, laterals, and drains are either dewatered after irrigation season (from approximately October 15 through April 15) or have the water lowered for inspection and maintenance every six years as required as part of the Review of O&M or on a case by case basis. Inspection includes checking the abutments, examining concrete and foundations, examining mechanical facilities, pipes, and gates. The amount of time necessary for inspection is based on size and specific facility.

As with other typical facilities, the C Siphon, which replaced the C Flume in 2018, would be operated, maintained, and monitored in a similar manner. Along with the external inspection of the facility, maintenance staff would enter the siphon, when de-watered, to perform an inspection of the siphon's internal features. Additionally, inspections of the concrete piers that support the siphon above the LRDC would be conducted. As necessary, hardware would be replaced throughout the life of the facility. Historically, dewatering of canals, laterals, and drains has included biological monitoring and (as needed) listed species salvage. This practice would continue under the current PA as described in Chapter 4.5.1.

The facilities are also cleaned to remove sediment and vegetation on a timeline ranging from annually to every 20 years. Inspections of all facilities take place on an annual basis. Inspections occur year-round or as concerns are raised by Project patrons; cleaning and maintenance takes place year-round on an as-needed basis. Cleaning the facilities may include removing sand bars in canals, silt from drains, or material filling the facilities. Animal burrows that may be impeding the facilities are dug up and compacted in order to repair them. Trees that are deemed to interrupt operations of facilities (and meet criteria outlined in the O&M guidelines) and/or pose a safety threat to the structural integrity of the facilities are removed and the ground returned to as close to previous conditions as practicable.

All gates, valves, and equipment associated with the facilities are to be exercised bi-annually before and after the irrigation season. Any pipes and structures located on dams or in reservoirs that are associated with irrigation facilities are replaced when needed and have an average lifespan of 30 years. Reclamation O&M staff replace approximately 10 sections of pipe per year

and attempt to perform this maintenance activity when the canals are dry. Additional information that describes associated maintenance activities performed when exercising gates at specific facilities are included as follows:

1. A Canal headgates include six gates that need to be checked. The A Canal headgates are only operated and exercised when the fish screens are in place. If the breakaway screens were to fail, the A Canal would still be operating until the screen is put back into place. This allows for uninterrupted operation at A Canal in the event that a screen needs to be replaced to their previous position. Screens typically break once or twice a year (during normal operation), and KID is notified through alarm and the screens are repaired at the earliest time practicable.

2. The A Canal headgates are typically exercised in the spring (February through March timeframe) and fall (October through November timeframe). This activity occurs when the bulkheads are in place and the A Canal is drained and empty.

3. The LRDC diagonal gates and banks should be inspected every six years. Review of O&M inspections alternate every six years and take place anywhere from October 15 through March 31. This inspection would require drawdown of the LRDC (i.e., drawdown at least once every six years; however, as maintenance requires, LRDC drawdowns may be more frequent). The drawdown of the LRDC would leave enough water to ensure that fish were not stranded during this activity. The appropriate drawdown level is coordinated by Reclamation O&M and fisheries staff. Biological monitoring would be incorporated, and, if necessary, flows would be increased for fish protection.

4. The gates in the concrete structure in the railroad embankment immediately upstream of the Ady Canal are exercised annually. This activity includes closing and opening the gates and this activity typically occurs in the July to September timeframe. All debris is also removed once a year, generally some time during the June through September timeframe.

4.3.3.3 Fish Screen Maintenance

The A Canal fish screens have automatic screen cleaners. Cleaning is triggered by timing or head difference. When cleaned on a timer, the timing intervals are set at 12 hours, but intervals can be changed at (KID) operator's discretion for a period defined by hours or on a continuous basis.

Fish screens at Clear Lake Dam are cleaned periodically when 6 to 12 inches of head differential between forebay one and forebay two is encountered. The need for cleaning the fish screen is dictated by water quality and lake elevation and varies from year to year. For instance, in some years, such as 2009, the screen was cleaned every other day beginning approximately the end of June/early July until it was shut off. Whereas in 2011, no cleaning took place during irrigation season. During irrigation season the head differential never exceeded 0.3 foot. There is an extra set of fish screens that the O&M crew uses during the cleaning process. The extra fish screen is lowered in place behind the first set of screens so that no fish will be allowed to pass. The primary screens are then lifted and cleaned and then placed behind the second pair of screens in the lineup. This process is continued until all screens are cleaned. This process can take up to 10 hours. Upon completion, the remaining set is stored away until the next cleaning which is

anytime a head difference of 0.5 foot occurs. During flood releases (when Clear Lake elevations are 4,543.0 feet or above), fish screens would not be in place.

4.3.3.4 Fish Ladder Maintenance

LRD fish ladder gate exercise activities include exercising both the head gate and the attraction flow gate which includes closing and opening the gates and physical inspection of the ladder. This activity occurs twice annually and generally occurs in the February/March timeframe and again in the November/December timeframe. The amount of time necessary for the gates to be exercised is no longer than 15 minutes. This activity includes biological monitoring by Reclamation staff biologists.

4.3.3.5 Roads and Dikes

Road and dike maintenance, including gravel application, grading, and mowing, occurs as necessary from April through October. Pesticides and herbicides are also used on Reclamation managed lands, primarily canal rights-of-way to control noxious weeds. This activity typically occurs annually. The activity of pesticide spraying occurs generally from February through October (in compliance with the Pesticide Use Plan) and is applied according to the label. Vegetation control occurs on facilities where necessary throughout the year. Techniques used to control noxious weeds may include cultural, physical, and chemical methodologies for aquatic and terrestrial vegetation. The effects of these activities have been evaluated in previous section 7 consultations, and incidental take coverage was provided in the USFWS's BiOps 1-7-95-F-26 and 1-10-07-F-0056 dated February 9, 1995 and May 31, 2007, respectively. In both BiOps, the USFWS determined that the maintenance action of pesticide application would not jeopardize the continued existence of LRS and SNS. The products used for this maintenance activity are still being used to minimize take and are in compliance with current Integrated Pest Management Plans required by the Reclamation Manual's Directive and Standard ENV 01-01. At this time, there have been no changes to the action.

4.3.3.6 Pumping Facilities

All pumping plants are monitored yearly by visual evaluation. Dive inspections occur every six years according to the Review of O&M inspection criteria. This activity would include dewatering of the adjacent facility and installation of coffer dams. Dive inspections and dewatering of the facilities typically occurs in the August to December timeframe. Biological monitoring occurs daily during the dewatering of the facility and has historically been, and will continue to be, incorporated into maintenance activities to ensure the protection of fish as necessary. Aquatic weeds that collect on trash racks and around pump facilities are monitored continuously throughout the irrigation season and removed as needed. Weed removal typically occurs on a daily basis for those pumps that are operating continually through the season.

All pumps are greased, oil checked, cleaned, and exercised monthly if they are not in regular use. Pumps used for irrigation are maintained daily during the irrigation season. Drainage pumps would be maintained and operated on a daily basis, year-round. Pumps are greased and oiled according to the pump manufacturer's specifications. Excess grease and oil are removed and cleaned. When oil is being changed oil spill kits are kept on site and used as necessary.

Should a pump require repair, the pump chamber would be isolated from the water conveyance facility by placement of a gate, bulkhead, or coffer dam. The chamber would then be de-watered

to allow for maintenance access. Appropriate staff would be on-site to perform fish salvage, as necessary, during the de-watering process.

4.4 Water Shortage Planning

Reclamation generally follows an established process for identifying and responding to the situation where available water supplies are inadequate to meet beneficial irrigation demands within the Project.

During the fall-winter period, Reclamation coordinates directly with KDD and the USFWS regarding Project water availability and demands (for both refuge and irrigation purposes). Reclamation does not make any public announcement of the volume of water available during the fall-winter period for delivery to the Project, including LKNWR.

Near the beginning of the spring-summer irrigation season, Reclamation issues an annual Operations Plan, which identifies the anticipated volume of water available from the various sources utilized by the Project, and the associated operating criteria applicable that year. The Operations Plan is posted on Reclamation's website, a press release is issued, and copies are sent by letter to Project water users and affected Tribes.

In the event of an anticipated shortage in the volume of water available for irrigation use from Clear Lake and Gerber reservoirs, Reclamation coordinates the allocation and delivery of limited supplies with LVID, HID, and others with a contractual right to receive stored water from these reservoirs.

In the event of an anticipated shortage in the volume of water available for irrigation use from UKL and the Klamath River, Reclamation will coordinate with irrigation districts and water users regarding anticipated irrigation demands within the Project. If the volume of water or the timing when it is available is less than the anticipated demands of these two districts, Reclamation may determine it necessary to issue an Annual Drought Plan (Drought Plan), which identifies and explains how water from UKL and the Klamath River is to be allocated among various entities with different contractual priorities to Project water (*see* Chapter 1.3.3., Reclamation Water Supply Contracts). The Drought Plan is posted on Reclamation's website, a press release is issued, and affected Project water users are provided a copy and notified by letter of the volume of water available under their respective contract.

The Drought Plan will identify an initial allocation for entities and individuals with a secondary priority to Project water from UKL and the Klamath River. Reclamation then updates the allocation (either increasing or decreasing the water available) as the irrigation season progresses and hydrologic conditions change, again notifying affected contractors by letter. Reclamation staff attends district board meetings, calls contractors by telephone, and answers direct inquiries related to the Drought Plan allocation.

In addition to possibly allocating the available water through the Drought Plan, there are other actions that Reclamation can take or directly facilitate, in response to a shortage in water available from the Project.

Consistent with Reclamation policy, Reclamation may administratively approve the transfer of water between districts and individual water users within the Project. Such transfers do not increase the amount of water available to the Project or expand the Project's service area but rather simply change the place of use within the Project. Prior to approval, Reclamation reviews each application on a case-by-case basis to make sure these basic conditions are met.

These internal transfers are generally used by irrigators to address a shortage in the water available under a given contract, based on the contractual priority it provides to Project water. Overall, these types of transfers promote the efficient and economical use of water.

Internal Project transfers are also available for irrigable lands within Lower Klamath and Tule Lake NWRs, subject to the approval of the USFWS. Water made available to an NWR through an internal transfer approved by Reclamation is separate from any water that may be available for delivery to the NWR consistent with the terms of this PA.

As has occurred in the past, Reclamation may also engage in irrigation demand reduction activities within the Project, on a year-by-year basis. There is no program currently in place for such activities, but such efforts have occurred periodically over the last two decades, subject to proper legal authority and the availability of federal appropriations. In the past, these activities have included agreements with individual landowners to forgo use of Project water or to produce supplemental groundwater.

4.5 Conservation Measures

The term "conservation measure" is defined as an action to benefit or promote the recovery of listed species that are included by the federal agency as an integral part of the PA. These actions will be taken by the federal agency or applicant, and serve to minimize or compensate for, project effects on the species under review. These may include actions taken prior to the initiation of consultation, or action which the federal agency or applicant have committed to complete in a BA or similar document. The conservation measures proposed assist Reclamation in best meeting the requirements under section 7 of ESA by (1) "…utilizing our authorities in furtherance of the purpose of this Act by carrying out programs for the conservation of endangered species…" and (2) avoiding actions that jeopardize the continued existence of listed species.

4.5.1 Canal Salvage

Fish salvage of Project canals occurs when canals are: (1) temporarily dewatered for a discrete action related to maintenance and/or repairs at Project facilities (described in Chapter 4.3.3), and (2) when canal systems are dewatered at the end of each irrigation season. Under both circumstances fish are salvaged from pools where they are stranded.

Reclamation proposes, in coordination with USFWS, to continue the salvage of suckers both for routine maintenance and repair at Project structures and at conclusion of the irrigation season when Project canals, laterals, and drains are dewatered consistent with past salvage efforts since 2005.

At conclusion of each irrigation season, Reclamation will coordinate fish salvage activities with irrigation districts, principally KID and TID. Future fish salvage of the canal system will include areas where suckers are annually encountered in reliable numbers since 2005, including the A Canal forebay, C4 Canal, D1 Canal, and D3 Canal within the KID and J Canal within the TID. Other locations within the Project canals will be periodically checked during dewatering and fish will be salvaged if deemed feasible and productive. Reclamation will also continue to pursue alternative methods of dewatering canals, laterals, and drains and which could result in less sucker presence within these facilities at the end of the irrigation season. Fish salvage will be coordinated with USFWS each year.

Reclamation will coordinate with USFWS on the disposition of endangered suckers resulting from salvage activities, including release to natural waters or retention for disease treatments, studies, and captive rearing.

4.5.2 Sucker Captive Rearing Program

Since 2000, Reclamation has supported various conservation measures within the upper Klamath Basin which have resulted in significant improvements to the Baseline (including fish screen installation at A Canal and Geary Canal, removal of Chiloquin Dam on the lower Sprague River, fish passage at LRD, increasing wetland and lake habitat at the Williamson River Delta, and annual salvage of suckers from canals). However, there are few, if any, practicable options for reducing incidental take which is an effect of the Project.

Reclamation proposes to continue support of a captive rearing effort by USFWS for LRS and SNS. The intention is to improve the numbers of suckers reaching maturity in UKL. Ultimately, the function of a captive rearing program would be to promote survival and recovery of the sucker populations that suffer losses from entrainment as a result of the Project or other threats. Captive propagation is already an important part of listed fish recovery efforts nation-wide, including at least three sucker species (i.e., June sucker, razorback sucker, and robust redhorse sucker).

The USFWS has already implemented initial efforts to rear LRS and SNS to a size that may increase individual survival. Sucker larvae collected from Williamson River were reared in tanks and holding ponds for approximately two years. Juvenile suckers salvaged from Project canals have also been held prior to release to UKL. Based on these efforts, captive rearing of LRS and SNS appears feasible and practicable. Reclamation envisions that future efforts by USFWS will expand on these initial efforts.

Specifically, Reclamation proposes support of a captive rearing program by providing funding in the amount of $300,000 annually. These funds will be used to cover costs associated with capture, rearing, release, and monitoring of released suckers in UKL. As requested by USFWS, Reclamation staff will provide personnel assistance with the rearing program when not in conflict with other necessary work. The USFWS will have oversight of the rearing program. Reclamation's support of the captive propagation program would be for the period of this consultation (April 1, 2019 to March 31, 2029) and adhere to regulations of an interagency agreement between USFWS and Reclamation. The program is envisioned as having a positive effect on the species that offsets impacts due to entrainment at LRD, A Canal, and other Project

facilities. Monitoring will determine the actual effectiveness and the program's continuation will be coordinated between Reclamation and USFWS.

4.5.3 Sucker Monitoring and Recovery Program Participation

Effects on suckers continue beyond the location of the Project (see Chapter 1.2 for a description and map), including the entirety of UKL, Clear Lake Reservoir, Gerber Reservoir, and Lake Ewauna, into a series of hydroelectric dams and reservoirs (Keno, J.C. Boyle, Copco I, Copco II, and IGD) owned and operated by PacifiCorp. Since about 2000, Reclamation has funded monitoring of sucker populations in the lakes and reservoirs of the Upper Klamath Basin. Reclamation has also funded projects identified through USFWS' Sucker Recovery Implementation Team since 2013 and participated in the Recovery Implementation Team discussions and project identification. In coordination with USFWS, Reclamation proposes to continue efforts to monitor adult suckers in UKL, Clear Lake and Gerber Reservoirs, monitor juvenile suckers in UKL and Clear Lake, and fund sucker research, restoration and recovery actions throughout the Upper Klamath Basin. Contingent upon Reclamation's annual budget process and appropriations, Reclamation anticipates annual funds of approximately $1.5 million base funding annually with an additional $700,000 for the first two years (fiscal year 2019 and 2020) for UKL adult monitoring, Clear Lake adult monitoring, and juvenile cohort monitoring, research, and recovery projects. Funding in fiscal years beyond 2020 will be supplemented with $700,000 should appropriations materialize. Reclamation envisions that monitoring and research projects funded through the Recovery Program will answer questions about sucker recruitment in UKL and sucker population trends in both UKL and Clear Lake Reservoir. Reclamation also envisions that projects under a sucker Recovery Program will improve the amount and quality of sucker habitats, sucker passage issues, and sucker survival in the Upper Basin thereby offsetting PA impacts to habitat and entrainment of suckers at UKL, Gerber Reservoir, and Clear Lake Reservoir.

In coordination with USFWS, Reclamation proposes to continue participation in the Klamath Sucker Recovery Program.

4.5.4 Coho Restoration Grant Program

Reclamation expects to provide $500,000 annually with an additional $700,000 for the first two years (fiscal year 2020 and 2021) for program administration and projects that address limiting factors for SONCC coho salmon in the Klamath Basin contingent upon Reclamation's annual budget process and appropriations. Funding in fiscal years beyond 2021 will be supplemented with up to $700,000 annually should such appropriations be authorized. The program targets projects that have both the greatest impact on promoting survival and recovery and provide sustainable and lasting ecological benefits in the Klamath River Basin for coho salmon. Projects given the highest priority under this program include access improvement and barrier removal, improved habitat and access to coldwater refugia, instream habitat enhancement and protections, and water conservation. Restoration projects minimize habitat related effects of the Project by individually and comprehensively improving critical habitat conditions for coho individuals.

5 Species Status for Lost River and Shortnose Suckers, Coho Salmon, and Southern Resident Killer Whale Distinct Population Segment

The following discussion on the Status of the Species contains a level of detail beyond what is generally required for a BA. However, select elements of the Status of the Species are discussed in this BA to provide a basis for the Effects Analysis contained in Chapters 7 8 and 9.

5.1 Shortnose and Lost River Sucker

5.1.1 Description

SNS and LRS are endemic to the Upper Klamath Basin (Moyle 2002a). As a member of the genus *Chasmistes*, SNS are closely related to cui-ui (*C. cujus*) of Nevada, the June sucker (*C. liorus*) of Utah, and the recently extinct Snake River sucker (*C. muriei*) of Wyoming (NRC 2008). LRS are currently the only extant species of the genus *Deltistes*. Hybridization is common among Basin suckers, specifically between SNS and Klamath largescale sucker (KLS; *Catostomus snyderi*), one of two non-listed, regional suckers (Dowling 2005; Tranah and May 2006; UWFWS 2007a, USFWS 2007d). Klamath smallscale sucker (*Catostomus rimiculus*) also co-occur regionally but do not appear to be introgressed with either endangered species (Dowling 2005; Tranah and May 2006; USFWS 2007a, USFWS 2007d). The degree of hybridization makes field identification of suckers in the Basin challenging, particularly in reservoirs within the Lost River drainage, such as Clear Lake and Gerber reservoirs (Barry and Janney 2004; Markle et al. 2005; Barry and Scott 2007). For the purposes of life history and population descriptions at these locations throughout this document, Reclamation has attempted to compile information on only the two endangered sucker species. However, for bodies of water where identification of species has proven difficult, (e.g. Clear Lake and Gerber reservoirs), this was not always possible, and Reclamation follows the USFWS approach in considering individuals in these populations to be endangered (USFWS 2008). Thus, SNS identifications in the Lost River drainage likely include an unknown number of misidentifications and hybrid suckers with morphological characteristics that are shared by SNS, LRS, and KLS.

5.1.2 Life History and Spawning

LRS and SNS are long-lived, lake-obligate fishes. Annual survival estimates for adults of both species are typically 90 percent, and on average LRS live 20 years while SNS live 12 years. However, there is substantial variation in life expectancy; the oldest aged specimens are 57 years for LRS and over 30 years for SNS (Buettner and Scoppettone 1990; Terwilliger et al. 2010). Reproductive maturity is reached between four and nine years for LRS and between four and six years for SNS (Buettner and Scoppettone 1990; Perkins et al. 2000b). Fecundity of females is

related to age and size, and other unidentified factors (Perkins et al. 2000b). LRS produce 44,000 to 236,000 eggs per female, whereas SNS produce 18,000 to 72,000 eggs per female (Perkins et al. 2000b).

In UKL there are two main spawning aggregations of LRS; those that spawn in the Williamson and Sprague Rivers (tributary-spawner) and those that spawn at springs emanating from the eastern shoreline of UKL. Presently, known spawning occurs along the shore of UKL at Sucker, Silver Building, Ouxy, and Cinder Flats springs (USBR 2018 therein; (Shively et al. 2000a; Hayes and Shively 2001; Hayes et al. 2002, 2004; Barry et al. 2007c). Both populations of LRS show a high degree of site fidelity though a small amount of mixing does occur (Hewitt et al. 2018b). SNS spawn only in the Williamson and Sprague Rivers (Hewitt et al. 2018b). Annual spawning migrations for tributary-spawners in UKL are triggered by average daily temperatures; 50 degrees Fahrenheit (°F,10 degrees Celsius [°C]) for LRS, and 54°F (12°C) for SNS (Hewitt et al. 2018b). Suckers begin spawning immediately after migrating up the rivers and peak egg-drift typically occurs within days of peak adult migration (Hewitt et al. 2011; Ellsworth and Martin 2012). Up to seven males may attempt to spawn with a single female, though two males and one female is most common (Buettner and Scoppettone 1990). Both male and female suckers quiver as females broadcast their eggs and males fertilize the eggs. Spawning typically occurs in water ranging from 0.4 to 2.3 feet (0.12 to 0.70 m) deep (both tributary and shoreline springs populations) over mixed gravel (20 to 64 mm; 0.80 to 2.5 inches) or course cobble (2.5 to 10 inches; 65 to 256 mm). Spawning has been observed in flows ranging from 0.49 to 2.69 feet/sec (15 to 82 centimeters (cm)/sec) in the tributaries. Eggs settle in the interstitial space in the substrate and typically develop in 8 days to 3 weeks. The rate of development is dependent upon temperature but other factors such as light conditions have also been identified as factors that change the rate of development (Ellsworth and Martin 2012; Stone and Jacobs 2015).

Suckers in the Clear Lake (LRS and SNS) and Gerber reservoir (SNS) drainages spawn primarily, if not entirely, in the tributary streams (Koch and Contreras 1973; Buettner and Scoppettone 1991; Perkins and Scoppettone 1996; BLM 2000; Barry and Janney 2004; Barry et al. 2007a). Migration of Clear Lake suckers up Willow Creek is initiated when stream temperatures reach or exceed 6°C and when sufficient flows in Willow Creek are available (Hewitt and Hayes 2013a). Spawning has been entirely skipped some years when flows and lake elevations were not sufficient for suckers to access Willow Creek and opportunistic spawning has been observed during high discharge events (Hewitt and Hayes 2013a; Burdick et al. 2018).

5.1.2.1 Larvae

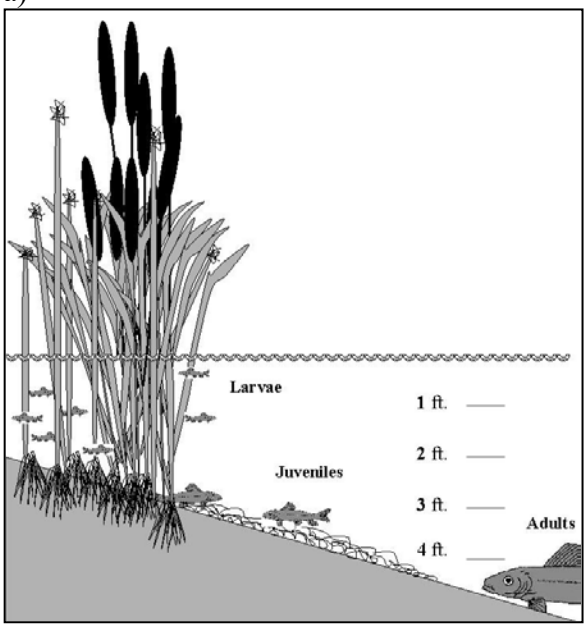
Approximately one week after fertilization, eggs develop into larvae, and larvae emerge from gravels about 10 days after hatch (Coleman et al. 1988; Buettner and Scoppettone 1990). Emerging larvae are about a third of an inch long (7 to 9 mm) and are mostly transparent with a small yolk sac (Buettner and Scoppettone 1990). Larval suckers need to begin feeding before they exhaust their yolk, or they will starve (The Klamath Tribes 1996; Cooperman and Markle 2003). Larvae spend relatively little time in the tributaries, and they drift toward the lake shortly after emergence (Buettner and Scoppettone 1990; Perkins and Scoppettone 1996; Cooperman and Markle 2003; Ellsworth and Martin 2012). The majority of larvae from tributary populations egress from the river toward the lake during dark hours (Buettner and Scoppettone 1990; Cooperman and Markle 2003; Ellsworth and Martin 2012), then exit the river current during daylight hours and move to nearshore shallow habitat (Buettner and Scoppettone 1990;

Cooperman and Markle 2000). Diurnal peak egress appears to vary among natal sites (Ellsworth and Martin 2012). While the majority of larval sucker research has been conducted on tributary populations, it is suspected that larval suckers hatched at shoreline spawning areas also emerge from the gravels in greatest numbers at night.

Once in UKL, peak larval sucker catches occur in late May or early June (Simon et al. 1996, 2000, 2009; Cooperman and Markle 2000; Burdick et al. 2009a). Larval suckers are found throughout UKL however the highest concentrations of larvae are generally near the mouth of the Williamson River, and in emergent wetlands (Simon et al. 1995, 1996, 2009; Burdick et al. 2009a; Burdick and Hewitt 2012). Larval habitat in UKL appears to vary between species; SNS are captured more often along the shoreline and are associated with emergent aquatic vegetation whereas LRS are more common in open-water habitat (Figure 5-1; Burdick et al. 2009b; Burdick and Brown 2010). Diets of sucker larvae generally consist of pelagic or surface food items including adult chironomids and indigestible pollen (Markle and Clauson 2006).

Larval sucker ecology and habitat use within the Lost River watershed, particularly Tule Lake, Lost River, and both Clear Lake and Gerber reservoirs, have not been directly studied. Given the lack of direct observations, larval sucker ecology in the Lost River watershed is assumed similar to the observations from UKL, except for the use of emergent vegetation, as that habitat type is generally scarce or absent along the shorelines of Clear Lake and Gerber reservoirs (USBR 2002).

a)



b)

Figure 5-1. a) Generalized lake habitat utilization by sucker life history stages (U.S. Fish and Wildlife Service 2008) and b) Life Stage Diagram (adapted from Reiser et al. 2001 pp. 4–3). Lost River suckers are represented by blue and shornose suckers are represented by yellow. Source: (U.S. Fish and Wildlife Service 2019a).

5.1.2.2 Young of the Year Juveniles

Larvae typically develop into young-of-the-year (YOY) juveniles by mid-summer. Transition from larvae to juvenile includes changes in physiology, diet, behavior, and ecology. Suckers are considered juveniles at about 0.75 to 1-inch TL (20 to 30 mm; Markle and Clauson 2006). Very few studies aimed at identifying prey items for larval and juvenile suckers have been conducted, and those that have been conducted are relatively inconclusive. However, juvenile suckers appear to consume more benthic oriented prey items than larvae (predominantly pelagic or

surface items), and this change in feeding ecology has been characterized as a developmental milestone (Markle and Clauson 2006). Identifiable prey items of juveniles (longer than 40 mm) include chironomid larvae and pupae, chydorids, ostracods, and harpacticoid copepods (Markle and Clauson 2006). Age-0 juveniles longer than 45 mm are habitat generalists and use all available habitat types in UKL; they are found near-shore, off-shore, and in vegetated and open-water habitats (Buettner and Scoppettone 1990; Simon et al. 2000, 2009; Terwilliger et al. 2004; Hendrixson et al. 2007a, 2007b; Burdick et al. 2009b; Burdick and Martin 2017).

Although adult LRS are about four times more abundant and are more fecund (females produce more eggs) than SNS, juvenile LRS are not proportionally more abundant. For example, in 2016 juvenile LRS only made up 51 percent of all suckers captured in 2016, 25 percent were SNS, 21 percent had genetic information from both species, and 3 percent were not identified to taxa (Burdick et al. 2018). Catches of age-0 suckers in UKL are typically highest in August when suckers are greater than 45 mm standard length (SL) (Burdick and Martin 2017). Catches generally decline throughout August, September, and October; and very few age-1 and almost no age-2 juvenile suckers are captured each year.

Some of the reduced abundance may be associated with advection from UKL including both emigration and entrainment (Markle et al. 2009). Directed movement patterns from north to south of age-0 juveniles were detected once in 2004 (Hendrixson et al. 2007a) but this trend was not apparent in other years (2001 to 2003 and 2005 to 2009; (Hendrixson et al. 2007b, 2007a; Bottcher and Burdick 2010; Burdick and Martin 2017). Advection of age-0 suckers from UKL into the Link River is greatest between July and October, generally peaking in August (Gutermuth et al. 1999, 2000b, 2000a; Foster and Bennetts 2006a; Tyler 2007; Markle et al. 2009). Advection of suckers from UKL may be a passive act indicative of compromised health. Generally, juvenile suckers (and other fishes) captured from the pumped fish bypass at the A Canal fish screen and headgates (at the southern end of UKL where advection occurs), have higher parasite loads, more disease, and more afflictions than suckers captured elsewhere in UKL (S. Foott; personal communication, August 2018).

The cause(s) of advection of juvenile suckers is not currently understood. Plausible hypotheses include passive movement due to compromised health, natural emigration, avoidance of or impairment from poor water quality events, diminished habitat in the north end of UKL (which may concentrate suckers in the southern end of UKL near the outlet), entrainment, or some other factors (USFWS 2002, USFWS 2008). While entrainment may account for some reductions in abundance; poor juvenile sucker survival (high mortality) appears to be the actual cause of reduced abundance of juvenile suckers (Burdick and Martin 2017). Poor juvenile sucker survival has resulted in a lack of substantial recruitment of juveniles into the adult spawning population since a relatively large cohort born in the early 1990s survived (Burdick and Martin 2017; Hewitt et al. 2018b). The cause of widespread juvenile mortality is unknown, but it is likely that some combination of poor water quality, disease, parasites, loss of habitat, non-native species (fish and cyanobacteria), and predation interact to reduce annual survival of juveniles to near zero.

In contrast to UKL, the majority of adult and juvenile suckers in Clear Lake Reservoir are SNS, or introgressed SNS/KLS (Hewitt and Hayes 2013a); for example, 80 percent of juveniles captured in 2016 were SNS or SNS/KLS, 17 percent were LRS, and 2 percent were introgressed

LRS/SNS (Burdick et al. 2018). As discussed earlier, the differences between KLS and SNS are not visually apparent at this life stage and genetic tools to differentiate between SNS and KLS are not available. Little is known about juvenile sucker distribution and habitat use in Clear Lake Reservoir but when reservoir elevations are high and both lobes have water (the East Lobe may be dry or extremely shallow some years), juvenile suckers are found almost equally in both lobes. For example, in 2016, 56 percent of juvenile suckers were captured in the West Lobe. Interestingly, the majority (77 percent) of juvenile LRS captured in 2016 were in the shallower East Lobe (Burdick et al. 2018).

5.1.2.3 Older Juveniles

The abundance of age-0 suckers in Clear Lake Reservoir during any given year is associated, at least in part, with the ability of adult suckers to make a spawning run up Willow Creek (Hewitt and Hayes 2013a). Adult suckers in Clear Lake Reservoir have skipped spawning during years when access to spawning tributaries is limited or made smaller runs (fewer individuals) when spring inflows and/or reservoir elevation limited access (Burdick et al. 2018). Recent years that produced larger year classes had lake elevations of at least 4,524 feet (1,378.9 m) during the February to May spawning run (Burdick et al. 2018). Lake elevations or tributary inflows were too low from 2013 to 2015 for adult suckers to make large spawning runs in Willow Creek, thus very few juveniles were present in Clear Lake Reservoir until 2016 (Burdick et al. 2018). In 2016, juvenile suckers were found in both lobes, though sampling in the East Lobe in September was limited due to low lake elevations (Burdick et al. 2018). With limited direct observations, Reclamation assumes that young of the year sucker habitat, abundance, and behavior in Gerber Reservoir is similar to that described in Clear Lake as both Clear Lake and Gerber reservoirs have similar hydrologic events (i.e., periods of both high and low inflows).

Relatively little is known about habitat use, diet, and ecology of age-1 and older juvenile suckers. A few age-1 suckers are captured each year; they are typically captured in water at least equal to or greater than 3.28 feet (1 m), as this depth is effectively sampled by trap nets. As lake elevations in UKL decline throughout the summer, some areas (like wetlands near the Williamson River Delta) become inaccessible for sampling, which limits researchers' ability to fully assess changes in abundance relative to habitat type and depth in UKL (Burdick 2012). Captures of juvenile suckers older than age-1 are extremely rare and trends are not discernable from sparse data. However, the real limitation in UKL is poor survival of age-0 and age-1 juveniles. Older juveniles are captured in Clear Lake; however, few extensive studies of juveniles in Clear Lake have been conducted. A consistent juvenile sucker monitoring program began in 2016 but followed several years of limited (2013) or no (2014 and 2015) adult sucker spawning in Willow Creek, an important tributary to Clear Lake for sucker spawning, due to inaccessibility of spawning grounds (Burdick et al. 2018).

Extensive habitat-use studies similar to those in UKL have not been conducted in Clear Lake Reservoirs. Unlike UKL, the Clear Lake Reservoir ecosystem is more homogeneous, primarily varying by depth. There are no surrounding wetlands, and there is limited submergent or emergent vegetation. However, juvenile suckers are found throughout Clear Lake Reservoir.

5.1.2.4 Adults

Distribution of adult suckers in UKL varies seasonally. In winter and fall, adult suckers are distributed throughout UKL. In the spring, adult suckers congregate in the north-eastern portion

of the lake, staging prior to making their spawning migration (Hewitt et al. 2018b). After spawning occurs (described in previous section), suckers return to UKL. As summer progresses and water quality conditions decline, suckers congregate in the northern portion of UKL (Reiser et al. 2001; Banish et al. 2009). When water quality conditions become especially stressful, adult suckers seek refuge in or near Pelican Bay where springs provide cooler water and higher DO concentrations (Banish et al. 2007, 2009). Many suckers moved to the western side of UKL into the Eagle Ridge trench in mid-September (Banish et al. 2007, 2009).

After suckers return from spawning locations in UKL, suckers are found in various depths, but are most often associated with depths greater than 6.56 feet (2 m). Depths greater than 6.56 feet (2 m) are thought to provide adequate cover and protection from avian predators including American white pelicans (*Pelecanus erthrorhynchos*) and provide for adequate food resources (Banish et al. 2007, 2009). In the summer, SNS and LRS prefer depths greater than 6.56 feet (2 m) and 9.84 feet (3 m), respectively. (Banish et al. 2007, 2009). When water quality conditions deteriorate, adult suckers may select depths less than 6.56 feet (2 m) near springs where conditions are better (Banish et al. 2007, 2009). Many suckers moved into the deepest part of UKL (up to 49 feet;15 m), the Eagle Ridge Trench, in mid-September (Banish et al. 2007, 2009).

In Tule Lake, where much of the lake is shallower than 3.28 feet (1 m), adult suckers are found primarily in the very limited areas where depths are greater than 3.28 feet (1 m; Buettner 2000; Hicks et al. 2000).

Adult sucker distribution in Clear Lake Reservoir has not been specifically studied; however, inferences can be made from other fish sampling efforts there. Adult suckers in Clear Lake Reservoir are sampled each fall and are found throughout the West Lobe and in the East Lobe when lake elevations are high enough for safe boat access (B. Hayes, personal communication 2018). Adult suckers appear to exhibit schooling behavior as researchers typically capture many or few suckers in trammel nets (B. Hayes, personal communication 2018). Within the West Lobe, the majority of suckers have been captured in either the north or south, but large numbers of suckers have also been captured in central quadrants (B. Hayes, personal communication 2018). Lake level and weather conditions may influence captures and distribution (B. Hayes, personal communication 2018).

Relatively little is known about the diets of suckers, however, the terminal mouth morphology and triangle gill rakers of LRS indicates they may be primarily benthic feeders. The subterminal or terminal mouth orientation, and branched gill rakers of SNS may indicate a more pelagic diet that may include filter-feeding zooplankton from the water column (Miller and Smith 1981; Scoppettone and Vinyard 1991).

5.1.3 Distribution

Historically, LRS and SNS occurred throughout the Upper Klamath Basin in suitable aquatic habitats. The higher elevation, cooler temperature tributaries, and the upper Williamson River (which is isolated by the Williamson River Canyon) were not inhabited by LRS and SNS (USFWS 2002). The historic range of LRS and SNS was extensively reduced by the loss of major populations in Tule Lake and Lower Klamath Lake, including Sheepy Lake (USFWS 1988). At the time of listing, LRS and SNS reportedly occurred in UKL and its tributaries, the Lost River, Clear Lake Reservoir, the Klamath River, and the three larger Klamath River

reservoirs (Copco, Iron Gate, and J.C. Boyle). The current geographic ranges of LRS and SNS have not changed substantially since they were listed. Only two additional populations of SNS and one additional population of LRS have been recognized since 1988. Each additional population occurs in isolated sections of the Lost River drainage, within the historical ranges of the species, and include an isolated population of SNS in Gerber Reservoir and a small group (limited to several hundred adults) of both species in Tule Lake (USFWS 2002). Presently, the Klamath River reservoir populations receive individuals carried downstream from upper reaches of the river, but they are isolated from the Upper Klamath Basin by dams and show no evidence of self-sustaining reproduction (Desjardins and Markle 2000a).

5.1.4 Legal Status

The LRS and SNS were federally listed as endangered throughout their entire range on July 18, 1988 (USFWS 1988, 53 FR 27130). Both species are also listed as endangered in California (1974) and Oregon (1991). In 2007, the status of each of these species was reviewed by the USFWS. It was recommended that no changes be made to the status of the SNS (USFWS 2007a). It was also recommended that LRS be downlisted to threatened (USFWS 2007b); however, recent data on population trends indicate continued decline so it is unlikely LRS will be downlisted.

A revised recovery plan for these species was published by the USFWS in 2012 (USFWS 2012a) and included designation of two recovery units for each species. The UKL Recovery Unit includes individuals in UKL, its tributaries, and any of the reservoirs along the Klamath River. The Lost River Basin Unit includes all individuals in lakes and flowing water in the Lost River sub-basin.

5.1.5 Upper Klamath Lake Species Current Condition

UKL in Oregon supports the largest remaining populations of LRS and SNS in the Klamath Basin (NRC 2004). Adult LRS in UKL appear to consist of two distinct subpopulations, fish that spawn along the eastern shoreline at upwelling areas (hereafter, lakeshore spawners), and fish that spawn in the Williamson and Sprague Rivers (hereafter, tributary spawners; (NRC 2004). Mark-recapture data has indicated that the two subpopulations maintain a high degree of fidelity to spawning areas and probably seldom interbreed (Hayes et al. 2002; Barry et al. 2007b; Janney et al. 2008; Hewitt et al. 2012). Tributary spawners make a springtime migration through the lower Williamson River, with most fish entering the lower Sprague River.

Chiloquin Dam, identified as a partial barrier to upstream passage that prevented a portion of the spawning run from migrating further upstream into the Sprague River (Scoppettone and Vinyard 1991; USFWS 1993a; NRC 2004), was removed during summer 2008. Adult sucker migrations in the Sprague River have been unimpeded since spring of 2009 (Ellsworth and Martin 2012). However, spawning above the former Chiloquin Dam site is limited. For example, in 2012, 25.5 percent of LRS detected at the weir were also detected at the Chiloquin Dam site however only 4 percent were detected at the Above Dam site 1.6 miles (2.5 kilometers) above the former Chiloquin Dam monitoring site; (Hewitt et al. 2014). Of the SNS that were detected at the weir in 2012, 12.1 percent were detected at the Chiloquin Dam site and 6.2 percent were detected at the Above Dam site (Hewitt et al. 2014).

Known areas of concentrated LRS spawning in the Williamson and Sprague Rivers include the lower Sprague River (below the former site of Chiloquin Dam), areas of the lower Williamson River from the confluence with the Sprague River to immediately downstream of the U.S. Highway 97 bridge, and in the Beatty Gap area of the upper Sprague River (Buettner and Scoppettone 1990; Ellsworth et al. 2007; Tyler et al. 2007).

Currently, SNS in UKL spawn in the lower Williamson and Sprague rivers (Buettner and Scoppettone 1990), principally below the site of former Chiloquin Dam (Ellsworth et al. 2007; Tyler et al. 2007). Few adult SNS are detected or captured at the shoreline spawning areas in UKL (Hayes et al. 2002, 2004; Barry et al. 2007b). While it is possible that spawning occurs near other springs or in other tributaries to UKL, extensive fisheries investigations have not identified other spawning aggregations (Reclamation 2007).

Adult LRS in UKL have relatively high survivorship; however, there has been little to no recruitment of juveniles into adult populations (Hewitt et al. 2018b). Mark-recapture analyses of adult LRS from the lakeshore-spawning subpopulation in UKL indicate annual survival from 2000 to 2015 ranged from 88 to 96 percent for females, and 80 to 98 percent for males (Hewitt et al. 2011, 2012, 2018b). LRS from the tributary-spawning subpopulation had annual survival ranging from 88 to 95 percent for females, and 70 to 96 percent for males during this same time period. Despite high survival for most years from 1999 to 2015, the abundance of LRS males in the lakeshore-spawning subpopulation declined approximately 64 percent and the abundance of females declined by approximately 56 percent (Hewitt et al. 2018b). Preliminary data from USGS indicate that lakeshore-spawning LRS have experienced additional declines of approximately 22 percent in the last two years (from 2016 to the spring of 2018). The estimated abundance of lakeshore spawning LRS in UKL was approximately 7,200 individuals in 2018; abundance estimates were nearly 10,000 in 2016 (Janney, E. and D. Hewitt, USGS, pers. comm., 16 August 2018).

Abundance has decreased most dramatically for tributary-spawning LRS. From 2000 to 2015, tributary-spawning LRS populations declined by 40-50 percent (Hewitt et al. 2012). Recently, the decline accelerated and the abundance of tributary-spawning LRS decreased an additional 55 percent from 2016 to 2018 (D. Hewitt, USGS, pers. comm., 30 June 2019). The estimated abundance of tributary-spawning LRS in UKL is approximately 32,000 individuals (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). A recent mortality event occurred in the summer of 2017. The majority of PIT-tagged suckers found dead during the 2017 mortality event belonged to the tributary-spawning population. While the declines primarily reflect a lack of recruitment of new individuals into the spawning populations, annual survival of tributary-spawning LRS has also declined from an average of 92 percent (females) and 91 percent (males) from 2011-2015 to 78 (2016) and 62 percent (2017) for females and to 77 (2016) and 65 percent (2017) for males (D. Hewitt, USGS, pers. comm., 30 June 2019). Individuals in this population have exceeded the average life expectancy for the species.

Annual survival for SNS in UKL were, until recently, lower than either population of LRS. Mark-recapture analyses of adult SNS indicate annual survival from 2000 to 2015 ranged from 68 to 95 percent for females, and 74 to 90 percent for males (Hewitt et al. 2011, 2012, 2018b). Annual survival for SNS was lower than average (84 percent for females, 82 percent for males)

in 2016 (76 percent for females, 73 percent for males) and 2017 (68 percent for females, 61 percent for males) (D. Hewitt, USGS, pers. comm., 30 June 2019). Similar to tributary-spawning LRS, recruitment events of new individuals into the SNS spawning population is less clear. Recruitment events may have occurred in some years though substantial data supporting these events is not comprehensive. Since 2001, the abundance of male SNS declined by 78 percent and the abundance of females declined 77 percent (Hewitt et al. 2018b). Preliminary data from USGS indicate that SNS have also experienced additional declines of approximately 40 percent from 2016 to the spring of 2018. The abundance of SNS is likely 20 percent of what it was in 2001 (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). The estimated abundance of SNS in UKL is approximately 7,900 individuals (Janney, E and D. Hewitt, USGS, pers. comm., 16 August 2018). Individuals in this population have exceeded average life expectancy and are near the maximum known age for the species (33 years).

Despite relatively high and consistent annual survival from 2000 to 2015 both species have experienced substantial declines in abundance because losses from mortality have not been balanced by recruitment of new individuals (Hewitt et al. 2011, 2012, 2018b). All adult sucker populations in UKL appear to be largely comprised of fish that were present in the late 1990s and early 2000s (Hewitt et al. 2011, 2018b). Survival analyses show that the two species do not necessarily experience poor survival in the same years and that poor survival on an annual scale is not always predictable from fish die-offs observed in the summer and fall (Hewitt et al., 2011). However, little to no recruitment has occurred into these sucker subpopulations in the last 20 years (Hewitt et al. 2011, 2012, 2018b).

5.1.6 Clear Lake Reservoir Species Current Condition

LRS and SNS reside in Clear Lake Reservoir (Figure 5-2); however, all studies conducted in Clear Lake have described the morphological characteristics of SNS as introgressed with KLS (Tranah and May 2006; Hewitt and Hayes 2013a; Smith et al. 2015; Dowling et al. 2016). Several studies aimed at identifying distinguishable genetic markers between these species throughout the Upper Klamath Basin have been unable to align genetic variation with observed differences in morphology and habitat use (Tranah and May 2006; Smith et al. 2015; Dowling et al. 2016). Thus, the population of SNS in Clear Lake Reservoir (and throughout the Lost River Basin) includes many suckers that are likely hybridized with KLS (Tranah and May 2006; Smith et al. 2015; Dowling et al. 2016).

Fish fauna studies were not conducted prior to the construction of Clear Lake dam but it is likely that suckers were present prior to construction in 1910 because there is no fish passage over the dam (Reclamation 2002). Sucker populations in Clear Lake Reservoir have periodically been sampled; first by (Koch et al. 1975) and most recently by USGS (Barry et al. 2007a, 2009; Leeseberg et al. 2007; Hewitt and Janney 2011; Hewitt and Hayes 2013a). Population assessments have varied from abundant with diverse age classes to in-decline with few age classes (Andreasen 1975; Koch et al. 1975; Buettner and Scoppettone 1991; Reclamation 1994a; Scoppettone et al. 1995). Fish surveys and monitoring from 1989 through 1993 indicate populations of LRS and SNS had low-to-moderate captures but at least two adult cohorts (often more for SNS), and usually many juvenile suckers (Buettner and Scoppettone 1991; Reclamation 1994a; Scoppettone et al. 1995). USGS began using PIT-tags and remote-monitoring of sucker populations in Willow Creek in 2004 and the Straits in 2014. After several extensive sampling

seasons, the population dynamics of suckers in Clear Lake are better understood, and survival and population estimates are more robust and precise (Barry et al. 2007c, 2009; Hewitt and Hayes 2013a; Hewitt et al. 2018a) The SNS population is estimated to be at least 20,000 adults, and the LRS population to be at least 11,000 adults (Hewitt et al. 2018a).

Assessments since 2009 suggest large cohorts have sporadically recruited into (at least 1 to 2 times per decade) adult spawning populations (Hewitt et al. 2018a). Unlike UKL, juveniles survive past 1 to 2 years in Clear Lake Reservoir (Barry et al. 2009; Hewitt and Hayes 2013a; Burdick et al. 2018; Hewitt et al. 2018a). In some years, cohorts are small but often disappear from the spawning population after a few years for unknown reasons (Hewitt and Hayes 2013a; Burdick et al. 2018; Hewitt et al. 2018a). Annual success or failure to recruit has often coincided for both LRS and SNS populations in Clear Lake Reservoir, though LRS cohorts are substantially smaller than SNS cohorts (Hewitt et al. 2018a).

Suckers in Clear Lake Reservoir are only known to spawn in its tributaries; no shoreline spawning has been documented. Consistent monitoring of the adult spawning migration in lower Willow Creek began in 2004 (Hewitt and Hayes 2013a). Willow Creek is Clear Lake Reservoir's primary tributary and sucker spawning is limited by spring-time reservoir elevation and spring flows in Willow Creek (Hewitt and Hayes 2013a; Hewitt et al. 2018a). When lake elevations are less than 4,524 feet spawning is impeded and suckers are unable to access Willow Creek (e.g., Spring 2014). Additionally, if inflows are too low, suckers do not make spawning migrations. Spawning migrations are triggered by high flows in Willow Creek and increasing temperatures. Clear Lake suckers spawn most years when Willow Creek flows are at least 40 cfs (Hewitt et al. 2018a). Both populations appear to make spawning migrations at low but increasing temperatures; 2 to 4°C (Hewitt et al. 2018a). This contrasts with UKL where spawning migrations are triggered by temperatures of 10 and 12°C for LRS and SNS, respectively (Hewitt et al. 2011). For populations in Clear Lake, spawning can occur as early as the beginning of February or as late as early May, depending on the timing of hydrologic conditions described above (Hewitt and Hayes 2013a; Hewitt et al. 2018a). LRS (especially males) will migrate up Willow Creek at lower flows than SNS but at the expense of increased bird predation (Hewitt et al. 2018a). Sucker populations have been noted in several small reservoirs within the Willow Creek subbasin until consecutive drought years in the 1990s (USFWS 2002). However, in summer of 2018, USGS sampled many of these small reservoirs and other locations in the tributaries and found juvenile suckers in some locations despite dry conditions and a small spawning run for adult suckers (Burdick, S., personal communication, October 16, 2018).

Compared to suckers in UKL, suckers in Clear Lake Reservoir have lower annual survival and are not as long-lived (Hewitt et al. 2018a). Annual survival ranged from 60 to 89 percent for LRS and from 49 to 89 percent for SNS from 2006 to 2015 (Hewitt et al. 2018a). Low survival of adult suckers is partially attributed to avian predation by American white pelicans and double-crested cormorants (Evans et al. 2016). The impact of bird predation was particularly apparent in years like 2009 and 2013 when large colonies of American white pelicans were nesting on islands in Clear Lake Reservoir (Evans et al. 2016). The amount of nesting habitat (islands on Clear Lake Reservoir) varies with lake elevation, though climatic conditions contribute to bird abundance and predation risk for suckers (Evans et al. 2016).

The amount of habitat available for suckers in Clear Lake Reservoir varies with lake elevation; and lake elevation can vary by over 20 feet among (but not within) years. Clear Lake Dam's spillway crest elevation is 4,543 feet but lake elevations are typically less than 4,529 feet (Ferrari 2009). Annual changes in elevation are 5 feet or less, though exceptions occur. Clear Lake Reservoir is comprised of two lobes, East and West. The West Lobe is deeper than the East Lobe (dry at 4,520 feet) but Willow Creek flows into the East Lobe via an excavated channel north toward the dam outlet before turning south to the East Lobe. The lobes are connected by a narrow and rocky section called she Strait. The Strait is shallower than either lobe and the lobes become hydrologically disconnected at elevations near 4,521 feet (Sutton and Ferrari 2010).

When Clear Lake Reservoir elevations are low, adult suckers are limited in their ability or willingness to move between lobes and may be at increased risk of predation. When Clear Lake Reservoir elevations were low in 2015, avian predation was confirmed for 8 percent of radio-tagged suckers (2 LRS, 4 SNS); whereas avian predation was not confirmed as a source of mortality for radio-tagged suckers in 2016 or 2017 when lake elevations were higher (N. Banet, USGS KFFS, personal communication, October 21, 2018). Additionally, when lake elevations were low (e.g., fall 2015) all radio-tagged suckers in Clear Lake Reservoir were found to be in the west lobe (N. Banet, personal communication, October 21, 2018), possibly seeking refuge in deeper water. Suckers were detected on remote detection antennas located in the Strait when lake elevations were 4,522 to 4,523 feet (dam gage), and 4,521 feet (west lobe elevations), apparently staging to spawn in Willow Creek. It is unclear how far spawners are able to move when lake levels are low because antenna arrays at the Strait in Clear Lake Reservoir have only been in place since 2014 (Hewitt et al. 2018a). Some suckers appeared to stage to spawn by entering the Strait in 2014 and 2015 when lake elevations were low but were largely unable to move to spawning grounds in Willow Creek (Hewitt et al. 2018a). At lower lake elevations, suckers in the West Lobe must navigate through the Strait into the East Lobe, then swim through a channel toward the dam outlet before entering Willow Creek to access spawning grounds in Willow Creek (USBR 2018, figures 6-5 and 6-6 therein). The channel between the dam and the East Lobe is hydrologically disconnected from the remainder of the lake at a surface elevation of about 4,522 feet (Sutton and Ferrari 2010). Suckers appear to be very limited in their ability to access Willow Creek unless lake elevations are 4,524 feet or greater (Hewitt and Hayes 2013a; Hewitt et al. 2018a), likely due to hydrologic constrictions at the Strait or the channel to the dam outlet. Evans et al. (2016) concluded that avian predation may be a factor that is limiting the recovery of ESA-listed suckers in Clear Lake Reservoir. Predation of suckers by avian predators in Clear Lake varied among years, bird colony size, sucker species, sucker size, and sucker age-class (Evans et al. 2016). The amount of bird nesting habitat and loafing areas (islands) also varies with lake elevation (Moreno-Matiella and Anderson 2005) which may contribute to avian predation. The specific relationship among many variables including lake elevation, nesting habitat, nesting success, avian predation, and sucker survival, is not fully understood, though avian predation has been documented as a (proportionally) large source of annual mortality for juvenile and adult suckers in Clear Lake Reservoir (Evans et al. 2016).

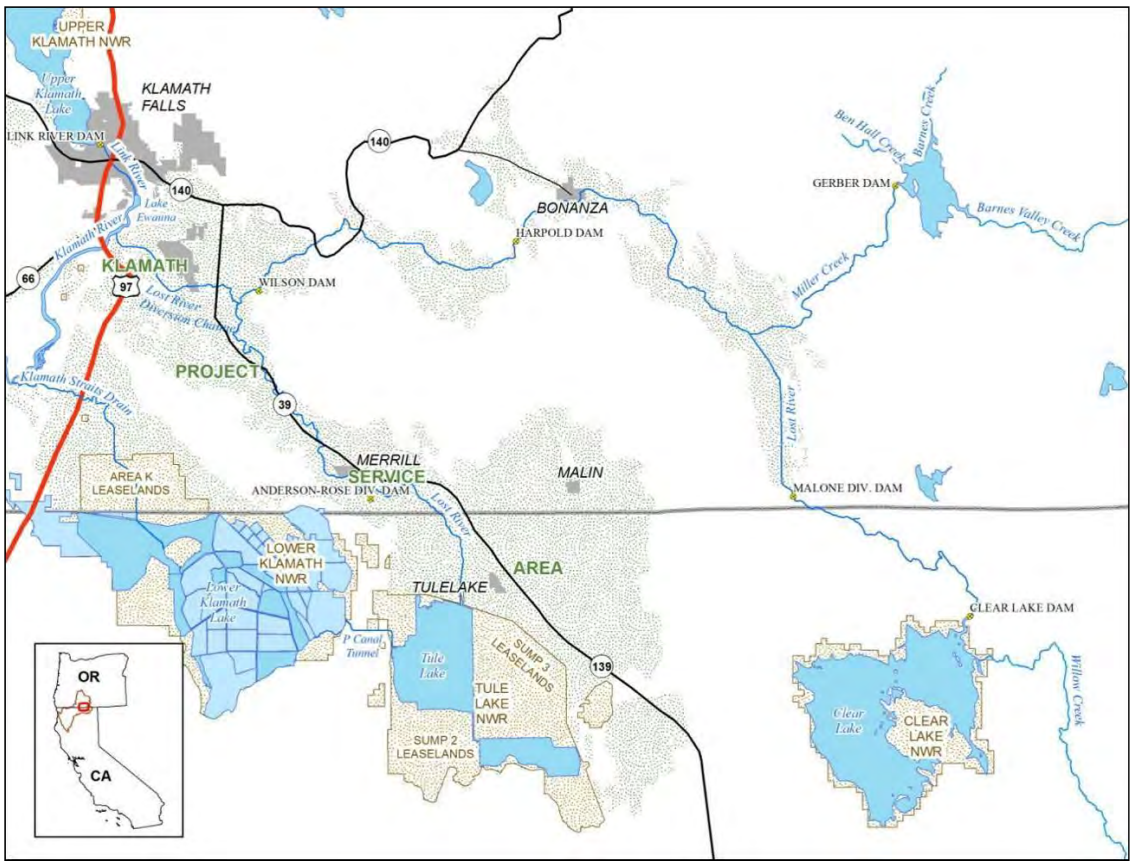


Figure 5-2. The Lost River drainage of northern California and southern Oregon and its connections to the Klamath River drainage. Project lands are shown as shaded. (Bureau of Reclamation 2018a)

5.1.7 Gerber Reservoir and Other Locations Species Current Condition

Data on other populations (i.e., Keno Impoundment, Klamath River Reservoirs, Tule Lake, Gerber Reservoir, and the Lost River proper) are extremely limited, but they suggest low numbers of individuals (Desjardins and Markle 2000b; Hodge and Buettner 2009). Gerber Reservoir may be an exception to this.

Intermittent monitoring in the Gerber Reservoir watershed since 1992 has documented a substantial SNS population with multiple size classes including many small individuals, which suggests regular recruitment occurs (Barry et al. 2007a; Reclamation 2018a). SNS in Gerber Reservoir are similar to those in Clear Lake Reservoir in that the morphology of many individuals include characteristics associated with KLS (Markle et al. 2005; Barry et al. 2007a). Despite the apparent hybridization, the USFWS considers the Gerber sucker population to be SNS until the status of these fish has been resolved (USFWS 2008). SNSs in Gerber Reservoir have endured large fluctuations in habitat size (reservoir down to 4,796 feet in the early 90s and 4,797.9 feet in 2016) and geographical isolation from other sucker populations in the basin (Piaskowski and Buettner 2003; Reclamation 2018a). This has likely restricted genetic variation and population size in the region. LRS were not observed in Gerber Reservoir during early or recent fisheries investigations (Barry et al. 2007a; Leeseberg et al. 2007), and are likely not present in Gerber Reservoir.

Spawning at Gerber Reservoir occurs in its tributaries, predominantly in Barnes Valley Creek but also in Ben Hall (Barry et al. 2007a), and possibly Barnes Creek. Shoreline spawning has not been observed at Gerber Reservoir (Leeseberg et al. 2007). Spawning surveys in 2006 detected approximately 1,700 SNSs of the nearly 2,400 that had been tagged the previous year (Barry et al. 2007a). Spawning migrations have not been regularly monitored by remote antennas. However, in 2006 suckers were present in tributaries from early March to mid-May (Barry et al. 2007a). Some suckers in Gerber have demonstrated great mobility; moving among spawning tributaries at opposite ends of the reservoir within 24 hours (Barry et al. 2007a). The most recent sampling effort in Gerber was conducted over 8 weeks in the spring of 2018 by Reclamation and over 1,200 individual suckers were captured (Reclamation 2018a). A few fish were re-captures, originally tagged in fall 2005 (Reclamation 2018a). Several cohorts were present, and individuals ranged in size from about 300 to 570 mm in fork length.

Current variability in population dynamics is largely unknown but given the relatively long-life expectancy of these species, populations are generally stable over the short-term. A long-life span and high fecundity enable these species to withstand unfavorable periods, and generally buffer against large fluctuations in abundance.

5.2 SONCC Coho Salmon Evolutionarily Significant Unit

SONCC coho salmon ESU were listed as threatened species by NMFS in 1997 (NMFS 1997, 62 FR 24588). This ESU included populations spawning in coastal watersheds from Elk River, Oregon, to Mattole River, California (Figure 5-3). The threatened status was reaffirmed in 2005, including the addition of three hatchery stocks (NMFS 2005b, 70 FR 37160) and again in 2016 (NMFS 2016a). The current boundary designations were recently confirmed by the genetic analysis of 18 polymorphic microsatellite DNA markers (Gilbert-Horvath et al. 2016). The four coho salmon populations in the upper portions of the drainage will experience the greatest magnitude and intensity of stressors, relative to the PA, on their viability based on their proximity to IGD. These four populations are the Upper Klamath, Shasta, Scott, and the Middle Klamath River populations.

5.2.1 Description and Distribution

Adult coho salmon can measure more than 60 cm in length and weigh up to 16 kilograms (kg), with an average weight of 3.6 kg. Coho salmon have dark, metallic-blue or green backs with silver sides and a light-colored abdomen. At maturity, they are often red along the side of the body. Within the marine environment, coho salmon display small black spots on their backs and the upper lobe of caudal fin. Coho salmon were historically distributed throughout the North Pacific Ocean from central California to Point Hope, Alaska, through the Aleutian Islands, and from the Anadyr River, Russia, south to Hokkaido, Japan. Given their wide distribution, it is likely that coho salmon historically inhabited most coastal streams in Washington, Oregon, and northern and central California.

5.2.2 Life History

Adult coho are anadromous and semelparous. However, the amount of time they spend rearing in the marine environment can vary (Quinn 2005), leading to different life history traits. Although these alternate life history traits are important at the population level (Roni et al. 2012),

a three-year life cycle is the most common. This life cycle is generally characterized by the first 14 to 18 months spent in freshwater, ocean residence for at least a full year, and a return to freshwater to spawn (Sandercock 1991; Quinn 2005).

5.2.2.1 Adult

In this document, adult life history will be classified into three stages: marine rearing, freshwater migration, and spawning.

5.2.2.1.1 Marine Rearing

Coho generally spend between 16 and 20 months rearing in the marine environment, though some early-maturing males may only rear for one year. Upon entering the ocean they feed on plankton in the nearshore environment, and as they grow, they move farther out, switching to a diet of larger prey such as herring and squid (Groot et al. 1995). Marine survival is influenced by a number of interacting factors including prey abundance, predator density, degree of intra-specific competition (including hatchery fish), and sport and commercial fisheries (NRC 1996).

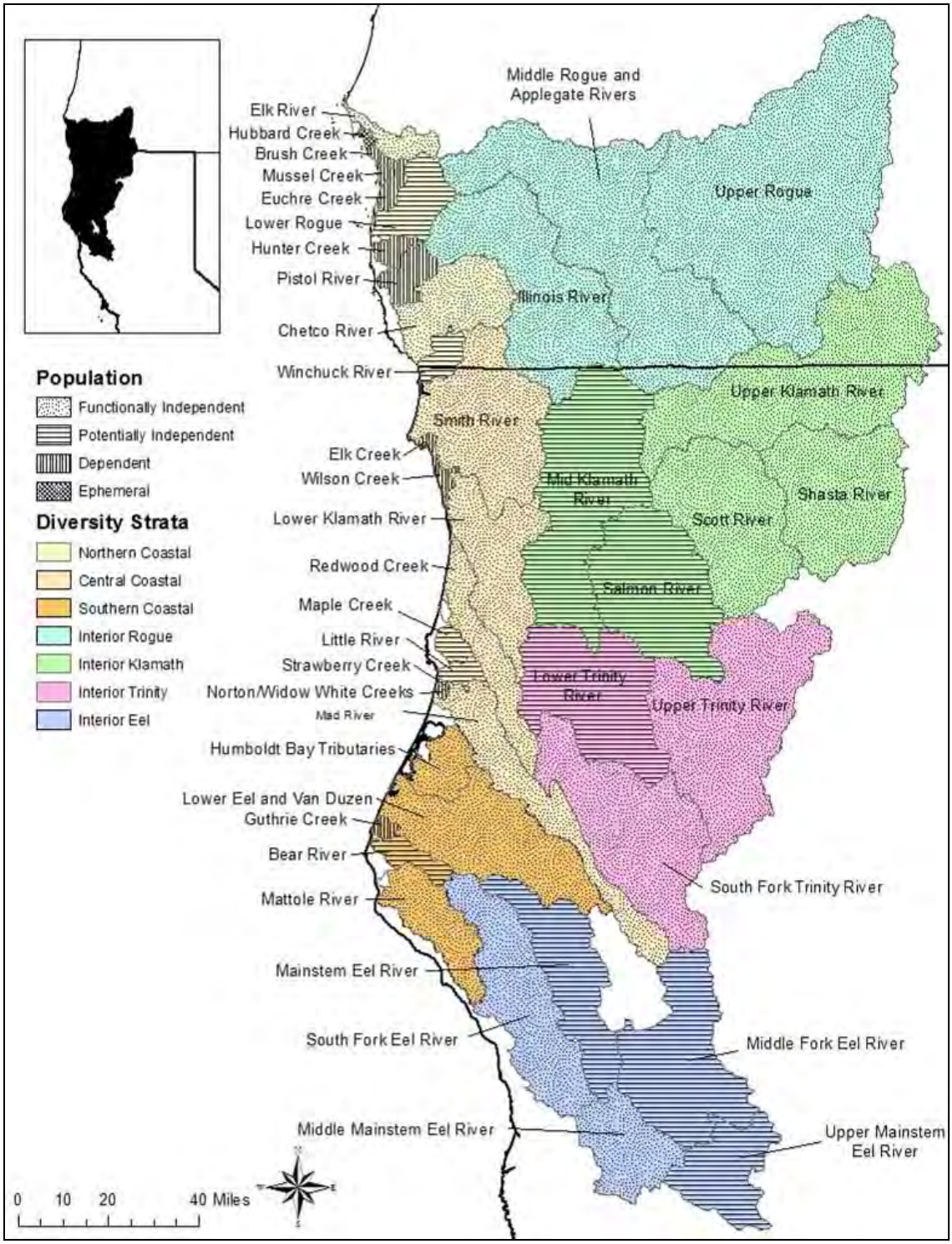


Figure 5-3. Historic population structure and seven diversity strata of the Southern Oregon/Northern California Coast coho salmon Evolutionarily Significant Unit. Source: modified from Williams et al. (2006c).

The relative importance of these factors is directly affected by ocean conditions (NRC 2004), particularly increasing water temperatures. Increases in water temperature influence survival in

most life-stages of coho via heat stress, changes in growth and development rates, lowering resistance to disease (NMFS 2016a), and by shifting feeding opportunities. Changes in feeding opportunities are particularly important as zooplankton communities shift to favor more warm-water-tolerant species that lack the lipid-rich tissue that colder-water species possess. For example, in 2016, the biomass of lipid-rich northern copepod species was the lowest ever observed, while in 2017, the lipid-deplete tropical and sub-tropical southern copepods had the highest biomass in recent records (Peterson et al. 2017). This finding coincided with an ocean-warming event in 2014, referred to as the "Warm Blob," characterized by exceptionally high epipelagic ocean temperatures in the Northeast Pacific Ocean.

The Warm Blob initially formed in the Gulf of Alaska in 2013 and moved across the North Pacific in the spring of 2014 (Peterson et al. 2017), affecting the Baja, southern, and central coasts of California. Between November 2015 and January 2016, warm conditions were exacerbated as the Warm Blob was met by an unusually strong El Niño Southern Oscillation event in the Northeast Pacific Ocean. These conditions initiated a series of cascading trophic events creating conditions that no longer provided favorable growth opportunities for Pacific salmon. For example, Pacific salmon prey were dominantly larval rockfish and anchovies, indicators of poor feeding opportunities (Peterson et al. 2017). Consistent with this, pelagic surveys in the Northern California Current (spanning the Canadian border to Cape Blanco, Oregon) indicate dramatic declines in coho salmon abundance between 2014 and 2017 (Morgan et al. 2019). These trends likely reflect both trophic changes in oceanic conditions and local processes, which also contribute to low adult returns. Consequently, Columbia River coho salmon returns were some of the lowest ever recorded during this period (Peterson et al. 2017).

Marine survival for populations south of Northern British Columbia, including the Klamath River, are typically below average in comparison to other northern states and provinces (Coronado and Hilborn 1998) and highly variable from year-to-year (Nickelson 2006). For example, marine survival of coho salmon smolts released from Fall Creek Hatchery (Alsea River, Oregon) ranged from near zero to 10 percent from 1970 to 1994 (Figure 5-4); low survival was attributed to ocean temperature and coastal upwelling (Emmett and Schiewe 1997). Moreover, Pearcy (1992) speculated that protected bays, inlets, and shallow littoral areas that favor survival are rare off California and Oregon and may contribute to these populations' poor marine survival rates. In addition, oceanographic variability, resulting from inter-annual fluctuations in the intensity of upwelling or El Niño Southern Oscillation events, appears to be greater in the southern part of the species' range (Lestelle 2007). In the Klamath River Basin, Nickelson (2006) found that the marine survival of hatchery-produced coho salmon was highly variable from year to year and presumed that wild coho salmon survival is similarly variable. It was estimated that the survival of Klamath River coho salmon originating from Iron Gate Hatchery (IGH) ranged from 0.12 percent to 5.7 percent from 1977 to 2001 (Nickelson 2006).

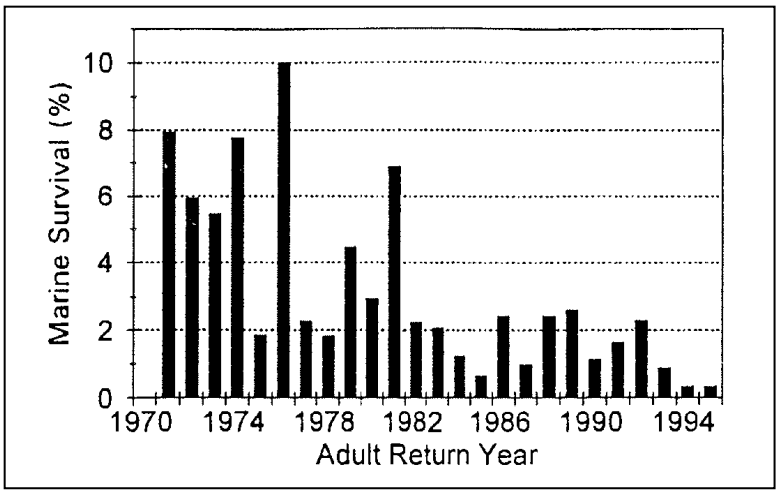


Figure 5-4. The influence of ocean temperature and coastal upwelling on marine survival of coho salmon released from Oregon hatcheries. Source: Emmett and Schiewe (1997).

Smolt-to-adult return (SAR) rates provide insight into salmon ocean survival. For example, Lindley et al. (2009) suggested the poor performance of Sacramento River Fall Chinook salmon in the 2004 and 2005 brood years resulted from anomalous ocean conditions including weak upwelling, warm sea surface temperatures, and low prey densities. These findings were supported by near-normal smolt abundance estimates at the entrance to the estuary and typical freshwater rearing conditions for both brood years. In recent years, coho SAR rates in the Shasta and Scott Rivers have ranged from 0.5 to 16 percent (Chesney and Knechtle 2015; Magranet and Yokel 2017). Just south of the Klamath River Basin in Freshwater Creek, a tributary to Humboldt Bay, SAR rates have remained relatively low since 2007 ranging from 0.01 to 0.05 percent (Figure 5-5). Warm temperatures, strongly positive Pacific Decadal Oscillation (PDO) values, as well as lipid-depleted zooplankton populations continue to contribute significantly to the poor observed and predicted SAR values since 2014 (Peterson et al. 2017). Moreover, Peterson et al. (2017) estimated SAR in 2017 to be less than 2 percent for all Pacific Northwest coho salmon (Figure 5-6), consistent with observed declining trends.(Peterson et al. 2017).

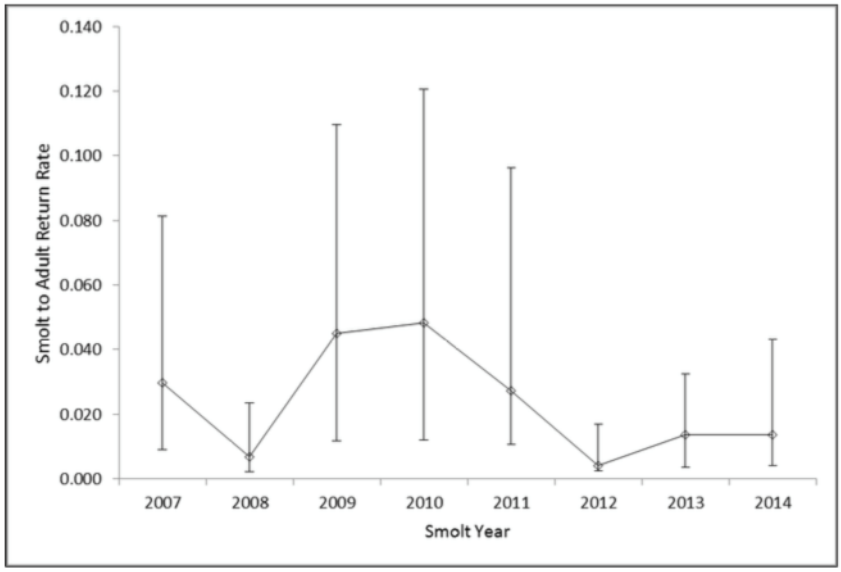


Figure 5-5. Smolt-to-adult return rates (95 percent confidence bounds) for Freshwater Creek coho salmon smolts by year of ocean entry, 2007 to 2014. Freshwater Creek is a tributary to Humboldt Bay in Northern California. Source: Anderson and Ward (2016).

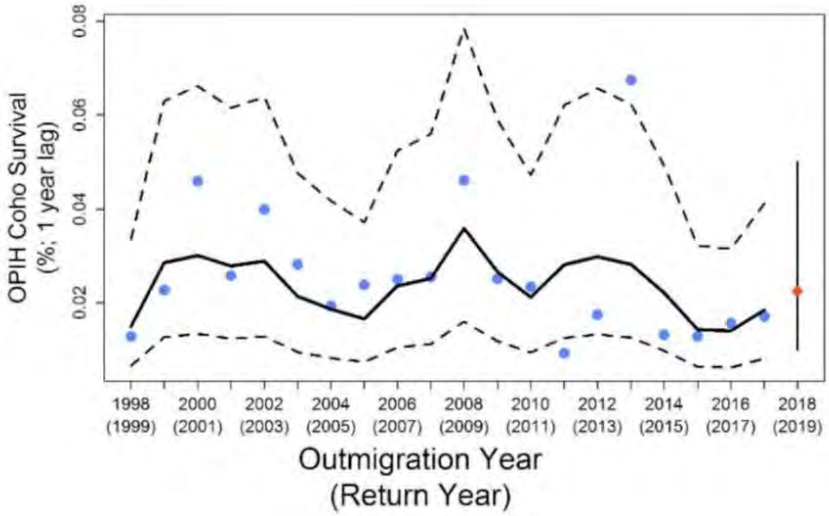


Figure 5-6. Time series of observed coho salmon smolt-to-adult returns rates (blue points) by outmigration year. The dark line represents dynamic linear model fit and dashed lines represent plus or minus 2 standard deviations from the mean model fit. Source: Peterson et al. (2018).

5.2.2.1.2 Adult Freshwater Migration

Adult coho salmon migrate into the Klamath River in September, with peak migration in mid-October (Ackerman et al. 2006). Upon entry into the Klamath River estuary, adult coho salmon quickly migrate upstream, without extensive estuarine residence. Strange (2004) observed four adult coho salmon migrants averaged 17 hours in the estuary prior to upriver migration and a single individual holding for 24.5 days in the estuary. After estuary passage, adult coho salmon use the mainstem Klamath River as the primary migratory pathway to tributary spawning areas (Dunne et al. 2011).

Most spawning occurs in large tributaries such as the Scott, Shasta, and Trinity Rivers, as well as some higher order tributaries (Figure 5-7). Recent observations indicate that adult coho salmon return to the Scott and Shasta Rivers beginning in mid-October, when flows are sufficient to allow upstream migration (Magranet and Yokel 2017; Chesney and Knechtle 2017). In addition to initiating migratory behavior, conditions in tributaries can determine availability of and access to important spawning habitat. For instance, low flow conditions in tributaries can be a significant barrier to reaching upstream spawning areas (Sutton 2007).

The numbers of adult coho successfully reaching spawning areas in Klamath River tributaries has been variable over the POR but in recent years, appears to be declining (Figure 5-8). In the Shasta River for instance, only 46 coho salmon passed upstream of the weir in 2014, 45 in 2015, 48 in 2016, and 39 in 2018 (Chesney and Knechtle 2015, 2017; Giudice and Knechtle 2019). Moreover, a substantial portion of the coho entering the Shasta River between 2008 and 2014 were identified as hatchery strays (Chesney and Knechtle 2017). Hatchery contributions were not estimated in 2015 or 2016 since no hatchery carcasses were recovered in either year. The Scott River adult returns were substantially higher than the Shasta in 2015, 2016, 2017, and 2018 (212, 226, 382, and 739 respectively); however, escapements to the Scott River have varied substantially over the POR (Table 5-1; Figure 5-9), with a low of 63 in 2008 to over 2,500 in 2013 (Knechtle and Chesney 2017). Return trends for Scott and Shasta River coho populations were based on adult counts at video weirs (Figure 5-10; Knechtle 2015 in Williams et al. 2016). The trend for the Shasta River population did not differ significantly from zero, indicating that this population is virtually static or that annual variability is simply too influential to detect significant changes, and no trend statistics were presented for the Scott River population (Williams et al. 2016). Williams et al. (2016) also noted that low adult returns in the Shasta River in 2014 and 2015 paired with the increasing scarcity of other SONCC ESU coho populations is particularly concerning for the viability of the entire ESU.

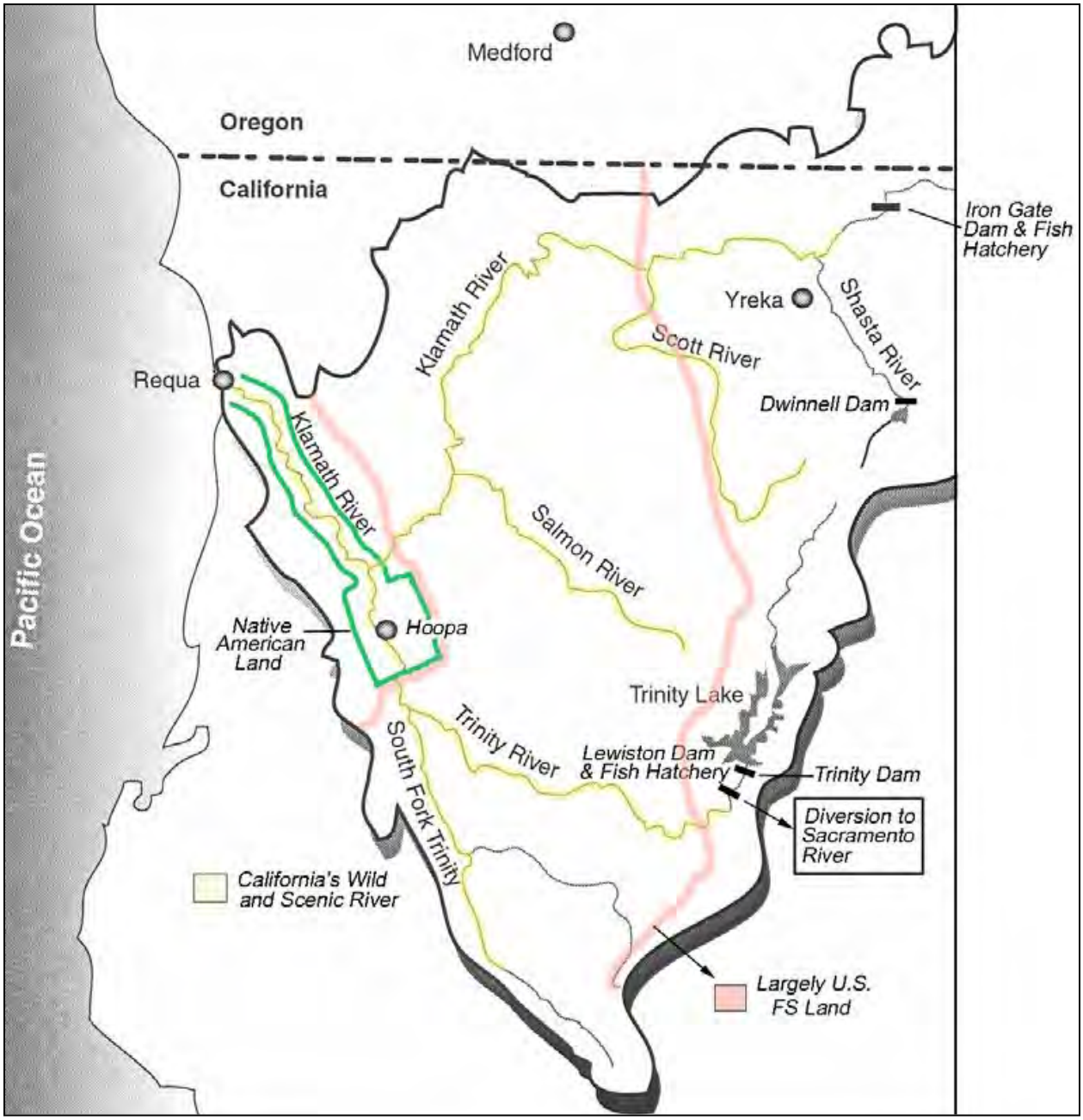


Figure 5-7. The Klamath River drainage downstream of the Iron Gate Dam. The Iron Gate Dam is currently an upstream barrier to anadromous salmonid migrations in the mainstem Klamath River. Green lines demonstrate the approximate boundaries of both the Yurok and Hoopa Valley tribal reservations. Pink lines demonstrate approximate boundaries of the watershed that are mostly federal lands (i.e., U.S. Forest Service). Yellow shaded rivers designate California Wild and Scenic River stretches. Source: (Bureau of Reclamation 2012a).

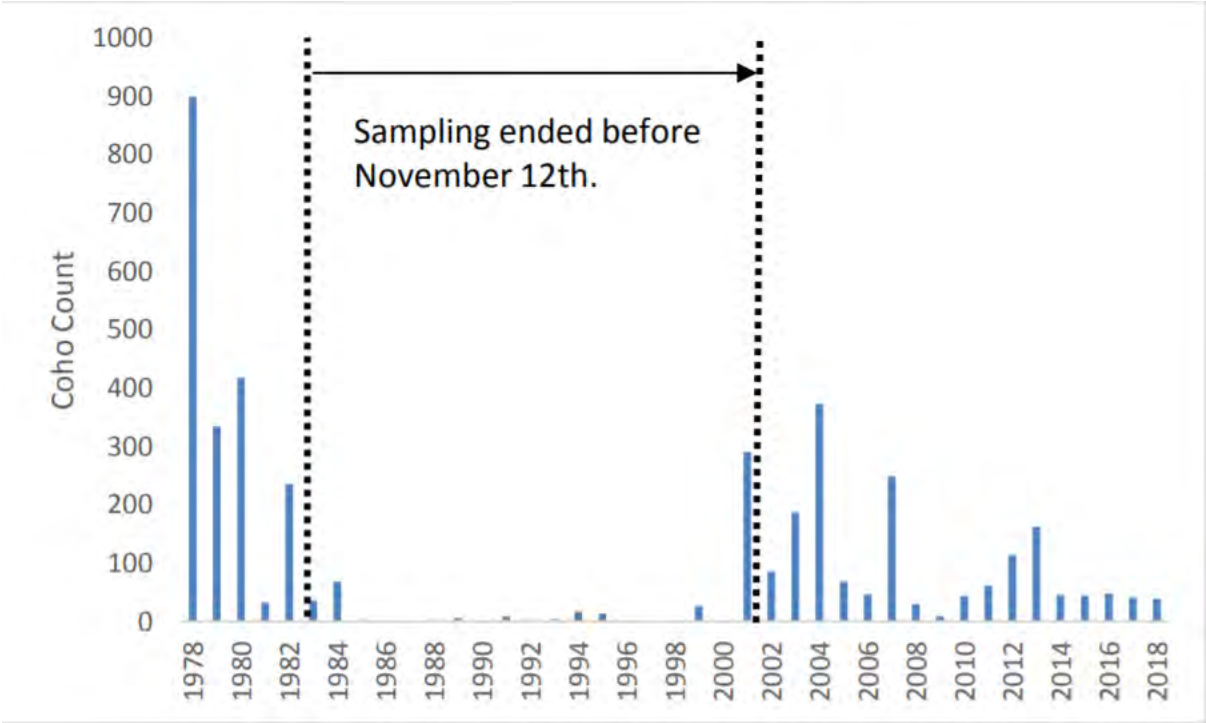


Figure 5-8. Returns of coho salmon to the Shasta River, California, 1978 to 2018. Dotted vertical lines indicate the period between 1984 and 2002 when the weir was removed (due to forecasted high flows) prior to November 11th, and the entirety of the coho return was not fully captured. Source: Giudice and Knechtle (2019).

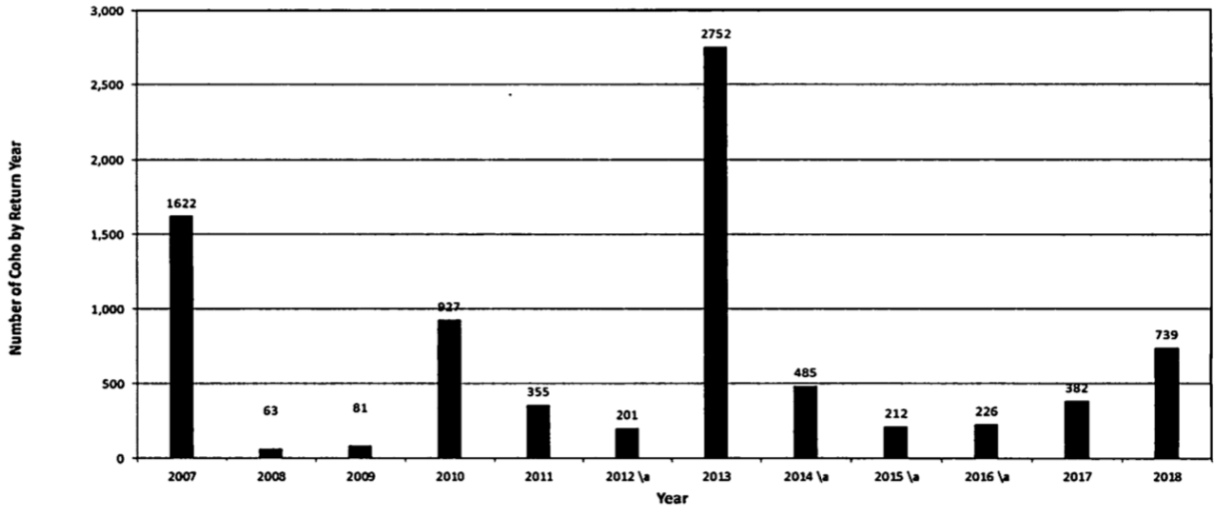


Figure 5-9. Estimated escapement by return year of adult and grilse coho salmon (age 2 and age 3) returning to the Scott River, 2007 to 2016. The symbol "\a" indicates a conservative estimate as weirs

were removed prior to the end of the run (due to high forecasted river flows). Source: Knechtle and Giudice (2019).

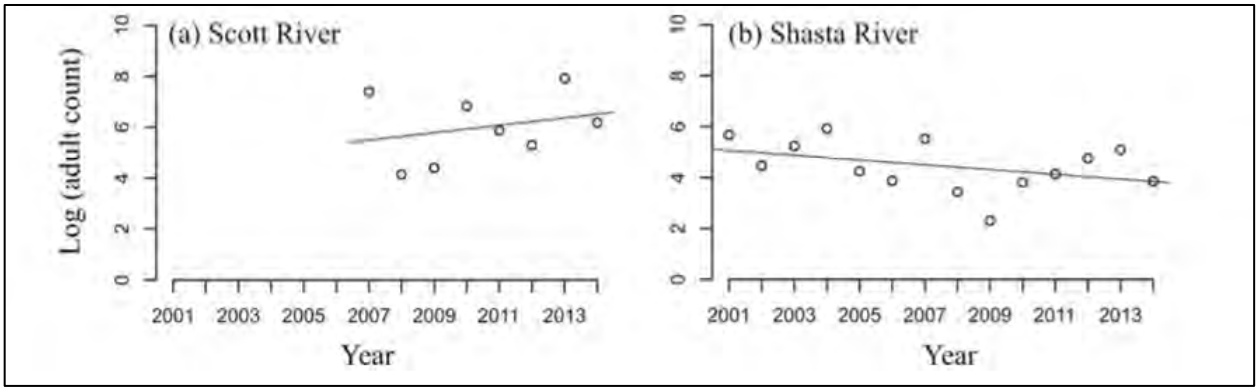


Figure 5-10. Population abundance trends for independent coho salmon populations in the Scott (a) and Shasta (b) Rivers from 2007 to 2014 and 2001 to 2014, respectively. Source: unpublished data from Knechtle (2015) presented in Williams et al. (2016).

5.2.2.1.3 Spawning

Most coho salmon spawning occurs in the tributaries of the Klamath River from November through January. Salmon migration into natal tributary streams often occurs during higher fall flows (Koski 1966). During fall, ambient air and water temperatures generally decrease while rainfall events increase in frequency (NMFS 2010a), encouraging adult migration into tributaries for spawning.

Both mainstem tributaries and higher-order tributaries support most spawning adult coho in the Klamath River Basin; however, distribution can be variable year to year. For instance, 2013 marked the largest return year of coho spawners since 2006 (Figure 5-12; (Bull et al. 2015), yet spawner distribution into tributaries was extremely limited as a result of severe drought conditions from 2013 to 2014 (CDFW 2016a).

Coho populations spawning in tributaries within the Middle Klamath River (between Portuguese Creek and the Trinity River confluence) were estimated to be between 0 and 1,500 individuals depending on the strength of a particular year's run (Ackerman et al. 2006). Slate, Boise, Red Cap, Clear, Camp, and Indian Creeks support substantial returns of coho salmon, although total spawner abundance and overall population productivity is unknown. From 2013 to 2014, 64 coho salmon redds were observed in other Middle Klamath River tributaries: Aikens, Camp, China, East Fork Elk, Independence, Indian, Mill (tributary to Indian), South Fork Clear, and Titus creeks (Corum 2014). Recently, the Middle Klamath River population was determined to be at a moderate extinction risk (NMFS 2016a).

As with most species of Pacific Salmon, coho salmon prefer spawning in tributaries, rather than mainstem rivers that may not have sufficient substrate, depth, and DO for egg development. Coho salmon spawning in the mainstem Klamath River occurs to a much more limited extent than in tributaries (Soto et al. 2016), resulting in sparse mainstem spawner data. Between 2001 and 2004, Ackerman et al. (2006) estimated that less than four percent of all returning adult coho spawned in the mainstem Klamath River. From 2001 to 2005, Magneson and Gough (2006) documented a cumulative total of 38 coho salmon *redds* in approximately 83 miles of the

mainstem Klamath River, between IGD (river mile [RM] 190.5) and the Indian Creek confluence (RM 107.4) between November 15 and December 18. Furthermore, roughly 68 percent of observed redds were within 12 RMs downstream of IGD; many of these fish likely originated from IGH (NMFS 2010a). In 2008, Slezak (2009) counted 9 coho salmon redds in the mainstem Klamath; eight of which were located in side or split channels. The highest concentration of these redds (4) were found in a side channel near the confluence of Barkhouse Creek (RM 159.5). The number of redds observed in this survey were similar to counts between 2002 and 2005 but were considerably lower than counts in 2001. It should be noted that tributaries appear to play an important role in coho spawning activities in the mainstem Klamath River. Magneson and Gough (2006) found all mainstem redds were constructed within approximately 1 RM of a tributary mouth, highlighting the importance of tributary confluences in spawning site-selection. More recently, extensive surveys of coho spawning in the mainstem Klamath River have not occurred. However, coho redds have been observed opportunistically during fall Chinook spawning surveys in the mainstem Klamath providing limited counts of coho spawning activity.

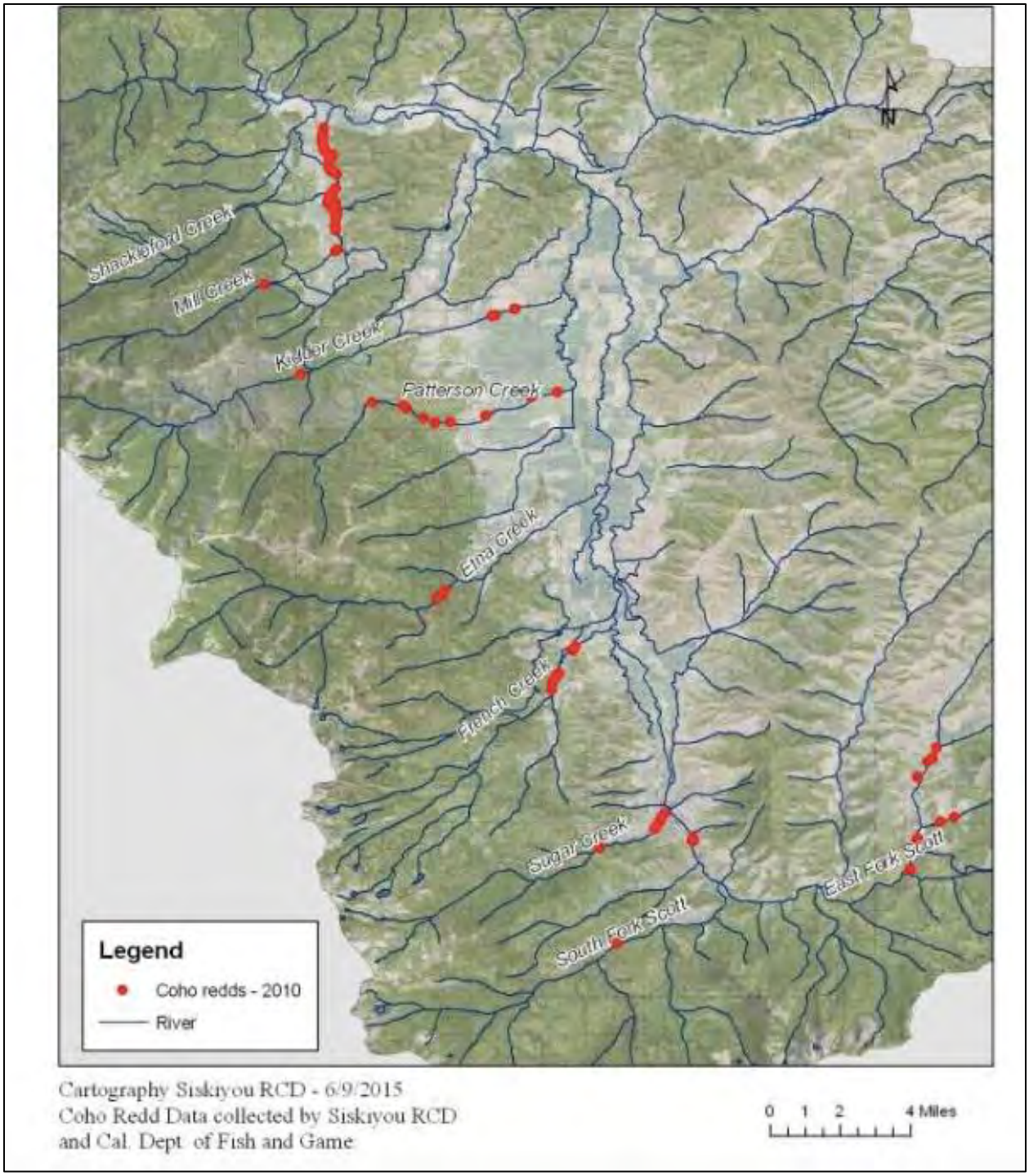


Figure 5-11. Scott River coho redd distribution for sampled reaches during 2010 (some reaches of the Scott River and its tributaries were not sampled). Surveys conducted by California Department of Fish and Wildlife. Source: Bull et al. (2015)

Table 5-1. Coho salmon redd density in the Scott River and tributaries for three cohorts. Table adapted from Magranet and Yokel (2017).

Stream	Reach	2014-2015 redds/mile	2015-2016 redds/mile	2016-2017 redds/mile
Shackleford	Lower	6.7	0	1.8
Shackleford	Middle	21.3	5.4	6.3
Mill Creek	Lower	22.9	31.4	20.6
Mill Creek	Upper	0	*not surveyed*	0
Kidder Creek	Upper	0	0	0
Patterson Creek	Middle	0	0	0.9
Patterson Creek	Upper	0	0	0
Patterson Creek	Lower	0	*not surveyed*	*not surveyed*
Etna Creek	Middle	0	0	0
French Creek	Lower	5.0	0	3.8
French Creek	Middle	8.0	2.7	11.7
French Creek	Upper	0	0	*not surveyed*
Miners Creek	Lower	*not surveyed*	2.2	15.8
Sugar Creek	Lower	0	10	7.8
Sugar Creek	Middle	1.7	0	9.4
Sugar Creek	Upper	0	0	0
Wildcat Creek	Middle	*not surveyed*	*not surveyed*	0
South Fork Scott	Middle	0	0	0
East Fork Scott	Middle	0	*not surveyed*	0.3
East Fork Scott	Upper	0	*not surveyed*	*not surveyed*
Mainstem Scott	Index Reach	0	*not surveyed*	0
Mainstem Scott	Index Reach	0	0	0
Mainstem Scott	Index Reach	1.9	*not surveyed*	0
Mainstem Scott	Index Reach	1.9	*not surveyed*	2.2
Mainstem Scott	Index Reach	1.9	*not surveyed*	4.8

5.2.2.2 Egg Incubation and Fry Emergence

Coho salmon embryos develop and hatch in 8 to 12 weeks, then remain in the gravel as alevins for another 4 to 10 weeks (Sandercock 1991) as they develop into the fry life stage. Fry emerge from the gravel as 30 to 50 mm fish and typically seek shallow stream margins for foraging and safety (NRC 2004). Within the Klamath River Basin, fry begin emerging in mid-February and continue through mid-May (Leidy and Leidy 1984).

5.2.2.3 Fry

After emergence from spawning gravels, coho salmon fry distribute themselves upstream and downstream, seeking favorable rearing habitat (Sandercock 1991). Coho fry prefer slower

velocities, favoring velocities between 0.33 and 1.64 feet/s (0.1 and 0.5 meters per second [m/s]), but occupy habitats ranging from 0 to 3.51 feet/s (1.07 m/s; (Hardy et al. 2006)). They use habitat with water depths ranging from 0.2 to 2.89 feet (0.06 to 0.88m), favoring depths between 0.69 and 1.31 feet deep (0.21 and 0.40 m; (Hardy et al. 2006). Coho fry prefer stream temperatures between 12 and 14°C; (Moyle 2002a), and coho are often associated with habitats containing large woody debris and other in-stream cover (Nielsen 1992; Hardy et al. 2006).

Although little is known about the drivers of coho fry movements immediately after emergence (Quinn 2005), early emigration is common. Dominant individuals will engage in agonistic and territorial behaviors as they begin exogenous feeding that can displace subordinates (Chapman 1962; Mason and Chapman 1965; Berejikian et al. 1999). Other, coho fry may migrate to estuarian habitats during summer and then into freshwater habitats for overwintering (Koski 2009) or remain in the estuary for the duration of their rearing (Hoem Neher et al. 2013). Relocation of fry may also result from physical displacement or density-dependent behaviors; however, the fate of those individuals is not well documented. In the Klamath River Basin, movement of fry from higher order tributaries to mainstem tributaries or to the mainstem Klamath River during the summer, when water temperatures are high, may preclude survival unless fish find suitable thermal refugia (NRC 2004).

5.2.2.4 Juveniles

While there is no sharp physiological distinction between the fry and juvenile life-stages in Coho, juveniles are characterized by increasing territoriality. Juvenile coho remain closely associated with slow velocity, low-gradient habitats (Quinn 2005; Lestelle 2007). They feed on insect drift, generally within an established territory, orienting upstream so they may dart out and grab food. Establishing feeding territories is a characteristic of most juvenile salmonids in streams and represents an important tradeoff between energy spent obtaining food and energy spent defending foraging territory. Moreover, juvenile coho will form a foraging hierarchy and exhibit three general behavioral patterns: dominants, subdominants, and floaters (Nielsen 1992).

Juvenile salmonids relocate to avoid adverse environmental conditions or to optimize foraging opportunities. The movement patterns and habitat-use of juvenile coho salmon can show considerable temporal variation. Non-natal streams often provide important rearing habitat for juvenile salmonids and are accessed through the mainstem Klamath River. Between May 2007 and May 2008, more than 2,700 juvenile coho salmon were successfully PIT-tagged and released to monitor movements throughout the Klamath Basin. Fish not only moved within small tributaries, they also used the mainstem Klamath River to travel between tributaries (Hillemeier et al. 2009). The longest distance traveled by an individual was 125 miles from Fort Goff Creek on September 18, 2007 and Salt Creek on May 10, 2008. The longest redistribution of a fish seeking overwinter habitat was 114 miles moving from China Creek on August 14, 2007 to Junior Pond Creek on January 2, 2008 (Hillemeier et al. 2009).

Monitoring coho populations in streams where spawning is rare, or doesn't occur, can provide insights into the extent the Klamath mainstem is used as a redistribution corridor. Two streams routinely monitored for fish abundance during spring, summer, and fall are the Independence Creek floodplain channel (RM94) and Cade Creek (RM112). While some natal production of coho salmon has been observed in Independence Creek, extensive use by non-natal, YOY coho has been documented (Hillemeier et al. 2009). Similarly, Cade Creek supports juvenile coho

salmon rearing but is rarely used for spawning. Hillemeier et al. (2009) found that when water temperature in the mainstem Klamath River exceeded stressful levels (approximately 19ºC), coho salmon utilized Cade Creek. Further, the authors observed increasing number of juvenile coho salmon moving into the stream as mainstem temperatures continued to rise. In addition to juveniles using the mainstream to access non-natal streams for refuge, others use the plumes at the confluence with the mainstem Klamath (e.g., Beaver Creek RM162) when temperatures are favorable (Sutton and Soto 2012).

Lestelle (2010) characterized seasonal habitat use and movement patterns by juvenile coho salmon in the Klamath Basin as four patterns: spring re-distribution (and rearing), summer rearing, fall re-distribution (and rearing), and winter rearing. Additionally, juvenile re-distribution during the summer rearing period has been documented throughout the basin (Sutton and Soto 2012; Soto et al. 2016; Manhard et al. 2018).

Spring Re-Distribution/Rearing. The spring re-distribution/rearing pattern can include small-scale movements within a tributary to areas with deeper water or large-scale movements both upstream (Hay 2004; CDFW 2016a) and downstream (CDFW, 2016a). Chesney et al. (2009) observed large-scale movements in the Shasta River as juvenile coho salmon migrated over four miles upstream to areas of cold, spring inflow after they experienced a rapid increase in maximum daily water temperatures

Other coho fry disperse downstream after emergence, often facilitated by spring runoff (Soto et al. 2016); some moving into the mainstem Klamath River, seeking low-velocity habitats to rear. Although limited, mainstem rearing habitat exists along the river shoreline and within backwater units (Beechie et al. 2005; Lestelle 2007).

Summer Re-Distribution/Rearing. Summertime movement patterns are largely driven by increases in water temperature. Few juveniles rear in the mainstem Klamath River during the summer as temperatures regularly exceed 24°C (NRC 2004), well above the thermal stress tolerance for juvenile coho rearing (review in Richter & Kolmes (2005). Sutton and Soto (2012) found that when water temperatures in the mainstem Klamath River approach approximately 19°C, juvenile coho begin to use thermal refugia. Furthermore, this study observed visual fish counts in these areas of refugia begin to decline as water temperatures exceeded 22 to 23°C, suggesting these areas became unsuitable habitats. In addition to temperature thresholds, juvenile coho can be limited by the availability of refugia areas in the mainstem Klamath River. Refugia are spatially and temporally variable with many factors impacting the size, shape, and function of the refugia habitat (Deas et al. 2006). In the mainstem Klamath River, changes in flow at IGD, meteorological conditions, and tributary contributions influence both the amount and extent of available refugia (Deas et al. 2006).

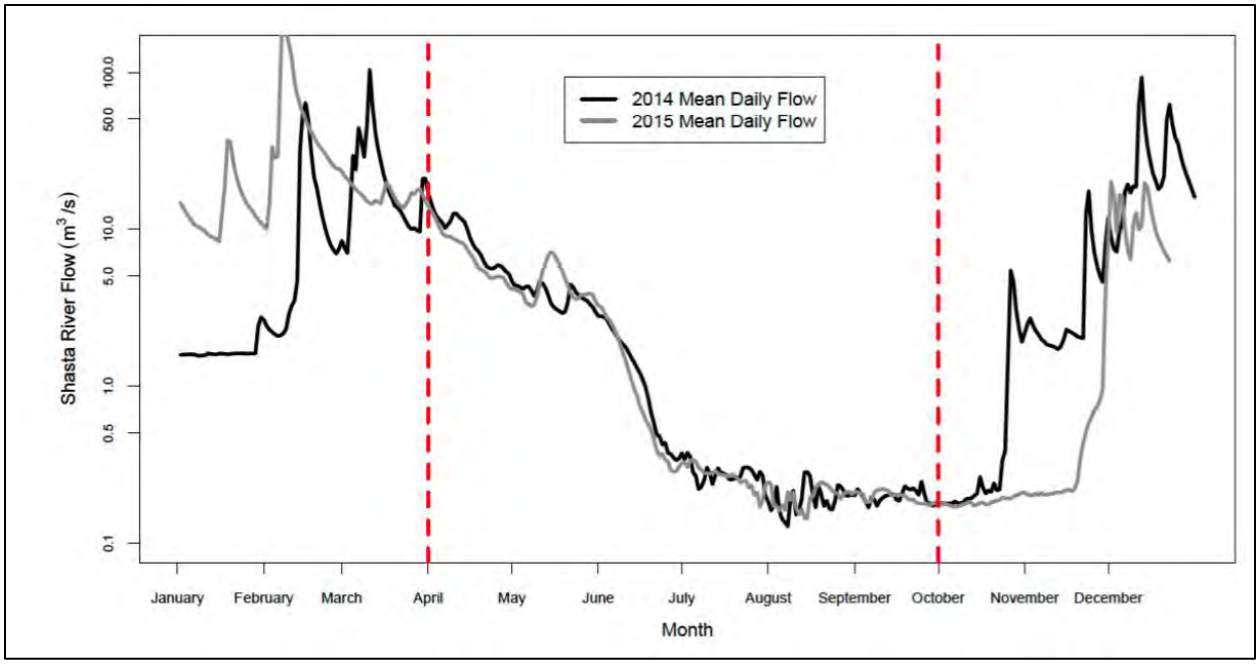


Figure 5-12. Mean daily flow in the Shasta River, measured at United States Geological Survey stream gage 11517500. Red dotted lines indicate irrigation season (April 1st – September 30th). Source: Gorman (2016).

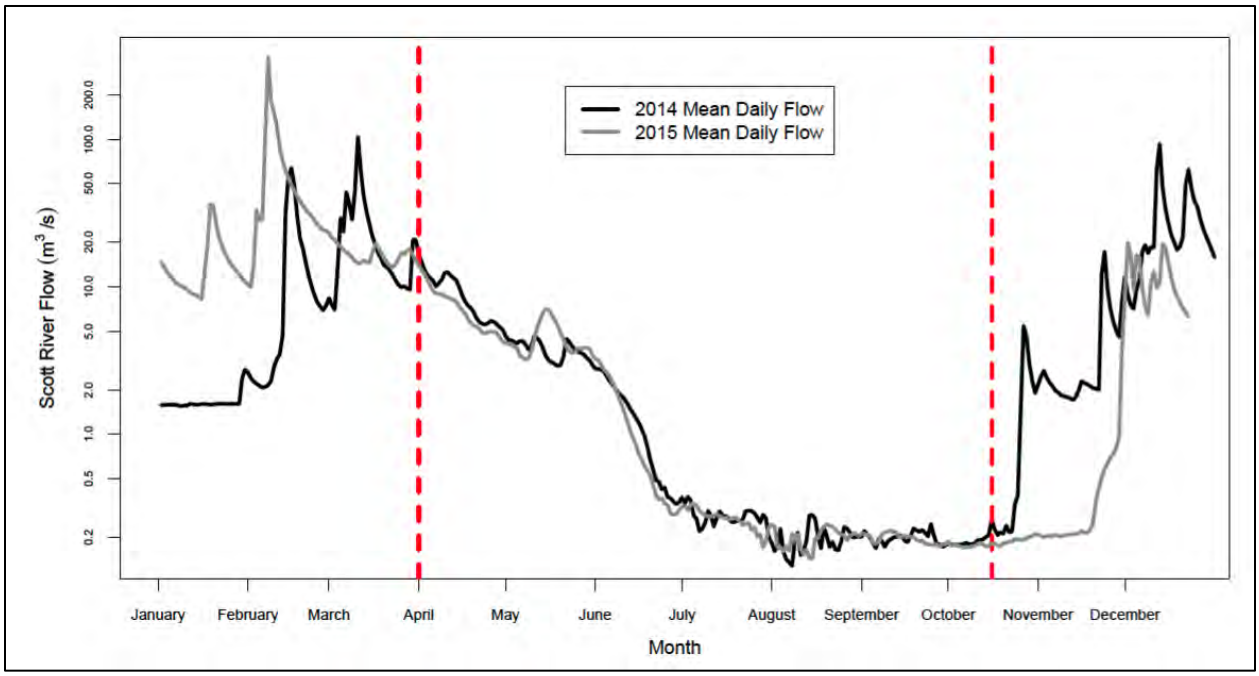


Figure 5-13. Mean daily flow in the Scott River as measured at United States Geological Survey stream gage 11519500. Red dotted lines indicate irrigation season (April 1st – October 15th). Source: Gorman (2016).

Although the mainstem offers only limited and patchy rearing habitats during the summer, it provides a corridor for redistribution to refugia in tributaries. Early-summer coho movements from natal tributaries to the mainstem Klamath corridor are well documented (Soto et al. 2016). Further, movement into and out of the Klamath mainstem is largely driven by increases in

summer water temperatures (Manhard et al. 2018) as juvenile coho seek rearing habitat in cooler water (Soto et al. 2016). Most summer redistribution occurs downstream, which ultimately shortens the length of seaward migration for smolts. Manhard et al. (2018) suggested that shortening this migratory distance may enhance survival for juveniles contending with virulent parasites such as *Ceratonova shasta*, which can become especially problematic under warm water conditions (*see* Chapter 6.1.6.4.2.). During summer, most juvenile coho salmon rear in cooler tributaries (Figure 5-14); however, redistribution may also occur within major tributaries such as the Shasta and Scott Rivers (Figures 5-12 and 5-13). For example, coho in the Shasta River moved and - upstream when stream temperatures remained above 20°C for several days (Adams and Bean 2016). Other juvenile salmonids cope with high mainstem tributary temperatures by moving to pockets of thermal refugia such as off-channel habitats and beaver ponds. Concentrated numbers of juvenile coho have been observed in cold, spring-water refugia in the upper Shasta River, some having migrated over 6 km upstream (Chesney et al. 2009).

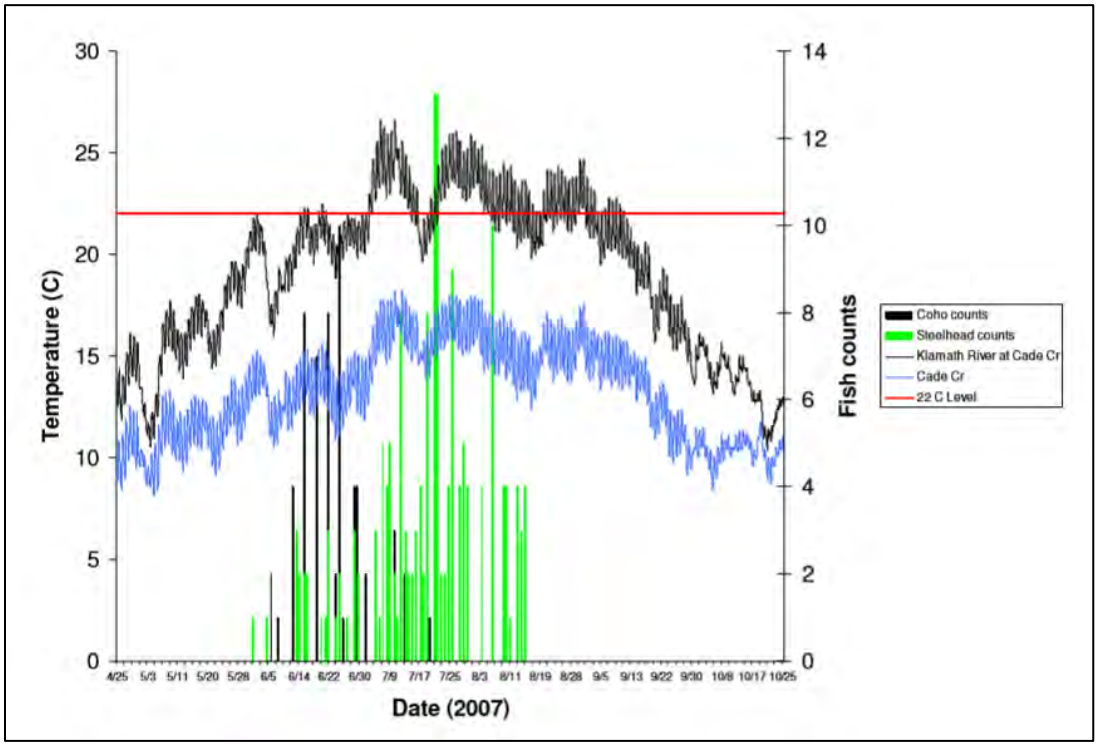


Figure 5-14. Timing of juvenile coho salmon movements into Cade Creek relative to mainstem Klamath and tributary temperatures during summer 2007. Black vertical bars are coho salmon catches. Fish numbers represent catches made by minnow traps in the lower reach of Cade Creek. Source: Sutton & Soto (2012).

Fall Re-Distribution/Rearing. Fall conditions (beginning in September) in the Klamath River and its tributaries that entice fish movement are characterized by declining water temperatures and increased flows and water velocities as storms become more frequent. Juvenile coho generally respond to fall conditions by moving to off-channel habitats such as ponds, floodplains, and higher-order tributaries (Peterson 1982; Swales and Levings 1989; Quinn 2005), which provide shelter from high velocity water. While there is some limited over-wintering habitat available in the mainstem Klamath, the most extensive fall re-distribution of juvenile coho in the Klamath basin occurs as individuals either move out of the mainstem or through the

mainstem (from natal tributaries) seeking over-winter habitats in off-channel locations or higher-order tributaries (Soto et al. 2016). During this period, juvenile coho in the mainstem Klamath River almost exclusively moved upstream to find suitable overwintering habitat and this movement was strongly correlated to high flow events in the mainstem between November and December (Soto et al. 2016). Furthermore, juveniles in this study did not leave suitable overwintering habitat until they emigrated as smolts. In the Klamath River, some juvenile coho will also migrate downstream to off-channel ponds near the estuary and are thought to remain there before emigrating as smolts the following spring (Voight 2008 in Reclamation 2018a); however, the frequency of this behavior is unclear.

Winter Rearing. The availability of overwintering habitat is one of the most important factors influencing the survival of juvenile coho salmon in streams (Moyle 2002a) Coho seek low velocity habitats to overwinter (Bisson et al. 1987), particularly off-channel habitats such as alcoves, backwaters, and off-channel ponds) (Swales et al. 1986, 1988; Nickelson et al. 1992; Bell et al. 2001). These habitats can provide cover from predators as well as buffer fish from high discharge events that might otherwise lead to mortality or emigration (McMahon and Hartman 1989; Sandercock 1991).

Winter rearing patterns of juvenile coho salmon within the mainstem Klamath River corridor have been observed through a multi-year study initiated by the Karuk and Yurok Tribes to assess seasonal life history tactics. The movements of PIT-tagged juvenile coho captured in fyke and seine nets (Hillemeier et al. 2009) and monitored using stationary PIT tag detectors (Soto et al. 2016) at numerous sites in the mainstem corridor indicated significant re-distribution between initial tagging in summer and fall and subsequent detections during winter (Hillemeier et al. 2009; Soto et al. 2016). Moreover, re-distribution was less extensive for fish tagged in the mainstem Klamath River upstream of Happy Camp (RM 110); which the authors suggest may be related to smaller variation in mainstem and tributary flows above the Trinity River.

In the Shasta River, some parts of the river seem to provide adequate overwinter habitat while others do not (Adams 2013). Adams (2013) observed that in the winter juvenile coho in Big Springs Creek, a tributary to the Shasta River, moved from areas dominated by macrophyte cover when the aquatic vegetation "died-off" to areas in the Shasta River with woody structures that created deep pools with low velocities. The upper reaches of the Shasta River also provide important winter rearing habitat where multiple springs produce water temperatures optimal for rearing juveniles (Stenhouse et al. 2012).

5.2.2.5 Smolt Outmigration

Juvenile coho transform into smolts in preparation for moving into the saltwater environment. This transformation involves many complex processes including changes in morphology, physiology, and behavior (Hoar 1976; Wedemeyer et al. 1980; Folmar and Dickoff 1980). The timing of smoltification is a response to fish-size, flow conditions, water temperature, DO, photoperiod, and food availability (Shapovalov and Taft 1954). During this process, smolts seek cover features (e.g., woody debris) that provide protection from high current velocities and predation. Shelter from higher velocities may be particularly important in preventing premature displacement (Hartman et al. 1982) since smolts exhibit reduced swimming abilities (Flagg and Smith 1981).

Smolts begin migrating downstream in the Klamath Basin between February and mid-June (NRC 2004). Long-term monitoring below IGD indicates Klamath River mainstem smolt outmigration occurs from mid-March through late-July (Gough et al. 2015; David et al. 2017a, 2017b) In tributaries, smolt outmigration varies depending on location within the basin. In the Scott and Shasta Rivers, migration can begin in February and extend through June, peaking from mid-April to mid-May (Adams and Bean 2016; CDFW 2016a). Outmigration in the Shasta River coincides with the drop in flows from irrigation withdrawal, typically in mid-April (CDFW 2016b). Smolts in the Trinity River begin outmigration in January and extend through June (Petros et al. 2017). Outmigration from Blue and McGarvey Creeks, lower Klamath River tributaries, occurs from March through early-June (Petros et al. 2017). Outmigration from Blue and McGarvey Creeks, lower Klamath River tributaries, occurs from March through early-June (Antonetti 2012; Antonetti and Partee 2013). Smolts usually leave the estuary by July (NRC 2004).

Survival rates of coho salmon smolts in the Klamath River are influenced by many factors. Survival rates, between the confluence of the Shasta River and IGD in 2009, had a positive correlation between survival and temperature, discharge, and fish weight, within the ranges studied (Beeman et al. 2012). However, Beeman et al. (2012) found the positive effects of increased discharge from IGD were small relative to seasonal increases in water temperature and concluded the greatest survival benefit of increased discharge would occur at lower water temperatures. In their study, Beeman et al. (2012) did not find any of these factors to affect survival rates downstream of the confluence with the Shasta River, but generally concluded that the survival of coho salmon smolts migrating seaward in the Klamath River were similar to, or greater than, survival rates in several other regulated river systems.

In the Klamath River Basin, smolt migration rates (km/day) tend to increase as fish move downstream, particularly for wild fish (Beeman et al. 2012). The pattern observed in this study was not clearly correlated with flow, fish length, release date, photoperiod or temperature predictor variables.

5.2.2.6 Mainstem Klamath River Usage

The Yurok and Karuk Tribes have studied the seasonal distribution and habitat use patterns of pre-smolt juvenile coho salmon within the mainstem of the Klamath River using PIT tagging technology in conjunction with extensive trapping and seining activities. These efforts have revealed extensive use of the mainstem Klamath as a corridor for re-distribution through monitoring the movements of individual fish. Their studies suggest the following movement patterns:

1. Fry dispersal from natal tributaries into the mainstem corridor during spring runoff (Soto et al. 2016).

2. Juveniles within mainstem corridor seek thermal refuge as water temperatures rise in early summer (Soto et al. 2016; Manhard et al. 2018).

3. Juveniles re-distribute in fall and early-winter in search of suitable overwintering habitats, typically during periods of increased flows. Patterns suggest that movement slows considerably once fish have either found suitable habitat or have emigrated (Soto et al. 2016).

4. Smolt migration occurs in spring from mid-March through late-July (Gough et al. 2015; David et al. 2017b, 2017a).

5.2.3 Status and Trend

5.2.3.1 Population Abundance

The limited long-term data on coho salmon abundance indicate that spawner abundance has remained low for populations in this ESU in recent years. Data from the Shasta River are the longest existing time series (13 years) at the population unit scale and while returning adult numbers have been variable over the POR, counts have remained low since 2014 (Chesney and Knechtle 2017; Giudice and Knechtle 2019). Spawner abundance in the Scott River has been monitored since 2007 and is also highly variable, with an exceptional return year in 2013 (Knechtle and Giudice 2019).

Though population-level estimates of abundance for most independent populations are lacking, the available data indicate that none of the seven diversity strata (Figure 5-3) support a viable population (NMFS 2016a). Nineteen independent populations in the ESU, including seven of the 10 populations in the Klamath River basin, are at high risk of extinction because they are below, or likely below, their depensation threshold (NMFS 2016a). The Middle Klamath River, Scott River, and Upper Trinity River populations are classified at a "moderate" risk of extinction. Populations that are under depensation have increased likelihood of being extirpated. The extinction risk of an ESU depends upon the extinction risk of its constituent independent populations (Williams et al. 2008), and because the population abundance of most independent populations are below their depensation threshold, the SONCC coho salmon ESU is at high risk of extinction and is currently not viable.

5.2.3.2 Population Productivity

Available data indicates that many populations have declined, which reflects a declining productivity. In general, SONCC coho salmon have declined substantially from historic levels. Because productivity appears to be negative for most, if not all SONCC ESU coho salmon populations, this ESU is not currently viable.

5.2.3.3 Spatial Structure

When the BA was conducted by the Reclamation in 2012, data were inadequate to compare the spatial distribution of SONCC ESU coho salmon since the 2005 listing. However, Gilbert-Horvath et al. (2016) reaffirmed the SONCC coho salmon ESU boundaries through genetic analysis. Although, there is considerable year-to-year variation in estimated occupancy rates, it appears there has been no change in the percent of streams occupied by coho salmon from the late 1980s and early 1990s to 2000 (Good et al. 2005). However, the number of streams and rivers currently supporting coho salmon in this ESU has been greatly reduced from historical levels, and watershed-specific extirpations of coho salmon have been documented (Brown et al. 1994; Good et al. 2005; Moyle et al. 2008). Recent information for the SONCC ESU of coho salmon indicates that their distribution within the ESU has been reduced and fragmented, as evidenced by an increasing number of previously occupied streams from which they are now absent (NMFS 2001). However, extant populations can still be found in all major river basins within the ESU (NMFS 2005b, 70 FR 37160). Although, there is considerable year-to-year

variation in estimated occupancy rates, it appears there has been no change in the percent of streams occupied by coho salmon from the late 1980s and early 1990s to 2000 (Good et al. 2005). However, the number of streams and rivers currently supporting coho salmon in this ESU has been greatly reduced from historical levels, and watershed-specific extirpations of coho salmon have been documented (Brown et al. 1994; Good et al. 2005; Moyle et al. 2008). However, extant populations can still be found in all major river basins within the ESU (NMFS 2005b, 70 FR 37160).

5.3 Southern Resident Killer Whales

Note: This Chapter originated from the NMFS 2019 BiOp (NMFS 2019) with portions of direct text included herein and has been adapted by Reclamation with the best available updated scientific information.

5.3.1 Rangewide Status of the Species

The SRKW DPS, composed of J, K and L pods, was listed as endangered under the ESA in 2005 (NMFS 2005c, 70 FR 69903). A 5-year review under the ESA completed in 2016 concluded that SRKWs should remain listed as endangered and includes recent information on the population, threats, and new research results and publications (NMFS 2016b).

The limiting factors described in the final recovery plan included reduced prey availability and quality, high levels of contaminants from pollution, and disturbances from vessels and sound (NMFS 2008a). This section summarizes the status of SRKWs throughout their range, using information taken largely from the recovery plan (NMFS 2008a), recent 5-year review (NMFS 2016b), as well as new data that became available more recently.

5.3.1.1 Status of Southern Resident Killer Whales

5.3.1.1.1 Abundance, Productivity, and Trends

SRKWs are a long-lived species, with late onset of sexual maturity (NMFS 2008a). Females produce up to six surviving calves over the course of their reproductive life span (Bain 1990; Olesiuk et al. 1990a). Calves surviving to be observed by researchers are referred to as recruited, and are used as an index of reproduction, since many calves die around the time of birth and are never observed with their mothers (Bain 1990; Wasser et al. 2017). Based on recruited calves, compared to Northern Resident killer whales (a resident killer whale population with a sympatric geographic distribution ranging from coastal waters of Washington State and British Columbia north to Southeast Alaska) SRKWs appear to have reduced recruitment (Ward et al. 2013; Velez-Espino et al. 2015); the average inter-recruitment interval for reproductive SRKW females is 6.1 years, which is longer than the 4.88 years estimated for Northern Resident killer whales (Olesiuk et al. 2005). Recent evidence has indicated pregnancy hormones (progesterone and testosterone) can be detected in SRKWs feces and have indicated several miscarriages, particularly in late pregnancy (Wasser et al. 2017). The authors suggest this reduced fecundity is largely due to nutritional limitation.

Mothers and offspring maintain highly stable social bonds throughout their lives, which is the basis for the matrilineal social structure in the SRKW population (Bigg et al. 1990; Baird 2000;

Ford et al. 2000a). Groups of related matrilines form pods. Three pods – J, K, and L – make up the SRKW population.

At present, the SRKW population has declined to the lowest levels seen in over 30 years (Figure 5-15). Since censuses began in 1974, J and K pods have steadily increased their sizes. However, the population suffered an almost 20 percent decline from 1995-2001 (from 98 whales in 1995 to 81 whales in 2001), largely driven by lower survival rates in L pod. The overall population had increased slightly from 2002 to 2010 (from 83 whales to 86 whales). During an international science panel review of the effects of salmon fisheries (Hilborn et al. 2012), the panel stated that during 1974 to 2011, the population experienced a realized growth rate of 0.71 percent, from 67 individuals to 87 individuals. In 2014 and 2015, there was a return to normal recruitment (a normal population has 5% calves of the year (Bain 1990) in the SRKWs population that was the result of multiple successful pregnancies that occurred in 2013 and 2014. However, as of July 2019, the population has decreased to only 73 whales, a historical low in the last 30 years. This conflicts with projections by the science panel of population increase, and Lacy et al. (2017) of slow decline to 75 by 2115, emphasizing the relevance of shifting baselines to understanding the status of the population.

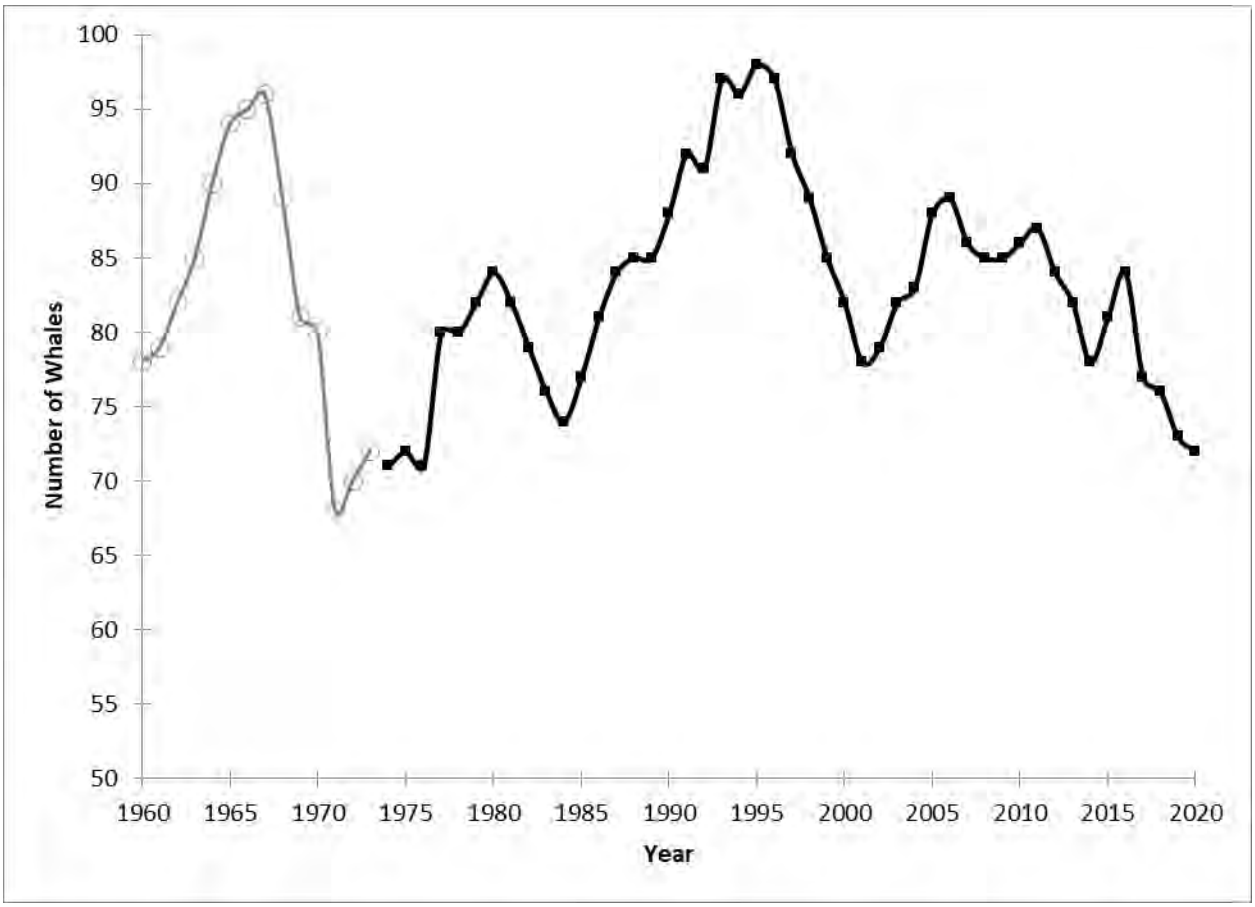


Figure 5-15. Population size and trend of Southern Resident killer whales, 1960-2018. Data from 1960-1973 (open circles, gray line) are number projections from the matrix model of Oleisuk et al (1990b). Data from 1974-2018 (diamonds, black line) were obtained through photo-identification surveys of the three

pods (J, K, and L) in this community and were provided by the Center for Whale Research (CWR; unpublished data) and NMFS (2008a).

There were 22 whales in J pod, 18 whales in K pod and 34 whales in L pod at the end of 2018. Although the age and sex distribution is generally similar to that of Northern Residents that are a stable and increasing population (Olesiuk et al. 2005), there are several demographic factors of the SRKW population that are cause for concern, namely reduced recruitment, sub-adult survivorship in L pod, and the total number of individuals in the population (NMFS 2008a). Based on an updated pedigree from new genetic data, most of the offspring in recent years were sired by two fathers, meaning that less than 30 individuals make up the effective reproducing portion of the population. Some offspring were the result of matings within the same pod raising questions and concerns about inbreeding effects, especially when the offspring of the two males reach breeding age. Research into the relationship between genetic diversity, effective breeding population size, and health is currently underway to determine how this metric can inform us about extinction risk and inform recovery (Northwest Fisheries Science Center (NWFSC) unpublished data).

Seasonal mortality rates among Southern and Northern Resident whales may be highest during the winter and early spring, based on the numbers of animals missing from pods returning to inland waters each spring. Olesiuk et al. (2005) identified high newborn mortality that occurred outside of the summer season. At least 12 newborn calves (nine SRKWs and three Northern Residents) were seen outside the summer field season and disappeared by the next field season. Additionally, stranding rates are higher in winter and spring for all killer whale forms in Washington and Oregon (Norman et al. 2004). Data collected from three SRKW strandings in the last five years have contributed to our knowledge of the health of the population and the impact of the threats to which they are exposed. Transboundary partnerships have supported thorough necropsies of L112 in 2012, J32 in 2014, and L95 in 2016, which included testing for contaminant load, disease and pathogens, organ condition, and diet composition.

The Northwest Fisheries Science Center continues to evaluate changes in fecundity and mortality rates, and has updated the work on population viability analyses conducted for the 2004 Status Review for SRKWs and the science panel review of the effects of salmon fisheries (Krahn et al. 2004; Hilborn et al. 2012; Hanson et al. 2013). Following from that work, the data now suggests a downward trend in population growth projected over the next 50 years. As the model projects out over a longer time frame (50 years) there is increased uncertainty around the estimates; however, if all of the parameters in the model remain the same the overall trend shows a decline in later years. This downward trend is in part due to the changing age and sex structure of the population, but also related to the relatively low fecundity rate observed over the period from 2011 to 2016 (Figure 5-16; NMFS 2016b). To explore potential demographic projections, Lacy et al. (2017) constructed a population viability assessment that considered sublethal effects and the cumulative impacts of threats (contaminants, acoustic disturbance, and prey abundance). They found that over the range of scenarios tested, the effects of prey abundance on fecundity and survival had the largest impact on the population growth rate. Furthermore, they suggested in order for the population to reach the recovery target of 2.3 percent growth rate, the acoustic disturbance would need to be reduced in half and the Chinook salmon abundance would need to be increased by 15 percent (Lacy et al. 2017). However, their model has proven overly optimistic, as the population has already declined below their projection for 2115, suggestion

stronger actions will need to be taken. The bias in projections by NWFSC and Lacy et al. (2017) may be due to inclusion of data from the mid-1970's, when the population was well below carrying capacity due to collections for public display, leading to a disconnect between environmental condition and population dynamics at the time (Velez-Espino et al. 2015).

Ford and Ellis (2006) and Ford et al. (2010) evaluated 25 years of demographic data from Southern and Northern Resident killer whales and found that changes in survival largely drive their population, and the populations' survival rates were strongly correlated with coast-wide availability of Chinook salmon. Ward et al. (2009) found that Northern and SRKW fecundity was highly correlated with Chinook salmon abundance indices and reported the probability of calving increased by 50 percent between low and high Chinook salmon abundance years. However, Ward et al.'s (2009) work was based on recruitment rather than calving. Wasser et al. (2017) suggested that fecundity remains high, and it is perinatal survival that changes with salmon abundance. More recently, Ward et al. (2013) considered new stock-specific Chinook salmon indices and found strong correlations between the indices of Chinook salmon abundance, such as the West Coast Vancouver Island (WCVI) used by the Pacific Salmon Commission, and killer whale demographic rates. However, no single stock or group of stocks was identified as being most correlated with the whales' demographic rates. Further, they stress that the relative importance of specific stocks to the whales likely changes over time (Ward et al. 2013).

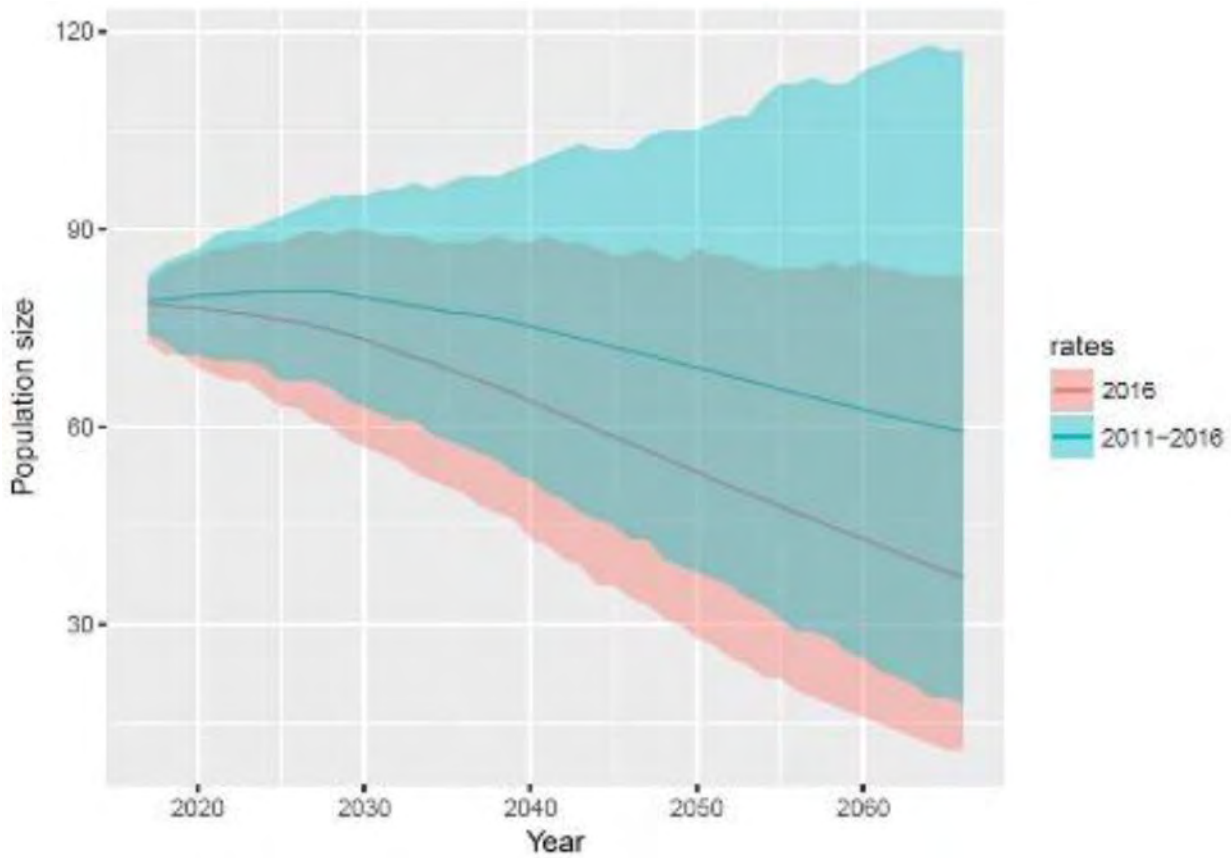


Figure 5-16. Southern Resident killer whale population size projections from 2016 to 2066 using 2 scenarios: (1) projections using demographic rates held at 2016 levels, and (2) projections using demographic rates from 2011 to 2016. The pink line represents the projection assuming future rates are

similar to those in 2016, whereas the blue represents the scenario with future rates being similar to 2011 to 2016 (NMFS 2016b).

Because of this population's small abundance, it is also susceptible to demographic stochasticity – randomness in the pattern of births and deaths among individuals in a population. Several other sources of stochasticity can affect small populations and contribute to variance in a population's growth and extinction risk. Other sources include environmental stochasticity (e.g., natural fluctuation in salmon abundance), or fluctuations in the environment that drive fluctuations in birth and death rates (e.g., epizootics and oil spills), and demographic heterogeneity, or variation in birth or death rates of individuals because of differences in their individual fitness (including sex ratio at birth and sex-specific survival rates). In combination, these and other sources of random variation combine to amplify the probability of extinction, known as the extinction vortex (Gilpin and Soulé 1986; Fagan and Holmes 2006; Melbourne and Hastings 2008). The larger the population size, the greater the buffer against stochastic events and genetic risks. A delisting criterion for the SRKW DPS is an average growth rate of 2.3 percent for 28 years (NMFS 2008a). In light of the current average growth rate of 0.29 percent (from 1974 to present), this recovery criterion reinforces the need to allow the population to grow quickly.

5.3.1.1.2 Geographic Range and Distribution

SRKWs occur throughout the coastal waters off Washington, Oregon, and Vancouver Island and are known to travel as far south as central California and as far north as Southeast Alaska (NMFS 2008b; Hanson et al. 2013; Carretta et al. 2017) (Figure 5-17). SRKWs are highly mobile and can travel up to 86 miles (160 km) in a single day (Erickson 1978; Baird 2000), with seasonal movements likely tied to the migration of their primary prey, salmon. During the spring, summer, and fall months, the whales spend a substantial amount of time in the inland waterways of the Strait of Georgia, Strait of Juan de Fuca, and Puget Sound (Bigg 1982; Ford et al. 2000a; Krahn et al. 2002; Hauser et al. 2007). In general, the three pods are increasingly more present in May and June and spend a considerable amount of time in inland waters through September. Late summer and early fall movements of SRKWs in the Georgia Basin are consistent, with strong site fidelity shown to the region as a whole and high occurrence in the San Juan Island area (Hauser et al. 2007; Hanson and Emmons 2010). All three pods generally remain in the Georgia Basin through October and make frequent trips to the outer coasts of Washington and southern Vancouver Island and are occasionally sighted as far west as Tofino and Barkley Sound (Ford et al. 2000b; Hanson and Emmons 2010); Whale Museum unpublished data). Sightings in late fall decline as the whales shift to the outer coasts of Vancouver Island and Washington.

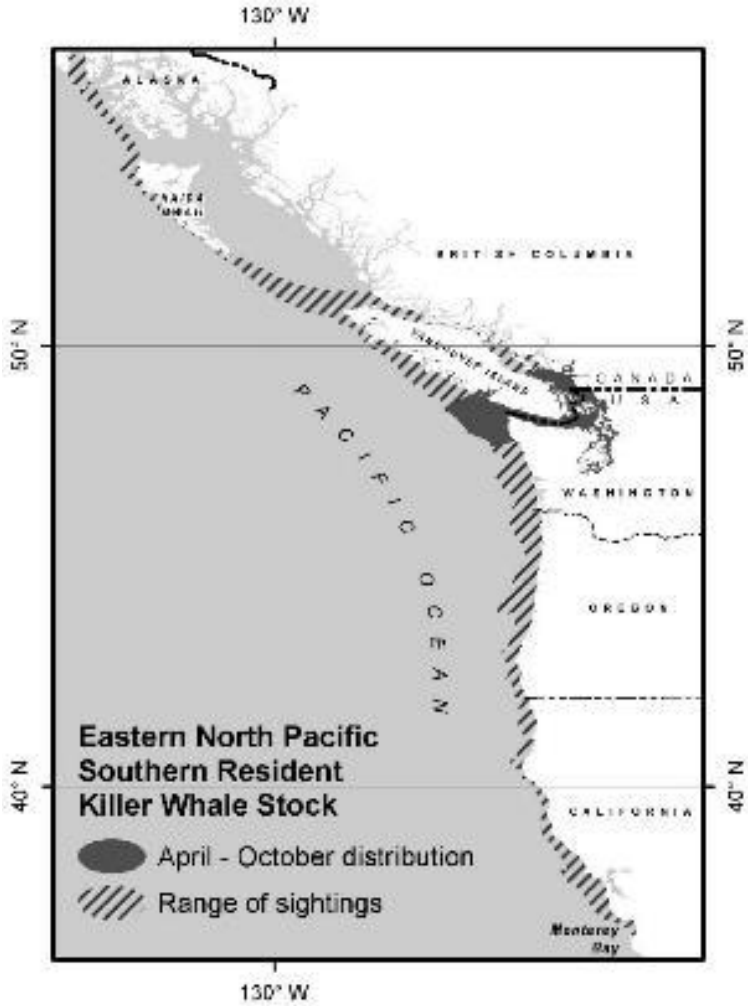


Figure 5-17. Geographic range of Southern Resident killer whales (Reprinted from Carretta et al. (2017)).

Although seasonal movements are generally predictable, there can be large inter-annual variability in arrival time and days present in inland waters from spring through fall, with late arrivals and fewer days present in recent years (Hanson and Emmons 2010; Shields et al. 2018); Whale Museum unpublished data). For example, K pod has had variable occurrence in June ranging from 0 days of occurrence in inland waters to over 25 days (Figure 5-18). Fewer observed days in inland waters likely indicate changes in their prey availability (i.e., abundance, distribution and accessibility). During fall and early winter, SRKW pods, and J pod in particular, expand their routine movements into Puget Sound, likely to take advantage of chum and Chinook salmon runs (Osborne 1999; Hanson et al. 2010).

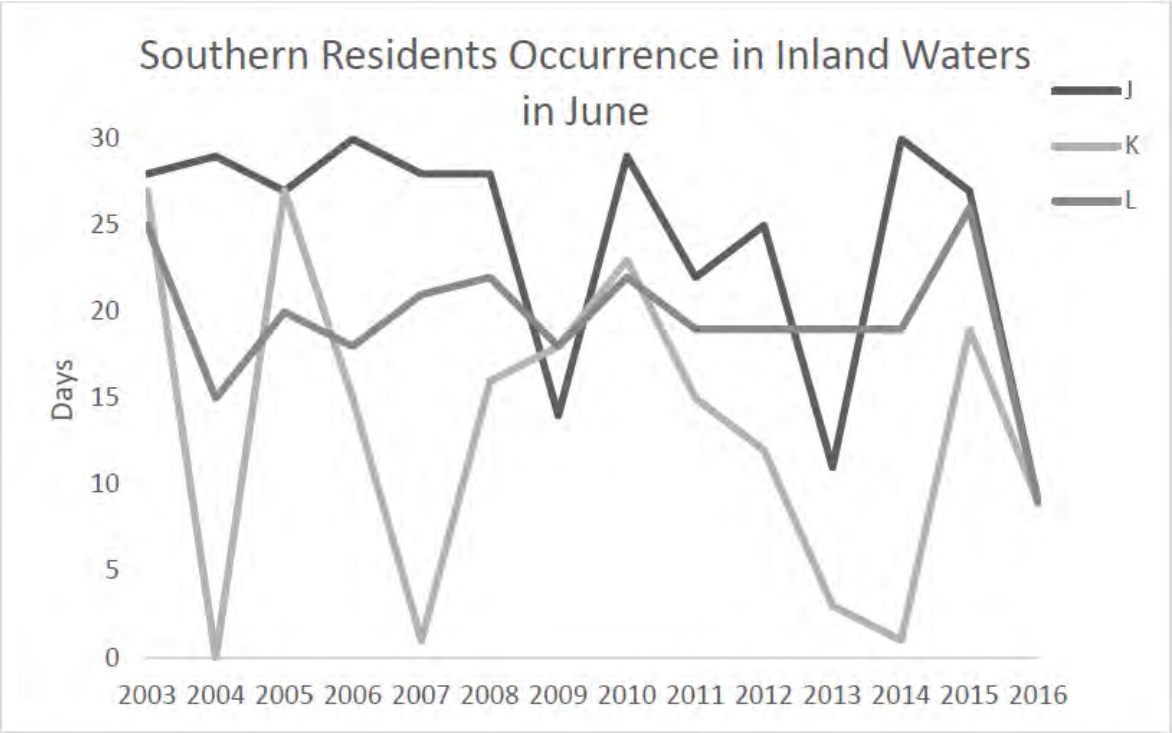


Figure 5-18. Number of days of Southern Resident killer whale occurrence in inland waters number in June for each year from 2003 to 2016 (data from The Whale Museum).

In recent years, several sightings and acoustic detections of SRKWs have been obtained off the Washington and Oregon coasts in the winter and spring (Hanson et al. 2010, 2013); NWFSC unpublished data). Satellite-linked tag deployments have also provided more data on the SRKWs movements in the winter indicating that K and L pods use the coastal waters along Washington, Oregon, and California during non-summer months (NWFSC unpubl. Data). Detection rates of K and L pods on the passive acoustic recorders occur with greater frequency off the Columbia River and Westport and are most common in March (Hanson et al. 2013). J pod has also only been detected on one of seven passive acoustic recorders positioned along the outer coast (Hanson et al. 2013). The limited range of the sightings/ acoustic detections of J pod in coastal waters, the lack of coincident occurrence during the K and L pod sightings, and the results from satellite tagging in 2012–2016 (NWFSC unpubl. data) indicate J pod has limited occurrence along the outer coast and extensive occurrence in inland waters, particularly in the northern Georgia Strait. However, the data indicate that most SRKWs spend most of the year on the outer coast, not in the Salish Sea.

5.3.1.2 Limiting Factors and Threats

Several factors identified in the final recovery plan for SRKWs may be limiting recovery. These are quantity and quality of prey, toxic chemicals that accumulate in top predators, and disturbance from sound and vessels. Oil spills are also a risk factor, as are disease and vessel strike. It is likely that multiple threats are acting together to impact the whales. Modeling exercises have attempted to identify which threats are most significant to survival and recovery (Lacy et al. 2017) and available data suggests that all of the threats are potential limiting factors (NMFS 2008a).

5.3.1.2.1 Quantity and Quality of Prey

SRKWs consume a variety of fish species (22 species) and one species of squid (Ford et al. 1998, 2000a, 2016; Ford and Ellis 2006; Hanson et al. 2010), but salmon are identified as their primary prey. SRKWs are the subject of ongoing research, including direct observation, scale and tissue sampling of prey remains, and fecal sampling. The diet data indicate that the whales are consuming mostly larger (i.e., older) Chinook salmon. Chinook salmon is their primary prey despite the much lower abundance in some areas and during certain time periods in comparison to other salmonids, for reasons that remain unknown, but factors of potential importance include the Chinook salmon species' large size, high fat and energy content, and year-round occurrence in the whales' geographic range. Chinook salmon have the highest value of total energy content compared to other salmonids because of their larger body size and higher energy density (kilocalories/kilogram(kcal/kg)) (O'Neill et al. 2014). For example, in order for a killer whale to obtain the total energy value of one Chinook salmon, they would need to consume approximately 2.7 coho, 3.1 chum, 3.1 sockeye, or 6.4 pink salmon (O'Neill et al. 2014). Caloric content and size at maturity are likely similar in wild and hatchery fish; however, size at return is dependent on age class and differences in wild and hatchery age classes are known to occur. Recent research suggests that Resident killer whales are capable of detecting, localizing and recognizing Chinook salmon through their ability to distinguish Chinook salmon echo structure as different from other salmon (Au et al. 2010).

Scale and tissue sampling from May to September in inland waters of WA and BC indicate that their diet consists of a high percentage of Chinook salmon (monthly proportions as high as >90 percent) (Hanson et al. 2010; Ford et al. 2016). Genetic analysis of the Hanson et al. (2010) samples indicate that when SRKWs are in inland waters from May to September, they consume Chinook salmon stocks that originate from regions including the Fraser River (including Upper Fraser, Mid Fraser, Lower Fraser, North Thompson, South Thompson and Lower Thompson), Puget Sound (North and South Puget Sound), the Central British Columbia Coast and West and East Vancouver Island.

DNA (deoxyribonucleic acid) quantification methods are used to estimate the proportion of different prey species in the diet from fecal samples (Deagle et al. 2005). Recently, Ford et al. (2016) confirmed the importance of Chinook salmon to the SRKWs in the summer months using DNA sequencing from whale feces. Salmon and steelhead made up to 98 percent of the inferred diet, of which almost 80 percent were Chinook salmon. Coho salmon and steelhead are also found in the diet in spring and fall months when Chinook salmon are less abundant. Specifically, coho salmon contribute to over 40 percent of the diet in late summer, which is evidence of prey shifting at the end of summer towards coho salmon (Ford et al. 1998, 2016; Ford and Ellis 2006; Hanson et al. 2010). Less than 3 percent each of chum salmon, sockeye salmon, and steelhead were observed in fecal DNA samples collected in the summer months (May through September). Prey remains and fecal samples collected in inland waters during October through December indicate Chinook and chum salmon are primary contributors of SRKW's diet (NWFSC unpubl. data).

Observations of whales overlapping with salmon runs (Wiles 2004; Zamon et al. 2007; Krahn et al. 2009) and collection of prey and fecal samples have also occurred in coastal waters in the winter months. Preliminary analysis of prey remains and fecal samples sampled during the

winter and spring in coastal waters indicated the majority of prey samples were Chinook salmon, with a smaller number of steelhead, chum salmon, and halibut (NWFSC unpubl. data). The occurrence of K and L pods off the Columbia River in March suggests the importance of Columbia River spring runs of Chinook salmon in their diet (Hanson et al. 2013). Chinook salmon genetic stock identification from samples collected in winter and spring in coastal waters included 12 U.S. west coast stocks, and over half the Chinook salmon consumed originated in the Columbia River (NWFSC unpubl. data). Columbia River, Central Valley, Puget Sound, and Fraser River Chinook salmon comprise over 90 percent of the whales' coastal Chinook salmon diet (NWFSC unpubl. data).

In general, over the past decade, some Chinook salmon stocks within the range of the whales have had relatively high abundance (e.g. WA/OR coastal stocks, some Columbia River stocks) compared to the previous decade, whereas other stocks originating in the more northern and southern ends of the whales' range (e.g. most Fraser stocks, Northern and Central B.C. stocks, Georgia Strait, Puget Sound, and Central Valley) have declined. Changing ocean conditions driven by climate change may influence ocean survival of Chinook and other Pacific salmon, further affecting the prey available to SRKWs.

In an effort to identify Chinook salmon stocks that are important to SRKWs and prioritize recovery efforts to increase the whales' prey base, NMFS and Washington Department of Fish and Wildlife (WDFW) released a priority stock report identifying the Chinook salmon stocks of most importance to the health of the SRKW populations along the West Coast (NOAA and WDFW 2018) [5]. The priority stock report was created by analyzing scat and prey scale/tissue samples to identify Chinook salmon stocks in the whales' diet, observing the killer whale body condition through aerial photographs, and estimating the spatial and temporal overlap with Chinook salmon stocks ranging from Southeast Alaska to California. Extra weight was given to the salmon runs that support the SRKWs during times of the year when the whales' body condition is more likely reduced and when Chinook salmon may be less available, such as in winter months. Table 5-3 is a summary of those stock descriptions.

However, the report indicated the analysis was incomplete, and not corrected for bias created by effort (e.g., a factor in ranking priorities was evidence that prey were consumed from a river). The absence scat and scale sampling effort within the core range of Klamath River Chinook ensured that the Klamath would receive a low rank, even though chemical signatures in blubber indicate SRKWs feed on important quantities of Klamath Chinook (Krahn et al. 2007, 2009; O'Neill et al. 2012). The report also did not consider historical abundance and potential for recovery of salmon stocks. Thus, rivers where runs had been decimated rated low priority, even though habitat restoration could result in tremendous benefits to SRKWs, and if older data existed, a river could rate much higher than it did in the report.

[5]https://www.westcoast.fisheries.noaa.gov/publications/protected_species/marine_mammals/killer_whales/recovery/srkw_priority_chinook_stocks_conceptual_model_report___list_22june2018.pdf

Table 5-2. Summary of the priority Chinook salmon stocks (adapted from NOAA and WDFW 2018).

Priority	ESU/Stock Group	Run Type	Rivers or Stocks in Group
1	North Puget Sound and South Puget Sound	Fall	Nooksack, Elwha, Dungeness, Skagit, Stillaguamish, Snohomish, Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal Systems
2	Lower Columbia and Strait of Georgia	Fall	Fall Tules and Fall Brights (Cowlitz, Kalama, Clackamas, Lewis, others), Lower Strait (Cowichan, Nanaimo), Upper Strait (Klinaklini, Wakeman, others), Fraser (Harrison)
3	Upper Columbia & Snake	Fall	Upriver Brights, Spring 1.3 (Upper Pitt, Birkenhead; Mid & Upper Fraser; North and South Thompson) and Spring 1.2 (Thompson, Louis Creek, Bessette Creak); Lewis, Cowlitz, Kalama, Big White Salmon
3	Fraser and Lower Columbia	Spring	Upriver Brights, Spring 1.3 (Upper Pitt, Birkenhead; Mid & Upper Fraser; North and South Thompson) and Spring 1.2 (Thompson, Louis Creek, Bessette Creak); Lewis, Cowlitz, Kalama, Big White Salmon
4	Middle Columbia	Fall	Fall Brights
5	Snake River	Spring/Summer	Snake, Salmon, Clearwater, Nooksack, Elwha, Dungeness, Skagit (Stillaguamish, Snohomish)
5	Northern Puget Sound	Spring	Snake, Salmon, Clearwater, Nooksack, Elwha, Dungeness, Skagit (Stillaguamish, Snohomish)
6	Washington Coast	Spring and Fall	Hoh, Queets, Quillayute, Grays Harbor
7	Central Valley	Spring	Sacramento and tributaries
8	Middle/Upper Columbia	Spring/Summer	Columbia, Yakima, Wenatchee, Methow, Okanagan
9	Fraser	Summer	Summer 0.3 (South Thompson, Lower Fraser, Shuswap, Adams, Little River, Maria Slough) and Summer 1.3 (Nechako, Chilko, Quesnel, Clearwater River)
10	Central Valley	Fall and late Fall	Sacramento, San Joaquin, Upper Klamath, and Trinity
10	Klamath River	Fall and Spring	Sacramento, San Joaquin, Upper Klamath, and Trinity
11	Upper Willamette	Spring	Willamette
12	South Puget Sound	Spring	Nisqually, Puyallup, Green, Duwamish, Deschutes, Hood Canal systems
13	Central Valley	Winter	Sacramento and tributaries
14	North/Central Oregon Coast	Fall	Northern (Siuslaw, Nehalem, Siletz) and Central (Coos, Elk, Coquille, Umpqua)
15	West Vancouver Island	Fall	Robertson Creek, WCVI Wild
16	Southern OR & Northern CA Coastal and California Coastal	Fall and Spring	Rogue, Chetco, Smith, Lower Klamath, Mad, Eel, Russian

Currently, hatchery production is a significant component of the salmon prey base returning to watersheds within the range of SRKWs (Barnett-Johnson et al. 2007; NMFS 2008b). Although hatchery production has contributed some offset of the historical declines in the abundance of natural-origin salmon within the range of the whales, hatcheries also pose risks to natural-origin salmon populations (Nickelson et al. 1986; Ford 2002; Levin and Williams 2002; Naish et al. 2007). Healthy natural-origin salmon populations are important to the long-term maintenance of prey populations available to SRKWs because it is uncertain whether a hatchery dominated mix of stocks is sustainable indefinitely and because hatchery fish can differ, relative to natural-origin Chinook salmon, for example, in size and hence caloric value and in availability/migration location and timing. However, the release of hatchery fish has not been identified as a threat to the survival or persistence of SRKWs. It is possible that hatchery produced fish may benefit this endangered population of whales by enhancing prey availability as scarcity of prey is a primary threat to SRKWs survival and hatchery fish often contribute to the salmon stocks consumed (Hanson et al. 2010). Further, changes to hatchery management could benefit SRKWs through selecting for changes in size at return and run timing. Habitat restoration and other improvements could increase both wild and hatchery salmon survival.

5.3.1.2.2 Nutritional Limitation and Body Condition

When prey is scarce, SRKWs are likely spend more time foraging than when prey is plentiful. Increased energy expenditure and prey limitation can cause poor body condition and nutritional stress. Nutritional stress is the condition of being unable to acquire adequate energy and nutrients from prey resources and as a chronic condition, can lead to reduced body size of individuals and to lower reproductive and survival rates of a population (Trites and Donnelly 2003). During periods of nutritional stress and poor body condition, cetaceans lose adipose tissue behind the cranium, displaying a condition known as “peanut-head” in extreme cases (Pettis et al. 2004; Bradford et al. 2012; Joblon et al. 2014) . Between 1994 and 2008, 13 SRKWs were observed from boats to have a pronounced “peanut-head”; and all but two subsequently died (Durban et al. 2009); Center for Whale Research unpublished data). None of the whales that died were subsequently recovered, and therefore definitive cause of death could not be identified. Both females and males across a range of ages were found in poor body condition.

Since 2008, NMFS’s Southwest Fisheries Science Center (SWFSC) has used aerial photogrammetry to assess the body condition and health of SRKWs, initially in collaboration with the CWR and, more recently, with the Vancouver Aquarium and SR3 (Sealife Response, Rehabilitation, and Research). Aerial photogrammetry studies have provided finer resolution for detecting poor condition, even before it manifests in “peanut heads” that are observable from boats. Annual aerial surveys of the population from 2013-2017 (with exception of 2014) have detected declines in condition before the death of seven SRKWs (L52 and J8 as reported in Fearnbach et al. (2018); J14, J2, J28, J54, and J52 as reported in Durban et al. (2017), including five of the six most recent mortalities (Trites and Rosen 2018). These data have provided evidence of a general decline in SRKWs body condition since 2008, and documented members of J pod being in poorer body condition in May compared to September (at least in 2016 and 2017) (Trites and Rosen 2018).

Although body condition in whales can be influenced by a number of factors, including prey availability, disease, physiological or life history status, and may vary by season and across years, prey limitation is the most likely cause of observed changes in body condition in wild

mammalian populations (Matkin et al. 2017). It is possible that poor nutrition could contribute to mortality through a variety of mechanisms (e.g., individuals in poor condition are less likely to recover from illnesses or injuries before perishing than individuals afflicted when they are in good condition). To demonstrate how this is possible, we reference studies that have examined the effects of energetic stress (caused by incremental increases in energy expenditures or incremental reductions in available energy) on adult females and juveniles from many different taxa, including marine mammals, e.g., adult females (Daan et al. 1996; Schaefer 1996; Gamel et al. 2005) and juveniles (Trites and Donnelly 2003; Noren et al. 2009). Small, incremental increases in energy demands should have the same effect on an animal's energy budget as small, incremental reductions in available energy, such as one would expect from reductions in prey. Ford and Ellis (2006) report that resident killer whales engage in prey sharing about 76 percent of the time. Prey sharing presumably would distribute more evenly the effects of prey limitation across individuals of the population than would otherwise be the case (i.e., if the most successful foragers did not share with other individuals). Therefore, although cause of death for most individuals that disappear from the population is unknown, poor nutrition could contribute to additional mortality in this population.

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6 Environmental Baseline

The environmental baseline, pursuant to federal regulation, refers to "the condition of a listed species or its designated critical habitat in the action area, without the consequences to the listed species or designated critical habitat caused by the proposed action" (NMFS 2012a; 50 C.F.R. §402.02). The environmental baseline includes "the past and present impacts of all federal, state, or private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early section 7 consultation, and the impact of State or private actions which are contemporaneous with the consultation in process." (NMFS 2012a; 50 C.F.R. §402.02). It does not include the effects of the action under review in the consultation; that is, the operations of the Klamath Project.

"The consequences to listed species or designated critical habitat from ongoing agency activities or existing agency facilities that are not within the agency's discretion to modify are part of the environmental baseline." (NMFS 2012a; 50 C.F.R. §402.02). As a result, "when a Federal agency has authority for managing or operating a dam, but lacks discretion to remove or modify the physical structure of the dam, the consequences from the physical presence of the dam in the river are appropriately placed in the environmental baseline and are not considered an effect of the action under consultation." (84 Fed. Reg. 44,978).

The environmental baseline "is a separate consideration from the effects of the action" (84 Fed. Reg. 44,978). It provides a reference point against which the effects of a PA, or the consequences caused by that PA, are measured. In order to be considered an effect of a PA, and thus not a part of the baseline, a consequence must be caused by the PA (i.e., "the consequence would not occur but for the Proposed Action and is reasonably certain to occur") (50 C.F.R. §402.17(b)). *See also* 50 C.F.R. §402.02 ("A consequence is caused by the Proposed Action if it would not occur but for the Proposed Action and it is reasonably certain to occur").

The environmental baseline projects the future "without-action" condition and the past, present, and ongoing impacts of human and natural factors, including the present and ongoing effects of current operations that were considered in prior consultations. These are included in the "Past and Present Impacts" section below.

By projecting the prospects for species survival and recovery without the action, the environmental baseline plays a necessary role in defining the effects of the action. That, in turn, allows for a determination of whether the action jeopardizes the continued existence of listed species or adversely modifies their critical habitat.

Consistent with these regulatory standards, this Environmental Baseline section provides a basis for the Effects Analysis contained in Chapters 7, 8, and 9 of this BA. Additional discussion can be found in prior ESA consultation documents as well (e.g., USFWS and NMFS 2013; USFWS 2019a).

6.1 Past and Present Impacts

The baseline includes the past and present impacts of all federal, state, and private actions and other human activities in the action area, the anticipated impacts of all proposed federal projects in the action area that have already undergone formal or early Section 7 consultation, and the impact of state or private actions that are contemporaneous with the consultation in process, including the past and present impacts of Klamath operations under 2013 biological opinions. The Klamath Project operates in an environment vastly different from the conditions under which native aquatic species evolved. Physical, hydrological, and biological alterations present novel conditions that result in stressors on endangered species and that pre-date the Klamath Project. During the last 150 years, human activities have dramatically altered and reshaped the habitat upon which the species addressed in this consultation depend for survival. Those activities, as well as others, have reduced and continue to reduce significantly the species' likelihood of survival and recovery.

6.1.1 Physical Alteration

Historically, the Upper Klamath Basin contained approximately 185,000 acres of shallow lakes and fringe wetland areas (USFWS 2016a). Since the 1880s, approximately 75 percent of the historical wetland habitat in the Upper Klamath Basin has been lost, primarily through levees and draining for agricultural use. Human settlement occurred throughout the 6,805-square-mile region, primarily in the first half of the twentieth century, as lands were reclaimed and converted to agriculture (see U.S. Census Bureau (1950)). Levees were built to drain land for agriculture and settlement, streams were dammed and diverted or alternatively, straightened and widened, and lakes and rivers were dredged for navigation purposes.

6.1.1.1 Dams

Water diversion for agriculture began in the Upper Klamath Basin in the 1870s, with small check dams along the Lost River and its tributaries. These rudimentary dams were used to flood meadows, flats and surrounding riparian lands in the spring, to grow native grasses for hay and livestock grazing when the water receded in the summer. More conventional dams and reservoirs began to be constructed around 1900, including Antelope, Adobe Flat, and Kilgore reservoirs on the East Branch of the Lost River, and Wilson Lake and Strawberry reservoirs on Miller Creek and its tributaries. There are more than 40 constructed impoundments upstream of Clear Lake Reservoir. There are more than a dozen impoundments upstream of Gerber Reservoir.

Similar small reservoirs and ponds were constructed on tributaries to UKL, primarily in the Sprague River basin, beginning around 1910. These waterbodies are more commonly used as a water source for livestock, in addition to irrigation. There are currently 186 water rights of record for use of stored water in the Williamson River watershed, including the Sprague and Sycan rivers and their tributary streams.

On the Klamath River, there are five dams currently owned and operated by PacifiCorp that control flows from river mile 190 to 233. Construction on the first of these dams, Copco No. 1, began in 1911 and was completed in 1918. Located at river mile 198.6, this concrete arch dam is 126 feet tall and has a crest length of 410 feet. The reservoir behind the dam is approximately 4.5 miles long, 1000 acres in size, and has a maximum depth of 115 feet. The estimated gross

storage capacity of the reservoir is 33,724 AF, but only 6,235 AF of this is active storage capacity. The normal annual operating fluctuation in Copco No. 1 is 6.5 feet and the average retention time for water in the reservoir is 12 days.

The smaller Copco No. 2 was completed in 1925 and is located half a mile downstream from Copco No. 1. A small 40-acre impoundment is formed behind Copco No. 2, which has no active storage capacity.

Copco Nos. 1 and 2 have historically been operated for peak-load production, generating power during the day and storing water at night and on the weekends. Initially there were no minimum release flow or ramping rate requirements and flows downstream of the dam ranged from 100 cfs to 3,200 cfs. In 1936, the California Oregon Power Company and the State of California made an informal agreement to not decrease releases from Copco Nos. 1 and 2 to below 200 cfs. Prior to this agreement, mean daily flows as low as 83 cfs were recorded.

J.C. Boyle Dam was constructed between 1956 and 1958 at river mile 225, just north of the California-Oregon border. This dam is an earthen embankment structure with a concrete spillway section that is 68 feet tall and 693 feet wide. The upstream reservoir is approximately 3.6 miles long, 420 acres in size, and has a maximum depth of 41.7 feet. The total storage capacity of the reservoir is 3,495 AF, of which 1,724 AF is active storage. The average retention time for water in the reservoir is 1.2 days. J.C. Boyle has historically been operated as a power peaking facility, especially when river flows are less than the rated turbine hydraulic capacity of 2,850 cfs, generally storing water during the night for power generation during the day.

IGD was constructed between 1960 and 1962 and is PacifiCorp's farthest downstream facility at river mile 190. Iron Gate is a 173-foot-tall, 740-feet-wide earthen embankment dam with a concrete spillway. The upstream reservoir is 6.8 miles long, 944 acres in size, and has a maximum depth of 162 feet. The dam is used to buffer upstream peaking operations at Copco Nos. 1 and 2 and provide stable downstream flows. As a result, the average passage time for water through the reservoir is 16 days. There are no fish passage facilities at the dam. A fish hatchery was constructed at the base of the dam in 1965 and is operated by the State of California.

Keno Dam was constructed between 1965 and 1966 and is located approximately 24 miles downstream from LRD at river mile 233. Keno Dam is 25 feet tall, 680 feet long, and operates to regulate releases out of UKL and the Lost River Diversion Channel while maintaining upstream water surface elevations in the Keno Impoundment. A 1968 contract between Reclamation and the Pacific Power and Light Company, PacifiCorp's predecessor, requires Keno Dam be operated to maintain water surface elevations in the Keno Impoundment between 4,185.0 and 4,186 feet (USBR datum). This contract remains in force so long as Keno Dam is operated by PacifiCorp pursuant to FERC license no. 2082. Operation of Keno Dam is also governed by dozens of agreements with landowners along the Keno Impoundment. In general, PacifiCorp maintains the Keno Impoundment to elevation 4,085.4 ± 0.1 feet from October 1 to May 15 and 4,085.5 ± 0.1 feet from May 16 to September 30.

In connection with construction of Keno Dam, the Pacific Power and Light Company made channel improvements for approximately 17 miles upstream of the dam. These improvements were intended to increase the channel capacity to approximately 15,000 cfs.

As part of the channel improvements, immediately downstream of the Highway 66 bridge, a 160-foot-wide, 9-foot-deep notch was dredged through the Keno Reef, with an invert (bottom) elevation of 4,071.0 feet (USBR datum). Originally the crest of this reef reached to 4,083.1 feet and resulted in a water surface elevation in the Keno Impoundment of generally between 4,084 and 4,088 feet (USBR datum). In 1931, in connection with construction of the original Keno Needle Dam, a 300-foot-wide, three-feet-deep channel was dredged through the reef.

Upstream of the Highway 66 bridge, the channel improvements completed by the Pacific Power and Light Company ranged between 150 and 250 feet wide, dredging between two and ten feet below the original channel bottom.

PacifiCorp currently operates these five dams pursuant to two separate licenses with FERC. License no. 14803 covers J.C Boyle, Copco Nos. 1 and 2, and IGD (collectively the "Lower Klamath Project"). License no. 2082 (the "Klamath [Hydroelectric] Project") covers the Fall Creek, Keno, East Side, and West Side developments. An application to transfer the license for the Lower Klamath Project No. 14803 from PacifiCorp to the Klamath River Renewal Corporation (KRRC) is currently before FERC. KRRC also has a separate application with FERC to surrender license no. 14803 and physically remove these four developments from the Klamath River. KRRC and PacifiCorp have asked FERC to act on the transfer application before the surrender application.

LRD is located at the head of Link River, the natural outlet of UKL. The dam was constructed by the California-Oregon Power Company (Copco) between 1919 and 1921, pursuant to a 1917 contract with Reclamation. The dam is a concrete slab and buttress structure, approximately 19 feet in height and 435 feet long. The dam has 44 separate bays – 24 bays with stoplogs for controlled overflow, six bays for discharges into Link River, seven bays for diverting water into the Ankeny Canal, six bays for diverting water into the Keno Canal, and one bay occupied by a fish ladder. Releases through the 19 combined bays that discharge to the Link River and Ankeny and Keno canals are controlled by cast iron gates, approximately five feet tall by seven feet wide.

Under the 1917 contract between Reclamation and Copco, the power company agreed to build LRD on the United States' behalf, to provide water for the Klamath Project. The dam is owned by the United States, though not the two power canals (East Side and West Side developments), which are now owned by PacifiCorp and operated under FERC license no. 2082. LRD has always been operated by the power company (PacifiCorp and its predecessors).

For context, the mean annual net inflow to UKL is approximately 1.2 million AF, ranging from a low of 594,000 AF to 2 million AF. The Klamath Project's average historical demand from UKL is approximately 430,000 AF, ranging from between 343,000 AF and 473,000 AF, depending on the hydrologic year type.

Subject to the first meeting the irrigation and related needs of the Klamath Project, the company has historically been allowed to operate Link River Dam, including discretion over daily releases, to facilitate its downstream hydroelectric power production (at the facilities now operated under FERC licenses nos. 2082 and 14803).

Since listing of LNS and SNS as endangered in 1988 and then coho salmon as threatened under the ESA, PacifiCorp's ability to operate discretion in operating LRD for power purposes has been restricted. Currently, PacifiCorp's 2012 Habitat Conservation Plan with NMFS (see Chapter 6.1.4.1) expressly requires PacifiCorp to regulate releases at IGD in accordance with applicable NMFS' BiOp on Reclamation's operation of the Klamath Project (NMFS 2012b). Meeting NMFS' required daily flows at IGD restricts PacifiCorp and Reclamation's discretion overflows at LRD.

Historically, Link River Dam has operated between water surface elevations in UKL of 4,136 feet and 4143.3 feet (USBR datum). Prior to the dam's construction water surface elevations in the lake ranged between approximately 4,140 and 4143 feet (USBR datum).

In connection with construction of Link River Dam, Copco excavated channels through the two natural reefs upstream the dam. The purpose of these channels was to facilitate outflow from UKL, allowing the lake to be drawn lower than occurred naturally. At Putnam Point, approximately half a mile upstream from the dam, a 30-foot-wide, nine-feet-deep channel was dredged through the marsh that naturally obstructed outflow from the lake. The invert (bottom) elevation on this channel was originally to 4,131 feet (USBR datum). The dredged material was used as fill in a portion of the adjacent marsh, above 4,143.3 (USBR datum). In its natural condition, the elevation of the natural sill at this point on the lake was 4,137 feet (USBR datum). Additionally, immediately upstream from LRD, Copco dredged two 40-foot-wide channels on both sides of the river, as well as a section across the river at the upstream face of the dam. The invert elevation of these channels was originally 4,131 feet (USBR datum).

The total storage capacity of UKL is approximately 882,000 AF, of which 562,000 AF is active storage capacity between water surface elevations of 4,136.0 and 4,143.3 feet (USBR datum). The reservoir is approximately 20 miles long, 64,000 acres in size, and has a maximum depth of 29 feet. Most of the reservoir, however, is between 10 and 15 feet deep, at full pool. Littoral wetlands on the north end of the lake (UKNWR and Williamson River Delta) and at Hanks Marsh at the south end, have depths of between two and four feet, at full pool. Average residence time for water in the reservoir is 185 days.

Clear Lake Reservoir is located at the head of the Lost River, in Modoc County, California, approximately five miles south of the state border with Oregon. Clear Lake Dam was originally built in 1910, but then replaced in 2003. The dam is a roller-compacted concrete structure, 42 feet tall and 564 feet long. The outlet works on the dam have a discharge capacity of 780 cfs. A flood control spillway is located at the dam's left abutment, with a maximum discharge capacity of 10,000 cfs. The spillway has never been used in the dam's history.
Clear Lake Reservoir has an active storage capacity of approximately 513,000 AF between water surface elevations 4,515.6 and 4,543.0 feet (USBR datum), although outflow from the lake is significantly impaired below 4,522 feet.

Gerber Dam is located approximately 14 miles east of the town of Bonanza on Miller Creek, tributary to the Lost River. Constructed in 1925, Gerber Dam is an arched concrete structure, 84 feet tall and 485 feet long. The outlet works on the dam have a maximum discharge capacity of 900 cfs. The reservoir has an active storage capacity of approximately 94,000 AF. An overflow-type spillway is located at the center of the dam. The largest spill on record was approximately 1,075 cfs, in February 1996.

6.1.1.2 Disconnected Waterbodies, Floodplains and Wetland Conversion

Prior to European settlement, the land along the Klamath River was subject to seasonal flooding. As floodwaters receded in the spring, the land would be exposed and would produce natural hay and wild grasses suitable for cattle feed. European settlers began coming into the area in the 1850s, and grazing cattle along the Klamath River, between Keno and Klamath Falls. After 1870, individuals began to claim and settle these lands under Oregon's various Swamp Land Acts. In certain cases, under these laws, settlers were required to demonstrate actual drainage and reclamation of the land. The construction of levees along the river, to control seasonal flooding of the land, likely started at this time, though it is not well documented.

The Klamath River would also seasonally overflow, draining through the Lost River slough to Tule Lake. Following flooding that occurred in the spring of 1890, John Frank Adams, Jesse Douglas Carr, and a company of ranchers from Tule Lake built a mile-long dike along the east bank of the Klamath River, to stop the flow of the Klamath River into Tule Lake via the Lost River Slough. This act marked the beginning of efforts to drain and reclaim Tule Lake. Tule Lake had historically fluctuated in size and was approximately 96,000 acres and 25 feet at its deepest when Congress authorized the Klamath Project in 1905. Today, only approximately 14,000 acres of Tule Lake remain, in the form of a diked sump (Tule Lake Sump 1). The remainder of the original lakebed has been reclaimed over the past century, including approximately 43,000 acres of homesteaded farms. 17,000 acres of the reclaimed area is within Tule Lake National Wildlife Refuge and managed by USFWS for the primary purpose of waterfowl conservation.

Similar diking efforts by individual settlers, with no connection to or assistance from Reclamation, also began around UKL in the late 1800s. The reclaimed lands were generally seasonally flooded marshes bordering the lake. In 1889, Eugene P. McCornack constructed a dike across what was called Little Wocus Marsh, approximately 500 acres in size. In 1897 McCornack constructed a crude dike to prevent the 4,150-acre Wocus Marsh from flooding. Drainage channels were also constructed as part of what was called the Wocus Reclamation and Irrigation Project. In 1914, the McCornacks began constructing a dike from the Skillet Handle to the head of Howard Bay, to reclaim Caledonia Marsh. This dike was not completed until 1918.

On the northwest shore of Agency Lake, the Fort Klamath Meadows Company began diking efforts around 1910, which were largely complete by 1920. Dikes were constructed along the shore of Agency Lake from the mouth of the Wood River to the straits connecting Agency and UKLs. Similar dikes were also constructed along both sides of the Wood River. The effect of these dikes was the reclamation of approximately 27,000 acres of former marshes.

On the northeast end of UKL, along the Williamson River delta, Copco agreed to construct approximately 23 miles of dikes to protect the Klamath Indian Reservation from the effects of storage operations in UKL, affected by construction of LRD. This work was completed between 1921 and 1924.

Other areas around UKL were also diked for timber purposes, to create log holding ponds and protect mills, for instance for the Lamm Lumber Company at Modoc Point. Between 1909 and 1913, the Southern Pacific Railroad also built an embankment north of Klamath Falls, along the eastern shore of UKL, which allowed reclamation of additional areas at Algoma and Shady Pine.

On the east side of the Klamath River, five miles east of Keno, the Southern Pacific Railroad and California Northeastern Railway Company began constructing an embankment across the Klamath Straits. Under a 1907 contract with the United States, the railroad agreed to build this embankment to serve as a levee in aid of the reclamation of Lower Klamath Lake.

In its natural condition, Lower Klamath Lake was approximately 29,000 acres in size, surrounded by an additional 59,000 acres of marshes, and connected to the Klamath River via a narrow channel called the Klamath Straits. Water would flow from the Klamath River through the Klamath Straits into Lower Klamath Lake. There are anecdotes of the flow reversing in the Klamath Straits and Lower Klamath Lake draining back into the Klamath River, although the precise volume and timing of such flows is unknown.

The Klamath Straits and Lower Klamath Lake were also used for navigation and thus constituted interstate navigable waterways, which could only be closed through authorization by Congress. In 1905, Congress authorized the Secretary of the Interior to lower the water levels of Lower Klamath Lake, among other waterbodies, and to homestead the lands as part of a federal reclamation project.

Southern Pacific Railroad constructed the embankment between 1907 and 1909, but initially a trestle bridge spanned the Klamath Straits, allowing water to continue to flow between the Klamath River and Lower Klamath Lake. In 1912, Reclamation authorized the railroad to fill in the channel and complete the embankment. At that point all flow from the Klamath River to Lower Klamath Lake went through a concrete structure the railroad had built in the embankment at Reclamation's instruction.

The flow between Klamath River and Lower Klamath Lake was largely consistent with historical conditions until 1914, when Reclamation began temporarily using stoplogs to obstruct flow through the concrete structure, at the request of local landowners who were attempting to reclaim portions of the lake and the surrounding marshes. In 1917, Reclamation and the landowners, who had now formed Klamath Drainage District (KDD), agreed to permanently close the gates in the railroad embankment. Stoplogs were used for this purpose until 1921, when Reclamation installed five cast iron gates in the structure, each approximately five-feet-wide. These gates can be lowered or raised to control flow though the railroad embankment.

Downstream from these gates, KDD constructed the Ady Canal and associated distribution works, which allow water that passes through the embankment to be diverted and delivered to

approximately 11,000 acres within the district. The USFWS also has a contractual right to use the Ady Canal for deliveries to LKNWR.

Today, Lower Klamath Lake no longer exists. USFWS has constructed diked units on the former lakebed, which are permanently or seasonally flooded and, in some cases, farmed for waterfowl conservation purposes.

6.1.1.3 Fine Sediment and Gravel Recruitment

Historical land use practices, including timber harvesting, mining, and agriculture, have altered sediment transport in the Klamath River.

Currently, natural and anthropogenic processes limit transportation of fine sediment to the Klamath River. UKL has historically served as a sink for fine sediment from tributary inflows to the lake. Downstream on the Klamath River, PacifiCorp's hydroelectric dams interrupt the movement of fine sediment. As a result, the Scott River and other tributaries downstream of IGD are the primary source of fine sediment for the Klamath River.

PacifiCorp's hydroelectric dams also impede course sediment transport within the Klamath River. Alterations of the natural hydrograph downstream these dams have also arrested course sediment movement, leading to armoring of the river bottom. The loss of streambed mobilization can also lead to fine sediment settling in interstitial spaces in the bed and resulting reduction in fish spawning habitat.

6.1.1.4 Timber Production, Fire Suppression, and Livestock Grazing

Hydrology within the watershed has been affected by timber harvesting, fire suppression, and associated road development since 1900. Timber harvesting in the Klamath Basin began in the early 1900s, increased during the 1950s, and peaked in the late 1970s and early 1980s (USFS 1994). Historical fire suppression has also resulted in the accumulation of downed woody material and other organic debris in forested stands (*id*.). In addition to timber operations and fire suppression, livestock grazing has contributed to a significant change in vegetation patterns in the watershed (Hessburg et al. 1999).

Timber production also has resulted in physical alteration to UKL and the Klamath River. As noted previously, portions of the lake were diked off and dredged for log holding ponds, at Modoc Point, Algoma, and just north of Klamath Falls. Navigation channels had to be dredged in various locations of the west and east sides of the lake, to allow logs to be rafted to mills near Klamath Falls. None of these log holding operations on UKL are still occurring. Only one timber mill currently remains adjacent UKL.

Log storing operations still occur in the Klamath River at Columbia Forest Products approximately three miles south of the Klamath Falls. Another timber mill, Collins Products, is adjacent the river, half a mile downstream. These mills are point sources for discharges into the Klamath River, and in-water log storing operations further contribute to poor water quality. Soluble organic matter leaches from logs floating in water and the bark that falls off the logs, forms benthic deposits that can reduce oxygen levels in the water.

Mining activities within the Klamath River began prior to 1900. Most of the river and creek bottoms downstream of Hornbrook were placer mined from valley wall to valley wall. This activity, and its scale, altered channel morphology by piling gravel into tailing deposits. The negative impacts of stream sedimentation on fish abundance were documented in the 1930s. Mining operations adversely affect spawning grounds through increased recruit of fine sediment, decreased mobilizing of coarse substrates, reduced prey abundance, and impacts river channels. Stricter environmental regulations since the 1970 have eliminated largescale mining operations in the river. In 2009, California suspended all instream suction dredge mining in the rivers (NMFS 2019).

6.1.2 Alterations to Address Effects

Physical alterations to the natural environment within the action area over the past century and a half have adversely affected fish, their habitat, and the natural ecological functions they naturally evolved under. Various land use activities have altered runoff and drainage patterns, and degraded water quality in the basin. Dams impede or prevent fish passage. Diversions entrain fish. Managed storage operations and downstream releases change habitat and food availability for fish and may further expose them to predation and poor water quality, make them susceptible to disease, and affect the viability and survival of their eggs, larvae, and juvenile. Filling and converting wetlands to other uses diminishes critical habitat for fish and other species they depend on, and further contributes to degraded water quality.

Given the collective effect of these basin-wide landscape and hydrologic alterations that have been detrimental to listed species, Reclamation, OWRD, ODFW, NMFS, and USFWS, as well as other federal, state, and local agencies, in addition to corporations, non-profit entities, and individuals, have undertaken various activities to address the effects of these past and present impacts. The following sections describe some, but not all of, beneficial physical alterations.

6.1.2.1 Fish Passage and Screening

Water from streams and rivers is redirected for irrigation, power, drinking water, and other uses. Diversions used to redirect water also pull fish into pumps, irrigation canals, and fields – reducing survival and preventing migration. Both fish that reside in streams for their entire lifecycle (resident) and fish that migrate to and from the ocean (anadromous) to complete their life cycle needs are susceptible to entrainment into diversions. Fish screens are devices placed at diversion entrances that allow water to pass through while preventing fish from entering. Fish screens come in a wide range of types and sizes including pump, cone, rotary drum, traveling belt, and panel screens. In Oregon, the first fish screening laws showed up over 100 years ago in 1898. From 1905 through 1946, and various other periods of time, state law required water diverters to screen diversions. The current statewide screening program began in 1947 when the Oregon State Game Commission, precursor to ODFW, embarked on an aggressive fish screening program. Since 1991, Oregon's Fish Screening Program has provided cost share incentives and technical assistance to encourage water users to voluntarily install fish-friendly screens at their water diversions. Under this program, the Geary Canal, which diverts water directly from UKL for the 4,200-acre reclaimed Wocus Marsh, was screened in 2010.

While the Fish Screening Program has made great progress, thousands of water diversions remain unscreened in the Upper Klamath Basin.

Removal of Chiloquin Dam

Chiloquin Dam was constructed in 1914 on the Sprague River near the town of Chiloquin, Oregon. The dam was identified as a barrier that potentially inhibited or prevented the upstream spawning migrations and other movements of endangered suckers, as well as other fish species. In 2002, Reclamation led a working group that examined several alternatives to improve fish passage at Chiloquin Dam. Ultimately it was decided that dam removal was the best alternative and the dam was removed in the summer of 2008. Removal of Chiloquin Dam restored connectivity with potential spawning habitat upstream. Although it was hypothesized that endangered suckers would utilize more spawning areas upstream of Chiloquin Dam once it was removed, PIT tag data showed only a small increase in the percentage of individuals passing the dam site in the 2 years after removal (Martin et al. 2013).

A Canal Fish Screens

The A Canal Fish Screens and related works are facilities of the Klamath Project. In 2002 and 2003, Reclamation reconstructed the A Canal headworks with a new fish screening system, including an automated trash-rack structure, fine-mesh fish screens, a fish bypass system, and a fish evaluation station. This screening system prevents entrainment of juvenile and adult suckers into the A Canal, but not larvae. The screens are in place any time diversions are made into the A Canal.

Link River Dam Fish Ladder

The fish ladder on Link River Dam is a Klamath Project Facility. Reclamation constructed this fish ladder in 2004 and became operational in 2005. This fish ladder is designed with specific criteria for suckers to allow these fish to migrate between the Keno Impoundment and UKL.

Clear Lake Fish Screen

The fish screens on Clear Lake are part of the Klamath Project. Fish screens were included when Clear Lake Dam was replaced in 2002 and 2003. These fish screens are in place during the irrigation season, to prevent juvenile and adult suckers, but not larvae, from passing through the dam's outlet works.

6.1.3 Habitat Restoration

Numerous agencies and organizations have *engaged in various restoration projects throughout the Klamath Basin for the benefit of fish and wildlife.*

6.1.3.1 Upper Klamath Lake

There have been several large projects to restore littoral wetland habitat and ecological functioning around UKL.

USFWS has led a Sucker Recovery Implementation Team, which Reclamation has funded since 2013. In addition to supporting monitoring and research on LRS and SNS in the Upper Klamath Basin, the Sucker Recovery Implementation Team funds projects intended to improve the amount and quality of sucker habitats, sucker passage issues, and sucker survival. Reclamation

has obligated $1.5 million annually between FY 2013 and 2018, along with $2.1 million in 2019, towards the Sucker Recovery Implementation Team and associated monitoring. Activities that have and will be undertaken with the funds already obligated are part of the baseline condition and not part of the PA.

In 1994, BLM acquired a 3,200-acre parcel (Wood River Wetland) on the north end of Agency Lake and adjacent the Wood River, and subsequently restored the land to a wetland. As part of this project, the channel of the Wood River was restored in 2001.

In 1998, Reclamation, with assistance from The Nature Conservancy and USFWS, acquired approximately 7,100 acres, along the northeast shore of Agency Lake, which had previously been diked and drained as part of the private diking efforts that occurred beginning in the early 1900s. USFWS currently administers these lands and is developing plans to remove the levees and restore the area to natural functioning wetlands.

In 2008, The Nature Conservancy and other groups acquired 7,700 acres at the mouth of the Williamson River, which is still being actively restored to a delta wetland.

Trout Unlimited is also undertaking an ambitious restoration plan for endangered bull trout in the Upper Klamath Basin, including instream and riparian restoration work on Sun, Annie, and Crane creeks. In connection with TU's work to restore Crane Creek, Reclamation has prepared a Resource Management Plan for a 1,200-acre tract two miles northwest of Agency Lake, which contains a portion of the creek's historical channel.

6.1.3.2 Klamath River

There are several restoration and recovery actions underway in the Klamath Basin aimed at improving habitat and water quality conditions for anadromous salmonids, some of which are supported by Reclamation (and proposed to continue as part of the PA).

Reclamation funds the Klamath River Coho Habitat Restoration Program (Program), which provides funding for restoration activities to improve habitat, water quality, water quantity, and fish passage for coho salmon.

From 2016-2018 Reclamation provided approximately $3 million for the Program, with an additional $700,000 in fiscal year (FY) 2019. This funding has already been obligated, so the work that has and will be accomplished with those funds is part of the baseline condition and not part of the PA. Restoration activities under this Program have and continue to occur. Restoration activities are confined to the mainstem Klamath River below IGD inclusive of all tributaries (except the Trinity River), with most restoration being conducted on the Shasta, Scott, and Salmon rivers and their tributaries. Restoration projects are typically implemented by state, tribal, local, or private non-governmental organizations.

Reclamation's funding for four grant cycles (2016, 2017, 2018, and 2019) has been obligated. 21 projects have been already been funded in grant cycles 2016-2018. An additional six grant pre-proposals were received in 2019 with four being advanced the "full proposal" stage. These grant applications are still being evaluated with selection and award anticipated in spring 2020. Reclamation, NMFS, and other partners have a role in the grant selection process.

NMFS also funds coastal salmonid restoration activities through the Pacific Coastal Salmon Recovery Fund. Since 2000, NMFS has issued grants for approximately $73 million for 924 projects along the northern California and southern Oregon coast. While not all, many of these projects are in the Klamath River Basin.

The USDA has also completed several salmonid restoration projects in the Klamath National Forest, including habitat restoration and placement of large woody debris.

In addition to these federal efforts, multiple local watershed groups exist in the Klamath Basin, including the Scott River Watershed Council, the Siskiyou Resource Conservation District, the Shasta River Coordinated Resource Management Planning Group, and the Salmon River Restoration Council. These types of groups have undertaken a number of restoration activities, including construction of off-channel ponds, side channels, and "beaver dam analogue structures".

6.1.4 Endangered Species Act Compliance

6.1.4.1 PacifiCorp Coho Habitat Conservation Plan

Since 2012, PacifiCorp has operated the Klamath Hydroelectric Project pursuant to Habitat Conservation Plan and 10-year incidental take permit for coho salmon issued by NMFS under section 10 of the ESA. The plan includes a number of measures intended to mitigate the effects of operation of PacifiCorp's hydroelectric facilities, including venting the turbines at IGD to increase dissolved oxygen downstream and placing gravel in the river for coho spawning. PacifiCorp also agreed to establish a Coho Enhancement Fund, which is administered by NFWF and provides grants for salmonid restoration and enhancement projects downstream of IGD. PacifiCorp has provided $510,000 to this fund annually since 2009 and issued more than 40 separate grants. Grants have been awarded for constructing off-stream ponds and side channels, installing fish screens, removing fish barriers, and acquiring water for instream flows.

6.1.4.2 PacifiCorp's Sucker Habitat Conservation Plan

Since 2013, PacifiCorp has operated the Klamath Hydroelectric Project pursuant to Habitat Conservation Plan and 10-year incidental take permit for LRS and SNS. As part of the plan, PacifiCorp proposed to shut down the East Side and West Side hydroelectric developments on the Link River, to reduce sucker mortality resulting from entrainment into the canals. PacifiCorp also established a Sucker Conservation Fund to support sucker conservation recovery and committed to continue support of the Nature Conservancy's Williamson River Delta Restoration Project. PacifiCorp has committed to providing $100,000 to the Sucker Recovery Fund over the course of the permit. PacifiCorp's Sucker Recovery Fund is separate from USFWS' Sucker Recovery Implementation Team, that Reclamation has provided funding for.

6.1.5 Hydrologic Alteration

6.1.5.1 Dams

See Chapter 6.1.1.1 for background information on dams in Klamath Basin.

The effect of storage operations on hydrology in UKL, compared to conditions prior to the dam's construction is three-fold: 1) lower the minimum water surface elevation (i.e., from approximately 4,140 feet to 4,136 feet); 2) maintain the water surface elevation at or near the maximum historical level (4,143 feet) longer into the spring and summer season; and 3) fill the lake more quickly during the fall and winter period (USBR datum). Subject to outflow capacity, LRD also allows for providing regulated daily flows at IGD, through coordinated operation of PacifiCorp's downstream hydroelectric facilities).

The effect of storage operations on Klamath River hydrology has been to reduce outflows from UKL during the fall through early spring period as the lake refills and to increase outflows during the late summer and early fall. Because of the natural channel dynamics on the outlet of UKL (i.e., restriction caused by the basalt reefs at Putnam Point and the head of Link River), it is likely that outflows in the mid-summer would have been higher prior to the dam's construction, and the lake filled more gradually.

Currently, releases from UKL are managed by PacifiCorp to achieve flow targets at IGD required in accordance with NMFS' applicable BiOp for Reclamation's operation of the Klamath Project. FERC license no. 14803 also contains the same conditions originally prescribed for IGD under license no. 2082, including minimum prescribed releases. These prescribed flows immediately downstream IGD range from a low of 710 cfs (June 1-July 31) to a high of 1,300 cfs (September 1-April 30). Under flood control conditions, releases from UKL may also be based on public safety considerations.

J.C. Boyle and Copco Nos. 1 and 2 are operated for peaking power production, and Iron Gate Dam is used to buffer these upstream peaking operations and provide stable downstream flows.

6.1.5.2 Diversions

Outside the Klamath Project, diversions for irrigated agriculture are the most common form of diversions of surface water in the Upper Klamath Basin. There are approximately 160,000 acres of irrigated land above and around UKL, most in the Williamson and Sprague river basins. Estimated average consumptive use of these diversions in the upper Klamath Basin is approximately 350,000 acre-feet per year (NRC 2004).

There are approximately 51,600 acres irrigated in the Shasta River watershed. There are an additional 33,000 acres irrigated in the Scott river watershed. The combined estimated consumptive use associated with this agriculture is approximately 170,000 acre-feet annually (Chesney et al. 2009)

The earliest diversion works in the Klamath Basin began in 1882, when John Frank Adams and the three Van Brimmer brothers began to dig a canal from White Lake and Lower Klamath Lake to provide water for approximately 4,500 acres on the east side of the Lost River. Adams later in 1904 extended the works to carry the water across the Lost River, to irrigate an additional 5,000 acres at the north end of Tule Lake.

On UKL, a small ditch was first constructed at the head of the Link River in 1878, to provide water to lots within what was then called Linkville (now Klamath Falls). In 1884, William Steele purchased an interest in this ditch and enlarged and extended it to provide water for

irrigation of lands in the Klamath Valley. Subsequent owners also enlarged and extended this canal, commonly known as the Ankeny Canal, approximately ten miles southeast of Klamath Falls. When Reclamation purchased the canal in 1905, the canal's capacity was 50 cfs and it was irrigating approximately 1,800 acres.

Separate from the Klamath Project, in 1908, private parties constructed Four Mile Dam, on the Cascade Divide, which was later was enlarged and improved. The dam stores and diverts water that would otherwise flow into UKL. The capacity of the dam is 15,600 AF. Water is diverted from the dam through the Cascade Canal, which conveys the water into the Rogue River watershed. Approximately 6,000 AF is annually diverted by Four Mile Dam for industrial and domestic purposes and irrigation of approximately 20,000 acres within the Rogue River Basin. First irrigation diversions on the Klamath Project began in 1907, with completion of the A Canal. The first diversion works from the Lost River were completed in 1912, with construction of Lost River Diversion Dam. The Klamath Project's service area subsequently grew over the decades, totaling approximately 23,000 acres by 1910; 45,000 acres by 1920; 60,000 acres by 1930; 75,000 acres by 1940; 192,000 acres by 1950; 215,000 acres by 1960; and finally, 230,000 acres by 1970. Large portions of the Klamath Project, around UKL and along the Klamath and Lost rivers, divert by private irrigation works, over which Reclamation has no direct operational control. Although these diversions are privately-owned and operated, the lands are covered by some form of contract with the United States that allow the landowner to exercise water rights associated with the Klamath Project (see Chapter 1.3 for more information on Klamath Project water rights and water contracts). Under current conditions, Reclamation has no direct physical control over these diversions and the associated water rights can be exercised in accordance with Oregon law regardless of Reclamation's instructions. These lands may also possess other non-Project water rights, of either earlier or later priority date.

Federally-owned Klamath Project facilities that divert water from UKL (either stored by LRD or from live flow) and the Klamath River for irrigation purposes are limited to the A Canal and the Lost River Diversion Channel. Federal diversion works on the Lost River include: Malone, Miller Creek, Lost River, and Anderson-Rose diversion dams and the North and South Poe Valley, Stukel, and Adams pumps.

Particularly significant to operation of the Klamath Project is diversions of the Lost River to the Klamath River through the Lost River Diversion Channel. Historically, although the Klamath River would at times overflow the Lost River Slough and eventually reach Tule Lake, water from the Lost River would not reach the Klamath River. The Lost River Diversion Channel was initially constructed in 1912 to a capacity of 250 cfs. The channel was enlarged to 1,200 cfs in 1930, and then again in 1950 to its current capacity of 3,000 cfs.

Throughout the year, Reclamation operates the Lost River Diversion Channel to divert all flow in the Lost River, up to the channel's capacity, to the Klamath River. As described further below, the diversion of water from the Lost River to the Klamath River via the LRDC is considered part of the baseline condition, as to operate otherwise would threaten the structural integrity of federal Reclamation facilities. During part of the irrigation season, flows from the Lost River into the Lost River Diversion Channel may be rediverted for agricultural use before reaching the Klamath River. Regardless of origin of the water (Lost River, Klamath River, or

UKL) diversions from the Lost River Diversion Channel for irrigation purposes are part of the PA and not a baseline condition.

6.1.5.3 *Water* Surface Elevation

A significant hydrological characteristic of UKL and Clear Lake and Gerber reservoirs are their water surface elevation. As water evaporates or is released from the reservoir for downstream beneficial use, the water surface elevation will decrease, along with the amount of habitat available for fish decreases (Buchanan et al. 2011). Tributary inflow, direct precipitation, and storage of water (i.e., reduction in releases) increase water surface elevations and available habitat for fish. For suckers, habitat needs vary by life stage. Suckers in Gerber and Clear Lake exclusively spawn in tributaries. LRS and SNS in UKL spawn in the Williamson River, and one spawning population of LRS spawns at shoreline springs in UKL.

Adult LRS in UKL need water surface elevations of at least 4,142 feet to access shoreline spawning grounds. In addition, following shoreline spawning by adults, a sudden decrease in water surface elevations (i.e., more than 0.6 feet in three weeks) may cause mortality for developing sucker embryos and larvae. Larval suckers need wetland-edge habitat for food resources and protection from predation. Wetland habitat is reduced at lower lake elevations. Young of the year suckers need habitat diversity, including rocky substrates, wetland ecosystems, and open lake habitat. Rocky substrates and wetland habitat vary with lake elevation but become scarce as water surface elevations on the lake decrease.

Young-of-the-year suckers in UKL have not survived to adulthood since 1992. Habitat needs for suckers in the first year of their lives are poorly understood. Adult suckers a year or older need habitat depths greater than two meters in the northern portion of UKL, and access to water quality refugia (Banish et al. 2009). Surface elevations greater than or equal to 4,138.3 feet at the end of September are thought to provide some protection for adult suckers in accessing Pelican Bay, where they can seek water quality refugia and better avoid predators (USFWS 2019a).

Prior to construction of Clear Lake Dam, the area now occupied by the reservoir was an ephemeral wet meadow. Clear Lake Reservoir was built to not only store water for irrigation purposes, but also to arrest the flow of the Lost River to facilitate the reclamation of Tule Lake. After the construction of the dam, a sub-population of suckers (that may have historically inhabited Tule Lake, the Lost River, and what is now the Clear Lake watershed) may have become confined to Clear Lake. Since the dam's construction, water surface elevations have been elevated over historical conditions. When water surface elevations in the reservoir are above 4,524 feet (USBR datum), suckers can physically access spawning grounds in Willow Creek and upstream tributaries. Additionally, high surface levels in Clear Lake Reservoir also provide suckers with more habitat and better protection from predation. Fish screens on the dam's outlet works prevent adult and juvenile suckers from being released downstream, but not larvae.

There are no fish screens on Gerber Reservoir, so suckers can potentially move downstream into Miller Creek. There are no LRS in Gerber Dam, only SNS. Elevated water surface elevations allow SNS access to spawning grounds in Barnes Valley Creek and Ben Hall Creek.

Additionally, high lake levels also provide suckers with more habitat and protection from predation.

6.1.5.4 Groundwater Withdrawals

Groundwater is an important water source for fish, wildlife, irrigators, and residents throughout the watershed, and in particular the upper Klamath River Basin, and Scott and Shasta valleys. Through natural discharges and the addition of pumped water to streams, groundwater provides cool, late summer stream flows to sustain fish at a critical time for spawning and rearing. Some irrigators use groundwater as a supplement when surface water supplies do not fully meet irrigation needs. Other irrigators depend solely on groundwater supplies. In addition, the City of Klamath Falls, the primary population center in the upper Klamath River Basin, is entirely supported by groundwater.

Prior to about 2000, natural recharge regularly replenished groundwater aquifer storage in the upper basin. Since 2001, the upper basin has experienced increased groundwater pumping, particularly within and near the Klamath Project. This is due, in part, to the reduced availability of surface water supplies for irrigation purposes.

The use of groundwater is under state jurisdiction and subject to state law. Reclamation has no direct control over these activities.

6.1.5.5 Contaminants

Pesticide use for agricultural purposes is estimated to occur on up to 60 percent of lands within the Klamath Project (120,000 acres). Surveys regarding pesticide impacts to suckers have largely focused on the Tule Lake Sumps as a likely place that agrochemicals may accumulate within the Klamath Project. Pesticide use is also common in urban areas (e.g., Klamath Falls, Merrill, Malin, Tulelake), and Klamath County operates a vector control program that involves pesticide application to waterbodies, including drains within the Klamath Project.

Pesticide residues in drainage water may also be discharged into the Keno Impoundment via discharges the Klamath Straits Drain. This reach also receives drainage from neighboring non-project areas such as Keno Irrigation District and private lands.

The risk to the suckers posed by pesticide use is dependent on many factors, including chemical toxicity, mobility, persistence, amount applied, ground water-surface water interaction, application method, and proximity of application area relative to nearby water bodies.

Once in a waterbody, pesticides volatilize, degrade, settle to the bottom with sediment, or remain in the water column where they are diluted (USFWS 2008). Studies on pesticide use on the leased lands with TLNWR concluded that pesticide use does not likely pose a threat to LRS and SNS in the Tule Lake Sumps when label directions are followed and when appropriate buffers are in place (USFWS 2008).

Since the late 1980s, low levels of pesticides have been detected in the Tule Lake Sumps, but generally at levels not acutely toxic to aquatic life (Sorensen and Schwarzbach 1991; Dileanis et al. 1996; Cameron 2008; Eagles-Smith and Johnson 2012)(, Cameron 2007b, Reclamation 2011, Reclamation unpublished data.;). In 2011, however, Reclamation detected bifenthrin and

prodiamine. The concentration of bifenthrin measured in 2011 could adversely impact aquatic life (Australian Government 2010; Syngenta Crop Production Inc 2015).

DaSilva (2016) monitored for 34 active pesticide ingredients at multiple sites around Tule Lake, including within TLNWR. While two herbicides were detected (2,4-D and dicamba) in multiple locations, neither exceeded the aquatic life benchmark values for fish (DaSilva 2016).

Between 1998 and 2000, several wildlife mortalities and fish die-offs were documented and investigated on TLNWR, but with the exception of one incident in which off-refuge use of acrolein caused a fish die-off, there was little supporting evidence that implicated pesticides as causative agents in any of the mortality events (Snyder-Conn and Hawkes 2004). However, the results of the study did reveal some evidence of trace wildlife exposure to the herbicides dicamba and 2,4-D and a few cases of limited acetylcholinesterase inhibition in birds, suggesting potential low-level exposure to organophosphate or carbamate insecticides (Snyder-Conn and Hawkes 2004; Eagles-Smith and Johnson 2012). However, some pesticides and herbicides in use within the Klamath Basin can be toxic at low concentrations (Eagles-Smith and Johnson 2012). While some products are listed as toxic, the actual risk of these products is a function of exposure or the amount released into the environment.

While most of the sampling to date in Tule Lake suggests pesticides may not be present in concentrations that would adversely affect suckers, a lack of detection of toxic pesticides does not necessarily mean they do not exist in the environment (USFWS 2008; Eagles-Smith and Johnson 2012). Highly toxic pesticides, like metam-sodium (Vapam), can harm fish at low concentrations and may escape detection during surveys. Many newer pesticides are difficult to monitor due breaking down in the environment rapidly (USFWS 2008). Reclamation (2011, Unpublished Data) collected bimonthly water samples from the Tule Lake Sumps during Vapam application period and did not detect this pesticide.

6.1.5.6 Water Quality

Upper Klamath Lake

In general, LRS and SNS are relatively tolerant of degraded water quality conditions. They tolerate higher pH, temperature, and un-ionized ammonia concentrations, and lower DO concentrations than many other fishes (Martin and Saiki 1999; Meyer and Hansen 2002; NRC 2004). Nonetheless, poor water quality events resulting in stressful and potentially lethal conditions for both LRS and SNS periodically occur at each water body within the Upper Klamath Basin. This section describes relationships between adverse water quality and other variables that have impacted suckers.

While UKL was historically eutrophic (Sanville et al. 1974; Johnson et al. 1985), large-scale watershed development from the late-1800s through the 1900s has likely contributed to the current hypereutrophic condition in UKL (Bortleson and Fretwell 1993). This legacy, combined with current nutrient loading from the watershed and lake sediment, facilitates extensive cyanobacteria blooms (Boyd et al. 2002) that typically result in large diel fluctuations in DO and pH, high concentrations of the hepatotoxin microcystin, and toxic levels of un-ionized ammonia during bloom decomposition (Boyd et al. 2002; Walker et al. 2012). Together, these conditions create a suboptimal environment for native aquatic biota and likely play a role in the decline of

ESA-listed SNS and LRS (Perkins et al. 2000a). Indeed, in recent decades, UKL has experienced serious water quality issues that have resulted in fish die-offs, as well as re-distribution of fish in response to changes in water quality (Buettner and Scoppettone 1990; Banish et al. 2007, 2009).

Phosphorus is the key driver of water quality issues in UKL (Boyd et al. 2002; Walker et al. 2012). Phosphorus occurs in relatively high levels in the local geology of the Upper Klamath Basin (Boyd et al. 2002; Walker et al. 2015), but has been, and continues to be, produced through past and current land use activities in the watershed (Walker et al. 2012, 2015). Specifically, average annual external phosphorus load to UKL is now approximately 40 percent higher than the natural background (Boyd et al. 2002; Walker et al. 2012). Additionally, the intact riparian areas and lake-fringe wetlands that historically filtered and retained phosphorus have been much diminished, further exacerbating the phosphorus loading issue. These factors, combined with internal loading as a result of current and historical external load (Boyd et al. 2002), result in summer water column phosphorus concentrations up to six times higher than the natural background (NRC 2004).

The focus on phosphorus loading and concentrations is critical to disrupt the processes directly linked to water quality issues in UKL, namely large cyanobacteria blooms during the growing season (Boyd et al. 2002). Of specific concern is the cyanobacteria species *Aphanizomenon flos-aquae* (AFA), which has only been present in UKL since the onset of large-scale watershed development in the late 1800s and early 1900s (Bradbury et al. 2004; Eilers et al. 2004). AFA, a nitrogen-fixing cyanobacteria, now dominates the UKL phytoplankton community during the growing season with bloom biomass reaching several orders of magnitude greater than that of other phytoplankton species (Nielsen et al. 2018)(Nielsen et al. 2017). During bloom development and proliferation, AFA photosynthesis facilitates an increase in pH (Jassby and Kann 2010; Nielsen et al. 2018)(Nielsen et al. 2017), often above levels thought to be stressful to SNS and LRS (Loftus 2001). At this same time, increasing water temperature and nighttime AFA respiration combine to reduce DO concentrations, which may pose additional challenges to listed suckers. Typically, by late July or early August, and often in tandem with hot and calm conditions, AFA blooms "crash" (Jassby and Kann 2010; Nielsen et al. 2018)(Nielsen et al. 2017), resulting in increased organic biomass available for decomposition at the sediment-water interface. Increased decomposition subsequently results in reduced DO and possibly increased un-ionized ammonia concentrations, both of which may be stressful or lethal to listed suckers (Saiki et al. 1999; Loftus 2001), depending on the extent and duration of the suboptimal concentrations. In addition to changes in these water quality parameters, AFA bloom crashes increase the amount of available nitrogen for uptake by other phytoplankton, primarily the toxin-producing cyanobacteria *Microcystis aeruginosa* (Jassby and Kann 2010); UKL is often under an Oregon Health Authority recreational use health advisory for the algal toxin microcystin, produced by *Microcystis aeruginosa*, by early July. While there isn't clear direct evidence that microcystin negatively affects listed suckers, it is another possible chronic stressor (Martin et al. 2015) and has been implicated in fish die-offs in other locations (Zanchett and Oliveira-Filho 2013). Regardless, adverse water quality events associated with AFA bloom dynamics may have lethal impacts to individual suckers (Perkins et al. 2000a; Janney et al. 2008)(Perkins et al. 2000b) and may reduce the reproductive capacity of the populations by reducing the numbers of larger and more fecund females (Buchanan et al. 2011). Adverse water quality may also affect

young suckers (Buchanan et al. 2011), Hereford et al. 2018), but the existing data has been unable to discern a clear relationship.

The most recent and best available science regarding water quality for the purposes of ESA section 7 consultations has not demonstrated a direct, consistent, and discernible relationship between UKL elevation and water quality (Wood et al. 1996; NRC 2002; Morace 2007; Jassby and Kann 2010; Nielsen et al. 2018; Wherry and Wood 2018) Nielsen et al. 2017, Evan Childress, pers. comm., November 20, 2018). Specifically, NRC (2002) did not find a relationship between UKL elevation and AFA density (represented by chlorophyll-*a* concentrations) and determined that the hypothesis that maintaining higher UKL elevations would effectively dilute internal phosphorus loading and reduce algal density was not supported.

Finally, there is some concern that winter water quality conditions under ice cover may also adversely impact suckers (Kann 2010). Ice cover can occur on UKL from November through March, though the extent and duration are dependent on winter air temperature, precipitation, and other meteorological conditions (USFWS 2008). The available data, while limited, indicates that winter water quality parameters do not generally fall within levels considered stressful for suckers (Reclamation 2012a).

Keno Impoundment

The 20-mile section of the Klamath River between LRD and Keno Dam is characterized by morphology and hydraulic residence time typical of shallow lakes, with the exception of the 1.5-mile-long Link River at the head of this reach. UKL is considered the source of greatest nutrient and biochemical oxygen demand (BOD) loads to this reach of the Klamath River during the irrigation season via export of substantial AFA biomass (NRC 2004; ODEQ 2017; Schenk et al. 2018). As documented during AFA bloom crashes in UKL, decomposition of senescing AFA in the Keno Impoundment regularly leads to suboptimal DO concentrations and pH, which persist through the growing season (ODEQ 2017). Additionally, the shallow channel morphology facilitates water temperatures typically in excess of 25°C during the summer months (ODEQ 2017). While AFA blooms are often observed in the Keno Impoundment, these blooms are typically less intense and are spatially and temporally more variable than those observed in UKL (Reclamation 2007).

During the irrigation season, very little water from the Project and Lost River watershed flows to the Klamath River. Generally, the Project has been characterized as a nutrient sink, rather than source (ODEQ 2017; Schenk et al. 2018), given that only 30 percent of the flow entering the Project is returned to the Klamath River (ODEQ 2017). However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Outside of the irrigation season, water quality in the Keno Impoundment is greatly improved, owing to lower water temperatures, and an increase DO concentrations as a result of reduced biomass in (and therefore, exported from) UKL and increased oxygen saturation with reduced

water temperatures (ODEQ 2017). During this period, the LRDC, which drains the Lost River watershed and the Project, flows towards the Klamath River and thereby contributes some nutrient and BOD load to the Klamath River (Schenk et al. 2018). However, this additional load tends to be relatively small compared to the total load from UKL (Schenk et al. 2018).

Clear Lake Reservoir

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. However, water quality monitoring over a wide range of lake levels and years documented water temperatures and DO concentrations that are periodically stressful to suckers but were generally adequate for sucker survival (Reclamation 2012b). Finally, recent water quality sampling from November to May of 2016-17 and 2017-18 indicates that DO concentrations under ice cover remain above 8 mg/L (Reclamation unpubl.). There are few large-scale impacts outside of cattle grazing and road infrastructure in the Clear Lake Reservoir drainage that likely influence water quality.

Gerber Reservoir

Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for sucker survival (Piaskowski and Buettner 2003; Phillips and Ross 2012). Generally, water quality is better in Gerber Reservoir than in other large reservoirs in the Upper Klamath Basin (Phillips and Ross 2012). Observed water quality conditions in Gerber Reservoir (i.e., temperature, pH, and DO concentrations) were adequate for suckers except low DO concentrations during portions of some winter months during ice cover conditions and portions of all summer months (Piaskowski and Buettner 2003). During summer and early fall, weak stratification of the water column develops occasionally in Gerber Reservoir particularly at sites near the outlet where depth is greatest (Piaskowski and Buettner 2003). When the reservoir is stratified, DO concentrations of less than four mg/L were observed at depths generally greater than four meters. This stratified condition, and associated hypoxia, typically persists for less than a month and over a small portion of the reservoir near the dam (Piaskowski and Buettner 2003). Winter stratification and the brief periods during summer months when DO concentration is low create stressful conditions for suckers. There have not been any observed fish die-offs reported from Gerber Reservoir.

Tule Lake

Tule Lake is classified as highly eutrophic because of high nutrient concentrations and resultant elevated biological productivity (ODEQ 2017). Tule Lake water quality is affected primarily by the import of UKL surface water through the LRDC and A Canal during the irrigation season, and secondarily by local runoff during winter and spring months from lands below Lost River Diversion Dam on the Lost River. Also, contributing to the eutrophic status of Tule Lake is its shallow bathymetry and internal nutrient cycling from lake sediment. Water quality can vary seasonally and diurnally, especially in summer. Water quality in the sumps is similar to UKL with large diurnal fluctuations in DO concentrations and pH (Buettner 2000; Hicks et al. 2000;

Beckstrand et al. 2001), largely due to high levels of aquatic macrophyte and green algal biomass during the growing season.

Water quality conditions in Tule Lake during the winter tend to be optimal for suckers, except during prolonged periods of ice cover when DO concentrations decline (USFWS 2008). A small adult sucker die-off occurred during the winter of 1992 to 1993 during an extended period of ice cover and low DO concentrations (Reclamation, unpublished data cited in USFWS 2008). A minimum elevation of 4,034.0 feet was set to provide adequate winter depths for cover and to reduce the likelihood of fish die-offs owing to low DO concentrations below ice cover (USFWS 2008).

Lost River

Local geology suggests that the Lost River was historically eutrophic (ODEQ 2017). However, as with the basin above UKL, largescale changes in land use practices in the early 1900s and manipulations of the river channel and associated waterbodies throughout the 20th century have contributed to hypereutrophic conditions in the Lost River; as a result, Lost River water quality conditions are often suboptimal for listed suckers. Nutrient loading, greatest in the middle and lower portions of the Lost River watershed (Schenk et al. 2018), contribute to growth and subsequent senescense of which facilitates a cycle of high pH and suboptimal or lethal DO and toxic ammonia concentrations (ODEQ 2017).

DO concentrations are seasonally suboptimal for listed suckers in numerous reaches of the Lost River (ODEQ 2017). Extremely low DO concentrations have been measured in Wilson Reservoir, Harpold Reservoir, and at Anderson Rose Dam in the Lost River (Reclamation 2009). Periodic fish die-offs occurred in the Lost River during the 1990s and 2000s (Reclamation 2009). Whereas DO concentrations can periodically reach stressful conditions throughout the Lost River, median DO concentrations indicate that the middle reach of the Lost River may be the most water quality impaired (Reclamation 2012b). Eight stations registered DO concentrations of 1 mg/L or less, which is likely to be acutely lethal for suckers (Saiki et al. 1999). Finally, ODEQ (2017) notes that biological productivity in the Lost River appears to be limited primarily by available nitrogen, suggesting that a reduction in nitrogen loading may improve water quality. The Oregon portion of the Lost River (including KSD) is listed as water quality impaired by Oregon under Section 303(d) of the Clean Water Act due to DO and chlorophyll-*a* concentrations, and pH and ammonia toxicity.

Klamath River (below IGD)

Klamath River water quality is primarily influenced by Upper Klamath Basin water quality conditions, land use practices (past and present), variations in hydrologic conditions (including tributaries to the Klamath River), PacifiCorp reservoirs, and Project operations. Reductions in some water quality parameters such as nutrient concentration, dissolved oxygen (DO), temperature, pH, and periphyton and macrophytes can directly impact coho salmon at every life stage. The interaction of these parameters (e.g., confounding effects) are not well documented in the lower Klamath Basin as to their effects on coho salmon. The Klamath River is somewhat unique in that it originates in shallow, naturally eutrophic UKL which delivers substantial biomass, nutrient, and thermal load to the Klamath River (NCRWQCB 2010; see Chapter 6.2.2

for details). As the river nears the Pacific Ocean, it becomes generally less eutrophic due to increased stream gradient and inputs of cooler, less eutrophic water from tributaries (NCRWQCB 2010a).

Portions of the Klamath River are listed as impaired under section 303(d) of the Clean Water Act due to microcystin, elevated nutrients, organic enrichment/low dissolved oxygen (DO), sedimentation/siltation, and/or elevated water temperature (NCRWQCB 2010a). Given the water quality dynamics in the Upper Klamath Basin above the California/Oregon state line (described in Chapter 6.2.2), the two states have coordinated Klamath River and UKL Drainage TMDLs to ensure they are complimentary (NCRWQCB 2010a). The water quality parameters (or pollutants) of concern in the Klamath River in California include water temperature, DO, carbonaceous biological oxygen demand, total phosphorus, total nitrogen, and microcystin (NCRWQCB 2010a). And finally, the "sources" of these pollutants have been generally categorized as water quality originating in Oregon (termed "stateline"), within PacifiCorp facilities, entering the Klamath River from Iron Gate Hatchery, and entering the Klamath River from tributaries (NCRWQCB 2010a).

During summer, water temperatures in the Klamath River are warmer than winter months. The highest annual maximum daily water temperature were recorded between 2001 and 2011, 28 to 29°C, at Happy Camp, CA (Asarian and Kann 2013). Generally, water temperatures immediately downstream of IGD are the lowest, with a steep upward trend downstream to Seiad Valley and Happy Camp, and then a gradual decreasing trend downstream to the mouth (Asarian and Kann 2013). While air temperature generally drives seasonal and longitudinal trends in water temperature in the Klamath River, the large thermal mass of storage reservoirs (including UKL) causes changes to seasonal water temperature as well. In particular, it is estimated that warming temperatures in the spring and cooling temperatures in the fall are delayed by 2 to 4 weeks as a result of PacifiCorp's Klamath Hydroelectic Project (NMFS 2012c). Due to PacificCorps releases, IGD release temperatures can be below the equilibrium in late spring to mid-summer and above the equilibrium throughout the fall (PacifiCorp 2012).

Water temperatures throughout mainstem Klamath River changes in response to hydrology and water storage. The magnitude of this response depends on three principal factors: 1) the temperature of the water as it is released from the impoundments; 2) the volume of the release; and 3) the meteorological conditions (e.g., ambient air temperature). The large thermal mass of storage reservoirs causes changes to seasonal water temperature, and water releases at IGD can influence diurnal temperature patterns. However, the relationship between IGD releases during the summer and mean, minimum, and maximum temperatures are difficult to distinguish (NRC 2004). In the past, under moderate flow conditions in mid-August (e.g., 1,000 cfs release from IGD) with typical accretions from tributaries, maximum daily temperatures can increase rapidly downstream of IGD. Daily minimum temperatures caused by nocturnal cooling reach a minimum of 20ºC within about the same distance. By the time this water reaches Seiad Valley (RM 129), maximums are greater than 26ºC, and minimums are 22ºC; the average gain from IGD to Seiad Valley was 2ºC (NRC 2004). Temperatures in the mainstem Klamath River are affected substantially by the Scott River and minimally by the Shasta River (NRC 2004).

Nutrient dynamics are key drivers of primary productivity in aquatic systems. Elevated levels of primary productivity can adversely affect aquatic organisms such as coho indirectly as a result of

suboptimal pH and DO concentrations associated with photosynthesis and respiration, respectively, and potentially harmful concentrations of cyanotoxins. Generally, nutrient concentrations are highest at Keno Dam and decrease longitudinally with increasing distance downstream (Asarian et al. 2010).

Due to tributary dilution and nutrient retention (nutrient sequestration via biological uptake and denitrification) in the river and reservoirs, the Klamath River is considered a nutrient sink from June – October; specifically, Asarian and Kann (2010) found that phosphorus and nitrogen concentrations and loads decreased substantially between Keno Dam and Turwar (near the mouth of the river) annually during this period.

Adequate concentrations of DO in freshwater streams and rivers are essential for the survival, growth, and development of salmonids. Reduced concentrations of DO can affect fitness and survival by shifting embryo incubation periods, reducing the size of fry, and decreasing feeding activity, and extremely low DO concentrations can be lethal to salmonids. To ensure sufficient DO concentrations for coldwater fishes, the Klamath River TMDL calls for specific DO concentrations at stateline, PacifiCorp reservoir tailraces, the IGH discharge point, and below the confluence with the Salmon River (NCRWQCB 2010a).

The lowest DO concentrations in the Klamath Basin are observed in summer and early fall in the reaches above Copco Reservoir (Reclamation 2012a; PacifiCorp 2018). These conditions are largely influenced by algal blooms in UKL that provide an influx of organic matter (PacifiCorp 2018) and the effect of UKL algal dynamics appears to attenuate further downstream. Generally, DO concentrations in the Klamath River below IGD exceed minimum DO requirements for salmonids and other coldwater species (Asarian and Kann 2013; PacifiCorp 2018). However, annual minimum DO concentrations from 2001 – 2011 were as low as 3.5 mg/L at IGD, with a general upward trend from 2001 – 2011 (Asarian and Kann 2013).

Generally, pH in the Klamath River below IGD is substantially lower than that observed in UKL, the Keno Impoundment, and PacifiCorp reservoirs. Highest annual maximum pH from 2001 to 2011 was between 9.0 and 9.5 at IGD, which tends to have the highest pH in the mainstem Klamath River (Asarian and Kann 2013). More generally, the highest pH concentrations (daily maximum pH, averaged over 2001 to 2011) occurs from mid-July to mid-September, with Klamath River maxima (8.6 to 9.0 when averaged over 2001 to 2011) occurring between IGD and rivermile 90 (approximately 10 miles downstream of Happy Camp, CA) (Asarian and Kann 2013). Ammonia toxicity can also be a concern in aquatic environments, like the Klamath River, where high nutrient concentrations coincide with elevated pH and water temperature.

Photosynthesis and respiration by periphyton and macrophytes are the primary drivers of the daily cycles of DO and pH and are related to temperature in the Klamath River. Periphyton (algae attached to the substrate or macrophytes) and macrophytes (rooted aquatic plants) have seasonal growth patterns in the Klamath River, with low biomass during high winter and spring flows and maximum biomass reached during the low-flow warm period in mid/late summer (Asarian et al. 2015). Factors affecting this seasonal cycle include water velocity, substrate, light, water temperature, and nutrient availability (Asarian et al. 2015; Gillett et al. 2016). High flows appear to limit periphyton and macrophyte biomass due to increasing water velocities dislodging/disrupting aquatic vegetation (Asarian and Kann 2013; Asarian et al. 2015).

The effect of periphyton and macrophytes on DO concentrations is influenced by biomass and water depth. Periphyton and macrophytes are attached to the riverbed, therefore, as water depth increases these organisms have less effect on water column DO concentrations because their oxygen production (photosynthesis) and consumption (respiration) is "diluted" by the increased water volume. Conversely, when water depth is low or temperatures high, the ratio between the bed surface area and the water volume is higher, and periphyton effects on DO concentrations are greater.

In addition to periphyton and macrophytes in the mainstem Klamath River, the cyanobacteria species *Microcystis aeruginosa* and AFA also influence water quality in the Klamath system, particularly in the PacifiCorp reservoirs and immediately downstream of IGD (Asarian and Kann 2011, 2013; PacifiCorp 2018). Furthermore, *Microcystis aeruginosa* produces the hepatotoxin microcystin, which can sometimes reach substantial concentrations in the reservoirs and the Klamath River, though it is unclear what effect toxin concentrations may have on listed coho. Biomass of both cyanobacteria species is substantially higher below the reservoirs than in the Klamath River above, suggesting that the reservoirs themselves are the source of these species and associated cyanotoxin to the Klamath River below IGD (Asarian and Kann 2011). The conditions that facilitate large cyanobacteria blooms are primarily driven by external nutrient loading, (i.e., export of nutrients from upstream reaches) and lacustrine conditions in the reservoirs, Asarian and Kann 2011); *see* Chapters 6.2.2.1 and 6.2.2.2 for details regarding upstream water quality and nutrient loading).

The Klamath River TMDL calls for specific targets and allocations associated with cyanobacteria populations in the PacifiCorp reservoirs (NCRWQCB 2010a); *see* Table 5.1 therein for details.

6.1.5.7 Klamath Basin Adjudication and Water Rights Regulation

As discussed further in Chapter 1.3.2., in 1975 the State of Oregon began a basin-wide adjudication of all pre-1909 and federally-reserved water rights to water from the Klamath River and its tributaries in the State of Oregon. The Klamath Basin Adjudication includes hundreds of separate water right claims, including those made by the United States on behalf of the Klamath Project, Lower Klamath and Tule Lake NWRs, and the Klamath Tribes.

Enforcement of water rights identified in the ACFFOD, particularly the instream flow water rights claimed on behalf of The Klamath Tribes, has significantly changed hydrology in the Upper Klamath Basin. These water rights vary by stream segment, but have a priority of "time immemorial", making them prior to (i.e., "senior" to all other water rights to water from those sources (*see* Chapter. 1.3.8., regarding The Klamath Tribes' water rights determined in the ACFFOD).

Through the BIA, calls have been made for OWRD to enforce The Klamath Tribes' instream flow water rights which has been done to varying degrees in every year since 2013. The level of enforcement has varied over the course of the year and by stream segment, but frequently, the call on behalf of The Klamath Tribes has curtailed surface water diversions throughout much of the Upper Klamath Basin.

USFWS' temporary water right transfer from the Agency Lake and Barnes Ranch properties is not part of Reclamation's PA, but instead within the environmental baseline. Collectively, the transferred water right from the Agency Lake and Barnes Ranch properties allows for diversions at the Ady Canal of up to approximately 31 cfs and 11,200 AF in total annually. This transferred water right has a priority date of September 13, 1920 and is potentially subject to water rights regulation in the Upper Klamath Basin based on calls by senior water rights holders, including potentially a call made on behalf of the water rights for the Project.

6.1.6 Biological Alteration

6.1.6.1 Harvest

The following excerpt from USFWS' 2019 BiOp succinctly describes the past and present harvest of LRS and SNS:

> *Migrating suckers were a historically important food source for the Klamath Tribes and were harvested in large numbers during the spring months (Bendire 1889 p. 444, Evermann and Meek 1897 p. 60). Settlers of European descent also utilized sucker migrations as a source of food and fish oil, including some commercial harvest. Historical accounts of sucker harvest from the late 19th century describe a large fishery on the Lost River for fish migrating upstream from Tule Lake (Bendire 1889 p. 444, Gilbert 1897 p. 6). The construction of dams on the Lost River and the draining of Tule Lake for agricultural purposes eliminated this fishery. However, a large recreational fishery for suckers developed in the Williamson and Sprague Rivers. In 1967, the Klamath Falls fisheries agent for the Oregon Fish and Game Commission was quoted in the newspaper as stating, "we've estimated that about 100,000 pounds—that's 50 tons—of mullet [suckers] were snagged out of the two rivers in a three-week period" (Cornacchia 1967, entire). This snag fishery, which targeted primarily LRS but included SNS (Bienz and Ziller 1987 p. X), existed in the Williamson and Sprague Rivers up to 1987 when the Oregon Fish and Game Commission outlawed harvest of both species. Until 1987, fishing pressure during the spawning migration likely contributed to population declines in Lost River and SNS in the Williamson and Sprague Rivers, but the magnitude of the effect is difficult to discern due to a lack of data on population sizes and harvest quantities during most of the 20th century. At present, some Lost River and SNS are inadvertently captured while anglers target other species in UKL; however, the numbers are likely small, and anglers are required by law to immediately release the fish. (pages 83-84)*

The following excerpt from NMFS' 2019 BiOp succinctly describes the past and present harvest of coho salmon:

> *Coho salmon have been harvested in the past in both coho- and Chinook-directed ocean fisheries off the coasts of California and Oregon. However, stringent management measures, which began to be introduced in the late 1980s, reduced coho salmon harvest substantially. The prohibition of coho salmon retention in commercial and sport fisheries in all California waters began in 1994 (NMFS 2014a). With the exception of some tribal harvest by the Yurok and Hoopa Valley*

for subsistence and ceremonial purposes, the retention of coho salmon is prohibited in all California river fisheries. Tribal fishing for coho salmon within the Yurok tribe's reservation on the lower Klamath River has been monitored since 1992. The median Yurok harvest from the entire area from 1994 to 2012 was 345 coho salmon, which approximates an average annual maximum harvest of 3.1 percent of the total run (NMFS 2014a). The recent Yurok Tribe Fall Harvest Management Plan (Yurok Tribe 2018b) includes weekly fishing closures intended to protect coho salmon from harvest. The majority of coho salmon captured by Hoopa Valley tribal fisheries are Trinity River Hatchery origin fish (Orcutt 2015). With regards to ocean fisheries, in 1995, ocean recreational fishing for coho salmon was closed from Cape Falcon in Oregon to the United States/Mexico border. In order to comply with the SONCC coho salmon ESU conservation objective, projected incidental mortality rates on Rogue/Klamath River hatchery coho salmon stocks are calculated during the preseason planning process using the coho salmon Fishery Regulation Assessment Model (Kope 2005). Specifically, the Pacific Fishery Management Council applies a SONCC coho salmon ESU consultation standard requirement of no greater than a 13.0 percent marine exploitation rate on Rogue/Klamath hatchery coho salmon, which applies to incidental mortality in the Chinook salmon ocean fisheries from Cape Falcon in Canada to the United States/Mexico border (PFMC 2018). In summary, while major steps have been taken to limit effects of harvest on SONCC coho salmon, the population is still impacted by incidental mortality associated with various Chinook salmon fisheries, and by subsistence and ceremonial tribal fisheries.

6.1.6.2 Predation

Several species of native and non-native fishes prey upon SNS and LRS, especially larvae and juvenile life stages. Native fish predators include redband trout (*Oncorhynchus mykiss newberrii*), blue chub (*Gila coerulea*), and Tui chub (*Gila bicolor*). Non-native fishes that prey on suckers include fathead minnow (*Pimephales promelas*) and yellow perch (Perca flavescens). Less abundant but likely also non-native and predators of suckers include bullheads (*Ameiurus species*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis species*), green sunfish (*Lepomis cyanellus*), pumpkinseed (*Lepomis gibbosus*), and Sacramento perch (*Archoplites interruptus*) (Koch et al. 1975; Logan and Markle 1993). These species may also compete with endangered suckers for food or space (Markle and Dunsmoor 2007).

Bird predation on endangered suckers has been studied at Clear Lake Reservoir and UKL. American White pelicans (*Pelecanus erythrorhynchos*) and double-crested cormorants (*Phalacrocorax auritus*) are the most abundant avian predators and both species have nesting colonies at Clear Lake Reservoir and UKL (Evans et al. 2016). Pelicans are more common at nesting colonies at Clear Lake Reservoir while cormorants are more common at nesting colonies at UKL. With their larger beak, pelicans are able to consume larger fish (up to 730 mm, Evans et al. 2016) than cormorants (up to 450 mm, Hatch and Weseloh 1999). Individual pelicans are able to forage on suckers up to 4 feet (1.25 m) deep, however, as cooperative foragers, pelicans often drive fish into shallow water (Anderson 1991). In contrast, cormorants can forage for fish in water up to 33 feet (10 m) deep but are more limited in the size of fish they can consume (Enstipp et al. 2017). Other avian predators of suckers in the Upper Klamath Basin including gulls (*Larus* sp.), herons (*Ardea* sp.), and Caspian terns (*Hydroprogne caspia*), nest among

pelicans and cormorants, and likely contribute to the sucker mortality (Evans et al. 2016). Avian predators in Clear Lake had the highest predation rates on suckers in Clear Lake; minimum avian predation rates for Clear Lake nesting birds are estimated to be 4.6 percent for LRS and 4.2 percent for SNS (Evans et al. 2016). Avian predation at UKL accounts for a minimum of 0.6 percent LRS and 1.8 percent SNS mortality. Recovered PIT tags from Clear Lake Reservoir included tags that were implanted in suckers that were released at other locations, principally UKL demonstrating that piscivorous water birds nesting on islands in Clear Lake Reservoir traveled to other Lakes and streams to consume PIT-tagged suckers (Roby et al. 2011; Evans et al. 2016). Interestingly, pelicans nesting at Clear Lake were more likely to prey upon adult suckers spawning at the springs on the east side of UKL, whereas UKL pelicans were more likely to prey upon suckers spawning in tributaries (Evans et al. 2016). Bald eagles also prey on suckers, especially at shoreline spawning grounds and the Sprague River near the Chiloquin Dam site, during the spawning season.

Adult and juvenile coho salmon are preyed upon by piscivorous fish, avian predators, pinnipeds (i.e., seals), and other mammals. The effect of predation on coho salmon in the action area is unknown. Pinniped predation on adult salmon originating from the Klamath River has, however, been documented. A study estimated that 223 adult coho salmon were eaten by pinnipeds in the Klamath River estuary between August and November, 1997. One study (Nickelson 2003) surmised that concentrated hatchery releases from IGH may increase predation rates of juvenile coho salmon by piscivorous fish (e.g., steelhead).

6.1.6.3 Hatcheries

Two fish hatcheries operate within the Klamath River Basin – the Trinity River Hatchery (near the town of Lewiston, California, and the Iron Gate Hatchery (IGH) on the mainstem Klamath River near Hornbrook, California. Both hatcheries mitigate for anadromous fish habitat lost as a result of the construction of dams on the Trinity and Klamath Rivers. Both hatcheries have historically focused on the production of Chinook salmon, coho salmon, and steelhead

6.1.6.3.1 Iron Gate Hatchery

IGH coho salmon production focuses on the conservation of the Upper Klamath Population Unit, which is currently below the high-risk abundance level established by NMFS (CDFW and Pacificorp 2014). To conserve the remaining genetic and phenotypic traits of the Upper Klamath Population Unit, the IGH coho program is operated as an "integrated type," where natural- and hatchery--origin fish are used as broodstock. A Hatchery and Genetic Management Plan (HGMP) for coho salmon was developed for IGH as part of the CDFW's application for an ESA section 10(a)(1)(A) permit for the IGH coho salmon program (NMFS 2013, NMFS 2014a; CDFW and Pacificorp 2014)(78 FR 6298 (January 30, 2013)). The HGMP is intended to guide hatchery practices toward the conservation and recovery of SONCC coho salmon; specifically, through protecting and conserving the genetic resources of the upper Klamath River coho salmon population.

When a program is well integrated, the proportion of natural--origin fish used in hatchery broodstock (pNOB) is greater than the proportion of hatchery fish on spawning grounds (pHOS) (CDFW and Pacificorp 2014). At IGH, the target minimum of 20 percent pNOB has been meet each year since goals were updated in 2009 (28 percent average), except in 2012. While pHOS

data are limited for many Upper Klamath tributaries, a weir on Bogus Creek, the largest tributary in the Population Unit, controls the number of hatchery fish allowed into spawning grounds. Available data indicate average pHOS of 46 percent in Bogus Creek, which is close to the pNOB/pHOS levels. These are considered acceptable levels under the 2014 Hatchery and Genetic Management Plan since there is no limit on pHOS when fewer than 310 natural origin spawners return. However, because pHOS typically exceeds pNOB, it is likely that the hatchery environment is driving population genetics and natural genetic traits are not being conserved (CDFW and Pacificorp 2014).

Hatchery fish also pose ecological threats, such as increased risk of predation and competition, to rearing natural origin salmonids (Collis et al. 1995; Nickelson 2003). Though these effects have not been quantified in the Klamath Basin, average annual releases of 5,766,512 Chinook salmon, 80,651 coho salmon, and 82,528 steelhead from IGH (CDFW 2014)(based upon data available since 2001; CDFW 2013, CDFW 2014, CDFW 2016) are assumed to have impacts on SONCC coho.

6.1.6.4 Fish Parasites and Disease

6.1.6.4.1 Suckers

Degraded water quality conditions may compromise fish health and increase their susceptibility to disease and parasites (Holt et al. 1997; Perkins et al. 2000a; ISRP 2005). Several parasites are common in the Upper Klamath Basin and when combined with other environmental stressors, can have synergistic effects on the health and survival of suckers. The extent that pathogens affect suckers is not fully understood but some parasites likely contribute to sucker mortality.

Lernaea sp., a parasitic copepod or "anchor worm," which feeds on fish tissues by puncturing the skin of its host (Briggs 1971), is a common parasite on suckers in the Upper Klamath Basin. *Lernaea* sp. are commonly found on juvenile suckers (both species) in UKL and Clear Lake during summer months (Burdick et al. 2017). Attachment sites can open a pathway for other pathogens or disease whereby causing secondary infections. Severe inflammation and necrosis (dead tissue) in the skin and muscle occur far and deep beyond the attachment site (Janik et al. 2018). The trematode metacercariae, *Bolbophorus* sp. (Janik et al. 2018), commonly called "black spot," is a flat worm that infects the skeletal muscle tissue of LRS and SNS in UKL. Number of metacercariae infections in suckers is typically higher for SNS than LRS; as many as 11 raised cysts have been observed on a single young of the year sucker (Burdick et al. 2017; Janik et al. 2018). Host response includes melanization of the skeletal muscle tissue that surrounds the encysted digenean metacercariae, however the surrounding tissue is typically unaffected (Burdick et al. 2015a, 2017).

A number of pathogens have been identified from moribund (dying) suckers, including Gram-negative bacterial infections of apparent *Flavobacterium columnare* which can damage gills, produce body lesions, which leads to respiratory problems, an imbalance of internal salt concentrations, and provides an entry route for lethal systemic pathogens (Foott 1997, 2004; Holt et al. 1997; ISRP 2005). One parasite that severely impacts young of the year SNS is the nematode larvae *Contracaecum* sp. (Janik et al. 2018). When present, the nematode enlarged and thinned the atrium, and prevented normal heart function (Janik et al. 2018). While not terribly common, *Contracaecum* sp. is expected to cause cardiovascular failure and inhibit

swimming performance (Janik et al. 2018). Affected suckers are not suspected to survive (Janik et al. 2018). While its prevalence in wild suckers is not known (Burdick et al. 2017)(Banner and Stocking 2007), *Ichthyobodo* sp. (formerly *Costia* sp.) is a parasite that attaches to the gills or skin (Callahan et al. 2002). This obligate ectoparasite can cause or contribute to mortality of wild juvenile suckers by impairing normal body functions (Hereford et al. 2016) (Hereford et al. 2018). For example, *Ichthyobodo* sp. infestations in fish can cause anorexia, surface cell-death, reduced oxygen uptake, reduced ion regulation, and impaired circulation (Lom and Dyková 1992).

Parasites were not identified as a threat at the time of listing, but recent information indicates they could be a threat to the suckers (Buchanan et al. 2011). Parasites can lead to direct mortality, provide a route for pathogens to enter fish through wounds, and can make fish more susceptible to predation (Robinson et al. 1998). While many parasites are common, especially in UKL, the role Project operations have on their occurrence is unknown.

The lack of information regarding disease, parasites, and stress affecting juvenile suckers is likely due to the inherit hardiness of the species and the difficulty for researchers to capture compromised and affected suckers using passive gear. Several studies (Saiki et al. 1999; Meyer and Hansen 2002; Lease et al. 2003)(Hereford et al. 2018) have found suckers show little to no sign of distress until immediately before death, despite high parasite loads, compromised water quality conditions, or other factors, which may explain why understanding causes of mortality for juvenile suckers is so difficult. Further, suckers with compromised health may be heavily predated upon.

6.1.6.4.2 Coho Salmon

Klamath River salmonids are exposed to various pathogens that cause infection and mortality. Prevalent pathogens include, but are not limited to, *Flavobacter columnare* (columnaris), *Ichthyopthirius multifilis* (ich), *Nanophyetes salmincola*, and the myxozoan parasites *Parvicapsula minibicornis* and *Ceratonova shasta* (Foott et al. 2002). Infection and disease proliferation are primarily dependent on water temperature and annelid density (Warren 1991; Stocking and Bartholomew 2007). However, stream flow can be a contributing factor, especially as it relates to habitat suitability (Som et al. 2016; U.S. Fish and Wildlife Service (USFWS) 2016b; Hillemeier et al. 2017) and dilution effects (Som and Hetrick 2016; Hillemeier et al. 2017) for *P. minibicornis* and *C. shasta*. More specifically, low, stable flows are thought to increase disease virulence (Som et al. 2016). However, there remains considerable debate about the nature of the relationship between flow management and disease conditions (Reclamation 2018a). Some evidence alludes to a possible link between flow management and disease proliferation (Som et al. 2016; U.S. Fish and Wildlife Service (USFWS) 2016b). Still, other studies conclude no apparent association between flow and other factors, such as annelid density, that influence disease conditions (Malakauskas et al. 2013).

<u>*Ceratonova shasta*</u>

Ceratonova shasta (*C. shasta*) are a part and present conditions in the action area and are thus part of the environmental baseline. The following description summarizes the baseline conditions with respect to *C. Shasta*, and not the effect of the PA on *C. Shasta* (see Part 8).

The life-cycle of *C. shasta* involves two hosts: salmonids and the annelid worm, *Manayunkia speciosa* (*M. speciosa*) (Bartholomew et al. 1997) (Figure 6-1). Annelid hosts release *C. shasta* actinospores (infectious to fish) and salmonid hosts release *C. shasta* myxospores (infectious to annelids) (Hallett and Bartholomew 2011). Actinospores are released from infected *M. speciosa* into the water column as temperatures warm, typically in late March or early April (Som et al. 2016). Actinospores released from *M. speciosa* infect fish through the gills (Bjork and Bartholomew 2010), traveling through the bloodstream to the intestine, where myxospore replication and maturation of *C. shasta* occurs. Parasite replication in the fish can cause extensive tissue damage resulting in the diseased state, enteronecrosis (previously termed ceratomyxosis) (Hallett and Bartholomew 2011). Upon maturation, myxospores are released from infected adult or juvenile carcasses and are available for uptake via suspension feeding by *M. speciosa*.

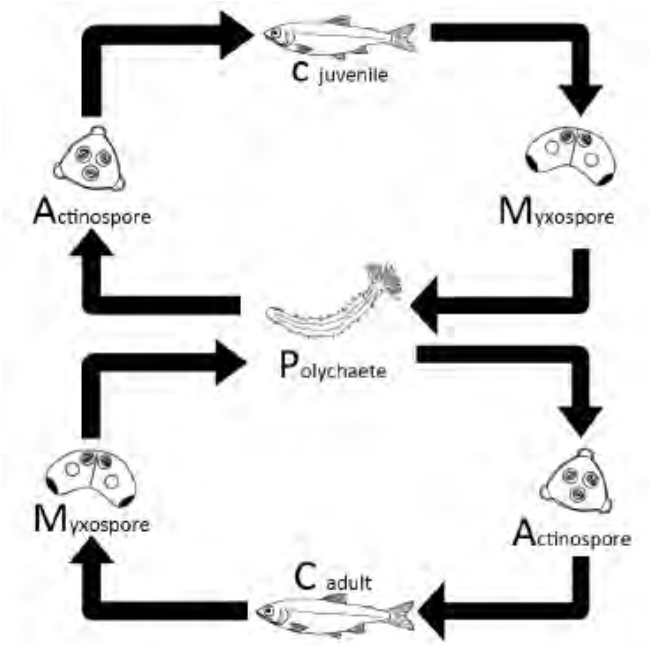

Figure 6-1. The life cycle of *Ceratonova shasta*. Actinospores released into fresh water from infected *Manayunkia speciosa* annelids develop into myxospores in the intestine of salmonids. Both juvenile and adult salmonids may become infected with actinospores and contribute myxospores to the system. Source: Foott et al. (2011).

Given the critical role of *M. speciosa* in the lifecycle of *C. shasta*, it is important to understand its lifecycle and habitat requirements. *M. speciosa* prefers depositional areas with low water velocity such as lake and reservoir in- and outflows, pools, eddies, riffles, and runs (Som et al. 2016). Runs and eddy-pools tend to have the highest relative *M. speciosa* densities and frequency of occurrence(Stocking and Bartholomew 2007). *M. speciosa* construct flexible tubes which allow them to suspension-feed (Som et al. 2016). *M. speciosa* reproduction typically peaks in the spring to early summer as temperatures increase (Som et al. 2016), and the reproductive cycle includes a stage in which non-feeding larva are brooded in the maternal tube until they reach suitable size for release (Som et al. 2016).

M. speciosa are thought to be infected with *C. shasta* myxospores through suspension feeding (Hallett and Bartholomew 2011), though infection in adult *M. speciosa* is relatively low (i.e., less than 6 percent prevalence of infection in the Klamath River from 2013 – 2018) (Bartholomew et al. 2018) . Neither horizontal (between *M. speciosa* individuals) nor vertical (adult to egg or larvae) *C. shasta* infection has been observed in *M. speciosa* (Hallett and Bartholomew 2011). Prevalence of infection is directly correlated with the number of adult salmon returning to spawn, but is also influenced by other factors contributing to myxospore production, survival, and availability (Som et al. 2018). Som et al. (2018) indicated that infected *M. speciosa* may occur in areas exhibiting a smaller range in water depth and velocity at peak flows, relative to areas with uninfected *M. speciosa* populations. Similarly, Som et al. (2018) noted that the highest *M. speciosa* prevalence of infection was observed during drought years with relatively homogenous Klamath River flow regimes. Finally, it appears that *M. speciosa* infection may be more likely if maturing *M. speciosa* leave maternal tubes during periods when myxospores are present in the water column and available for uptake (Alexander 2018).

Once myxospores have infected *M. speciosa*, the myxospores develop into actinospores (Hallett and Bartholomew 2011), a process that takes approximately 700 degree-days (Alexander 2018), or 7 weeks at 17°C (as cited in Hallett and Bartholomew 2011). Several hundred actinospores can be released each day from a single infected *M. speciosa* (Hallett and Bartholomew 2011). Actinospore concentrations (and presumably the rate at which actinospores are released from *M. speciosa* individuals) increase to measurable concentrations when water temperatures reach approximately 10°C, continuing to increase with increasing water temperatures up to 17°C and then decline as temperatures exceed 17°C (Foott et al. 2011). Actinospores are viable for up to 13 days at 11°C, but only 3 to 7 days at 18°C (Hallett and Bartholomew 2011). In the Klamath River system, actinospore concentrations typically peak in the late spring or early summer (Bartholomew et al. 2018, 2019), depending on water temperatures and degree-days within a given year. Annual maximum actinospore concentrations vary substantially between years (Bartholomew et al. 2018) due to a number of factors related to salmonid and *M. speciosa* life stage timing and densities as well as hydrologic and meteorological conditions (Som and Hetrick 2016; USFWS 2016b; Som et al. 2019). Similarly, actinospore concentrations tend to vary intra-annually between sampling sites, though the highest spore concentrations typically occur near the confluence of Beaver Creek (Bartholomew et al. 2018), where spawner carcass densities are typically highest.

Actinospores attach to salmonid gills, migrate to the gill blood vessels where replication occurs, and then migrate via the circulatory system to the intestine and other internal organs ((Hallett and Bartholomew 2011). Once in the intestines, actinospores develop into myxospores, typically taking 2 weeks at 18°C (Hallett and Bartholomew 2011). The progression of myxospore development is often fatal to the salmonid host; clinical signs of the disease state include necrosis of intestinal tissues, often accompanied by a severe inflammatory reaction (Hallett and Bartholomew 2011). Myxospores are released when the salmonid host dies (Hallett and Bartholomew 2011). As such, years with greater adult salmon returns, and areas with concentrated spawning and associated mortality may contribute substantially to the Klamath River myxospore load (Som and Hetrick 2016). Finally, neither horizontal (fish to fish) nor vertical (adult to egg) *C. shasta* infection has been observed in salmonids (USFWS 2016c).

The severity of *C. shasta* infection and related mortality in salmonids is affected by a variety of factors including dose (a mechanism of velocity and spore concentration), exposure duration, exposure temperature, fish rearing temperature, and the inherent resistance of the fish strain (Hallett et al. 2012; Som et al. 2019). For example, Som et al. (2019) estimated that the probability of survival in juvenile coho exposed to *C. shasta* spores dramatically declines with exposure time (Figure 6-2). Hallett et al. (2012) found that 5 genotype II actinospores per liter led to ≥ 40 percent mortality in coho at water temperatures greater than 15°C. Further, the authors found that time from exposure to mortality was influenced by water temperature and spore concentration, and water temperature explained a substantial part of this variation. Ray et al. (2012) also found that water temperature was negatively correlated with "mean days to death" after exposure to *C. shasta* in Chinook and coho salmon. Finally, it is also important to acknowledge that *C. shasta* infection does not always result in mortality. Indeed, infection at low doses does not necessarily lead to a diseased state and subsequent mortality unless the fish is overwhelmed by spores (Hallett et al. 2012).

Concentrations of specific genotypes of *C. shasta* spore may influence infection rate and severity and associated mortality in specific salmonid species (Atkinson and Bartholomew 2010). There are three genotypes of *C. shasta*, each correlating to specific salmonid hosts (Atkinson et al. 2018): genotype O - steelhead and redband trout, genotype I – Chinook salmon, and genotype II – coho salmon. Although, salmonids can be infected by all *C. shasta* genotypes, the response of hosts varies by genotype. Accordingly, genotype II is of particular interest in this BA, since it causes mortality for coho (Atkinson and Bartholomew 2010), and can successfully replicate in other host species. Hurst et al. (2019) found that Chinook salmon exposed to genotype I and genotype II had a more virulent response to genotype I, primarily early mortality of hosts, and that genotype II replicated more slowly but produced more myxospores. Furthermore, coinfection of genotypes versus sequential infection of different genotypes is also likely to influence the relative success of myxospore production. For example, coinfection inhibited maximum myxospore production in genotype II because genotype I caused host mortality too rapidly (Hurst et al. 2019). While the response of coho to mixed infections is unclear, the ability of *C. shasta* strains to coinfect and to replicate among different hosts warrants further attention in coho. It should also be noted that in natural systems, susceptibility to *C. shasta* varies among salmonid life stages and strains, which may influence the response of the host to mixed infections (Hurst et al. 2019).

The timing of spore release relative to the life stage and strain of the salmonid host also influences the susceptibility of fish to *C. shasta* infection. Juvenile salmon, including re-distributing young of year individuals, are particularly susceptible to infections by *C. shasta* during migration from April through July (NMFS 2012). Consequently, there is extensive monitoring of *C. shasta* prevalence of infection (POI) and associated mortality during this period each year. Between 2009 and 2019, *C. shasta* maximum observed POI at the Kinsman trap on the Klamath River (prior to the date at which 80 percent of outmigrating salmon juveniles passed the trap) ranged from zero percent in 2010 and 2013 to 100 percent in 2015 (Voss et al. 2018). In some years (e.g. 2010, 2013, 2014, 2016, 2017, and 2018), annual maximum POI occurred after the 80 percent outmigration date (True et al. 2017; Voss et al. 2018), suggesting that in some years the timing of juvenile salmon outmigration may influence exposure risk.

Since 2007, Oregon State University scientists have monitored mortality related to *C. shasta* exposure and infection through "sentinel studies" in which Klamath River (Iron Gate Hatchery and/or Trinity River Hatchery) Chinook, rainbow trout, and coho are held in live cages in the river (and thereby exposed to *C. shasta*) at various sites in April, May, June, and September (Bartholomew et al. 2018, 2019). From 2009 to 2018, April mortality was generally less than 15 percent for Chinook and close to 0 percent for coho, however, coho have not been monitored in all years (Bartholomew et al. 2019). In May during the same time period, Chinook mortality ranged from 90 (2015, Seiad Valley) to zero percent, with the highest observed percent mortality in 2014 and 2015 (Bartholomew et al. 2018). In June during the same time period, Chinook mortality ranged from 80 percent (2016, Orleans) to zero percent, with the highest percent mortality in 2009, 2014, 2015, and 2016 (Bartholomew et al. 2018). Similarly, for coho in June of 2009 through 2017, mortality ranged from approximately 70 (2014, Seiad Valley) to zero percent, with the highest percent mortality in 2009, 2011, and 2014 (Bartholomew et al. 2018). The relative impact of high mortality during these sentinel studies should be considered in the context of juvenile outmigration timing since the highest percent mortality often occurred after the 80 percent outmigration date.

Given the complex lifecyle of *C. shasta*, opportunities exist to disrupt *C. shasta* dynamics in the Klamath River. Increased flow is the primary mechanism known to facilitate mechanical disruption of potential and occupied *M. speciosa* habitat, dilute pathogen concentrations, and decrease in-stream temperatures. Thus, the disturbance created by high flow addresses the assertion that for an infectious zone to exist, there must be adequate *M. speciosa* habitat, stable flow, proximity to salmon spawning areas where release of myxospores occurs, and temperatures above 15°C (Som et al. 2016; USFWS 2016c). Accordingly, management actions to disrupt *C. shasta* have largely been focused on flow disturbance.

Sediment maintenance flows, or flushing flows, are a type of flow disturbance known to displace *M. speciosa*. Sediment maintenance flows are defined as any flow event that exceeds 6,030 cfs for at least 72 hours. The flushing flows mobilize the fine sediment surface layer and occur naturally in wet water years. Sediment mobilization can cause dislodgement and redistribution or reduction of benthos (e.g., Giller et al. 1991; Mosisch and Bunn 1997), such as *M. speciosa* and their preferred substrate. Indeed, monitoring of *M. speciosa* densities in 2017, a high flow year, revealed low densities relative to previous years (Bartholomew et al. 2018). However, the behavioral plasticity of *M. speciosa* allows the species to tolerate a wide range of velocities and can persist, disperse, and redistribute to more suitable habitat following dislodgment (Malakauskas et al. 2013; Alexander et al. 2014). In particular, microhabitat associated with *Cladophora* buffers against sediment disturbances from high flow events., and indeed, *M. speciosa* densities have been shown to be unaffected within those microhabitats in flow events greater than 5,000 cfs (Stocking and Bartholomew 2007).

It is also possible that increased discharge can dilute spore concentrations (Hallett et al. 2012). Hillemeier et al. (2017) recommended implementation of spring dilution flows when spore concentrations exceed 5 spores per liter or POI exceeds 20 percent. While these thresholds were based on mortality observations by Hallett et al. (2012), they do not account for the effect of water temperature Hallett et al. (2012). Although spore concentrations decreased following high flows in 2005, POI remained steady at approximately 40 percent (Hillemeier et al. 2017),

emphasizing the importance of other factors, such as temperature, that influence *C. shasta* infection in Chinook, as described above.

In 2018, Reclamation implemented two flows intended to disrupt *C. shasta* dynamics largely based on the Klamath River Disease Guidance Document (Hillemeier et al. 2017). A surface flushing flow (6,030 cfs for 72 hours) was released from IGD in early April to scour preferred *M. speciosa* fine sediment habitat. Additionally, a dilution flow (3,000 cfs until 50,000 AF is expended) was implemented in May with the intention of diluting *C. shasta* actinospore and myxospore concentrations within the water column (and to reduce salmon prevalence of infection). *M. speciosa* density was substantially reduced after the surface flushing flow in April 2018, relative to what was observed earlier in the spring (Alexander 2018). However, *M. speciosa* density rebounded by the time the dilution flow was implemented in May 2018 (Alexander 2018) . This information suggests that a surface flushing flow prior to February would likely allow for rebound of *M. speciosa* populations during the outmigration period (Alexander 2018), which would likely have implications for disease dynamics. Despite this rebound in *M. speciosa* in 2018, the POI in Chinook Salmon juveniles during the outmigration period was low relative to the 2009 – 2018 period of record.

In 2019, a surface flushing flow again occurred in April and dilution flow in June. Despite this, the majority of juvenile Klamath River Chinook Salmon were infected with *C. shasta* (Voss et al. 2019). In fact, POI in the first detection of 2019 was the highest value of the past 11 years of monitoring (Voss et al. 2019). The authors surmise that changes in environmental conditions and other factors that influence disease severity in salmonids (i.e. river temperatures, flows, and myxozoan exposure dose) may explain this unexpected POI. Indeed, 2019 was unique in the period of record, having severe spring spore concentrations (up to 160 spores per liter) despite wet water year conditions and an early season sediment flushing event (Bartholomew 2019).

Understanding the factors that influence *C. shasta* parasite abundance and their interactions is a critical need particularly given the unexpected spore concentrations observed in 2019. In Hillemeier et al. (2017) it is hypothesized that spore concentrations are influenced by flow, water temperature, annelid density, and salmonid carcass density. Reclamation frequently implements two types of flow releases to reduce spore concentrations: Surface flushing flows and dilution flows. Surface flushing flows mobilize fine sediment substrate, which displaces annelids and reduces available annelid habitat to areas with lower velocity and stable substrate (Malakauskas et al. 2013). Annelid displacement is supported by the Som et al. (2016) conceptual model for *C. shasta* spore concentration which suggests that annelid densities are reduced following late winter and early spring flushing events and the reestablishment of annelids to approximately pre-flush event densities occur the following fall (Reclamation 2018a). Dilution flows are intended to instantaneously reduce spore concentrations through release of water at Iron Gat Dam (Hillemeier et al. 2017). However, no clear relationship between dilution flows and spore concentration has been quantified to date. This is likely a result of having an insufficient number of dilution flow events occurring during periods of high spore concentrations (Som and Hetrick 2018).

Similarly, water temperatures have been shown to be closely related to spore concentration and infection prevalence. For example, water temperature increases up to 17C have been found to

cause higher rates of actinospore release by *M. speciosa* (Foott et al. 2011). Water temperature is also associated with risk of fish mortality from *C. shasta* (Foott et al. 2011; Som et al. 2019). Therefore, increased water temperature may have a twofold effect increasing spore concentrations, as well as infection potential and fish mortality.

Salmonid carcasses are an intermediate host for *C. shasta* and a single carcass can produce large amounts of actinospores (Foott et al. 2013), thus contributing to the likelihood of infection and mortality. However, Foott et al. (2016) found carcass removal did not measurably decrease spore concentrations, indicating that the relationship between carcasses and disease prevalence requires further investigation. In addition, annelid infection rates and density are also hypothesized to be associated with *C. shasta* prevalence (Foott et al. 2011). Relatively high rates of annelid infection (greater than 1%) coincided with high spore concentrations observed in 2015 (Bartholomew et al. 2016), although further observations and analysis would be needed to quantify the relationship between annelid infection and *C. shasta* proliferation.
While these empirical examples provide the basis for a theoretical model for *C. shasta* prevalence in the Klamath Basin, clear relationships to predict the influence of these factors on spore concentrations and salmonid mortality have not been quantified. Moreover, given the severity of disease conditions in 2019, increased sampling frequency of spore concentration and consistent monitoring of environmental conditions are essential for improving our understanding of disease dynamics in the Klamath. This highlights the need for quantification of flow, temperature, annelid density, and salmonid carcass density effects on spore concentrations and infection rates and subsequent mortality.

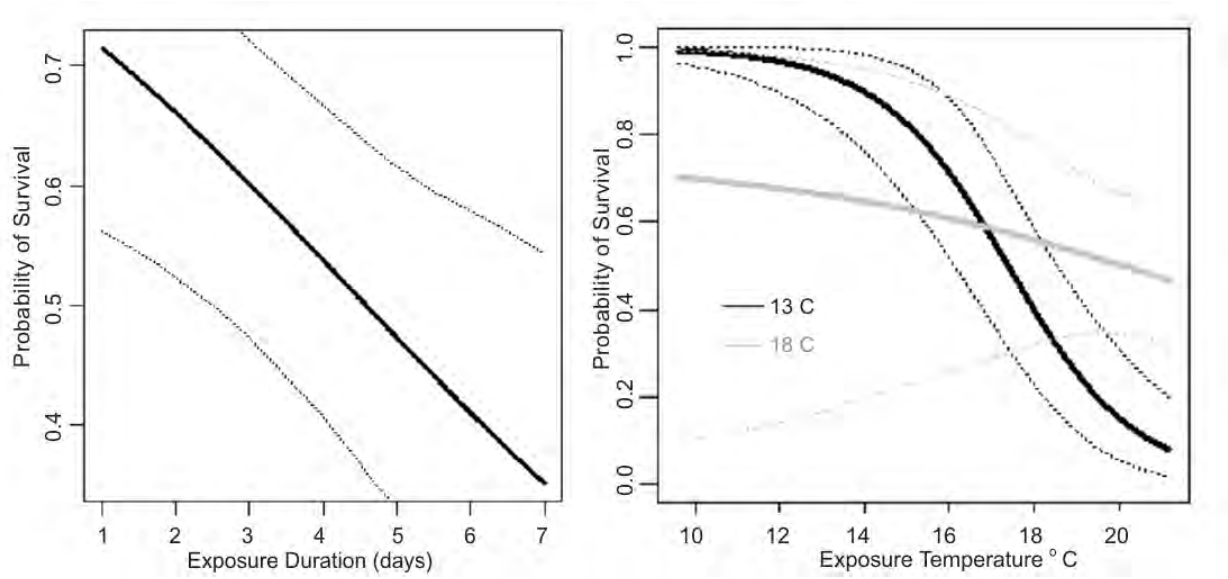

Figure 6-2. Left: the estimated effects of exposure duration to *C. shasta* (days) on the probability of survival of Klamath River coho. Solid lines computed as means of posterior distributions and dotted lines indicate 95% credible intervals. Right: the estimated effects of exposure temperature for two rearing temperatures (13°C black lines, 18°C gray lines) on the probability of survival of Klamath River coho. Source: adapted from Som et al. (2019)

6.1.6.5 Scientific Research

Excerpt directly from the USFWS 2019 BiOp (Page 89):

> *In 2018, the Service* [USFWS] *consulted (08EKLA00-2018-F-0065) on the effects to LRS and SNS of issuing scientific permits for the purpose of promoting recovery of the species under section 10(a)(1)(A) of the ESA. The consultation addressed purposeful take of the species using a variety of scientific collection techniques, marking, transport and relocation, and biological sampling. Take authorized as part of scientific research includes purposeful lethal take of 15 adults, 30 juveniles, 1,000 larvae, and 2,000 eggs. Additionally, non-lethal harm of 20 adults, 40 juveniles, 500 larvae, and 1,000 eggs was authorized. The Service considered the effects of the issuance of scientific permits (as currently proposed) on the reproduction, abundance, and distribution of the species, as well as how the aggregation of these effects will affect the overall survival and recovery of the species. The Service determined that the action was not likely to jeopardize the continued existence of the LRS and SNS, nor adversely modify the designated critical habitat of the species*.

6.1.7 Alterations to Address Effects

6.1.7.1 Rearing Programs

<u>Klamath Basin Sucker Rearing Program</u>

Excerpt directly from the USFWS 2019 BiOp (Page 90):

> *The Service started an assisted rearing program for Lost River and SNS in 2015 to supplement populations in UKL through augmentation. The primary target of the effort is SNS, but the lack of an effective way to identify live larvae and juveniles means that both species are collected and reared. In 2013, the Bureau of Reclamation agreed to fund such a program as a way to improve the environmental baseline of the species to minimize impacts to suckers that may result from Klamath Project operations with a 10-year target of releasing a total of 8,000 to 10,000 suckers with lengths of at least 200 mm. The Service funded expansion of the program and aims to collect around 20,000 larval suckers for assisted rearing in spring of 2019.*
>
> *The program was designed to maximize retention of genetic diversity and maintain natural behaviors post-release as much as possible (Day et al. 2017 pp. 306–307). Larvae are collected as they drift downstream in the Williamson River, so no brood stock are maintained, and the effects of artificial breeding are avoided. Collection efforts are currently spread across the drift season to maximize the genetic variability. Juveniles are stocked into semi-natural ponds and growth depends on a combination of natural and artificial feed.*
>
> *The first release of reared suckers into UKL occurred in spring 2018, and the proportion of released individuals that will join the spawning population is unknown. Thus, the assisted rearing program is likely to be a source of recruitment*

for both SNS and LRS in UKL, but the specific impact on population trajectories will be uncertain until information on survival and recruitment probabilities of released individuals is available. Support for the ongoing operation of this program is a component of the current proposed action.

Klamath Tribes Sucker Rearing

Excerpt directly from the USFWS 2019 BiOp (Page 90):

Included in the programmatic consultation on the issuance of recovery permits for actions involving LRS and SNS (08EKLA00-2018-F-0065) is assisted rearing, which allows for the collection of up to 75,000 wild-hatched larvae from the UKL system. The Klamath Tribes established a rearing program in 2018, and the first collections under the program were performed in spring 2018. A total of 20,000 larvae from the UKL system were brought into captivity. This first cohort is currently in captivity with an anticipated release date in spring 2020. The current permit allows for collection of up to 20,000 larvae per year. Although the scale of releases and the specific of effects of this action are unknown at present, it may result in additional recruitment to populations of LRS and SNS in UKL.

6.1.8 Ocean (for the Southern Resident Killer Whale)

6.1.8.1 Toxic Chemicals[6]

Various adverse health effects in humans, laboratory animals, and wildlife have been associated with exposures to persistent pollutants. These pollutants have the ability to cause endocrine disruption, reproductive disruption or failure, immunotoxicity, neurotoxicity, neurobehavioral disruption, and cancer (Reijnders 1986; Subramanian et al. 1987; de Swart et al. 1996; Bonefeld-Jørgensen et al. 2001; Reddy et al. 2001; Schwacke et al. 2002; Darnerud 2003; Viberg et al. 2003, 2006; Darnerud 2008; Legler and Brouwer 2003; Ylitalo et al. 2005; Fonnum et al. 2006; Legler 2008). SRKWs are exposed to a mixture of pollutants, some of which may interact synergistically and enhance toxicity, influencing their health. Contaminants of various types, including persistent organic pollutants that are believed to pose significant risks for SRKWs and other marine life, enter marine waters from numerous sources throughout the action area but are typically concentrated near populated areas of high human activity and industrialization (Mongillo et al. 2016). High levels of these pollutants have been measured in blubber biopsy samples from SRKWs (Ross et al. 2000; Krahn et al. 2007, 2009), and more recently, these pollutants were measured in fecal samples collected from SRKWs providing another potential opportunity to evaluate exposure to these pollutants (Lundin et al. 2016b, 2016a). Others come from agricultural areas (Krahn et al. 2007).

Killer whales are exposed to persistent pollutants primarily through their diet. For example, Chinook salmon contain higher levels of some persistent pollutants than other salmon species,

[6] *Note: This section originated from the NMFS 2019 BiOp (NMFS 2019) with portions of direct text included herein and has been adapted by Reclamation with the best available updated scientific information.*

but only limited information is available for pollutant levels in Chinook salmon (Krahn et al. 2007; O'Neill and West 2009; Veldhoen et al. 2010; Mongillo et al. 2016). The majority of growth in salmon occurs while feeding in saltwater (Quinn 2005). Therefore, the majority (> 96 percent) of persistent pollutants in adult salmon are accumulated while feeding in the marine environment (Cullon et al. 2009; O'Neill and West 2009). The marine distribution of salmon is an important factor affecting pollutant accumulation as is evident across the different salmon populations. For example, Chinook salmon populations feeding in close proximity to land-based sources of contaminants have higher concentrations (O'Neill et al. 2006). As SRKWs appear to be flexible in where they feed, the abundance in runs in clean areas relative to contaminated areas will influence the quantity of toxins consumed.

Upon consumption of prey species that contain these pollutants, these harmful pollutants are stored in the killer whale's blubber and can later be released. When the whales metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of other reasons, the pollutants are redistributed to other tissues. The release of pollutants can also occur during gestation or lactation. Once the pollutants mobilize into circulation, they have the potential to cause a toxic response. Therefore, nutritional stress from reduced Chinook salmon populations may act synergistically with high pollutant levels in SRKWs and result in adverse health effects.

6.1.8.2 Disturbance from Vessels and Sound [7]

Vessels have the potential to affect killer whales through the physical presence and activity of the vessel, increased underwater sound levels generated by boat engines, or a combination of these factors. Vessel strikes are rare, but do occur and can result in injury or mortality (Gaydos and Raverty 2007). In addition to vessels, underwater sound can be generated by a variety of other human activities, such as dredging, drilling, construction, seismic testing, and sonar (Richardson et al. 1995; Gordon and Moscrop 1996; NRC 2003). Impacts from these sources can range from serious injury and mortality to changes in behavior. In other cetaceans, hormonal changes indicative of stress have been recorded in response to intense sound exposure (Romano et al. 2004) and lower noise levels from vessel traffic when prey are in short supply (Ayres et al. 2012). Chronic stress is known to induce harmful physiological conditions, including lowered immune function, in terrestrial mammals and likely does so in cetaceans (Gordon and Moscrop 1996).

Killer whales rely on their highly developed acoustic sensory system for navigating, locating prey, and communicating with other individuals. While in inland waters of Washington and British Columbia, SRKWs were the principal target species for the commercial whale watch industry (Hoyt 2001; O'Connor et al. 2009) and encounter a variety of other vessels in their urban environment (e.g., recreational, fishing, ferries, military, shipping). The commercial whale watch industry has changed its focus to other whales (transient killer whales, humpback whales, and gray whales) due to decreasing presence of SRKWs in the Salish Sea and to reduce impact on them when they are present (Freedman, personal communication). Several main threats from

[7] *Note: This section originated from the NMFS 2019 BiOp (NMFS 2019) with portions of direct text included herein and has been adapted by Reclamation with the best available updated scientific information.*

vessels include direct vessel strikes, the masking of echolocation and communication signals by anthropogenic sound, and behavioral changes (NMFS 2008a). There is a growing body of evidence documenting effects from vessels on small cetaceans and other marine mammals (NMFS 2010b, NMFS 2016e, NMFS 2018b). Research has shown that the whales spend more time traveling and performing surface active behaviors and less time foraging in the presence of all vessel types, including kayaks, and that noise from motoring vessels up to 400 meters away has the potential to affect the echolocation abilities of foraging whales (Holt 2008; Lusseau et al. 2009; Noren et al. 2009; Williams et al. 2010). Masking by noise from vessels at much greater distances would be expected to influence foraging efficiency (Bain and Dahlheim 1994; Bain et al. 2014).. Individual energy balance may be impacted when vessels are present because of the combined increase in energetic costs resulting from changes in whale activity with the decrease in prey consumption resulting from reduced foraging opportunities (Williams et al. 2006a; Lusseau et al. 2009; Noren et al. 2009, 2012).

At the time of the whales' listing under the ESA, NMFS reviewed existing protections for the whales and developed recovery actions, including vessel regulations, to address the threat of vessels to killer whales. NMFS concluded it was necessary and advisable to adopt regulations to protect killer whales from disturbance and sound associated with vessels, to support recovery of SRKWs. Federal vessel regulations were established in 2011 to prohibit vessels from approaching killer whales within 200 yards (182.9 meters (m)) and from parking in the path of the whales within 400 yards (365.8 m). These regulations apply to all vessels in inland waters of Washington State with exemptions to maintain safe navigation and for government vessels in the course of official duties, ships in the shipping lanes, research vessels under permit, and vessels lawfully engaged in commercial or treaty Indian fishing that are actively setting, retrieving, or closely tending fishing gear (NMFS 2011a, 76 FR 20870).

Washington State enacted stricter regulations in 2019. Watching from within 300 yards from the side and 400 from behind were added to the 400 yards in front restriction. Further, vessel speed was restricted to 7 knots within ½ nautical mile (13 km/h within 926 m, WA SSSB 5577), since vessels going at no wake speed tend to be far quieter than vessels operating at cruising speed. This has the effect of reducing the typical received level from small craft from a maximum of 120 dB re 1μPa to 95 dB while observing SRKWs, and 105 dB while cruising by.

In the final rule, NMFS committed to reviewing the vessel regulations to evaluate effectiveness, and also to study the impact of the regulations on the viability of the local whale watch industry. In March 2013, NMFS held a killer whale protection workshop[8] to review the current vessel regulations, guidelines, and associated analyses; review monitoring, boater education, and enforcement efforts; review available industry and economic information and identify data gaps; and provide a forum for stakeholder input to explore next steps for addressing vessel effects on killer whales.

In December 2017, NMFS completed a technical memorandum evaluating the effectiveness of regulations adopted in 2011 to help protect endangered SRKWs from the impacts of vessel traffic and noise (Ferrara et al. 2017). In the assessment, Ferrara et al. (2017) used five measures:

[8] The presentations and supporting documents (including workshop notes) can be found at: http://www.westcoast.fisheries.noaa.gov/protected_species/marine_mammals/killer_whale/vessel_regulations.html.

education and outreach efforts, enforcement, vessel compliance, biological effectiveness, and economic impacts. For each measure, the trends and observations in the 5 years leading up to the regulations (2006-2010) were compared to the trends and observations in the 5 years following the regulations (2011-2015). The memo finds that the regulations have benefited the whales by reducing impacts without causing economic harm to the commercial whale-watching industry or local communities. The authors also find room for improvement in terms of increasing awareness and enforcement of the regulations, which would help improve compliance and further reduce biological impacts to the whales.

Most ships operating out of the Port of Vancouver have agreed to operate at lower speeds while killer whales are present. This results in a reduction of source levels by 5-110 dB and received levels by approximately 2.5 dB (other noise sources may exceed the received level from the slowed ship). The Port of Seattle has begun to explore implementing a similar system.

6.1.8.3 Oil Spills[9]

In the Northwest, SRKWs are the most vulnerable marine mammal population to the risks imposed by an oil spill due to their small population size, strong site fidelity to areas with high oil spill risk, large group size, late reproductive maturity, low reproductive rate, and specialized diet, among other attributes (Jarvela Rosenberger et al. 2017). Oil spills have occurred in the range of SRKWs in the past, and there is potential for spills in the future. Oil can be discharged into the marine environment in any number of ways, including shipping and rail accidents, refineries and associated production facilities, and pipelines. Despite many improvements in spill prevention since the late 1980s, much of the region inhabited by SRKWs remains at risk from serious spills because of the heavy volume of shipping traffic and proximity to petroleum refining centers in inland waters. In addition to the potential for major spills, small spills are common, and over 6.5 million liters of oil from cars and trucks are estimated to reach Puget Sound each year.

Repeated ingestion of petroleum hydrocarbons by killer whales likely causes adverse effects; however, long-term consequences are poorly understood. In marine mammals, acute exposure to petroleum products can cause changes in behavior and reduced activity, inflammation of the mucous membranes, lung congestion and disease, pneumonia, liver disorders, neurological damage, adrenal toxicity, reduced reproductive rates, changes in immune function (Geraci and Aubin 1990; Schwacke et al. 2013; Venn-Watson et al. 2015; de Guise et al. 2017; Kellar et al. 2017), and potentially death and long-term effects on population viability (Matkin et al. 2008; Ziccardi et al. 2015). At least 13 killer whale deaths were attributed to the Exxon Valdez spill, and additional 20 disappeared around the time of the spill, although were from poorly known pods, so it is less likely those were spill related. Further, 122 cetaceans stranded or were reported dead within 5 months following the Deepwater Horizon spill in the Gulf of Mexico (Ziccardi et al. 2015). An additional 785 cetaceans were found stranded from November 2010 to June 2013, which was declared an Unusual Mortality Event (Ziccardi et al. 2015). In addition, oil

[9] *Note: This section originated from the NMFS 2019 BiOp (NMFS 2019) with portions of direct text included herein and has been adapted by Reclamation with the best available updated scientific information.*

spills have the potential to adversely impact habitat and prey populations, and, therefore, may also adversely affect SRKWs by reducing food availability.

6.1.8.4 Quantity and Quality of Prey

Excerpt directly from the NMFS 2019 BiOp (Page 225):

> *There are many factors that affect the abundance, productivity, spatial structure, and diversity, of Chinook salmon and thus affect prey availability for the whales. For example, Lower Columbia River Chinook salmon populations began to decline by the early 1900s because of habitat alterations and harvest rates that were unsustainable, particularly given changing habitat conditions. Human impacts and limiting factors come from multiple sources, including hydropower development, habitat degradation, hatchery effects, fishery management and harvest decisions, and ecological factors that include environmental variability and predation of salmonids by a number of marine mammals and other marine species. Following along these lines, in 2011 NMFS convened an independent science panel to critically evaluate the effects of salmon fisheries on the abundance of Chinook salmon available to SRKWs. Overall, the panel concluded that at a broad scale, salmon abundance will likely influence the recovery of the whales, but the impact of reduced Chinook salmon harvest on future availability of Chinook salmon to SRKWs is not clear, and the panel cautioned against overreliance on correlative studies or implicating any particular fishery (Hilborn et al. 2012). Following the independent science panel approach on the effects of salmon fisheries on SRKWs (Hilborn et al. 2012), NMFS and partners have actively engaged in research and analyses to fill gaps and reduce uncertainties raised by the panel in their report.*

6.1.8.5 Salmon Harvest Actions

Excerpt directly from the NMFS 2019 BiOp (Page 238):

> *Coho salmon have been harvested in the past in both coho- and Chinook-directed ocean fisheries off the coasts of California and Oregon. However, stringent management measures, which began to be introduced in the late 1980s, reduced coho salmon harvest substantially. The prohibition of coho salmon retention in commercial and sport fisheries in all California waters began in 1994 (NMFS 2014a). With the exception of some tribal harvest by the Yurok and Hoopa Valley for subsistence and ceremonial purposes, the retention of coho salmon is prohibited in all California river fisheries. Tribal fishing for coho salmon within the Yurok tribe's reservation on the lower Klamath River has been monitored since 1992. The median Yurok harvest from the entire area from 1994 to 2012 was 345 coho salmon, which approximates an average annual maximum harvest of 3.1 percent of the total run (NMFS 2014a). The recent Yurok Tribe Fall Harvest Management Plan (Yurok Tribe 2018b) includes weekly fishing closures intended to protect coho salmon from harvest. The majority of coho salmon captured by Hoopa Valley tribal fisheries are Trinity River Hatchery origin fish (Orcutt 2015). With regards to ocean fisheries, in 1995, ocean recreational fishing for coho salmon was closed from Cape Falcon in Oregon to the United States/Mexico border. In order to comply with the SONCC coho salmon ESU conservation objective, projected incidental mortality rates on Rogue/Klamath River hatchery coho salmon stocks are calculated during the preseason planning process using*

the coho salmon Fishery Regulation Assessment Model (Kope 2005). Specifically, the Pacific Fishery Management Council applies a SONCC coho salmon ESU consultation standard requirement of no greater than a 13.0 percent marine exploitation rate on Rogue/Klamath hatchery coho salmon, which applies to incidental mortality in the Chinook salmon ocean fisheries from Cape Falcon in Canada to the United States/Mexico border (PFMC 2018). In summary, while major steps have been taken to limit effects of harvest on SONCC coho salmon, the population is still impacted by incidental mortality associated with various Chinook salmon fisheries, and by subsistence and ceremonial tribal fisheries (p. 102-3).

6.1.8.6 Scientific Research

Excerpt directly from the NMFS 2019 BiOp (Page 239):

Research activities on SRKWs are typically conducted between May and October in inland waters, and some permits include authorization to conduct research in coastal waters as well. In general, the primary objective of this research is population monitoring or data gathering for behavioral and ecological studies. Recent permits issued by NMFS include research to characterize the population size, structure, feeding, ecology, behavior, movement patterns and habitat use of the SRKWs, especially during the winter and spring when SRKWs are using coastal waters extensively. Impacts from permitted research include temporary disturbance and potential short term disruptions or changes in behavior such as feeding or social interactions with researchers in close proximity, and any minor injuries that may be associated with biopsy samplings or attachment of tags for tracking movements and behavior. We note that in 2016, a SRKW (L95) was found to have died of a fungal infection that may have been related to a satellite tag deployment approximately 5 weeks prior to its death (Carretta et al. 2018) (p. 239).

6.2 Status of the Species in the Action Area

Oregon and California federally-listed native freshwater fishes have declined as a result of the aforementioned anthropogenic influences and climate change and have benefited by anthropogenic improvements as also discussed above in Chapter 6.1. These species will likely continue to suffer population declines in the future in the action area due to existing stressors as well as long-term meteorological variability and extreme weather events. For this consultation, the action area (see Chapter 1.4 and 4.1) encompasses most if not all of the range of the species. Therefore, please refer to *Chapter 5, Aquatic Status of the Species and Designated Critical Habitat*, for more information on the status of the species in their entire range and the action area.

6.2.1 Lost River Sucker:

Lost River suckers (*Deltistes luxatus*; LRS) are a long-lived, and naturally occurring in lakes and tributaries in the Upper Klamath Basin (Moyle 2002a). Historically, LRS were so abundant that they were one of three sucker species used as sustenance for regional tribes. The LRS and SNS were federally listed as endangered throughout their entire range on July 18, 1988 (USFWS 1988, 53 FR 27130). The historical range of LRS has been severely reduced by drainage and

management of Lower Klamath and Tule lakes. Both species are present in UKL and tributaries, Clear Lake Reservoir and tributaries, Klamath River impoundments downstream to IGD, the Lost River, and the Tule Lake sumps (USFWS 2002). UKL supports the largest remaining populations of LRS (NRC 2004). The loss of historic populations and range is a continued threat to both the LRS and SNS. The range of LRS and SNS has not expanded nor contracted substantially since listing under the ESA in 1988. Two distinct spawning subpopulations of LRS are present in UKL, the shoreline spawning population spawns at springs along the eastern shoreline and a population that spawns in the Williamson and Sprague Rivers (NRC 2004). UKL supports the largest remaining populations of LRS (NRC 2004). For populations in UKL, abundance estimates are lower than ever. Abundance estimates for LRS-tributary spawners were at least 123,000 in 2010, and 62,000 in 2017. For populations in UKL, abundance estimates are lower than ever. Abundance estimates for LRS-tributary spawners were approximately 123,000 in 2010 and declined to 62,000 in 2017. Abundance estimates for LRS shoreline-spawners were approximately 14,000 in 2007 and declined to 8,000 in 2017. The majority of LRS in UKL are expected to be 25 to 27 years old. While LRS have been aged up to 52 years, not all suckers live this long. No recent recruitment of juveniles into the adult population has been documented. In contrast, recruitment has occurred in Clear Lake Reservoir for SNS, and adult populations are estimated to be less than 10,000.

6.2.2 Shortnose Sucker:

Shortnose suckers (*Chasmistes brevirostris*; SNS) are a long-lived, and naturally occurring in lakes and tributaries in the Upper Klamath Basin (Moyle 2002a). Historically, SNS were so abundant that they were one of three sucker species used as sustenance for regional tribes. SNS were federally listed as endangered throughout their entire range on July 18, 1988 (USFWS 1988, 53 FR 27130). The historical range of SNS has been severely reduced by drainage and management of Lower Klamath and Tule lakes. SNS are present in UKL and tributaries, Clear Lake Reservoir and tributaries, Klamath River impoundments downstream to IGD, the Lost River, the Tule Lake sumps, and Gerber Reservoir (USFWS 2002). The loss of historic populations and range is a continued threat to SNS. The range of SNS has not expanded nor contracted substantially since listing under the ESA in 1988. UKL supports the largest remaining populations of SNS (NRC 2004). Abundance estimates for SNS were approximately 26,000 in 2010 and decrease to approximately 11,000 in 2017. The majority of LRS in UKL are expected to be 25 to 27 years old. The oldest wild SNS was aged to be 32. No recent recruitment of juveniles into the adult population has been documented. In contrast, recruitment has occurred in Clear Lake Reservoir for SNS, and adult populations are estimated to be less than 25,000. There is relatively little data on suckers in Gerber Reservoir, but it is likely that there are at least 2,000-3,000 adult suckers.

6.2.3 Southern Oregon Northern California Coast Coho Salmon

The distribution of SONCC coho salmon within the whole ESU is reduced and fragmented, as evidenced by an increasing number of previously occupied streams from which SONCC coho salmon are now absent (NMFS 2001; Good et al. 2005; Williams et al. 2011, 2016). Populations of SONCC coho in the Klamath River include: the Upper Klamath River (comprised of tributaries and mainstem Klamath River from the mouth of Portuguese Creek at RM 128 upstream to IGD at RM 190 excluding the Shasta and Scott Rivers), the Middle Klamath River (comprised of tributaries and mainstem Klamath River from the Trinity River confluence at RM 43 upstream to the mouth of Portuguese Creek excluding the Salmon River), the Lower Klamath

River (comprised of tributaries and mainstem Klamath River downstream of the Trinity River confluence to the Klamath River mouth at RM 43), the Salmon River (RM 66), the Scott River (RM 144), and the Shasta River (RM 177; NMFS 2019). In recent years, the highest recorded escapement of adult coho salmon in the Klamath River has been to the Scott River sub-basin with an estimated 681 spawning individuals in 2018.

6.2.4 Southern Resident Killer Whale

While the overall range of SRKWs has remained from Central California to Southeast Alaska since at least the 1860's, usage of the range has been changing. They regularly occupied Hood Canal in the early 1900's but have not been observed there since 1995. Their regular presence in the eastern Salish Sea during the summer was documented for forty years but has been declining in recent years (Shields et al. 2018). Still, their wintertime use continues at similar levels to what it was decades ago. In the 1980's, they were observed in the southern part of their range about every five years, but now they are observed moving between California and British Columbia essentially every year. The SRKW population peaked at 98 in 1995 after recovering from collections for public display but was reported to be back down to 72 in early 2020 (Center for Whale Research, unpublished data).

6.3 Without Action Analysis

Environmental baseline is a concept that both courts and agencies have struggled to address for ongoing actions, but it is important in understanding the status of the species and factors affecting species environment within the Action Area but for the PA. In a consultation on a new action, where the status quo does not include the effects of the action under consultation because the action has not yet taken place, a simple projection of the status quo can often represent the without-action scenario. However, in a consultation on an ongoing action, the without-action scenario cannot be defined by simply projecting the status quo into the future, because doing so would improperly include in the baseline the continued effects of the action under consultation. Instead, in a consultation on an ongoing action, such as operation of the Klamath Project, the baseline analysis must project a future condition without the action. This allows for isolation of 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. Thus, to provide a snapshot of the species' survival and recovery prospects without the PA, Reclamation is analyzing a without-action scenario. The without-action scenario entails no future operations of the Klamath Project: in other words, no discretionary regulation of flows through the system, including, for example, storing and releasing water from reservoirs and delivering water otherwise required by contract.

Reclamation reviewed consultations on other ongoing water project actions to inform this analytical approach. Recently, in the USACE (2014) consultation with NMFS on the ongoing operation of the Daguerre Point and Englebright Dams in California, the agencies recognized that "effects attributable to the existence of a dam over which the agency has no discretion," as well as "to non-discretionary operations and maintenance should be included in the environmental baseline rather than attributable to the proposed action" (NMFS 2014b). The biological opinion utilized a predominantly qualitative analysis to represent the environmental

baseline, explaining how the existence of the dams as a baseline condition had multiple effects on the action area.

With this and other examples and the foregoing principles in mind, in the without-action scenario, Reclamation would not operate the Klamath Project to meet any environmental or contractual obligations, or other discretionary water deliveries. The without-action scenario is consistent with Reclamation's mandatory obligation to preserve the integrity of the facilities (per the Reclamation Safety of Dams Act P.L. 95-589). Described in more detail below, this condition essentially entails each of the facilities simply passing inflows.

Reclamation considered multiple types of structural configurations and gate positions to identify a configuration to protect the long-term integrity of the structures in a without-action scenario, regardless of hydrology. Therefore, settings for dams, gates and other structures, that could be damaged under high flow events, such as the river release gate and spillway bay settings at LRD, will be opened or set to ensure facility integrity is maintained.

Review of the hydrologic and operational record identified a historical example where Reclamation and the Klamath Project operated most Klamath River facilities with gates essentially fully open to pass inflow for the purpose of preserving the integrity of structures pursuant to the National Dam Safety Program. Reclamation selected a point in the historical record with high inflows and runoff, December 1964 through January 1965, that resulted in releases and overall operations that were solely intended to preserve the integrity of the Klamath Project facilities and human safety. The 1964-1965 event is the flood of record for the Klamath River, with large inflows at UKL and tributary runoff on the Lost River sub-watershed. Reclamation and the Pacific Power and Light Company (predecessor to PacifiCorp) operated Klamath Project facilities for the purpose of preserving the integrity of the facilities.

During the event, maximum flows in the Lost River at the Lost River Diversion Dam were 6,220 cfs. The gates on the Lost River Diversion Channel were fully open, resulting in up to 3,000 cfs being discharged to the Klamath River by gravity flow. The remaining flow (3,220 cfs) spilled over the stoplogs on Lost River Diversion Dam and subsequently accumulated in the Tule Lake Sumps. The water surface elevation in the Tule Lake Sumps increased from 4,033.7 to 4,035.5 feet (USBR datum), equating to 22,744 acre-feet of stored water. To prevent overtopping Tule Lake Sump dikes, portions of the Tule Lake Reserved Sumps (Sump 2 and 3) were intentionally flooded by opening canal headgates and selectively breaching dikes. In the without-action scenario, these measures would not occur, resulting in the Tule Lake Sump dikes being overtopped at elevation 4,035.5 feet, flooding Sumps 2 and 3 initially, but also potentially homesteaded lands and municipalities (Newell, Tulelake, and Malin) within the former lakebed of Tule Lake

During the 1964-1965 flood, the 3,000 cfs discharged from the Lost River Diversion Channel into the Klamath River by gravity flow was combined with releases from LRD of up to 7,500 cfs, which would be expected to be similar in a without-action scenario, with the gates and stoplog bays on LRD fully open. The combined flow in the Keno Impoundment was released by Pacific Power and Light from Keno Needle Dam and then conveyed through the company's remaining hydroelectric facilities before being released to the lower Klamath River.

One important physical change to take into account is that following the 1964-1965 flood, Pacific Power and Light replaced Keno Needle Dam with the current Keno Dam and made approximately 17 miles of upstream channel improvements. This work was designed to allow for up to 15,000 cfs to be passed through the Keno Impoundment without raising water surface elevations in the Klamath River above normal operating levels (4,086.5 feet, USBR datum).

The resulting situation is an example of where the infrastructure is operating "without action," for the purpose of preserving the existence of the structures. This is not a separate alternative, but a historical snapshot that provides the basis for isolating the causal effects of operations and, thus, determining whether the effects of operations would jeopardize the species. Consistent with this example, the existence of the dams as a component of the without-action scenario is represented by setting the outlet works on storage facilities to release inflows in a way that ensures the structural integrity of the facilities in any hydrologic condition over the period of the PA.

To establish the species' conditions absent operations, Reclamation used professional judgement and expert opinion to describe the resulting ecological effects. This approach represents the absence of the action under consultation using the qualitative analytical method. Based on the information available, this approach provides the most reasonable representation of the without-action component of the environmental baseline in this consultation.

While all demands continue to exist, the without-action scenario assumes that the Klamath Project will not be operated to meet those demands. However, with respect to irrigation, landowners with water rights independent of the Klamath Project and who are able to exercise such rights without the use of Project facilities, would reasonably be expected to continue to divert available supplies. Such diversions include approximately 17,000 acres irrigated by direct diversions from UKL, through private facilities over which Reclamation holds no discretionary control. There are also approximately 7,300 acres irrigated by direct diversions from the Keno Impoundment reach, again through private facilities that Reclamation has no control over. There are also landowners and entities along the Lost River with non-federal diversion works that would continue to operate. Most notably, Horsefly Irrigation District serves approximately 10,000 acres of irrigable land around Bonanza, through district- and individually-owned pumps in the Lost River. Horsefly Irrigation District has water rights independent of the Klamath Project that are recognized by the State of Oregon and which the district would presumably continue to exercise in a without-action scenario. Also, certain lands within the Project have with groundwater wells and associated water rights that can be used for irrigation purposes without any reliance upon Project facilities.

The detailed assumptions regarding hydrology, facilities, and other criteria in the without-action scenario are explained below.

6.3.1 UKL, Link River Dam, and the A Canal

In the without-action scenario, the headworks on the A Canal would remain closed and the fish screening system off, so no diversions would occur through the A Canal to irrigated lands within the Klamath Project. Other direct diversions from UKL, for irrigation and other purposes, would

continue consistent with historical practices, as Reclamation has no discretionary control over non-federal diversion works.

The gates and spillway bays on LRD would be set to the fully open position in order to pass flood flows while maintaining the integrity of the dam. While PacifiCorp currently operates LRD, including making daily adjustments to releases for purposes of facilitating downstream hydroelectric power production, Reclamation owns the dam. In the hypothetical without-action scenario, Reclamation would instruct PacifiCorp to open the gates on the dam and PacifiCorp would not be able to operate the dam independently for downstream power production purposes.

The gate on LRD discharging water into the fish ladder would be closed, to avoid damage to the facility due to lack of maintenance, making the ladder inaccessible for fish. The separate gates that discharge into the Eastside (Ankeny) and Westside (Keno) power canals are operated by PacifiCorp, subject to its license for these facilities with FERC. Currently, PacifiCorp is not regularly operating these power canals and has plans to put stoplogs in front of the gates on LRD for these canals. For the without-action scenario, this current condition is assumed to continue, meaning no active diversions into these two power canals.

As described previously, in 1921, the California-Oregon Power Company dredged a channel through the marsh at Putnam Point on the outlet of UKL, approximately half a mile upstream from LRD. The invert (bottom) of this 30-foot-wide channel originally had an elevation of approximately 4,131.0 feet (USBR datum). Additionally, the company dredged two 40-feet-wide approach channels through the reef immediately upstream LRD, with an invert elevation of 4,130.0 feet (USBR datum). These dredged channels at the outlet of UKL are assumed to exist in the without-action scenario.

With the gates open and stoplogs removed on LRD, outflow from UKL would be controlled through these channels and would be a function of water surface elevation and inflows to the lake. At the lower elevations, the hydraulic backwater effect of these channels causes the outflow capacity to be significantly reduced. For instance, when the water surface elevation is at 4,136.0 feet, the maximum outflow capacity is approximately 300 cfs or less.

With continuous inflow to the lake, even under drier conditions, the reduction in outflow capacity will generally cause the water surface elevation in UKL not to fall below 4,136.0 feet, although it is assumed that under extremely dry hydrologic conditions, the water surface elevation could potentially go lower. Without historical operating experience, it is unclear how low the water surface elevation on UKL could potentially go.

Generally, in most years, it is anticipated that the water surface elevation in UKL would range between 4,136.0 and 4,140.0 feet. In drier years, the lake would not exceed 4,138.0 feet. In wetter years, the lake could be above 4,141.0 feet, sometimes for several months, but only above 4,142.0 under the most extreme hydrologic conditions.

Outflow from UKL would, except under the most extreme circumstances, range from roughly 200 to 4,000 cfs. Outflow would be dependent upon a combination of water surface elevation and inflow.

The existence of any link between water surface elevations and water quality conditions in UKL has been investigated, but to date, no discernable relationship has been identified. Accordingly, it is assumed that water quality in UKL would remain unchanged from current conditions under the without-action scenario.

6.3.2 Klamath River, PacifiCorp Hydroelectric Facilities, and Yurok Boat Dance

Keno, J.C. Boyle, Copco 1, Copco 2, and IGDs are all owned and operated by PacifiCorp, pursuant to operating licenses with the Federal Energy Regulatory Commission (FERC). The without-action scenario assumes that PacifiCorp will continue to operate these dams consistent with its federal operating license.

The dams have limited storage capacity – less than 12,000 AF combined – and are generally operated near full pool to produce head for hydroelectric power production. Accordingly, there is usually little capacity in these reservoirs to store water, resulting in inflows generally being passed through and continued downstream of the reservoirs. The without-action scenario assumes that flows in the Klamath River, both upstream and downstream PacifiCorp's dams will be influenced by current hydrologic conditions and existing past and present impacts.

In the Keno Impoundment, flows are expected to constitute the aggregate of releases from LRD out of UKL and gravity discharges from the Lost River Diversion Channel. Other natural accretions in this reach are relatively small, with the Klamath Straits Drain not in operation. Flows would also be affected by diversions assumed to continue in the without action scenario, including diversions to Klamath Drainage District and Lower Klamath National Wildlife Refuge through the Ady and North canals.

The maximum capacity of the Lost River Diversion Channel is approximately 3,000 cfs. Runoff in the Lost River watershed generally occurs very quickly. During rain events and with the annual snowmelt, the Lost River Diversion Channel would likely release 3,000 cfs to the Klamath River for extended periods, but runoff generally diminishes to less than 100 cfs in the mid-summer each year.

As noted previously, under the without-action scenario, with the gates open and stoplogs removed on LRD, the water surface elevation on UKL is not expected to exceed 4,142.0, except under extreme hydrologic circumstances. When the water surface elevation of the lake is at 4,142.0 feet, the maximum release capacity (depending on inflows) is approximately 4,000 cfs. Between the releases from LRD and the discharges from the Lost River Diversion Channel, the maximum combined flow in the Klamath River at Keno Dam is estimated to be approximately 7,500 cfs.

Through operation of Keno Dam, PacifiCorp maintains the water surface elevation in the Keno Impoundment between 4,085.0 and 4,086.5 feet above sea level (USBR datum). Under high flow conditions, it is assumed that PacifiCorp will operate Keno Dam in a manner to pass the flow necessary to avoid flooding private and public lands, consistent with its various operating agreements with landowners and other public and private entities (including Reclamation). As Keno Dam and the associated channel improvements are designed to pass up to 15,000 cfs, the dam should be able to safely handle anticipated flows under the without-action scenario.

Because operation of Keno Dam would follow historical operations and given the water quality conditions in UKL are assumed to remain consistent with current conditions, it is assumed that water quality in the Keno Impoundment would also remain consistent with current conditions.

Natural accretions to the Klamath River between Keno and IGDs are generally small and dependent upon hydrologic conditions. Under wetter conditions, such as a rain-on-snow event, accretions in this reach can temporarily be upwards of 5,000 cfs, but outside such events, the influence of accretions in this reach on the flow of Klamath River at IGD is relatively small.

During a hydrologic event with accretions of 5,000 cfs, it is anticipated that flows at IGD could be in excess of 10,000 cfs. Generally, these conditions occur in the winter period, when UKL is likely still filling and outflow capacity constrained, thus attenuating flows in the river. UKL would be expected to reach its maximum outflow capacity, as the water surface elevation approaches 4,142.0 feet, later in the spring or summer (March to June), when accretions between Keno Dam and IGD are less likely to be elevated.

Between the continuous runoff from the Lost River watershed, particularly during the winter period, when UKL is still filling, followed by the subsequent filling and steady outflow from UKL during the late spring and summer, flows at IGD would, under wetter conditions, be in excess of 3,000 cfs for extended periods, from mid-winter through mid-summer. Under drier conditions, particularly years when the water surface elevation on UKL does not exceed 4,138.0 feet, flows at IGD may not exceed 3,000 cfs over the course of the year, and may be less than 1,000 cfs for longer than two months in the late summer and fall. Conditions would generally range between these extremes depending on hydrologic conditions in the Upper Klamath Basin.

Downstream of IGD, other tributaries, such as the Scott, Shasta, and Trinity rivers, significantly contribute to the flow of the Klamath River. Current contributions from these sources, reflecting past and present impacts, are assumed to continue under the without-action scenario.

In the without-action scenario, releases from UKL would not be made for supporting the Yurok Boat Dance ceremony. The ceremony occurs in August or September and requires flows of at least 3,000 cfs downstream of IGD. Whether such flows would occur would depend on natural hydrology and/or other actions outside the scope of this analysis.

6.3.3 Lost River Diversion Dam and Lost River Diversion Channel

Under the without-action scenario the gates of the Lost River Diversion Channel would be set fully open on both ends of the channel. The gates are set at open as opposed to closed to preserve Project facilities, particularly facilities downstream of the Lost River Diversion Dam (e.g., Anderson-Rose Dam, Tule Lake Sump dikes, multiple pumping plants) to the maximum possible extent. If the gates on the Lost River Diversion Channel are closed, all the flow of the Lost River would flow to the Tule Lake Sumps and eventually (i.e., within 1-2 years) flood and damage Project facilities (in addition to other public and private infrastructure and property).

With the gates on the channel open and regular gravity diversions to the Klamath River, it is uncertain to what extent Tule Lake would flood and Project facilities are less likely to be inundated.

The stoplogs in the spillway bays on the Lost River Diversion Dam would remain in place, to preserve proper functioning of the Lost River Diversion Channel for the same reason the gates on the diversion channel would be open – for the maximum preservation of downstream facilities. The stoplogs in the Lost River Diversion Dam maintain an upstream water surface elevation of 4,092.0 feet (USBR datum), allowing gravity flow through the diversion channel. The concrete sill on the spillway bays with the stoplogs removed is at the elevation 4,087.0 feet.

Note that the effect of keeping the gates on the Lost River Diversion Channel open and the stoplogs on the Lost River Diversion Dam in would be to continue diverting the entire flow of the Lost River, up to 3,000 cfs, to the Klamath River at all times of the year. This condition would not have occurred historically, prior to construction of the Lost River Diversion Channel. Historically, no water from the Lost River drained to the Klamath River.

In a without-action scenario, during a 100-year event like the 1964-65 flood, it is unlikely that there would be any difference in flow through the Lost River Diversion Channel with or without the stoplogs in place on Lost River Diversion Dam; however under more typical flows in the Lost River, without the stoplogs in place, the flow through the channel would be constrained (even reversed), resulting in additional water being released to Tule Lake Sumps and eventually damaging other Project facilities.
All the structures on the Lost River Diversion Channel that operate to divert water from the channel for irrigation purposes, most notably at Station 48 and the Miller Hill Pumping Plant, would be closed.

6.3.4 Gates in the Railroad Embankment at Ady

As discussed previously, through a 1907 agreement with the Southern Pacific Company and California and Northeastern Railway Company (predecessors to Union Pacific), Reclamation authorized the railroad to construct an embankment across the Klamath Straits adjacent the Klamath River. The Klamath Straits was closed in 1912 and then all flow was controlled through the concrete structure that Reclamation had the railroad install in the embankment.

Permanent gates were installed in the structure in 1921. These gates can be operated to control flow through the embankment. Reclamation's contracts with the railroad and Klamath Drainage District provide that the United States retains absolute control over operation of the gates and control of the flow of water through the embankment.

In the without-action scenario, it is assumed that because Reclamation is not taking discretionary actions, Reclamation would not be exercising its authority to control flow through the gates in the concrete structure in the railroad embankment. Maintaining these gates in the open position creates no additional risk to the structural integrity of other Klamath Project facilities and is more protective of the gates themselves.

Immediately downstream of the gates in the railroad embankment, Klamath Drainage District has constructed a control structure, that serves as the headworks of the Ady Canal. The gates on these headworks are manipulated to control diversions into the Ady Canal, which is a non-federal facility. The U.S. Fish and Wildlife Service has an agreement with Klamath Drainage

District to use the Ady Canal for conveying water to LKNWR, but Reclamation has no administrative jurisdiction over that agreement or the canal itself.

In the without-action scenario, with the gates in the railroad embankment open, it is assumed that Klamath Drainage District and the U.S. Fish and Wildlife Service would continue to divert water from the Klamath River through the Ady Canal because the water would physically be available for diversion and there would be no water right or other legal limitations to prevent them. As a result, water diversions from the Klamath River into the Ady Canal are expected to be consistent with historical demands of KDD and LKNWR. The Ady Canal serves approximately 15,200 acres within Klamath Drainage District, including lands in the Oregon portion of LKNWR.

6.3.5 North Canal

Diversions into the North Canal would continue under the without-action scenario, as the North Canal is owned and operated by Klamath Drainage District. Reclamation has no discretionary control over the gates that control diversions from the Klamath River into the North Canal. The North Canal serves approximately 10,700 acres within Klamath Drainage District.

6.3.6 Lower Klamath National Wildlife Refuge

Because Reclamation would not exercise its discretionary authority to close the gates in the railroad embankment, the USFWS would continue to exercise water rights, including federal reserved water rights, appurtenant to lands within LKNWR and independent of the Klamath Project. LKNWR comprises approximately 51,000 acres, of which approximately 47 percent is open wetland areas, 38 percent is rangelands/pasturelands, and 15 percent is croplands. The federal reserved water rights for LKNWR, established by the Executive Orders reserving these lands, provide for the use of water for waterfowl conservation purposes and as currently determined in the Klamath Basin Adjudication, allow for up to approximately 113,000 acre-feet of water to be diverted annually from the Klamath River.

6.3.7 Klamath Straits Drain

In the without-action scenario, Pumping Plants E, EE, F, and FF on the Klamath Straits Drain would be turned off to avoid breakage and destruction of the facilities due to lack of maintenance. Water that accumulates in the Klamath Straits Drain (from agricultural operations, natural precipitation, or otherwise) would not be pumped to the Klamath River. Klamath Drainage District and USFWS would have to find alternative means of disposing excess drainage, such as storing it in Miller Lake or retaining it in flooded wetlands. As currently the Klamath Straits Drain is the only physical means of exporting drainage from Lower Klamath to the Klamath River, it is assumed that no water will be discharged into the river from Klamath Drainage District or LKNWR. Ceasing return flows to the Klamath River via the Klamath Straits Drain would eliminate one source of excess nutrients and other contaminants that contribute to poor water quality conditions in the Keno Impoundment; however, impaired water quality is expected to continue to occur given the water quality conditions in UKL remaining unchanged.

6.3.8 Tule Lake Sumps, Anderson-Rose Dam, and Pumping Plant D

In the without-action scenario, the gates on the J Canal would be closed and all flow in the Lost River downstream of Lost River Diversion Dam would enter the Tule Lake Sump 1. Pumping Plant D would be turned off to avoid breakage and destruction of the facilities due to lack of

maintenance. The other pumps that also pump water from or to the Tule Lake Sump 1 would similarly be turned off.

Water would gradually accumulate in the Tule Lake Sump 1 until breaching or overtopping the surrounding dikes and flooding Sump 2 and 3. The active storage capacity of Sump 1 is approximately 30,000 acre-feet. With Pumping Plant D turned off and all flow in the Lost River above 3,000 cfs being spilled over the Lost River Diversion Dam, it is likely that Sump 1 would be full in less than one year. When Sump 1 is full to elevation 4,035.5 feet, the dikes will likely breach or be overtopped, filling Sump 2 and 3. The dikes surrounding Sumps 2 and 3 are constructed to an elevation of between 4,040.0 and 4,041.0 feet but will be structurally compromised at the water surface elevation of 4,037.0 feet. The storage capacity of Tule Lake Sumps 1, 2, and 3 at this elevation is 170,500 acre-feet. When this capacity is met, dikes will likely begin to breach, causing additional flooding on private lands surrounding the Tule Lake Sumps. The duration, magnitude, and frequency of flooding areas outside the Tule Lake Sumps will depend on hydrologic conditions.

Inflows to Tule Lake Sumps are anticipated to be larger than historically observed, given the additional releases from Clear Lake and Gerber reservoirs that would occur with the gates on the dams fully open. To what extent these additional releases from Clear Lake and Gerber reservoirs would gravity flow through the Lost River Diversion Channel to the Klamath River, versus being spilled to Tule Lake, would depend on the hydrologic conditions at the time. To the extent that Lost River flows at the Lost River Diversion Dam are at or less than approximately 1,300 cfs, the additional combined releases through the outlet works on Clear Lake and Gerber reservoirs of up to 1,680 cfs will gravity flow to the Klamath River.

Inflows to Tule Lake Sumps are also anticipated to increase over recent historical conditions based on the lack of irrigation diversions into the J Canal. Water that is typically diverted for irrigation purposes would instead pass through or over Anderson-Rose Dam and be flow into the sumps.

6.3.9 Clear Lake Reservoir

Under the without-action scenario, the gates on Clear Lake Dam would be set to the fully open position in order to pass flood flows while maintaining the integrity of the dam. The maximum release capacity through the gates on Clear Lake Dam is 780 cfs.

Because the gates are assumed to be in the fully open position, the water surface elevation of Clear Lake Reservoir would be lower than observed since construction of the dam in 1911. There would be times, particularly in the spring months, when inflows to Clear Lake would exceed release capacity at the gates, resulting in water being temporarily impounded. However, it is not expected that there would be any sizable interannual storage in the reservoir (i.e., above the “dead pool” elevation), given the combined effect of outflow and evaporation from the water surface.

Recent operational experience has shown that when water surface level in Clear Lake Reservoir reaches the elevation of 4,522.0 feet, the channel between the lake and the dam is significantly constrained, to the point of ceasing all outflow. This channel was historically dredged, but has not been since the 1980s and has silted in.

At a water surface elevation of 4,522.0 feet, the channel between Willow Creek and the east lobe of Clear Lake Reservoir also become hydrologically disconnected at that elevation, with Willow Creek flowing directly to the dam forebay. The volume of stored water at 4,522.0 feet is approximately 58,000 acre-feet and the surface area roughly 14,500 acres.

6.3.10 Gerber Reservoir

In the without-action scenario, Gerber Dam release gates would be set to the fully open position in order to pass flood flows while maintaining the integrity of the dam. The maximum outlet capacity of the gates on Gerber Dam is 900 cfs.

Similar to Clear Lake Reservoir, although there would be times, particularly in the spring, when inflow to the reservoir would exceed outlet capacity, causing the impoundment of water, this storage would be only temporary and it would be expected the reservoir would completely drained each year (i.e., with a surface area of less than 100 acres). The outlet works are located at the base of the dam, at an elevation 4,772.5 feet (USBR datum), with no inactive "dead pool" storage.

The volume, duration, and frequency of temporary storage of water behind Gerber Dam would vary based on hydrologic conditions, particularly the rate and timing of snowmelt and associated runoff upstream.

6.3.11 Other Diversion Works

Similar to Anderson-Rose Dam, both Malone and Miller Creek diversion dams would be fully open, to pass all flows and protect the integrity of the structures. At Miller Creek Diversion Dam the stoplogs between the concrete piers would be removed, allowing the channel to generally function at its normal capacity up to 1,500 cfs. At Malone Diversion Dam, the two manually-operated radial gates on the dam's outlet works would be fully opened to allow up to 4,000 cfs to pass. Based on historical inflows, there would be no temporary storage behind Malone Dam, even with maximum outflow through the gates on Clear Lake Dam. The gates on the three canals that divert from Malone and Miller Creek diversion dams would all be fully closed, preventing any diversions from occurring.

Reclamation has no discretionary control over the operation of other non-federal diversions along the Lost River, including operation of various small dams in the stream channel. Among these dams are included Harpold Dam (owned and operated by Horsefly Irrigation District) and the check dam at the Lost River Ranch (privately owned). In the without-action scenario, it is assumed that these dams (and associated irrigation operations) will continue consistent with historical practices.

6.3.12 Non-Operational Actions

Under the without-action scenario, Reclamation would not undertake the various conservation measures undertaken in connection with the Klamath Project. Reclamation would not provide funding to continue support of USFWS' sucker captive recovery program and Sucker Recovery Implementation Team. Reclamation would also not fund USFWS' sucker monitoring in UKL, Clear Lake Reservoir, and Gerber Reservoir. Additionally, Reclamation would not fund the

Coho Restoration Grant Program. Reclamation would not provide funding to OSU and USFWS for salmon disease monitoring on the Klamath River.

7 Effects of the Action on the Lost River Sucker and the Shortnose Sucker

7.1 Analytical Approach

Chapter 7 of the BA evaluates and characterizes impacts of implementing the PA to individuals and populations of both LRS and SNS and their designated critical habitat in beneficial and adverse ways relative to the without-action alternative and historic operations. The species status and environmental baseline (Sections 5 and 6) are aggregated with the effects of the PA to assess the overall effects on the species. Specifically, this section analyzes the effect of storing and diverting water for Klamath Project purposes on the endangered LRS and SNS. When effects to individuals and populations of both species are addressed, the generic expression "*suckers*" is used. When species differentiation is required, the text names the species of interest. This section is organized by hydrologic watersheds of the Upper Klamath Basin: the Klamath River Basin and the Lost River Basin. These watersheds closely emulate Recovery Units and management units within the Revised Recovery Plan for the LRS and SNS (herein referred to as the Recovery Plan; USFWS 2012a).

The PA is the continued operation of the Project including storage and delivery of irrigation water, and the continued operation and maintenance of canals, dams, and pumps (*see* Chapter 4.3, Proposed Action). The Effects Analysis of the PA are measured against the without-action scenario (Environmental Baseline) on suckers in UKL is conducted by reviewing model output on lake surface elevation provided by the Klamath Basin Planning Model (KBPM) and its impact on sucker habitats at each life history stage, and direct impacts from lake surface elevations to individual suckers. The effects analysis also discusses anticipated impacts without-action to operate and maintain the Project infrastructure as described in Chapter 6. Environmental Baseline. Impacts from the PA are considered in relation to impacts from the without-action scenario, in an effort to better understand and evaluate the impacts of the PA itself.

The PA includes storage and delivery of irrigation water from Clear Lake Reservoir and Gerber Reservoir, and regulating surface elevations of Tule Lake and the Keno Impoundment, consistent with the 2019 Biological Opinion (USFWS 2019a), including maintenance of surface elevations at or above minimum levels for each body of water. The PA contains a minimum September 30 surface elevation for both Gerber and Clear Lake reservoirs. At Gerber and Clear Lake reservoirs, inflow forecasts, evaporative and seepage estimates, and outflow measurements are monitored during in-season management to provide for elevations at or above the respective September 30 minimum surface elevations. In order to analyze the extent of impacts to endangered suckers at both locations resulting from the PA, a review of surface elevations, in conjunction with biological information at Gerber and Clear Lake reservoirs is used to evaluate the frequency of lake elevations that are likely to occur relative to those that would occur in the Without-action scenario, and relative to historic surface elevations at these facilities. The PA is to operate Keno Impoundment with a consistent surface elevation of 4,086.5 feet and to operate

the Tule Lake Sumps with relatively consistent surface elevation at or above 4,034.0 feet. At Tule Lake Sump 1A, minimum surface elevations are maintained April through September to facilitate irrigation deliveries and protect endangered suckers. Minimum surface elevations are maintained October through March to protect endangered suckers and for flood control purposes (USFWS 1992). Surface elevations in the Keno Impoundment are maintained to facilitate irrigation and water operation infrastructure maintenance.

7.1.1 Use of the Period of Record Hydrograph and Klamath Basin Planning Model as a Tool to Analyze Project Effects

This analysis assesses a range of hydrologic scenarios and the associated water levels for LRS and SNS habitats in the Upper Klamath Basin, describes a range of possible conditions that could occur in the term of this Biological Assessment, and assesses the potential impacts of storing and delivering water to these listed species. Specifically, historic hydrologic conditions were modeled where the Period of Record (POR) for different reservoirs were water years 1911–2019 for Clear Lake, 1925–2018 Gerber Reservoir, and 1981-2019 for Upper Klamath Lake (UKL). The POR for UKL is shorter because the model relies on reconstructed NRCS forecasts of water supply, for which relevant data is only available beginning October 1980 (water year 1981). The Klamath Basin Planning Model (KBPM) was developed in Water Resource Integrated Modeling System software (WRIMS) and is described in detail in Section 4 and appendix 4A. Recent climate trends and current water-uses are likely captured in the POR used for this analysis which includes dry, average, and wet years.

During the hydro modeling process, the PA was being refined simultaneously with development of the species effects chapters (chapters 7, 8, and 9). For this reason, the species effects analysis was conducted on model output from a slightly different PA that was previously considered. In order to provide an updated PA at the earliest opportunity, the update PA was developed and selected as the species effects analysis continued. Ultimately, the selected PA (Chapter 4) is nearly identical to the previously considered PA, upon which many of the effects analyses were based. The primary difference is that the selected PA results in flushing flows in approximately 70 percent of the water years analyzed, whereas the previously considered PA resulted in nearly annual flushing flows. The differences between the two operational scenarios were evaluated and it was determined that differences are minimal. Reclamation evaluated end of month Upper Klamath Lake surface elevations between the proposed action defined in chapter 4 (resulting in flushing flows in approximately 70 percent of years) and a very similar model run that produced flushing flows a nearly annual basis over the 39-year POR. Given the similarities of the model runs, there are minor differences in end of month lake elevations. The largest single simulated elevation difference was 0.31 feet, occurring in September of 2019, though many of the simulated differences in monthly exceedance were much smaller and the average monthly difference across the 39-year POR is less than 0.05 feet in all months. Given the very slight change in anticipated UKL elevations, Reclamation concludes that the following analysis, including evaluations of available spawning, rearing, and adult habitat are valid.

7.2 Effects of the Proposed Action to Lost River Sucker and Shortnose Sucker Populations in the Upper Klamath Lake Recovery Unit

The Revised Recovery Plan for the LRS and the SNS (USFWS 2013a) identifies two recovery units for both species: (1) the UKL recovery unit; and (2) the Lost River sub-basin recovery unit (*See* Section 7.3). This analysis anticipates the effects of the Proposed Action on these species relative to a without-action scenario. Because Reclamation uses the KBPM to manage water storage and deliveries from the west side of the project, we compare modeled output for 39 scenario years ("modeled POR") to a without--action scenario. Reclamation does not use a modeled approach to predict water storage and deliveries for east side operations (e.g. Clear Lake and Gerber Reservoirs), but instead predicts how a continuation of storage and deliveries similar to those that have occurred in the PORs (e.g. delivering approximately 35 TAF from each Clear Lake and Gerber Reservoirs) would affect SNS and LRS relative to future conditions without the action.

7.2.1 Effects of the Proposed Action to Lost River Sucker and Shortnose Sucker in Upper Klamath Lake

Under the without action condition, lake elevations in UKL would slowly decrease from a seasonal high elevation in spring. In general, water elevations would remain lower than the simulated elevations anticipated under the PA as all gates in the LRD would be left in the fully open position in order to pass flood flows and maintain the integrity of the LRD (see section 6.3-Without-Action Baseline). Gates for the A Canal would be shut, and no deliveries would be made through the A Canal. As described in the without-action scenario, UKL elevations would likely range from 4,136.1 to 4,141.7 ft (USBR datum). Under the Without-action condition, UKL elevations would be a function of inflows that vary seasonally and by water year. Without-action lake elevations would be increasing during late winter, reaching their highest in the spring and early summer months. However, during the dry season (July to October) surface elevation, surface area, and water depths in UKL would be substantially reduced in the without-action scenario. A without-action scenario would include all LRD gates fully open would result in lower lake levels than have been observed for the modeled POR (1981-2019). Lake depth would be substantially reduced during dry years and mud flats may develop in UKL's most shallow areas (Figure 7-1).

The PA provides various amounts of habitat available for each sucker life history stage, including embryos, pre- and post-swim up larvae, age-0 or young of the year (YOY) juveniles, older juveniles, and adults, in UKL as hydrologic conditions allow. Each sucker life history stage (Figure 5-1; USFWS 2019 figure 6-1 therein) has different habitat needs and specific seasonal time periods when they use each habitat type. In comparison to the Without-action condition, modeled UKL surface elevations under the PA are much higher throughout the year, do not fluctuate as widely (i.e., the difference between the highest and lowest elevation) in most years, and the end of season (end of September) lake elevations are substantially higher than those that would occur in the Without-action scenario (Figure 7-1, Figure 7-2).

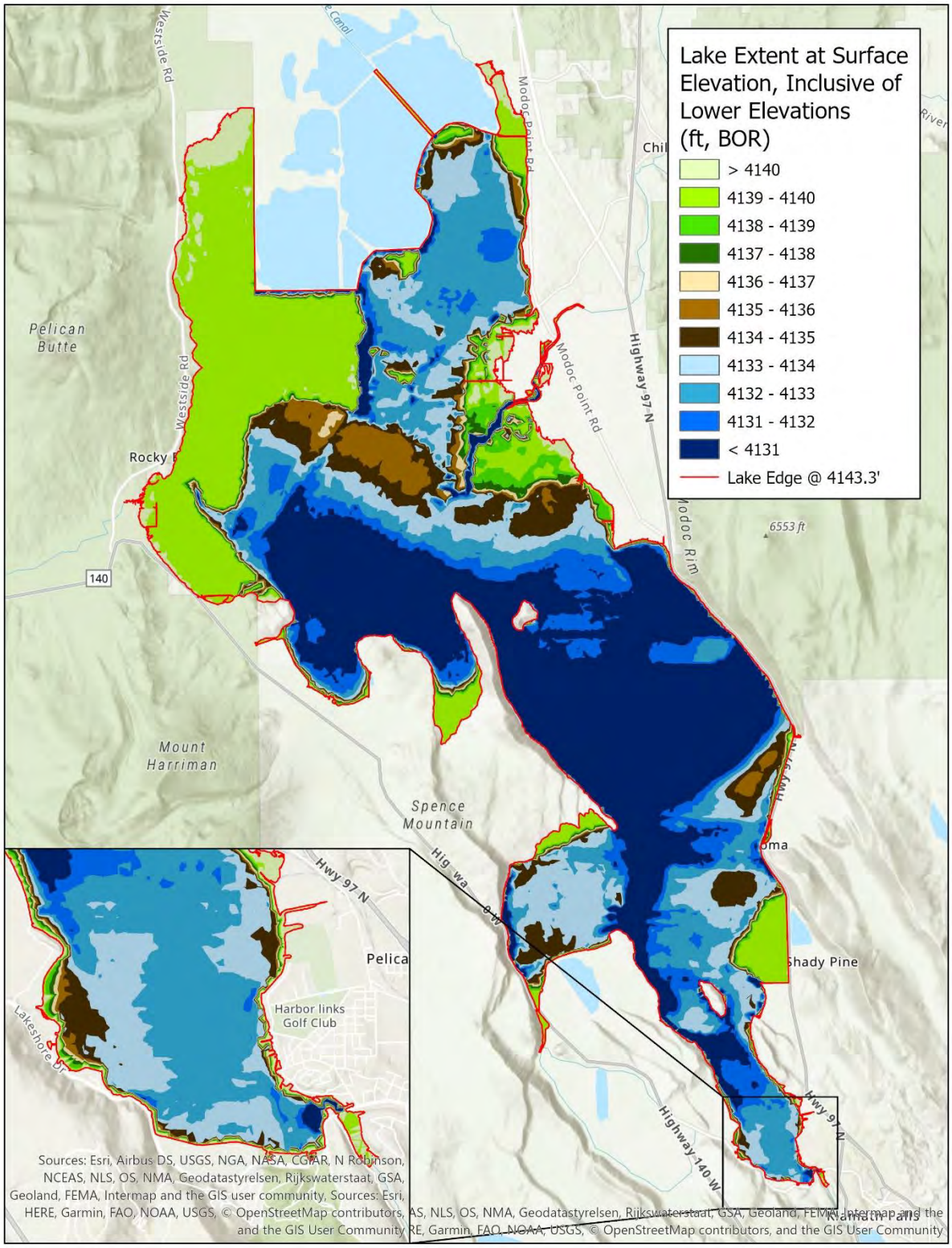

Figure 7-1. Relative water surface areas of Upper Klamath Lake at various low-water elevations ranging from 4140 ft to less than 4,131 ft (USBR datum). A without-action scenario which includes all Link River

Dam gates fully open would result in lower lake levels than have been observed for the modeled Period of Record (1981-2019). Lake levels derived using bathymetry described in Neuman (2017).

7.2.1.1 Effects to Shoreline Spawning Habitat

For the subpopulation of LRS that spawn at shoreline springs in UKL, spawning starts as early as the beginning of March, peaks in April, and can last through May (Buettner and Scoppettone 1990; Barry et al. 2007c; Janney et al. 2009; Burdick et al. 2015b; Hewitt et al. 2018c). Burdick et al. (2015b) observed fewer sucker detections at the lakeshore spawning areas in 2010, when lake surface elevation was lower than 4,141.3 feet throughout the spawning season. These results suggest that lake surface elevation at or above 4,142.0 feet by the beginning of March (or earlier) is important for lakeshore spawning access and activity. Lake elevations in 2010 were 4140.49 in March, 4141.00 in April, and 4141.28 in May (Figure 7-2). During 2010 there were fewer suckers observed at the springs area (14% fewer females and 8% fewer males) and of the suckers observed, each spent less time at spawning grounds (36% less for females, 20% less for males) than other years when UKL elevations were 4,142 ft or greater (Burdick et al. 2015b). A lake surface elevation of 4,142.0 feet provides approximately 74 percent of shoreline spawning habitat inundated to a depth of at least 1.0 foot (Burdick et al. 2015, figure 4 therein). Because of the amount of habitat provided at this elevation, USFWS (2019a) has determined that lake levels less than 4,142.0 ft will result in adverse effects to suckers.

Without-action UKL surface elevations do not reach EOM surface elevations of 4,142 ft during February through May. The without-action scenario results in overall lower lake elevations than the PA. The LRD and dikes surrounding UKL allow for surface elevations to be greater under the PA than those provided by the natural reef. The natural reef was notched in 1921 to allow UKL elevations to go lower than lake elevations that occurred prior to notching or pre-dam (Figure 7-2). The LRD gates in the without-action scenario are in the fully-open position, so lake elevations are expected to mimic inflows and accretions, with some uncertainty surrounding water residency time and evaporative losses. The without-action scenario results in less spawning habitat and less time (fewer months) for shoreline spawning LRS. The amount of unusable spawning substrate varies with lake elevation at the various shoreline spawning areas. In the without-action scenario, 13 to 18 percent of shoreline spawning habitat would be available for LRS in average years (averages for EOM February would be 4,138.8 ft, EOM March would be 4,139.3 ft, and EOM April would be 4,139.4 ft; Burdick et al. 2015b, Table 7-2). In the wettest years of the without-action scenario, EOM lake surface elevations would be 4,141.03 ft in February, 4,141.48 ft in March, 4,141.09 ft in April, and 4140.92 ft in May, which would provide 50-62 percent of shoreline spawning habitat for LRS. It is likely that fewer suckers will spawn for shorter durations in the without-action scenario.

The modeled output from the POR indicates that the PA provide lakeshore-spawning suckers with UKL elevations sufficient to inundate 74 percent or more of shoreline spawning habitat with 1 foot or more of water (a UKL elevation of at least 4,142 feet) in all months from the end of February to the end of June in 22 of 39 years (56 percent). More specifically, the PA is predicted to provide lake elevations greater than or equal to 4,142 feet in 79 percent of years at EOM February, 97 percent of years at EOM March, 92 percent of years at EOM April, 87 percent of EOM May, and 56 percent of EOM June (Table 7-1). The earliest February and March spawners will have lake elevations greater than 4,142 feet in 31 of 39 years under the PA which is suspected to provide adequate spawning habitat in most years. Additionally, lake elevations

are typically increasing between EOM February and EOM March due to the natural hydrology so the amount of spawning habitat inundated will typically increase during March and April.

In the 39-year POR analyzed, there were eight years (model years 1991, 1992, 1993, 1994, 2005, 2014, 2016 and 2019) where the surface elevation of UKL did not reach at least 4,142 feet by the end of February (Table 7-1 and Table 7-2). Additionally, The PA provides suckers lake surface elevations at or above 4,142 feet by the end of March in 97 percent of years (Table 7-3). The PA results in one year (1992) from the 39-year POR analyzed in which the surface elevation of UKL failed to reach at least 4,142 feet by the end of March, and in fact the hydrologic conditions of a year like 1992 never allow the lake to increase above 4,142 feet (Table 7-2; Figure 7-2).

The modeled output for the PA (Table 7-1, Table 7-2) indicates that the frequency at which reduced habitat may concentrate spawning or compel suckers to skip spawning at the shoreline areas is relatively low. The extent that slightly lower than 4,142-foot lake elevations at the end of February in 8 of 39 years affects lakeshore spawners is unclear but is likely to be small. LRS have high reproductive output (Perkins et al. 2000b) that may offset occasional low reproduction years when conditions are poor with substantial gains in years when spawning habitat conditions are good if juveniles survive.

Table 7-1. Summary statistics for simulated end of month elevations for Upper Klamath Lake under the Proposed Action over the 39-year Period of Record. Number of years when lake elevations are projected to be less than or equal to 4,142.0 feet end-of-month (EOM) during the spawning season (EOM February to EOM May) identified by Burdick et al. (2015b) and USFWS (2019a) as minimum lake elevations unlikely to limit the duration or number of individuals spawning at lakeshore spawning grounds.

Month	Average ± Standard Deviation (feet)	Minimum, Maximum (feet)	Number of years ≤ 4142.0 feet, percent of years
February	4142.3 ± 0.4	4141.0, 4142.7	8 years, 21 percent
March	4142.7 ± 0.3	4141.4, 4143.1	1 year, 3 percent
April	4142.9 ± 0.5	4141.1, 4143.3	3 years, 8 percent
May	4142.7 ± 0.6	4140.6, 4143.3	5 years, 13 percent
June	4142.1 ± 0.7	4139.9, 4143.1	17 years,44 percent

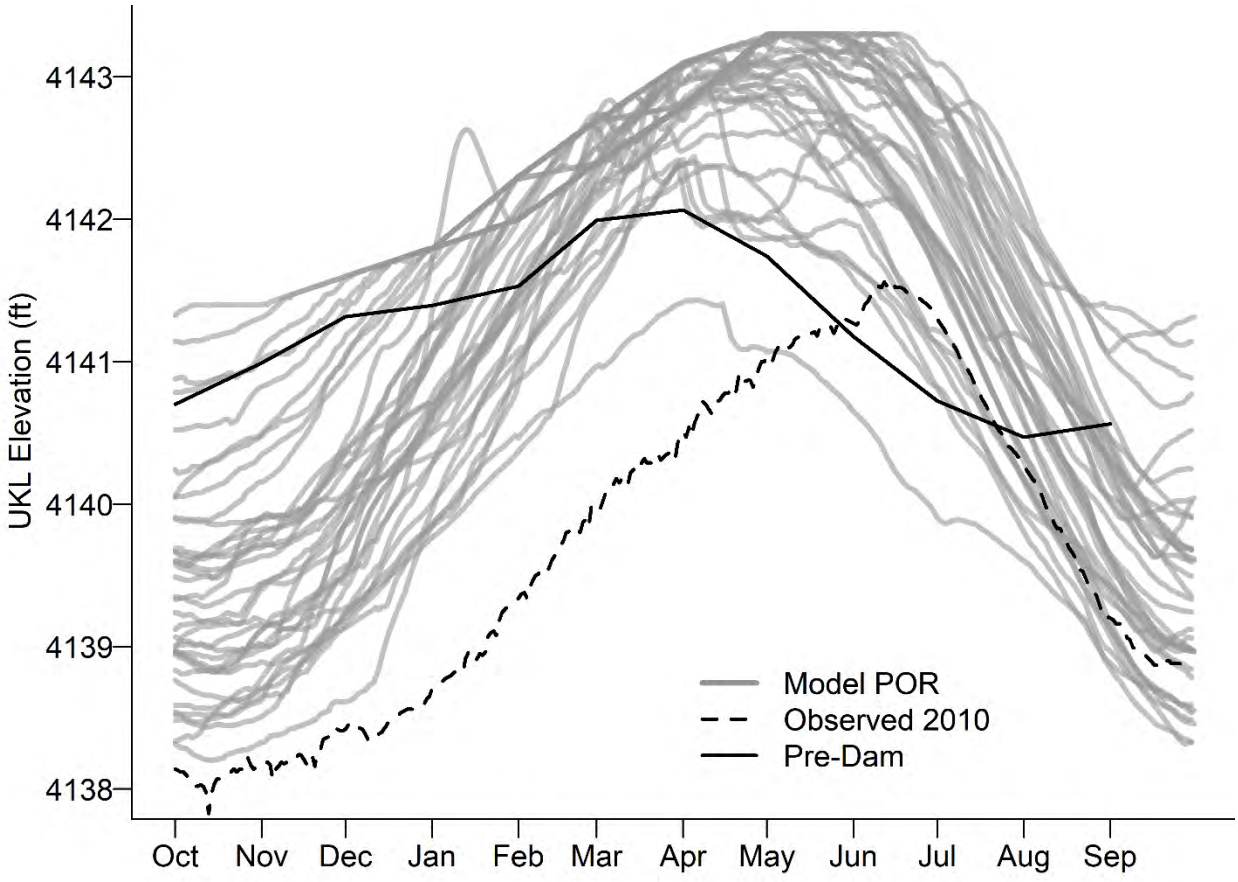

Figure 7-2. Modeled Upper Klamath Lake surface elevation for the Proposed Action period of record (gray lines), the observed lake surface elevation in 2010 when spawning at the shoreline springs was reduced by lake elevations (black dashed line), and the average end of month elevations prior to the installations of Link River Dam (1906-1921; black solid line).

Table 7-2. Modeled end of month Upper Klamath Lake surface elevations (feet above mean sea level, Reclamation datum) for the Period of Record (water year 1981 – through water year 2019) from the Proposed Action.

Model Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
1981	4139.15	4139.55	4140.56	4141.48	4142.61	4142.81	4142.86	4142.56	4141.66	4140.35	4139.11	4138.33
1982	4138.75	4139.84	4141.23	4141.99	4142.69	4142.79	4143.23	4143.26	4142.67	4142.23	4141.05	4140.77
1983	4141.05	4141.56	4141.78	4141.99	4142.39	4142.79	4143.12	4143.26	4142.81	4142.08	4141.38	4141.14
1984	4141.30	4141.59	4141.79	4141.99	4142.39	4142.79	4143.24	4143.25	4142.92	4141.93	4141.07	4141.32
1985	4141.40	4141.59	4141.79	4141.99	4142.39	4142.71	4143.28	4142.97	4142.40	4141.00	4140.31	4140.52
1986	4140.82	4141.34	4141.79	4142.28	4142.73	4142.80	4143.01	4143.16	4142.41	4141.23	4140.06	4140.02
1987	4140.46	4141.01	4141.79	4142.28	4142.67	4143.06	4142.99	4142.44	4141.79	4141.18	4140.34	4139.90
1988	4139.89	4140.27	4141.22	4142.28	4142.69	4142.98	4142.94	4142.53	4142.24	4140.93	4139.64	4138.97
1989	4139.01	4139.83	4140.68	4141.59	4142.32	4142.79	4142.98	4143.00	4142.17	4140.65	4139.49	4139.12
1990	4139.42	4139.84	4140.48	4141.47	4142.35	4142.82	4142.84	4142.45	4142.10	4140.95	4140.06	4139.69
1991	4139.69	4140.00	4140.34	4141.06	4141.76	4142.37	4142.00	4141.97	4141.14	4140.21	4139.34	4138.78
1992	4138.70	4139.23	4139.85	4140.48	4140.97	4141.42	4141.07	4140.65	4139.91	4139.60	4138.89	4138.55
1993	4138.61	4139.19	4139.98	4140.85	4141.54	4142.79	4143.28	4143.06	4142.90	4141.47	4140.45	4139.68
1994	4139.90	4140.06	4140.70	4141.36	4141.86	4142.30	4141.89	4141.70	4141.05	4139.96	4138.99	4138.49
1995	4138.50	4139.14	4139.83	4140.78	4142.20	4143.09	4143.28	4143.22	4142.91	4141.84	4140.31	4139.36
1996	4139.44	4139.69	4141.00	4142.28	4142.40	4142.79	4143.28	4143.29	4142.60	4141.37	4140.14	4139.60
1997	4139.77	4140.41	4141.62	4141.99	4142.39	4142.77	4143.28	4142.97	4142.46	4141.42	4140.49	4140.25
1998	4140.47	4141.14	4141.79	4142.28	4142.69	4142.80	4143.27	4143.30	4143.09	4142.01	4140.66	4139.92
1999	4140.15	4140.98	4141.69	4141.99	4142.39	4142.79	4143.28	4143.24	4142.86	4141.77	4141.27	4140.89
2000	4140.99	4141.40	4141.79	4142.28	4142.40	4142.79	4143.28	4143.18	4142.46	4141.30	4140.01	4140.04
2001	4140.33	4140.88	4141.63	4142.28	4142.69	4142.78	4142.81	4142.17	4141.14	4140.20	4139.16	4138.59
2002	4138.69	4139.38	4140.58	4141.81	4142.39	4142.94	4142.88	4142.60	4141.70	4140.39	4139.16	4138.54
2003	4138.64	4139.12	4139.91	4141.23	4142.24	4142.48	4142.62	4142.54	4141.66	4140.40	4139.41	4138.97
2004	4138.89	4139.20	4140.24	4141.18	4142.29	4142.79	4142.95	4142.64	4141.82	4140.76	4139.55	4138.97
2005	4139.10	4139.49	4140.26	4141.00	4141.67	4142.41	4142.01	4142.73	4142.20	4140.94	4139.65	4138.84
2006	4138.98	4139.94	4141.22	4141.99	4142.39	4142.79	4143.28	4143.11	4142.49	4141.53	4140.26	4139.50
2007	4139.63	4140.33	4141.21	4142.03	4142.69	4143.09	4143.23	4142.66	4141.77	4140.81	4139.90	4139.33
2008	4139.89	4140.33	4141.03	4141.96	4142.69	4143.09	4143.29	4143.25	4142.88	4141.56	4140.38	4139.62
2009	4139.77	4140.37	4140.99	4142.06	4142.69	4143.06	4143.13	4142.87	4142.58	4141.32	4140.34	4139.59
2010	4139.71	4140.04	4140.50	4141.43	4142.19	4142.57	4142.31	4142.14	4141.89	4140.81	4139.68	4139.25
2011	4139.38	4139.96	4141.05	4141.99	4142.64	4143.09	4143.12	4143.18	4142.66	4141.72	4140.50	4139.68
2012	4139.82	4140.22	4140.72	4141.68	4142.51	4143.09	4143.09	4142.63	4141.83	4140.75	4139.62	4138.97

Model Year	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
2013	4139.03	4139.45	4140.62	4141.40	4142.13	4142.72	4142.76	4142.15	4141.22	4140.21	4139.44	4138.97
2014	4139.19	4139.27	4139.75	4140.35	4141.46	4142.29	4141.86	4141.61	4140.83	4140.00	4139.45	4139.07
2015	4139.11	4139.51	4140.64	4141.47	4142.50	4142.38	4142.18	4141.68	4140.85	4139.85	4138.88	4138.34
2016	4138.33	4138.62	4139.82	4140.95	4141.95	4142.95	4143.07	4142.64	4141.84	4140.57	4139.17	4138.46
2017	4138.96	4139.60	4140.37	4141.31	4142.40	4142.79	4143.24	4143.05	4142.56	4141.17	4140.28	4139.71
2018	4139.80	4140.31	4140.91	4141.63	4142.25	4142.75	4142.69	4142.48	4141.90	4140.84	4139.82	4139.21
2019	4139.10	4139.29	4140.09	4141.05	4141.82	4142.80	4143.28	4143.07	4142.39	4141.17	4140.07	4139.58

Table 7-3. Modeled percent exceedances for Upper Klamath Lake end-of-month surface elevations (feet above mean sea level, Reclamation datum) for the Period of Record (water year 1981 through water year 2019) from the Proposed Action.

Exceedance Value	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
10%	4140.97	4141.39	4141.79	4142.28	4142.69	4143.09	4143.28	4143.26	4142.90	4141.93	4141.05	4140.77
20%	4140.29	4140.96	4141.69	4142.06	4142.69	4142.98	4143.28	4143.22	4142.67	4141.56	4140.45	4140.02
30%	4139.87	4140.33	4141.22	4141.99	4142.51	4142.81	4143.24	4143.11	4142.56	4141.37	4140.31	4139.69
40%	4139.75	4141.59	4141.03	4141.99	4142.40	4142.79	4143.13	4143.00	4142.41	4141.18	4140.14	4139.60
50%	4139.52	4140.15	4140.72	4141.68	4142.39	4142.79	4143.07	4142.73	4142.20	4140.95	4140.01	4139.36
60%	4139.17	4139.95	4140.62	4141.47	4142.35	4142.79	4142.95	4142.63	4141.89	4140.81	4139.65	4139.12
70%	4139.05	4139.52	4140.48	4141.36	4142.24	4142.77	4142.84	4142.53	4141.79	4140.65	4139.49	4138.97
80%	4138.90	4139.31	4140.24	4141.06	4141.95	4142.57	4142.62	4142.17	4141.66	4140.35	4139.34	4138.78
90%	4138.65	4139.19	4139.85	4140.85	4141.67	4142.37	4142.00	4141.70	4141.05	4140.00	4139.11	4138.49

7.2.1.2 Effects of the Proposed Action to Lost River Sucker and Shortnose Sucker Embryo and Larval Pre-swim-up Habitat at Shoreline Springs in Upper Klamath Lake

Changes in lake levels in the without-action scenario would vary seasonally relative to inflows and accretions. While lake levels are predicted to increase during some periods of larval development, it is likely that lake levels are only high enough to provide a portion of shoreline spawning habitat in the without-action scenario. Lake elevations during spring months, especially March and April, which coincides with the majority of embryo and larval development, are expected to have the highest lake elevations of about 4,141.5 ft. Thus, without-action lake elevations at least provide some of the deepest shoreline spawning habitat (Table 7-2) for embryo and larvae development, though lake levels may not stay high enough for embryos and larvae to be protected from desiccation. Under the without-action scenario, lake elevations are expected to rarely decrease at a rate of 0.6 ft in 3 weeks. Therefore, during wet years when lake levels are high enough for suckers to use shoreline spawning habitat, the without-action scenario may provide some protections for developing embryos and larvae. However, lake levels less than 4,142 ft will substantially reduce shoreline habitat availability for developing embryos and swim up larvae.

LRS embryos deposited at shoreline springs and pre-swim-up larvae typically develop within 3 weeks following spawning and fertilization (Coleman et al. 1988). If lake elevations that provided sufficient depth for spawning decrease rapidly, embryos and larvae may be susceptible to exposure and desiccation. LRS have been observed spawning in water as shallow as 0.6 ft (0.18 m) (Buettner and Scoppettone 1990) so surface elevation changes greater than 0.6 ft within 3 weeks will impact this life stage at the shallowest spawning sites. During the modeled POR, the maximum surface level decrease within 3 weeks of any date in March-May from the modeled POR was 0.72 ft. The maximum decrease in surface elevation in 3 weeks of any March-May date was less than 0.47 ft in 95% of cases and less than 0.59 ft in 99% of cases (Figure 7-3). The effect of implementing a surface flushing flow, especially a forced surface flushing flow (which primarily uses water stored in UKL and is described in detail in sections 4 and 8) to mitigate salmon disease is small, but rapid decreases in lake surface elevations, may occasionally affect developing embryos and larvae.

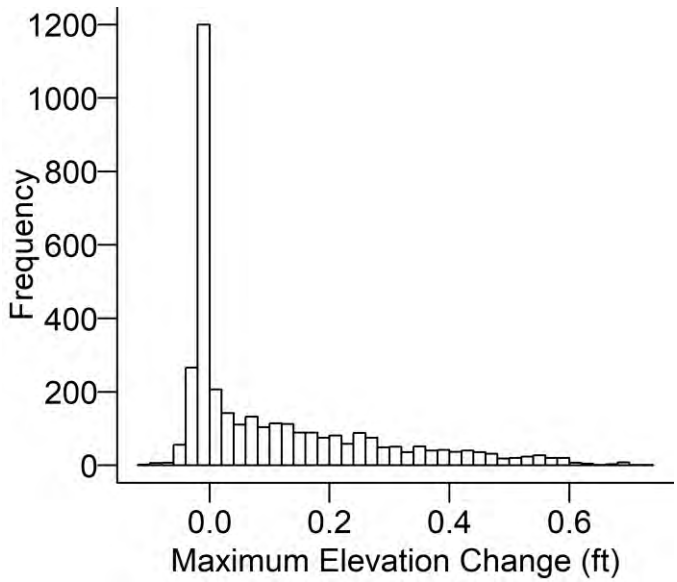

Figure 7-3. Frequency of maximum surface elevation changes in Upper Klamath Lake within three weeks of potential egg deposition dates (all dates in March-May) for the modeled period of record (1981-2019). Positive numbers are decreases in surface elevation and changes greater than 0.6 ft may dewater Lost River sucker embryos at the shallowest sites.

7.2.1.3 Effects to Larval Sucker Habitat in Upper Klamath Lake

Shallow, near-shore areas, particularly with emergent vegetation, provide habitat for larval suckers (especially SNS; USFWS 2008). This type of vegetation affords larval suckers with some protection from predators (Markle and Dunsmoor 2007), more diverse food resources (Cooperman and Markle 2004), and protection from turbulence during storm events (The Klamath Tribes 1996). Larval suckers begin to appear in UKL in March, with peak abundance occurring in mid-May to mid-June. Larvae transform to juveniles by mid- to late-July (Buchanan et al. 2011).

Although emergent wetland habitat exists at locations around UKL, wetlands at the Williamson River Delta (Delta) are particularly important (USFWS 2008). Wetlands at the Delta are adjacent to the major source of larvae emigrating from spawning areas in the Williamson and Sprague Rivers (Dunsmoor et al. 2000), and this area consistently has the highest densities of larvae in UKL during late spring surveys (Terwilliger et al. 2004).

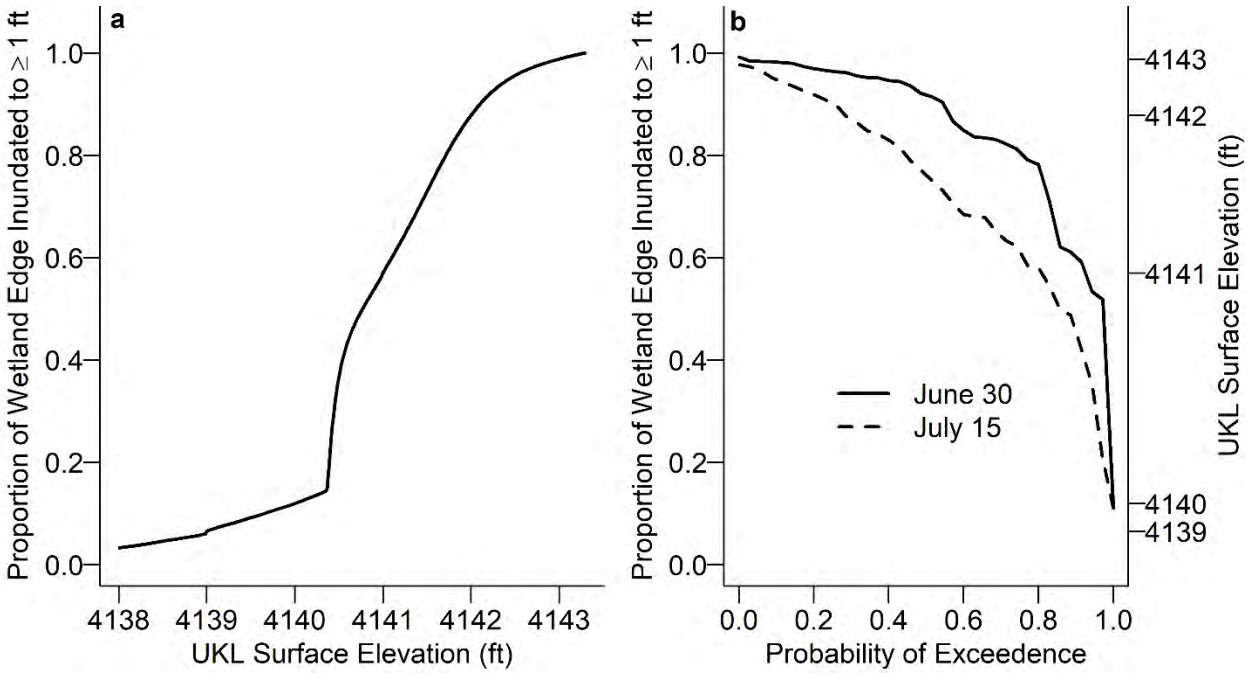

Figure 7-4. a) The proportion of emergent wetland-edge habitat inundated at least 1 ft relative to Upper Klamath Lake (UKL) surface elevation (modified from U.S. Fish and Wildlife Service's Biological Opinion (2019a) and Hereford and Roberts (2019)). b)The probability of exceedance and the proportion of wetland-edge habitat inundated at least 1 ft on June 30 (solid line) and July 15 (dashed line) derived from model output for the 39 year period of record (modified from U.S. Fish and Wildlife Services's Biological Opinion (2019a)).

The amount of emergent vegetation inundated at least one-foot decreases with lake elevations such that at 4140.8 ft (1,262.1 m) about 50 percent of emergent wetland habitat is available (Figure 7-4a). Nursery habitat for larval suckers is influenced by lake elevations (Dunsmoor et al. 2000; Terwilliger 2006; Markle and Dunsmoor 2007). Lake elevations that decrease quickly are likely to reduce larval survival by reducing food resources, increasing exposure to predation, or by displacement. Decreasing lake elevations under the PA are associated with decreases in accretions and inflows, increased water deliveries, and increased flows in the Klamath River. Larvae, whose movements are vulnerable to river and lake currents, could be carried to open water or entrained in the outlet of Upper Klamath Lake if lake elevations decrease rapidly.

Wetland availability for developing sucker larvae in the without-action scenario would be significantly reduced. The majority of wetlands important for larval and juvenile suckers are at lake elevations greater than 4,138 ft, and very little wetland-edge habitat is available for lake elevations less than 4,138 ft (Figure 7-4). The driest conditions in the without-action scenario occur in water year 1992 when less than 3 percent of wetlands are inundated at least one foot deep in March and only 1 percent of wetland habitat is inundated at least 1 ft in June when lake elevations are approximately 4,136.3 ft. The wettest conditions in the without-action scenario occur in model years like 1984 and 1987 when lake elevations are 4,141.7 ft (without-action year 1987) and 79 percent of wetlands are inundated at least one foot deep at some point in March and 53 percent of wetland habitat is inundated at least 1 ft in June when lake elevations are approximately 4,140.9 ft (without-action year 1984). EOM lake elevations where less than 50 percent wetland habitat is inundated at least one foot occurs in 85 percent of months for March

(33 of 39 without-action years), 79 percent for Aprils (31 of 39 without-action years), 87 percent for Mays (34 of 39 without-action years), and 100 percent for Junes and Julys. Thus, very little wetland habitat inundated at least one foot would be available for larval suckers in the without-action scenario.

The driest conditions in the modeled POR occur in water year 1992 and approximately 11 percent of wetland-edge habitat is inundated to at least 1 ft at the end of June when lake elevations are 4,139.9 ft (1,261.8 m) and on July 15 when elevations are 4,139.84 (1,261.8 m). These conditions only occur in 1 of 39 years in the POR, and these conditions are considered unlikely to occur under the PA. In most years (33 of 39 years; 85 percent), 50 percent or more wetland-edge habitat will be inundated with at least 1 ft of water on July 15. Thus, the majority of wetland-edge habitat will be available for larval suckers through mid-July when they are typically large enough to be considered juveniles. When lake elevations are less than 4,140.8 ft (1,262.1 m), and less than 50% wetland-edge habitat is available, predation, food resources become limited, and entrainment in the outlet of the lake are real risks to larvae. The proposed lake elevations will likely provide sufficient larval rearing habitat in most years. Changes in wetland depth have been identified as beneficial for wetland development and maintenance, and in this way, changes in lake elevation, as a function of Project operations may benefit suckers if wetland habitat is improved (Middleton 1999).

When lake elevations are less than 4,140.8 ft (1,262.1 m), and less than 50% wetland-edge habitat is available, predation, starvation and entrainment in the outlet of the lake are real risks to larvae (USFWS 2019a).

7.2.1.4 Effects to Age-0 Juvenile Habitat in Upper Klamath Lake

Age-0 sucker larvae are typically considered juveniles by late July; they prefer shallow habitat and use a variety of habitats (Buettner and Scoppettone 1990; Burdick et al. 2008). Observed movement patterns of age-0 juveniles have varied among studies; Terwilliger (2006) found young of the year juveniles moved from nearshore areas to offshore areas as the lake elevation decreased and reached its annual minimum (Terwilliger 2006), though more recent juvenile sampling has not observed this trend (Hendrixson et al. 2007b; Burdick et al. 2008). Age-0 juveniles have been found in all habitat types available in UKL including all substrate types, and vegetated and unvegetated habitats (Hendrixson et al. 2007b; Burdick et al. 2008). Different authors report weak habitat selection for age-0 suckers with weak evidence for the selection of sandy, vegetated habitats (Hendrixson et al. 2007b; Burdick et al. 2008), rocky substrates (Terwilliger et al. 2004), and mud or sand (Buettner and Scoppettone 1990); no study has found a strong relationship between young of the year sucker distribution and vegetation or substrate type. Complex habitat structure (e.g., vegetation or rocky substrates) provides more cover for fish, and is typically associated with higher survival and increased growth (Strayer and Findlay 2010). Water quality conditions also vary among substrates (e.g. organic-rich sediments have high DO demand) and location (dependent upon lake current strength (Wood 2001 pp. 7–8). In UKL rocky substrates are only found nearshore where waves and lake currents sweep sediments away (Eilers and Eilers 2005), DO is expected to be higher in rocky areas than where mud predominates. Lake elevations that provide access to diverse habitat types has been identified by USFWS as important for age-0 juvenile sucker growth and survival (USFWS 2019a).

Habitat diversity and complexity vary with lake elevation. Approximately 50% of wetland-edge habitat is dewatered when lake elevation is 4,140.8 ft (1,262.1 m), and 90% of wetland-edge habitat is dewatered at 4,139.6 ft (1,262.0 m) (Figure 7-4a). Rocky substrates are rare below 4,138.0 ft (1,261.3 m), and nearshore habitats are predominantly mud (Simon et al. 1995; Eilers and Eilers 2005). Little habitat diversity is available for juvenile suckers at lake elevations below 4,139.6 ft (1,261.6 m), and habitat diversity is especially limited below 4,138.0 ft (1,261.3 m). Lake elevations less than 4,139.6 ft (1,261.6 m) and below 4,138.0 ft (1,261.3 m) are suspected to force age-0 juveniles to move into areas where conditions (e.g., food, water quality, or predation) are less favorable, which could reduce their fitness and survival.

Habitat diversity and complexity would be reduced in the without-action scenario as lake surface elevations would rarely inundate much of the wetland-edge habitat (Figure 7-4b). Little habitat diversity is available for juvenile suckers at lake elevations below 4,139.6 ft (1,261.6 m), and habitat diversity is especially limited below 4,138.0 ft (1,261.3 m). Lake elevations less than 4,139.6 ft (1,261.6 m) and below 4,138.0 ft (1,261.3 m) are suspected to force age-0 juveniles to move into areas where conditions (e.g., food, water quality, or predation) are less favorable, which could reduce their fitness and survival. In the without-action scenario, lake elevations are expected to be less than 4,139.6 ft in every modeled year from EOM July, August, September, and October, providing juvenile suckers less than 10 percent habitat inundated one foot or more. In the without-action scenario, EOM lake elevations are expected to be less than 4,138.0 ft in 77 percent (30 of 39 without-action years) in July, 97 percent (38 of 39 without-action years) in August, 77 percent (38 of 39 without-action years) in September, and all 39 of 39 without-action years in October, providing juvenile suckers less than 3 percent habitat inundated one foot or more during most years. Lake elevations of 4,137.4 ft are the average EOM July in the without-action scenario and thus, would often occur. Minimum annual lake elevations below 4,139.6 ft (1,261.3 m) are expected to occur in 100 percent of years in the modeled POR. Moreover, more habitat diversity will be available for young of the year juvenile suckers most years under the PA than the without-action scenario.

Lake elevations below 4,138.0 ft (1,261.3 m) are not expected under the PA, though minimum annual lake elevations below 4,139.6 ft (1,261.3 m) are expected to occur in 74 percent of years in the modeled POR. Moreover, some habitat diversity for young of the year juveniles will be available under the PA.

7.2.1.5 Effects to Habitat of Older (Age 1+) Juveniles and Adults in Upper Klamath Lake

Little is known about specific habitat needs for age 1+ juveniles because very few have been captured in UKL. The limited data available suggests that age-1+ juvenile suckers have habitat preferences more similar to adult suckers than larval suckers (Burdick et al. 2009c; Burdick and Vanderkooi 2010). Telemetry studies have found adult suckers in open water in the portion of UKL north of Bare Island from June to September (Peck 2000; Reiser et al. 2001; Banish et al. 2007). The amount of preferred habitat for adult suckers varies with lake elevation. We followed the approach used in USFWS's 2019 Biological Opinion and quantified the area of preferred depths available using a bathymetric layer from various sources (Shelly et al. 2019; USFWS 2019a) and lake elevations from the modeled POR output. The analysis is for habitat available in UKL north of latitude 24°24'47" N, including Shoalwater Bay, Ball Bay, and the Delta because radio-telemetry studies have found suckers primarily use this area during summer months (Banish et al. 2009). In the summer, both species are found primarily in water 6.6 to 13.1 ft (2

and 4 m) deep and avoid water less than 6.6 ft (2 meters; Banish et al. 2009). Suckers were never observed in water depths greater than 25 ft (8 meters; Banish et al. 2007). Deep water may provide refuge from poor water quality such as warm temperatures, protection from avian predators, and access to preferred food resources (Banish et al. 2009).

The lowest end of September UKL surface elevation is 4,138.33 ft (1,261.36 m) and only occurs during extremely dry years. In the northern portion of UKL, approximately 9,428 ac (3,815 ha) or 33 percent of available habitat greater than 6.6 ft (2 m) is available at 4,138.33 ft (1,261.37 m) lake elevation (Figure 7-5). While suckers prefer depths greater than 6.6 ft (2m), Banish et al. (2009) found radio-tagged suckers frequently used areas in the northern part of UKL including Ball Bay, and the areas north of Ball Point, between Ball Bay and Fish Banks, between Eagle Ridge and Bare Island, and the area north of Ball Bay to the mouth of Pelican Bay (Banish et al. 2009). Distribution is likely associated with food resources, water quality, and predation risk. Thus, the actual amount of preferred habitat greater than 6.6 ft (2 m) deep is likely less than 9,428 acres.

After water quality conditions improve in late summer, adult suckers are distributed throughout the lake (Banish et al. 2007). Thus, lake elevations don't appear to define preferred habitat from November to February (USFWS 2019a). Lake elevations are typically increasing during this time, though low DO concentrations may occur when ice cover prevents oxygen exchange with the atmosphere (Reclamation 2012a). Low DO events in the winter do not appear to compromise adult suckers.

While winter water quality conditions are not often considered to be causes of mortality for adult suckers, summer water quality conditions can be stressful, and have been identified as contributing or causing adult fish die-offs (Perkins et al. 2000a). When water quality conditions are poor, adult suckers have been observed seeking refuge in Pelican Bay beginning in mid-July and lasting through September (Banish et al. 2009). The entrance to Pelican Bay is shallow, and while water quality is good in this location, low lake elevations may limit suckers' use of this refugia. The shallow, and clear water of Pelican Bay may increase suckers' risk to avian predation. For example, American white pelicans can prey upon suckers as large as 730 mm length, and pelicans typically forage in water 3.3-6.6 ft (1-2 m) deep (Anderson 1991; Mcmahon and Evans 1992; Findholt and Anderson 1995a, 1995b). Suckers are more vulnerable to pelican predation when water depth is less than 6.6 ft (2 m) and Scoppettone et al. (2014) suggested water depths greater than 3.3 ft (1 m) may reduce pelican foraging success on suckers.

The northern portion of UKL and specifically Pelican Bay, has been identified as important habitat for older juveniles and adults to seek refuge from poor water quality (Banish et al. 2009). Adequate depth is necessary for suckers to safely access water quality refuge areas in Pelican Bay and preferred habitat in mid-September. Suckers seeking water quality refugia in Pelican Bay are likely to be more vulnerable to predation by American white pelicans, especially during dry years. The bottom elevation of Pelican Bay is 4,134.5 ft (1,260.2 m; Shelly et al. 2019). The lowest UKL surface elevation in the model POR in July through September was 4,138.33 ft (1,261.36 m), which results in 3.8 ft (1.2 m) of water to the entrance of Pelican Bay (Table 7-4). This is deeper than 3.3 ft (1 m), so this may provide some protection for suckers against the most severe impacts to predation (Scoppettone et al. 2014). However, the depth of the entrance to

Pelican Bay is expected to be between 4 and 6 ft (1.2 and 1.8 m) during August and September in all but the wettest years, which may result in increased risk of predation for suckers by pelicans (Table 7-4, Figure 7-6).

Adult suckers in UKL have also been observed in small numbers in the Delta, which is somewhat deeper than the entrance to Pelican Bay (USFWS 2019a). The Delta also has better water quality than UKL and may be a refuge for suckers during poor water quality events. Limited areas of refuge (Pelican Bay and the Delta may result in over-crowding of suckers during poor water quality events. Over-crowding could spread disease among individual suckers and deplete food resources.

The lowest end of September UKL surface elevation is 4,136.2 ft and only occurs during extremely dry years in the without-action scenario. The average EOM September UKL surface elevation is 4136.8 ft. In the northern portion of UKL, approximately 9,428 ac (3,815 ha) or 33 percent of available habitat greater than 6.6 ft (2 m) is available at 4,138.33 ft (1,261.37 m) lake elevation (Figure 7-5). Under the without-action scenario Reclamation anticipates less than 33 percent of habitat greater than 6.6 ft deep at EOM September elevations.

Lake elevations don't appear to define preferred habitat for age-1 and adult suckers from November to February (USFWS 2019a). Thus, low lake elevations in the without-action scenario may provide conditions similar for adult suckers.

As described earlier, when water quality conditions are poor, adult suckers have been observed seeking refuge in Pelican Bay beginning in mid-July and lasting through September (Banish et al. 2009). Suckers seeking water quality refugia in Pelican Bay are likely to be more vulnerable to predation by American white pelicans, especially during dry years. The bottom elevation of Pelican Bay is 4,134.5 ft (1,260.2 m; Shelly et al. 2019). The lowest UKL surface elevation in the without-action scenario in July through September was 4,136.2 ft (1,261.36 m), which results in 1.7 ft of water to the entrance of Pelican Bay (Table 7-4, Figure 7-6). This is approximately half of 3.3 ft, the minimum depth recommended to avoid the most severe pelican predation (Scoppettone et al. 2014). This depth is not expected to provide protection for suckers against additional predation impacts.

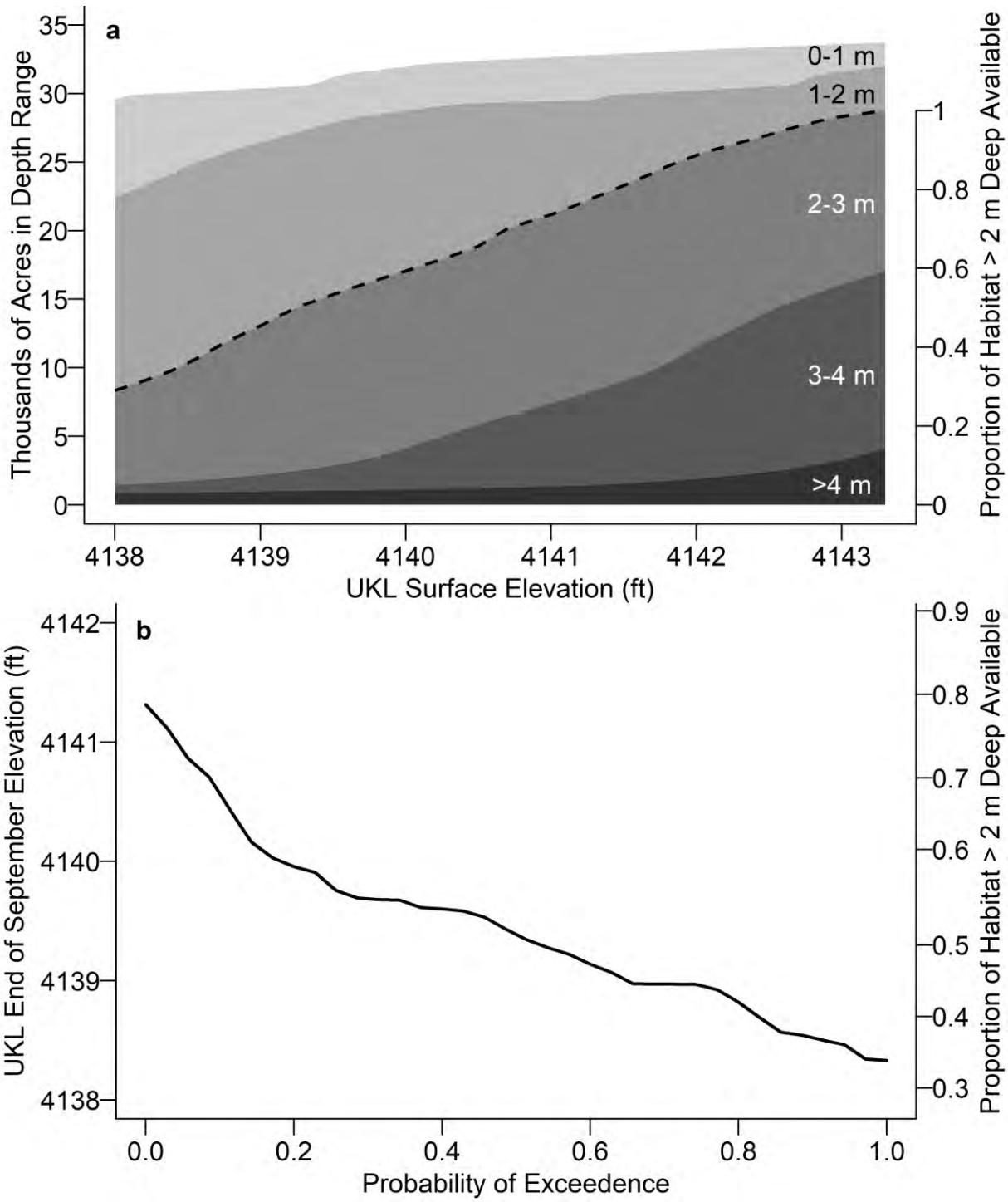

Figure 7-5. a) Availability of habitat of various depths in Upper Klamath Lake (UKL) north of latitude 24°24'47" N—including all of Ball Bay, Shoalwater Bay, and the Williamson River delta—at varying surface elevations based on UKL bathymetry (Shelly et al. 2019). Lost River sucker and shortnose sucker tend to avoid depths less than 2 m, except when seeking refuge from poor water quality conditions. Shaded areas representing the area in depth categories are stacked, and the dashed line represents the available area (or proportion) of habitat deeper than 2 m relative to availability at full pool. b) The

expected frequency of lake elevations and the associated proportion of habitat deeper than 2 m that is available under the Proposed Action based on the model Period of Record.

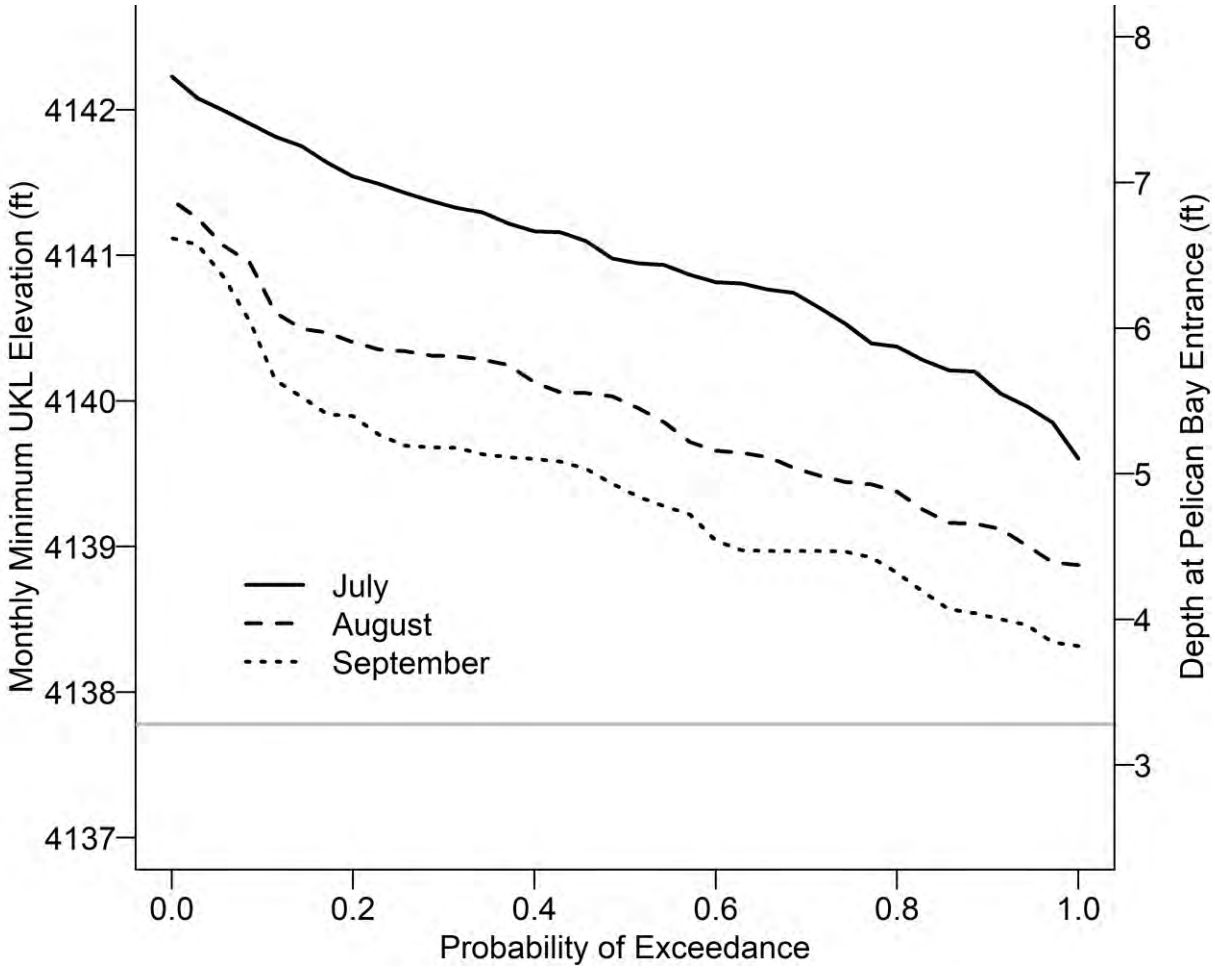

Figure 7-6. Probability of exceedance of monthly minimum Upper Klamath Lake (UKL) surface elevation in July (solid line), August (long dashes), and September (short dashes) for the model Period of Record and the associated depth at the entrance to water quality refuge contained in Pelican Bay. Suckers are expected to avoid depths shallower than 1 m (3.3 ft; gray line).

Table 7-4. Water depths at the entrance to Pelican Bay at various Upper Klamath Lake elevations. The minimum bottom elevation at the entrance to the bay is approximately 4134.5 ft (1,260.2 m; Shelly et al. 2019).

Lake Surface Elevation (ft)	Depth of Entrance to Pelican Bay (ft)
4,143.0 (1,262.8 m)	8.5 (2.6 m)
4,142.5 (1,262.6 m)	8.0 (2.4 m)
4,142.0 (1,262.5 m)	7.5 (2.3 m)
4,141.5 (1,262.3 m)	7.0 (2.1 m)
4,141.0 (1,262.2 m)	6.5 (2.0 m)
4,140.5 (1,262.0 m)	6.0 (1.8 m)
4,140.0 (1,261.9 m)	5.5 (1.7 m)
4,139.5 (1,261.7 m)	5.0 (1.5 m)
4,139.0 (1,261.6 m)	4.5 (1.4 m)

Lake Surface Elevation (ft)	Depth of Entrance to Pelican Bay (ft)
4,138.5 (1,261.4 m)	4.0 (1.2 m)
4,138.0 (1,261.3 m)	3.5 (1.1 m)

7.2.1.6 Effects to Upper Klamath Lake Water Quality

Best available science does not demonstrate a direct, consistent, and discernable relationship between UKL elevation and water quality. For further detail on studies and analyses between lake level and water quality studies for UKL see the 2019 USFWS Biological Opinion (USFWS 2019a).

Adverse water quality and fish disease likely impact suckers in UKL at both the individual and the population levels (Perkins et al. 2000b). The PA is not anticipated to influence water quality or fish disease in UKL aside from the possibility of periodic, but infrequent, concentrating of fish in limited habitat during late summer months when disease could be more-readily spread among individuals (*see* Chapter 6.1.6.4. Fish Parasites and Disease). Furthermore, there have been no known large winter fish die-offs documented in UKL (Buettner 2007, pers. comm. cited in USFWS 2008). As such, the PA is not anticipated to impact water quality conditions for suckers during the summer months or during under ice cover conditions.

Lacking direct observations of water quality in UKL under without-action conditions, water quality is anticipated to be no different than that observed from a historical context or from that occurring with the PA. Lower surface elevations may result in warmer water temperatures during the summer months, although lacking specific observations, the extent that water temperatures would increase under the without-action scenario is unknown. Lower lake surface elevations under the without-action scenario could result in increased mixing on windy days, which could mix more soft sediments into the water column which could increase turbidity and increase available nutrients. As a result, dissolved oxygen concentrations could also increase at low lake elevations if stratification events occur less frequently. It is unclear if increased mixing (due to low surface elevations) on windy days, would be a net-benefit (due to higher DO concentrations, and higher turbidity- similar conditions to Clear Lake Reservoir and Gerber Reservoir which may reduce sunlight available for AFA photosynthesis) or a negative effect as increased nutrients may increase growth of AFA and other cyanobacteria. On calm days that cause the cyanobacteria bloom to crash, low lake elevations, such as those in the without action scenario, could result in more stressful conditions for suckers because there are fewer areas for suckers to seek water-quality refuge. Regardless, lacking direct observations of water quality conditions at low lake elevations similar to those in the without action scenario, it is unclear how suckers would be impacted.

7.2.1.7 Entrainment Losses of Lost River Sucker and Shortnose Sucker from Upper Klamath Lake

Without action, flow through LRD does not result in entrainment as fish remain in the natural environment. Those fish transported downstream with LRD gates open would either continue downstream through PacifiCorp's Klamath Project or take up residency in Keno Impoundment. In comparison, the PA may result in fewer fish carried from Upper Klamath Lake at the LRD through the seasonal operation to store and divert water. The PA results in less water through

LRD than the without-action scenario from April through October when diversions are made into A Canal.

The PA will adversely impact larvae, YOY juvenile, and both older juvenile and adult suckers through entrainment on diverted water through numerous diversion points, principally at A Canal and LRD. The numbers of suckers at each life history stage will vary annually dependent on the amount of water transported and the numbers of suckers exposed to entrainment at each life history stage, a function of annual sucker production at earliest life history stages, and perhaps other factors such as wind speed and direction and water quality. Relatively low numbers of older juvenile and adult suckers entrained from UKL are anticipated due to the screening of the A canal (Gutermuth et al. 2000c, 2000a; USFWS 2007b, USFWS 2008; Tyler 2012).

Sucker entrainment losses at LRD and A Canal resulting from the PA can be estimated. Based on estimates for sucker entrainment by life history stages (Gutermuth et al. 2000c, 2000a) and applying assumptions to account for changes since the Gutermuth et al. efforts (e.g., construction of A Canal fish screen and bypass, reduced sucker populations in UKL etc.), entrainment estimates can be calculated from modeled output. Applying seasonal occurrences of sucker life history stages, based on Gutermuth et al. (2000c, 2000a), to the volume of water that Reclamation anticipates delivering through the Link River and A Canal and a sucker population reduction of approximately 80 percent (USFWS 2013), the PA could result in about 3.1 million larval suckers, 136,000 juvenile suckers, and 113 adult suckers encountering or passing infrastructure at either LRD or A Canal fish screen and trash rack (Table 7-6). Reclamation is not distinguishing between harass and harm for the incidental take of suckers as a result of entrainment. Entrainment has adverse impacts to all life stages of both species of suckers. Sucker entrainment at LRD and A Canal will occur under the PA. Construction and continued operation of the A Canal fish screen reduces the negative impact of entrainment by preventing juvenile and adult suckers from entering the Project canal system.

Table 7-5. Estimated sucker entrainment at Link River and A Canal for the Proposed Action from the period of record based on seasonal periodicity of life history stages and previous estimates of Gutermuth et al. (2000c, 2000a) with assumption of an 80 percent reduction in Upper Klamath Lake sucker populations since Gutermuth et al. estimated entrainment. Estimates assume encounters at the A Canal fish screen and trash rack result in entrainment.

Year	Larvae at Link River	Larvae at A Canal	Juveniles at Link River	Juveniles at A Canal	Adults at Link River	Adults at A Canal
1981	916571.2	441508.5	63876.0	37525.2	2.1	78.6
1982	1851414.6	568920.1	67217.1	55128.5	3.4	108.3
1983	2440786.2	561055.7	69661.6	56012.7	4.2	108.5
1984	2269242.9	608859.9	69900.3	51841.6	4.0	108.5
1985	1562017.4	646723.9	61577.6	43618.2	2.9	103.3
1986	1345004.5	615227.6	63621.8	46881.8	2.7	103.9
1987	960730.1	546864.3	56985.4	39742.0	2.1	90.3
1988	901325.4	426817.2	66748.2	38237.4	2.2	78.0
1989	1863933.7	583800.5	56967.9	50034.0	3.3	104.3
1990	837714.7	425991.5	58811.0	37334.0	2.0	77.0
1991	1049892.4	295994.5	58950.6	26988.3	2.2	54.6
1992	889516.0	16305.8	56056.2	913.0	2.0	2.4
1993	2212868.3	482041.7	66695.7	49124.4	3.9	94.3

Year	Larvae at Link River	Larvae at A Canal	Juveniles at Link River	Juveniles at A Canal	Adults at Link River	Adults at A Canal
1994	1001444.1	170168.3	64415.3	10326.2	2.3	26.0
1995	1588510.6	466226.1	67466.9	51450.2	3.1	95.3
1996	1613298.3	504873.2	75862.9	46635.1	3.2	93.7
1997	1256518.6	540497.4	62508.0	40071.7	2.6	90.1
1998	2156663.5	441993.7	73019.8	60121.2	3.9	102.2
1999	2220280.6	578472.1	64639.2	48410.4	3.8	102.2
2000	1515391.7	564738.7	58400.9	41706.1	2.8	94.0
2001	867087.7	433782.9	55457.7	36150.7	2.0	76.5
2002	1105152.0	525384.8	60242.3	39602.9	2.3	88.2
2003	1075748.6	476579.4	58201.6	42465.2	2.3	86.9
2004	867788.5	507609.3	63246.7	42082.1	2.1	89.2
2005	1074233.9	371623.5	60330.3	43333.6	2.3	78.4
2006	2238053.7	597872.6	70739.6	51399.5	4.0	107.0
2007	1147803.9	528976.3	52389.9	39006.2	2.3	87.9
2008	1456633.1	490520.5	66866.2	45911.5	2.9	91.7
2009	1085887.5	450532.5	67535.4	42333.1	2.4	84.4
2010	809398.2	410092.1	66028.2	38763.0	2.0	77.1
2011	1891044.8	508134.2	71994.9	49991.7	3.5	97.5
2012	1363343.8	477278.5	66237.4	43134.4	2.8	87.6
2013	818880.3	451740.3	66105.9	35760.4	2.1	77.7
2014	1000709.1	214765.7	62677.9	16151.9	2.2	36.0
2015	823698.0	323721.1	62552.8	29187.1	2.0	59.4
2016	1018467.9	501862.5	70039.6	41006.9	2.4	87.6
Minimum	809398.2	16305.8	52389.9	913.0	2.0	2.4
Average	1363807.1	465487.7	64000.8	40788.4	2.7	84.1
Maximum	2440786.2	646723.9	75862.9	60121.2	4.2	108.5

7.2.1.8 Effects of Deliveries to Lower Klamath National Wildlife Refuge

In the without-action scenario, Reclamation would not exercise its discretionary authority to close the gates in the railroad embankment, and the USFWS would continue to exercise water rights, including federally reserved water rights, appurtenant to lands within LKNWR and independent of the Klamath Project. The federally reserved water rights for LKNWR, established by the Executive Orders reserving these lands, provide for the use of water for waterfowl conservation purposes and as currently determined in the Klamath Basin Adjudication, allow for up to approximately 113,000 acre-feet of water to be diverted annually from the Klamath River. In the without-action scenario, the refuge would receive up to 113,000 acre-feet. The without-action scenario would provide conditions that would allow LKNWR to exercise their water right more often and with greater seasonal flexibility than under the PA which limits deliveries to LKNWR to leftover portions of Project Supply. Distribution of suckers in LKNWR are not well documented. It is possible that some individuals, or unknown populations would benefit from increased water deliveries that would occur under the without action scenario.

The PA allows for the possible delivery of Project Supply to LKNWR, which may result in changes to UKL elevations relative to the simulated output. Although the PA specifically states that such deliveries would not result in an increase in the volume of water delivered from UKL, the timing of deliveries is likely to change due to differences in seasonal demand and when the

approximate volume of unused Project Supply is known. Generally, in the modeled POR, water delivery was assumed to be distributed across the irrigation season with a peak in July, whereas LKNWR deliveries would occur in August through November. Therefore, delivery of Project Supply to LKNWR would be expected to delay the delivery of a portion of Project Supply, resulting in a temporary increase in UKL elevations in summer that would gradually diminish as water is delivered to LKNWR. This change would result in slight, temporary increases to the available habitat for juveniles and adults in UKL relative to the analysis above and would thus be considered within the scope of this effects analysis. Distribution of suckers in LKNWR are not well documented. It is possible that some individuals, or unknown populations, benefit from water deliveries of the PA.

7.2.2 Effects to Lost River Sucker and Shortnose Sucker Populations in the Keno Impoundment and Below Keno Dam

The maximum capacity of the Lost River Diversion Channel is approximately 3,000 cfs. Runoff in the Lost River watershed generally occurs very quickly. During rain events and with the annual snowmelt, the Lost River Diversion Channel would likely release 3,000 cfs to the Klamath River for extended periods, but runoff generally diminishes to less than 100 cfs in the mid-summer each year.

As noted previously, under the without-action scenario, with the gates open and stoplogs removed on LRD, the water surface elevation on UKL is not expected to exceed 4,142.0, except under extreme hydrologic circumstances. When the water surface elevation of the lake is at 4,142.0 feet, the maximum release capacity (depending on inflows) is approximately 4,000 cfs. Between the releases from LRD and the discharges from the Lost River Diversion Channel, the maximum combined flow in the Klamath River at Keno Dam is estimated to be approximately 7,500 cfs.

Through operation of Keno Dam, PacifiCorp maintains the water surface elevation in the Keno Impoundment between 4,085.0 and 4,086.5 feet above sea level (USBR datum). Under high flow conditions, it is assumed that PacifiCorp will operate Keno Dam in a manner to pass the flow necessary to avoid flooding private and public lands, consistent with its various operating agreements with landowners and other public and private entities (including Reclamation). As Keno Dam and the associated channel improvements are designed to pass up to 15,000 cfs, the dam should be able to safely handle anticipated flows under the without-action scenario (section 6.3.2).

Under the without action scenario, flows are likely to increase, especially in the spring season in the Keno Impoundment. Currently, relative to other populations, few suckers are suspected to be present in this reach. However, sucker populations may increase their use of this habitat if increased flows improve habitat conditions and fish that would have been entrained under the PA are no longer entrained (in the without-action scenario), but are instead able to navigate through habitat with less risk of entering irrigation canals. Indeed, some entrainment would occur for suckers entering Ady and North Canals, though this entrainment would be a result of without action. Some suckers entering these canals may end up at LKNWR, which may, depending on management decisions of USFWS, provide habitat for suckers. Flows in the without action scenario are likely to improve conditions for suckers in dams when flows are high, may have no

effect on conditions when flows are similar, and would decrease conditions if flows through the dams decrease.

Under the PA, flows through the Keno impoundment would be more consistent and less variable. This would be beneficial in comparison to times when flows are reduced under the without-action to below those in the PA.

Reclamation's responsibility below Keno is the release of UKL surface water at the LRD (Section 6.3.2). The flows are anticipated to provide adequate habitat to individual suckers that reside in reservoirs below Keno Dam. Impacts of potential take of listed suckers below Keno Dam resulting from degradation and loss of habitat due to low instream flows on the overall population is likely minimal (PacifiCorp 2013). This is consistent with USFWS' conclusions contained in the 2013 BiOp (USFWS 2013) that indicated that while PacifiCorp's current operation and associated minimum instream flow requirements below Keno, J.C. Boyle, and Copco No. 2 dams may affect individual suckers in this area, these effects are minimal within the context of the overall population size and geographic range of the LRS and SNS. These reaches are not part of the original habitat complex of the listed suckers and are inherently unsuitable for completion of life cycles of these suckers given the dams prevent movement (USFWS 2013). The focus of this section will be on the LRD and the Keno Impoundment where Project Operations have the greatest influence on the two endangered sucker species.

7.2.2.1 Effects to Keno and Downriver Spawning Access and Fish Passage

Large sucker spawning aggregations have not been observed in the Link River. However, there was one documented case of spawning activity in the lower Link River, upstream of the West Side hydropower facility during May 2007 (Smith and Tinniswood 2007), and spawning habitat is available in the Link River. Sucker spawning has not been observed in the Klamath River downstream of the Link River mouth to the Keno Dam (Buchanan et al. 2011), and generally, the low gradient, slow moving water, and fine sediments are unlikely to provide adequate spawning habitat in this reach. While few tagged adult suckers move around in the Link River, it appears that their movements are not constrained; up to 100 LRS and SNS are detected on the antenna array in the Link River each year (B. Hayes, USGS, pers. Comm., October 19, 2018). Additionally, suckers have been detected moving up and down using a fish ladder on the LRD.

The without-action scenario is expected to provide seasonally variable flow conditions that vary similar to inflows from the Williamson River, other tributaries to UKL, and other accretions. The LRD fish ladder would not be operational. Instead, fish would be able to move up the river through the fully-open gates. It is unclear if all life stages will be able to pass during higher flows. Under the without-action scenario, flows for sucker spawning and movement are expected to be adequate.

The PA includes the release of surface water from UKL through the LRD (*see* Chapter 4.3.2) and these releases during spring months are likely adequate for spawning in and movement through the Link River. The frequency of brief but higher flows than the without-action scenario, and velocities resulting from the PA may periodically hinder passage in the Link River for small suckers. Additionally, sucker movement through fully-open Link River gates is likely easier than through a fish ladder, thus, while the impact may be minimal, the PA likely results in a small reduction in ability to move through the Link River (and fish ladder) when high flows occur

under the PA, especially for juvenile suckers. However, most of the year, the PA is not likely to affect spawning access or fish passage for suckers in this reach.

7.2.2.2 Effects to Keno and Downriver Young-of-the-Year Juvenile Habitat

All life stages of listed suckers have been found in the Link River in recent years, based on monitoring below UKL and the LRD. This habitat is primarily a migration corridor for large numbers of larval and juvenile suckers dispersing downstream from UKL (Gutermuth et al. 2000c; Foster and Bennetts 2006b). Young suckers often migrate to the Keno Impoundment, however, it is unclear if this is a destination that meets their needs, or if their pre-settlement life history was such that they migrated to other lake habitats, such as the historic Lower Klamath and Tule lakes.

The Keno Impoundment is relatively shallow (average depth of 7.5 feet) and long (22.5 miles) and receives most of its water from UKL via the Link River (PacifiCorp 2012). Substantial quantities of water are also diverted from, and discharged to, the Keno Impoundment through and from facilities managed by Reclamation and several private permit holders (USFWS 2007c). Due to overall reductions in irrigation deliveries under the PA, Reclamation anticipates that Project return flows in the Keno Impoundment may be reduced.

YOY juvenile suckers in the Keno Impoundment likely use near-shore habitats of emergent vegetation or the transition zones between vegetation and open water. More YOY juvenile suckers were captured in trap nets fished close to the shoreline near emergent vegetation than in open water areas in Lake Ewauna of the Keno Impoundment (Tyler and Kyger 2012). Furthermore, sampling in a reconnected wetland bordered by North and Ady canals captured more YOY juvenile suckers in transition zones near emergent vegetation than in open water or in vegetation (Phillips et al. 2011).

Surface elevations in the without-action scenario are expected to be consistent with PacifiCorp's current operations at Keno Dam, which provide for a surface elevation in this reach of 4,085.5 feet. This operation is consistent with past operations of surface elevations in the Keno Impoundment. similar in this area as this area is owned and operated by Pacificorp. It is anticipated that the without-action surface elevation will be similar to those in the Proposed Action. In contrast, flows in this area would vary seasonally under the without-action scenario, which would improve habitat when flows are increased above those in the PA. If flows are ever lower than those in the PA, conditions in this reach may negatively impact YOY suckers in this area.

The PA is consistent with PacifiCorp's current operations at Keno Dam, which provide for a surface elevation in this reach of 4,085.5 feet. This operation is consistent with past operations of surface elevations in the Keno Impoundment. The ongoing management to operate for stable surface elevations in the Keno Impoundment impacts development of additional wetland habitats and degrades the quality of existing wetlands through controlled water depth (USFWS 2007c). However, stable surface elevations do provide sucker access to the established wetland habitats for rearing during sucker early life history stages. Relative to surface elevations, the PA will no impacts on YOY juvenile habitat in the Keno Impoundment. The adverse impacts from this PA would result from seasonally decreased flows relative to flows in the without-action scenario.

Benefits of the PA relative to the without action scenario would be during times when flows are lower in the without-action scenario than in the PA.

7.2.2.3 Effects to Keno and Downriver Older Juveniles and Adults Habitat

Little is known about habitat use in the Keno Impoundment by older juvenile and adult suckers. Limited available information suggests adult suckers still migrate into the Link River during the spring and summer (Piaskowski 2003; Kyger and Wilkens 2011), and juveniles apparently reside in the Link River, Lake Ewauna, and/or the Keno Impoundment below the LRD throughout most of the year (USFWS 2002; Phillips et al. 2011). Some efforts to evaluate sucker passage at the Link River fish ladder has observed congregations of adult suckers in Lake Ewauna near the Link River during late winter and spring months (Kyger and Wilkens 2011, 2012). However, this effort did not survey elsewhere in the Keno Impoundment for adult suckers at that time of year or attempt to define adult sucker habitat in Lake Ewauna. The relatively low number of tagged adult suckers detected at the Link River fish ladder and the relatively high recapture of tagged suckers in the Keno Impoundment, in relationship to the numbers of adult suckers that were tagged in 2008 through 2010 (Kyger and Wilkens 2011) suggests adult suckers do not exit the Keno Impoundment in high numbers or with much frequency. It is likely that older juvenile and adult suckers in the Keno Impoundment occupy similar habitats as suckers in UKL, such as areas that provide depth and access to water quality refuge. The lower Link River is an important water quality refuge area for juvenile and adult suckers during periods of low DO in the Keno Impoundment (USFWS 2007c). It is assumed that older juveniles and adult suckers in the Keno Impoundment utilize water depth as they do in UKL.

Under the without-action scenario, surface elevations are expected to be similar to those in the PA. Under the without-action scenario, flows into the Keno Impoundment and via the Link River and LRDC will vary seasonally, and mimic the summation of all flows into UKL (e.g. Williamson and Wood Rivers) plus accretions, and accretions from the east side of the basin, Gerber and Clear Lake basins. It is likely that this flow regime would improve habitat for older juvenile and adult suckers in this reach when flows are higher than those in the PA. If flows are ever lower than those in the PA, suckers in this area may be negatively affected.

The surface elevation of PA is not expected to impact offshore, deeper habitats available to older juvenile and adult suckers. The PA is not anticipated to appreciably impact flows in the Link River during summer months when suckers use the lower Link River as water quality refuge. However, reduced flows during the spring, a result of building storage capacity in reservoirs, may impair habitat conditions relative to the without-action scenario.

7.2.2.4 Effects to Keno and Downriver Water Quality

Relative to surface elevation, the without action scenario is anticipated to result in water quality conditions that are similar to those observed under the PA. When flows are similar among the two scenarios, the without-action scenario is anticipated to result in water quality conditions that are no different than those that would occur under the PA, although direct observations in the Keno Impoundment are not available. However, in the spring months when flows are substantially higher due to snowmelt, run off, precipitation, and other accretions, water quality conditions are likely improved relative to those in the PA. Water temperatures would be lower and dissolved oxygen concentrations would be higher. Additionally, any season when flows are greater in the without-action scenario relative to the PA, water quality in this reach (which is

typically characterized as having some of the worst water quality in the basin), would be improved. Additionally, since the majority of flows coming down LRDC (locked in the fully-open position) would not be return flows but instead waters from Clear Lake and Gerber Reservoir watersheds, it is likely that water quality would be improved; nutrient loading would be reduced and DO concentrations would be greater. In addition, because some project lands would not be irrigated and operated, nutrient loading and pesticides from run off would decrease, which would be beneficial for fish in this area.

Despite the relatively high tolerance for poor water quality by LRS and SNS, suckers are likely affected by impaired summer water quality in the Keno Impoundment (Saiki et al. 1999; NRC 2004). The PA includes continued surface water releases from UKL to this reach for Project irrigators and other downstream needs and thus will likely influence water quality in the Keno Impoundment. Reclamation suspects that deliveries under the PA will have little return flows to the Keno Impoundment which may alleviate some concerns about the quality (specifically nutrient load) of water returning from the Project.

Two sources of nutrients into the Keno Impoundment from the Project include the LRDC and the KSD (*see* Chapter 6.1.5.6 for additional details). Water returning to the Klamath River from these facilities contains nutrients, organics, and sediment. The use of agrichemicals on Project lands, particularly fertilizers, may increase nutrient concentrations of flows returning to the Klamath River via the LRDC and the KSD. However, the quality of water entering, within, and leaving the Keno Impoundment is largely a result of the export of algal biomass from UKL, and subsequent decomposition within this reach (ODEQ 2017). Adverse water quality events in the Keno Impoundment impact suckers that reside there. Quantifying the role of return flows in creating adverse water quality events is difficult to ascertain, because the eutrophic outflow from UKL confounds the ability to separate water quality effects of the Project from other factors. However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Improvements in Project infrastructure that allow recirculation of return flows within the Project may reduce the volume of return flow reaching the Klamath River. Similarly, the PA does not count re-diversion of return flows against Project Supply in the spring/summer (meaning that Project irrigators are likely to redivert this water), which will also likely result in reduced return flow to the Klamath River. Finally, the Project may reduce overall nutrient loads to the Klamath River given that only about 30 percent of UKL/Klamath River water diverted onto the Project returns to the Klamath River (ODEQ 2017).

In conclusion, the PA has impacts to water quality in the Keno Impoundment reach of the Klamath River. The impact of the amount of nutrients from the PA (e.g. nutrient loading from run-off of project fields) is minimal relative to the large contribution of nutrient and organic matter arriving from UKL. As such, Reclamation concludes that the PA is likely to have moderate effect on nutrient loading to Keno Impoundment and Klamath River.

7.2.2.5 Entrainment Losses Keno and Downriver

Unscreened diversions from the Keno Impoundment of the Klamath River have an adverse impact to individual suckers at each life history stage. The impacts due to the loss of larval, juvenile, and adult suckers are uncertain (PacifiCorp 2012) but the magnitude of impacts is likely related to the amount of water diverted and both the seasonal and diurnal timing of diversions.

Under the without-action scenario, deliveries to irrigation districts and the LKNWR would continue as some of these gates are privately owned and Reclamation has no discretionary control over privately-owned gates. Because fish screens are not present at Ady and North canal diversion points or at multiple other diversion sites, suckers that do not find their way to LKNWR would be considered entrained in canals, ditches, or fields. If under the without-action scenario, LKNWR diverts their full water right (113,000 acre-feet), conditions at LKNWR, may provide improved habitat (relative to the PA), dependent upon management practices.

The Proposed Action results in entrainment of sucker early life history stages at Project features (i.e., Ady, LRDC, and small canals delivery to Plevna) adjacent to Keno Impoundment similar to entrainment that would occur in the without-action scenario except that conditions at LKNWR may provide adequate habitat for suckers such that they would not be considered entrained.

7.3 Effects of the Proposed Action to the Lost River Subbasin Recovery Unit of the Lost River Sucker and the Shortnose Sucker

The Lost River Basin Recovery Unit is comprised of the following management units: Clear Lake Reservoir and tributaries, Tule Lake, Gerber Reservoir and tributaries, and Lost River proper (USFWS 2013b). While robust information about the timing, triggers, and basic needs for spawning migrations, as well as meaningful annual survival estimates for both species have been available from UKL for past consultations, this information has not been available for suckers in Clear Lake until the 2018 BA and 2019 BiOp consultation. Even still, few LRS are tagged in Clear Lake, limiting researcher's ability to estimate annual survival with meaningful confidence intervals (Hewitt et al. draft 2018a). information on early sucker life history ecology and habitat use within the Lost River watershed, particularly Tule Lake, Lost River, and both Clear Lake and Gerber Reservoirs, is sparse though juvenile monitoring has occurred in Clear Lake since 2015 (Burdick et al. 2018). Given a lack of direct observations, larval sucker ecology in the Lost River watershed is assumed to be similar to UKL, except for the use of emergent vegetation by larval and juvenile suckers. Permanent emergent vegetation is generally scarce or absent along the shorelines of Clear Lake and Gerber Reservoirs (USFWS 2019a). It is possible that high turbidity at both of these locations provides cover to early sucker life history stages (USFWS 2019a).

7.3.1 Effects to Lost River Sucker and Shortnose Sucker in Clear Lake

Management of Clear Lake Reservoir under the PA will continue the on-going operation to provide for a minimum surface elevation of no less than 4,520.6 feet on September 30 each year. Dam releases become impaired at a surface elevation below 4,522 feet due to a sediment deposit between the east lobe and Clear Lake dam (Sutton and Ferrari 2010). Similar to processes described in past consultations (USFWS 2002, 2003, USFWS and NMFS 2013c, USFWS 2019a)

around April 1 of each year, the April through September inflow forecast, current Reservoir elevation, estimated leakage and evaporative losses, and an end of September minimum elevation of 4,520.6 feet are used to determine available irrigation water from Clear Lake Reservoir. The amount of irrigation water available is periodically updated with new inflow forecasts and surface elevations as the irrigation season progresses. In-season updates inform the decisions to curtail or terminate irrigation deliveries to avoid going below the minimum surface elevation.

Lake elevation and high tributary inflows are necessary for adult suckers to make annual spawning migrations between the two lobes in Clear Lake Reservoir and access spawning grounds in Willow Creek (Hewitt et al. draft 2018a). Suckers in Clear Lake will spawn at temperatures as cool as 6°C and will stage to spawn (move from the west lobe to the east lobe) as early as January (Hewitt et al. draft 2018a). Suckers in Clear Lake opportunistically spawn when lake elevations are 4,524 feet or higher, and inflows are approximately 42 to 45 cfs or higher in Willow Creek; typically, early March through the end of May (Hewitt et al. draft 2018a). Several age classes are represented in population surveys for both species, indicating successful recruitment occurs some years (Hewitt et al. draft 2018a).However, meaningful additions to the population are most apparent after large spawning events, which do not occur every year (Hewitt et al. draft 2018a). Annual survival of LRS is 60 to 89 percent and 42 to 89 percent for SNS in Clear Lake (Hewitt et al. draft 2018a); substantially lower than survival of suckers in UKL which is typically 90 percent, (Hewitt et al. 2017). Unlike UKL, the LRS population in Clear Lake is smaller than the SNS population. Abundance estimates are not yet available for suckers in Clear Lake. Entrainment at Clear Lake was estimated to be 270,000 larval suckers and 3,700 juvenile suckers in 2013 (Sutphin and Tyler, 2016a). It is unclear how entrainment varies among years, spawning timing and conditions in tributaries, and lake elevations, though the estimate derived in 2013 is suspected to be high (*see* Sutphin and Tyler 2016 for more information). However, available information indicates that the Clear Lake sucker populations have persisted under recent management of the lake (USFWS 2019a).

7.3.1.1 Effects to Adult Sucker Spawning and Migration

When water is stored in Clear Lake Reservoir, surface elevations increase; when water is delivered from Clear Lake to irrigators, lake surface elevations decrease. Relative to a without-action scenario, surface elevations in Clear Lake are artificially high due to Clear Lake Dam. Storing water in Clear Lake Reservoir benefits populations of both SNS and LRS. The geomorphology of Clear Lake is such that the area may not have provided lake habitat, thus it is unclear how often suckers from the historical Tule Lake and Lost River populations would have spawned in Willow Creek and other tributaries to Clear Lake instead of in the Lost River. Low lake levels can adversely affect LRS and SNS by limiting access to Willow Creek (USFWS 2002, 2003, 2008; Hewitt et al. 2018a). The PA to store and divert surface water from Clear Lake Reservoir while maintaining an end of September minimum surface elevation of 4,520.6 feet each year will adversely impact adult suckers in years when lake elevations are at this minimum followed by a year (or years) when lake elevations do not increase by 3.4 feet to 4,524 feet or greater prior to the end of February or March; and during any spawning season when lake elevations are less than 4,524 ft. Suckers in Clear Lake are opportunistic spawners; moving into tributaries as early as March during large inflow events when temperatures are 6°C. Spawning in Clear Lake may be limited in years following 4,520.6 feet EOM September lake level. The

exception to this is when tributary inflows are large in January, February, and March such that lake elevation reaches 4,524 feet and flows remain high in Willow Creek. While not an annual occurrence, these events do occur; for example, lake levels increased by more than 5 feet by the end of February in WYs 2016 and 2017.

While the 4,520.6 feet September EOM minimum is established, this minimum has not occurred with great frequency; only in 90 to 95 percent exceedance years. For the POR (WY1911 to 2018), end of September elevations were at or below 4,520.6 feet in only ten years (9.2 percent). In one of these years (WY 2016), lake elevations increased by 3.4 feet or more such that lake level was at least 4,524 feet by the end of February, allowing suckers access to spawning grounds. In five of these years (50 percent), lake elevations increased by 3.4 feet or more such that lake levels were at least 4,524 feet by the end of March, presumably allowing suckers to spawn in April and May if flows were sufficient in Willow Creek. Spawning migrations in Willow Creek have been remotely monitored since 2006 and flows in Willow Creek have been remotely monitored since 2013. However, lake levels were too low in 2014 and 2015 for suckers to access Willow Creek. Thus, little is known about annual frequency, seasonal timing, and flows (e.g., cfs) necessary for suckers to make a spawning migration (*see* Parts 5.1.2, 6.1.5.3).

Lake levels in Clear Lake end above the elevation necessary for suckers to access spawning grounds in most years. End of September lake levels for the POR were less than 4,524 feet in 26.6 percent (29/109) of years. Thus, only in the 25 percent driest years (75 percent exceedance), are lake elevations expected to be less than 4,524 feet during the following spring when suckers attempt to spawn in Willow Creek.

Seasonal increases of lake elevation in Clear Lake typically increase from EOM December to EOM April. The largest increases occur most often in March but lake elevations also increase throughout February and April. Average ± standard deviation increases in lake level are 0.05 ± 0.26 foot in November, 0.40 ± 0.74 foot in December, 0.59 ± 0.89 foot in January, 0.90 ± 1.32 foot in February, 1.22 ± 1.68 foot in March, 0.73 ± 1.24 feet in April for the POR (WY 1911 to 2019). Understanding the seasonality of accretions provides a tool for managers to predict when lake elevations may be sufficient for suckers to access spawning tributaries and to understand the timing of discharge events in Willow Creek. Flows necessary for suckers to spawn in Willow Creek, as well as their frequency of occurrence, is expected to be better understood in the coming years.

Changes in lake elevation from EOM October to EOM April among years reflect differences in hydrologic conditions. Changes in lake elevation from EOM October to EOM April varies among years, including decreasing 0.62 foot (WY 1977) during dry years and increasing 14.31 feet (WY 1956) during wet years. For the POR (WY 1911 to 2019), lake elevations in Clear Lake Reservoir typically change an average ± standard deviation (min-max) of 0.90 ± 1.60 feet (-1.51 to 7.63 feet) from EOM September to EOM January, 1.79 ± 2.24 feet (-0.91 to 9.75 feet) from EOM September to EOM February, 3.01 ± 2.81 feet (-0.98 to 12.23 feet) from EOM September to EOM March, and 3.75 ± 3.45 feet (-1.47 to 14.11 feet) from EOM September to EOM April. Thus, if lake elevations end near 4,520.6 feet, on average, lake elevations will not be high enough for suckers to access Willow Creek until sometime in April, after the spawning season.

When low lake levels early in the season are followed by high inflows such as those that occurred in 2011, access to Willow Creek is available for suckers because lake levels increase rapidly (Reclamation 2018a). There are very few years between 1986 and 2019 (the period for which inflow estimates are available) when hydrologic conditions would increase from end of September minimums of 4520.6 ft to lake elevations high enough for suckers to access spawning grounds (4,524 ft or greater). These hydrologic conditions have occurred by end of January in 12% of years, end of February in 24% of years, and end of March in 41% of years, limiting access to spawning habitat in Willow Creek.

The frequency that Clear Lake elevations are less than 4,524 ft (1,378.9 m) at the end of September has occurred more frequently (57%) in the last 21 years (water years 1999 to 2019) than in the last 109 years (27%), indicating that dry conditions are more common. Additionally, the frequency that Clear Lake elevations are less than 4520.6 ft (1,377.9 m, and the proposed minimum) has occurred more frequently (14% of water years) from 1999 to 2019 than they occurred in the POR (8.2%). The frequency that Clear Lake elevations have been less than 4,524 ft (1,378.9 m) at the end of February, March, and April has occurred in 16.5%, 11%, and 10.1% for the POR (1911to 2018) and in 42.9%, 33.3%, and 33% at the end of February, March, and April in the last 21 years (water years 1999-2019). It is likely that suckers will be able to access spawning grounds in Willow Creek in most years because lake levels are likely to stay at levels that will allow for refill during wet years. Spawning may be limited or unavailable during dry years. While not fully understood, reduced flows in dry years may preclude sucker spawning despite low lake elevations.

The PA is likely to impact the frequency in which adult suckers can make spawning migrations in the driest years. However, as future operations are intended to be similar to historic operations, it is likely that the adult suckers will be able to access spawning grounds in Willow Creek 80 percent of years (presuming inflows are also sufficient in Willow Creek to support a spawning migration). The PA at Clear Lake Reservoir is consistent with the historic operations at the reservoir; therefore, the impacts are not anticipated to be greater than those described in the Environmental Baseline.

Without-action year-round surface elevations at Clear Lake are anticipated to be much lower than with the PA. Without-action, the remaining lake habitat is the west lobe at a surface elevation of about 4520.5 ft. The east lobe likely does not contain water by about April or May and is best described as a wet meadow throughout much of the year. Thus, without-action, access to the known spawning tributary of Willow Creek, across a much shallower or non-existent east lobe, occurs with a much lower frequency than the PA.

7.3.1.2 Effects to Habitat for Larvae and Age-0 Juveniles

At Clear Lake Reservoir, larval and YOY juvenile suckers likely utilize habitat similar to older juveniles and adults including depth, surface area, and areas near-shore. Earlier life history stages may show more association with the shoreline at Clear Lake Reservoir than later stages; however, shoreline and lake surface area both decrease with reduced surface elevations. Thus, the description of lake surface area and depth as habitat for adult suckers is applicable to larvae and both YOY and older juveniles (*see* Chapter 7.2.1.3., Effects to Clear Lake Habitat for Older Juvenile and Adult Suckers).

7.3.1.3 Effects to Habitat of Older Juveniles and Adults

The PA of a minimum surface elevation of 4,520.6 feet at the end of September preserves a lake surface area of 10,680 acres of habitat, of which 7,940 acres is at least 3 feet deep. At the minimum surface elevation of 4,520.6 feet, the west lobe averages approximately 5.5 feet of water depth. Of the 10,680 acres of habitat available at 4,520.6 feet lake elevation, 7,940 acres are at least 3 feet deep, 7,540 acres are 4 feet deep, and 7,100 acres are 5 feet deep. At the minimum surface elevation, the east lobe has a water depth of 7 inches, except for the pool nearest the dam into which Willow Creek flows. At 4,520.6 feet, the east lobe provides no habitat for suckers and the east lobe is dry at 4,520 feet. Despite 4,520.6 feet as the minimum, lake elevations have occasionally been below 4,520.6, especially during dry years due to additional losses from evaporation and seepage. Lake elevations were less than 4,520.6 feet in one month or more in at least ten years between 1911 and 2019. Throughout the full POR, Clear Lake Reservoir lake elevations were at or below minimums (4,520.6 ft) at the end of September in 8 percent or fewer years. However, Clear Lake elevations were greater than 4,520.6 ft for at least some years because silting of the dam's approach channel made withdrawing more water impracticable below 4,523.0 ft and BiOp minimums were historically higher in Clear Lake (Reclamation 1992). Perhaps as a result of different BiOp minimums or due to the current drier climatic cycle, the minimum threshold has occurred more often (14% of years) in the last 21 years. Still, it is relatively uncommon that Clear Lake Reservoir will get to minimum lake elevations.

In Clear Lake, the east lobe habitat is effectively unavailable for suckers when lake elevations are less than 4,523 ft (1,379 m) (USFWS 2019a). Clear Lake elevations have been less than or equal to 4,523 ft (1,379 m) at some time during the year in 31 percent of years in the full POR (WY 1911-2019) and more recently, in 62 percent of years since 1999. Although the Proposed Action has not changed since 1999, deliveries well in excess of the average demand from this reservoir have occurred in a few years within the recent POR resulting in more frequent lake levels of 4,523 ft or less (conditions that cause adults suckers to avoid the east lobe). It's also possible that drier climatic conditions since that time have played a role in the increased frequency of lower reservoir elevations, a trend that may continue during the duration of this action.

When lake levels are low, surface area and depth of habitat are reduced for suckers. Sucker populations are concentrated as evidenced by increased trammel net catches at low lake elevations (Hewitt and Hayes 2013b). Crowding may result in increased parasite levels or decreased growth rates due to limited resources. For example, when lake levels were low in 1992, body condition decreased slightly and afflictions increased, though these effects were no longer apparent by summer (Reclamation 1994b). While not fully understood, avian predation, including but not limited to double-crested cormorants and American white pelicans, is higher when lake elevations are low. This has been detected in lower survival estimates of adult suckers during low lake elevations, and in greater proportions of available PIT tags found at nesting colonies and loafing areas (Evans et al. 2016; see Chapter 5.1.6).

During the majority of months and years, surface elevations are anticipated to be above surface elevations that substantially impact older juveniles and adult suckers through reduced habitat (Table 7-2). The PA is anticipated to adversely affect larvae, juveniles, older juveniles, and adult

suckers by reducing habitat availability, particularly lake surface area and depth, during infrequent periods of prolonged drought. During consecutive years of low inflow, individual suckers may also experience reduced body condition, which can lead to mortality, and populations may contract in size if substantial numbers of adults are lost to mortality or individual reproductive health is compromised to the point that there is a reduction in recruitment.

Without-action year-round surface elevations at Clear Lake are anticipated to be much lower than with the PA. Under the without-action scenario, the remaining lake habitat is the west lobe at a surface elevation of about 4520.5 ft, and the east lobe is likely dry by April or May. This results in considerably less habitat as surface area, shoreline, and areas of water depth for older juvenile and adult suckers when compared to the PA. Thus, Clear Lake, without-action would likely support a smaller population of suckers than it is expected to support with the PA resulting in a beneficial impact from the PA.

7.3.1.4 Effects to the Lost River Sucker and the Shortnose Sucker in Clear Lake from Water Quality

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. However, water quality monitoring over a wide range of lake levels and years documented water quality conditions that were adequate for sucker survival (Reclamation 1994a, 2000, 2001a, 2007).

Low lake levels in Clear Lake Reservoir pose an unquantified risk to listed suckers from adverse water quality (USFWS 2008). In October 1992, the water surface elevation of Clear Lake was as low as 4,519.4 feet before the onset of a hard winter, and no fish die-offs were observed, although suckers showed poor condition factors in the following spring (Reclamation 1994b). It is uncertain if water quality conditions or crowding and competition for resources were responsible for impacts to suckers following the winter 1992 to 1993.

The proposed minimum lake level for Clear Lake at the start of the winter period from October to February is 4,520.6 feet. This elevation is anticipated to provide adequate water depths for protection against winter-kill of suckers (USFWS 2008). Implementation of the PA is not anticipated to substantially impact water quality as sucker habitat in Clear Lake Reservoir.

Without action, although Clear Lake becomes confined to the west lobe, water quality parameters are anticipated to largely remain unchanged in comparison to the PA. Surface elevation without-action will be lower than the PA which can increase risk to suckers as a result of winter-die-off;; however, this is an unquantified risk that may resemble impacts that were observed in winter 1992 (Reclamation 1994b).

7.3.1.5 Effects of Entrainment and Stranding Losses of Lost River Sucker and Shortnose Sucker at Clear Lake

Without-action, suckers of all life history stages would either inhabit the remaining west lobe of Clear Lake reservoir or be transported to habitats downstream in the Lost River system. This assumes no entrainment at Clear Lake Dam, as suckers have access to natural habitat downstream in the Lost River. Additionally, entrainment downstream of Clear Lake Dam is not anticipated to occur as downstream canals will be closed without the action.

The Proposed Action is to operate consistent with historical operations, which have supported sucker populations in Clear Lake Reservoir. The PA includes releases through Clear Lake Dam for irrigation use downstream and operating a fish screen at the dam to reduce entrainment losses. Thus, Reclamation anticipates potential impacts from entrainment will be greater under the PA than without-action; however, the entrainment impact is not anticipated to be greater than those in the recent past, which have supported the recruitment of several cohorts of suckers in Clear Lake Reservoir.

The outlet at Clear Lake Dam is screened against fish entrainment. The screen was designed for a fish approach velocity not to exceed 0.75 feet per second, and with a mesh size no larger than 1/4 inch. The required total area of the fish screens was determined based on a flow of 200 cfs and the above screening criteria. With full screen submergence and a discharge of 200 cfs, the screen approach velocity is approximately 0.53 feet/s. Reclamation assumes no downstream losses of all fish greater than about 35 mm TL. It is assumed that YOY juvenile suckers attain this size in Clear Lake Reservoir by about July of each year based on larval and juvenile emigration sampling in Willow Creek (Scoppettone et al. 1995). Based on sampling in 2013, entrainment of larval and juvenile suckers is occurring at the Clear Lake Dam (Sutphin and Tyler 2016b). Older juveniles and adult suckers may become impinged on the fish screen; however, the screen was designed with a maximum approach velocity intended to prevent impingement.

Periodically, fish stranding of all sucker life history stages has occurred in Clear Lake Reservoir when the pool nearest the dam disconnects from the east lobe of Clear Lake Reservoir at a surface elevation of about 4,522.0 feet (Reclamation 2012a). This disconnect in 2009 resulted in the capture and relocation of 48 juvenile suckers and the observation of three adult sucker mortalities (Reclamation 2012a). The pool nearest the dam is the only area identified at Clear Lake Reservoir that poses a stranding risk.

In 2013, a one-year effort to measure entrainment at Clear Lake Dam estimated that millions of larval fish and thousands of juvenile fish are being entrained through the fish screen at Clear Lake Dam (Sutphin and Tyler 2016b). Among this estimate are thousands of larval and juvenile suckers. Adult suckers were detected in Willow Creek during 2013 although lake elevation remained relatively low throughout the spring months (Hewitt et al. draft 2018a). The proximity of Willow Creek to Clear Lake Dam and the overlap between the seasonal timing of larval sucker emigration from the creek and irrigation deliveries suggest that larval and small YOY juvenile sucker are susceptible to entrainment at Clear Lake Dam (Reclamation 2012a). This was verified in the 2013 effort when sucker entrainment estimates were developed from fish sampling behind the fish screen (Sutphin and Tyler 2016b). Entrainment losses of larval and small juvenile suckers are an adverse impact of the PA on individuals.

In 2013, Reclamation estimated that about 270,000 larval suckers and about 3,700 juvenile suckers passed through or around the fish screen into the Lost River at Clear Lake Dam (Sutphin and Tyler 2016b). An estimate of the total larval and juvenile suckers was not developed from the effort to measure larval sucker drift in nearby Willow Creek in 2013 or any other year. Therefore, it is difficult to relate the losses from entrainment at the dam to a population level for suckers in Clear Lake. Although unknown, entrainment is likely variable among years and is

likely influenced by annual larval and juvenile production, timing of larval outmigration from Willow Creek, juvenile sucker distribution within the East and West lobes, and the timing, lake elevations, and magnitude of irrigation releases. If the numbers of entrained individuals are a substantial proportion of the number available in any year, then there is likely an adverse impact to sucker populations at Clear Lake Reservoir resulting from entrainment losses that result from the PA.

Larval entrainment likely varies among years but because these data are challenging to collect, we use data derived from 2013 to estimate entrainment as a function of water releases. Estimates of larval entrainment were estimated to be 22.3027 larvae/AF from April 22 to June 30, 2013 (Sutphin and Tyler 2016b; USFWS 2019a). Larval entrainment varies among years and is a function of lake elevations, flows in Willow Creek, and run timing for adult suckers. Estimates of annual larval entrainment range from 0 in years when no deliveries occurred, to 574,000 in 2001 when deliveries from Clear Lake were above the average volume of approximately 35,000 AF. On average, larval entrainment from Clear Lake was 241,000 from 1986 to 2018, with the exception of a few years where Reclamation was operating for flood control or drawing down the reservoir for dam reconstruction (USFWS 2019a). Due to interannual variation in spawn timing, water released from Clear Lake between April 1 and June 30 is used to estimate entrainment (USFWS 2019a). The PA at Clear Lake is consistent with the historic operations at the reservoir, therefore the potential entrainment impacts are not anticipated to be greater than those described above.

Juvenile sucker entrainment is similarly estimated, though no seasonal trend was observed in the 2013 study. Total releases are thus multiplied by 0.1867 juveniles/AF to estimate take (Sutphin and Tyler 2016b; USFWS 2019a). When juvenile take was estimated for the 1986 to 2018 period, the mean estimate was 5,050 juveniles, ranging from 0 to 12,200. The fish screen was installed to prevent adult entrainment (USFWS 2019a).

Because there is no spawning habitat and no upstream fish passage at Clear Lake Dam or Gerber Reservoir Dam, all suckers entrained from these facilities are lost from the spawning population because they would not be able to complete their life cycle should they survive. Additionally, it is expected that at up to 2 percent are killed as they pass through the dam, as described for the LRD (Whitney et al. 1997; Muir et al. 2001).

Stranding of juveniles is likely to occur in drought conditions. When lake surface elevations were 4,522 ft in July of 2009, the dam forebay was disconnected from the East lobe and 48 juvenile suckers were salvaged from the pool and 2 adults were found dead. Reclamation moved these juveniles to the west lobe in 2009. It is likely that the pool near the dam is the only known area that poses a risk to stranding and only at low lake elevations. The frequency of observing these low lake elevations such that stranding occurs is not likely to occur at greater frequency than the recent POR from 1999 to 2019. Stranding of suckers in remaining pools at and near Clear Lake reservoir is anticipated to occur equally in both the without-action and PA scenarios.

7.3.2 Effects to the Shortnose Sucker in Gerber Reservoir

The PA for Gerber Reservoir is to operate the reservoir volume so that the surface elevation is at or above 4,798.1 feet annually on September 30. Reclamation determines the available irrigation supply, around April 1 of each year, by evaluating the annual April through September inflow

forecast, current Reservoir elevation, estimated leakage and evaporative losses, and an end of September minimum elevation of 4,798.1. The amount of irrigation water available is updated with new inflow forecasts and surface elevations as the irrigation season progresses. In-season updates inform the decisions to curtail or terminate irrigation deliveries to avoid going below the minimum surface elevation.

The without-action scenario at Gerber Reservoir consists of fully opening Gerber Dam gates. Gerber Dam gates are estimated to have a maximum discharge of 900 cfs. Project diversion canal gates downstream remain closed. Thus, without-action, Gerber Reservoir is a temporary lake during inflow events that exceed 900 cfs which occur for about 2-6 weeks annually from February through April. At other times of the year, Gerber Reservoir will resemble small to medium creeks, similar to the three primary tributaries.

7.3.2.1 Effects to Gerber Reservoir Adult Shortnose Sucker Spawning and Migration

Access to Gerber Reservoir tributaries, where SNS spawning occurs, requires a minimum surface elevation of about 4,805.0 feet during February through May (USFWS 2008). During very dry years both Barnes Valley and Ben Hall creeks typically have low spring flows that may not provide adequate upstream passage for spawning adults regardless of lake elevations (Reclamation 2001a). Although surface elevations at the end of September have been observed below the proposed minimum elevation of 4,798.1 feet in 5 years from the POR (1925 to 2018) at Gerber Reservoir (1931, 1960, 1961, 1991, and 1992), surface elevations of at least 4,805.0 feet were reached the following spring by the end of March (USBR 2018). Based on review of surface elevations from the POR for Gerber Reservoir, the PA, which maintains the current lake management of a minimum surface elevation at or above 4,798.1 feet at the end of September, will not impact SNS access to spawning habitat during the succeeding spring months based on the hydrology of Gerber Reservoir. Without action, no surface elevation is maintained in Gerber Reservoir. Spawning access by SNS would be unimpeded except for natural features, such as the Miller Creek canyon downstream, which are not part of the Project. The PA at Gerber Reservoir provides the benefit of improved spawning access for suckers residing upstream of Gerber Dam except for years with extreme dry conditions, and a negative impact for any suckers downstream of Gerber Dam as a result of no fish passage features.

7.3.2.2 Effects to Gerber Reservoir Habitat for Larvae and Young-of-the-Year Juveniles

Sucker habitat requirements are less understood for endangered sucker populations in the Lost River Basin. Assumptions regarding sucker habitat use at each life history stage are based on observations from UKL and are described in Clear Lake Reservoir sections above. The description of lake surface area and depth as habitat for older juvenile and adult suckers at Gerber Reservoir is applicable to larvae and both YOY and older juveniles (*see* Chapter 7.3.2.3., Effects to Gerber Reservoir Habitat for Older Juvenile and Adult Suckers). Without-action at Gerber Reservoirs removes all lake habitat except during inflow events that exceed the open gates ability to pass the event. All assumptions about habitat for larvae and YOY juveniles are based on a lake environment. Thus, without action there is no habitat for these life history stages at Gerber Reservoir. The PA of storing and diverting inflows at Gerber Reservoir includes the beneficial impact of maintaining at least some lake habitat year-round, in all years.

7.3.2.3 Effects to Gerber Reservoir Habitat for Older Juvenile and Adult Suckers

The effects of low water elevations at Gerber Reservoir on the resident SNS population in terms of population size, age-class distribution, recruitment, or decreased body condition are not fully understood. However, available information (Leeseberg et al. 2007) USBR 2018a) indicates that the Gerber Reservoir sucker population has remained viable under the past management regime (USFWS 2008).

Without-action at Gerber Reservoir results in no lake habitat for older juvenile and adult suckers. By contrast, the PA of storing and diverting inflows at Gerber Reservoir includes the beneficial impact of maintaining at least some lake habitat year-round, in all years. The resulting surface elevations at Gerber Reservoir from the PA, which will resemble the range and frequency of past surface elevations, will have beneficial impacts through increased lake habitat during wet hydrologic conditions and negative impacts at low elevations when dry conditions persist. It is unlikely that the PA will limit the persistence of SNS in Gerber Reservoir.

7.3.2.4 Effects to Gerber Reservoir Water Quality as Habitat

Periodic stratification during summer and fall in the deepest portion of Gerber Reservoir can result in DO concentrations that are stressful to suckers (Piaskowski and Buettner 2003). Stratification at Gerber Reservoir has been observed persisting for less than a month, over a small portion of the Reservoir near the dam (Piaskowski and Buettner 2003) and is likely more the result of meteorological conditions than lake surface elevations.

Blue-green algae blooms can reach densities high enough to prompt advisories from the State of Oregon in the fall and winter, but it is unclear if these blooms are associated with project operations or if they directly or indirectly impact SNS.

The without-action scenario results in temporary storage behind Gerber Dam. Water quality of the remaining streamflow is anticipated to be that of ambient conditions characterized by moving water having a lower temperature and higher DO than impounded water. However, any reference to water quality relative to suckers in the Klamath Basin typically is in discussion of lake habitats. The PA results in lake habitat with periodic low surface elevations at Gerber Reservoir during late summer and fall (USBR 2018). These lower surface elevations could result in higher pH, warmer water temperatures, and lower DO. DO impacts result through concentrating fish into a small, remaining pool. Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for sucker survival (Reclamation 2001a, 2007; Piaskowski and Buettner 2003; Phillips and Ross 2012). The PA is anticipated to result in water quality that is also adequate for sucker survival. The PA may infrequently impact SNS in Gerber Reservoir by contributing to degraded water quality conditions through low surface elevations. The adverse impacts can be to both individuals and populations through loss of individual body condition or loss of individuals through mortality.

7.3.2.5 Effects of Entrainment Losses at Gerber Reservoir

Without action, all life history stages of suckers would pass through open gates at Gerber Dam toward habitats downstream in the Lost River. Under the PA, entrainment of early life history stages occurs with irrigation releases because they are subsequently entrained into North Canal

on lower Miller Creek. Thus, the without-action scenario results in no entrainment while some entrainment is anticipated to occur under the PA.

Under the PA, larval sucker entrainment occurs because releases from Gerber Reservoir are not screened, though entrainment estimates remain unquantified. Past efforts to quantify entrainment or salvage stranded suckers in Miller Creek downstream of Gerber Reservoir suggest approximately 200 to 250 YOY and older juvenile suckers are annually entrained as a result of project operations (see Chapter 6, Hamilton et al. 2004). Past efforts to measure larval sucker losses from Gerber Reservoir have not produced reliable catches that could be used to develop entrainment estimates for larvae. The unquantified larval entrainment at Gerber Reservoir is likely proportional to the amount of deliveries made from Gerber Reservoir and annual sucker production in any given year.

During irrigation season, flows in Miller Creek are typically 50-200cfs. After the irrigation season or when irrigation deliveries are curtailed (which has been as early as July), flows are reduced to approximately 2 cfs, plus accretions from seepage and storm run-off. This amount of flow may not allow for stream pool connectivity but is believed provide enough water to prevent mortalities of fish stranded in stream pools at the end of the irrigation season. It is unknown if the number of entrained individuals adversely impacts SNS populations in Gerber Reservoir as a result of the PA; however, the available information (Leeseberg et al. 2007)(Barry et al. 2007a,) indicates that the Gerber Reservoir SNS population has remained viable under the historic management regime (USFWS 2008, 2019a).

7.3.3 Effects to Tule Lake Individuals

Small populations of Lost River and shortnose suckers are present in Tule Lake which is comprised of two sumps called Sump 1A (9,000 ac [3,642 ha]) and Sump 1B (4,000 ac [1,619 ha]). In a study of radio-tagged suckers placed in Tule Lake Sump 1B, all moved into Sump 1A when 1A became accessible. Within Sump 1A, radio-tagged suckers have shown preference, especially during the summer months for the “donut hole”, or the deepest spot in Tule Lake. The populations in Tule Lake are thought to be maintained by emigration of individuals from UKL, Clear Lake and/or Gerber Reservoir. Historically, surface elevations were 4,034.6 ft from April 1 to September 30, and 4,034.0 ft from October 1 to March 31. Surface elevations in the Proposed Action maintain an elevation of 4,034.0 ft (1,229.6 m) throughout the year which provides some habitat with water depth greater than 3 ft in the area that adult suckers have been observed during summer months.

7.3.3.1 Effects to Tule Lake Adult Spawning and Migration

Without action, Tule Lake sumps would likely contract in size during dry conditions (no seasonal irrigation deliveries) and expand, possibly overtopping levees at the sumps, during consecutive wet hydrologic conditions with uncontrolled inflows from the Lost River. Without action allows adult suckers to migrate upstream of Anderson Rose Dam (gates open) up to at least the Lost River Diversion Dam on inflow events.

Most past consultations established a minimum surface elevation of 4,034.6 feet from April 1 to September 30 for Tule Lake Sump 1A to provide access to spawning areas below Anderson Rose Diversion Dam (USFWS 2002, 2008; NMFS and USFWS 2013) and for delivery of irrigation water to lands east and south of Sump 1A. However, despite some SNS and LRS observed

making a spawning run up the Lost River, spawning appears to be limited by a lack of suitable substrates and flows from the Anderson Rose Dam. Thus, sucker populations in Tule Lake do not successfully reproduce. The PA includes management of Tule Lake Sump 1A for a minimum surface elevation of 4,034.0 ft throughout the year. Based on the best available information, this surface elevation is not expected to limit sucker access into the lower Lost River. Operation of Anderson Rose Dam under the PA in the lower Lost River impacts the travel distance of adult suckers attempting to spawn.

7.3.3.2 Effects to Tule Lake Habitat for Larvae and Young-of-the-Year Juveniles

Under the without-action scenario, water would gradually accumulate in the Tule Lake Sump 1 until breaching or overtopping the surrounding dikes and flooding Sump 2 and 3 (see section 6.3.8). It is likely that Sump 1 would be full in less than one year. When Sump 1 is full to elevation 4,035.5 feet, the dikes will likely breach or be overtopped, filling Sump 2 and 3 which will be structurally compromised at the water surface elevation of 4,037.0 feet. This will likely cause additional flooding on private lands surrounding the Tule Lake Sumps. The duration, magnitude, and frequency of flooding areas outside the Tule Lake Sumps will depend on hydrologic conditions, however, inflows to Tule Lake Sumps are anticipated to be larger than historically observed after the establishment of the Klamath Project, given the additional releases from Clear Lake and Gerber reservoirs that would occur with the gates on the dams fully open. Inflows to Tule Lake Sumps are also anticipated to increase over recent historical conditions based on the lack of irrigation diversions into the J Canal. Water that is typically diverted for irrigation purposes would instead pass through or over Anderson-Rose Dam and be flow into the sumps. The amount and quality of habitat in Tule Lake would be significantly improved for all life stages of suckers under the without-action scenario. The without-action scenario would provide habitat and habitat connectivity such that a population of suckers might increase in Tule Lake.

In comparison to the without-action scenario, the habitat available for larval and juvenile suckers is substantially reduced under the PA. However, because there are very few larval and juvenile suckers in Tule Lake, the wetland area of Tule Lake Sump 1A near the Lost River mouth likely provides sufficient habitat for assuming that larval and YOY juvenile suckers in Tule Lake utilize near-shore and vegetated habitats similar to suckers in UKL. The proposed minimum surface elevation of 4,034.0 ft (1,229.6 m) should provide sufficient habitat for these life stages. The PA likely provides for a minimum amount of lake habitat that a without-action condition does not but constrains increases of habitat that would not occur without action.

7.3.3.3 Effects to Tule Lake Habitat for Older Juveniles and Adults

Under the without-action scenario, the amount and quality of habitat in Tule Lake would be significantly improved for older juvenile and adult suckers. Namely, increased depths, greater surface areas, and habitat connectivity would provide beneficial conditions for suckers. Without action, Tule Lake sumps would likely contract and expand in surface elevation, surface area, and depth frequently with hydrologic conditions.

In contrast, under the PA water depth as cover for older juvenile and adult suckers is limited due to the shallow bathymetry of the Tule Lake sumps (less than 4 ft, 1.2 m). Surface elevations in Tule Lake Sump 1A of 4,034.0 feet may provide adequate habitat (though never preferred depth; 6.6 ft, 2 m) with some areas where water depth is greater than 3 feet for older juveniles and

adults; however, there is continued concern about the shallow bathymetry of the sumps, the possibility of continued sedimentation, and high predation risk for suckers by American white pelicans (USFWS 2008, 2019a). Some of the sedimentation may be from lands that use Project water. The PA may adversely impact older juvenile and adult suckers in Tule Lake Sump 1A due to limiting habitat, largely water depth. The PA likely provides for a minimum amount of lake habitat that a without-action scenario does not but constrains increases of habitat that would not occur without action.

7.3.3.4 Effects to Tule Lake Water Quality as Habitat

Without action, Tule Lake sumps would likely expand and contract in surface elevation, surface area, and depth with hydrologic conditions. Generally, as described in section 6.3.8, Tule Lake would be full and breach, and in general, inflows to Tule Lake Sumps would also increase over recent historical conditions based on the lack of irrigation diversions into the J Canal. Habitat would increase relative to current operations (and those described in the PA). While lake habitat over the course of the four years, will likely increase or decrease depending on hydrology, variation in elevation has been identified as beneficial for wetlands, and wetlands are beneficial for water quality.

Because of shallow depths in Tule Lake sumps, the PA of water level management may contribute to the poor water quality in Tule Lake (USFWS 2008). Poor water quality in Tule Lake is associated with high nutrient concentrations and pesticides in surface water inflows into Tule Lake (USFWS 2019a). These conditions are thought to reduce the body condition and survivorship of individual suckers, especially for younger suckers that have higher metabolic rates. While water quality may negatively affect suckers, especially young suckers in Tule Lake, there are very few suckers present, and even fewer young suckers due to lack of spawning habitat available below Anderson Rose Dam.

7.3.3.5 Effects of Entrainment Losses at Tule Lake

There are five federally-owned, unscreened diversion points from Tule Lake sumps (R Pump, R Canal, Q Canal, D Pumping Plant, and N-12 Lateral Canal; Loyd and Bolduc 2004). These diversions are an unquantified risk to suckers in Tule Lake through entrainment. Without action at these locations, there would be no entrainment, as these facilities would not divert water from Tule Lake sumps. Under the PA, entrainment is likely to occur, although the amount of entrainment is unquantified. Under the PA, the impact and risk to suckers is likely low due to the low numbers of early life history stages present (Hodge and Buettner 2008, 2009), and due to the assumptions that adult suckers tend to avoid diverted flows and are better able to avoid diverted flows than earlier life history stages.

7.3.3.6 Effects of Possible Sucker Relocation from Tule Lake Sumps

During dry conditions with significant reductions in available surface water, elevations in the Tule Lake sumps may recede to levels that may adversely impact suckers in the sumps. If Reclamation and the USFWS, through discussions, deem it necessary to relocate suckers from Tule Lake, Reclamation, USFWS, and the Refuges will coordinate on a proposal to relocate suckers from the Tule Lake sumps before seasonally stressful water conditions develop. In the rare instance that dry winter conditions would precipitate sucker relocation from Tule Lake sumps, it is anticipated that approximately 500 adult suckers could be captured and relocated in a two-week effort (Courter et al. 2010). With advance planning and additional effort, it is

estimated that up to 1,000 adult suckers could be captured and relocated. The observed short-term (i.e., within 48 hours after release) mortality from capture, transport, and release of adult suckers was less than five percent (Courter et al. 2010). If the mortality associated with the capture and relocation of 1,000 adult suckers from Tule Lake is double the previous short-term observation, then it is anticipated that 100 adult suckers will die as a result of stresses from capture and relocation.

In the unlikely event that a relocation effort is needed at the Tule Lake sumps, this action will result in an adverse impact to suckers through the stress of up to 1,000 individuals and the mortality of up to 100 individuals from the action of capture, transport, and release. This action under the PA has a temporary negative impact on individuals from handling stress that may result in mortality for up to 10% of the fish handled and relocated. However, it is expected that this action will result in the benefit to those individuals relocated from an assumed fate of mortality.

Without action, no effort would be made to relocate suckers from Tule Lake sumps. This action results in no short-term handling stress to suckers but could result in assumed mortality of nearly all suckers in the sumps under dry hydrologic conditions.

7.3.4 Effects to Lost River Proper Individuals

7.3.4.1 Effects to Lost River Proper Adult Spawning and Migration

Much of the fish habitat, including spawning habitats, in both the upper and lower Lost River is fragmented by the presence of dams and irregular flows that affect adult sucker movements (Reclamation 2009; Kirk et al. 2010)(Shively et al. 2000). The PA which seasonally controls flows in the Lost River will result in adverse impacts by limiting adult sucker access to spawning habitat in the Lost River and its tributaries. Without action allows passage at many dams in the Lost River; however, spawning migration from Tule Lake sumps would still be impacted by no passage at the Lost River Diversion Dam.

7.3.4.2 Effects to Lost River Proper Habitat for Larvae and Young-of-the-Year Juveniles

Very few larval and age-0 juvenile suckers are likely to be present in the Lost River because dams fragment the habitat and prevent adult sucker movements for spawning. Additionally, there is little spawning and rearing habitat, and water quality is poor in the Lost River. As a result of the PA to operate the Lost River for water delivery during the irrigation season and flood control during fall and winter, individual YOY juveniles are adversely impacted through a reduction of habitat availability. During the irrigation season, habitats in the Lost River are suitable for early sucker life history stages. However, beginning in October, fall and winter habitats become fragmented as irrigation flows in the Lost River recede. Periodic weather and low elevation runoff events will temporarily increase Lost River flows during fall and winter and may temporarily allow connectivity between impounded areas and deep pools. Reduced flows in the fall and winter in both the upper and lower Lost River may lead to stress from crowding, lack of food and cover, increased predation and disease, and increased risk of poor water quality (Reclamation 2007).

The PA will contribute to poor habitat conditions for age-0 suckers in the Lost River. However, USFWS determined the Lost River is not necessary habitat for the survival and recovery of Lost River and shortnose suckers.

7.3.4.3 Effects to Lost River Proper Habitat for Older Juveniles and Adults

Based on Shively et al. (2000b), older juvenile and adult endangered suckers reside in impounded areas or deep pools in the Lost River except during the spring spawning period when they migrate (Reclamation 2001b; USFWS 2002; Sutton and Morris 2005). Most of the adult sucker observations in the Lost River are from the upper Lost River above Bonanza, Oregon (Shively et al. 2000b). There are few older juvenile or adult suckers residing in the lower Lost River, below Lost River Diversion (Wilson) Dam (Reclamation 2001b; USFWS 2002).

Dams and historical channelization fragmented adult sucker habitat in the Lost River in the same way it has for earlier life history stages; habitat quality is degraded, and connectivity is reduced (Reclamation 2009). Increased crowding of adult suckers into remaining available habitat at either the impoundments or deep pools and following reduced flows at the end of the irrigation season adversely impact individual adult suckers in the Lost River. Inflows from groundwater and low elevation runoff during weather events in the fall and winter periodically lessen the impacts of reduced habitat during the fall and winter months by reconnecting isolated areas of habitat (i.e., reservoirs and deep pools).

As with earlier life history stages, seasonal flow diversions under the PA, particularly flow reduction at the end of irrigation season in the Lost River, will have negative impacts to habitat for older juveniles and adult suckers in the Lost River.

7.3.4.4 Effects to Lost River Proper Water Quality as Habitat

Under the without-action scenario, water quality conditions in the Lost River are expected to be substantially improved as flows would increase from Clear Lake drainage, and runoff from irrigation fields would not exist. Without-action the Lost River may become adequate habitat for suckers.

Run-off and drain water likely contain nutrients, organics, and sediment, which have adverse effects to LRS and SNS habitat by deteriorating water quality (USFWS 2008). The effects under the PA would most likely be due to low DO concentration from decay of algae and macrophytes, and from organics that decompose and consume oxygen (USFWS 2008). Adverse effects to LRS and SNS from Project runoff and drainage are most likely to occur in the middle and lower Lost River system because these habitats are downstream from large agricultural areas (USFWS 2008). It is difficult to partition and assess water quality impacts related to nutrients between those carried on return flows and those carried on waters from Clear Lake Reservoir, Gerber Reservoir, and accretions in the Lost River. However, periods of adverse water quality, regardless of the source in the Lost River, adversely impact individual suckers that are present. The PA will adversely impact water quality in the Lost River through an incremental contribution of nutrients transported on return flows.

7.3.4.5 Effects of Entrainment Losses at Lost River Proper

Without action, entrainment losses at Reclamation's diversions from the Lost River are absent. The PA increases entrainment potential through unscreened diversions in the Lost River. The

impact of entrainment through these diversions pose an unquantified adverse impact to individual suckers at each life history stage. Both lethal and non-lethal impacts related to entrainment are anticipated as a result of the PA within the Lost River, consistent with what has been described in the Environmental Baseline.

7.4 Effects of Operation and Maintenance Activities Associated with Klamath Project Operations

Without action, the exercise of operation and maintenance at Project facilities, principally gates and diversion structures, is anticipated to be unnecessary. Therefore, under the without-action scenario, there is no impact, beneficial or adverse, to suckers from operation and maintenance activities. Under the PA, gates at Gerber Dam, Clear Lake Dam, LRD and fish ladder, Lost River Diversion (Wilson) Dam, the LRDC, and A Canal are exercised twice each year before and after irrigation season, March through November. The exercising of irrigation gates will likely have short-term, temporary impacts to larval, juvenile, and adult suckers in the immediate vicinity of the dam during exercise operations. It is anticipated that most individuals will move away from the exercised gate due to the sudden change in the surrounding environment; however, an unknown quantity of individuals may be entrained through the gates during exercises. The component of the PA that includes O&M of Project facilities related to dam and diversion gates is anticipated to possibly have adverse impacts to suckers largely through harassment and entrainment. Sucker captive rearing and funding of sucker-related habitat restoration projects are anticipated to offset some adverse impacts due to operation and maintenance of Project facilities.

7.4.1 Effects of Clear Lake Dam Maintenance

Typically, once each year before the start of irrigation season in March or April, gates at Clear Lake Dam are opened to flush sediment that accumulates in front of the dam gates. This activity creates a maximum release of 200 cfs and lasts for approximately 30 minutes. Periodically, the fish screens at Clear Lake Dam need to be manually cleaned during the irrigation season dependent on lake elevations and sediment. During the cleaning, one of the two fish screen sets is always in place to prevent entrainment of juvenile and adult fishes.

Sudden opening of the Clear Lake Dam gate may entrain individual larval, juvenile, and adult suckers, but it is anticipated that a number of fish will move away from the disturbance created by the open gate. However, it is likely that a small number of suckers at each life history stage could be entrained through the dam during a 30-minute flushing release. The downstream transport of sediment into the Lost River during gate openings is short-term and temporary in nature with most of the sediment settling in pools in the upper Lost River between Clear Lake Reservoir and Malone Reservoir. Manual cleaning of the fish screens at Clear Lake Dam are anticipated to have insignificant impacts to suckers. Without action has no impact as this activity is not performed.

7.4.2 Effects of A Canal Headworks Maintenance

Gates at A Canal are only operated and exercised with the fish screens in place. Should an occasion occur where the fish screens become inoperable during irrigation season, it is likely that all flows will need to be truncated in order to replace or repair the fish screen. These activities at

A Canal are not anticipated to impact suckers. At the end of irrigation season, the A Canal gates are closed and the forebay between the trash rack and head gates is slowly dewatered. Annual fish salvage occurs within the dewatered forebay during late October or early November. During the fish salvage, up to 1,500 YOY and older juvenile suckers are captured through seining and electrofishing (Kyger and Wilkens 2011, 2012; Reclamation 2018b).

Continued monitoring (and fish salvage when fish are observed) in the A Canal forebay during the week following initial salvage indicates very few fish remain in the forebay (Kyger and Wilkens 2011, 2012). Salvaged suckers were typically measured, tagged, and returned to UKL. Since 2016, salvaged suckers are treated for inflictions by USFWS prior to tagging and releasing to UKL. Adverse impacts to several hundred juvenile suckers are anticipated during this salvage process through stress. Observed mortality of salvaged suckers has been relatively low; however, stranding prior to, or in absence of, fish salvage results in mortality (Kyger and Wilkens 2012). The without-action scenario has no impact as this activity is not performed.

7.4.3 Effects of Lost River Diversion Channel Maintenance

Inspection of the gates and canal banks within the LRDC takes place once every six years. Inspections require a drawdown of water within the channel and can occur any time of the year. A drawdown of the channel would be coordinated with fish biologists to ensure adequate water is left to improve fish survival in pools during short term periods of low water levels. During drawdown, pools will be monitored to prevent stress to fish stranded until flows return. Adverse impacts in the form of stress are anticipated at each sucker life history stage but will likely be short term and temporary in nature. If necessary due to inadequate depth or disconnection between remaining pools, suckers will be salvaged from the remaining LRDC pools. Fish salvage is anticipated to result in harassment of up to 50 suckers, usually YOY or older juvenile life stage, during each occurrence. It is likely that stress will lead to harm of fewer than 5 suckers during each occurrence. Fish salvage will be coordinated with USFWS prior to the occurrence to determine the appropriate treatment and release sites for captured suckers. When practical, drawdown of the LRDC will occur during late fall through early winter when fewer suckers may be present in the channel to reduce impacts to suckers. Without action has no impact as this activity is not performed.

7.4.4 Effects of Link River Dam Fish Ladder Maintenance

Gates to the LRD fish ladder are exercised twice each year: once between January and April, and again between October and December. While the gates are exercised, the fish ladder is often dewatered and the entire structure is inspected. Fish are salvaged from the ladder while dewatered and returned to either the Link River or UKL. These activities have a short-term, temporary impact to suckers in and adjacent to the ladder. No more than 5 suckers of any life history stage have been encountered in the fish ladder during previous fish ladder inspections. Without action has no impact as this activity is not performed.

7.4.5 Effects of Canals, Laterals, and Drains Maintenance

Nearly all canals, laterals, and drains are annually dewatered at the end of irrigation season, as late as November and early December for Project canals in California. Canals remain dewatered until the following spring (as early as late March) except for localized precipitation runoff. In an effort to minimize effects associated with dewatering canals Reclamation has proposed a conservation measure for the salvaging of suckers from Project canals in both Oregon and

California as described in Chapter 4.5.1. Some maintenance of canals occurs during irrigation season such as removal of plant material from trash racks at water control structures. These temporary activities are not anticipated to impact suckers.

Most canal, lateral, and drain maintenance occurs while canals are dewatered and includes removal of sediment, vegetation, concrete repair, and culvert/pipe replacement. Gates, valves, and equipment associated with canals and facilities are exercised before and after the irrigation season (i.e., before April and after October). In the past, these activities have typically occurred after dewatering of the canals and after fish salvage of Project canals. Some activities such as culvert and pipe replacement may temporarily increase sediment transportation. Based on the presence and abundance of suckers in Project canals (Kyger and Wilkens 2011, 2012), adverse impacts to suckers are anticipated in regard to seasonal canal dewatering and routine maintenance on canal infrastructure. Most impacts such as increase in sedimentation are temporary and result in stress for fish. Other impacts may include mortality through long-term stranding, such as may occur when canals are dewatered and pools become disconnected. Fish salvage of remaining pools following dewatering has prevented mortality losses of approximately 100 to 1,000 juvenile suckers each year since 2008 (Kyger and Wilkens 2012). The without-action scenario has no impact as this activity is not performed.

7.4.6 Effects of Pest Control

Roads and dikes are mowed as necessary from March through October to control plant growth. Some pest control along dikes and on Reclamation property require the application of pesticides. Reclamation applies pesticides annually from February through October at select areas in accordance with our approved Pesticide Use Proposals and product labels. For the most recent Comprehensive Conservation Plan and Environmental Impact Statement regarding the use of pesticides on Reclamation and USFWS property including for Lower Klamath, Clear Lake, Tule Lake, Upper Klamath and Bear Valley NWRs, *see* https://www.fws.gov/refuge/Tule_Lake/what_we_do/planning.html (USFWS 2016). The effects of these activities have also been evaluated in previous section 7 consultations and incidental take coverage was provided in the USFWS's BiOps 1-7-95-F-26, 1-10-07-F-0056, 08—EKLA00-2013-F-0014 dated February 9, 1995, May 31, 2007, and May 2013, respectively. For additional information on pesticide and herbicide applications see Chapter 6.1.5.5. Without action has no impact as this activity is not performed.

7.4.7 Effects of Right-of-Way and Access Maintenance

Right-of-way and access maintenance may temporarily cause sedimentation into adjacent waterways, principally canals. Gravel is periodically added to roadbeds or boat ramps and vehicle access points. Roadbeds are periodically re-graded. The impact of sedimentation is likely to have a temporary impact to individual suckers that may be present. When these activities occur, seasonal consideration and soil retention cloth are used to mitigate sedimentation of waterways. The without-action scenario has no impact as this activity is not performed.

7.4.8 Effects of Water Measurement

Water measurement devices, such as gages, require annual maintenance to flush sediments from stilling wells, replace faulty gages, or modification/replacement of supporting structures. Flushing sediment from stilling wells occurs during irrigation season (April through October) and may temporarily increase sedimentation downstream of the gage. Sediment volumes are

often very small and the sediment settles a short distance downstream. In some instances, when a large amount of sediment is present, the sediment is removed from the stilling well and deposited at nearby upland locations. Other activities such as replacement or repositioning of a measurement device and associated infrastructure may require the construction of a small, coffer dam or be conducted during low flow periods. Measurement device sites are anticipated to need replacement or repair once every 5 to 10 years. If construction of a coffer dam is required, then fish will be salvaged from behind the dam prior to replacement of infrastructure. Replacement or repositioning of a site will have short term adverse impacts to suckers. Suckers will likely avoid the disturbance during activity but may need to be captured and moved to a location further from the impacted area. Replacement of equipment and flushing of stilling wells will have temporary impacts to suckers present in the immediate area of the gage. Most of these impacts are anticipated as non-lethal stress during site activity. If fish salvage is necessary, as in the instance that a coffer dam is needed to conduct repairs or replacement, it is anticipated that no more than 50 suckers of all life history stages will be encountered (harassed) for each occurrence. Fish salvage, and its non-lethal impacts, are likely the best approach to removing suckers away from additional harm due to these activities. The without- action scenario has no impact as this activity is not performed.

7.5 Effects to Critical Habitat

On January 10, 2013 USFWS finalized the proposed rule to designate critical habitat for LRS and SNS (77 FR 73740, USFWS 2012b). Critical habitat designation is defined in section 3 of the ESA as: (1) specific areas within the geographical area occupied by the species, at the time it is listed in accordance with the Act, on which are found physical or biological features (a) essential to the conservation of the species and (b) which may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time it is listed, upon a determination that such areas are essential for the conservation of the species.

In defining the physical and biological features and habitat characteristics required for LRS and SNS conservation, USFWS identified physical and biological features essential to the conservation of LRS and SNS in areas occupied at the time of listing, focusing on the features' primary constituent elements. Primary constituent elements are the specific elements of physical and biological features that are essential to the conservation of the species (77 FR 73740, USFWS 2012b). Based on our knowledge of the physical or biological features and habitat characteristics required to sustain the species' life-history processes at the time of the proposed critical habitat, the primary constituent elements specific to self-sustaining LRS and SNS populations are: (1) Water; (2) Spawning and rearing habitat; and (3) Food; (77 FR 73740, USFWS 2012b). These three primary constituent elements are described as follows (77 FR 73740, USFWS 2012b):

1. *Water. A*reas with sufficient water quantity and depth within lakes, reservoirs, streams, marshes, springs, groundwater sources, and refugia habitats with minimal physical, biological, or chemical impediments to connectivity. Water should exhibit depths ranging from less than 3.28 feet (1.0 m) up to at least 14.8 feet (4.5 m) to accommodate each life stage. The water quality characteristics should include water temperatures of less than 28.0°C (82.4°F); pH less than 9.75;

DO levels greater than 4.0 mg per L; low levels of algal toxins such as microcystin (amount not specified); and un-ionized ammonia (less than 0.5 µg per L). Elements also include natural flow regimes that provide flows during the appropriate time of year or, if flows are controlled, minimal flow departure from a natural hydrograph.

2. *Spawning and rearing habitat*. Streams and shoreline springs with gravel and cobble substrate at depths typically less than 1.3 m (4.3 feet) with adequate stream velocity to allow spawning to occur. Areas identified in PCE1 [sic primary constituent element 1] containing emergent vegetation adjacent to open water that provides habitat for rearing. This facilitates growth and survival of suckers, as well as protection from predation and protection from currents and turbulence.

3. *Food.* Areas that contain an abundant forage base, including a broad array of chironomidae, crustacea, and other aquatic macroinvertebrates.

7.5.1 Effects to Critical Habitats in UKL and Tributaries

7.5.1.1 Effects to Water

While there has been some concern that Project operations may affect UKL water quality through management of UKL elevation, the best available science has not demonstrated a clear, discernible, and consistent relationship between UKL elevation and water quality. This does not mean that UKL elevation or water depth does not have an effect on water quality, only that the best available science has not demonstrated a clear, consistent, and discernable relationship especially within the range of UKL elevations observed from 1990 to 2016, nor over the range of UKL elevations analyzed in the KBPM output for the POR. *See* Parts 6.1.5.6 and 7.2.1.6 for further discussion and analysis. The PA and its resulting surface elevations could potentially influence nutrient cycling within UKL (NMFS and USFWS 2013). At present, the empirical information lacks a causal link between water quality impacts (both negative and positive) and surface elevations in UKL.

The PA is unlikely to impact sedimentation or nutrient input into UKL because much of the input of lake nutrients occurs upstream of UKL and independent of Project operations (NMFS and USFWS 2013). Nutrients available in the lake substrates (e.g., internal nutrient loading) are not likely influenced by the surface elevations in the PA, although the storage and delivery of water from UKL could impact amounts of nutrients both stored and exported from UKL. The net effect of water storage and delivery in UKL on nutrient cycling is not well understood but could have both negative and positive impacts on water quality.

The PA has no effect on water quality in the tributaries to UKL within the critical habitat for LRS and SNS. Much of this critical habitat in the tributaries is above the influence of water storage in UKL. Water management described in the PA will only impact the lower reaches of the Williamson River, those reaches that are influenced by UKL surface elevations of (NMFS and USFWS 2013).

Lacking direct observations of water quality in UKL without action, water quality is anticipated to be no different than that observed from a historical context or from that anticipated to occur

under the Proposed Action. Thus, impacts to suckers from water quality are anticipated to be equal for both the Proposed Action and the without-action scenario.

Lacking direct observations of water quality in UKL under without-action conditions, water quality is anticipated to be no different than that observed from a historical context or from that occurring with the PA. Lower surface elevations may result in warmer water temperatures during the summer months, although lacking specific observations, the extent that water temperatures would increase under the without-action scenario is unknown. Lower lake surface elevations under the without-action scenario could result in increased mixing on windy days, which could mix more soft sediments into the water column which could increase turbidity and increase available nutrients. As a result, dissolved oxygen concentrations could also increase at low lake elevations if stratification events occur less frequently. It is unclear if increased mixing (due to low surface elevations) on windy days, would be a net-benefit (due to higher DO concentrations, and higher turbidity- similar conditions to Clear Lake Reservoir and Gerber Reservoir which may reduce sunlight available for AFA photosynthesis) or a negative effect as increased nutrients may increase growth of AFA and other cyanobacteria. On calm days that cause the cyanobacteria bloom to crash, low lake elevations, such as those in the without action scenario, could result in more stressful conditions for suckers because there are fewer areas for suckers to seek water-quality refuge. Regardless, lacking direct observations of water quality conditions at low lake elevations similar to those in the without action scenario, it is unclear how suckers would be impacted. those in the without action scenario, it is unclear how suckers would be impacted.

7.5.1.2 Effects to Spawning and Rearing Habitat

As discussed in Chapter 7.2.1., the PA will result in lake surface elevations that inundate 74 percent or more of shoreline spawning habitat with 1 foot or more of water (a UKL elevation of at least 4,142 feet) in all months from the end of February to the end of June in 22 of 39 years (56 percent). There is more spawning habitat is all years of the PA relative to the without-action scenario. A subpopulation of LRS begin spawning at the shoreline area as early as the beginning of March, peaks in April, and can last through May (Buettner and Scoppettone 1990; Barry et al. 2007c; Janney et al. 2009; Burdick et al. 2015b; Hewitt et al. 2018c). An objective of the PA is to store water in UKL from November through March. This objective results in EOM lake elevations in February through May which, in most years, provides sufficient depths for lakeshore spawning LRS populations.

The modeled output from the POR indicates that the PA provide lakeshore-spawning suckers with UKL elevations sufficient to inundate 74 percent or more of shoreline spawning habitat with 1 foot or more of water (a UKL elevation of at least 4,142 feet) in all months from the end of February to the end of June in 22 of 39 years (56 percent). More specifically, the PA is predicted to provide lake elevations greater than or equal to 4,142 feet in 79 percent of years at EOM February, 97 percent of years at EOM March, 92 percent of years at EOM April, 87 percent of EOM May, and 56 percent of EOM June (Table 7-1). The earliest February and March spawners will have lake elevations greater than 4,142 in 31 of 39 years under the PA which is suspected to provide adequate spawning habitat in most years. Additionally, lake elevations typically increase under the PA between EOM February and EOM March so the amount of spawning habitat inundated will typically increase during March and April.

In the 39-year POR analyzed, there were eight years (model years 1991, 1992, 1993, 1994, 2005, 2014, 2016 and 2019) where the surface elevation of UKL did not reach at least 4,142 feet by the end of February (Table 7-1 and Table 7-2). Additionally, The PA provides suckers lake surface elevations at or above 4,142 feet by the end of March in 97 percent of years (Table 7-3). The PA results in only one year (1992) from the 39-year POR analyzed in which the surface elevation of UKL failed to reach at least 4,142 feet by the end of March, and in fact the hydrologic conditions of a year like 1992 never allow the lake to increase above 4,142 feet (Table 7-2; Figure 7-1).

The without action scenario would never provide depths experienced with surface elevations of 4,142 ft in EOM February to EOM May. UKL surface elevation of 4,142 ft has been identified by USFWS as protective of eastside shoreline spawning habitat for LRS. The without-action scenario results in lower lake elevations because LRD and dikes surrounding UKL allow for surface elevations to be greater than those provided by the natural reef and because the natural reef in UKL was notched which allow current UKL elevations to be lower than pre-dam conditions (Table 7-2, Figure 7-2). The LRD gates in the without-action scenario are in the fully-open position, so lake elevations are expected to mimic inflows and accretions, with some uncertainty surrounding water residency time for the without-action scenario. The consequences for shoreline spawning LRS habitat under the without-action scenario are unclear, but it is likely that less shoreline spawning habitat would be available (lower lake elevations) and for less time (fewer months). The amount of unusable spawning substrate varies with lake elevation at the various shoreline spawning areas (Table 7-2; Burdick et al. 2015b; USFWS 2019). In the without-action scenario, 13 to 18 percent of shoreline spawning habitat would be available for LRS in average years (averages for EOM February would be 4,138.8 ft, EOM March would be 4,139.3 ft, and EOM April would be 4139.4 ft; Burdick et al. 2015b, Table 7-2). In the wettest years of the without-action scenario, EOM lake surface elevations would be 4,141.3 ft in February, 4,141.7 ft in March, and 4,141.5 ft in April, which would provide 50-62 percent of shoreline spawning habitat for LRS. It is likely that fewer suckers will spawn for shorter durations in the without-action scenario.

7.5.1.3 Food

Lacking direct observation in the without-action scenario food resources are not expected to be appreciably reduced in UKL. However, it is possible that because habitat diversity would be substantially reduced in the without-action scenario, zooplankton and benthic macro-invertebrates dependent upon wetland habitat may be less abundant; therefore, food-resource diversity could decrease in the without-action scenario.

The PA is not anticipated to appreciably reduce food availability in UKL due to the relatively high abundance of zooplankton and benthic macro-invertebrates in UKL (Hazel 1969). The PA is not anticipated to affect food resources for suckers in UKL (NMFS and USFWS 2013).

7.5.2 Effects to Critical Habitat in Keno Reservoir

7.5.2.1 Water

Under the PA, flows for agriculture and downstream environmental needs will be released from LRD. Surface elevations in the Keno Impoundment, which is owned and operated by PacifiCorp, pursuant to operating licenses with the Federal Energy Regulatory Commission (FERC) will maintain the water surface elevation in the Keno Impoundment between 4,085.0 and 4,086.5 feet

above sea level (USBR datum). Because PacifiCorp owns and operates the Keno Impoundment pursuant to their FERC licenses, Reclamation does not anticipate water depth to be different in Keno Impoundment under the PA or the without-action scenario.

The quality of water entering, within, and leaving the Keno Reservoir is largely due to poor quality water from UKL containing large amounts of organic matter with an associated high Biological Oxygen Demand (BOD) (Doyle and Lynch 2005; Deas and Vaughn 2006). Water from UKL, and the organic matter and nutrients carried with the water, may incrementally reduce water quality in the Keno Reservoir, particularly during warm weather periods. It is expected that operations of the PA will be similar as nutrient loading and pesticide use will likely continue.

Under the without-action scenario, nutrient loading and pesticides are expected to be less, as flows from LRDC would be predominantly sourced from Clear Lake and Gerber Reservoirs and not return flows off irrigated fields, which, given the gates would be in the fully-open position, would vary seasonally. Additionally, water temperatures may be reduced, and as a result, dissolved oxygen may be increased in this reach. Thus, it is likely that water quality conditions would higher in the without-action scenario in comparison to the PA in the Keno Impoundment reach.

7.5.2.2 Spawning and Rearing Habitat

Spawning activity in the lower Link River, upstream of the West Side hydropower facility, was observed during May 2007 (Smith and Tinniswood 2007). No other spawning habitat exists between the Link River and Keno dams (Buchanan et al. 2011). The PA releases water from UKL at LRD for downstream needs. The releases under the PA are anticipated to have no impact to spawning habitat in the Link River. Under the without-action scenario, flows from LRD would be higher under the PA. It is unclear if increased flows would improve or impair potential spawning habitat in the Link River in the without-action scenario. In either scenario, access would be available for suckers, thus, Reclamation concludes since there has only been one observed case of suckers spawning in the Link River, the effects of the PA and the without-action scenarios would be similar for spawning suckers in the Link River.

The ongoing management to operate for stable surface elevations in the Keno Reservoir impacts development of additional wetland habitats and degrades the quality of existing wetlands through controlled water depth (USFWS 2007d). However, stable surface elevations do provide sucker access to the established wetland habitats for rearing during sucker early life history stages. The PA has some negative effects to the recovery-support function of critical habitat in Keno Reservoir for both LRS and SNS (NMFS and USFWS 2013).

Since Keno Impoundment surface elevations are operated by PacifiCorp and will be have the same licensed operating criteria for the Proposed Action and without-action scenarios, the presence of, and ease of access to wetland habitats would not differ between scenarios. As such, the without-action scenario would provide access to adjacent wetland habitat but stagnant impoundment elevations may degrade the quality of these wetlands.

7.5.2.3 Food

Abundance of benthic macro-invertebrates is high in the Lost River (Shively et al. 2000b) and UKL (Hazel 1969). There is a lack of information on prey species abundance in the Link to Keno Reservoir reach; however, under the PA, prey species are assumed to be relatively high as the water at this location arrives primarily from UKL.

Under the without-action scenario, prey species are expected to be similar. Generally, there are fewer benthic macro-invertebrates and zooplankton in waters from Gerber and Clear Lake, though it is unclear if having some proportion of water from these bodies would change diversity, abundance, or both. As such, Reclamation does not anticipate food resources to be different between the PA and the without action scenarios.

7.5.3 Effects to Critical Habitat in Clear Lake Reservoir and Tributaries

7.5.3.1 Water

No water quality impact is anticipated in the west lobe of Clear Lake in the without-action scenario. The east lobe of Clear Lake would largely resemble a shallow lake or wet meadow during spring months and would be mostly non-watered in late summer through winter without action. Reclamation assumes suckers would not inhabit the east lobe without action. Thus, lake habitat of surface area and depth at Clear Lake reservoir is confined to the west lobe. Under the PA, more lake habitat is expected creating a beneficial impact to critical habitat in Clear Lake. The PA is not anticipated to affect water quality in the Clear Lake Reservoir or its tributaries. Although periodic low water levels at Clear Lake Reservoir could periodically contract the amount of available area in reservoir with water depth that may be utilized by older life history stages of both LRS and SNS. Particularly, in consecutive drought years, the PA may decrease the amount of critical habitat in Clear Lake Reservoir to shallower depths that may become periodically limiting to sucker use. The minimum Clear Lake Reservoir elevation will likely provide adequate protection from drought in most years. Extended drought may result in a significant reduction in lake area and depth.

At Clear Lake Reservoir, lower water levels may result in degraded water quality, particularly higher water temperatures and lower DO. Consequently, very low lake levels in Clear Lake Reservoir during consecutive drought years could adversely impact water quality (USFWS 2008; NMFS and USFWS 2013). However, water quality monitoring over a wide range of lake levels and years documented water quality conditions that were adequate for sucker survival (Reclamation 1994b, 2001a, 2007).

7.5.3.2 Spawning and Rearing Habitat

Access to spawning and rearing habitat would be negatively impacted under the without-action scenario. Without action results in the absence of an east lobe which is the migration route for sucker spawning in Willow Creek. The PA surface area, and depths for the east lobe, which provides access to Willow Creek, the only spawning habitat in upstream of Clear Lake. While surface elevations under the PA may periodically be too low for suckers to access to Willow Creek at Clear Lake Reservoir, these conditions are not expected to occur more than 17 percent of years for EOM February, 11 percent of years for EOM March, and 10 percent of years for EOM April. Suckers are able to access to Willow Creek when lake surface elevations are approximately 4,524.0 feet and creek discharge is sufficient (exact cfs not specified, Hewitt et al. 2018a). A minimum lake elevation of 4,520.6 feet above mean sea level by the end of September

each year is intended to conserve lake surface area and water depth as fish habitat into the winter months and into the following year. This lake elevation is also intended to reduce the likelihood of reduced spawning access the following spring. Extended drought may result in consecutive years of reduced surface elevations which are likely to adversely impact access to Willow Creek. The PA is not anticipated to affect spawning habitat in the tributaries to Clear Lake Reservoir.

Relatively little is known about rearing habitat requirements at Clear Lake Reservoir. Assuming that lake surface area, water depth, and shoreline are important components of rearing habitat, then the amount of habitat available in any given year will fluctuate relative to surface elevations. However, the amount of lake habitat would be substantially increased if Clear Lake were operated as a storage reservoir (as it is in the PA) in comparison to the without-action scenario. The PA may periodically reduce rearing habitat in Clear Lake Reservoir at low surface elevations when habitat contracts. Food resources are expected to be appreciably reduced without action as lake area will be confined to the west lobe. The seasonally wet east lobe is not anticipated to provide a prey base for suckers without action.

7.5.3.3 Food

Abundance of benthic macro-invertebrates is high in the Lost River (Shively et al. 2000b) and UKL (Hazel 1969). There is a lack of information on prey species abundance in Clear Lake Reservoir. Based on the abundance of macro-invertebrates in other basin waters, Reclamation assumes that prey species are also relatively high in Clear Lake Reservoir. Prolonged drought may concentrate fish into remaining habitat and reduce food availability through competition in Clear Lake Reservoir. Although prey species may be entrained on water delivery from Clear Lake, the PA is not anticipated to appreciably reduce food availability based on the assumption that prey species are abundant. Food resources are expected to be appreciably reduced without action as lake area would be confined to the west lobe. The seasonally wet east lobe is not anticipated to provide a prey base for suckers without action.

7.5.4 Effects to Critical Habitat in Gerber Reservoir and Tributaries

7.5.4.1 Water

Without action, Gerber Reservoir would likely be a small lake for several weeks during mid-February through April when inflows exceed the gate openings on the dam (about 900 cfs). Such a small lake would be short-lived. Thus, without action, designated critical habitat, as sufficient water in a lake habitat, at Gerber Reservoir would be negatively impacted. The PA may reduce surface area, water depth, and shoreline areas as habitat during periods of prolonged drought at Gerber Reservoir; however, when compared to without action, the PA has a beneficial impact of providing designated critical habitat for suckers in the reservoir defined by adequate surface area, depth, and sufficient water quality. Low lake elevations may also result in degraded water quality including higher pH values and lower DO concentration. Water quality monitoring over a wide range of lake levels and years has documented water quality conditions that are periodically stressful to suckers but were generally adequate for SNS survival (Reclamation 2001a, 2007; Piaskowski and Buettner 2003; Phillips and Ross 2012).

7.5.4.2 Spawning and Rearing Habitat

Neither without-action nor the PA are anticipated to impact spawning habitat at Gerber Reservoir. Sucker access into Barnes Valley and Ben Hall creeks, the principal spawning

tributaries for suckers in Gerber Reservoir, requires a minimum spring (February through April) elevation of about 4,805.0 feet (USFWS 2008). Surface elevations of at least 4,805.0 feet were reached each spring by end of April in all years for the POR and were reached by the end of March in all years except 1992. However, in very dry years both Barnes Valley and Ben Hall creeks typically have low spring flows that may not provide adequate upstream passage for spawning adults regardless of lake elevations (Reclamation 2001a).

The PA is anticipated to have minimal impact to rearing habitat at Gerber Reservoir. At Gerber Reservoir, larval and juvenile suckers likely utilize lake surface area, water depth, and shoreline as habitat. At 4,800 feet, the surface area of the lake decreases to about 750 surface acres. As lake surface elevation decreases so does the amount of available rearing habitat.

7.5.4.3 Food

Food resources for suckers, such as zooplankton and macro-invertebrates, are anticipated to be less without action compared to the PA. It is assumed that zooplankton and benthic macro-invertebrate abundance in Gerber Reservoir is similar to other aquatic lake environments in the Upper Klamath Basin (Hazel 1969; Shively et al. 2000b) under the PA. The PA provides for food availability in the lake environment except during prolonged drought which may concentrate fish into remaining habitat and reduce food availability through competition in Gerber Reservoir. Food resources are expected to be appreciably reduced without action as lake area will be confined. The remaining creek channels are anticipated to provide limited prey base for suckers without action.

8 Effects of Implementing the Proposed Action on Coho Salmon

Chapter 8 of the BA evaluates the effects of the PA on Southern Oregon Northern California Coastal (SONCC) coho salmon and its designated critical habitat. The effects of the PA are measured against the without action scenario. The PA is the continued operation of the Project including storage and delivery of irrigation water, from bodies of water in the Upper Klamath Basin, and the continued operation and maintenance of canals, dams, and pumps consistent with water storage and delivery (see Chapter 4.3, Proposed Action) for the period April 1, 2020 to March 31, 2024. The effects analyses of the PA on coho salmon in the Klamath River was conducted by reviewing model output on stream flows downstream of IGD provided by the Klamath Basin Planning Model (KBPM).

8.1 Hydro-Modeling

Reclamation will use results generated by the KBPM (a water balance model, within the WRIMS modeling platform, developed specifically for the Upper Klamath Basin that is within a WRIMS modeling platform) to identify the Klamath River hydrograph that is likely to occur as a result of implementing the PA. WRIMS is a generalized water resources modeling system, broadly accepted by the hydrologic community, for evaluating flexible operational alternatives for large, complex river basins. WRIMS integrates a simulation language for flexible operational criteria specification, a linear programming solver for efficient water management decisions, and graphics capabilities for ease of use. These combined capabilities provide a comprehensive and powerful modeling tool for water resource systems simulation.

Under the without-action scenario, the minimum elevation of UKL in the KBPM was set at 4,136.15. At this elevation, it is assumed that inflow will approximate outflow due to the hydraulic backwater effect of the reefs at the southern end of UKL (Neuman 2017) and that less than 10 TAF water will remain upstream of the reef. One of the reefs at the outflow of UKL was historically notched to an elevation of 4,131 (*See* Chapter 6) with a width of approximately 100 feet; however, the reef continues upgradient (to the north and into UKL) at an elevation ranging from 4,132 - 4,133. Therefore, when the UKL's water surface elevation is at 4,136.0 feet, the maximum outflow capacity is assumed to be less than 300 cfs. Reclamation does not have any other readily available information that can be incorporated into the KBPM in terms of release capacity at LRD at elevations below 4,136.15 to determine the true minimum lake elevations.

During the hydro modeling process, the PA was being refined simultaneously with development of the species effects chapters (Chapters 7, 8, and 9). For this reason, the species effects analysis was conducted on model output from a slightly different PA that was previously considered. In order to provide an updated PA at the earliest opportunity, the updated PA was developed and selected as the species effects analysis continued. Ultimately, the selected PA (Chapter 4) is nearly identical to the previously considered proposed action, upon which the effects analyses

were based. The primary difference is that the selected PA results in flushing flows in approximately 70 percent of water years, whereas the previously considered PA would have resulted in nearly-annual flushing flows. The differences between these two operational scenarios were evaluated and determined to be minimal and given time sensitivity surrounding the upcoming irrigation season Reclamation determined the additional delay and expense that working through revision of plots and the entire analysis would have entailed would not further a timely or productive outcome. The basis for concluding that model output from the previously considered action is appropriate for conducting the effects analysis for an action with a slight change in flushing flow frequency is provided in subsections below and can be addressed further as needed.

8.2 Period of Record

Reclamation used the POR of October 1, 1980 to November 30, 2019, from which to run the daily time step WRIMS model. October 1, 1980 to November 30, 2019, includes a reasonable distribution of dry, average and wet years. With this range of data, the WRIMS model is able to evaluate a particular water operation strategy across a reasonably foreseeable range of hydrologic patterns. Reclamation's analyses use WRIMS to estimate mainstem Klamath River flows at IGD that would likely be realized through implementation of the PA during the POR. Reclamation considers the resulting model outputs to reflect the range of flows reasonably expected to occur during the 4-year period of the PA (April 1, 2020 through March 31, 2024). However, it is important to note that each year in the POR has unique hydrologic and meteorological characteristics. While the hydrology observed in the POR captures the range of conditions, the unique sequencing and patterns of meteorological and hydrologic events that will occur in the future cannot be predicted. As such, unique meteorological and hydrologic events not captured in the POR may occur, resulting in conditions not simulated by WRIMS.

While the 39-year POR reflects a range of dry and wet water years, actual conditions may deviate from the representative trend in future years, possibly due to climate change. However, there is currently a lack of reliable forecasting tools available to adequately quantify the influence of global climatic changes on local hydrologic conditions. Therefore, the effects of possible future climate change, and the associated impacts on species and hydrology, are not explicitly incorporated into the analyses.

The historical IGD flows observed during the POR represent a component of the Environmental Baseline. Thus, the IGD flows included in the POR incorporate past and present impacts of all Federal, State, private actions and other human activities in the action area. Reclamation also modeled IGD flows as if the PA was implemented during the same POR. As mentioned above, Reclamation considers the resulting model outputs reflective of the range of flows reasonably expected to occur during the 4-year period of the PA (April 1, 2020 through March 31, 2024).

Flows during the POR are available on a daily timestep. Modeling output for the PA is also available on a daily timestep.

8.3 Ecological Effects

In this section, Reclamation assesses the effects to the hydrology and water quality with the implementation of the PA, relative to the without-action scenario. For reasons discussed in Chapter 6, the analysis will focus on impacts to the hydrology and water quality downstream of IGD. In subsequent sections, any effects of hydrology and water quality on federally listed coho salmon and designated critical habitat will be discussed.

8.3.1 Altered Hydrology

In the following analysis, Reclamation evaluated modeled without-action scenario flows at IGD during the POR and measured against modeled PA flows at IGD over the same POR. This section will discuss how IGD flows under the PA may alter hydrologic conditions. PA flows at IGD during the POR will be evaluated for the four components of a hydrograph including subsistence flows, base flows, high-flow pulses, and overbank flows.

Generally, uncontrolled flows released from IGD in the without-action scenario would likely result in more variable Klamath River conditions throughout the water year when measured against the PA. Simulating the without-action scenario showed that there were generally higher flows during the winter and spring when measured against the Proposed Action over the POR (Figure 8-1). Furthermore, the without-action scenario hydrograph typically shifts peak flows to occur later in the water year relative to the PA. Although higher flows are maintained throughout the majority of the water year under the without-action scenario, flows in late summer and early fall are sometimes higher under the PA relative to without-action scenario (Table 8-1 to 8-3).

8.3.1.1 Subsistence Flow

Subsistence flow is the minimum flow required during critical drought periods to maintain acceptable water-quality conditions and to provide minimal aquatic habitat space for the survival of aquatic species (NRC 2005) and can change by season and between years. Hardy et al. (2006) considers subsistence flows to represent flows between approximately the 80 and 95 percent exceedance ranges. During the POR under without-action scenario at IGD, the average flow between the 80 and 95 percent exceedance was 1,261 cfs. NMFS and USFWS (2013) determined that a mainstem flow of 1,000 cfs is expected to provide sufficient flow to maintain connectivity to tributaries for re-distributing juvenile coho salmon. An evaluation of the frequency of flows below 1,000 cfs was used to assess potential impacts of the PA on subsistence flows.

When the PA is applied to the POR, 18.7 percent (n=2,671) of the daily average flows are below 1,000 cfs (Table 8-1). Of those modeled flows below 1,000 cfs, the mean value is 937 cfs (range 900 – 999 cfs). Flows likely to occur under without-action scenario during the POR had a slightly lower frequency of daily average flows below 1,000 cfs, 16.9 percent (n = 2,422), and the mean of daily flows below 1,000 cfs was 732 cfs (Table 8-1). This suggests that implementation of the PA will result in an increase in the frequency of flows below 1,000 cfs, though the resulting flows in this range are of a greater magnitude relative to the without-action scenario.

8.3.1.2 Base Flow

Base flow is the “normal” flow condition between storms (NRC 2005) and can change throughout the year. For the purpose of this evaluation, the base flow will be considered to be

between 1,000 cfs and 6,000 cfs. Base flows accounted for 81 percent (n = 11,611) of without-action scenario flows during the POR with a mean of 2,302 cfs (Table 8-1). When the PA is applied to the POR, 78 percent (n = 11,170) of the daily average flows are considered base flow, with mean base flows of 1,792 cfs (Table 8-1). Although mean base flows under the PA are expected to be slightly lower when measured against the without-action scenario, they are within expected bounds to maintain tributary connectivity for re-distributing juveniles. Further, the PA maintains flows between July and October that more closely adhere to NMFS and USFWS (2013) base flow recommendations of 1,000 cfs; 95% exceedance flows under without-action scenario during this same time period (July to October) are predicted to fall well below 1,000 cfs suggesting that tributary connectivity and fish access may be impaired under without-action scenario in fall months.

8.3.1.3 High-Flow Pulses

High-flow pulses are punctuated events, typically following storms (NRC 2005) and can be defined differently throughout the year. Lack of high-flow pulses may result in the stabilization of gravel bars, promoting thick riparian vegetation at the river edges. Similarly, the loss of high-flow pulses may also cause alluvial barriers to seasonally form at the mouths of upper Klamath River mainstem tributaries (NMFS 2012c). The reduced frequency and magnitude of high-flow pulses may further increase the need for overbank flows to mobilize sediment and ensure tributary connectivity is maintained (Junk et al. 1989; Poff et al. 1997).

For the purpose of this analysis, high-flow pulses were defined as equal to or greater than 6,000 cfs but less than 12,000 cfs. This range is consistent with the USGS/USFWS mapping protocol in determining split channels, which are defined as a “permanent,” vegetated (trees) island that is not inundated even at a “high flow” of, which Hardy et al. (2006) defines as approximately 10,000 cfs in the lower Klamath River. In addition to the frequency of high-flows, the sustained duration of these events is also an important component of the hydrograph. To address this, high-flow pulse events were enumerated that were equal to or greater than 6,000 cfs but less than 12,000 cfs occurring over at least a three-day period.

When the PA is applied to the POR, 3.2 percent (n = 455) of the daily average flows are characterized as high-flow pulses, with an average value of 7,405 cfs (Table 8-1). High-flow pulses accounted for 1.9 percent (n = 269) of the daily average flows modeled under without-action scenario, with an average value of 6,750 cfs (Table 8-1). When the PA is applied to the POR, there are approximately 56 high-flow pulse events (equal to or greater than 6,000 cfs but less than 12,000) that are at least three days. Under the without-action scenario during the POR, approximately 37 high-flow pulse events occurred that were at least three days. Implementation of the PA will likely increase the frequency of high-flow pulse events that are three days or more in duration, a benefit to coho, relative to without-action scenario.

8.3.1.4 Overbank Flow

Overbank flow is an infrequent, high-flow event that breaches riverbanks (NRC 2005). These high flows facilitate the mobilization and transport of sediment and provide connectivity between the channel and floodplain (Poff et al. 1997) that supports both channel and riparian maintenance (Hardy et al. 2006). Geomorphic analyses, including initiation of bed load movement, suggested the flow threshold for bed mobility below IGD was approximately 13,000 cfs (Hardy et al. 2006). However, Shea et al. (2016b) described geomorphically effective flows as those required

to maintain channel form and reduce riparian encroachment. They classified discharges exceeding 15,000 cfs as geomorphically effective flows. Furthermore, the duration and magnitude of these overbank or geomorphically effective flows may be critical for channel maintenance (USFWS 2016b). For the purpose of this discussion, overbank flows are considered equal to or greater than 12,000 cfs.

When the PA is applied to the POR, 0.06 percent (n = 9) of the mean daily flows will be characterized as overbank flow, with an average of 14,549 cfs (range 12,815 – 16,865 cfs with an average duration of 3 days). Overbank flows accounted for 0.02 percent (n = 3) of without-action scenario daily flows, with an average of 15,311 cfs (Table 8-1). Implementation of the PA, would likely result in more frequent occurrences of overbank flows relative to the without-action scenario, creating a benefit for coho.

8.3.1.5 Flow Variability

Low variability in flows can result in reduced habitat complexity, and ultimately, a loss of diversity (Poff et al. 1997). Maintaining natural variability in the flow regime is important for conserving the structure and function of a riverine ecosystem (Sanford et al. 2007). The intent of the increased flow variability with the implementation of the PA is to restore a more natural riverine ecosystem, which is assumed to benefit coho salmon.

In addition, the PA allows for additional flexibility in managing water in-season. In-season adjustments to the modeled PA flows in the coho salmon Effects Analysis are difficult to incorporate because these management determinations are based upon conditions. In recognition of these limitations, the PA will allow for greater daily IGD flow variability compared to past water management practices during the POR. However, it is unclear how flow variability under the PA will change relative to without-action scenario. While the PA is likely to stabilize flows during certain hydrologic conditions and operations (e.g., increasing storage in UKL), it is difficult to determine how over the entire POR variability will change under the PA relative to without-action scenario. Additionally, the flow variability experienced within a single year (e.g., difference between peak and minimum flows) under the PA appears to be greater, relative to without action conditions. It is likely that flow variation, a benefit to coho, occurs more frequently (on a smaller time step) without-action scenario relative to the PA. A summary of IGD daily exceedance flows for both the PA and without-action scenario are included in Tables 8-1 and 8-2 in Appendix 8A).

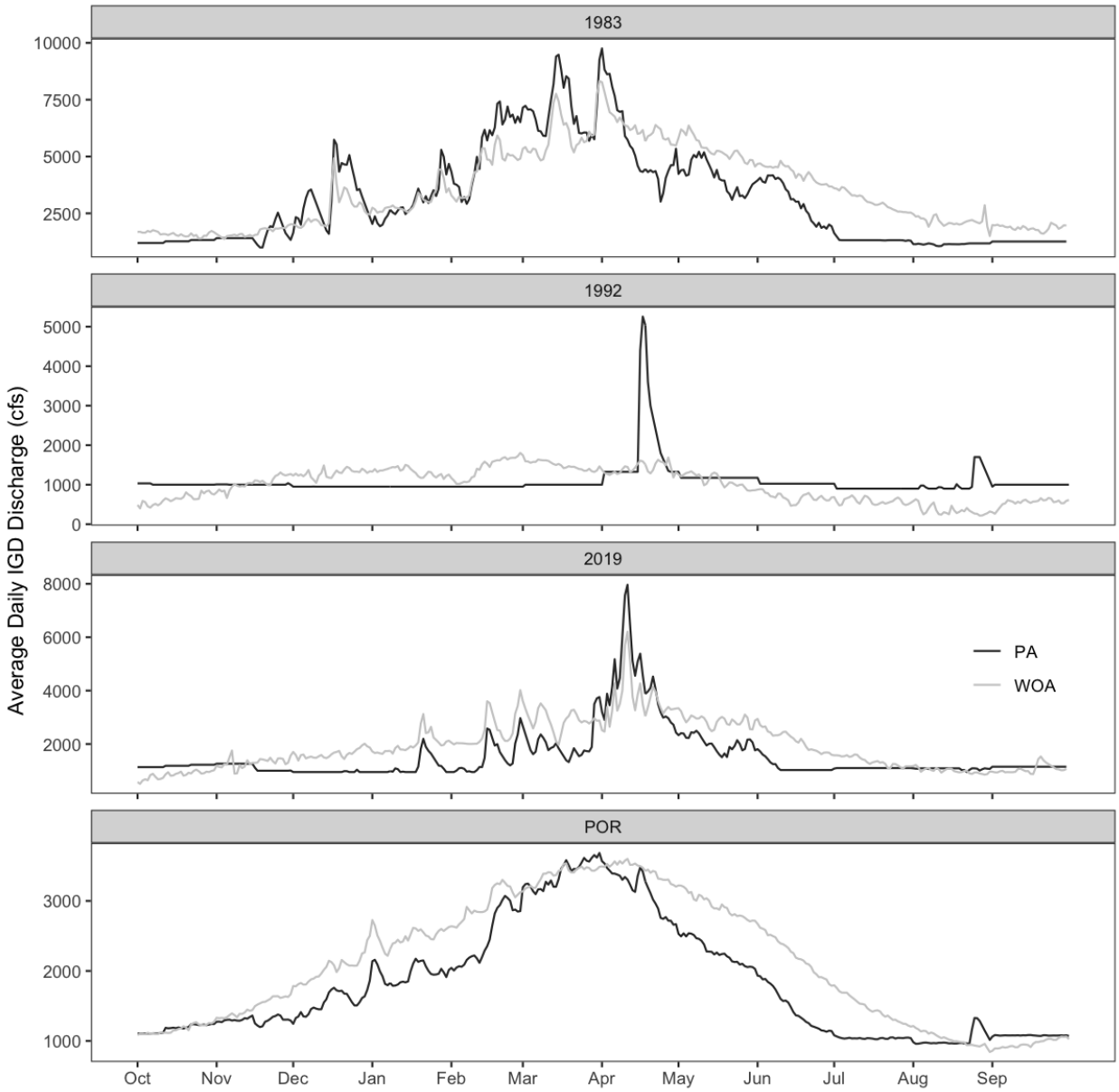

Figure 8-1. Simulated average daily discharge at Iron Gate Dam for a wet (1983), dry (1992), and average (2019) water year, and for the period of record (1980 – 2019) for the Proposed Action (PA) (black line) and the Without-action (grey line) scenarios (WOA).

Table 8-1. Summary of Iron Gate Dam simulated without-action scenario and Proposed Action average daily flows during the Period of Record (October 1, 1980 to November 30, 2019).

Criteria	Proposed Action	Without-action scenario	Difference
Count (Total Daily Flows)[1]	14,305	14,305	0
Average Daily Flow (cfs)[1]	1819	2,122	-303
Percent of the Modeled Proposed Action[1]	100%	116.7%	-16.7%
Count (Flows <1,000 cfs)[2]	2,671	2,422	249
Percent of Total Count[2]	18.7%	16.9%	1.7%
Average Daily Flow (cfs)[2]	937	732	205
Count (Flows ≥1,000 cfs but <6,000 cfs)[3]	11,170	11,611	-441
Percent of Total Count[3]	78.1%	81.2%	-3.1%
Average Daily Flow (cfs)[3]	1,792	2,302	-510.85
Count (Flows ≥6,000 cfs but <12,000 cfs) [4]	455	269	186
Percent of Total Count[4]	3.2%	1.9%	1.3%
Average Daily Flow (cfs) [4]	7,405	6,750	655
Count (Flows ≥12,000 cfs) [5]	9	3	6
Percent of Total Count[5]	0.063%	0.021%	0.042%
Average Daily Flow (cfs) [5]	14,549	15,311	-762

[1] – Total Daily Flows
[2] – Flows less than 1,000 cfs
[3] – Flows greater than or equal to 1,000 cfs but less than 6,000 cfs
[4] – Flows greater than or equal to 6,000 cfs but less than 12,000 cfs
[5] – Flows greater than or equal to 12,000 cfs

This section evaluates how the implementation of the PA may modify water quality downstream of IGD. In particular, this section discusses potential effects on water temperature, nutrient loading, and DO concentrations, from both the proposed action and a without-action scenario.

8.3.2.1 Temperature

Klamath River water temperatures are largely correlated with air temperature. Generally, ambient air temperatures in the fall and winter in the Klamath Basin do not result in water temperatures that would negatively affect salmonids. Therefore, the effect of the PA on Klamath River water temperatures during these seasons will not be further discussed here.

In addition to air temperature, there is also evidence that Klamath River discharge affects water temperature. Asarian and Kann (2013) found statistically significant negative relationships between mean monthly flow and mean water temperature for June and July (2001 – 2011) at lower river sites: Orleans, Weitchpec, Tully Creek, and Turwar. There were no significant relationships between flow and water temperature at the sites most affected by IGD releases (i.e.,

immediately below IGD, Seiad Valley), suggesting that IGD flow releases influence water temperature less than factors affecting flow below Seiad Valley, such as tributary inflow.

Given the statistically significant relationship between water temperature and discharge below Seiad Valley, Reclamation analyzed the effect of IGD flow releases simulated from the PA on Klamath River water temperatures using the River Basin Model-10 (RBM10; Yearsley et al. 2001; Yearsley 2009; Perry et al. 2011). The RBM10 is a heat budget model that allows the user to model the effects of discharge on water temperature at numerous points along a river channel (Perry et al. 2011). Reclamation analyzed RBM10 output from January 1, 1980 – December 31, 2017, for RMs 189.8 (IGD), 174.0 (downstream of the confluence with the Shasta River), 136.8 (downstream of the confluence with the Scott River), and 62.5 (downstream of the confluence of the Salmon River) for 1981 to 2014 (Appendix 8A, Tables 8-4 through 8-7). Reclamation determined that this combination of sites and months was appropriate to assess the effect of the PA over the time periods and locations relevant for juvenile outmigration, juvenile rearing, and adult migration. The period from 1980 – 2017 was selected because the model is only parameterized (e.g., with meteorological data, etc.) through 2017. The RBM10 output indicates that modeled temperatures expected under the PA from 1980 – 2017 could result in small temperature increases (i.e., no more than 1.8°C) in water temperatures at the four sites assessed during this period (Appendix 8A, Tables 8-4 through 8-7). Given this, Reclamation concludes that the IGD releases modeled under the PA will have minor effects on water temperature at the four nodes examined.

Without running the RBM10 model on the without-action scenario, it is unclear how temperature will change relative to without-action. Without-action scenario flows, generally characterized as relatively higher discharge November through July, could result in lowering water temperatures. Low flows in July, August, and September without-action scenario are anticipated to result in warm water temperatures downstream in the Klamath River from water originating from a shallow Upper Klamath Lake. Reduced water temperatures in spring and summer from the without-action scenario are a benefit to coho, and we anticipate greater benefit from the without-action scenario relative to the PA for spring and summer water temperatures. Warmer water temperatures in late summer and fall are a negative impact to coho. Reclamation anticipates an increased negative impact from late summer and fall temperatures from without-action scenario relative to the PA.

8.3.2.2 Nutrient Loading

Project return flows from the LRDC and KSD contribute nutrient load to the Klamath River although UKL is the source of greatest nutrient and BOD loads. In particular, UKL exports substantial AFA biomass during the irrigation season (NRC 2004; ODEQ 2017; Schenk et al. 2018). During the irrigation season, very little water from the Project and Lost River watershed flows to the Klamath River. Generally, the Project has been characterized as a nutrient sink, rather than source (ODEQ 2017; Schenk et al. 2018), given that only 30 percent of UKL/Klamath River water entering the Project is returned to the Klamath River (ODEQ 2017). However, there is evidence to suggest that discharge from the LRDC can have a substantial negative impact on DO concentrations at Miller Island in the Keno Impoundment, though the magnitude and duration of the effect is less than that resulting from releases from UKL (ODEQ 2017) and is highly dependent on Project operations.

Outside of the spring/summer irrigation season, water quality in the Keno Impoundment is greatly improved, owing to lower water temperatures, an increase DO concentrations as a result of reduced biomass exported from UKL, and increased oxygen saturation with reduced water temperatures (ODEQ 2017). During this period, the LRDC, which drains the Lost River watershed and the Project, flows towards the Klamath River and thereby contributes some nutrient and BOD load to the Klamath River (Schenk et al. 2018). However, this additional load tends to be relatively small compared to the total load from UKL (Schenk et al. 2018).

In conclusion, although the Project does contribute nutrient load to the Klamath River via the LRDC and KSD, any negative effect of these loads on water quality parameters is largely masked by substantial export of algal biomass from UKL and the fact that water quality is further affected by a series of reservoirs, dams, and meteorological and hydrologic conditions downstream of the Project. Thus, it is not known at this time how this increase in nutrient concentration within the Keno Impoundment impacts the nutrient concentration within PacifiCorp reservoirs and below IGD. Additionally, there is suggestion that the Project acts as a nutrient sink, reducing nutrient load from UKL to the Klamath River through diversions at the A Canal headworks and North and Ady canals. Similarly, improvements in Project infrastructure that allow recirculation of return flows within the Project may reduce the volume of return flow (and nutrient load) reaching the Klamath River. Furthermore, the PA does not count re-diversion of return flows against Project Supply in the spring/summer; Project irrigators are likely to redivert this water which could result in reduced return flow to the Klamath River, relative to that observed without action.

Given the upstream impacts on nutrient loads, there is not expected to be much difference between the without-action conditions and the PA with regards to nutrients. However, during the late summer and early fall under the without-action scenario, UKL will be at its lowest elevation and the decreased pool size could contribute to reduced water quality parameters in the river, such as nutrient loading.

8.3.2.3 Dissolved Oxygen

Low DO concentrations immediately downstream of IGD do occur during the summer. These low DO concentrations are largely driven by the effects of the PacifiCorp Hydroelectric Project (NMFS 2007) and the highly eutrophic outflow from UKL. However, Project operations may influence DO concentrations since they directly affect Klamath River discharge, which is related to DO concentration at certain Klamath River sites (Asarian and Kann 2013). Because DO is affected by algal blooms, temperature and discharge, the effect of the PA on DO cannot be determined. However, in late summer and fall without-action scenario, flows can fall below minimums established by the PA, which could potentially result in a slight, but negligible, increase in DO under the PA relative to without-action scenario.

Table 8-2. Modeled and observed monthly average discharge (cfs) at Iron Gate Dam for each month from June – August (1980 – 2019).

Month	Modeled Proposed Action (cfs)	Actual (cfs)	Difference (cfs
June	1,461	1,392	70
July	1,040	893	148
August	1,027	963	63

Table 8-3. Monthly average observed discharge (cfs) at various Klamath River USGS gage sites from June – August (1981 – 2019), and the relative portion of flow attributed to Iron Gate Dam (IGD) releases.

Month	Near IGD (cfs) (RKM = 311)	Seiad Valley (cfs) (RKM = 208)	IGD Release Contribution (%)	Near Orleans (cfs) (RKM = 95)	IGD Release Contribution (%)	Near Klamath (cfs) (RKM = 13)	IGD Release Contribution (%)
June	1,461	2,936	50	6,210	24	11,766	12
July	1,040	1,511	69	2,775	37	5,198	20
August	1,027	1,214	85	1,876	55	3,325	31

8.4 Effects on Coho Salmon Survival, Growth, and Reproduction

A literature-based approach to assess the potential influence of the PA on different life stages of coho salmon in the mainstem Klamath River. The effects of the PA on coho salmon and salmonid disease conditions were examined first in the context of WRIMS model output, which modeled IGD flows if the PA was implemented during the POR from October 1980 – November 2019 (Table 8-4). Second, we used a similar literature-based approach to assess the influence of water temperatures on coho salmon and salmonid disease conditions using the River Basin Model-10 (RBM10) model (Yearsley et al. 2001; Yearsley 2009). This model was parameterized for the Klamath River by Perry et al. (2011) and run for the period October 1980 – November 2017 (Table 8-5).

8.4.1 Flow Effects

Metadata: This meta-analysis of existing literature provides a tool for assessing the temporal effects of different flows on several key life stages of coho. The utility of a meta-analysis approach is to examine the relationship between specific flow conditions predicted for the Proposed Action and positive and negative thresholds for physiological and behavioral effects on coho salmon based on existing literature. Reclamation examined predicted flows for the PA in the 2002 and 1997 water years to represent examples of low and high water-years, respectively.

To demonstrate the variability in flows, Figure 8-2 shows the intersection between the 90 percent, 50 percent, and 10 percent exceedance flows at IGD if the PA was implemented during the POR (1980 – 2019) and the generalized effects of flow on coho salmon adults, embryos, juveniles, smolts, and disease risks to fish. Flow ranges can affect survival, successful reproduction, and or growth. The length of each rectangle represents the period that each life-stage is active in the freshwater environment while the height indicates the range of flows.

Effects on adult coho salmon: Adult freshwater migration occurs from September through mid-January (Hardy et al. 2006). Guillen (2003) asserted that adult Chinook migration was inhibited in 2002 as a result of extreme low flows, which can limit the depth of water available for cover and navigation as well as olfactory cues from natal streams. Coho have been shown to respond similarly to low-flow conditions (Sandercock 1991), and therefore we have assumed that the observations of Guillen (2003) apply to coho as well (Figure 8-2). Flow releases in September 2002 at IGD averaged 759 cfs (Lynch and Risley 2003); a significant reduction in flow from

unimpaired discharges (>1,110 cfs) estimated by Hardy and Adley (2001). When the 2002 water-year was related to the metadata (Figure 8-3, Table 8-4), simulated flows had a negative impact on adult migration during most of October – December 2001 and all of September 2002, roughly 85 percent of the migration period. Conversely, during the simulated high-flow scenario (1997), conditions were favorable for adult migration during approximately 98 percent of the migration period (Figure 8-4, Table 8-4).

Flows would likely be higher during winter, spring, and early summer under the without-action scenario than if the PA were implemented. Therefore, the PA may impact adult coho during the adult migration and spawning period, in relation to the without-action scenario. In a low flow year, it is unclear if the PA would result in a negative effect on adult coho in relation to the without-action scenario. This is because both scenarios may result in low flows (<1,100 cfs) that are considered to have a negative impact on migrating adults (Figure 8-1). During a high-flow water year, flow conditions would have positive impacts on adult migration under both the without-action scenario and the PA.

Effects on embryos: Coho embryo development typically occurs from November through the end of March (Hardy et al. 2006). Only a small portion of natural coho salmon spawning occurs in the mainstem Klamath River (Dunne et al. 2011), thus minimizing the effects of the PA on this life stage. Nevertheless, high flows are likely to affect embryos via mechanical damage as substrate is moved or by physical displacement from the redd. Ericksen et al. (2007) estimated that scouring of spawning gravels (gravels with a median diameter of 2 inches) would occur at flows above 5,163 cfs in the Klamath River. There is a dearth of literature on the effects of flows below 5,163 cfs and, therefore, the effects of a low-flow scenario are unclear (Figure 8-3). During the 1997 high flow simulation, the PA had a negative effect on egg survival for approximately 31 percent of the period when development could take place in the mainstem, primarily during January and February (Figure 8-4).

There is very little information on how low-flow conditions affect coho eggs; however, flows in excess of 5,163 cfs will negatively influence eggs (Ericksen et al. 2007). Based on flow conditions during the period of incubation (November – June) (Stillwater Sciences 2009), neither an average or low-flow water year for the PA or without-action scenarios are likely to meet this threshold. During a higher flow year (e.g., 1983; Figure 8-1) both the PA and without-action scenario conditions result in flows high enough to scour redds, though the magnitude is slightly higher if the PA was implemented. Thus, under average conditions there are no negative impacts to coho embryos expected if the PA were implemented relative to the without-action scenario condition. Further, during extreme low-flow water years it is unclear how ova would be impacted for either a without-action scenario condition or PA condition. However, both scenarios are expected to have a negative impact under a high-flow water year.

Effects on fry: Coho fry emerge as free-swimming fish February through mid-May (Hardy et al. 2006). Hardy et al. (2006) estimated maximum fry habitat availability occurs at flows between 1,954 cfs and 4,674 cfs. The fry life stage typically overlaps temporally with spring freshets in the Klamath River (Figure 8-2). As a result, flows are adequate for fry approximately 46 percent of their development period in a dry water-year (Figure 8-3, Table 8-6). During wet water years (e.g. 1997), flows correspond with positive effects for 67 percent of their development period

(Figure 8-4, Table 8-6), except in February and April when flows were higher and lower (respectively) than the preferred flow range. High flows during early spring could potentially displace fry if adequate refugia is unavailable, however, there is a data gap for the effects of high flow ranges on coho fry in the Klamath.

During low flow years, without-action would likely improve flows for fry compared to the PA during the emergence period. For example, 90 percent exceedance flows at IGD under the without-action range between 1,612 and 1,948 cfs (Appendix 8A, Table 8-2) whereas the PA 90 percent exceedance flows range between 950 and 1,598 cfs (Appendix 8A, Table 8-1). However, it should be noted that under both scenarios, low-flow conditions are below the optimal threshold (1,954 cfs) for fry. For average water years, there is likely no effect from the PA relative to the without-action scenario, since there is adequate water for both conditions (Figure 8-1). For high water years, both scenarios result in flows > 4,674 cfs, above the optimal range for emerging fry. Given that very few adults spawn in the mainstem Klamath compared to tributaries, it is unlikely that emerging fry will be significantly impacted by the effects of the PA relative to without-action conditions.

Effects on juvenile coho (parr): Juvenile coho are present year-round in the Klamath River. (Hardy et. al. 2006) estimated maximum parr habitat availability occurs at flows between 1,384 cfs and 5,507 cfs. Simulated flows for 2002 frequently fell below this optimized ranged, however, there are punctuated flows during winter and spring pulse events that create positive effects for juveniles (Figure 8-3) amounting to roughly 34 percent of the year. By comparison, flows during the simulated wet water year had a positive effect on juvenile coho approximately 43 percent of the year (Figure 8-4, Table 8-6), however, there is a data gap for the effect of flows exceeding 5,507 cfs and falling below 1,384 cfs.

During low and average flow water years, juvenile coho are likely to experience lower flows if the PA were implemented relative to the without-action in the winter and spring (Figure 8-1). However, during summer and fall, the PA typically produces higher flows than the without-action scenario (Figure 8-1). Given the lack of information on flows outside the optimal range, it is unclear how this difference will affect rearing juveniles.

Effects on smolts: Smolts typically out-migrate through the Klamath River mainstem from mid-March through late- July. Beeman et al. (2012) predicted hatchery coho smolt survival to exceed 80 percent at flows between 1,500 cfs and 10,000 cfs. During a particularly low-flow year in spring of 2015, observations of coho were scarce when flows fell below 1,500 cfs (David et al. 2017b). During 2002, flow conditions were predicted to negatively affect coho smolt survival during roughly 50 percent of the emigration period, with the remaining 50 percent experiencing positive flow effects (Figure 8-3, Table 8-6). During the high flow water year in 1997, simulated flows under both the without action conditions and PA were within the flow range where smolt survival is anticipated to exceed 80 percent. (Figure 8-4, Table 8-6).

During most of the out-migration period (March – June, peak period April and May), 90 percent exceedance flows at IGD are between 68 and 735 cfs lower during implementation of the PA than for without-action conditions (Appendix 8A, Table 8-3). Both scenarios include 90 percent exceedance flows <1,500 cfs, suggesting that under low-flow conditions, coho smolts would be

negatively affected by flows under both without-action and PA scenarios, but the magnitude may be greater if the PA were implemented. During average or high-flow water year conditions, the PA would likely result in lower instream flow relative to the without-action scenario, although both scenarios would produce flows within the range where smolt survival would be expected to exceed 80 percent (Appendix 8A, Table 8-1, Table 8-2).

Effects on Ceratonova shasta (*C. shasta*) *disease:* Salmonids in the Klamath River are exposed to a number of pathogens and parasites that can impact all coho salmon life stages. *C. shasta* is the focal parasite of this meta-analysis, which is regarded as a prominent threat to juvenile salmonids in the Klamath River. High flow events can potentially disrupt the parasite's life-cycle by disrupting and constraining suitable habitat of the annelid host, *Manayunkia speciose* (*M. speciosa*), and thereby limiting effective parasite spore production (Bjork and Bartholomew 2009; Malakauskas et al. 2013; Alexander et al. 2016). The PA results in annelid-disrupting flows in excess of 6,000 cfs at IGD in both dry and wet water years (Figures 8-3 and Figure 8-4, respectively). The magnitude and duration of flows exceeding 5,000 cfs, the minimum flow for disease mitigation are greater in wet years within the POR; in the 1997 water year (wet year) flows of at least 5,000 cfs were achieved for approximately 1.4 percent of days, whereas in 2002 (dry year), that same flow rate was achieved in roughly 0.8 percent of days (Table 8-6). Flows between 2,500 cfs and 5,000 cfs represent a large portion of the water-year and fall into flow ranges for which there is a large gap in the literature; therefore, the effects of these flow ranges on coho are unclear.

The magnitude of peak flows between February and June are higher under the PA compared to the without-action condition (Figure 8-1), resulting from the implementation of surface-flushing flow events. The PA would likely reduce disease severity relative to without-action conditions as a result of these higher magnitude flow events in the spring. Conversely, flows under the without-action condition are generally higher than the PA during most water years, although the magnitude of these flows is typically less than the minimum flow rate thought to provide disease benefits (Figure 8-1). Given the limited data available on flow effects on parasites, spore concentrations, and infection rates for flows between 2,500 and 5,000 cfs, it is unclear how elevated flows under the without-action scenario would affect disease conditions relative to the PA.

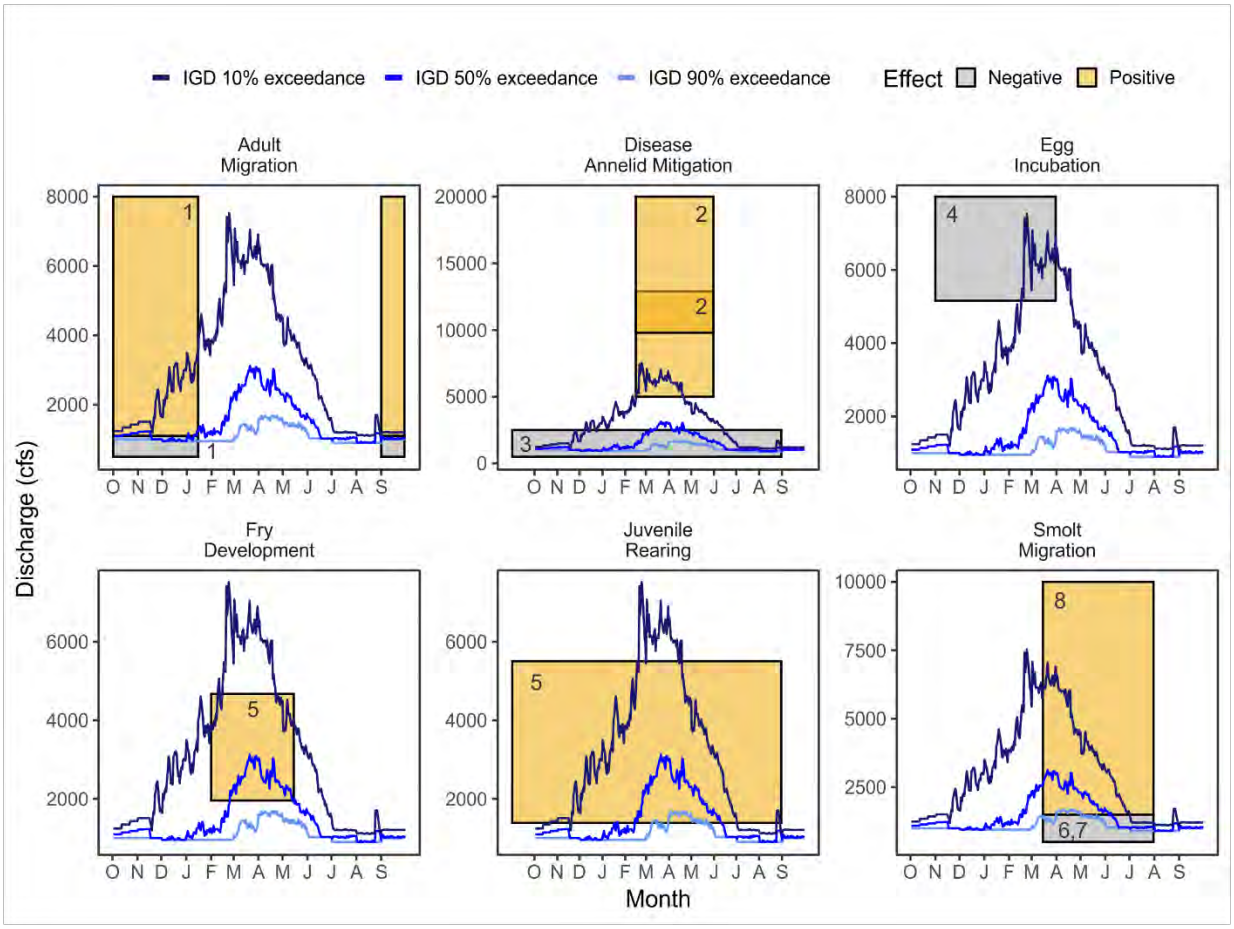

Figure 8-2. Analysis of the temporal effects of different flow ranges on coho salmon adults, embryos, juveniles, and smolts, and fish affected by disease mitigation. Numbers in the plotting area indicate the metadata references: 1. (Guillen 2003); 2. (U.S. Fish and Wildlife Service (USFWS) 2016b); 3. (Holmquist-Johnson and Milhous 2010); 4. (Ericksen et al. 2007); 5. (Hardy et al. 2006); 6. (David et al. 2017a); 7. (David et al. 2017b); 8. (Beeman et al. 2012). The 90%, 50%, and 10% exceedance flows from IGD are indicated by the colored blue lines. Source: Mount Hood Environmental (2020).

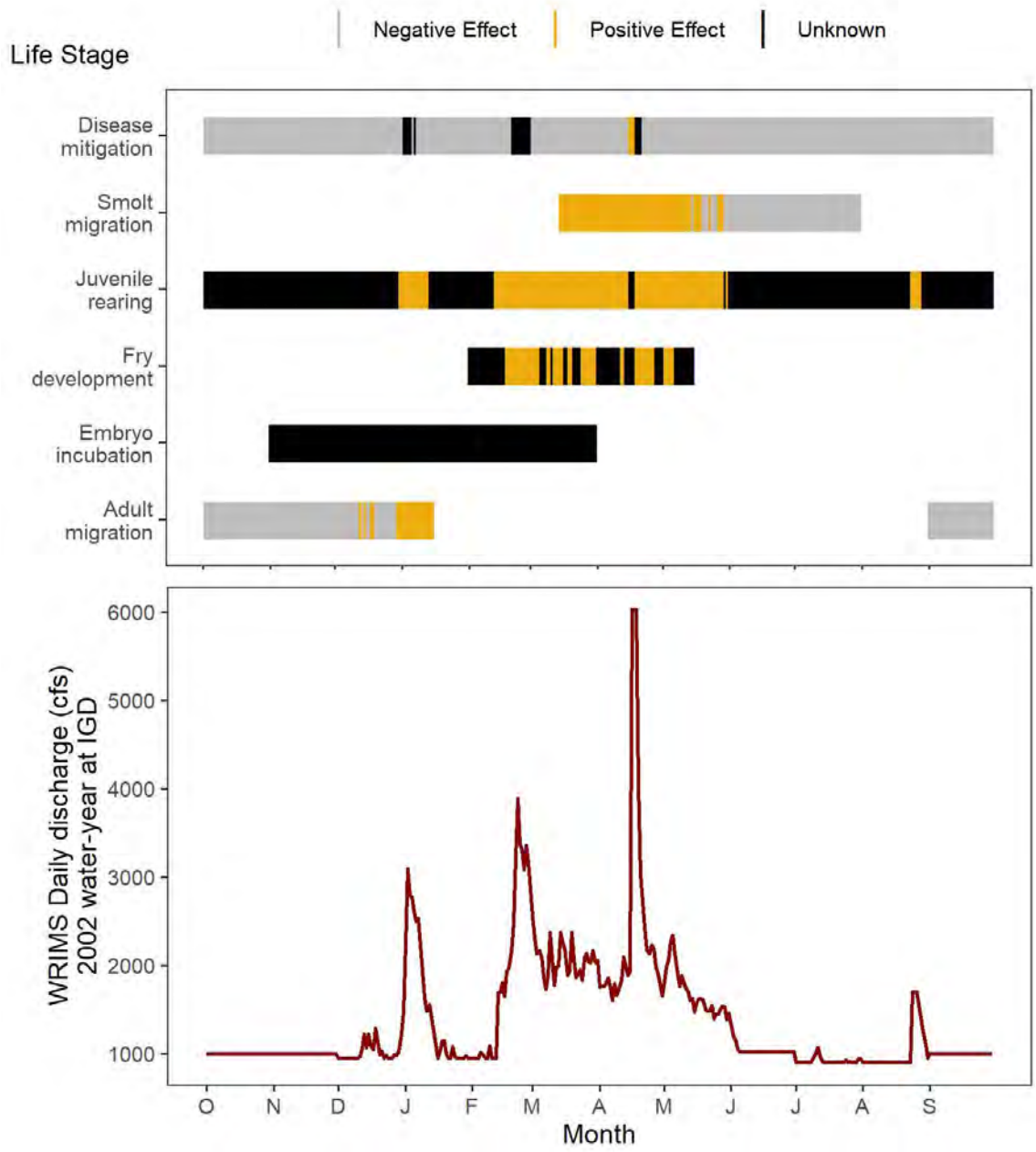

Figure 8-3. Low flow water year (2002; lower plot) effects on coho salmon based on meta-data (upper plot). Black regions indicate coho life stage is active but a data gap exists in the literature at the given discharge value. Source: Mount Hood Environmental (2020).

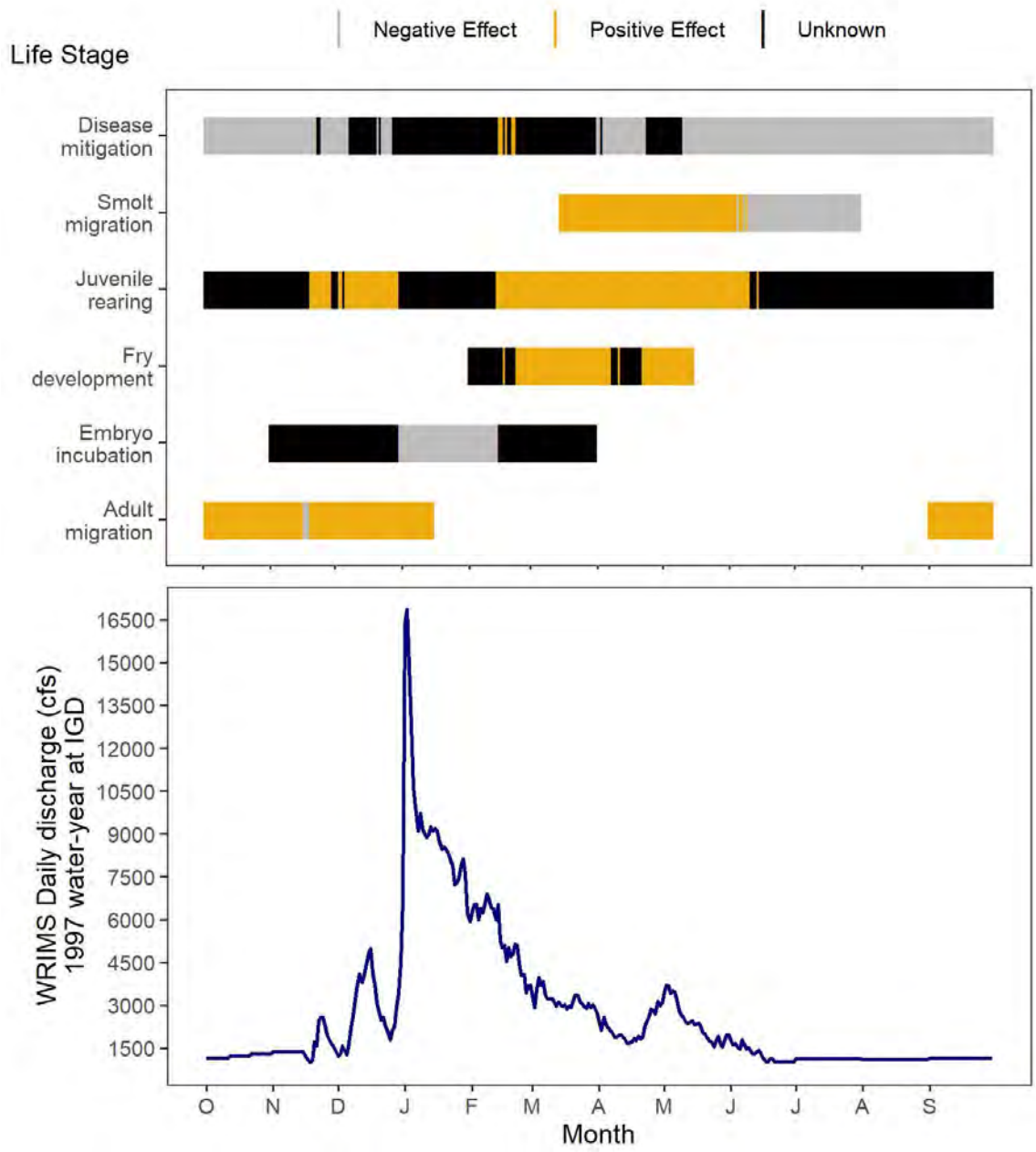

Figure 8-4. High flow water-year (1997, lower plot) effects on coho salmon based on meta-data analysis (upper plot). Black regions indicate coho life stage is active but a data gap exists in the literature at the given discharge value. Source: Mount Hood Environmental (2020).

Table 8-4. The number of days coho salmon are positively or negatively affected by simulated Water Resource Integrated Modeling System water year (WY) flow scenarios based on meta-analysis of literature. Parentheses indicate the percentage of days effected of the total days each life stage is active. Source: Mount Hood Environmental (2020).

Life Stage	Simulated High Flow WY 1997	Simulated High Flow WY 1997	Simulated Low Flow WY 2002	Simulated Low Flow WY 2002
	- days (%)	**+ days (%)**	**- days (%)**	**+ days (%)**
Adult (migration)	3 (2.2)	133 (97.8)	115 (84.6)	21 (15.4)
Disease (annelid host)	236 (64.8)	5 (1.4)	344 (94.5)	3 (0.8)
Embryo	46 (30.5)	0	0	0
Fry	0	70 (67.3)	0	48 (46.2)
Juvenile	0	155 (42.6)	0	123 (33.8)
Smolt	54 (38.8)	85 (61.2)	70 (50.4)	69 (49.6)

8.4.2 Temperature Effects

Metadata: There is a dearth of continuous water temperature data in the mainstem Klamath River for the reach from IGD to the Shasta River and consequently there are few studies that directly quantify the impact of temperature on coho. This meta-analysis of existing literature in the Klamath River basin, as well as other locations, provides a tool for assessing temperature effects on discrete coho salmon life stages. For this analysis, temperature data for the PA was simulated by the RBM10 model as the average daily temperature for the period 1980 – 2017 for five locations between IGD and Humbug Creek: IGD to Bogus Creek (rm 189.8), Bogus Creek to Willow Creek (rm 187.3), Willow Creek to Cottonwood Creek (rm 183.6), Cottonwood Creek to the Shasta River (rm 179.4), and the Shasta River to Humbug Creek (rm 174). Because tributaries downstream of IGD (e.g. the Shasta River, the Scott River, and the Salmon River) substantially influence flow and temperature in the mainstem Klamath River, this analysis focused on the section of river between IGD and just below the confluence of the Shasta River where the PA is most likely to impact fish.

The following sections regarding specific life stages of coho will focus on the positive, negative, and lethal thresholds for behavioral and physiological effects of temperatures simulated for the PA. Since most life stages of coho are negatively affected by high temperatures, an examination of both daily average and maximum daily average temperature for the period of record was performed. Figure 8-5 shows the intersection between the simulated PA temperatures between IGD and Humbug Creek (1980 – 2017) and the generalized effects of temperature on coho salmon adults, embryos, juveniles, smolts, as well as *C. shasta* spore conditions derived from existing literature resources. Temperature can affect survival, successful reproduction, and development. The length of each rectangle represents the period that each life stage is active in the freshwater environment and the height indicates the range of temperatures described as having positive, negative, or lethal effects.

It is unclear how water temperatures for the without-action scenario differ from the PA as these scenarios were not simulated in RBM10; therefore, the relative nature of effects between scenarios is undetermined. However, the PA may result in cooler water temperatures in the late summer and early fall flows whereas conditions from without-action scenario could result in reduced temperatures during spring and early summer. Water temperature differences between the PA and the without action scenario and anticipated to be appear minor.

The PA will reduce water temperatures in spring and summer from the without-action scenario are a benefit to all life stages of coho salmon. Reclamation anticipates greater benefit from the without-action scenario relative to the PA for spring and summer water temperatures due to higher flows having a small temperature influence. Conversely, warmer water temperatures in late summer and fall are a negative impact to coho due to the lower flows in the without action scenario.

Effects on adult coho salmon: Adult freshwater migration occurs from mid-September through mid-January (Hardy et al. 2006). Peak river entry of migrating coho adults was observed after temperatures fell below 20 °C (Strange 2004), and 21 to 22 °C was reported as the lethal limit for migrating adult coho in the Columbia River during summer (Richter and Kolmes 2005). More than 80 percent of the migration period had temperatures that would positively affect migrating adults under the PA (Table 8-5). There were 8 days under the PA that were considered lethal temperatures when we assessed daily average maximum temperatures; however, average daily temperatures over the POR did not produce any lethal temperatures indicating migration conditions are typically satisfactory. It should be noted that modeled temperatures only cover the river reach between IGD and just below the confluence of the Shasta River, which includes only a portion of the migratory pathway for some fish.

Spawning adults are typically active from October through the mid-January (migration and spawning). Optimal temperatures for spawning range from 10 to 13 °C and when temperatures exceed 20 °C, ova will rapidly deteriorate (Richter and Kolmes 2005). More than 80 percent of the spawning season had maximum daily temperatures that were optimal for spawning adults (Figure 8-5, Table 8-5). In October, there were approximately 21 days when the maximum of daily average temperature exceeded the optimal range, however, it was well below the temperature threshold for negative effects.

Water temperatures should be initially higher in early fall and then lower by November under the without-action scenario due to the higher flows in early fall and winter, which will benefit adult coho salmon during peak migration and spawning. Similar positive impacts are anticipated to occur under the PA.

Effects on embryos: Coho embryo development typically occurs from November through the end of March (Hardy et al. 2006). Only a small portion of natural coho salmon spawning occurs in the mainstem of the Klamath River (Dunne et al. 2011), thus minimizing the effects of the PA on this life stage. Nevertheless, extreme temperatures can affect embryo survival when they fall below 1.3 °C (Tang et al. 1987) or when they exceed 11 °C (Richter and Kolmes 2005). The lethal limit for coho embryos is 14 °C (Richter and Kolmes 2005). The maximum of daily average temperature for the PA was predicted to produce favorable conditions for embryo

development for 75 percent of the incubation period (Figure 8-5, Table 8-5). There were no days that included lethal temperatures, however, 22 percent of days during the incubation period had temperatures that would negatively affect coho egg development (Figure 8-5, Table 8-5). However, this should also be similarly beneficial under the without-action scenario because flows are anticipated to be slightly higher and presumably cooler. The without-action scenario could experience extreme low temperatures and could have a negative impact on coho embryo development.

Effects on fry: Coho fry emerge as free-swimming fish February through mid-May (Hardy et al. 2006), preferring temperatures between 4.0 °C and 10.9 °C (Tang et al. 1987). Fry were positively affected by maximum of daily average temperatures for the PA approximately 41 percent of days during their expected presence in the mainstem Klamath River (Figure 8-5, Table 8-5). While temperatures in April and May exceeded the preferred thermal range, there is a data gap for temperature effects on coho salmon fry outside the optimal range. Given temperatures exceeded the optimum range for most of this development period, the PA will likely have some negative impacts on fry development relative to without-action conditions.

Effects on juveniles (parr): The upper range used for negative effects of temperature on juvenile coho was 17.0 – 25.8 °C, which combined thermal ranges from several studies (25.8 °C lethal limit, Beschta et al. 1987; >20.0 °C, NRC 2004; >17 °C, Richter and Kolmes 2005; Hillemeier et al. 2009; >19.9 °C, Sutton and Soto 2012; Adams and Bean 2016). The maximum daily average temperatures for the POR were predicted to negatively affect juvenile coho for approximately 43 percent of their rearing period (Figure 8-5, Table 8-5), primarily during the summer and fall. Rearing coho were positively affected by temperatures approximately 57 percent of the year, mostly between winter and spring when temperatures were moderate under the PA. The without-action scenario would have similar temperatures, perhaps slightly lower, in spring months to the PA. The without-action condition is anticipated to have greater temperature impacts to juveniles remaining in the mainstem river during late summer and early fall when flows are lower and temperatures potentially higher.

Effects on smolts: Smolts typically out-migrate from the Klamath River mainstem from mid-March through late-July (Gough et al. 2015; David et al. 2017a). Richter and Kolmes (2005) suggested the threshold temperature range for smoltification is 2.5 – 15.5 °C. Beeman et al. (2012) observed increased coho salmon smolt survival at temperatures greater than 10.0 °C, however, a review of temperature effects on chinook salmon smolts indicated that physiological processes involved in smoltification are inhibited at temperature >13.0 °C (McCullough 1999). For the purposes of this analysis, we will consider temperatures from 15.5 – 30.0 °C to result in negative effects on coho smolts. Temperatures with the PA were unfavorable for smolts 59 percent of their active period, and likely to have positive effects the remaining 41 percent of their active period (Figure 8-5, Table 8-5). Similar to migrating adults, these estimations only pertain to a small portion of the migratory pathway that is used by some smolts. Temperatures in the without-action scenario are anticipated to be similar with a slightly higher percent of days with temperatures more tolerable to smolt due to elevated flows during spring and late summer.

Effects on disease (C. shasta) infection: Salmonids in the Klamath River are exposed to a number of pathogens and diseases that can impact all life stages. In this meta-analysis, we will

focus on *C. shasta* infection in coho. Fryer and Pilcher (1974) suggested that coho infected with *C. shasta* exhibited high survival at a temperature range of 3.9 to 15.5 °C and low survival at temperatures above 15.5 °C. Similarly, Ray et al. (2012) found that temperatures between 18.0 °C and 21.0 °C were positively related to mortality. Furthermore, warm water temperatures are associated with higher *C. shasta* spore concentrations (Som et al. 2019) and springtime water temperatures above 12 °C can significantly contribute to disease severity. In a meta-analysis of *C. shasta* literature (Figure 8-5), the maximum of daily average temperatures simulated for the PA were likely to negatively affect coho salmon via elevated spore concentrations for approximately 64.5 percent of the water year (Table 8-5). The combination of temperatures above 15.5 °C and elevation spore concentrations likely result in elevated disease risk for coho salmon if those conditions coincide with the outmigration period. It is likely that the without action scenario likely produces cooler water temperatures, and potentially reduced disease risk, relative to the PA.

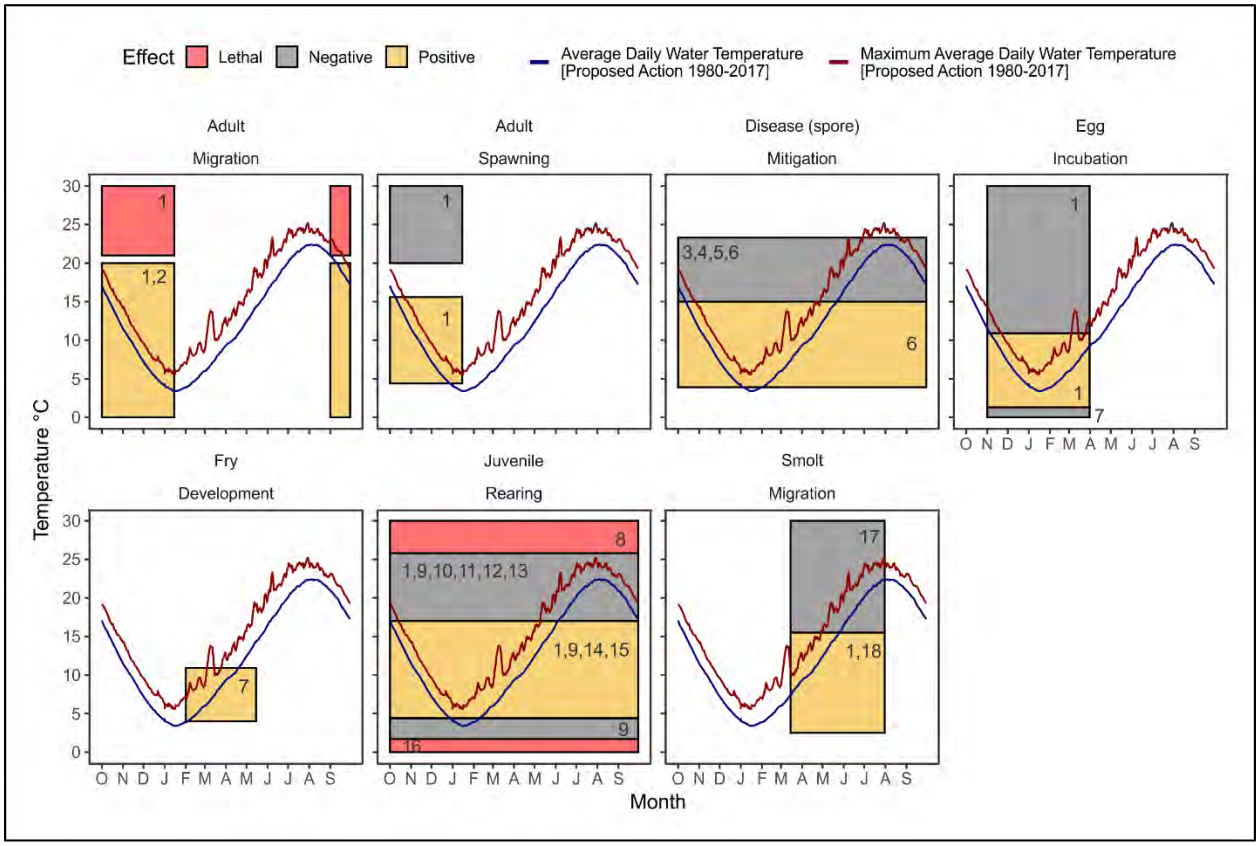

Figure 8-5. Analysis of the temporal effect of water temperatures on coho salmon adults, embyros, juveniles, and smolts, and disease mitigation for *C. shasta*. Temperatures are daily averages of five sites located between Iron Gate Dam and Humbug Creek [rm 189.8 – 174.0], 1980-2017. Numbers in the plotting area indicate the metadata references**:** 1. (Richter and Kolmes 2005); 2. (Strange 2004); 3. (Ray et al. 2012); 4. (Hallett et al. 2012); 5. (Som et al. 2019); 6. (Fryer and Pilcher 1974); 7. (Tang et al. 1987); 8. (Beschta et al. 1987); 9. (Stenhouse et al. 2012); 10. (Sutton and Soto 2012); 11. (Hillemeier et al. 2009); 12. NRC (2004); 13. (Adams and Bean 2016); 14. (Foott et al. 2014); 15. (Reiser and Bjornn 1979); 16.(Brett 1952); 17.(McCullough 1999); 18. (Beeman et al. 2012). The modeled daily average and maximum of daily average temperatures from Iron Gate Dam to Humbug Creek are indicated by the blue line and red lines, respectively. Source: Mount Hood Environmental 2020.

Table 8-5. The number of days coho are positively, negatively, or lethally affected by Proposed Action temperatures simulated by the River Basin Model-10 over the period or record 1980-2017. Effects are based on meta-data analysis of literature. Parentheses indicate the percentage of days affected of the total days each life stage is active.

Life Stage	Lethal days[1]	- days[1]	+ day[1]	Lethal days[2]	- days[2]	+ days[2]
Adult Migration	0	0	128 (92.8)	19 (13.8)	0	113 (81.9)
Adult Spawning	0	0	80 (74.1)	0	0	87 (80.6)
Disease Mitigation	0	144 (39.3)	193 (52.7)	0	182 (49.7)	184 (50.3)
Egg Incubation	0	4 (2.6)	147 (96.7)	0	37 (24.3)	115 (75.7)
Fry Development	0	0	75 (72.1)	0	0	43 (41.3)
Juvenile Rearing	0	118 (32.2)	204 (55.7)	0	156 (42.6)	210 (57.4)
Smolt Migration	0	48 (34.5)	91 (65.5)	0	82 (59)	57 (41)

[1] Proposed Action Daily Average
[2] Proposed Action Maximum of Daily Average

8.5 Effects on Designated Coho Salmon Critical Habitat

Effects of the PA on coho salmon critical habitat were assessed with a similar analytical approach to the 2013 BiOp (NMFS and USFWS 2013), specifically sections 11.4.1.2.3.1 and 11.4.1.2.3.2 to describe PA effects. This analysis contains an evaluation of the simulated PA flows relative to without-action conditions.

The principal tool to describe the PA is a habitat quantification tool for the mainstem Klamath River developed by Texas State University, USGS, and USFWS, and was used to estimate habitat availability across a range of IGD discharges from 100 to 10,000 cfs in increments of 100 cfs. Estimates of habitat availability were summarized for fry and parr for three river reaches (IGD to Shasta River, Shasta River to Scott River, and Scott River to Salmon River) and four sites (R Ranch, Trees of Heaven, Seiad Valley, and Rogers Creek) downstream of IGD[15]. In the 2013 BiOp, effects of the PA on habitat area were assumed to be negative if there was both a positive relationship between flow and habitat area, and, if habitat area was less than 80 percent of the maximum prediction. Exceedance tables were used to highlight flow volumes predicted for the PA within each river reach and site that would be expected to reduce habitat availability. The exceedance table is intended to predict the frequency and timing of impacts to coho habitat resulting from the PA.

[15] This analysis excluded reaches below the Salmon River since IGD water releases represent the majority of river flow volume in the Klamath River and downstream inputs could potentially mask the effects of the PA on salmon habitat in upstream reaches.

The PA will result in general habitat results similar to the without-action scenario with seasonal flows characterized as relatively high in the spring. However, it is anticipated that habitat is more available in winter to early summer in the without-action scenario, and less available in the fall compared to the PA (Figure 8-1).

8.5.1 Habitat Area Simulation Methods

IGD flows (100 cfs increments) were used as inputs in a hydrodynamic model developed for the main stem Klamath River (Hardy et al. 2006) to generate habitat availability predictions for coho fry and parr. The model estimated fine-scale changes in daily depth, velocity, and surface area in eight distinct geomorphic river reaches[16] as a function of IGD discharge and river accretions. Weighted usable area (WUA) curves[17] were generated for 86 unique, meso-habitat units by (1) running two-dimensional (2D) hydrodynamic models over a range of river flows, (2) calculating univariate habitat suitability criteria (HSC) for each life stage based on distance to nearest cover, water velocity, and depth, for each computational cell in the model, (3) calculating the geometric mean of the univariate HSCs, and (4) estimating the weighted usable area (WUA) for each habitat unit as the sum of the product of the computational cell's surface area and geometric mean HSC for all cells. Model results were extrapolated for the entire length of the Klamath River downstream of IGD by applying one of the modeled WUA curves to each remaining habitat unit. WUA curves were chosen for each habitat unit based on geomorphic similarity to one of the modeled habitat units. These assignments were made by consensus within a team of fish habitat experts from the USFWS, USGS, and Texas State University. Finally, to rescale a WUA curve from source to target, WUA (expressed as units of area m^2) was divided by channel length to produce weighted useable width curves, representing the mean width of the unit that is suitable habitat. Once expressed as channel width, the WUA curves were scaled from source to target unit by multiplying by the ratio of channel widths between source and target, as calculated using a "downriver" continuity equation at common exceedance flows among units, following modified methods in Leopold and Maddock (1953). Lastly, the re-scaled weighted usable width was multiplied by the target unit's length to convert it to WUA.

The resulting WUA curves for the three reaches of the Klamath River (IGD to Shasta River, Shasta River to Scott River, and Scott River to Salmon River) that underlie our critical habitat analysis differ from NMFS and USFWS (2013) (Figure 8-9). While the HSC values for the PA are the same in both analyses (Figure 8-6), the 2013 BiOp WUA curves are derived from a methodology designed to develop reach-scale WUA estimates, rather than mesohabitat scale estimates used in this analysis. More specifically, the 2013 BiOp methodology assumed an average of site-specific values, whereas the approach for this BA used an extrapolation method. The WUA data presented here represents the best and most current information available on the relationship between river discharge and coho fry and parr habitat availability.

This discussion is limited to the PA's effect on coho salmon parr rearing habitat during spring. This is because juvenile coho salmon are most abundant in the mainstem Klamath River from

[16] A "reach" is a spatially explicit section of river with distinct geomorphic and stream flow properties. The eight river reaches selected during hydrodynamic model development were representative of the diversity of habitat types found throughout the Klamath River between IGD and the Klamath River mouth.
[17] A WUA curve is the plotted relationship between WUA (habitat suitability index) and river flow.

March to June (Justice 2007) and limited in the summer due to limited habitat that provides thermal refugia.

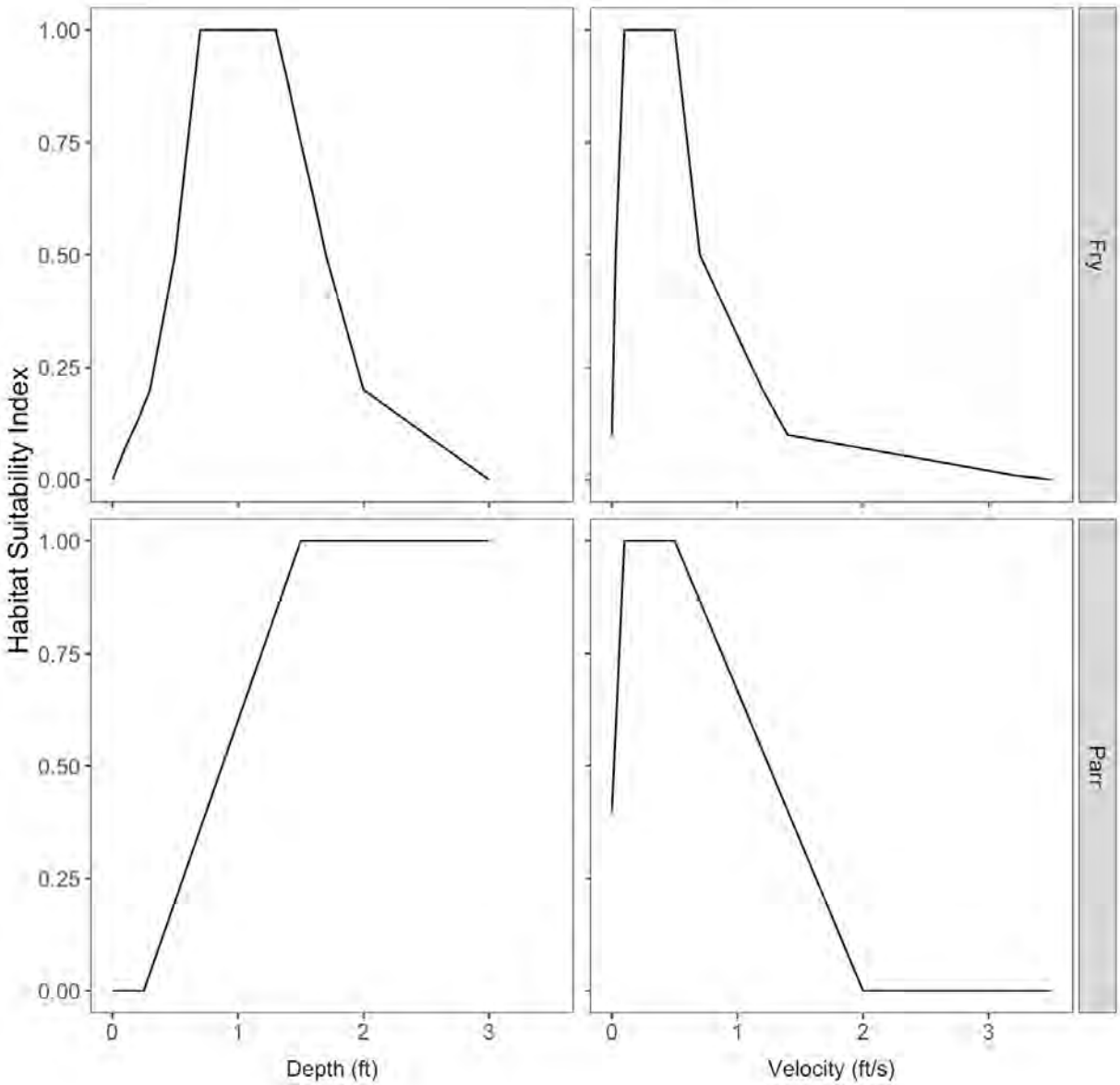

Figure 8-6. Coho salmon fry and parr depth and velocity habitat suitability criteria (Hardy et al. 2006). Source: Mount Hood Environmental (2020).

8.5.2 Habitat Area Simulation Results

The effects of reduced flows on habitat availability for coho salmon fry and parr depend on the flow volume and habitat area at each site (Figure 8-9). For example, flow increases at the R Ranch site between 100 and 3,000 cfs were predicted to increase fry habitat availability, while flow increases above 3,000 cfs were predicted to reduce habitat availability. The following discussion provides general observations about potential flow impacts and Figure 8-9 provides specific flow volumes predicted to impact coho fry and parr habitat availability as a result of the Proposed Action and without-action scenario.

The PA impacts coho fry habitat availability in the mainstem Klamath River between IGD (rkm 310) and the Salmon River (rkm 107) in March-June, with the highest frequency of negative effects occurring between the Shasta River (rkm 289) and the Scott River (rkm 232) and from the Scott River to the Salmon River (Figure 8-10, Table 8-6, Table 8-13). Specifically, the reaches between the Shasta and Scott Rivers and between the Scott and Salmon Rivers reached 80 percent of the maximum WUA on 6 percent and 7 percent of days, respectively, over the period of record (Table 8-6). The effects of the PA would likely provide the best habitat benefit during dry years when average daily spring flows range from 1,000 – 2,600 cfs; during these periods the PA allows for deviations to the formulaic approach to EWA, such that the volume maximizes the ecological benefits (Table 8-7).

The PA impacts parr habitat availability across a broad range of flow exceedance values at the R Ranch, Trees of Heaven, Seiad Valley, and Rogers Creek sites during the spring (Tables 8-8 through 8-12; Appendix 8A, Figures 8-8 through 8-12). Effects of the PA are predicted to occur most frequently at the Trees of Heaven and Seiad Valley sites. The Trees of Heaven site reached 80 percent of maximum WUA for 4 percent of days over the period of record while the Seiad Valley site reached this threshold for 3 percent of days (Table 8-8).

Despite declines in habitat availability for coho salmon fry and parr, the PA provides flow variability during precipitation and snowmelt events in the mainstem Klamath River that is reflective of actual hydrologic conditions above Upper Klamath Lake. The PA also includes managed flushing flows and the flexibility to deviate from the formulaic approach to EWA distribution that can address both habitat availability and other potential factors (e.g., *C. shasta* spore concentrations, prevalence of infection, etc.) impacting coho salmon. These flow measures are expected to improve survival of rearing and migrating coho salmon in the mainstem Klamath River.

Under the without-action scenario, river discharge is anticipated to be generally higher from winter (about November) through summer (about July) and relatively low in August, September, and October. Without-action scenario flows will exhibit a high frequency of discharge variability as unrestricted flows from hydrologic events of rain and snow melt occur in the upper basin. Most variability of flow is likely to occur in spring months as ambient temperature causes freezing and thawing of the snowpack but could also occur with significant rainfall events in the upper basin during fall months. The high spring discharge corresponds with juvenile coho presence in the Klamath River and is anticipated to provide juvenile coho more habitat at high flows (winter, spring, and into summer). The low discharges of late summer and fall under the without-action scenario are anticipated to contract habitat availability.

Relative to the without-action scenario, the PA is predicted to cause flows from November to May between 40 percent and 95 percent exceedance probabilities to decline (Appendix 8A, Table 8-3) between 3 and 53 percent (Appendix 8A, Table 8-2). However, during March, exceedance flows between 35 and 5 percent are expected to increase slightly (approximately 1 - 25 percent), likely due to implementation of disease flushing and flexible EWA augmentation flows. Low flow periods in August, September, and October are also expected to increase under

the PA relative to the without-action scenario, which may result in increased fry and parr habitat availability.

The proposed action does not force implementation of a flushing flow nearly every year, as it did under the Services' 2019 BiOp. Without a forced flushing flow every year, there are opportunities to redistribute flow from large discharge events later into the spring months. Simulated output shows that such flow redistribution, along with a flexible flow augmentation approach to EWA, may increase the amount and the duration of juvenile salmon habitat during critical spring months. For example, in 2007 flows would not drop as sharply as they would right after the flushing flow (Figure 8-7). In 2009, there would be higher flows at the end of March if there was not a flushing flow earlier in the same month (Figure 8-8). These examples demonstrate how the volume of water from a flushing flow event can be reshaped to extend habitat benefits into spring months for juvenile coho habitat. In both figures, the black line represents flushing flow implementation, as modeled under NMFS' 2019 BiOp, and the red line represents the PA

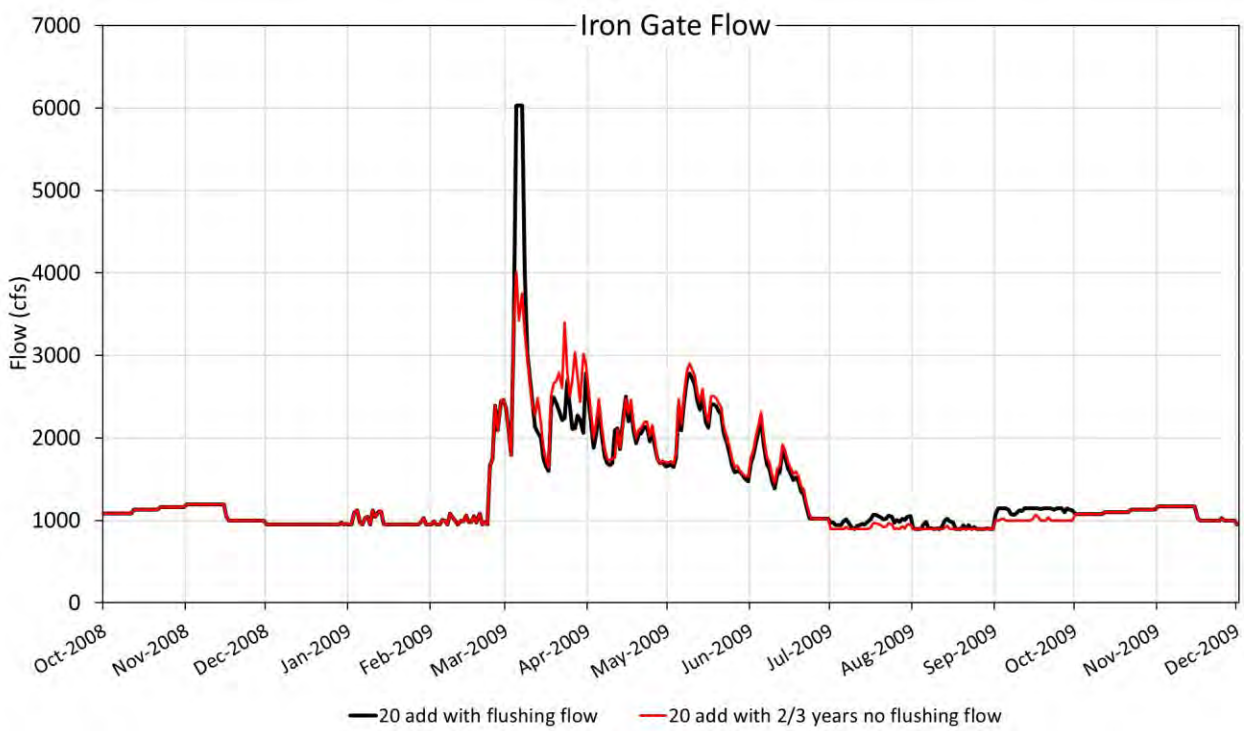

Figure 8-7. Demonstration of surface flushing flow implementation versus an alternative to utilize the volume of water for coho habitat in spring months with 2007 hydrology.

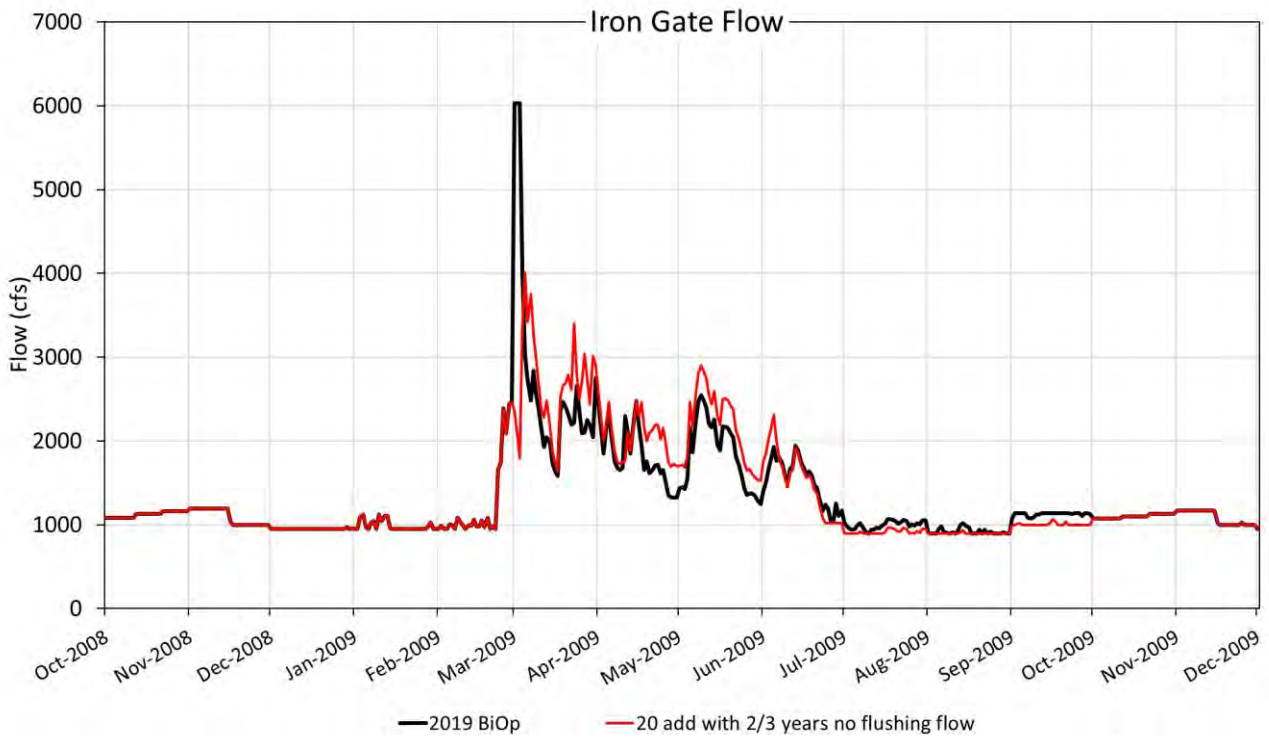

Figure 8-8. Demonstration of surface flushing flow implementation versus an alternative to utilize the volume of water for coho habitat in spring months with 2009 hydrology.

Table 8-6. Number and percentage of days over the period of record (14,000 days total) at which habitat availability is at or above 80 percent of maximum WUA for 7 sites and 3 reaches for Coho Salmon fry and parr.

Site	Coho Fry	Coho Fry	Coho Parr	Coho Parr
R. Ranch (rkm: 296 – 298)	3,640	13%	2,166	8%
Trees of Heaven (rkm: 272 – 275)	1,670	6%	1,270	4%
Brown Bear (rkm: 238 – 240)	1,691	6%	1,461	5%
Seiad Valley (rkm: 205 – 208)	1,398	5%	770	3%
Roger's Creek (rkm: 112 – 114)	2,964	10%	5,096	18%
Orleans (rkm: 93 – 95)	1,542	5%	5,331	19%
Saint's Rest Bar (rkm: 68 – 70)	4,009	14%	5,292	18%
Reach				
IGD to Shasta R. (rkm: 289 – 312)	3,092	11%	7,672	27%
Shasta R. to Scott R. (rkm: 232 – 289)	1,745	6%	1,369	5%
Scott R. to Salmon R. (rkm: 107 – 232)	2,031	7%	1,332	5%

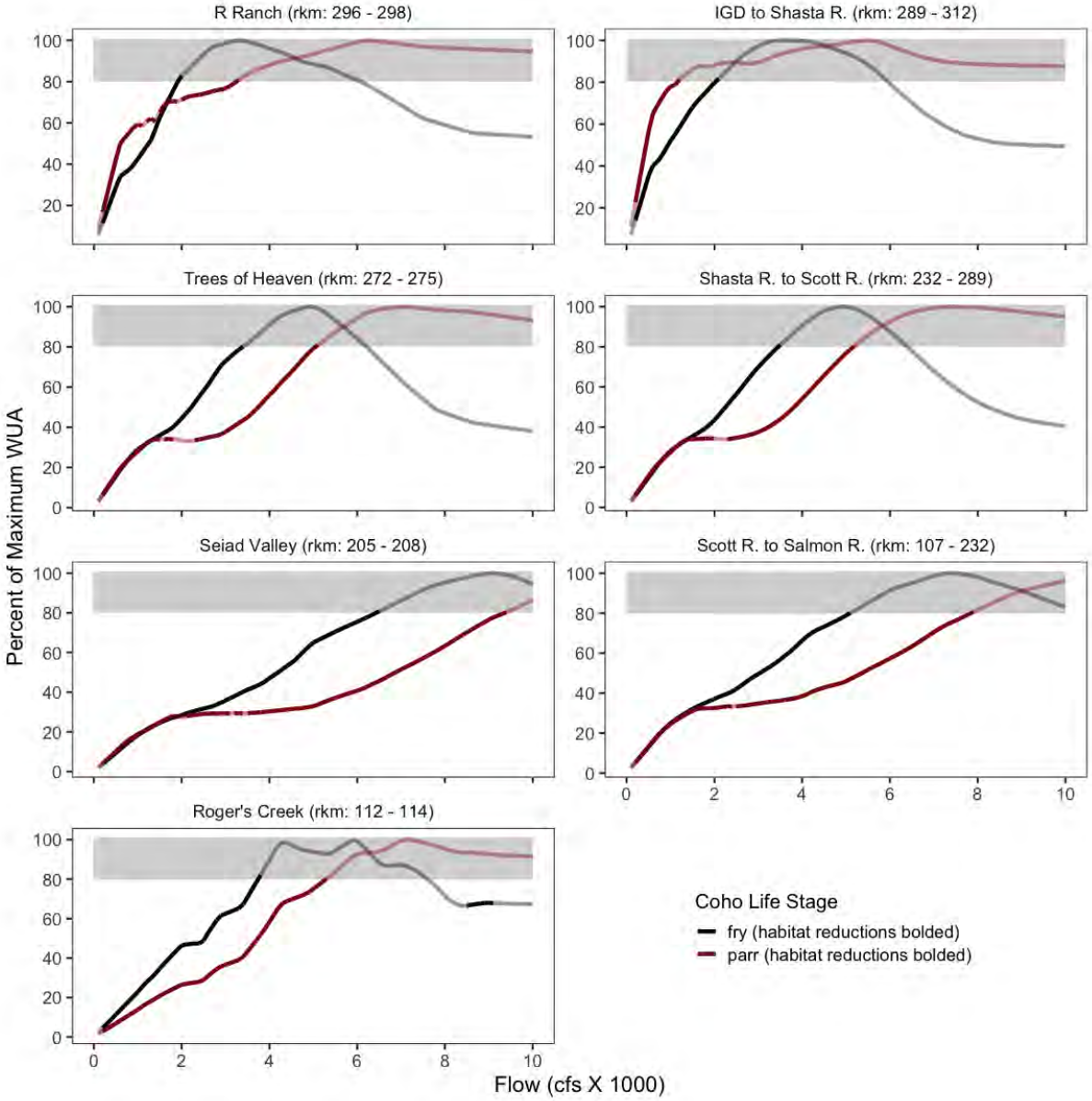

Figure 8-9. Coho salmon fry and parr habitat availability relative to mainstem flows for three reaches and four sites downstream of Iron Gate Dam. Flows account for tributary accretions and were estimated for each habitat unit when calculating weighted usable area (WUA). Gray horizontal bands indicate WUA values ≥ 80% of maximum. Potential habitat reductions due to the Proposed Action are bolded. Source: Mount Hood Environmental (2020).

Table 8-7. Daily average mainstem flows (cfs) within nearest 5 percent exceedance for the Proposed Action that likely reduce coho salmon fry habitat availability to below 80 percent of maximum (orange highlight). Flows estimated for the midpoint of each reach with Reach 1 from river km 289 to 312 (totaling 23 km), Reach 2 from river km 232 to 289 (totaling 57 km), and Reach 3 river km 107 to 232 (totaling 125 km). Source: Mount Hood Environmental (2020).

Exceedance Rates	Reach 1 March	Reach 1 April	Reach 1 May	Reach 1 June	Reach 2 March	Reach 2 April	Reach 2 May	Reach 2 June	Reach 3 March	Reach 3 April	Reach 3 May	Reach 3 June
95%	1122	1556	1276	1057	1452	1798	1454	1128	2622	2675	2049	1354
90%	1367	1742	1428	1070	1755	2008	1651	1166	2944	2986	2337	1472
85%	1660	1821	1576	1082	2018	2140	1800	1206	3253	3377	2632	1545
80%	1801	1926	1649	1093	2196	2261	1919	1230	3594	3744	2878	1649
75%	1924	2021	1706	1110	2340	2444	2010	1276	3986	4108	3183	1759
70%	2087	2164	1756	1125	2541	2605	2139	1319	4324	4515	3458	1918
65%	2229	2265	1826	1145	2755	2745	2237	1374	4722	4795	3780	2055
60%	2447	2467	1908	1175	3011	3033	2357	1431	5121	5296	4091	2180
55%	2721	2682	1988	1215	3349	3318	2481	1514	5820	5755	4503	2358
50%	3008	2946	2114	1303	3730	3576	2662	1586	6479	6293	4863	2565
45%	3316	3212	2378	1417	4094	3887	2933	1685	7041	6853	5298	2883
40%	3636	3489	2594	1492	4527	4307	3232	1828	7584	7543	5867	3196
35%	4172	3879	2793	1619	5090	4738	3529	2037	8322	8167	6445	3481
30%	4560	4291	3020	1787	5711	5282	3766	2241	9222	8744	6932	3932
25%	5102	4827	3248	1946	6418	5832	4052	2462	10325	9394	7477	4450
20%	5961	5207	3496	2156	6884	6294	4402	2718	11444	9960	7891	4985
15%	6495	5741	3903	2393	7714	6663	4903	3073	12589	10548	8840	5572
10%	7211	6159	4314	2727	8752	7190	5353	3588	14388	11466	9740	6452
5%	9092	6723	5041	3420	10825	8031	6205	4272	17779	12544	10736	7565

Reach 1 = The mainstem Klamath River from Iron Gate Dam to the confluence of the Shasta River (rkm 289-312).
Reach 2 = The mainstem Klamath River from the confluence of the Shasta River to the confluence of Scott River (rkm 232-289).
Reach 3 = The mainstem Klamath River from the confluence of the Scott River to the confluence of the Salmon River (rkm 107-232).

Table 8-8. Daily average mainstem flows (cfs) within nearest 5 percent exceedance for the Proposed Action that will likely reduce coho salmon juvenile habitat availability (blue highlight) in the R Ranch reach. Source: Mount Hood Environmental (2020).

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1007	1021	984	1003	1027	1122	1456	1175	1025
90%	1011	1030	992	1018	1048	1367	1598	1346	1025
85%	1024	1036	1002	1038	1071	1660	1680	1438	1025
80%	1042	1043	1011	1060	1096	1801	1731	1484	1025
75%	1066	1050	1022	1082	1136	1924	1802	1524	1025
70%	1092	1060	1030	1101	1192	2087	1884	1569	1025
65%	1114	1084	1042	1129	1266	2229	2032	1611	1025
60%	1132	1110	1057	1176	1368	2447	2177	1655	1025
55%	1151	1167	1083	1245	1515	2721	2382	1733	1025
50%	1167	1210	1124	1374	1747	3008	2565	1857	1113
45%	1184	1245	1170	1538	2056	3316	2822	2038	1223
40%	1200	1261	1235	1712	2380	3636	3098	2238	1319
35%	1215	1278	1370	1949	2744	4172	3430	2395	1401
30%	1235	1313	1624	2310	3048	4560	3848	2587	1504
25%	1261	1368	1871	2682	3541	5102	4314	2823	1648
20%	1298	1432	2224	3118	4142	5961	4628	3045	1795
15%	1320	1506	2644	3616	4900	6495	5211	3311	2048
10%	1381	1685	3371	4647	6114	7211	5613	3777	2377
5%	1486	3058	5115	6403	9125	9092	6112	4453	2991

Table 8-9. Daily average mainstem flows (cfs) within nearest 5 percent exceedance for the Proposed Action that will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Trees of Heaven reach. Source: Mount Hood Environmental (2020).

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1114	1183	1146	1189	1231	1350	1712	1364	1098
90%	1135	1197	1163	1218	1265	1612	1891	1561	1121
85%	1154	1210	1188	1251	1300	1912	1996	1696	1148
80%	1183	1222	1201	1278	1343	2047	2099	1786	1167
75%	1205	1238	1219	1318	1385	2160	2240	1852	1195
70%	1232	1258	1242	1351	1452	2375	2357	1950	1221
65%	1251	1283	1260	1393	1545	2539	2499	2037	1265
60%	1269	1327	1290	1443	1676	2743	2753	2129	1313
55%	1297	1367	1328	1532	1858	3101	3003	2236	1368
50%	1327	1406	1391	1672	2102	3448	3266	2391	1443
45%	1349	1432	1450	1849	2412	3754	3536	2650	1555
40%	1371	1455	1547	2054	2747	4203	3885	2876	1678
35%	1396	1480	1716	2371	3129	4679	4321	3125	1825
30%	1409	1533	1972	2758	3478	5177	4790	3361	2009
25%	1443	1593	2241	3121	4118	5832	5373	3649	2207
20%	1467	1661	2645	3706	4920	6479	5773	3944	2432
15%	1511	1743	3167	4272	5694	7198	6275	4389	2698
10%	1568	1889	3978	5500	7352	8036	6632	4804	3108
5%	1712	3687	6074	7567	10868	10044	7375	5585	3771

Table 8-10. Daily average mainstem flows (cfs) within nearest 5 percent exceedance wherefor the Proposed Action that will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Seiad Valley reach. Source: Mount Hood Environmental (2020).

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1152	1255	1294	1400	1581	2035	2240	1805	1224
90%	1173	1324	1340	1490	1701	2305	2500	2057	1303
85%	1205	1360	1390	1640	1840	2597	2801	2322	1365
80%	1260	1380	1440	1730	1968	2844	3019	2527	1453
75%	1284	1420	1496	1847	2092	3107	3206	2736	1550
70%	1314	1455	1573	1945	2201	3327	3560	2977	1658
65%	1342	1503	1650	2063	2398	3663	3866	3212	1775
60%	1371	1539	1730	2190	2673	4070	4240	3451	1896
55%	1402	1560	1823	2353	3027	4501	4644	3708	2032
50%	1431	1613	1979	2590	3413	5079	5034	4033	2235
45%	1462	1640	2149	2899	3755	5573	5502	4389	2446
40%	1501	1706	2330	3229	4186	5997	6118	4826	2696
35%	1537	1774	2589	3594	4649	6757	6751	5257	2994
30%	1576	1861	2906	4374	5279	7584	7235	5660	3366
25%	1614	1957	3414	5206	6248	8268	7756	6024	3824
20%	1667	2068	4189	5923	7389	9157	8282	6591	4223
15%	1734	2226	5078	7313	8849	10304	8704	7140	4797
10%	1835	2767	6950	9121	11446	11538	9440	8093	5515
5%	2022	5174	10355	12360	17304	14696	10419	9099	6653

Table 8-11. Daily average mainstem flows (cfs) within nearest 5 percent exceedance for the Proposed Action that will likely reduce coho salmon juvenile habitat availability (blue highlight) in the Rogers Creek reach. Source: Mount Hood Environmental (2020).

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
95%	1226	1518	1691	1949	2772	3760	3462	2677	1645
90%	1332	1604	1887	2432	3181	4284	4043	3068	1787
85%	1368	1731	2035	2982	3661	4910	4811	3283	1979
80%	1430	1811	2295	3349	4032	5391	5311	3647	2165
75%	1514	1866	2514	3653	4442	6126	6070	4238	2326
70%	1582	1915	2780	4000	4940	6605	6647	4614	2532
65%	1630	1960	3060	4483	5467	7222	7107	5004	2689
60%	1660	2029	3435	4907	5979	8028	7733	5630	2894
55%	1694	2090	3871	5351	6612	9017	8464	6127	3098
50%	1744	2164	4299	6001	7099	9977	8995	6695	3447
45%	1788	2272	4735	6848	7730	10678	10067	7426	3856
40%	1817	2449	5405	7646	8755	11389	10840	8189	4251
35%	1874	2638	6065	8381	9710	12426	11738	9024	4618
30%	1943	2978	7011	9791	11459	14137	12685	9753	5150
25%	2058	3321	8288	11781	13017	15537	13283	10468	5799
20%	2179	3946	9763	14514	15960	17011	14046	11594	6369
15%	2408	4826	12492	17329	18914	18384	15080	12553	7354
10%	2647	7069	17180	20963	23798	21277	16535	13619	8579
5%	3606	12134	26858	26346	33631	25520	18498	14684	10466

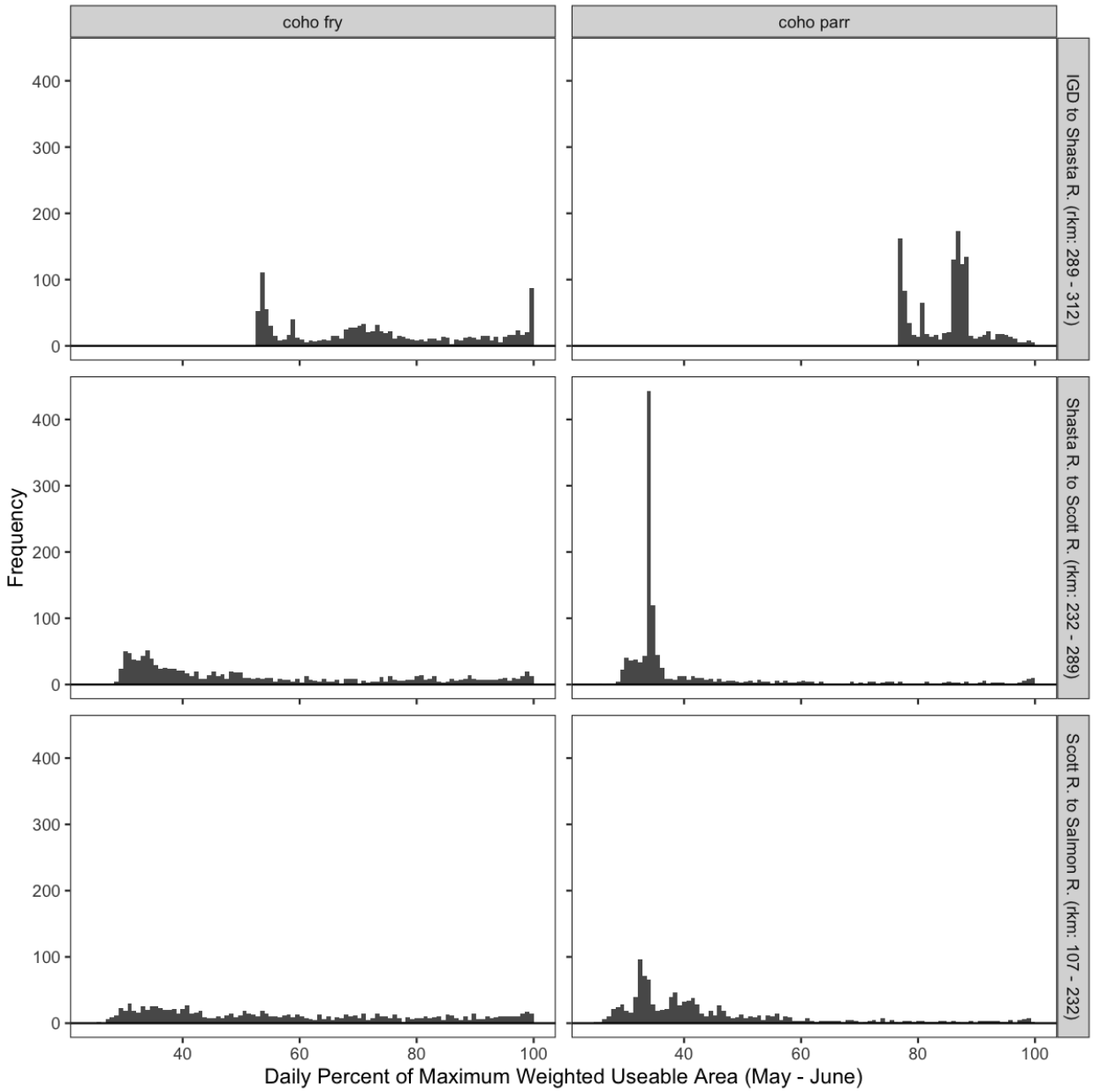

Figure 8-10. Predicted frequency of daily percent of maximum Weighted Usable Area values for coho salmon fry and parr in three reaches downstream of Iron Gate Dam during the months of May and June 1980-2019. Source: Mount Hood Environmental (2020).

Table 8-12. Exceedance flows and corresponding Weighted Usable Area values for coho parr in three reaches downstream of Iron Gate Dam. Flows were estimated at the midpoint of each reach. Source: Mount Hood Environmental (2020).

Exceedance	[1]May Flow (cfs)	[1]June Flow (cfs)	[2]May Flow (cfs)	[2]May WUA	[2]May % of Max	[2]June Flow (cfs)	[2]June WUA	[2]June % of Max	[3]May Flow (cfs)	[3]May WUA	[3]May % of Max	[3]June Flow (cfs)	[3]June WUA	[3]June % of Max	[4]May Flow (cfs)	[4]May WUA	[4]May % of Max	[4]June Flow (cfs)	[4]June WUA	[4]June % of Max
0.95	1,175	1,025	1,230	3,176	81%	1,043	3,031	77%	1,432	18,22	34%	1,120	16,05	30%	2,168	14,08	33%	1,425	12,00	28%
0.9	1,346	1,025	1,393	3,279	83%	1,050	3,891	99%	1,634	18,29	34%	1,154	16,38	30%	2,512	14,39	33%	1,540	12,17	28%
0.85	1,438	1,025	1,519	3,395	86%	1,057	3,105	79%	1,775	18,56	34%	1,191	16,75	31%	2,755	14,66	34%	1,631	12,47	29%
0.8	1,484	1,025	1,579	3,406	87%	1,063	3,115	79%	1,885	18,57	34%	1,215	16,99	32%	3,016	14,84	34%	1,759	13,24	31%
0.75	1,524	1,025	1,628	3,414	87%	1,072	3,356	85%	1,967	18,41	34%	1,257	17,37	32%	3,384	15,83	37%	1,888	13,02	30%
0.7	1,569	1,025	1,675	3,417	87%	1,081	3,046	77%	2,091	18,17	34%	1,295	17,74	33%	3,712	16,47	38%	2,033	13,91	32%
0.65	1,611	1,025	1,734	3,393	86%	1,092	3,279	83%	2,190	18,16	34%	1,349	18,14	34%	4,019	16,78	39%	2,182	14,07	33%
0.6	1,655	1,025	1,792	3,388	86%	1,108	3,084	78%	2,304	18,15	34%	1,402	18,26	34%	4,372	17,24	40%	2,310	14,41	33%
0.55	1,733	1,025	1,876	3,402	86%	1,134	3,031	77%	2,419	18,37	34%	1,479	18,21	34%	4,825	17,91	41%	2,514	14,42	33%
0.5	1,857	1,113	2,003	3,450	88%	1,217	3,278	83%	2,596	18,70	35%	1,555	18,19	34%	5,223	18,79	43%	2,746	14,62	34%
0.45	2,038	1,223	2,228	3,463	88%	1,338	3,052	78%	2,853	19,25	36%	1,654	18,37	34%	5,690	20,09	46%	3,059	15,76	36%
0.4	2,238	1,319	2,442	3,469	88%	1,426	3,031	77%	3,148	20,50	38%	1,800	18,60	35%	6,334	19,87	46%	3,445	16,19	37%
0.35	2,395	1,401	2,611	3,472	88%	1,514	3,412	87%	3,433	22,51	42%	1,980	18,34	34%	6,909	21,12	49%	3,710	16,46	38%
0.3	2,587	1,504	2,855	3,455	88%	1,666	3,034	77%	3,651	24,58	46%	2,186	18,09	34%	7,490	22,38	52%	4,202	17,13	40%
0.25	2,823	1,648	3,052	3,482	88%	1,817	3,463	88%	3,952	27,80	52%	2,407	18,31	34%	8,011	24,18	56%	4,741	17,76	41%
0.2	3,045	1,795	3,282	3,550	90%	1,957	3,452	88%	4,295	31,75	59%	2,645	19,16	36%	8,634	26,24	61%	5,242	19,30	45%
0.15	3,311	2,048	3,644	3,646	93%	2,212	3,407	87%	4,765	37,84	70%	2,988	19,54	36%	9,694	34,56	80%	5,872	20,32	47%
0.1	3,777	2,377	4,045	3,698	94%	2,575	3,206	81%	5,213	43,09	80%	3,494	23,00	43%	10,54	32,39	75%	6,800	22,28	51%
0.05	4,453	2,991	4,775	3,810	97%	3,225	3,057	78%	6,072	49,95	93%	4,084	29,25	54%	11,41	41,00	95%	8,156	29,42	68%

[1]IGD [2]IGD-Shasta (rkm 289-312) [3]Shasta-Scott (rkm 232-289) [4]Scott-Salmon (rkm 107-232)

Table 8-13. Exceedance flows and corresponding WUA values for coho fry in three reaches downstream of IGD. Flows were estimated at the midpoint of each reach. Source: Mount Hood Environmental (2020).

Exceedance	[1]May Flow (cfs)	[1]June Flow (cfs)	[2]May Flow (cfs)	[2]May WUA	[2]May % of Max	[2]June Flow (cfs)	[2]June WUA	[2]June % of Max	[3]May Flow (cfs)	[3]May WUA	[3]May % of Max	[3]June Flow (cfs)	[3]June WUA	[3]June % of Max	[4]May Flow (cfs)	[4]May WUA	[4]May % of Max	[4]June Flow (cfs)	[4]June WUA	[4]June % of Max
0.95	1,175	1,025	1,230	14,08	59%	1,043	12,71	53%	1,432	130,8	81%	1,120	48,02	30%	2,168	14,08	10%	1,425	38,97	29%
0.9	1,346	1,025	1,393	15,46	65%	1,050	12,75	53%	1,634	60,35	37%	1,154	48,85	30%	2,512	14,39	11%	1,540	39,91	30%
0.85	1,438	1,025	1,519	16,40	68%	1,057	12,79	53%	1,775	148,2	92%	1,191	49,73	31%	2,755	14,66	11%	1,631	40,93	30%
0.8	1,484	1,025	1,579	16,53	69%	1,063	12,83	54%	1,885	55,91	35%	1,215	50,29	31%	3,016	14,84	11%	1,759	43,27	32%
0.75	1,524	1,025	1,628	17,10	71%	1,072	12,89	54%	1,967	54,55	34%	1,257	51,33	32%	3,384	15,83	12%	1,888	43,02	32%
0.7	1,569	1,025	1,675	17,20	72%	1,081	12,94	54%	2,091	59,85	37%	1,295	52,23	32%	3,712	16,47	12%	2,033	47,98	36%
0.65	1,611	1,025	1,734	17,49	73%	1,092	13,01	54%	2,190	148,9	92%	1,349	53,43	33%	4,019	16,78	12%	2,182	48,52	36%
0.6	1,655	1,025	1,792	17,85	75%	1,108	13,11	55%	2,304	108,6	67%	1,402	54,53	34%	4,372	17,24	13%	2,310	48,51	36%
0.55	1,733	1,025	1,876	18,26	76%	1,134	13,26	55%	2,419	114,7	71%	1,479	55,95	35%	4,825	17,91	13%	2,514	51,04	38%
0.5	1,857	1,113	2,003	18,96	79%	1,217	13,78	58%	2,596	80,70	50%	1,555	57,63	36%	5,223	18,79	14%	2,746	55,72	41%
0.45	2,038	1,223	2,228	20,02	84%	1,338	14,74	62%	2,853	127,6	79%	1,654	59,48	37%	5,690	20,09	15%	3,059	57,96	43%
0.4	2,238	1,319	2,442	21,01	88%	1,426	15,59	65%	3,148	135,9	84%	1,800	62,28	39%	6,334	19,87	15%	3,445	66,23	49%
0.35	2,395	1,401	2,611	21,95	92%	1,514	16,36	68%	3,433	82,06	51%	1,980	68,57	42%	6,909	21,12	16%	3,710	72,33	54%
0.3	2,587	1,504	2,855	22,72	95%	1,666	17,25	72%	3,651	149,1	92%	2,186	75,94	47%	7,490	22,38	17%	4,202	75,29	56%
0.25	2,823	1,648	3,052	23,30	97%	1,817	18,05	75%	3,952	71,80	44%	2,407	84,30	52%	8,011	24,18	18%	4,741	87,89	65%
0.2	3,045	1,795	3,282	23,47	98%	1,957	18,64	78%	4,295	91,46	57%	2,645	93,99	58%	8,634	26,24	19%	5,242	97,72	72%
0.15	3,311	2,048	3,644	23,86	100%	2,212	19,87	83%	4,765	116,3	72%	2,988	111,8	69%	9,694	34,56	26%	5,872	102,5	76%
0.1	3,777	2,377	4,045	23,69	99%	2,575	21,74	91%	5,213	112,4	70%	3,494	127,9	79%	10,54	32,39	24%	6,800	109,7	81%
0.05	4,453	2,991	4,775	23,07	96%	3,225	23,73	99%	6,072	91,87	57%	4,084	145,8	90%	11,41	41,00	30%	8,156	128,7	95%

[1]IGD [2]IGD-Shasta (rkm 289-312) [3]Shasta-Scott (rkm 232-289) [4]Scott-Salmon (rkm 107-232)

8.6 Effects of Disease Mitigation Flows on Disease (*C. shasta*) Conditions for Coho Salmon

The PA includes flow measures for juvenile coho salmon disease mitigation between March 1 and September 30. The analysis described below indicates the potential effect of the proposed mitigation flows on salmonid disease caused by *C. shasta* infection. The PA allows for control of discharge timing, magnitude, and duration with the flow options described in this section.

Without-action scenario flows can be characterized as large flow events from late winter and spring months, with moderate flows in late fall through winter and again in spring into summer months. Without-action scenario flow magnitude will be variable with seasonal changes in ambient air temperatures causing freeze and melt cycles with snowpack early in the spring. Without-action scenario river flows are low during late summer and fall months (Figure 8-1, Tables 8-1, 8-2, and 8-3). Substantial rain events are likely to contribute to flow variability during spring, summer, and fall months.

8.6.1 Surface Flushing Flow

As described in Chapter 4.3.2.2.2.4, Reclamation has modeled the implementation of surface flushing flows from the EWA.

Surface flushing flows mobilize sediment and scour *M. speciosa* from benthic substrate, thereby decreasing *M. speciosa* density in their preferred habitat. It has been asserted that decreased *M. speciosa* density leads to diminished *C. shasta* actinospore production thereby reducing disease incidence and severity in salmonids (Hillemeier et al. 2017; Reclamation 2018. A surface flushing flow constitutes a release of at least 6,030 cfs from IGD for at least 72 consecutive hours. Surface flushing flows in the KBPM reflect those described as Disease Management Guidance #1 in the *Measures to Reduce Ceratonova shasta Infection of Klamath River Salmonids. A Guidance Document* (Hillemeier et al. 2017), with the exception that Reclamation's proposed time period is more limited (see Chapter 4.3.2.2.2.4 for additional details).

In 2011, and between 2016-2019 Reclamation implemented flow events at or near 6,030 cfs, events that met the flow and duration specifications of a surface flushing flow (Table 8-14). A significant reduction in *M. speciosa* density was observed following these flushing flow events (Bartholomew 2012; Bartholomew et al. 2016, 2017). For example, in 2016 *M. speciosa* density at Beaver Creek (KBC) was reduced approximately 15-fold following the 9,610 cfs flushing flow event (Bartholomew et al. 2017). Furthermore, *M. speciosa* density remained low through the end of summer; this was followed by recolonization in November. A similar pattern was observed in 2017 (Bartholomew et al. 2018).

In 2018, Reclamation implemented two flow measures to mitigate for *C. shasta* infection that were shaped based on the Guidance Document. In early April, a surface-flushing flow released at IGD successfully scoured preferred *M. speciosa* fine sediment habitat and decreased density compared with spring observations (J. Alexander, Oregon State University, personal

communication, 2018). A subsequent dilution flow in May (3,000 cfs until 50,000 AF was expended) was implemented to reduce POI. However, observations in May 2018, revealed that *M. speciosa* density rebounded to pre-event conditions, indicating that in some years, late winter or early spring surface-flushing flows may provide ample time for annelid recovery prior to the coho outmigration period (April/May). Although annelid density can recover to pre-event densities, it is possible that the number of infected annelids remains low (J. Alexander, Oregon State University, personal communication, 2018). Similar management actions were implemented in 2019, with a flushing flow (flows exceeded 9,000 cfs for 24 hours) in mid-April and an enhanced flow (max discharge of approximately3,000 cfs) in mid-June. Despite these flow measures, spore concentrations remained relatively high (USFWS 2019), potentially due to elevated annelid infection rates prior to the managed flow events occurring.

Despite elevated spore concentrations in early May 2019, following the implementation of a flushing flow in excess of 9,000 cfs, the available evidence indicates that surface-flushing flows are effective at reducing *M. speciosa* density and *C. shasta* spore concentrations. While surface-flushing flows may be an effective measure for reducing spring spore concentrations, further data and analyses are needed to establish the causal relationship between *M. speciosa* density and *C. shasta* disease parasite incidence in coho salmon.

Variability in annual salmon parasite incidence and mortality data suggests factors other than flow contribute to disease severity. For example, in 2016, *M. speciosa* density declined immediately following the surface-flushing flow event, yet spore concentrations increased (>10 spores/L) within a month and were followed by a 30-60 percent Chinook infection rate within two months (Table 8-14). Conversely, in 2017 low actinospore concentrations and salmon POI and mortality were sustained for at least six months following the surface-flushing flow (Table 8-14). Abiotic variables, such as water temperature, and biotic factors, such as fall Chinook carcass (intermediate *C. shasta* host) deposition, may influence spring spore concentrations. For example, 2010 was a water year that can be characterized by relatively low and constant flow in the Klamath River and that also experienced relatively low POI in juvenile salmon (USFWS 2016d).

Based on these results, the PA will mitigate disease impacts by providing frequent and seasonally targeted surface-flushing flow conditions, with the assumption that low and stable flows promote *C. shasta* proliferation (Hillemeier et al. 2017). Specifically, the PA will provide surface flushing flows (greater than or equal to 6,030 cfs for at least 3 days) in approximately 70 percent of years. Further, the PA will result in an increase in frequency of flows within a 1.5- and 2-year flood frequency compared to without action conditions and observed conditions (especially for the POR between 2001 and 2015 (Table 8-16; (USFWS 2016b)). Consequently, the frequency of surface flushing flows created through the PA may lower *M. speciosa* densities and actinospore concentrations via mobilizing and removing preferred annelid habitat, and therefore reducing disease risk for outmigrating coho salmon relative to without action conditions.

Despite the increased frequency of surface-flushing flows, immobile bed conditions (flows at IGD of 0 - 2,500 cfs from (USFWS 2016b)) are predicted to occur during more than 70 percent of the water year for most years in the POR and more than 50 percent of the water year for all but two

years in the POR with the PA (Figure 8-11). The highest actinospore concentrations and salmon POI and *C. shasta*-related mortality observed in the last decade (since monitoring began) occurred from 2013 – 2015 (Bartholomew et al. 2018), a sequence of drought years with homogenous flow regimes and few (if any) flows that would have effectively reduced *M. speciosa* densities in the Klamath River. While the PA resulted in surface-flushing flows in all three of these years (an average increase in March and April daily IGD discharge of 499 and 335 cfs, respectively, relative to what was observed; see Appendix 8A, Table 8-1 and 8-2), there were also periods of immobile bed conditions that are conducive to establishment of aquatic vegetation, ideal conditions for proliferation of *C. shasta.*

The without-action scenario is anticipated to create large discharge events in the Klamath River that meet the criteria of a surface-flushing flow on an interval less frequent than that of the PA. Without action scenario is anticipated to result in more days with mobilizing flows above 2,500 cfs at IGD. Surface flushing flows on a recurring interval are expected to reduce the densities of *M. speciosa* and are anticipated to reduce spore concentrations of *C. shasta*. This is expected to reduce fish disease conditions in the river.

Reclamation anticipates that the frequency with which the PA produces surface flushing flows (more than 70 percent of the years within the POR) will likely result in reduced *M. speciosa* densities and consequent reductions in actinospore concentrations, POI, and *C. shasta*-related mortality for salmonids in the years they are implemented (Hillemeier et al. 2017; Reclamation 2018a). While surface-flushing flows are more likely to occur under the PA, relative to the without-action scenario, the PA can result in minor reductions in flow variability (relative to the without action scenario) that could increase spore concentrations and infection risks to coho salmon.

The PA and without-action scenario both provide surface flushing flows on a similar recurring interval, although the PA provides these events more frequently and more controlled in regard to timing, magnitude, and duration (*see 8.3.1.3)*. The without action scenario produces a higher frequency of mobilizing flows above 2,500 cfs, relative to the PA. Generally, Reclamation anticipates that the PA will results in reduced C. shasta disease risk to coho, relative to the without action scenario, principally due to the frequency with which surface flushing flows occur.

8.6.2 Deep Flushing Flow

Similar to surface-flushing flows, empirical evidence confirms the effectiveness of deep flushing flows in reducing *M. speciosa* densities and their preferred habitat in the Klamath River (Bartholomew et al. 2018). Specifically, IGD flows between 8,700 and 11,250 cfs are effective in removing fine sediment deposited within the armored layer of the riverbed (e.g., large boulders, bedrock), which cannot be achieved with surface-flushing flows alone (USFWS 2016b). Although deep flushing flows are not specifically triggered through the PA (as are surface flushing flows), Reclamation's PA does not preclude the potential for a deep flushing flow when hydrologic conditions develop, principally through combining flows under the PA with tributary accretions.

In the 39-year modeled POR, flows meeting deep flushing flow criteria (11,250 cfs for 24 hours) occur in 4 years (1982, 1986, 1996, and 1997), less than the 5-year recurrence interval for this

discharge (USFWS 2016b). It should be noted that flows approached 11,250 cfs in 2006 (9,962 cfs) and 2017 (9,334 cfs). In both 2006 and 2019, the PA did not result in a deep flushing flow due to how inflow data were treated in the KBPM (i.e., smoothed to remove noise). This is a legacy of time step and operational rules in the model. In real-time operations, Reclamation would respond to real-time hydrology and likely implement a much higher flow (e.g., in 2019, under very similar operating rules, the actual 24-hour average peak flow achieved was 9,584 cfs, much larger than the simulated flows within the KBPM).

Under the without-action scenario, Reclamation anticipates hydrologic conditions would produce large discharge events that can be characterized as meeting the definition of a deep flushing flow in 7 of 39 years within the POR; using the same POR, the PA would produce deep flushing flows in 4 years. The model output indicates four deep flushing flows are possible under the PA, if health and human safety considerations permit implementation. Deep flushing flows are difficult to implement as the maximum release capacity at LRD is substantially lower than 11,250 cfs; therefore, the PA is limited to implementing deep flushing flows to periods of high tributary accretions. The combination of deep flushing flows and surface-flushing flows in this PA are likely to reduce *M. speciosa* density and its preferred habitat in the Klamath River. The without action scenario is likely to provide similar disease mitigation benefits relative to the PA.

8.6.3 Dilution Flow

The Proposed Action provides the flexibility for managed dilution-like events to occur during spring salmon outmigration. A dilution-like flow consists of a sustained peak discharge of lower magnitude and greater duration than flushing flows. The magnitude and duration of a dilution-like flow depends on river conditions for both habitat and fish disease and the volume of water available in the environmental water account. These events are intended to dilute *C. shasta* spore concentrations below critical disease thresholds and increase water velocity to reduce disease transmission rates (Hillemeier et al. 2017). Some evidence suggests that increased discharge directly dilutes spore concentrations, thereby reducing POI and *C. shasta*-related mortality in Klamath River coho (Som et al. 2016), although there remains uncertainty surrounding the efficacy of this measure (USFWS 2018). For example, increased flow in late May 2014 effectively diluted spore concentrations, yet, the effect was short-lived (Bartholomew et al. 2015). An increased flow event in June 2019, also resulted in lowered total daily *C. shasta* spore concentrations through the sustained peak discharge of the event at two continuously monitored river sites (USFWS 2019b). Due to changes in the prevalence of infection of natural fish at Kinsman site in the weeks prior to and during the event, the impact to infection rates of fish has been difficult to ascertain (USFWS 2019b).

Under the without-action scenario, flows are anticipated to reduce parasite occurrence, and possible fish disease infection, as a result of relatively high spring flows. The without-action scenario generally has a prolonged descending hydrograph into summer. This is also anticipated to reduce fish disease infection. However, there is no ability to control or shape flows under the without-action scenario, in contrast to the PA; as such, the without action scenario would not provide any ability to respond to a potential fish disease concern.

In general, the PA is expected to provide reduced flows in the late spring and summer relative to without-action conditions, which could lead to elevated *C. shasta* spore concentrations (Table 8-15). However, this PA generally emphasizes disease remediation through surface-flushing flows

and does not explicitly implement, nor exclude, dilution flows from occurring. Although it is unclear if flow manipulation will reduce the potential negative effects of elevated spore concentration when coho are in the river during periods of exposure (USFWS 2019b), the PA allows for these managed events to occur, whereas the without action scenario does not.

Table 8-14. Flushing flow effects on *M. speciosa* density and surface water *C. shasta* spore concentration in the lower Klamath River "infectious zone". Source: Mount Hood Environmental (2020).

Regulated Flow Event Timing	**Sampling Dates**	**Average IGD Flow (cfs)**	**% Mortality by *C. shasta* infection sentinel studies)** [18]	**% Mortality by *C. shasta* infection sentinel studies)**	**% Mortality by *C. shasta* infection sentinel studies)**	**% Mortality by *C. shasta* infection sentinel studies)**	**[*C. shasta*] (mean spores/ L)**	**[*C. shasta*] (mean spores/ L)**	**[19]Approx. Polychaete Density [20] (#m^{-2})**	**Approx. Polychaete Density (#m^{-2})**	**Temp. (deg C)**	**Temp. (deg C)**
			KBC Chinook	**KBC coho**	**KSV Chinook**	**KSV coho**	**KBC**	**KSV**	**KBC**	**KSV**	**KBC**	**KSV**
Feb 9-12, 2011	Pre-Flow (Oct.'10)	1620	NS	NS	NS	NS	<1	NS	5,000	24,000	6.8-12.9	6.3-12.6
	During	3200	NS	NS	NS	NS	<1	NS	250	NS	4.5	4.5
	Post-Flow (04/25-28)	4310	0	NS	0	NS	NS	<1	300	NS	10.6-11.3	10.6-11.1
	Post-Flow (05/17-20)	3215	0	8	0	0	<1	<1	200	0	12.8-14.4	11.6-13.8
	Post-Flow (06/21-24)	2060	18	55	10	60	<3	<5	13,000	2,000	19.1-19.4	16.1-16.4
March 15-18, 2016	Pre-Flow (Nov. '15)	1020	NS	NS	NS	NS	5	10	150,000	150,000	6.1-14.1	4.6-14.2
	During (03/16)	9610	NS	NS	NS	NS	0	0	NS	NS	8	8.3
	Post-Flow (03/21)	4480	NS	NS	NS	NS	0	0	10,000	NS	9	8.2
	Post-Flow (04/24)	2140	NS	NS	NS	NS	38	18	NS	NS	13.9	11.9
	Post-Flow (05/16-19)	1520	0	NS	5	NS	60	17	NS	NS	16.7-18.1	12.8-13.9
	Post-Flow (06/07)	1200	NS	NS	NS	NS	50	40	15,000	10,000	22	17.7
	Post-Flow (06/21-24)	1040	30	0	60	0	53	68	NS	NS	20.4-20.9	20.8-21.7

[18] Bartholomew et al 2012 report to BOR.
[19] Approximate density, derived from, Bartholomew et al reports to BOR (2016, 2017)
[20] Deep flushing flow

Regulated Flow Event Timing	**Sampling Dates**	**Average IGD Flow (cfs)**	**% Mortality by *C. shasta* infection sentinel studies)** [18]	**% Mortality by *C. shasta* infection sentinel studies)**	**% Mortality by *C. shasta* infection sentinel studies)**	**% Mortality by *C. shasta* infection sentinel studies)**	**[*C. shasta*] (mean spores/ L)**	**[*C. shasta*] (mean spores/ L)**	[19]**Approx. Polychaete Density** [20] **(#m^{-2})**	**Approx. Polychaete Density (#m^{-2})**	**Temp. (deg C)**	**Temp. (deg C)**
			KBC Chinook	**KBC coho**	**KSV Chinook**	**KSV coho**	**KBC**	**KSV**	**KBC**	**KSV**	**KBC**	**KSV**
	Post-Flow (08/07)	1000	NS	NS	NS	NS	10	10	17,500	15,000	22.2	22.5
	Post-Flow (09/17-20)	1000	30	NS	80	NS	13	18	NS	NS	19-20	19-20
Feb 10-13, 2017	Pre-Flow (Nov.'16)	1000	NS	NS	NS	NS	0	0	100,000	1,000,000	12-15	12-15
	Pre-Flow (02/07)	4000	NS	NS	NS	NS	0	0	NS	NS	6.1	6
	During (02/11)	8280	NS	NS	NS	NS	NS	NS	NS	NS	6.2	5.9
	Post-Flow (03/08)	2980	NS	NS	NS	NS	0	0	NS	NS	7.4	6.8
	Post-Flow (Apr.)	4680	NS	NS	NS	NS	<1	<2	1,000	10	10-12	10-12
	Post-Flow (05/25-28)	2380	0	NS	0	NS	6-May	2	NS	NS	18	15
	Post-Flow (06/24-27)	1020	7.5	20	2.6	0	9	3	1,000	1,000	22	20
	Post-Flow (09/14-17)	1200	0	NS	0	NS	0	0	100,000	10,000	19	19

Table 8-15. Dilution flow effects on surface water *C. shasta* spore concentration and salmonid infection in the lower Klamath River "infectious zone". Source: Mount Hood Environmental (2020).

Regulated Flow Event Timing	**Sampling Dates**	**Average IGD Flow (cfs)**	**% Mortality by *C. shasta* infection (sentinel studies)**	**% Mortality by *C. shasta* infection (sentinel studies)**	**% Mortality by *C. shasta* infection (sentinel studies)**	**% Mortality by *C. shasta* infection (sentinel studies)**	**[*C. shasta*] (spores/L)**	**[*C. shasta*] (spores/L)**	**Temp. (deg C)**	**Temp. (deg C)**
			KBC Chinook	**KBC coho**	**KSV Chinook**	**KSV coho**	**KBC**	**KSV**	**KBC**	**KSV**
[21]May 25-41, 2014	Pre-Flow (05/13-17)	1150	41	49	33	93	15	47	17.1-18.5	17-19
	Pre-Flow (05/19)	1170	NS	NS	NS	NS	32	38	17.1	17
	Pre-Flow (05/26)	1150	NS	NS	NS	NS	65	31	18.5	19.5
	During (05/28)	1700	NS	NS	NS	NS	NS	NS	17.8	17.9
	Post-Flow (06/03)	990	NS	NS	NS	NS	9	18	20	20.8
	Post-Flow (06/10)	1160	NS	NS	NS	NS	13	22	21.7	21.7
	Post-Flow (06/16)	1270	NS	NS	NS	NS	32	NS	19.6	20
	Post-Flow (06/17-20)	1220	40	42-52	67	72	NS	NS	20	20
	Post-Flow (09/18-21)	1010	2.4	NS	5	NS	<1	<1	20	20
May 7-29, 2018[22]	Pre-Flow (05/07)	1270	0	NS	2.6	NS	4	3.8	11.5 - 13.9	11.5 - 13.9
	During (05/09)	2980	0	NS	0	NS	2.5	NS	18 - 20	18 - 20

[21] Bartholomew et al 2014 report to BOR.
[22] https://microbiology.science.oregonstate.edu/content/monitoring-studies

Regulated Flow Event Timing	Sampling Dates	Average IGD Flow (cfs)	% Mortality by *C. shasta* infection (sentinel studies)	% Mortality by *C. shasta* infection (sentinel studies)	% Mortality by *C. shasta* infection (sentinel studies)	% Mortality by *C. shasta* infection (sentinel studies)	[*C. shasta*] (spores/L)	[*C. shasta*] (spores/L)	Temp. (deg C)	Temp. (deg C)
			KBC Chinook	**KBC coho**	**KSV Chinook**	**KSV coho**	**KBC**	**KSV**	**KBC**	**KSV**
	Post-Flow (05/29)	1130	NS	NS	NS	NS	2.5	0.1	19.8	19.7
	Post Flow (06/18)	1120	12.5	NS	2.5	NS	4.3	1.8	19.7	20.1
	Post-Flow (09/14-17)	990	0	NS	0	NS	1.7	1.45	18.1-18.6	17.9-18.5
	Post-Flow (09/24)	1010	NS	NS	NS	NS	5	2.3	17.3	17.3
June 4-14, 2019 Error! Bookmark not defined.	Pre-flow (4/19-4/22)	2970	0	NS	2.5	NS	5	8	12 - 14	12 - 14
	Pre-flow (5/15-5/18)	1390	50	NS	15	NS	59	10	12 - 18	12 - 18
	During (6/12-6/15)	2040	56.4	NS	51.5	NS	29	15	20 - 21.8	20 - 21.8
	Post-flow (9/17-9/20)	1000	2.5	NS	0	NS	7	1	16.7 - 19	16.7 - 19

Table 8-16. Flood frequency analysis on the Klamath River for IGD gaging station observed (historic), PA, and without-action scenario daily discharge at IGD gaging station and projected daily discharge under the PA for the period of record from 1981-2019.

Flood Frequency	Exceedance Probability	Observed Daily	Proposed Action Daily	Without-action scenario Daily
1.5-year	66.6%	3,772	6,013	3,667
2-year	50%	5,202	6,599	4,547

Flood Frequency	Exceedance Probability	Observed Daily	Proposed Action Daily	Without-action scenario Daily
5-year	20%	9,446	8,716	7,221
10-year	10%	12,694	10,677	9,409
25-year	4%	17,188	13,895	12,702
50-year	2%	20,769	16,922	15,574
100-year	1%	24,517	20,582	18,835

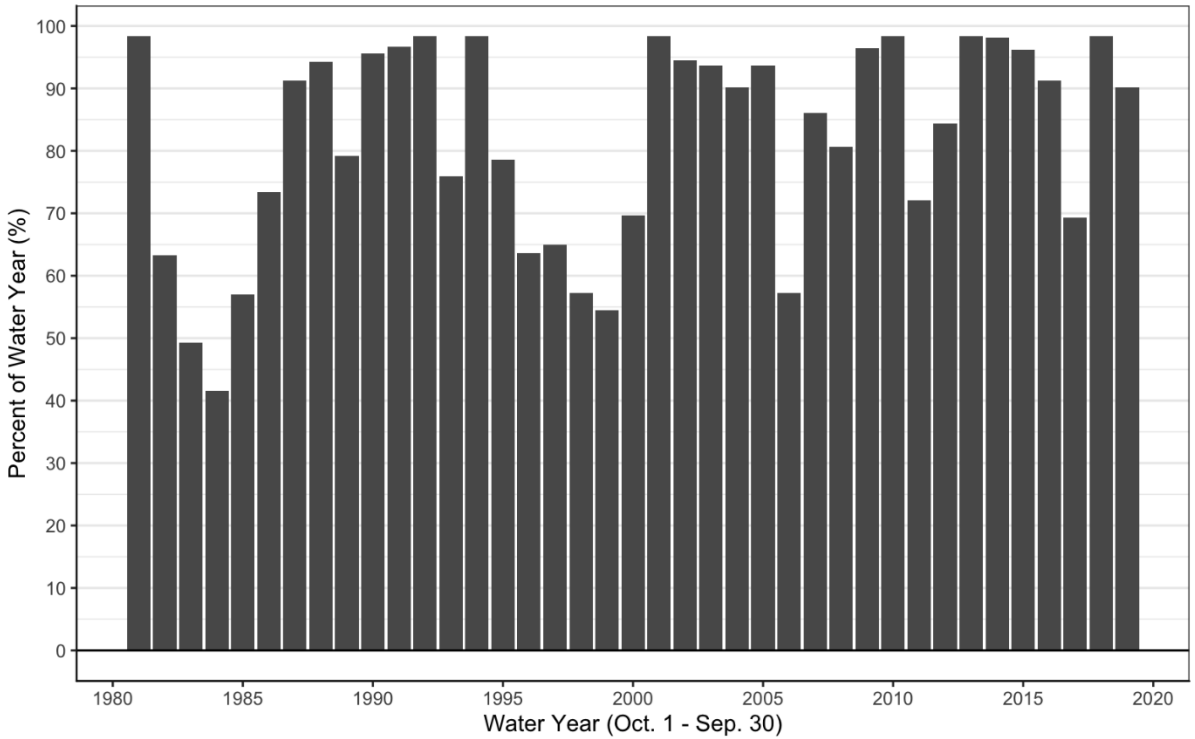

Figure 8-11. Immobile Bed Conditions. Percent of each water year where immobile bed conditions occur at IGD under the PA during the period of record from 1981-2019. Immobile bed conditions are considered to occur when daily average discharge is less than 2,500 cfs at IGD (USFWS 2016b).

8.7 Effects of Conservation Measure – Klamath River Basin Coho Restoration Grant Program

8.7.1 Grant Program

Restoration and recovery actions in the Klamath River Basin can improve habitat and water quality conditions for anadromous salmonids. Reclamation has provided $500,000 per year from fiscal year (FY) 2016 through 2018 (approximately $3 million) and $700,000 in 2019 for the Klamath River Coho Habitat Restoration Program (Program). Since the initiation of the Program, 21 restoration projects have been funded with an additional 4 proposals selected in FY 2019 for the "full proposal" phase.

As part of its PA, Reclamation expects to provide $500,000 annually, with an additional $700,000 for the first two years (fiscal year 2020 and 2021), and with funding in fiscal years beyond 2021 supplemented with up to $700,000 annually should such appropriations be authorized. At this funding level it is anticipated that between four and eight projects per year would be funded. Projects that address limiting factors for SONCC coho salmon in the Klamath River Basin will be given the highest priority. More specifically, the program will target restoration projects that have both the greatest impact on promoting survival and recovery and provide sustainable and lasting ecological benefits in the Klamath River Basin for coho salmon. Projects with the highest priority include those focused on the following elements: access improvement and barrier removal, improved habitat and access to coldwater refugia, instream habitat enhancement and protections, and water conservation.

Projects under the conservation measure only occur under the PA. A without-action scenario does not include the beneficial impacts of projects described in this section.

Restoration activities that require instream activities will be implemented during low flow periods between June 15 and November 1. The specific timing and duration of each individual restoration project will vary depending on the project type, specific project methods, and site conditions. Implementing individual restoration projects during the summer and or low-flow period will minimize exposure to emigrating coho salmon smolts and coho salmon adults at all habitat restoration project sites.

Most restoration projects have the potential to result in short-term adverse effects. Despite the different scope, size, intensity, and location of these proposed restoration actions, the potential adverse effects to coho salmon result from dewatering, fish relocation, channel realignment, structure placement, and increased sediment will be short-term. Dewatering, fish relocation, channel realignment, and structural placement may result in direct effects to listed salmonids, where a small percentage of individuals may be injured or killed. The effects from increased sediment mobilization into streams are usually indirect effects, where the effects to habitat, individuals, or both, are reasonably certain to occur and are later in time.

Riparian Habitat Restoration: Riparian habitat restoration techniques, if done properly, should not have long-term negative effects on listed salmonids or their habitat. All vegetation planting

or removal (in the case of exotic species) would likely occur on streambanks and floodplains adjacent to the wetted channel and activities should not occur in flowing water. Thus, the long-term benefit from riparian restoration would be the establishment of a vibrant, functional riparian corridor providing juvenile and adult fish with abundant food and cover. Under the PA, by restoring degraded riparian systems, listed salmonids will be more likely to survive and recover in the future.

Riparian fencing and vegetation restoration projects would result in increased stream shading and instream cover habitat for rearing juveniles, moderated stream temperatures, and improved water quality through pollutant filtering. Beneficial effects of constructing livestock exclusionary fencing in or near streams include the rapid regrowth of grasses, shrubs, and other vegetation released from grazing, and reduced nitrogen, phosphorous, and sediment loading into the stream environment (Brenner and Brenner 1998; Line et al. 2000). Further, Owens et al. (1996) found that stream fencing has proven to be an effective means of maintaining appropriate levels of sediment inputs from uplands in the stream channel. Another documented, beneficial, long-term effect is the reduction in bankfull width of the active channel and the subsequent increase in pool area in streams (Magilligan and McDowell 1997). Most riparian restoration projects contribute to a properly functioning ecosystem for listed species by providing additional habitat relative to their current condition.

Water Conservation: Implementing water conservation measures under the PA will benefit coho salmon by returning instream flow at a time when coho salmon require adequate habitat to rear and migrate. Increasing instream flow levels by diminishing water diversions will provide juvenile coho salmon with better access to suitable rearing habitat, especially during the summer and early fall when flows are lowest. Water conservation projects are most likely to occur in the tributaries, such as the Shasta and Scott Rivers.

Summary: Reclamation's funding for restoration activities will likely result in short-term negative effects during implementation, and the expectation is that the suite of restoration activities may result in long-term improvements to the function and role of critical habitat in the action area. The PA's restoration program will minimize habitat related effects of the Project by individually and comprehensively improving critical habitat conditions for coho individuals, populations, and overall. Consequently, restoration projects funded under the PA will contribute to increased salmon habitats relative to the without-action scenario, where funding of this Program would not occur and existing habitat in the mainstem Klamath River and its tributaries would likely maintain current conditions.

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9 Southern Resident Killer Whale Distinct Population Segment

Note: This Chapter originated from the NMFS 2019 BiOp (NMFS 2019) with portions of direct text included herein and has been adapted by Reclamation with the best available updated scientific information and utilizing Reclamation's Environmental Baseline as described in Chapter 6.

9.1 Effects of the Action

As discussed below, the primary potential effect of the PA on SRKWs is through potential reductions in availability of preferred prey, Chinook salmon, in the coastal waters where Chinook salmon from the Klamath River may be encountered by SRKWs. The most recent review (Lacy et al. 2017) indicates that non-prey factors in other parts of the range also impact SRKW population dynamics, so there is uncertainty in the extension of the statistical correlations to precise predictions of the effect of Chinook salmon abundance on the SRKW population. To date there are no data or alternative explanations that contradict fundamental principles of ecology that wildlife populations respond to prey availability in a manner generally consistent with the analyses that link Chinook salmon abundance and SRKWs. As a result, and based on evidence discussed in Chapter 5, Status of the Species, the best available science suggests that relative changes in Chinook salmon abundances are likely to influence the SRKW population.

9.1.1 Impacts to the Abundance of Chinook as a Result of the Proposed Action

Chinook salmon in the Klamath River are not listed under the ESA; however, the effects of the PA on Chinook salmon are analyzed because they are a primary food source for SRKWs and Klamath River Chinook salmon are potential prey for SRKWs along the coast. As described in Chapter 5, best available science suggests that any effects of the PA that reduce Chinook salmon production could negatively impact SRKWs. Likewise, actions that increase Chinook salmon abundance could benefit SRKWs. Much like ESA-listed coho salmon, Chinook salmon utilize the Klamath River during multiple life stages and the life history requirements of both Chinook and coho salmon overlap. Therefore, we largely rely on the effects analysis[18] conducted for coho salmon (see Chapter 8) to inform the effects analysis of the PA on Chinook salmon. However, there are life history strategies and habitat preferences of Chinook salmon that do differ from coho salmon. Both Chinook salmon specific information as well as relevant coho salmon information are summarized to help analyze the effects the PA may have on Chinook salmon production. In turn, Chinook salmon abundance at sea is an important driver of SRKW

[18] Similar to the discussion in Chapter 8.1, the analysis in this subsection considers the effect of surface flushing flows in all years, whereas the PA described in Chapter 4 only results in surface flushing flows in approximately 70 percent of years. Given similarities between the actions and flushing flow frequency, it is unlikely to result in measurable differences with the analytical tools applied.

population dynamics (Ward et al. 2009; Ford et al. 2010; Hilborn et al. 2012; Velez-Espino et al. 2015; Lacy et al. 2017), and coho have been shown to be an important part of the diet in times and places where more preferred species (Chinook and chum) are not available.

9.1.1.1 Klamath River Chinook Salmon

9.1.1.1.1 Klamath River Chinook Salmon Life History

Chinook salmon display two types of life history strategies in the Klamath River, spring-run and fall-run, named for the season of adult freshwater entry and migration upstream. Unlike coho salmon, Chinook salmon typically spawn in larger waterways such as the mainstem Klamath River and large tributaries including the Trinity, Salmon, Scott, and Shasta rivers. Fry emerge from redds between December and February. Juvenile Chinook salmon can display either a "stream type" or "ocean type" life history strategy where the "stream type" rears for a greater length of time in freshwater than the "ocean type." However, Williams et al. (2013) determined that juvenile Chinook salmon in the Upper Klamath Trinity River (UKTR) ESU typically do not display the "stream type" strategy. Therefore, juveniles in the Klamath and Trinity rivers will usually outmigrate shortly after emergence between March and June. Chinook salmon typically mature and return to freshwater between three and six years of age (Snyder 1931).

9.1.1.1.2 Chinook Salmon Spatial Structure/Distribution

Chinook salmon distribution has been greatly reduced in the Klamath Basin, first by the construction of Copco 1 Dam starting in 1912 (Hamilton et al. 2016). Currently, IGD, which was constructed in 1962, represents the upstream limit of anadromy in the Klamath River. Additionally, construction of Dwinnell Dam in the Shasta River blocked portions of habitat starting in 1928, while the Lewiston Dam built in 1963 on the Trinity River prevented access to many tributary habitats including East Fork, Stuart Fork, Upper Trinity River, and Coffee Creek (Campbell and Moyle 1991). The significant loss of habitat because of dams has resulted in two mitigation hatcheries, Iron Gate and Trinity River Hatcheries.

Although both spring-run and fall-run Chinook salmon are present in the Klamath basin, no spring-run Chinook salmon have been observed spawning in the mainstem Klamath River (Shaw et al. 1997). Instead, adult spring-run Chinook salmon only use the mainstem as a migratory corridor to reach their spawning grounds in the tributaries. Currently, known distribution of spring-run Chinook salmon are limited to the Salmon River and Trinity River sub-basins. As described in our analysis of effects of the PA on coho salmon, the effects of the PA are ameliorated substantially downstream as tributary accretions influence water quality, water quantity and other physical and ecological factors. Because the Salmon River is approximately 125 RMs downstream of IGD with several large tributary influences upstream, we do not anticipate more than negligible effects on spring-run Chinook salmon. Conversely, a large portion of the fall-run Chinook salmon population in the Klamath basin are exposed to portions of the mainstem Klamath River that are impacted by the PA's modified flows, as described below.

9.1.1.1.3 Chinook Salmon Abundance and Productivity

Natural-spawned Chinook salmon abundance has declined dramatically since dams were constructed in the Basin. CDFG (1965) estimated spawning escapement of Chinook salmon at approximately 168,000 adults with the number split about evenly between Klamath and Trinity

rivers. Hatchery production in the Basin increases the overall abundance of Chinook salmon in the Klamath. The IGH releases nearly six million fall-run Chinook salmon juveniles each year, while Trinity River Hatchery releases 4.3 million juvenile spring-run and fall-run Chinook salmon combined. Figure 9-1 shows the natural spawner abundance of fall-run Chinook salmon in the Klamath Basin from 1978 to 2018, and Figure 9-2 shows the entire escapement of fall-run Chinook salmon during the same period but with hatchery fish included (CDFW 2018, 2020). Spring-run Chinook salmon have a much lower abundance in the Klamath River. Figure 9-3 summarizes the escapement of hatchery and wild spawning adult spring-run Chinook salmon.

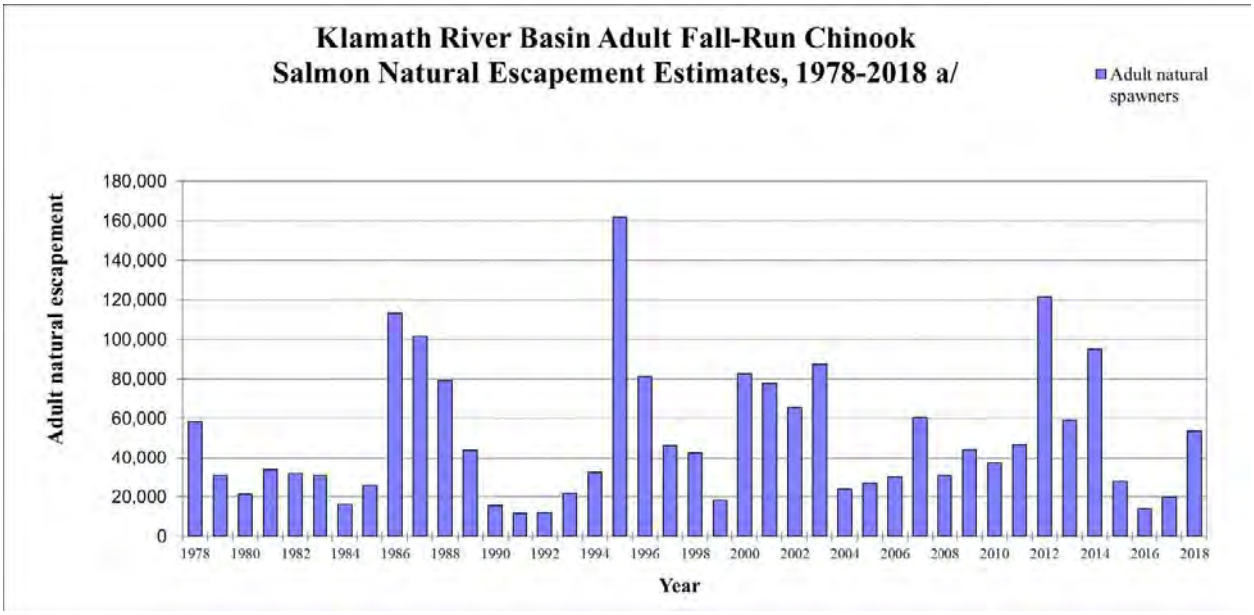

Figure 9-1. Adult natural escapement of fall-run Chinook in the Klamath Basin, including Trinity River fish (CDFW 2018). 2018 a/ is preliminary.

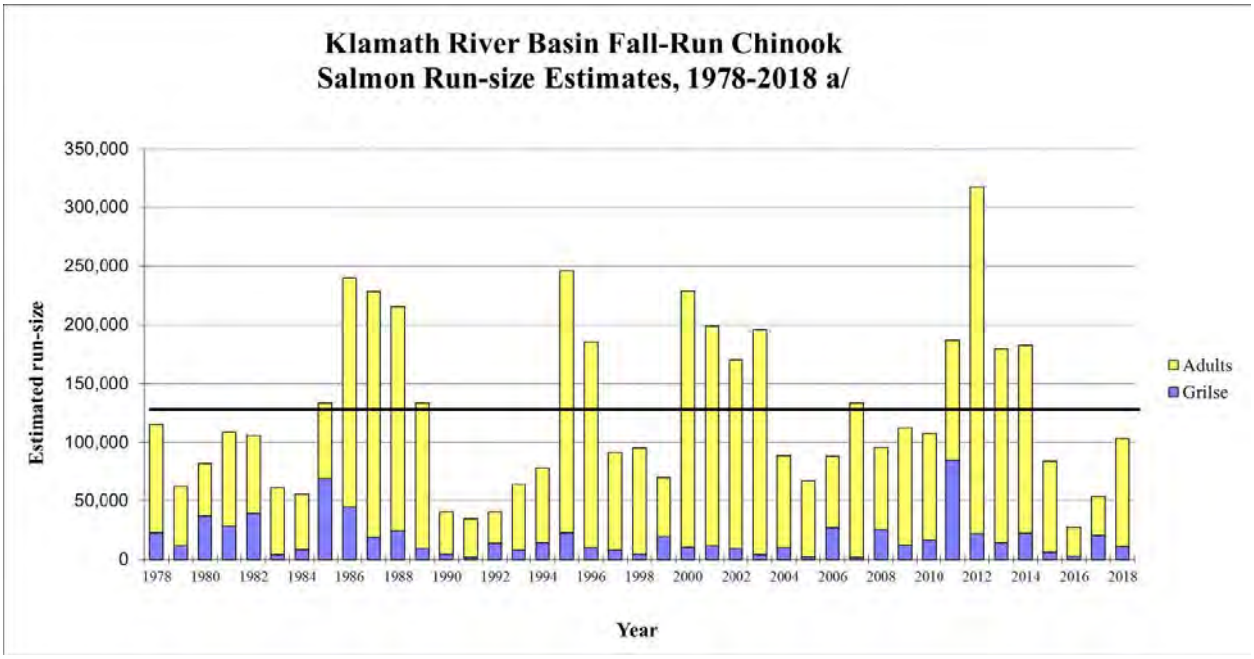

Figure 9-2. Adult escapement of fall-run Chinook in the Klamath Basin, including hatchery fish, in the Trinity and Klamath Rivers (CDFW 2018). 2018 a/ is preliminary.

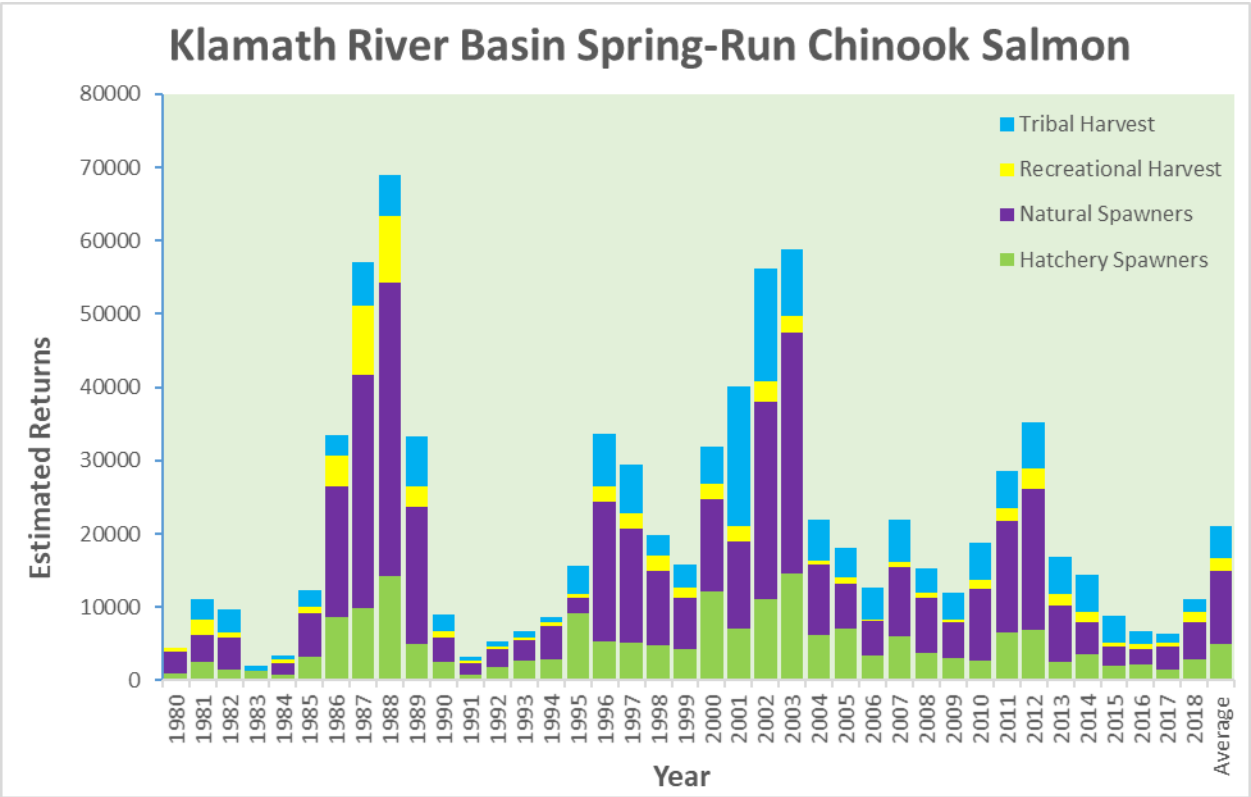

Figure 9-3. Klamath Basin adult spring-run Chinook salmon abundance estimates (CDFW 2020).

9.1.1.1.4 Chinook Salmon Diversity

Diversity within the Chinook salmon population is represented by the differing life history strategies described above. These include spring and fall-run adult migration timing, different

timing for freshwater rearing and smolt emigration, and different periods for adult maturation ranging from less than one-year-old precocious males to six-year-old adults.

Hatcheries can also play a role in shifting genetic diversity within populations. Releasing hatchery-origin fish can result in lower productivity of natural-origin salmonids. Between 1998 and 2016, Iron Gate and Trinity River Hatcheries released roughly 9.8 million hatchery Chinook salmon annually (CDFW, unpublished data). Hatchery-origin Chinook salmon found in the wild are typically spawned adjacent to the two hatcheries and gene flow from hatchery-origin fish is mostly limited to those areas (Kinziger et al. 2013).

9.1.1.2 Effects of the Proposed Action on Chinook Salmon Individuals

As described in Chapter 8, the PA affects salmonid habitat in the action area through operations of the Project and annual Coho Restoration program. The PA's greatest effects to Chinook salmon production are associated with effects to the Klamath River hydrology. As a result of operating the Project, the Klamath River annual flow volume, spring peak magnitude and duration, deep flushing flows, and flow variability will be altered, relative to a without action scenario. Based on the hydrological analysis of the POR, flushing flows are less likely to occur in the without-action scenario (15 of 39 years) than under the PA (occurring in approximately 74 percent of years, although as analyzed herein, almost annually), and peak flows are higher under the PA than without-action, even in most years that would result in a flushing flow without action. Minimum flows in summer are higher under the PA than they would be under without action in dry years, but lower in wet years. Similar to the anticipated effects described in Chapter 8, Chinook populations proximal to IGD (i.e., Klamath River mainstem, Iron Gate Hatchery, Bogus, Shasta, Scott rivers) will experience the greatest effects of Project operations, whereas populations in the lower Klamath River (i.e., Salmon River) will be less likely to be affected.

9.1.1.2.1 Exposure and Response

9.1.1.2.1.1 Adults

Fall-run Chinook salmon adults enter the Klamath River from July through September and may remain in the mainstem until spawning in late October and early November (Snyder 1931). Adult Chinook salmon can be susceptible to disease such as Ich (*Ichthyophthirius multifiliis*) and columnaris (caused by *Flavobacterium columnare*) when habitat conditions include exceptionally low flows, high water temperatures, and high densities of fish (such as adult salmon migrating upstream in the fall and holding at high densities in pools). In 2002, these habitat factors were present, and a disease outbreak occurred, killing more than 33,000 adult salmon and steelhead (Guillen 2003). Under the without-action scenario, summer flows supporting returning adults would be lower in dry years than under the PA, but higher in wet years. Low flows at IGD may contribute to conditions that increase risks of disease to adult Chinook salmon that enter the Klamath River in late summer and early fall. Thus, by maintaining adequate flows in both wet and all but the driest years, adults are likely to do better under the PA than without-action scenario.

9.1.1.2.1.2 Eggs

The flows provided for in the PA, combined with cooler fall and winter water temperatures, relative to the without action, should be sufficient to provide suitable conditions for egg

incubation. Therefore, fall-run Chinook salmon eggs in the mainstem Klamath River are not expected to be adversely affected by the PA.

9.1.1.2.1.3 Juveniles

Fall-run Chinook salmon fry, parr, and smolt will experience modified flows resulting from the PA relative to the without-action scenario. When fry emerge from their redds (December – February) they seek slow water habitat located on the channel fringes and in off-channel habitat features. The majority of juvenile Chinook salmon rear as parr for a short period prior to outmigration in March to mid-June. During this spring freshwater rearing period, habitat availability will be reduced under some hydrological conditions relative to the WOA (see Chapter 8), with a decreased amount of suitable habitat. However, in dry years, it's likely that habitat availability will be better under the PA than under the without-action scenario. Reclamation's habitat availability analysis uses a hydrodynamic model developed for the mainstem Klamath River (Hardy et al. 2006) and weighted usable area (WUA) curves to simulate habitat availability for Chinook salmon under the PA (Figure 9-4). Reach level habitat estimates for the proposed action are shown in Figure 9-5 and Table 9-1. The effects of the PA would likely be most beneficial during dry years with the greatest impacts occurring in June for all stream reaches. Habitat reduction increases competition with other salmonids and may force fish to relocate to less suitable habitat. These effects will likely result in reduced growth and survival of juvenile fall-run Chinook salmon in the mainstem Klamath River between IGD and the Salmon River. In addition, the reduction in magnitude, frequency and duration of sediment maintenance flows (specifically the frequency of immobile bed conditions) under the PA contributes to increased exposure to disease in the mainstem Klamath River. To offset some of the potential risks to juvenile salmonids during the outmigration period, the PA augments the EWA, such that volumes can be distributed to maximize ecological benefits (i.e., reduce disease risk and increase habitat availability). Established ramp down rates at IGD under the PA minimize stranding risk of juvenile Chinook.

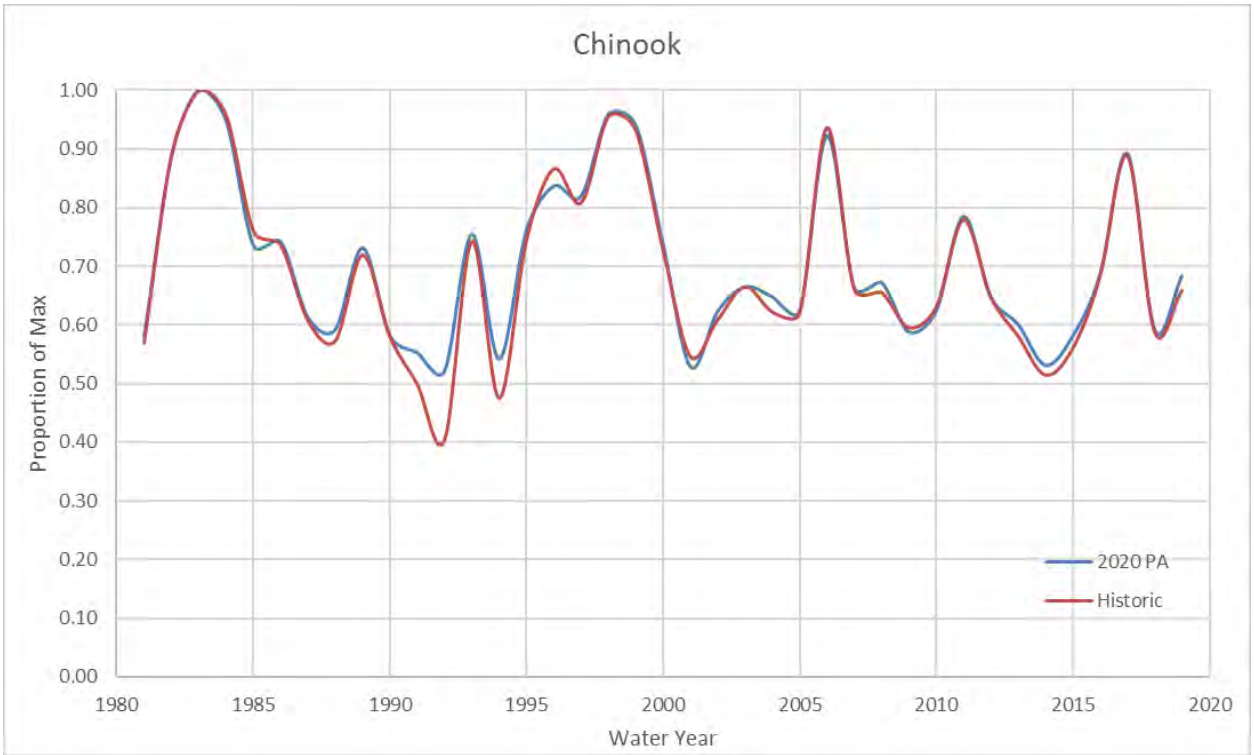

Figure 9-4. This figure shows the weighted usable area for Chinook for the Period of Record under the Proposed Action in blue and under the historical flow regime. Note that in almost all years, the area available under the Proposed Action would have been greater than or equal to that with the actual historical flow.

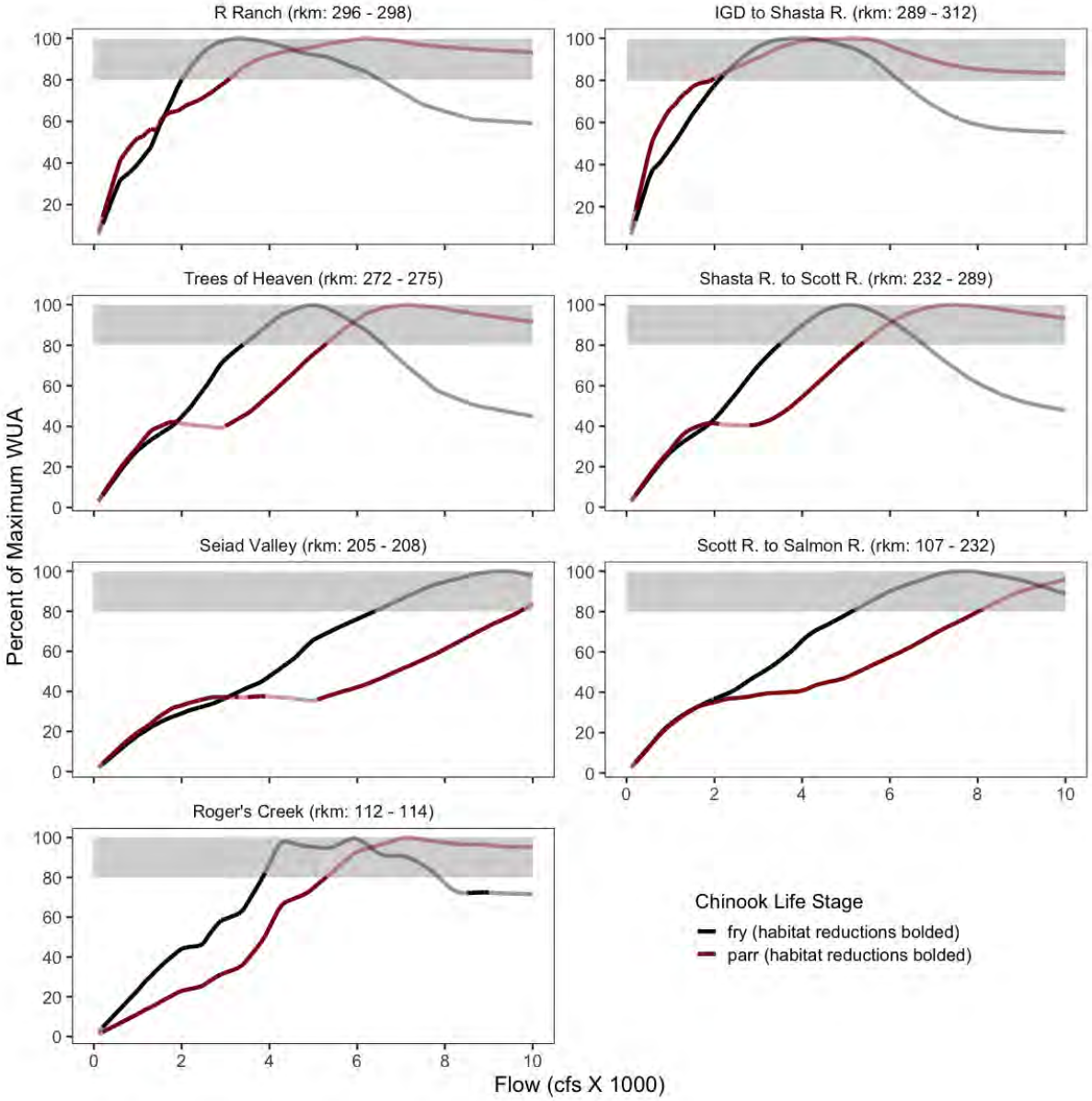

Figure 9-5. Chinook salmon fry and parr habitat availability relative to mainstem flows for three reaches and four sites downstream of IGD. Flows account for tributary accretions and were estimated for each habitat unit when calculating WUA. Gray horizontal bands represent 80 percent of maximum weighted usable area.

Table 9-1. Daily average mainstem flows (cfs) within nearest 5% exceedance where the Proposed Action will likely reduce Chinook salmon fry habitat availability to below 80 percent of maximum (orange highlight). Flows estimated for the midpoint of each reach.

Exceedance	Reach 1 March	Reach 1 April	Reach 1 May	Reach 1 June	Reach 2 March	Reach 2 April	Reach 2 May	Reach 2 June	Reach 3 March	Reach 3 April	Reach 3 May	Reach 3 June
95%	1122	1556	1276	1057	1452	1798	1454	1128	2622	2675	2049	1354
90%	1367	1742	1428	1070	1755	2008	1651	1166	2944	2986	2337	1472
85%	1660	1821	1576	1082	2018	2140	1800	1206	3253	3377	2632	1545
80%	1801	1926	1649	1093	2196	2261	1919	1230	3594	3744	2878	1649
75%	1924	2021	1706	1110	2340	2444	2010	1276	3986	4108	3183	1759
70%	2087	2164	1756	1125	2541	2605	2139	1319	4324	4515	3458	1918
65%	2229	2265	1826	1145	2755	2745	2237	1374	4722	4795	3780	2055
60%	2447	2467	1908	1175	3011	3033	2357	1431	5121	5296	4091	2180
55%	2721	2682	1988	1215	3349	3318	2481	1514	5820	5755	4503	2358
50%	3008	2946	2114	1303	3730	3576	2662	1586	6479	6293	4863	2565
45%	3316	3212	2378	1417	4094	3887	2933	1685	7041	6853	5298	2883
40%	3636	3489	2594	1492	4527	4307	3232	1828	7584	7543	5867	3196
35%	4172	3879	2793	1619	5090	4738	3529	2037	8322	8167	6445	3481
30%	4560	4291	3020	1787	5711	5282	3766	2241	9222	8744	6932	3932
25%	5102	4827	3248	1946	6418	5832	4052	2462	10325	9394	7477	4450
20%	5961	5207	3496	2156	6884	6294	4402	2718	11444	9960	7891	4985
15%	6495	5741	3903	2393	7714	6663	4903	3073	12589	10548	8840	5572
10%	7211	6159	4314	2727	8752	7190	5353	3588	14388	11466	9740	6452
5%	9092	6723	5041	3420	10825	8031	6205	4272	17779	12544	10736	7565

Reach 1 = Iron Gate Dam to Shasta River (rkm 289-312)
Reach 2 = Shasta to Scott Rivers (rkm 232-289)
Reach 3 = Scott to Salmon Rivers (rkm 107-232)

9.1.1.2.2 Effects of the Klamath River Coho Restoration Grant Program

Reclamation proposes to fund the restoration grant program during the duration of the PA, to improve habitat conditions for coho salmon. It is anticipated these restoration projects will improve conditions for Chinook salmon, especially in key Chinook salmon-producing tributaries such as the Shasta and Scott rivers, because Chinook salmon occupy many of the same habitats at the same time as coho salmon. Based on implementation information from prior years (2016, 2017, and 2018) of the restoration program (as detailed in Chapter 4 and analyzed in Chapter 8) four to eight projects are anticipated to be funded annually. Although Reclamation's funding for restoration activities will likely result in minor and short-term negative effects during implementation, it is expected that the suite of restoration activities will result in longer term improvements to the function and role of instream habitat in the Action Area and thus improve conditions for Chinook salmon.

9.1.1.2.3 Summary of Effects on Chinook Salmon Individuals

The effects analysis (Chapter 8) for SONCC coho salmon helps describes the effects to non-ESA-listed Chinook salmon. Because Chinook salmon occupy many of the same habitats at the same time as SRKWs, this analysis can inform effects of Reclamation's PA on the species.

Considering the analysis provided in the SONCC coho salmon effects section (Chapter 8) and the overlap of exposure to stressors that may occur, fall-run Chinook salmon juveniles and adults could be impacted by the PA.

In terms of productivity and abundance, Klamath River Chinook salmon are largely comprised of the fall-run and, to a much lesser degree, spring-run Chinook salmon. This is reflected in annual spawning escapement estimates for the Klamath River and its associated tributaries; fall-run Chinook salmon escapement estimates are typically on the order of one to three hundred thousand adults, compared to less than twenty thousand for spring-run Chinook salmon combined on average during the POR (Figures 9-2 and 9-3). Relative to the without-action scenario, the PA increases the likelihood of ensuring adequate flows for spring-run Chinook during the summer, as well as reducing the concentration of pathogens faced by returning fall-run adults.

Overall, the PA would mitigate various stressors and increase the fitness and survival of fall-run Chinook salmon relative to the without-action scenario, primarily in drier water years when environmental stressors are heightened (Table 9-1). Drier years are likely to occur during the period of effects of the PA. This analysis of effects of the PA to Chinook salmon generally describes and summarizes those effects in a qualitative manner based on the available information, since actual results will depend on unpredictable future natural conditions such as rainfall and temperature patterns, and policy decisions beyond the scope of this analysis. We generally cannot quantify the effects of the underlying and ongoing impact of Project operations on juvenile survival under the PA, with the notable exception of explicit quantification of the relative improvements in overall juvenile survival and characterization of changes in survival of adult Chinook salmon in the ocean relative to historical conditions that are anticipated to result from the PA.

Because the available analytical methods are limited, the absolute magnitude of increased prey that results from effects of the PA relative to without-action conditions to Klamath River Chinook salmon cannot be further described at this time. This restricts our ability to provide more specific quantifiable expectations for the increases in the abundance of fall-run Chinook salmon in the ocean available as prey for SRKWs. Nevertheless, the analysis in this consultation indicates that prey availability will be higher under the PA than under the without-action scenario and the Period of Record.

Negative effects in the mainstem Klamath River would mostly likely occur during dry years and in periods of elevated water temperatures. These adverse effects could include increased disease exposure during the juvenile rearing and outmigration period and reduced fry habitat availability leading to increased competition. These effects could reduce growth and survival of fry and juvenile Chinook salmon. Adult Chinook salmon could be exposed to lower flows in the mainstem Klamath River and, when combined with elevated water temperatures in late summer and early fall, may delay migration, which would reduce reproductive success. The proposed action is expected to contribute beneficially to reduced disease infection over the duration of the proposed action, due to the frequency of surface flushing flows and EWA augmentation that occurs in roughly 50 percent of years. Reclamation's funding for restoration activities while likely to result in minor and short-term adverse effects during implementation, anticipated restoration activities will result in longer term improvements to the function and role of instream habitat in the action area, and thus improve conditions for Chinook salmon.

9.1.2 General Effects of Reduced Prey Base for Southern Resident Killer Whales

The information described above suggests that the population dynamics of SRKWs are related to the abundance of Chinook salmon available as prey throughout their range. As a result, any changes in availability of preferred prey (Chinook salmon) may affect the survival and reproductive success of SRKWs. As described in Chapter 5 on Species Status, and Chapter 6 on the Environmental Baseline, SRKWs (particularly members of K and L pod) are likely to spend at least some time in coastal waters where they would be affected by any changes in Klamath River Chinook salmon abundance due to the proposed action. Contaminant signatures confirm that SRKWs (particularly members of K and L pod) are likely to consume Chinook salmon from California (Krahn et al. 2007). As described in (Chapter 5), Chinook salmon from the Klamath River, especially fall-run Chinook salmon, can constitute a sizeable proportion of the total abundance of Chinook salmon that is available throughout the coastal range of SRKWs (approximately 4 percent on average, but varying substantially between 1 and 9 percent during any given year). Klamath River Chinook salmon become an increasingly substantial portion of the prey base during transits of SRKWs along the coast of Oregon and California that may occur during the winter and spring, and Klamath River Chinook salmon may constitute as much as 45 percent of local abundance of Chinook salmon in these areas when SRKWs are there.

SRKWs are believed to take advantage of local prey concentrations created by topographic features, upwelling, and returns to areas just offshore of river mouths. These concentrations are ephemeral in time and space. They abandon areas with low prey concentration in search of more abundant prey or expend substantial effort to find prey resources in response to a decrease in the amount of available Chinook salmon due to the proposed action. These changes in behavior can result in increased energy demands for foraging individuals as well as reductions in overall energy intake, increasing the risks of being unable to acquire adequate energy and nutrients from

available prey resources (i.e., nutritional stress). SRKWs are known to consume other species of fish, including other salmon, but the relative energetic value of these species is substantially less than that of Chinook salmon (i.e., Chinook salmon are larger and adults have high fat content and thus have more energy value). Reduced availability of Chinook salmon would likely increase predation activity on other species (and energy expenditures) and/or reduce energy intake. Numerous studies have demonstrated the effects of energetic stress (caused by incremental increases in energy expenditures or incremental reductions in available energy) leading to reduced body size and condition and lower reproductive and survival rates for adults (e.g., Daan et al. 1996; Gamel et al. 2005) and juveniles (e.g., Trites and Donnelly 2003; Noren et al. 2009). In the absence of sufficient food supply, adult females may not successfully become pregnant or give birth (Wasser et al. 2017) and juveniles may grow more slowly or die shortly after birth if the mother is unable to obtain the two to four times more food required to support lactation than what is required during pregnancy or after weaning. Any individual may lose vitality, succumb to disease or other factors as a result of decreased fitness, and subsequently die or not contribute effectively to future productivity of offspring necessary to avoid extinction and promote recovery of a population. Ultimately, the effect of reduced prey for SRKWs could lead to behavior changes and nutritional stress that could negatively affect the animal's growth, health, reproductive success, and/or ability to survive.

9.1.3 Effects of the Proposed Action on Prey Availability

The direct effects of the PA are on prey available to SRKWs. The magnitude of this effect can be considered both in the context of alternative water management scenarios for the Klamath and separately for coastwide salmon abundance.

Four management scenarios were considered: 1) without-action scenario; 2) observed operations for the period of record (1981-2019); 3) operations under the 2019 BiOp; and 4) the PA.

S3 was not run for the without-action scenario, so flows were reviewed to assess in which years a flushing flow adequate to minimize *C. shasta*-related mortality would have occurred. Summer flows were also reviewed. S3 was used to estimate actual juvenile Chinook salmon production under observed operations within the period of record. S3 was not run for the 2019 BiOp plan, so similar to the without-action scenario, flows were reviewed. S3 was also used to estimate what Chinook salmon production would have been throughout the period of record, had the PA been in place. This allowed a qualitative comparison between the without-action scenario, the 2019 BiOp plan, and the PA. A quantitative model run was used to compare the PA to observed operations during the Period of Record, but for reasons provided below, it is best to only draw qualitative conclusions rather than treat the results as quantitative predictions.

The FRAM model was used to place the Klamath River runs in the context of coastwide salmon abundance. The FRAM model output is considered most reliable for the period 1992-2016, so this analysis focuses on that time frame.

9.1.4 Effects of Prey Availability on Population Dynamics

The SRKW population is closed to immigration and emigration, and the demography is exceptionally well studied. Every individual is known, and births and deaths are recorded in an annual census that spans decades. A population viability analysis (PVA, Boyce 1992; Lacy 2000) was conducted to predict demographic consequences of interannual variability in expected

levels of at-sea abundance of the whales' preferred prey, Chinook salmon, based on two project-related scenarios (below). The PVA was conducted in program Vortex 10.3.8 (Lacy and Pollak 2020). Vortex is an individual based model (i.e., not a deterministic model; see Grimm 1999) that takes into consideration: the observed demographic rates (i.e., age-sex composition) of the population in the period of interest (i.e., 1992-2016, to coincide with the period when reliable Chinook data are available from the FRAM model); demographic stochasticity (i.e., an element of chance in the reproduction and survival); random sex ratios at birth; projections of loss of genetic diversity due to inbreeding; and anthropogenic threats (e.g., PCBs, noise-mediated impacts on prey acquisition, and prey limitation). After parameterizing input scenarios, 1000 simulations of the individual based model for each scenario were run. Population growth was quantified and compared under the two project-related scenarios as the mean exponential rate of increase ($r = \ln[N_{t+1}/N_t]$), plus their standard deviation, from those 1000 trajectories.

The Vortex model was informed by two previous studies that related interannual variability in Chinook abundance indices to SRKW mortality in all age-sex classes (Ford et al. 2010), and age-specific fecundity rates of females (Ward et al. 2009). On the killer whale side, the population was modelled based on its size and composition over the period 1992-2018 (Center for Whale Research, unpublished). Note that additional years of SRKW demographic data are available, but would necessitate the use of other Chinook salmon indices than those that include the Klamath (Ward et al. 2009; Ford et al. 2010; Lacy et al. 2017), and Vélez-Espino et al. 2015). On the salmon side, the Chinook time series was extracted from the FRAM and Klamath scenarios (the "FRAM+K" index, described above). The prey-demography link is derived from two previous studies (Ward et al. 2009; Ford et al. 2010) with the implicit assumption that the shape of the relationship between SRKW demography and salmon should be similar, whether the salmon covariate is represented by a coastwide index or the FRAM+K index. For the purposes of this assessment, the model is not being used to predict absolute trends of SRKWs, but rather the relative impact of the two project-related scenarios. In other words, the prey-demography relationship may include some bias, but this should not impact the ability to assess relative differences between the two scenarios.

The model projects the SRKW population forward from 2018 to 2042, assuming that the whales experience the same patterns of Chinook availability under each scenario as they did in the time period 1992-2016. The decision to use the observed indices (1992-2016) rather than drawing randomly from a normal distribution (e.g., Lacy et al. 2017) reflects the fact that environmental factors affecting Chinook salmon survival and recruitment are often temporally autocorrelated (e.g., appear in clusters of good and bad years; Walter 1990). Rather than trying to replicate that process, the observed data were used instead. The question becomes, what would happen to the SRKW population, as it existed in 2018, if it were exposed to 25 years of observed levels of salmon abundance, with and without the PA?

Two management scenarios were modelled:
1. The FRAM+K Chinook index for the Period of Record (in blue in Figure 9-6); and

2. The FRAM+K Chinook index for the PA (called "Proposed action" in red in Figure 9-6).

Results

In both scenarios, the population appears to be relatively stable, but this may reflect the time period chosen to coincide with availability of salmon data (i.e., 1992-2016; see Caveats and Limitations, below). Predictions of absolute values of SRKW population size may not be reliable, because this model ignores anthropogenic threats and natural stressors known to be affecting this population (e.g., noise-mediated disruption of foraging, PCBs, inbreeding), but the relative differences between the two scenarios should be robust.

The PVA found no difference between the two scenarios: Historical flows (e.g., observed operations; blue line, Figure 9-6) and PA (red line, Figure 9-6). Both scenarios predicted that the population of 74 animals in 2018 would decline slightly to 71.6 by 2042. Although there may appear to be slight differences in the two trajectories, the average rate of population change does not differ significantly: (Historical flows: r=-0.0020, SD=0.044; Proposed action: r=-0.0019, SD=0.044). Note that historical flows are not the same scenario as the without action baseline, and the PA is likely to have a slightly more positive effect relative to the without action scenario than relative to historical flows.

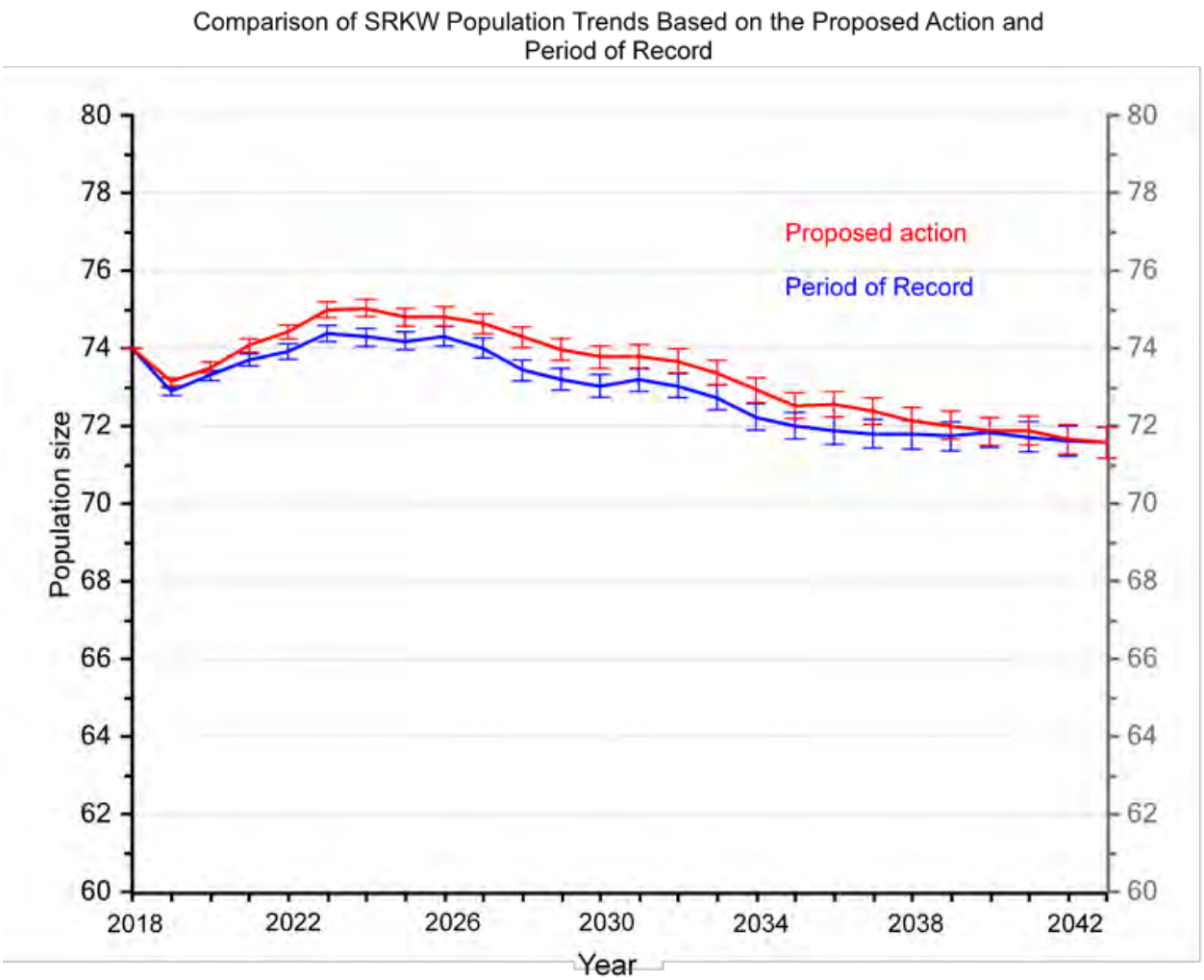

Figure 9-6. Comparison of SRKW population trends based on the proposed action and observed operations over the Period of Record.

The slight gap between the two trajectories in the early years of Figure 9-6 may be the result of a particularly good year for salmon in the 4th year of the time series (i.e., 1995 in the original data; 2021 in the projections). In most runs of the individual-based model, this one good salmon year results in higher than average survival and fecundity that propagates through the population for a few years, but the two scenarios end up at the same population size after 25 years, despite the variability.

The PA is not expected to appreciably improve SRKW demography over what would be projected if historical flows over the period of record continued, but there is no evidence to suggest that it will worsen it. This result is not unexpected. Klamath River returns are about 4% of the coastwide total on average. Given the small difference between scenarios, the resulting difference in coastwide returns between scenarios averaged <0.01%. The absence of flushing flows in most years under the without action scenario would be expected to result in substantially higher juvenile Chinook mortality than under the PA, and the difference may be enough to result in a consistently higher SRKW population under the PA relative to the without action scenario.

Caveats and Limitations

1. The projection of relative stability of SRKWs over the next 25 years is in marked contrast to other PVAs that consider a wider time period as its baseline (Lacy et al. 2017) Vélez-Espino et al. 2015). The period when reliable FRAM indices are available (e.g., 1992-2016) happens to cover one period of growth and one period of decline of SRKWs. The average of these two demographically distinct periods may create a false appearance of relative stability of the population, whereas a longer time series and a model taking into account other anthropogenic threats shows that the population is declining at approximately 1% annually (Lacy et al. 2017). That is more consistent with observed declines in recent years.
2. The use of a new Chinook index warrants a larger investment into testing new prey-demography relationships, but that was beyond the scope of this assessment.
3. As SRKWs are spending more time on the west coast, the Klamath may become more important to SRKW demography than it has been in previous decades (e.g., Ward et al. 2009; Ford et al. 2010). Although small changes to Chinook abundance may be absorbed into relatively minor changes to a coastwide Chinook index, it may be important to SRKWs, especially at a seasonal scale. This warrants additional research.

Of the scenarios considered, the without-action scenario offered the least benefit to SRKWs in terms of prey availability. Adequate flows to minimize *C. shasta* related mortality would have occurred in only 15 of 39 years. In contrast, adequate flows would have occurred in at a much higher frequency under both the 2019 BiOp (nearly annual) and the PA (approximately 70 percent of years).

The prey available to SRKWs would be similar under the other scenarios considered (observed operations from period of record, 2019 BiOp, 2020 PA). This is because the Klamath is typically a source of about 1-9 percent of overall salmon availability, and the S3 runs suggest the different management scenarios only vary Klamath Basin production by a small percentage for each year. Thus, the difference in overall coastwide salmon availability will typically vary by less than 1% under any of the three scenarios. Even if this difference would be expected to result

in the survival of an additional whale in a given year, that extra whale would likely be lost in a subsequent year when predicted population size rounds to the same number under each of the three scenarios.

However, this analysis should be considered the minimum effect. SRKWs are known to travel between British Columbia and Central California. A gap in abundant salmon along this route would make it less efficient to utilize resources on both sides of the gap. So, while Klamath River salmon are a small fraction of all salmon available to SRKWs, they make up a much larger fraction of prey available in Northern California and Southern Oregon. Further, while this analysis has focused on Chinook, coho make up a significant portion of the diet in the Salish Sea when more preferred species are scarce, so Klamath River coho numbers could be important to SRKWs, as well.

Further, the other factors affecting species status cited in Chapter 5 result in variability in the significance of prey availability to population size. That is, while effects of different approaches to managing Klamath River flows will result in differences in Klamath basin salmon production, the effect on coastwide salmon availability will depend on production in other watersheds, and the effects of coastwide salmon availability on SRKW population trends will depend on other factors like how vessel traffic is managed, whether disease outbreaks or oil spills occur, and stormwater management practices affecting toxic chemicals reaching the marine environment, etc.

Thus, it is not possible to make reliable, quantitative predictions of how particular management plans will actually affect SRKW numbers. However, at a qualitative level, plans that result in higher juvenile salmon production within the Klamath basin would be expected to be better for SRKWs than plans that result in lower salmon production.

9.1.5 Project Operations Related Impacts of Reduced Prey Base for Southern Resident Killer Whales

Based on the analyses of expected effects of the PA to Chinook salmon populations in the Klamath River, qualitative expectations can be established relative to other scenarios. In contrast to the without action scenario, the PA produces flushing flows almost every year, which should minimize juvenile salmon loss to *C. shasta*. Regulating spring flows is likely to make more habitat available to juveniles than the without action scenario. Maintaining adequate flows in the summer in most years to protect returning adults from high temperatures and pathogen exposure also means the PA is likely to perform better than the without action scenario.

A quantitative comparison using S3 indicated that the PA performed slightly better than practices in place during the period of record.

While on average, the PA is likely to be better for salmon than the without action scenario, and the 2019 BiOp, there may be rare years where other scenarios would perform better. In those years, reductions in the survival and productivity of Chinook salmon populations may be expected to occur.

Based on the analyses of expected effects of the PA to Klamath River Chinook salmon, we generally cannot quantify the impacts due to the operational effects of the PA on SRKWs. Based

on modeling results described earlier, we anticipate that juvenile survival should be improved compared to the S3 POR as a result of changes in operations associated with the PA, especially during years when there are potential threats associated with disease and limited suitable habitat. As a result of improved juvenile survival, we anticipate that at times several hundreds or thousands more adult Chinook salmon could be available as prey for SRKWs in the action area especially after drier water years when potential stress on juvenile Chinook salmon broods and their survival on the way to the ocean would be highest. Based on the general relative analyses that have been described above, all members of K and L pod are expected to be at risk of reduced fitness due to decreased Chinook salmon abundance in the ocean resulting from PA-related operations on those rare occasions, should they ever occur, that fewer salmon are produced. Further, they may abandon the Pacific Coast and return to the Salish Sea briefly (see Shields et al. 2018) where they would compete with J Pod for prey there, resulting in potential harm to J Pod as well.

9.1.6 Overall Effects of Increased Prey Base for Southern Resident Killer Whales as a Result of the Proposed Action

Based on the analysis above, the PA will generally increase the amount of Klamath River fall-run Chinook salmon available in the ocean for SRKWs to forage. Increased abundance, in a range of magnitudes dependent upon other environmental factors, will extend to the potential return of the 2023 cohort (up to 2027). The result of increased ocean abundance of Klamath River Chinook salmon over this time period is that SRKWs, especially for K and L pod whales, are expected to periodically face conditions where individuals present in the action area may be able to spend less time foraging, which would decrease energy expenditures and the potential for nutritional stress, which would otherwise negatively affect the animal's growth, body condition, and health. It should be emphasized that the PA is expected to result in greater Chinook salmon abundance than the Without Action alternative, so the reverse consequences would be expected under the without action scenario.

As described in Chapter 5, Chinook salmon from the Klamath River are expected to constitute a sizeable component of the diet of SRKWs in coastal waters within the action area where they overlap. SRKWs are expected to detect and respond to increased Klamath River Chinook salmon abundance and an enhanced prey field during foraging, likely resulting in SRKWs spending less time searching for other Chinook salmon and more abundant prey fields, either within the action area and/or other parts of their range. While Chinook salmon are expected to be the preferred prey with high nutritional value, SRKWs are capable of taking advantage of other prey sources to supplement their nutritional needs and are known to do so in the immediate absence of sufficient Chinook salmon resources. Any nutritional and energetic stress impacts prevented by the PA are most likely to occur in the more southerly range of SRKWs. Based on research and the known distribution of SRKWs described in Chapter 5, we conclude that while SRKWs are known to have used the southerly end of their range during all recent years, it is also likely that this population may limit or avoid use of this area altogether during some years.

Ford and Ellis (2006) report that SRKWs engage in prey sharing about 76 percent of the time during foraging activities. Prey sharing presumably would distribute more evenly any effects of prey limitation across individuals of the population than would otherwise be the case (i.e., if the most successful foragers did not share with other individuals). While the overall absolute impact of the proposed project on the survival and abundance of Klamath River Chinook salmon is not

quantified, there are components of the PA that offer benefits in terms of reducing the potential impacts of disease and limitations on suitable habitat that are expected to improve survival, especially for the Chinook populations most impacted by Project operations. There are also restoration actions that are anticipated to occur that should improve Chinook salmon survival under the PA. Additionally, we anticipate that the benefits of reducing the potential impacts of disease and limitations on suitable habitat that lead to improved survival will be accrued during drier water years when the potential for the diminished survival of juvenile Chinook salmon in the Klamath River would be expected to occur as described above. Based on the S3 model results, we conclude that Chinook salmon productivity will likely increase for the Upper Klamath, Middle Klamath, Shasta, and Scott river population in relation to the S3 POR over the period of effects of the PA. Based on these improved conditions for Klamath River Chinook salmon, the ability of SRKWs to take action to search out other areas with more abundant Chinook salmon prey fields or take advantage of other prey sources to supplement their nutritional needs in the immediate absence of sufficient Chinook salmon resources, the variable contribution of Klamath Chinook to the available prey within the action area and total abundance of Chinook available in the ocean for SRKWs across their range on an annual basis, and the likelihood that SRKWs may avoid the southern end of their range in some years (where Klamath Chinook can be an important food source), we conclude that the relative magnitude of positive effects resulting from the behavioral changes and reduced nutritional stress that may occur in response to increased abundance of Klamath River Chinook salmon prey in the ocean available to SRKWs in the ocean each year over the duration of the effects of the PA would likely be limited in extent and moderated to some degree by the factors discussed above. As a result, we do not anticipate large, beneficial effects such as preventing immediate or delayed mortality or increased reproductive rates for individuals as a result of the PA. Further, the PVA analysis indicates that random fluctuations in riparian and ocean conditions are more important in determining long-term population size than small but sustained differences in conditions. (NMFS 2008a, NMFS 2012a; 50 CFR 402.02).

Chapter 10 Other Species

The following discusses the effects of implementing the PA, on southern DPS of green sturgeon, southern DPS of North American Pacific eulachon, bull trout, Oregon spotted frog, and Applegate's milkvetch.

10.1 Southern Distinct Population Segment Green Sturgeon

Green sturgeon are members of the class of bony fishes, and the skeleton is composed mostly of cartilage. Sturgeon lack scales; however, they have five rows of characteristic bony plates on their body called scutes. The green sturgeon backbone curves upward into the caudal fin, forming their shark-like tail. On the ventral, or underside, of their flattened snouts are sensory barbels and a siphon-shaped, protrusible, toothless mouth. Recent genetic information suggests that green sturgeon in North America are taxonomically distinct from morphologically similar forms in Asia.

10.1.1 Legal Status

NMFS (2006) published a final rule listing the southern DPS of green sturgeon as threatened. NMFS (2018) defined two DPSs for green sturgeon – a southern DPS that spawns in the Sacramento River and a northern DPS with spawning populations in the Klamath and Rogue rivers. The southern DPS includes all green surgeon spawning populations south of the Eel River in California, of which only the Sacramento River currently contains a spawning population. NMFS (2018) has declared the northern DPS a Species of Concern.

NMFS designated critical habitat for the southern green sturgeon DPS in 2009 (NMFS 2009). NMFS in its critical habitat listing designated the following specific primary constituent elements (PCEs) which are essential for the conservation of the southern DPS green sturgeon in freshwater river systems:

Food resources: abundant prey items for larval, juvenile, sub-adult, and adult life stages.

Substrate: substrates suitable for egg deposition and development, larval development, and sub-adults and adults. Spawning is believed to occur over substrates ranging from clean sand to bedrock, with preferences for cobble (Moyle et al. 1995).

Water: 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.

Water quality: suitable water quality for normal behavior, growth, and viability of life stages, including temperature, salinity, oxygen content, and other chemical characteristics.

10.1.2 Life History

Green sturgeon are believed to spend the majority of their lives in nearshore oceanic waters, bays, and estuaries. Early life-history stages reside in fresh water, with adults returning to freshwater to spawn when they are more than 15 years of age and more than 4 feet (1.3 meters (m)) in size. Spawning is believed to occur every 2 to 5 years (Moyle 2002b). Adults typically migrate into fresh water beginning in late February; spawning occurs from March to July, with peak activity from April to June (Moyle et al. 1995). Females produce 60,000 to 140,000 eggs (Moyle et al. 1992). Juvenile green sturgeon individuals may enter the ocean and transition to the subadult life stage in their first year, but typical length of fish encountered in the ocean suggests ocean entry occurs at a later age (NMFS 2018). They disperse widely in the ocean after their out-migration from freshwater (Moyle et al. 1992).

Spawning: The southern DPS green sturgeon typically spawn every three to four years (range two to six years) (NMFS 2018). Their spawning period is March to July, with a peak in mid-April to mid-June (Moyle et al. 1992). Preferred spawning areas are associated with deep pools in large, turbulent river mainstems (Moyle et al. 1992). Spawning habitat preferences are likely large cobble substrates but may range from clean sand to bedrock substrates. Green sturgeon broadcast their eggs over the large cobble substrates where they settle into the interstitial spaces between cobbles. Green sturgeon females produce 60,000 to 140,000 eggs (Moyle et al. 1992). NMFS (NMFS 2018) notes "the upper lethal temperature for developing embryos is 22-23°C, with sub-lethal effects occurring at 17.5 to 22.2°C".

The southern DPS of green sturgeon spawns in the Sacramento River basin. The northern DPS of green sturgeon spawns in the Rogue River in southern Oregon and the Klamath River in northern California (NMFS 2018). The Klamath Basin is thought to support the largest green sturgeon spawning population (Moyle et al. 1992). In the Klamath River, sturgeon courtship behaviors such as breaching have been observed in "The Sturgeon Hole" upstream of Orleans, CA (rkm 96). Larvae and juveniles have been caught in the Karuk Tribe's Big Bar trap (rkm 80) on the Klamath and in the Willow Creek trap (rkm 40) on the Trinity River. In the Sacramento River, according to NMFS (2018), the southern DPS green sturgeon spawn in late spring and early summer from the Glenn Colusa Irrigation District area (rkm 332.5) to Cow Creek (rkm 451) based on adult distribution, with egg mat sampling confirming spawning between the Glenn Colusa Irrigation District area and Inks Creek (rkm 426).

Early Life History: Green sturgeon larvae first feed at 10 days post hatch, and metamorphosis to the juvenile stage is complete at 45 days. Larvae grow fast, reaching a length of 66 mm and a (Ford et al. 2000a) weight of 1.8 g in 3 weeks of exogenous feeding. Juveniles averaged 29 mm at the peak of occurrence in June/July at the Red Bluff Diversion Dam (California) fish trap and 36 mm at their peak abundance in July at the Glenn-Colusa Irrigation District (GCID) trap (NMFS 2005a). These growth rates are consistent with rapid juvenile growth to 300mm in 1 year and to over 600mm within 2 to 3 years in the Klamath River (Nakamoto et al. 1995). Juvenile green sturgeon in the Klamath River appear to spend 1 to 3 years in freshwater before they enter the ocean (Nakamoto et al. 1995).

Ocean Residence: Green sturgeon disperse widely in the ocean after outmigrating from freshwater (Moyle et al. 1992). The pattern of a northern migration is supported by the large concentration of green sturgeon in the Columbia River estuary, Willapa Bay, and Grays Harbor

which peaks in August. "Genetic evidence suggests that Columbia River green sturgeon stocks are a mixture of fish from at least the Sacramento, Klamath, and Rogue rivers (Israel et al. 2004).

Age and Growth: Green sturgeon are long lived and slow growing, similar to other sturgeon species (Nakamoto et al. 1995; Farr et al. 2002). Size-at-age is consistently smaller for fish from the Klamath River (Nakamoto et al. 1995) in comparison to fish from Oregon until around age 25, but thereafter the pattern is reversed. This could be the result of actual differences in growth or in ageing techniques. The asymptotic length for Klamath fish of 218 cm is close to the maximum observed size of 230 cm reported by (Moyle et al. 1992) and substantially larger than other Sturgeon species captured in Oregon (females 182cm, males 168cm).

Feeding: Little is known about green sturgeon feeding in the Klamath River as most feeding studies have occurred in other watersheds. Adults in the Sacramento-San Joaquin Delta feed on benthic invertebrates including shrimp, mollusks, amphipods, and even small fish (Moyle et al. 1992). Juveniles in the Sacramento River Delta feed on opossum shrimp (*Neomysis mercedis)*, and *Corophium* amphipods (Radtke 1966). (Adams et al. 2002) reported opisthobranch mollusks (*Philline* sp.) were the most common prey for one 100 cm green sturgeon from the Sacramento-San Joaquin estuary.

10.1.3 Distribution

Green sturgeon use riverine, estuarine, and marine habitats along the west coast of North America, spending substantial portions of their lives in marine waters (NMFS 2018). Southern DPS green sturgeon populations are known to congregate in coastal waters and estuaries, including non-natal estuaries, such as the Rogue River. Bemis and Kynard (1997) suggested that green sturgeon move into estuaries of non-natal rivers to feed. Information from fisheries-dependent sampling suggests that green sturgeon only occupy large estuaries during the summer and early fall in the northwestern United States.

Green sturgeon are known to enter estuaries along the Washington coast during summer (Moser and Lindley 2007). Commercial catches peak in October in the Columbia River estuary, and records from other estuarine fisheries (Willapa Bay and Grays Harbor, Washington) support the idea that sturgeon are only present in these estuaries from June until October (Moser and Lindley 2007). This information suggests that southern DPS green sturgeon are likely to use the Klamath River estuary only during the summer and fall months. As southern DPS sturgeon spend the majority of their life in the ocean, and individuals spend some time in a number of estuaries along the West Coast in the summer and fall, only a small proportion of the southern DPS green sturgeon would be expected to be present in the Klamath River estuary in any given year.

San Francisco Bay and its associated river systems contain the southern-most spawning population of green sturgeon. White sturgeon supports a large fishery in this area, particularly in San Pablo Bay, which has been extensively studied by CDFW since the 1940s. While green sturgeon are not common in San Pablo Bay, they are collected incidentally in trammel net monitoring during most years in numbers ranging from 5 to 110 fish. Green sturgeon juveniles are found throughout the Delta and San Francisco Bay.

The Columbia River has supported a large white sturgeon fishery for many years in which green sturgeon are taken as bycatch. In the mid-1930s before Bonneville Dam was constructed, green

sturgeon were found as far upstream as the Cascade Rapids. Green sturgeon are presently found as far upstream as Bonneville Dam (rkm 235) but are predominately found in the lower 60 rkm. Willapa Bay, along with the Columbia River and Grays Harbor, is one of the estuaries where green sturgeon populations concentrate in summer. Generally, green sturgeon are more abundant than white sturgeon in Willapa Bay (Emmett et al. 1991).

Grays Harbor in Washington is the northernmost estuary where green sturgeon populations concentrate in the summer months. NMFS (2018) notes that adult and subadult southern DPS green sturgeon occur in relatively large concentrations from late spring to autumn within coastal bays and estuaries including the Columbia River estuary, Willapa Bay, Grays Harbor and the Umpqua River estuary, with peaks in abundance in summer and autumn.

10.1.4 Species Current Condition

Population size and trends in the Southern DPS have been estimated by comparing the relative size of the Sacramento-San Joaquin green sturgeon population (Southern DPS) with the Klamath River population (Northern DPS) (Beamesderfer et al. 2004). The Klamath River population (Northern DPS) is thought to be the largest spawning population of green sturgeon (Adams et al. 2007).

Based on Dual Frequency Identification Sonar surveys in the Sacramento River, which began in 2010, combined with a conceptual demographic structure applied to that adult population, NMFS (2018) estimated a southern DPS subadult population estimate of 11,055 individuals.

Without action, river flows in the lower Klamath River near the estuary, are anticipated to result in slightly higher discharge during spring and early summer months and slightly lower discharge in late summer and fall. Due to the number of tributaries and their contributing flows, upper basin flows (those above IGD) constitute a relatively a small proportion of the overall discharge near the estuary where southern DPS green sturgeon are known to occur.

10.1.5 Effects to Green Sturgeon

Due to the tributary accretions that contribute to flows in the lower Klamath River it is difficult to wholly discern flow contributions from the upper basin (above IGD) during moderate to low flow periods. Without action hydrological conditions in the lower Klamath River are likely to result in relatively high flows in the late winter and spring months and relatively low flows in the summer and fall months. Project operations under the PA, depending on hydrological conditions in a given year, may reduce the cumulative flow in the lower Klamath River during spring and summer when southern DPS green sturgeon are known to occupy the Klamath River estuary as compared to flows without action. Variation in flows to the estuary resulting from the PA will not inhibit marine migration of southern DPS green sturgeon to the Klamath River estuary zone. Project operations are not expected to alter, reduce, or change the availability of food resources or meaningfully modify water temperature in the estuary zone during the summer months when green sturgeon can be expected to be in the estuary. Due to the relatively small contribution of upper basin contributions to the overall flow in the lower Klamath River, no impacts to southern DPS green sturgeon are expected to be meaningfully measured, detected, or evaluated. Reclamation concludes that the PA may affect but is not likely to adversely affect the green sturgeon southern DPS.

10.2 Southern Distinct Population Segment Pacific Eulachon

Eulachon *Thaleichthys Pacificus* (commonly called smelt, candlefish, or hooligan) are a small, anadromous fish from the eastern Pacific Ocean that are a short-lived, highly-fecund forage fish, that tend to have extremely large population sizes. NMFS (2017) describes eulachon as a slender-bodied fish with an average weight of 40 grams (g) and typically reaching 150 to 200 millimeters (mm) standard length, with compressed, elongated bodies and large mouths, the maxilla usually extending just past the middle of the eye. The opercula possess strong concentric striations and the pectoral fins, when pressed against the body, reach about two-thirds of the way to the bases of the pelvic fins. The jaws have small, pointed teeth which may be missing from spawning fish, especially males. The lining of the gut cavity is pale with dark speckles. Live fish are dark brown to dark blue on the back and head with a silvery white belly and unmarked fins. Spawning males develop a distinct midlateral ridge and numerous distinct tubercles on the head, body, and fins. Females may also have tubercles but they are poorly developed. Eulachon feed on plankton only while at sea.

10.2.1 Legal Status

NMFS listed the southern DPS Pacific eulachon as threatened under the ESA on March 18, 2010 (NMFS 2010c, 75 FR 13012). This DPS encompasses all populations within the states of Washington, Oregon, and California and extends from the Skeena River in British Columbia (inclusive) south to the Mad River in Northern California (inclusive). The DPS is divided into four sub-areas: Klamath River, Columbia River, Fraser River, and British Columbia coastal rivers south of the Nass River.

NMFS designated approximately 539 km (335 mi) of freshwater creeks and rivers and their associated estuarine habitat in California, Oregon, and Washington within the geographical area occupied by the southern DPS Pacific eulachon as critical habitat (NMFS 2011b). NMFS designated critical habitat for eulachon based upon areas which contain one or more physical or biological features essential to the conservation of the species that may require special management considerations or protection. NMFS (2011b) designated critical habitat for 10.7 miles of the Klamath River from the mouth upstream to the confluence with Omogar Creek.

10.2.2 Life History

Eulachon typically spend three to five years in saltwater before returning to fresh water to spawn. Eulachon generally spawn in rivers that are rain and snowmelt dominated systems that experience spring freshets. Spawning grounds are typically in the lower reaches of larger rivers (Hay and McCarter 2000). Spawning typically occurs at night. Spawning occurs between 4°C to 10°C throughout the range of the species and is largely limited to river reaches that are tidally influenced (NMFS 2017).

Spawning cues and entry into rivers appear to be related to water temperature and the occurrence of high tides (Smith and Saalfeld 1955; Spangler 2002; NMFS 2017) in January, February, and March in the northern part of the DPS, and later in the spring in the southern parts of the DPS. Most eulachon adults die after spawning. Eulachon broadcast their eggs which are fertilized in the water column, sink, and adhere to the river bottom typically in areas of gravel and coarse sand. It has been argued that because freshets rapidly move eulachon eggs and larvae to estuaries, it is likely that eulachon imprint and home to estuaries (Hay and McCarter 2000).

Eulachon eggs hatch in 20 to 40 days. Newly hatched young, transparent and 4 to 7 mm in length, are carried to the sea with the current (Hay and McCarter 2000).

Juvenile eulachon enter the ocean once they move from shallow nearshore areas to deeper areas over the continental shelf. Larvae and young juveniles become widely distributed in coastal waters, where they are typically found near the ocean bottom in waters 20 to 150m deep (66 to 292 feet) (Hay and McCarter 2000) and sometimes as deep as 182m (597 feet) (Barraclough 1964). There is currently little information available about eulachon movements in nearshore marine areas and the open ocean. However, eulachon occur as bycatch in the pink shrimp fishery (NMFS 2017), which indicates that the distribution of these organisms overlaps in the ocean. Adult Pacific eulachon have been recorded from several locations on the Washington and Oregon coasts, and were previously common in Oregon's Umpqua River, and the Klamath River in northern California (Hay and McCarter 2000; Willson et al. 2006; NMFS 2010b).

10.2.3 Species Current Condition

There are few direct estimates of abundance available for eulachon, and there is an absence of monitoring programs in the U.S. Most population data comes from fishery catch and landing records, which when combined with anecdotal information, indicate eulachon historically were present in large annual runs and that significant declines in abundance have occurred (NMFS 2017). Starting in 1994, the southern DPS of eulachon experienced an abrupt decline in abundance throughout its range, and although eulachon abundance in monitored rivers improved in the 2013–2015 return years, recent conditions in the northeast Pacific Ocean are likely linked to the sharp declines in eulachon abundance in monitored rivers in 2016 and 2017. The likelihood that these poor ocean conditions will persist into the near future suggests that subpopulation declines may again be widespread in the upcoming return years (NMFS 2017). The Columbia River, estimated to have historically represented half of the taxon's abundance, experienced a sudden decline in its commercial eulachon fishery landings in 1993–1994 (WDFW and ODFW 2001; JCRMS 2007). Similar declines in abundance have occurred in the Fraser River and other coastal British Columbia rivers (Hay and McCarter 2000; Moody 2008). In the Klamath River, eulachon abundance has likely decreased below the minimum viable population size (NMFS 2010b); NMFS (2017) provides Yurok tribal fisheries seine/dip net survey data over a four year period showing a large variation, from 7 eulachon in 2011 to 1000 in 2014.

There has been no long-term monitoring program targeting eulachon in California, making estimates of historical abundance and abundance trends difficult to generate (Gustafson et al. 2008).

Without action, river flows in the lower Klamath River near the estuary, are anticipated to result in slightly higher discharge during spring and early summer months and slightly lower discharge in late summer and fall. Due to the number of tributaries and their contributing flows, upper basin flows (those above IGD) constitute a relatively a small proportion of the overall discharge in the lower river and estuary where southern DPS Pacific eulachon are known to occur.

10.2.4 Effects to Pacific Eulachon

The southern DPS Pacific eulachon are only known to occupy the Action Area in the lower Klamath River during the winter and spring for spawning, incubation, and early rearing. Without action hydrological conditions in the lower Klamath River are likely to result in

relatively high flows in the late winter and spring months and relatively low flows in the summer and fall months. Project operations under the PA, depending on hydrological conditions in a given year, reduce the cumulative flow in the lower Klamath River from late winter through spring in comparison to without action hydrology. Thus, the PA could affect southern DPS Pacific eulachon populations by impacting essential habitat features for spawning, incubation, and migration. Eulachon are documented to spawn in the lower Klamath River reach in association with spring freshets and rearing does occur in the estuarine and near-shore areas at the mouth of the Klamath River. Project operations, depending on hydrological conditions in a given year, could reduce the rate of flow in the Klamath River during times when southern DPS Pacific eulachon are present. However, because the winter/springtime flows in the lower 10.7 miles of the Klamath River are largely driven by tributary accretions below IGD, Project operations and resultant effects to flow in the lower Klamath River are not expected to substantially alter habitat elements for the southern DPS Pacific eulachon. Therefore, Reclamation concludes that the PA may affect, but is not likely to adversely affect the southern DPS Pacific eulachon.

Critical habitat has been finalized in the lower Klamath River for the southern DPS Pacific eulachon. Flows as a result of implementing the PA, when compared to without action, may alter the physical or biological features for migration and spawning in the lower Klamath River that have been designated for the southern DPS Pacific eulachon. However, due to the relatively small contribution of upper basin contributions to the overall flow in the lower Klamath River with either the PA or without action, no impacts to southern DPS Pacific eulachon are expected to be meaningfully measured, detected, or evaluated. Therefore, the PA may affect, but is not likely to adversely affect designated critical habitat of the southern DPS Pacific eulachon.

10.3 Bull Trout

Bull trout are listed under the ESA as a threatened species in the Klamath River basin due to habitat isolation, loss of migratory corridors, poor water quality, and the introduction of nonnative species (USFWS 1999, 64 FR 58910). Bull trout are native to the Pacific Northwest and occurred historically throughout much of the Oregon portion of the Klamath Basin with observations in several tributaries to UKL, including Sevenmile Creek and the Wood River. In a late-1800's account, Gilbert (Buchanan et al. 1997) reported observing bull trout in the Williamson River. The Smithsonian Institute has a preserved 330 mm bull trout specimen which was captured in 1876 from Fort Creek, a tributary of the Wood River (Buchanan et al. 1997).

10.3.1 Legal Status

The USFWS designated critical habitat for the Klamath River and Columbia River distinct population segments of bull trout in 2002. In the Klamath Basin, USFWS revised critical habitat designation to protect foraging, migration, and overwintering habitat considered essential to re-connect isolated bull trout populations (USFWS 2010, 75 FR 63898).

10.3.2 Life History

Bull trout are members of the char sub-group of the family *Salmonidae* and are native to the Pacific northwest and western Canada. Bull trout adults typically range in size from an average of 200 to 305 mm for resident individuals, 405 to 610 mm in length for migratory river spawning

individuals, and over 685 mm (27 inches) in length for adfluvial individuals (McPhail and Baxter 1996).

Bull trout adults normally reach sexual maturity in 4 to 7 years and live as long as 12 years. Bull trout typically spawn from August to November during periods of decreasing water temperatures. Spawning temperatures generally range from 4 to 10°C (39 to 51°F), with redds often constructed in stream reaches fed by springs or near other sources of cold groundwater (Pratt 1992; Rieman and McIntyre 1996). Bull trout require spawning substrate consisting of loose, clean gravel relatively free of fine sediments (Fraley and Shepard 1989). Egg incubation is normally 100 to 145 days (Pratt 1992) and fry typically emerge from gravel early April through May depending upon water temperatures and increasing stream flows (Pratt 1992; Ratliff and Howell 1992).

Bull trout exhibit a number of life history strategies. Stream-resident bull trout complete their entire life cycle in the tributary streams where they spawn and rear. Most bull trout are migratory, spawning in tributary streams where juvenile fish usually rear from one to four years before migrating to either a larger river (fluvial) or lake (adfluvial) where they spend their adult life, returning to the tributary stream to spawn (Fraley and Shepard 1989).

10.3.3 Current Conditions

Bull trout in the Klamath Recovery Unit currently occur only as resident forms isolated and separated by long distances in higher elevation headwater streams within three core areas: (1) Sycan River core comprised of Sycan Marsh, Sycan River, and their tributaries, (2) Upper Sprague River core comprised of the North Fork and South Fork of the Sprague River upstream of their confluences, inclusive of Deming, Boulder, Dixon, Brownsworth, and Leonard creeks, and (3) UKL core comprised of the northern portion of the lake and its immediate major and minor tributaries (USFWS 2015). Factors contributing to reduced distribution within this recovery unit are habitat degradation and fragmentation, past and present land use practices, water diversions, and past fisheries management practices (USFWS 2015).

Without action, lake surface elevations in UKL and Agency Lake are expected to be relatively low year-round, seasonally fluctuating from about 4,136 ft during late summer into winter and less than 4,142 ft during spring months. Reclamation anticipates that corresponding surface area and water depth will also fluctuate in a similar pattern.

10.3.4 Effects to Bull Trout

The PA, which includes the storage of water in UKL, will create seasonal fluctuations of lake surface elevation (and water depth) in UKL and Agency Lake. Agency Lake is identified as a foraging, migration, and overwintering habitat type for bull trout. For much of the year, occupancy of bull trout in Agency Lake is likely water temperature or water quality limited. However, bull trout may migrate through this habitat during winter months. Reclamation anticipates the seasonal lake level fluctuations will have no effect on bull trout that may use Agency Lake as a migration corridor.

The primary constituent elements of bull trout critical habitat include: (1) Springs, seeps, groundwater and subsurface water connectivity, (2) Migration habitats with minimal physical, biological, or water quality impediments, (3) Abundant food base, (4) Complex river, stream,

lake, reservoir, and marine shoreline aquatic habitats,(5) Water temperatures that range from 2 to 15° C, (6) Sufficient substrate amount and composition in spawning and rearing areas, (7) Natural hydrograph, (8) Sufficient water quality and quantity, and (9) Sufficiently low levels of nonnative predatory, interbreeding, or competing species (USFWS 2010). The three critical habitat subunits in the Klamath Basin are identified as the UKL, Sycan River, and Upper Sprague River critical habitat subunits.

Without action results in low surface elevations of Agency Lake (the northern portion of UKL) from spring through winter resulting in limited habitat for bull trout to migrate or feed in this lake. The PA to store water in and divert water from UKL beneficially influences lake surface elevations in Agency Lake (northern portion of surface water considered part of UKL) and to a lesser extent the lowest reaches of tributaries to Agency and Upper Klamath lakes through maintaining surface elevations higher than the without action. These lake surface elevation changes are seasonal and temporary in nature and can be characterized as high elevations in late winter through early summer and low elevations in late summer through early winter. However, the PA has the beneficial result of higher surface elevations than the without action year-round.

The seasonal lake elevations in UKL resulting from the PA are likely to beneficially affect designated critical habitat in Agency Lake or the lowest reaches of tributaries such as Wood River and Sevenmile Canal, which bull trout could potentially utilize as migratory habitat Therefore, Reclamation concludes that the PA may affect, but is not likely to adversely affect bull trout.

10.4 Oregon Spotted Frog

10.4.1 Legal Status

The Oregon spotted frog (OSF) was listed as threatened under the Endangered Species Act in 2014 (USFWS 2014, 79 FR 51658).

10.4.2 Life History

Historically, the OSF ranged from British Columbia to the Pit River drainage in northeastern California. Oregon spotted frog habitat in Oregon was historically found in Deschutes, Klamath, Lane, Wasco, and Jackson counties.

OSF is an aquatic frog that seldom strays from areas of standing water. Upland habitat is avoided by the OSF relative to wetland habitats. OSFs are generally found in slow-moving aquatic edge habitat along streams and marshes or beaver ponds. Oregon spotted frogs use shallow oviposition sites consistently across their range, with average depths per site ranging from 5.9 to 25.6 cm (Reclamation 2018). This frog is often associated with submergent, floating, and low emergent vegetation, which it uses for basking sites and escape cover. Springs and spring-fed stream reaches are likely overwintering sites and may be a key habitat component.

During the breeding season (February through May), OSF prefer sedge-dominated and sedge/rush mix (*Carex* spp. and *Juncus* spp.) wetland vegetation for oviposition. During this season, OSF emerge from winter habitats and move into breeding areas of hardhack (*Spiraea douglasii*) and sedge-dominated vegetation. Within wetlands, OSF select sedge and hardhack

dominated vegetation and avoid dense stands of reed canarygrass (cover greater than 50 percent) and areas of other grasses where closure is greater than 75 percent (Watson et al. 2003). Oviposition sites tend to be above gently sloping substrates with herbaceous vegetation such as sedges, rushes, and grasses (McAllister and Leonard 1997; Pearl and Hayes 2004). Oviposition sites usually lack significant vertical vegetation comports and structures; however, taller vegetation (e.g., cattails, *Typha* spp.) can be nearby and used as cover.

Adults are thought to return to the same general breeding location across years, although actual locations of eggs shift within these regularly used areas based on water depth at the time of breeding. Eggs are generally laid in water less than 30 centimeters (cm) deep but can be laid in as little as 4-5 cm. However, it is not unusual for the tops of egg masses to be exposed above the water surface. Water-level fluctuations after oviposition can result in egg masses being stranded or inundated by deeper water (Pearl et al. 2010). In drought years, eggs laid on the margins of deeper, permanent waters may be the only source of population recruitment. Most OSFs avoid laying eggs in permanent waters, perhaps because eggs and hatching tadpoles are more vulnerable to predation at these locations, and water temperatures are colder compared to the temporary, shallow pools used in the floodplain wetlands (Watson et al. 2003).

After breeding, OSFs often redistribute themselves across a broader summer range. This summer range can include wetlands more than 0.3 km from the original breeding site (Watson et al. 2003; Pearl et al. 2010). OSFs inhabit relatively shallow water with cover from emergent or aquatic plants and will redistribute in response to changing water levels. During periods of prolonged and severe cold, they may become inactive, possibly burying themselves in silty substrates or clumps of emergent vegetation (McAllister and Leonard 1997).

After relocating to summer habitat, adult OSFs often stay within a relatively small area until fall. In summer, adult OSF's bask and forage near moderate to dense vegetation; deeper pools or flocculant substrates are used by adults as retreats when disturbed (Watson et al. 2003). Summer is the season of maximum growth but also highest predation. OSF may balance basking and feeding opportunities against vulnerability of predators such as garter snakes (Pearl et al. 2010), herons, nonnative fish and bullfrogs (McAllister and Leonard 1997). The diet of OSFs at a site in British Columbia included slugs, snails, spiders, crickets, grasshoppers, dragonflies, damselflies, true bugs, beetles, butterflies, moths, bees, ants, and wasps (Pearl et al. 2010).

OSFs are generally inactive during the winter season, although some individuals may be observed at the water surface on warmer days (Hayes 1994) and in lowland habitats that do not freeze. At higher elevations with harsher winters, OSFs appear to use nonfreezing aquatic environments such as springs, channels, beaver runs, and areas of deep water. Telemetry studies at montane sites in Washington and Oregon suggest that OSFs can be active under ice during portions of the winter (Pearl et al. 2010). In areas where snow and ice cover their habitat for months, OSFs are believed to retreat to springs where they spend the winter in a state of torpor in the highly oxygenated and ice-free water (McAllister and Leonard 1997).

10.4.3 Current Conditions

Critical habitat for OSF was designated in 2016 and includes three occupied habitat units in Klamath Basin (USFWS 2016e, 81 FR 29336). The Williamson River unit (Unit 12) consists of the Williamson River (and a tributary, Jack Creek) and seasonally wetted areas along the river in

Klamath Marsh NWR to the northeast of UKL. Upper Klamath Lake (United 13) includes the Wood River and its adjacent seasonally wetted areas from its headwaters downstream to the confluence with Agency Lake as well as the length of the Wood River Canal (USFWS 2016e). The Upper Klamath unit (Unit 14) consist of lakes and creeks in Jackson and Klamath counties near Buck Lake and Spencer Creek and Parsnip Lakes and seasonally wetted areas near Keene Creek (USFWS 2016e).

The UKL unit includes multiple areas in the Wood River and Sevenmile Creeks areas north of UKL. The Wood River area is inclusive of the Wood River to the levee road near its confluence with Agency Lake and all of Fort Creek and Annie Creek downstream of the Annie Creek Sno-park to its confluence with the Wood River. This unit also includes portions of Sevenmile, Crane, and Fourmile creeks and associated wetted areas and springs that are located to the northwest of UKL (USFWS 2016e).

The UKL unit has all of the essential physical or biological features found within the unit but are impacted by invasive plants, woody vegetation plantings and succession, hydrological changes, and nonnative predators (USFWS 2016e).

Without action, lake surface elevations in UKL and Agency Lake are expected to be relatively low year-round, seasonally fluctuating from about 4136 ft during late summer into winter and less than 4142 ft during spring months. Reclamation anticipates that corresponding surface area and water depth will also fluctuate in a similar pattern.

10.4.4 Effects to Oregon Spotted Frog

OSF populations are far enough upstream, or behind a levee near the Wood River, that proposed fluctuations in lake elevations in UKL (and Agency Lake) will have no effect on individual frogs or populations under both the without action or PA hydrology.

The PA, to store water in and divert water in the Upper Klamath Basin (particularly from UKL) as described in Chapter 4 herein, will not adversely modify critical habitat in the Upper Klamath and Williamson River critical habitat units. Implementation of the PA will result in a seasonal range of surface elevations in UKL, and the lowest portions of tributaries to UKL such as the Williamson and Wood rivers, that can be generalized as relatively high-water surface elevations in late winter through early summer and low surface elevations from late summer through early winter. Both the Upper Klamath and the Williamson River critical habitat units, while in the PA area, are upstream from impacted areas relative to lake surface elevations in UKL or river flows in the Klamath River. The UKL critical habitat unit includes several tributaries to Agency Lake and includes an area along the Wood River adjacent to Agency Lake (i.e., UKL) that may be impacted during February through June by relatively high surface elevations in UKL and in the lower Wood River. The influence of UKL surface elevations could extend as far up the Wood River to the BLM south levee road but is expected to only reduce velocity of the Wood River in the area of the levee. The influence of lake surface elevations does not extend upstream to areas of OSF critical habitat on other tributaries to Agency Lake within the UKL critical habitat unit.

The PA may result in changes to OSF critical habitat nearest the south end of the Wood River wetland through reducing the Wood River currents and increasing river stage as water backs up as a result of high surface elevations in UKL and Agency Lake. These impacts, anticipated to

occur in spring months, are small seasonal increases to habitat identified as primary constituent elements (PCE) 1 and 2 for OSF (USFWS 2016e) . More specifically, increased river stage and slower currents could improve wetted movement corridors for OSF (PCE 2) or increase the amount of seasonal non-breeding habitat if the river stage inundates adjacent depressions (PCE 1). Reclamation concludes that the PA is not likely to adversely affect OSF critical habitat resulting from the PA.

Given the distribution of OSF populations – at elevations higher than the water fluctuations anticipated under a without action scenario or under the PA – Reclamation concludes there will be no effect on individual frogs or populations as a result of the PA.

10.5 Applegate's Milkvetch

10.5.1 Legal Status

Applegate's milkvetch was federally listed as endangered without critical habitat in 1993 (USFWS 1993b, 58 FR 40547). The USFWS subsequently published a recovery plan for Applegate's milkvetch in 1998 (USFWS 1998).

10.5.2 Life History

Applegate's milkvetch is a slender, low growing, vine-like herbaceous perennial plant in the Fabaceae (pea) family. The plant's physical appearance is characterized with multiple sprawling stems 12 to 36 inches long and small white to light-pink to lavender pea-like flowers, measuring up to 7mm (0.3 inch). The tip of the keel is faintly lilac-tinged. Flowers are present from June to September. The anthers and stigma ripen simultaneously, enabling self-pollination. The leaves are typically 3.5 to 7cm (1.4 to 2.8 inches) long with 7 to 11 leaflets, with stems 3 to 4 decimeters (12 to 16 inches) long. Plants produce 0.3- to 0.5-inch seed pods during June and July and are widely spreading or declined.

10.5.3 Current Conditions

Applegate's milkvetch is a narrowly distributed endemic plant known to occur only in southern Klamath County, Oregon, with currently 8 occupied sites located within 13 miles of the city of Klamath Falls. Applegate's milkvetch was believed extinct up until its re-discovery in 1983. At the time of the Services listing decision, it was known from two extant sites and one historical site (USFWS 2009). These extant sites were identified as Miller Island and Ewauna Flat Preserve, which supported an estimated 30 to 80 and 30,000 plants, respectively. The historical occurrence identified in the listing was the Keno site. Herbarium records indicate this site was last found in 1931 and was located approximately two miles east of the town of Keno, Oregon (USFWS 2009).

Populations today are known to primarily colonize three large sites; however, presence has also been documented at several smaller sites south of Klamath Falls, Oregon. Sites where populations occur in highest numbers are OC & E, Ewauna Flats Preserve, Collins Tract, and the Klamath Falls Airport (Figure 10-1). It is thought this species was historically more prevalent, based on habitat surveys. Urban development, agriculture, weeds, fire suppression, flood control and land reclamation have contributed to the decline of this species (USFWS 2009).

Activities, characterized as routine O&M, such as weed control roadbed improvement, and canal embankment, would not be conducted without action. Without action may prolong seasonal inundation of areas near known populations of Applegate's milkvetch, likely providing a slight benefit to the plant.

10.5.4 Effects to Applegate's Milkvetch

Each of the three sites of Applegate's milkvetch is within the Project boundaries. However, Reclamation does not anticipate effects to the sites or individual plants as a result of water storage and delivery within the Project. Routine O&M activities of the PA described in Element Three of the PA are also not expected to impact Applegate's milkvetch or habitats in the 13 sites where it is known to occur. Reclamation's activities such as road maintenance, seasonal mowing and weed abatement will not occur at occupied sites or near known plants; thus, the PA and without-action scenario will have no effect to designated critical habitat. The PA is anticipated to have no effect on Applegate's milkvetch.

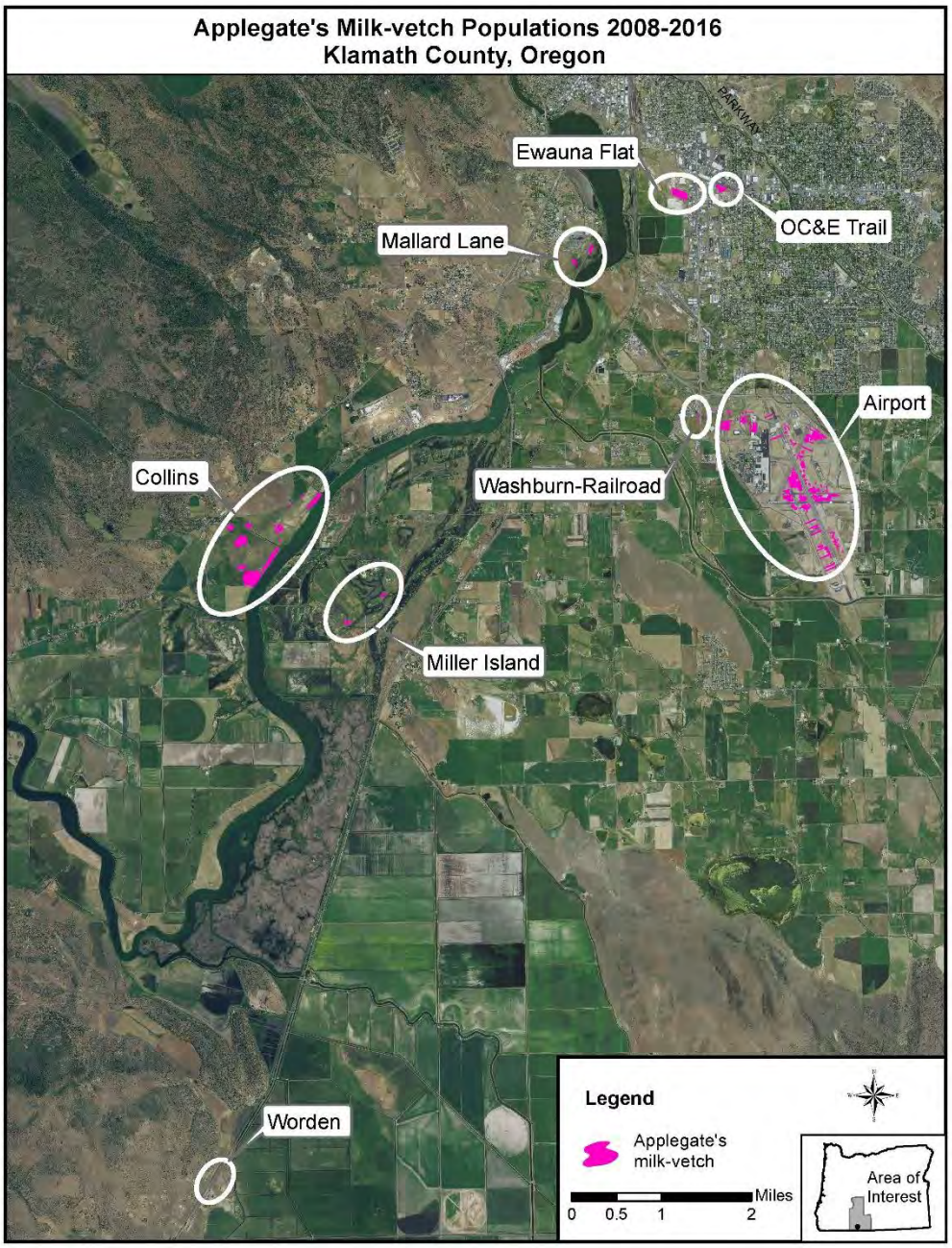

Figure 10-1. Map of the area near Klamath Falls and the Keno Reservoir, Oregon, showing both the known populations of Applegate's milkvetch and locations of historic populations. Source: (Spaur 2018).

Chapter 11 Cumulative Effects

11.1 Cumulative Effects (Impacts of Future State, Tribal, Local, or Private Actions)

Cumulative effects are those effects of future state or private activities, not involving federal activities, that are reasonably certain to occur within the action area of the federal action subject to consultation. (50 CFR 402.02). Such future state and private activities and their effects, to the extent they are reasonably certain to occur and can be ascertained, have been considered in conjunction with the above analysis of the without-action scenario. The effects of federal activities proposed to be undertaken pursuant to the PA have likewise been considered in the overall analysis. This consideration of both the cumulative effects of future state and private activities, and the anticipated effects of the federal action proposed under the PA, represents an overall framework for this impact analysis.

Tribal lands are excluded from the designation of critical habitat for the SONCC coho salmon ESU, and Reclamation is unaware of Tribal actions that are reasonably certain to occur within the area of the action subject to ESA section 7 consultation. Future federal actions will be subject to the consultation requirements established in section 7 of the Act, and therefore are not considered cumulative to the PA. Cumulative effects are discussed below.

11.1.1 Lost River and Shortnose Suckers

The federal Clean Water Act (43 U.S.C. §§1251 to 1376) requires states to develop plans with goals and pollution targets for improving water quality in water bodies that are designated as impaired because of excessive quantities of various pollutants. This process includes establishing limits known as Total Maximum Daily Loads (TMDLs) for designated pollutants. Governmental entities (local, state, and federal) and/or private entities are responsible for addressing pollution under their control by developing management strategies, implementation plans, and schedules that are designed to collectively meet TMDL requirements. ODEQ released an updated TMDL analysis and report for the Upper Klamath and Lost River subbasins within the Klamath Basin in 2017 (ODEQ 2017). The mainstem Klamath River TMDL was released by the state of California in 2010 (NCRWQCB 2010b). Implementation of the resultant water quality management plans will aid in improving water quality in UKL and its tributaries as well as the mainstem Klamath River in habitats occupied by listed suckers, which is beneficial to listed suckers and their habitats.

The non-Federal actions that are expected in the Action Area are habitat restoration, water quality improvements, and other actions that are regularly funded by Partners for Fish and Wildlife, the Oregon Watershed Enhancement Board, the National Fish and Wildlife Foundation, as well as through other entities. For example, past work has been done by the Klamath Basin Rangeland Trust, Klamath Watershed Partnership, The Klamath Tribes, The Nature Conservancy, Trout Unlimited, Sustainable Northwest, Klamath Soil and Water Conservation

District, and Klamath Water Users Association. Funding has been consistent through these entities for years, but uncertainty always remains. Much of the uncertainty surrounding progress in ecosystem restoration is the willingness of private land-owning entities and persons to participate in voluntary restoration actions. However, given the amount of focused effort and the involvement of several key organizations in the Upper Klamath Basin, progress is expected toward the groups' priorities over the next four years that will be measurable at some scales.

11.1.2 Coho Salmon

11.1.2.1 Fish Hatcheries

The information available indicates that the influence of the hatchery stocking program on the genetic fitness of natural-origin coho salmon populations in the Klamath and Trinity Rivers is significant. NMFS (2010a; 2013)stated that they anticipated hatchery releases to remain constant into the near future. However, the primary factors affecting the diversity of SONCC ESU coho salmon can be attributed to low population abundance, the influence of hatcheries, and out-of-basin introductions (NMFS 2013). Furthermore, the future condition for naturally produced coho salmon populations may be continually degraded due to detrimental impacts from density-dependent mechanisms in the freshwater environment. For example, mainstem natural-origin juvenile coho salmon during the winter rearing period may be significantly impacted when the effects of future releases of juvenile salmonids from IGH are added to the environment.

There are differences between hatchery and wild fish due to the differences between artificial and natural environments (Hey et al. 2005) that manifest in changes in morphology and life-history traits (Kostow 2004) and behavior (Fleming et al. 1997; Olla et al. 1998). Flagg et al. (2000) found that, depending on the carrying capacity of the system, increasing release numbers of hatchery fish often negatively impacts naturally-produced fish because these fish can get displaced from portions of their habitat. Competition between hatchery and naturally-produced salmonids can also lead to reduced growth of naturally produced fish (McMichael et al. 1997).

11.1.2.2 Habitat Restoration – PacifiCorp

PacifiCorp, which owns and operates the Klamath Hydroelectric Project, developed a Habitat Conservation Plan for coho salmon. As part of PacifiCorp's conservation strategy, the Klamath River Coho Enhancement Fund was developed to fund projects that will restore, enhance, and improve habitat, flows, and fish passage for the SONCC coho salmon in the Klamath River and/or its tributaries downstream of Iron Gate Dam. In order to be eligible for funding, projects must have a direct benefit to SONCC coho salmon and address one or more of PacifiCorp's Habitat Conservation Plan for coho Salmon goals.
Funding priorities for this program include:

- Barrier removal projects that improve access to critical habitat;
- Rearing habitat creation and enhancement;
- Water transaction funding to increase instream flows during low water levels to improve water quality and quantity; and
- Mainstem and tributary habitat creation, enhancement and protection projects.

PacifiCorp provides approximately $500,000 annually to the Coho Enhancement Fund. Since 2009, the Klamath River Coho Enhancement Fund has awarded over $2.4 million to 26 projects.

These projects will leverage over $6.4 million in additional matching funds and in-kind contributions. The projects awarded meet the Habitat Conservation Plan goals, including the improvement of fish passage and connectivity, spawning and rearing habitat enhancements, and flow augmentation through water transactions. For the past two years, PacifiCorp and Reclamation have combined their Request for Proposal process since both programs enhance the survival and recovery of coho salmon.

11.1.2.3 Agriculture Practices

Off-project agricultural operations on Klamath River tributaries, if unaltered, will continue to reduce the quantity, and alter the timing, of water availability and may negatively affect riparian and wetland habitats through upland modifications that lead to increased siltation or reductions in water flow in stream channels. Grazing activities from dairy and cattle operations can degrade or reduce suitable critical habitat for ESA-listed coho salmon by increasing erosion and sedimentation, as well as introducing nitrogen, ammonia, and other nutrients into the watershed. Storm water and irrigation discharges related to both agricultural and urban activities contain numerous pesticides and herbicides that may negatively affect salmonid reproductive success and survival rates. Furthermore, agricultural practices can alter the hydrograph (e.g., timing of peak runoff, base flows, return flows and contamination, etc.) and therefore impact salmonid habitats.

Also, with agricultural practices, the cultivation of marijuana, legal and illegal, can also impact salmonid habitats. Watersheds within the action area have been used to produce marijuana crops both legally and illegally. Illegal marijuana production within the action area can result in grow operations of over 100,000 plants; often these illegal grow operations occur on federal lands. These grow operations can adversely affect coho salmon habitat by diversion of water for irrigation, resulting in the drying of streams or draining of pools that provide rearing habitat for coho salmon juveniles. The operations can also contaminate nearby streams by the discharge of pesticides, rodenticides, and fertilizers to nearby streams. Such influx of contaminants can be lethal to exposed coho salmon or result in the alteration of stream habitats via eutrophication.

11.1.2.4 Timber Harvest

Timber harvest/management activities allow more water to reach the ground and alters the timing of water releases. These impacts may alter water infiltration into forest soils such that less water is absorbed, or the soil may become saturated faster, thereby increasing surface flow. Road systems, skid trails, and landings where the soils become compacted also accelerates runoff (NMFS 2010a). The adverse effects from timber harvest are expected to continue for the 4-year duration of the PA, and for years to follow.

Sedimentation from modern-day harvest units, harvest-related landslides and an extensive road network continues to impact habitat although at much reduced levels as compared to early logging. Ground disturbance, compaction, and vegetation removal during timber harvest has modified drainage patterns and surface runoff resulting in increased peak storm flows which has increased occurrences of channel simplification and channel aggradation. Simplification of stream channels and sediment aggradation results in loss or destruction of salmonid habitat as pool complexes and side channel winter rearing habitat are often lost or degraded to such an extent as to no longer provide refugia for developing juveniles.

Control of wildland fires may include the removal or modification of vegetation due to the construction of firebreaks or setting of backfires to control the spread of fire. This removal of vegetation can trigger post-fire landslides as well as chronic sediment erosion that can negatively affect downstream coho salmon habitat. Also, the use of fire retardants may adversely affect salmonid habitat if used in a manner that does not sufficiently protect streams causing the potential for coho salmon to be exposed to lethal amounts of the retardant. This exposure is most likely to affect summer rearing juvenile coho salmon. As wildfires are unpredictable events but are increasing in frequency and severity, it cannot be determined the extent to which suitable coho salmon habitat may be degraded or modified by these wildfire and suppression activities.

11.1.2.5 Residential Development and Infrastructure

Human population growth in the action area is expected to remain relatively stable and some development will continue to occur which, on a small-scale, can impact coho salmon habitat. Once development and associated infrastructure (e.g., roads, drainage, and water development) are established, the impacts to aquatic species are expected to be permanent. Anticipated impacts to aquatic resources include loss of riparian vegetation, changes to channel morphology and dynamics, altered hydrologic regimes (increased storm runoff), increased sediment loading, and elevated water temperatures where shade-providing canopy is removed. The infrastructure and roads waters may lead to the removal of large woody debris. There are also effects of home pesticide use, roadway runoff of automobile pollutants, introductions of invasive species to nearby streams and ponds, attraction of salmonid predators due to human occupation (e.g., raccoons), increased incidences of poaching, and loss of riparian habitat due to land clearing activities. These factors associated with residential development can have negative impacts on salmon populations.

11.1.2.6 Recreation

Expected recreation impacts to salmonids include increased turbidity, impacts to water quality, barriers to movement, and changes to habitat structures. Streambanks, riparian vegetation, and spawning redds can be disturbed wherever human use is concentrated. Campgrounds can impair water quality by elevating nutrients in streams. Construction of summer dams to create swimming holes causes turbidity, destroys and degrades habitat, and blocks migration of juveniles between summer habitats. Impacts to salmonid habitat are expected to be localized, mild to moderate, and temporary. Fishing within the action area, typically for steelhead or Chinook salmon, is expected to continue subject to CDFW regulations. Fishing for coho salmon directly is prohibited in the Klamath River. The level of impact to coho salmon within the action area from angling is unknown, but is expected to remain at current levels.(National Marine Fisheries Service (NMFS) 2010a)

11.1.3 Southern Resident Killer Whale

Pertinent cumulative effects that relate to the Southern Resident Killer Whale and their preferred prey (Klamath River basin Chinook salmon) in the freshwater environment are likely to be similar to those described for coho salmon above in Chapter 11.1.2.

With respect to cumulative effects related to Southern Residents and Chinook salmon in the marine waters of the Pacific Ocean within the action area, future tribal, state, and local government actions will likely be in the form of legislation, administrative rules, policy

initiatives, or fishing permits. Activities are primarily those conducted under state and tribal management. These actions may include changes in ocean policy and increases and decreases in the types of activities that currently occur, including changes in the types of fishing activities, resource extraction, or designation of marine protected areas, any of which could impact Southern Residents, Chinook salmon, or their habitat. Government actions are subject to political, legislative and fiscal uncertainties. These realities, added to the geographic scope, which encompasses several government entities exercising various authorities, and the changing economies of the region, make analysis of cumulative effects in this regard highly speculative. Although state, tribal and local governments have developed plans and initiatives to benefit Southern Residents and Chinook salmon, they must be applied and sustained in a comprehensive way they can be considered reasonably certain to occur and subject to a cumulative effects analysis. Private activities in this portion of the action area are primarily associated with boating related activities and other potential sources of marine pollution.

Actions outside the action area that may affect SRKW population dynamics, and hence the significance of the PA to survival of the SRKW DPS but beyond the scope of this analysis, include new regulations on whale watching in Washington, changes in shipping best practices by the ports of Vancouver and Seattle, increases in diluted bitumen exports through the Salish Sea, decisions regarding fish farming in British Columbia and Washington, and decisions regarding land use and restoration throughout salmon-bearing coastal watersheds.

In summary, these potential factors are ongoing and expected to vary in the future, so the level of their impact is uncertain. For these reasons, it is not possible to predict what the cumulative effects of future non-Federal actions will be on prey available to SRKWs or their other effects on survival and recovery.

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Chapter 12 Essential Fish Habitat Assessment

This section will include an Essential Fish Habitat Assessment under with Magnuson-Stevens Fishery Conservation and Management Act in March 2020.

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Chapter 13 Conclusion

The determination of effects for listed species and their designated critical habitat in this biological assessment considers direct and indirect effects of the PA together with the effect of other activities that are interrelated or dependent on the PA. The BA further considers the effects of the PA as measured in relation to the environmental baseline without that action. This chapter presents a summary of the effects for listed species and their designated critical habitat.

13.1 Analytical Approach

Population and critical habitat analyses are included in this BA to assist the fishery agencies in making the determination of whether the PA would reasonably be expected to "directly or indirectly, reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of that species." (NMFS 2012a). Three possible determinations exist regarding a PA's effects on listed species:

• No effect - "No effect" is the appropriate conclusion when it is determined that the PA will not affect a listed species or designated critical habitat.

• "May affect, but is not likely to adversely affect" is the appropriate conclusion when effects to listed species or critical habitat are expected to be discountable (extremely unlikely to occur), insignificant (never resulting in take), or completely beneficial (positive effects without adverse effects).

• May affect, likely to adversely affect is the appropriate conclusion if any adverse effect may occur to listed species or critical habitat as a direct result of the PA, and the effect is not discountable, insignificant, or beneficial. If incidental take is anticipated to occur as a result of the PA, an "is likely to adversely affect" determination is made.

The ongoing stressors associated with existing dams and other structures are part of the environmental baseline. Reclamation does not currently have the authority or discretion to remove these structures and alter these baseline conditions. The PA includes storing, diverting and conveying water in accordance with existing water contracts and agreements, including refuge deliveries, consistent with water rights and applicable laws and regulations. The PA also includes habitat restoration and other actions to benefit species.

In consideration of the foregoing effects assessments, incidental take could potentially occur as a result of the PA. A main objective in this consultation is incidental take coverage for the operation of the Klamath Project. Incidental take is take of listed fish or wildlife species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by a Federal agency or applicant. [50 CFR §402.02]. The definition of take is to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect a listed species or attempt to engage in any such conduct. [ESA §3(19)] Harm means an act which actually kills or injures wildlife. Harm is

further defined by USFWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering. Harass is defined by USFWS as encompassing actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding or sheltering. [50 CFR §17.3]

Although the effects analysis describes effects to listed species in a holistic, species-level manner throughout the action area, Reclamation also considered whether the effects analysis indicated effects to listed species at the individual level to determine whether incidental take coverage for the PA would be necessary. Reclamation provides this biological assessment to help the USFWS and NMFS develop their biological opinions. The determination of jeopardy or adverse modification by USFWS and NMFS is based on the effects of the PA on the continued existence of the entire population of the listed species or on a listed population, and/or the effect on critical habitat. An action that does not result in jeopardy or adverse modification can nevertheless result in incidental take.

Table 13-1. Determination of Effects.

Species	Scientific Name	Status	Effect of the Proposed Action
SONCC coho salmon	*Oncorhynchus kisutch*	Threatened	May affect, likely to adversely affect
Lost River sucker	*Deltistes luxatus*	Endangered	May affect, likely to adversely affect
Shortnose sucker	*Chasmistes brevirostris*	Endangered	May affect, likely to adversely affect
Southern Resident DPS killer whale	*Orcinus orca*	Endangered	May affect, not likely to adversely affect
Southern DPS North American green sturgeon	*Acipenser medirostris*	Threatened	May affect, not likely to adversely affect
Southern DPS Pacific eulachon	*Thaleichthys Pacificus*	Threatened	May affect, not likely to adversely affect
Bull trout	*Salvelinus confluentus*	Threatened	No effect
Oregon spotted frog	*Rana pretiosa*	Threatened	No effect
Applegate's milk-vetch	*Astragalus applegatei*	Endangered	No effect
SONCC Coho salmon Critical Habitat	*Oncorhynchus kisutch*	Designated	May affect, likely to adversely affect
Lost River sucker Critical Habitat	*Deltistes luxatus*	Designated	May affect, likely to adversely affect
Shortnose sucker Critical Habitat	*Chasmistes brevirostris*	Designated	May affect, likely to adversely affect

Species	Scientific Name	Status	Effect of the Proposed Action
Southern DPS Pacific eulachon Critical Habitat	*Thaleichthys Pacificus*	Designated	May affect, not likely to adversely affect
Southern DPS North American green sturgeon	*Acipenser medirostris*	Designated	Not in Proposed Action Area and not analyzed
Bull trout	*Salvelinus confluentus*	Designated	Not likely to adversely affect
Oregon spotted frog Critical Habitat	*Rana pretiosa*	Designated	Not likely to adversely affect
Applegate's milk-vetch Critical Habitat	*Astragalus applegatei*	Endangered	No effect

13.2 Summary and Determination of Effects of the Proposed Action on Lost River and Shortnose Sucker and Designated Critical Habitat

13.2.1 Determination of Effects on Lost River and Shortnose Sucker

The PA results in beneficial effects for suckers through surface elevation management during water storing operations at each of the reservoirs. Management of Upper Klamath Lake results in higher elevations from late winter into fall and improves the amount of habitat at multiple life history stages by extending the periodicity and amount of shoreline spawning area, emergent vegetation habitat for larvae, and habitat diversity, water depth, and surface area for young-of-the-year juveniles, older juveniles and adults of both sucker species. Higher lake elevations also increase diversity of prey base for feeding suckers, at each life history stage, with the benefit of improving individual fitness. Beneficial results are anticipated through the PA from Reclamation's conservation measures to continue funding monitoring, research, and recovery activities.

It is anticipated that results of dry hydrologic conditions from the environmental baseline can diminish the beneficial outcome for suckers by precluding Reclamation from managing surface elevations in a manner that maximizes habitat access for all life history stages throughout seasons when these habitats are beneficial. However, impacts from low surface elevations during important life history stages at each reservoir are expected to be less frequent and less extreme in the PA, within the context of the environmental baseline. Several factors influencing suckers from the baseline carry forward largely without influence from the PA, such as wetland/habitat loss, stressful water quality conditions, and predation.

An action carried forward in the PA from the baseline is entrainment. Sucker entrainment, while it continues to occur, is expected to be less at both Clear Lake and A Canal due to a fish screen and changes in sucker abundance over the last several decades. Sucker entrainment at other

reservoirs, and at subsequent other diversion points, also carries forward from the baseline to the future conditions for suckers. Sucker entrainment at other reservoirs, and at subsequent diversion points, also carries forward from the baseline to the future conditions for suckers but entrainment may be less in the in the future under this PA based on diversion volumes from and recent declines in sucker abundance.

The PA provides numerous benefits for suckers through surface elevation management that provides available habitat for each life history stage. The PA also may affect and is likely to adversely affect individual suckers from UKL at each life history stage through entrainment of larvae at A Canal, and multiple life history stages at LRD, LRDC (Keno), and Ady Canal (Keno). The PA also may affect and is likely to adversely affect individuals at both Clear Lake and Gerber Reservoir through continued entrainment and reduced spawning access in dry years.

After considering the best available scientific and commercial information, the analysis indicates that LRS and SNS are likely to be exposed to environmental consequences and will respond in a negative manner to the exposure to adverse stressors. Thus, Reclamation concludes that implementing the PA, including the beneficial conservation measures intended to offset adverse impacts, may affect, and is likely to adversely affect the LRS and SNS.

13.2.2 Determination of Effects on Designated Lost River and Shortnose Sucker Critical Habitat

The PA is not anticipated to influence water quality at UKL, Clear Lake Reservoir, and Gerber Reservoir. The PA is anticipated to provide relatively high surface elevations in lakes and reservoirs which is anticipated to provide habitat for each life history stage (described above in individual impacts) within the context of the baseline.

The PA is anticipated to increase access to spawning habitats in each reservoir within the context of the baseline, except in dry hydrologic years. Periodic, though infrequent and temporary, low surface elevations as a result of low inflows may impact proposed critical habitat through limiting sucker access to spawning habitat at shoreline spawning areas in UKL, tributaries to Tule Lake sump 1A, as well as Clear Lake and Gerber reservoirs. Reclamation anticipates habitat impacts to be seasonal and temporary with surface elevation fluctuations within the PA. Reclamation anticipates that adverse impacts to designated critical habitat would be offset with funding conservation measures described in Part 4. Reclamation anticipates that the PA may affect, and is likely to adversely affect designated critical habitats for both Lost River and shortnose suckers.

13.3 Summary and Determination of Effects of the Proposed Action on Coho Salmon and Designated Critical Habitat

13.3.1 Determination of Effects on Coho Salmon

After considering the best available scientific information, implementing the PA may affect, and is likely to adversely affect coho salmon survival, growth, and reproduction. The PA has beneficial impacts of providing flow events that are anticipated to mitigate fish disease conditions in the river. Minimum flows into the late summer and fall months increase available

habitat and tributary connectivity for adult migration. The PA likely reduces the quantity of juvenile coho rearing habitat in the mainstem Klamath River between IGD and the Salmon River during the spring outmigration. While there will be reductions in rearing habitat availability, particularly during spring and early summer, the PA augments the EWA in dry and critically dry years to increase habitat availability and respond to coho disease concerns while also ensuring minimum flows in all years. The adverse effects to coho salmon juvenile and fry habitat in the Klamath River are likely to be somewhat moderated by flow variability provided through the PA when hydrological conditions in the upper Klamath Basin result in additional releases and enhanced flow variability. The Klamath Coho Restoration Program is likely to result in improvements and increases in coho habitat through aquatic habitat restoration designed to improve conditions for adult and juvenile coho salmon in the areas most likely to result in improved survival, growth, and reproduction.

The PA contains components that will result in a net benefit to coho salmon relative to without action conditions. Factors that can affect juvenile salmon survival include disease exposure, temperature and available habitat. The PA provides for increased flow augmentation to address habitat and disease issues in the Klamath River. The frequency of flushing flows is expected to substantially reduce disease risk and overall mortality of juvenile coho during the spring outmigration. The PA likely reduces the quantity of habitat for juvenile coho rearing habitat in the mainstem Klamath River between IGD and the Salmon River during the spring outmigration. While there will be reductions in rearing habitat availability, particularly during spring and early summer, the PA augments the EWA in dry and critically dry years to increase habitat availability and respond to coho disease concerns (an impossibility without action).

Reclamation anticipates both some improvements and some adverse effects to SONCC coho with the PA. However, the PA is also likely to result in some incidental take as a result of reduced fry and juvenile habitats, particularly during dry hydrologic conditions in the spring months. Incidental take of SONCC coho salmon is also likely through disease-related infection and mortality.

After considering the best available scientific information, it is concluded that implementing the PA may affect, and is likely to adversely affect coho salmon survival, growth, and reproduction. However, increased flow augmentation to address habitat and disease issues in the Klamath River paired with the Klamath Coho Restoration Program which is expected to result in aquatic habitat restoration designed to improve conditions for adult and juvenile coho salmon in the areas most likely to result in improved survival, growth, and reproduction will minimize the effects of implementation of the PA.

13.3.2 Determination of Effects on Designated Coho Salmon Critical Habitat

The PA likely reduces the quantity of juvenile coho rearing habitat in the mainstem Klamath River between IGD and the Salmon River, especially in the spring. While there will be reductions in rearing habitat availability, particularly during spring and early summer, the PA does have flexibility to provide habitat, such as ensuring a minimum flow in critically dry years and a minimum summer flow in all years. The PA is also likely to reduce the quantity of coho fry rearing habitat; however, such reduction is likely to occur in below average water years late in the spring when coho fry are less common. The adverse effects to coho salmon juvenile and fry

habitat in the Klamath River are likely to be somewhat moderated by flow variability provided through the PA when hydrological conditions in the upper Klamath Basin allow. Effects to designated critical habitat are seasonal and temporary in nature. The Klamath River Coho Restoration Program could result in improvements and increases in coho habitat but has the potential to cause temporary adverse conditions to critical habitat. After considering the best available scientific information, Reclamation concludes that implementing the PA may affect, and is likely to adversely affect designated coho salmon critical habitat. However, the PA provides for increased flow augmentation to address quantity of habitat in the Klamath River. The flexible EWA augmentation scheme is anticipated to provide additional habitat in dry and critically dry years.

13.4 Summary and Determination on Effects of the Proposed Action on Southern Resident Killer Whale and Designated Critical Habitat

13.4.1 Determination of Effects on Southern Resident DPS Killer Whale

The PA contains components that will result in a net benefit to Chinook salmon relative to without action conditions. Factors that can affect juvenile salmon survival include disease exposure, temperature and available habitat. The PA provides for increased flow augmentation to address habitat and disease issues in the Klamath River. The frequency of flushing flows is expected to substantially reduce disease risk and overall mortality of juvenile Chinook. Minimum flows into the late summer and fall months increase available habitat and tributary connectivity for adult migration. The PA likely reduces the quantity of habitat for juvenile Chinook rearing habitat in the mainstem Klamath River between IGD and the Salmon River during the spring outmigration. While there will be reductions in rearing habitat availability, particularly during spring and early summer, the PA augments the EWA in dry and critically dry years to increase habitat availability and respond to disease concerns.

The impact on competition for available habitat is less clear. Lowered fry habitat availability leads to increased competition, which, could reduce growth and survival of fry and juvenile Chinook salmon. The PA also ensures monthly minimum flow in all years. The PA is likely to reduce the quantity of Chinook fry rearing habitat; however, such reduction is likely to occur in below average water years late in the spring when Chinook fry are less common. The adverse effects to Chinook salmon juvenile and fry habitat in the Klamath River are likely to be somewhat moderated by flow variability provided through the PA when hydrological conditions in the upper Klamath Basin result in additional releases and enhanced flow variability. Further, consistent ramping rates will reduce stranding risk after high flow events. The PA also emphasizes the storage of water in UKL in early spring, such that the volume is sufficient to meet the needs of Chinook over the summer. In dry years, this will help by decreasing temperatures and diluting pathogens to improve adult survival as they move upstream to spawn.

In wet years, flow will increase under both the PA and without action scenario. Flows may be higher at times under the without action scenario, but the PA will perform better in wet years than it does in dry years, and thus will provide greater consistency in the habitat quality that Chinook need to survive.

Restoration activities will increase the availability of high-quality habitat that will improve survival of all life stages. Reclamation's funding for restoration activities while likely to result in minor and short-term adverse effects during implementation, are anticipated to will result in longer term improvements to the function and role of instream habitat in the action area, and thus improve conditions for Chinook salmon.

In turn, these components of the PA will increase salmon abundance within the killer whale range. SRKWs feed preferentially on Chinook but will eat coho when Chinook and chum salmon are not available. While it is not possible to quantify the benefit to SRKWs, numerous studies have shown increased prey availability is correlated with increases in the population growth rate. Although the Klamath River basin is currently a small part of the overall prey base, a difference on the order of 2% in Klamath production resulted in a larger SRKW population in some years in our population viability analysis. Further, the range of Klamath River Chinook overlaps with the part of the range where females are often nursing calves, so abundant salmon there is especially important to SRKWs, and Klamath River Chinook are a large percentage of the available salmon within that part of the SRKW range.

After reviewing and analyzing the current status of the listed species, the environmental baseline within the action area, the effects of the PA, and cumulative effects, Reclamation concludes that the PA may affect but is not likely to adversely affect the Southern Resident Killer Whale DPS.

13.4.2 Determination of Effects on Southern Resident Killer Whale Critical Habitat

Reclamation's PA does not impact Southern Resident Killer Whale DPS designated critical habitat, defined as inland marine waters of Washington, except for Hood Canal and areas excluded for military exercises. Though not final at this time, NMFS developed a proposed rule in September 2019 proposing additional critical habitat to include Pacific coastal waters from Washington through Central California, with exclusions for military exercises off the Washington Coast.

Klamath River Chinook pass through the proposed critical habitat during their time at sea. A primary constituent element of critical habitat is prey availability, and Klamath River Chinook will contribute to this. The PA is expected to increase prey availability relative to the without-action scenario. Thus, the PA will provide net benefits to SRKW critical habitat relative to the without-action scenario.

After considering the best available scientific information, Reclamation concludes that implementing the PA will have no effect on designated critical habit for Southern Resident Killer Whales. The PA may affect but is not likely to adversely affect proposed Southern Resident Killer Whale critical habitat.

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Appendix 1A: Project Map

Upper Klamath Lake
A Canal Headworks
Link River Dam
Klamath Falls
Enterprise ID
Altamont
A Canal
B Canal
Pine Grove ID
Lost R. Div. Channel
Miller Hill P. P.
Station 48
Lost River Div. Dam (Wilson)
Pleva Dist Improv. Co.
Keno Dam
Pioneer Dist Improv Co
Keno
Midland
Midland Dist Improv Co.
Klamath ID
Pumping Plants F/FF
Stukel Drain
Ady Dist Improv Co
Pumping Plants E/EE
Klamath Drainage Dist
Center Canal
Ady Canal
Area K Leaselands
North Canal
C Canal
Stukel P. P.
G Canal
Adams P. P.
E Canal
N. Poe Valley P. P.
S. Poe Valley P. P.
Poe Valley Improv. Dist.
F Canal
Dairy
Horsefly ID
Harpold Dam
Gerber Dam
Gerber Reservoir
Miller Creek
North Canal
Langell Valley ID
Miller Diversion Dam
West Canal
Lost River
Malone Dam
Shasta View ID
Malin ID
D Canal
J Canal
Van Brimmer Ditch Co
Anderson-Rose Dam
Sunnyside
P-J Canal
Lost River
Tule Lake ID
Tulelake
Lower Klamath NWR
P Canal
West Side Improv Dist Pumping Plant D
Tule Lake NWR
Sump 1A
Sump 3 Leaselands
N Canal
"A" Pumps
M Canal
Sump 2 Leaselands
R Canal
Sump 1B
Area J
Clear Lake Dam
Clear Lake
Clear Lake Reservoir
Clear Lake NWR
Warren Act Contracts
Klamath Basin Improvement District
CALIFORNIA
Klamath Project
Southern Oregon – Northern California
Miles
0 1 2 3 4

Appendix 1B: Species List Correspondence

The federally-listed species that may be affected by the PA and therefore considered in this document were identified in coordination with the Services. The list of species considered was generated based on the correspondence Reclamation conducted with the Services during the consultation effort. Reclamation received confirmation that the species identified to be within the Action Area and under the jurisdiction of the either USFWS or NMFS are correct for consideration under section 7 analysis for operation of the Klamath Project. The below documentation reflects coordination between Reclamation and the Services on concurrence regarding species and critical habitat located within the Action Area.

From: Blake, Daniel
To: Campbell Miranda, Tara Jane
Cc: Johnson, Adam G; Rasmussen, Josh; Nettleton, Jeffrey (Jeff) L; Hiatt, Kristen; Bottcher, Jared L
Subject: Re: Request for Concurrence on Species/Critical Habitat
Date: Wednesday, February 5, 2020 9:37:40 AM

Tara Jane:
We can confirm that the species list provided in your February 4, 2020, email is accurate and suitable for proceeding with section 7 Endangered Species Act consultation on the Klamath Project using the defined action area. We appreciate that you have also recognized the authorities provided by the Bald and Golden Eagle Protection Act and Migratory Bird Treaty Act, particularly for bald and golden eagles as they occur within the action area. We appreciate the Bureau of Reclamation's efforts and will continue to work with you to complete consultation in a timely manner.
Sincerely,

Dan Blake
Field Supervisor
U.S. Fish and Wildlife Service
1936 California Ave.
Klamath Falls, OR, 97601
541-885-2512 (office)
541-591-9905 (cell)

From: Campbell Miranda, Tara Jane <tcampbellmiranda@usbr.gov>
Sent: Tuesday, February 4, 2020 5:21 PM
To: Blake, Daniel <Daniel_Blake@fws.gov>
Cc: Johnson, Adam G <adam_johnson@fws.gov>; Rasmussen, Josh <josh_rasmussen@fws.gov>; Nettleton, Jeffrey (Jeff) L <JNettleton@usbr.gov>; Hiatt, Kristen <khiatt@usbr.gov>; Bottcher, Jared L <jbottcher@usbr.gov>
Subject: Request for Concurrence on Species/Critical Habitat

Dan,

As you are aware, the Bureau of Reclamation is currently in the process of preparing a Biological Assessment (BA) to evaluate the potential effects of and determine if Klamath Project (Project) operations may affect Endangered Species Act (ESA) listed species and/or their designated or proposed critical habitat. Specifically, Reclamation proposes to divert, store, and convey Project water to meet authorized Project purposes and contractual obligations in compliance with applicable law.

Current analysis indicates the action area associated with Reclamation's proposed action includes the area within the boundaries of the Project located in southern Oregon and northern California, and the Klamath River from Upper Klamath Lake to the mouth of the river

at Klamath, California.

To appropriately evaluate and determine if the proposed action has the potential to affect threatened and/or endangered species, Reclamation is requesting your review and concurrence of the attached list of ESA-listed species and their respective critical habitats (50 CFR 402.12(c)) to be included in the biological assessment for the proposed action. Our data indicates that these species are under the jurisdiction of the U.S. Fish and Wildlife Service, and are documented present or potentially present within the action area.

We recognize that also potentially present in the vicinity of the project are bald eagle (*Halia eetus leucocephalus*) and golden eagle (*Aquila chrysaetos*), and although the bald eagle is no longer protected under the ESA, the bald eagle and golden eagle are protected under the federally-administered Bald and Golden Eagle Protection Act (BGEPA) and Migratory Bird Treaty Act (MBTA). We understand that the MBTA prohibits the taking, killing, possession, and transportation among other actions of migratory birds, their eggs, parts, and nests, except when specifically permitted by regulations.

Reclamation requests that you respond via email by no later than close of business on February 5, 2020, with your concurrence or an updated species and critical habitat list.

If you have any questions, please feel free to contact Kristen Hiatt, Environmental Branch Chief, at 541-880-2577, or via electronic mail at khiatt@usbr.gov.

Tara Jane Campbell Miranda, MNR
Senior Natural Resource Specialist
Bureau of Reclamation
Interior Region 10 California-Great Basin
Klamath Basin Area Office
Office: (541) 880.2540
Cell: (541) 274-1413
Fax: (541) 884.9053
Email: tcampbellmiranda@usbr.gov

Table 1.B.1. Federally endangered (E), threatened (T), proposed (P), and candidate (C) species and critical habitat under U.S. Fish and Wildlife Service jurisdiction documented present or potentially present in the action area.

Species	Scientific Name	Status	Critical Habitat Status
Lost River sucker	*Deltistes luxatus*	E	Designated
Shortnose sucker	*Chasmi stes brevirostris*	E	Designated
Bull trout	*Salvelinus confluentus*	T	Designated
Oregon spotted frog	*Rana pretiosa*	T	Designated
Gray wolf	*Canis lupus*	E	Designated
Fisher	*Pekania pennant*	p	*N/A*
North American Wolverine	*Gula gulo luscus*	p	*N/A*
Northern spotted owl	*Strix occidentalis caurina*	T	Designated
Yellow-billed cuckoo	*Coccyzus americanus*	T	Proposed
Applegate's milk-vetch	*Astagalus applegatei*	E	None
Greene's tuctoria	*Tuctoria greenei*	E	Designated
Slender Orcutt grass	*Orcuttia tenuis*	T	Designated
Whitebark's pine	*Pinus albicau lis*	C	*N/A*

From: Jim Simondet - NOAA Federal
To: Campbell Miranda, Tara Jane
Cc: Bottcher, Jared L; James Montesi; FW8 Arcata FWO NOAA - Seth Naman
Subject: [EXTERNAL] Re: Request for Concurrence on Species/Critical Habitat
Date: Friday, February 7, 2020 3:44:16 PM

Tara Jane- NMFS concurs that the species list Reclamation used in your 2018/2019 consultation package is still up to date, and can be used for your future 2020 BA. Regards-- Jim

From: Campbell Miranda, Tara Jane
Sent: Tuesday, February 4, 2020 5:28 PM
To: FW8 Arcata FWO NOAA - Jim Simondet <jim.simondet@noaa.gov>
Cc: James Montesi - NOAA Federal <james.montesi@noaa.gov>; FW8 Arcata FWO NOAA - Seth Naman <seth.naman@noaa.gov>; Hiatt, Kristen <khiatt@usbr.gov>; Bottcher, Jared L <jbottcher@usbr.gov>; Nettleton, Jeffrey (Jeff) L <JNettleton@usbr.gov>
Subject: Request for Concurrence on Species/Critical Habitat

Jim,

As you are aware, the Bureau of Reclamation is currently in the process of preparing a Biological Assessment (BA) to evaluate the potential effects of and determine if Klamath Project (Project) operations may affect Endangered Species Act (ESA) listed species and/or their designated or proposed critical habitat. Specifically, Reclamation proposes to divert, store, and convey Project water to meet authorized Project purposes and contractual obligations in compliance with applicable law.

Current analysis indicates the action area associated with Reclamation's proposed action includes the area within the boundaries of the Project located in southern Oregon and

northern California, and the Klamath River from Upper Klamath Lake to the mouth of the river at Klamath, California.

To appropriately evaluate and determine if the proposed action has the potential to affect threatened and/or endangered species, Reclamation is requesting your review and concurrence of the attached list of ESA-listed species and their respective critical habitats (50 CFR 402.12(c)) to be included in the BA for the proposed action. Our data indicates that these species are under the jurisdiction of the National Marine Fisheries Service, and are documented present or potentially present within the action area.

Due to the accelerated schedule, *Reclamation requests that you respond via email by no later than close of business on February 5, 2020, with your concurrence or an updated species and critical habitat list.* The list provided for your consideration is the exact list provided during our coordinated ESA section 7 consultation effort which was completed in March 2019.

If you have any questions, please feel free to contact Kristen Hiatt, Environmental Branch Chief, at 541-880-2577, or via electronic mail at khiatt@usbr.gov.

Tara Jane Campbell Miranda, MNR
Senior Natural Resource Specialist
Bureau of Reclamation
Interior Region 10 California-Great Basin
Klamath Basin Area Office
Office: (541) 880.2540
Cell: (541) 274-1413
Fax: (541) 884.9053
Email: tcampbellmiranda@usbr.gov

Table 1.B.2. Endangered Species Act-listed species and their respective critical habitats (50 CFW 402. 12(c)) to be included in the Bureau of Reclamation's 2020 Biological Assessment for the Proposed Action.

Species	Scientific Name	Status	Critical Habitat
Southern Oregon/Northern California Coast coho salmon	Oncorhynchus kisutch	Threatened	Designated
Southern Resident Distinct Population Segment killer whale	Orcinus orca	Endangered	Designated
Southern Distinct Population Segment Northern American green sturgeon	Acipenser medirostris	Threatened	Designated
Southern Distinct Population Segment Pacific eulachon	Thaleichthys paficicus	Threatened	Designated

Campbell Miranda, Tara Jane <tcampbellmiranda@usbr.gov>

[EXTERNAL] Re: Klamath ROC: Request for Concurrence on Species/Critical Habitat

1 message

Jim Simondet - NOAA Federal <jim.simondet@noaa.gov> Mon, Nov 26, 2018 at 2:15 PM
To: Tara Jane Campbell Miranda <tcampbellmiranda@usbr.gov>
Cc: James Montesi <james.montesi@noaa.gov>, Don Reck - NOAA Federal <don.reck@noaa.gov>, "Hiatt, Kristen L" <khiatt@usbr.gov>, "Bottcher, Jared" <jbottcher@usbr.gov>, "Jeffrey (Jeff) Nettleton" <jnettleton@usbr.gov>

Tara Jane- We have reviewed the attached species list and we concur the included species and their designated critical habitat are correctly identified and comprise all of the species for our consultation. Please contact me or Don Reck if you have any questions- Regards Jim

On Wed, Nov 21, 2018 at 8:54 AM Campbell Miranda, Tara Jane <tcampbellmiranda@usbr.gov> wrote:

On Behalf of Jeff Nettleton, Area Manager, Klamath Basin Area Office, Bureau of Reclamation:

Jim,

As you are aware, the Bureau of Reclamation (Reclamation) is currently in the process of preparing a Biological Assessment to evaluate the potential effects of and to determine if Klamath Project operations may affect Endangered Species Act listed species and/or their designated or proposed critical habitat. To accomplish this, please find attached a list of species and critical habitat under the jurisdiction of the National Marine Fisheries Service that may be in the project area of Reclamation's Proposed Action. Your review and concurrence of the attached list is requested at your earliest convenience. This list is being transmitted both via electronic and postal mail.

Should you have any questions or concerns, please do not hesitate to contact Kristen Hiatt at 541-880-2577, or khiatt@usbr.gov.

Best regards,
Tara Jane
--
Tara Jane Campbell Miranda, MNR
Senior Natural Resource Specialist
Klamath Basin Area Office
Bureau of Reclamation
Office: (541) 880.2540
Cell: (541) 274-1413
Fax: (541) 884.9053
Email: tcampbellmiranda@usbr.gov

--
Jim Simondet
Klamath Branch Chief
California Coastal Area Office
West Coast Region
National Marine Fisheries Service
(707) 825-5171

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Region
Klamath Basin Area Office
6600 Washburn Way
Klamath Falls, OR 97603-9365

IN REPLY REFER TO:
KO-300
2.2.1.06(ENV-7.00)

NOV 2 0 2018

Mr. Jim Simondet
National Marine Fisheries Service
1655 Herndon Road
Arcata, CA 95521

Subject: Request for Concurrence Regarding Species and Critical Habitat Located Within the Action Area of the Informal Consultation on the Operations of the Klamath Project

Dear Mr. Simondet:

The Bureau of Reclamation is currently in the process of preparing a Biological Assessment (BA) to evaluate the potential effects of and determine if Klamath Project (Project) operations may affect Endangered Species Act (ESA) listed species and/or their designated or proposed critical habitat. Specifically, Reclamation proposes to divert, store, and convey Project water to meet authorized Project purposes and contractual obligations in compliance with applicable law.

Current analysis indicates the action area associated with Reclamation's proposed action includes the area within the boundaries of the Project located in southern Oregon and northern California, and the Klamath River from Upper Klamath Lake to the mouth of the river at Klamath, California.

To appropriately evaluate and determine if the proposed action has the potential to affect threatened and/or endangered species, Reclamation is requesting your review and concurrence of the following ESA listed species and their respective critical habitats (50 CFR 402.12(c)) to be included in the biological assessment for the proposed action. Our data indicates that these species are under the jurisdiction of the National Marine Fisheries Service and are documented present or potentially present within the action area.

Species	Scientific Name	Status	Critical Habitat
Southern Oregon/Northern California Coasts coho Salmon	*Oncorhynchus kisutch*	Threatened	Designated
Southern Resident DPS Killer Whale	*Orcinus orca*	Endangered	Designated
Southern DPS North American green sturgeon	*Acipenser medirostris*	Threatened	Designated
Southern DPS Pacific eulachon	*Thaleichthys Pacificus*	Threatened	Designated

Please respond at your earliest convenience, with your concurrence or an updated species and critical habitat list.

If you have any questions, please contact Kristen Hiatt at 541-880-2577, or via electronic mail at khiatt@usbr.gov.

Sincerely,

Acting For

Jeffrey Nettleton
Area Manager

cc: Daniel Blake
Evan Childress

Appendix 4: Proposed Action

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Figure B3. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1983.

Figure B4. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1984.

Figure B5. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1985.

Figure B6. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1986.

Figure B7. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1987.

Figure B8. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1988.

Figure B9. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1989.

Figure B10. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1990.

Figure B11. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1991.

Figure B12. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1992.

Figure B13. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1993.

Figure B14. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1994.

Figure B15. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1995.

Figure B16. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1996.

Figure B17. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1997.

Figure B18. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1998.

Figure B19. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1999.

Figure B20. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2000.

Figure B21. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2001.

Figure B22. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2002.

Figure B23. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2003.

Figure B24. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2004.

Figure B25. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2005.

Figure B26. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2006.

Figure B27. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2007.

Figure B28. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2008.

Figure B29. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2009.

Figure B30. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2010.
Figure B31. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2011.
Figure B32. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2012.
Figure B33. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2013.
Figure B34. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2014.
Figure B35. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2015.
Figure B36. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2016.
Figure B37. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2017.
Figure B38. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2018.
Figure B39. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2019.

Section C - LKNWR Historical Deliveries

Table C1. Historical Deliveries to Lower Klamath National Wildlife Refuge (LKNWR).
Figure C1. Historical deliveries to LKNWR by water year for the 39-year period of record (WY 1981-2019) considered in the Proposed Action. Deliveries are graphed as those delivered through Ady Canal (i.e. direct diversion from the Klamath River), D Plant pumping (i.e. deliveries made from Tule Lake Sumps), and total delivery through both delivery arcs.

Section D - Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D1. Clear Lake Reservoir Operational Forecast Model
Table D2. Gerber Reservoir Operational Forecast Model

Section E - Re-scaling NRCS forecasts of net inflow into Upper Klamath Lake

A.4.1. Model Overview

The Klamath Basin Planning Model (KBPM) was used to simulate the operation of the Klamath River system over a range of hydrologic conditions. The model is a generalized reservoir-river basin simulation model that allows for specification and achievement of user-defined goals. Figure A.4.1.1 shows the overall Klamath River watershed and the Klamath and Lost rivers. The KBPM extent covers from Upper Klamath Lake (UKL) to Iron Gate Dam (IGD), just upstream of the Shasta River confluence.

Figure A.4.1.1 Location of Upper Klamath Basin, Oregon and California, and locations of major rivers.

Inputs to the KBPM were developed at a daily timestep and include water diversion requirements (demands), system gains and losses (accretions), UKL net inflows, inflow from the Lost River through the Lost River Diversion Channel (LRDC) and return flows. The Klamath Basin daily

inflow data set was developed by a working team of hydrologists and modelers from various organizations using historical data from a variety of sources for the 39-year period of record (POR) including water years 1981 through 2019. The resulting hydrology represents the water supply available from the Klamath River system, including UKL, to the service area at the current level of development. This data development is discussed further in Section A.4.3.

The KBPM produces daily outputs for river flows, Klamath Project (Project) diversions (including deliveries to the Lower Klamath National Wildlife Refuge [LKNWR]) and reservoir storage. The model output also serves as input data for other analysis tools.

It's important to note that the KBPM is a planning tool that assisted in the development of the Proposed Action and, though modelers have strived to make modeled actions implementable in actual operations, some of the processes built into the model cannot be implemented. For example, perfect foresight of Project diversion of return flows was used to ensure that all water available to the Project in a given year was utilized. While the assumption that the Project will utilize all water made available for irrigation under this management regime is sound, there is no assurance that all available return flows will be captured and reused for irrigation purposes in real-time operations. Real-time implementation of the Proposed Action may not result in fully efficient use of these flows. The actual availability and efficiency of use of Project return flows is heavily dependent upon current hydrologic and meteorological conditions and will vary from year to year. This is just one example of how some of the processes built into a planning model may not be implemented during actual operations. Therefore, although much effort has been made to make the KBPM as operationally realistic as possible, its output cannot be viewed as the certain outcomes that will be realized when implementing the Proposed Action.

A.4.2 WRIMS and WRESL Code

The KBPM is built on the Water Resources Integrated Modeling System (WRIMS) platform. WRIMS uses a mixed integer linear programming solver to route water through a user-defined network of flow arcs and nodes representing locations in the river system. Policies and priorities for water routing are implemented through user-defined weights applied to flow arcs and storage nodes in the network. System variables and the constraints on them are specified with a scripting language called the "water resources engineering simulation language" (WRESL). WRESL code is developed in simple ascii text files. Time series input data and model results are stored in HEC-DSS files. Relational data (lookup tables) are stored in ASCII text files.

A.4.3 Model Representation

A.4.3.1 Modeled Rivers, Lakes, Conveyance Facilities, and Model Schematic

The KBPM simulates water-supply related operations of the Project within the Klamath River system. Because this model operates on a mass-balance basis, Project operations which do not affect water supply such as pesticide use or intermittent maintenance operations were not modeled. Within this system, the components that are specifically modeled include UKL, Lake Ewauna (i.e., Keno Reservoir), the Klamath River from Keno Dam to IGD, and all associated Reclamation-owned facilities that are expected to be operable over the time period covered by this Biological Assessment. Facilities include the Link River Dam (LRD), A Canal, LRDC, North Canal, Ady Canal, Klamath Straits Drain (KSD), and all associated pumping

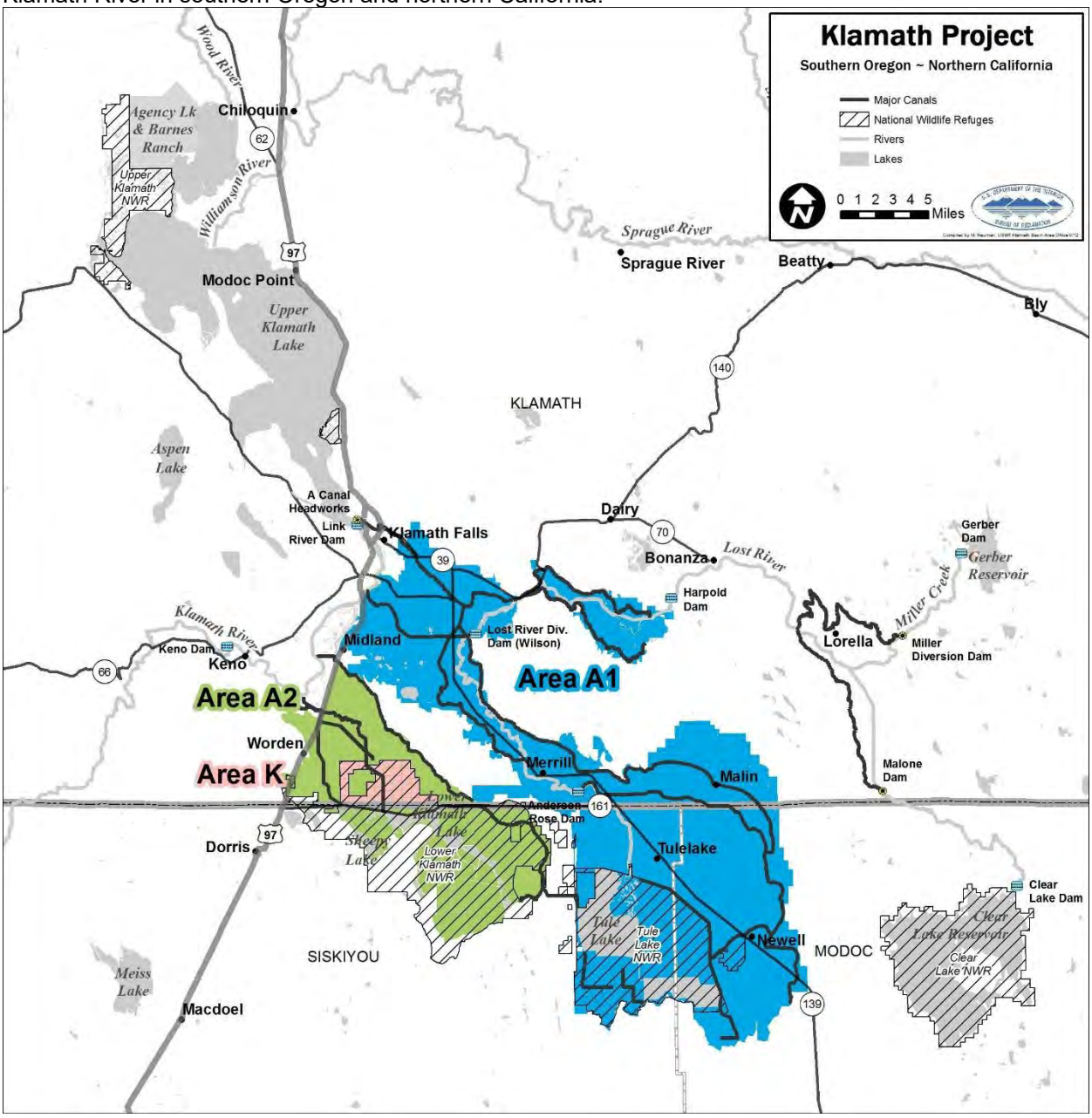
facilities. Note that Reclamation does not own the North Canal headworks, and Reclamation therefore has limited control over deliveries through this canal.

The model does not simulate the Lost River system upstream of Harpold Dam. After runoff from the Lost River catchment has subsided, the area upstream of Harpold Dam is typically operated as a closed system during the irrigation season when the releases from Clear Lake and Gerber reservoirs (and any natural flow) equal the water used prior to flows reaching Harpold Dam. Harpold Dam is a flash board dam where the flash boards are added and removed as needed. The boards are up when releases are being made from Clear Lake and Gerber reservoirs (typically during the spring/summer operational period) and are removed once Clear Lake and Gerber dams stop releases for the fall/winter operational period.

Downstream of Harpold Dam, agricultural water diversions are largely supplied by A Canal diversions from UKL. Flow passing Harpold Dam mixes with return flow, and the combined flow is measured at the headworks of the LRDC at Lost River Diversion Dam, into which the Lost River is diverted. This diversion either flows into Station 48 or Miller Hill pump station (when open) or continues flowing into the Klamath River. The KBPM accounts for flows from the Lost River to the LRDC through a historical daily input time-series (I91). This value is very low when Harpold Dam is operational because it is comprised only of Harpold Dam leakage, runoff and return flows between Harpold and Wilson Dams. When Harpold Dam is not operational, this value can be very high as it includes the entire flow of the Lost River.

Return flows from the Area A2 (which receives water from North and Ady canals) and the LKNWR are also incorporated (Figure A.4.3.1.1) as flows through the Klamath Straits Drain (pumping plants E/EE and F/FF). The direct effect of Project operations ends at the KSD above Keno Dam, Oregon, which is the last feature of Project infrastructure, although the model itself simulates operations down to IGD with the daily accretion between Keno Dam and IGD based on historical data. The model schematic is shown in Figure A.4.3.1.2. For a more detailed description of each link and object referenced in the schematic, please see the definitions in Table A.4.3.4.1 – Key Model Variables.

Figure A.4.3.1.1 Upper Klamath Lake and the portion of the Klamath Project served by UKL and the Klamath River in southern Oregon and northern California.



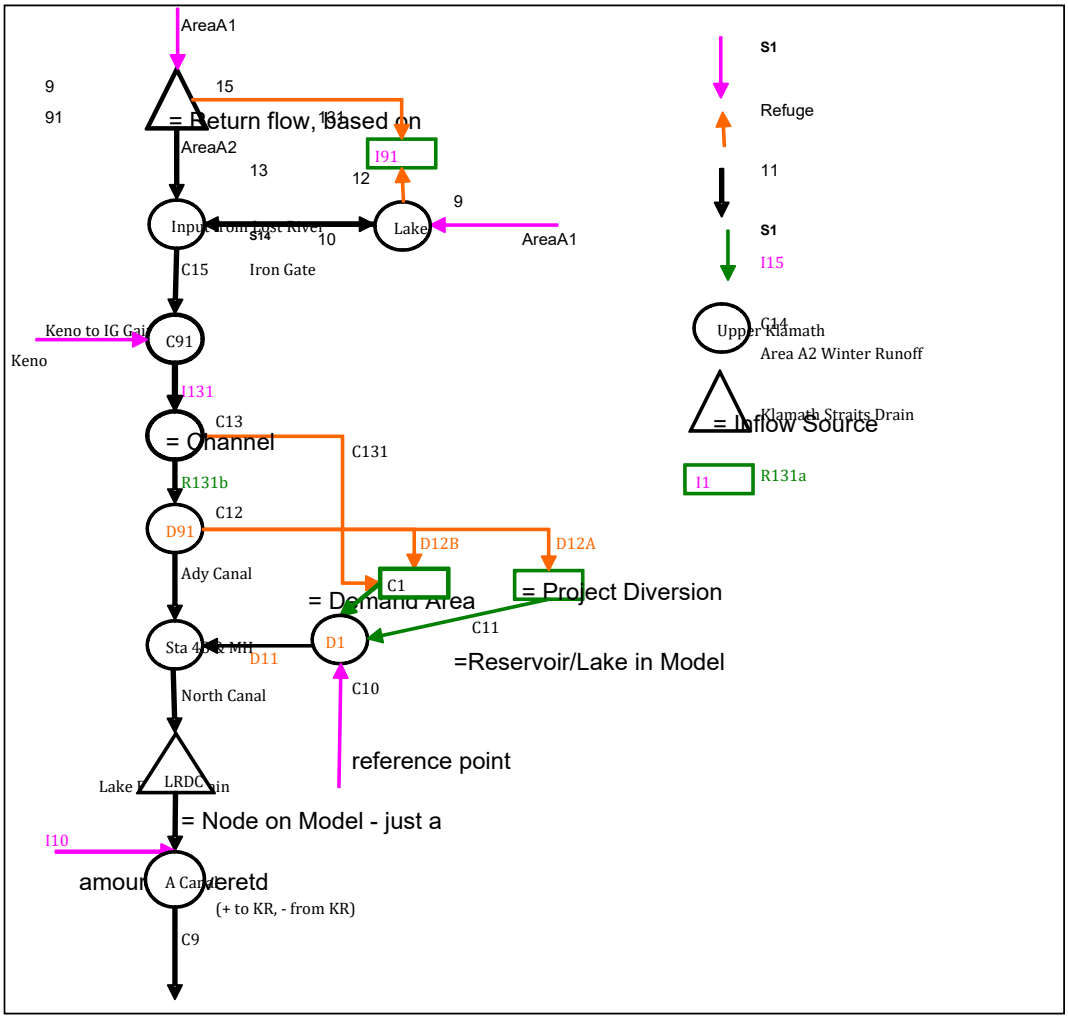


Figure A.4.3.1.2 Model schematic

A.4.3.2 Period of Record

The current KBPM uses a daily timestep, starting October 1, 1980 and running through November 30, 2019. Three full years were added to the POR simulated in support of the 2018 BA, which extended through November 30, 2016. The period between water years 1981 through 2019 includes a reasonable distribution of wet, average and dry years. With this range of data, the model can evaluate a particular operations strategy across a wide range of inflows.

A.4.3.3 Hydrology Inputs

A.4.3.3.1 Definitions

Area 1 is the portion of the Project that includes lands served by A Canal and the LRDC including Klamath Irrigation District (KID), Tulelake Irrigation District, and Warren Act contractors and Districts served by KID.

Area 2 is the portion of the Project that includes Klamath Drainage District and LKNWR served by the Ady and North canals.

Quality Assurance is process oriented to ensure the correct steps are completed in the correct manner. Additionally, planned and systematic activities are implemented in a quality system so that quality requirements for a product or service will be fulfilled. In the context of data sets for the WRIMS model, quality assurance will relate to the configuration of the physical infrastructure of water diversions structures, gauging systems, and how data are collected.

Quality Control (QC) is product oriented to ensure the results meet the expectations of the project. It includes the techniques and activities used to fulfill requirements for quality. QC emphasizes testing of products to uncover defects. In the context of data sets for the WRIMS model, quality control will relate to proofing of the data and correcting/adjusting data so that a final reliable dataset is created.

A.4.3.3.2 Data Sets

1. Project Daily Data and Project Historical Use Data
2. UKL net inflow
3. Lake Ewauna (Keno Reservoir) accretions
4. Keno Dam to IGD accretions
5. LRDC inflow from the Lost River
6. Area 2 winter runoff
7. NRCS forecasts

A.4.3.3.3 Project Daily Data and Project Historical Use Data

All data sets utilized in the 2012 Biological Assessment were updated to include the additional years (2012-2019) in the POR, and all data were subjected to extensive QC. As a term and condition of the 2013 Biological Opinion, gages at A Canal, LRDC, Ady Canal at Highway 97 (Klamath Drainage District delivery), Ady Canal above LKNWR (Refuge delivery), North Canal, and KSD are regularly maintained and recalibrated. Using these more accurate gage data, all relevant data from the 2012 BA was QC'ed via comparison with the new data sets. Comprehensive detail on all data analysis and correction to Project diversion data can be found in Dunsmoor (2017a). Quality control was conducted and finalized on daily data for A Canal, LRDC total flow, Station 48, Miller Hill Pump, Miller Hill Spill, North Canal, Ady Canal, Ady Canal to LKNWR, and F/FF pumps via KSD.

The QC'ed daily dataset was finalized for October 1, 1974 through November 30, 2016 for Area 1, and January 1, 1980 through November 30, 2019 for Area 2. Where possible, approved daily

data from U.S. Geological Survey (USGS) gages have been used, replacing older data. Where these records do not exist, other approaches were taken. For the most recent time periods, provisional USGS data were used. For older time periods that predate USGS monitoring, appropriate corrections have been applied to existing data sets to bring them in line with USGS measurements and/or other best available measurement standards. All gaps in the record have been examined and appropriately filled. For more detail see Dunsmoor (2017a).

Project daily data are contained in the spreadsheet:
Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017_UPDATE.xlsx.

A.4.3.3.4 Upper Klamath Lake Net Inflow and Maximum Release

The UKL daily net inflow dataset is calculated from QC'ed data (Dunsmoor 2017b) for (1) A Canal diversions (Reclamation), (2) average daily flows for the Link River at LRD (USGS), (3) Westside Power Canal (often referred to as the Keno Canal) flows (PacifiCorp), (4) Agency Lake Ranch operations (Reclamation), and (5) active storage data for UKL (Reclamation). No additional revisions to this data set beyond those included in the 2018 BA were made.

The KBPM uses both raw daily data and a single exponential smooth of daily data for UKL inflow . The raw daily data input variable is I1_raw, and it is used to calculate the 60-day trailing average inflow into UKL, an important component of the UKL control logic (*see* section A.4.4.1.1). The variable I1 is the main expression of UKL net inflow in the KBPM, and results from applying a single exponential smoother to I1_raw. This smoothed I1 is used throughout the KBPM as the expression of daily UKL net inflow .

The raw UKL daily net inflow is calculated using the following equation:

Raw Net Inflow (I1_raw) = {(UKL storage volume today – UKL storage volume yesterday) + (Link River + Westside Canal) + A Canal +/- (Volume pumped to/from Agency Lake Ranch) – (Volume from Caledonia Marsh)}.

The smoothed daily UKL net inflow is calculated using the following simple exponential smoothing equation:

Smoothed Net Inflow (I1) = I1(-1) + (α * (I1_raw(-1) – I1(-1))

where: (-1) indicates yesterday's value, α = 0.22.

Upper Klamath Lake net inflow data and data for the UKL elevation-capacity curve are contained in the spreadsheet: **Daily_UKL_net_inflow_Apr2017_FINAL_UPDATE.xlsx**. In the KBPM, the time series I1_raw and I1, for UKL daily net inflow and single exponential smooth data are contained in the file named **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss,** and the elevation-capacity data are contained in the files named **res_info.table** and **res_info2.table**.

In addition to changes to UKL net inflow datasets, the 2018 BA developed (and this 2020 BA continues to use) a new relationship describing the maximum possible release from LRD relative

to the range in possible lake elevations and the associated head behind the dam. The basis for these data are contained in the Upper Klamath Lake Flood Operations Review and Risk Assessment, table 3.2-2 (PacifiCorp 1996). This document provided maximum UKL discharge at 1 ft. intervals; releases were then linearly interpolated to 0.01 ft. intervals for use in the KBPM. The UKL elevation/maximum discharge relationship can be found in the file: **20170502_UKLElev_LinkQ_Relation.xlsx**. In KBPM, these data are in the file: **Link_max.table**.

A.4.3.3.5 Lake Ewauna (Keno Reservoir) Accretions

The Lake Ewauna daily accretion dataset is calculated from QC'ed data for (1) LRDC spill to the Klamath River, (2) LRDC delivery to Area 1 from the Klamath River, (3) pumps F/FF, (4) North Canal, (5) Ady Canal, (6) ungauged Area 2 diversions, (7) PacifiCorp data for the Westside Power Canal, and (8) USGS average daily flow data for Link River at LRD and Klamath River at Keno Dam.

The Lake Ewauna accretions are calculated using the following equations:

Accretions = (Measured Keno Flow) – (Computed Keno Flow), and
Computed Keno Flow = [(Link River + Westside Canal) + (LRDC spill to the Klamath River) + (Pumps F/FF) – (LRDC delivery to Area 1 from the Klamath River) – (North Canal) – (Ady Canal) – (Ungauged Area 2 diversions)]

The WRIMS model uses a 3-day moving average of the daily Lake Ewauna accretion data. The input variable is I10.

Lake Ewauna accretions data are contained in the spreadsheet: **Keno Reservoir accretions UPDATE.xlsx**. In KBPM, Lake Ewauna accretion data are contained in the file: **PA_4Jan2017_newBathy_I1ExpSm1x_SV.dss**.

A.4.3.3.6 Keno Dam to Iron Gate Dam Accretions

In the version of the KBPM used to develop the Proposed Action analyzed in the 2013 Biological Opinion, accretions to the reach of the Klamath River between Keno Dam and IGD (the KIG reach) were treated as known inputs. That is, a time series of daily estimates of the KIG accretions was developed and assigned to the KBPM variable named I15. When calculating such things as the release from LRD necessary to provide the targeted flow at IGD, the KBPM used the value of this variable from the previous day.

Several shortcomings have become apparent in the prior treatment of KIG accretions. First, the I15 variable was developed in a manner that did not account for the change in storage of the three hydroelectric reservoirs (JC Boyle, Copco, and Iron Gate reservoirs) in the KIG reach. Second, prior estimates of I15 did not account for travel time through the KIG reach. Finally, use of I15 was confined to its value on the prior day. Now that surface flushing flow events (flows of 6,030 cfs or greater for at least 72 hours measured at the IGD gauge) are management targets, it is important to use forecasted KIG accretions as part of the calculation of LRD releases needed to achieve a targeted flow at the IGD gauge. Use of forecasts will allow managers to use water stored in UKL more efficiently by triggering surface flushing flows when KIG accretions

are forecasted to be relatively high, thereby requiring less UKL water to achieve the IGD flow target.

In this section, the time series of historical KIG accretions is recomputed, taking account of travel time and daily change in reservoir storage, and development of sub-models used to forecast KIG accretions is described. Incorporation of KIG accretion forecasts into the KBPM is addressed in subsequent sections. Before the KIG accretion forecast model could be developed, a model estimating the combined daily storage of the hydroelectric reservoirs had to be developed to fill gaps in the storage record, a necessary precursor to computing a daily time series of accretions to the KIG reach.

A.4.3.3.6.1. Temperature and Precipitation Variables

Temperature and precipitation variables were developed from data obtained from the PRISM Climate Group. Parameter-elevation Relationships on Independent Slopes Model (PRISM) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al. 2008). Because the PRISM web page (http://prism.oregonstate.edu/explorer/) providing access to daily time series uses a map overlaid by the 4km PRISM grids, a map from this web page was used to delineate the approximate boundaries of sub-basin 18010206 along the edges of the PRISM grids (Figures A.4.3.3.6.1.1 and A.4.3.3.6.1.2). The closed basin of Butte Valley was excluded, as were the areas draining to the Klamath River downstream of the IGD gauge or upstream of the Keno gauge, thus crudely delineating the catchment within the KIG reach. This area was stratified by the PRISM grid elevations as being either lower or higher than 4,500 ft. Four PRISM grids were then randomly selected from each elevation stratum, conditioned on selected grids being separated by at least 3 grids (Figure A.4.3.3.6.1.1). Daily time series of average temperature (°F) and precipitation (inches) were downloaded for these 8 grids for the period from 1/1/1981-11/30/2016.

Monthly PRISM data for total monthly precipitation and average temperature at the same locations were downloaded for the period from 10/1/1980-12/31/1980. These monthly data were disaggregated to daily data, as follows. Daily data for precipitation and maximum temperature for the period from 10/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.3.3.6.1.1): Howard Prairie Dam, OR (Station USC00354060), Copco #1 Dam, CA (Station USC00041316), and Keno, OR (precipitation only; Station USC00354403). Across these stations within each month, the daily average of maximum temperature or precipitation was divided by the monthly average maximum temperature or monthly total precipitation, as appropriate. Monthly PRISM variables were disaggregated to daily values by multiplying them by this daily proportion. Use of the maximum daily temperature to disaggregate the average daily temperature variable was unintentional; clearly, average daily temperature should have been used instead. This mistake was not discovered until after the entire analysis was complete but has been retained in the analysis because it affects only the first 3 months of the POR, and average daily and maximum daily temperatures display very similar patterns.

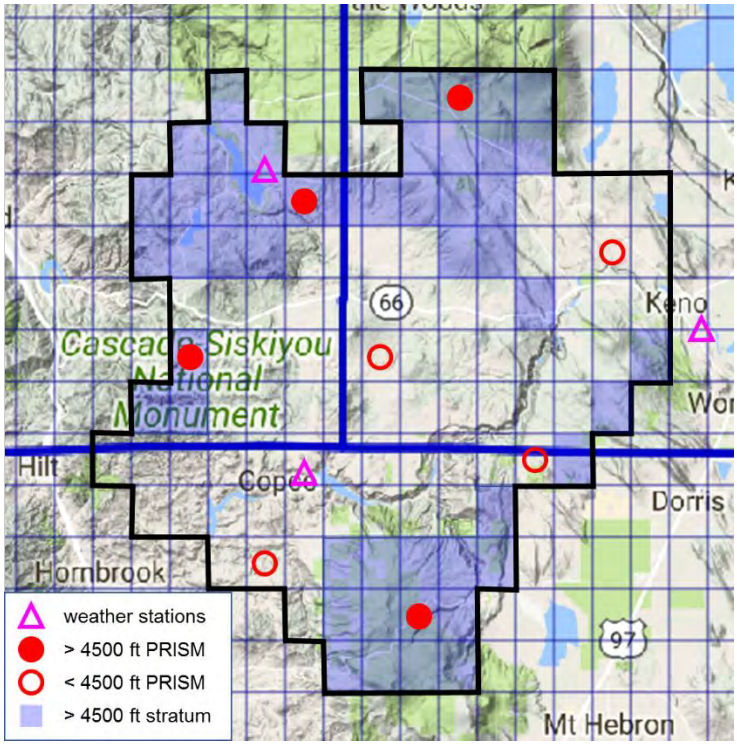
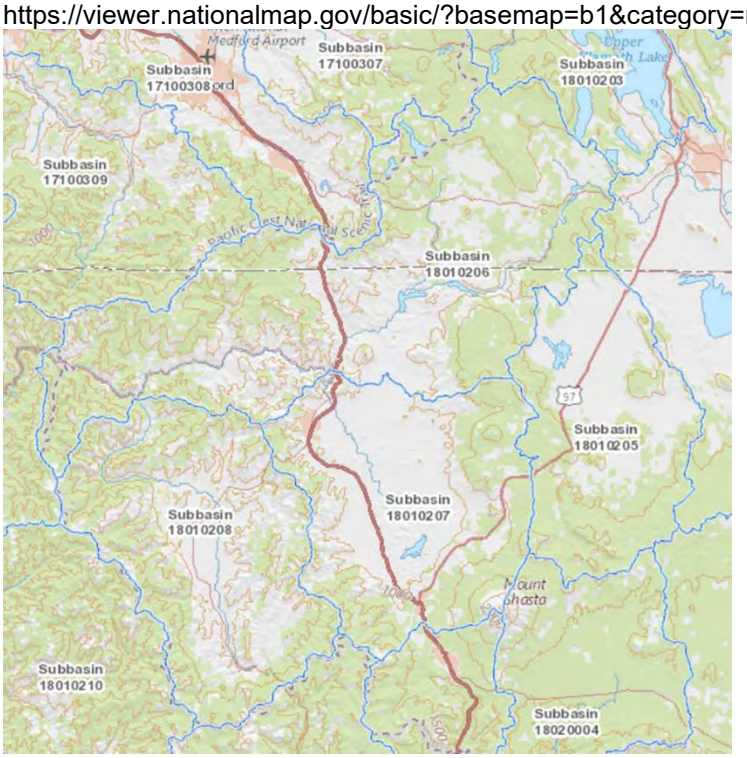


Figure A.4.3.3.6.1.1. PRISM grids and sampled grids, weather stations, and elevation strata in the KIG catchment.

Figure A.4.3.3.6.1.2. Sub-basins encompassing the KIG and mid-Klamath (MK) reaches of the Klamath River. From the USGS National Map: https://viewer.nationalmap.gov/basic/?basemap=b1&category=nhd&title=NHD%20View



Treatment of temperature and precipitation for the mid-Klamath (MK) reach was nearly identical to that of the KIG reach, except that different PRISM grids and weather stations were used, and sampled grids were separated by at least 5 grids (Figure A.4.3.3.6.1.3a). That portion of sub-basin 18010206 contributing runoff to the Klamath River downstream of the IGD gauge, and all of sub-basins 18010208 (Scott River) and 1801207 (Shasta River) were included in the catchment for the MK reach (Figures A.4.3.3.6.1.2 and A.4.3.3.6.1.3a), hereafter called the MK catchment. Weather stations used to disaggregate monthly data to daily time steps for the MK catchment included: Callahan, CA (USC00041316); Yreka, CA (USC00049866); and Big Red Mountain, OR (USS0022G21S). Removing the Scott and Shasta river catchment area from the MK catchment leaves the ungauged MK catchment (Figure A.4.3.3.6.1.3b), for which accretions are also estimated.

After assembling the daily time series of precipitation and average temperature for each sampled PRISM grid, variables were computed that summarized these climate data in various ways. Daily (i = day) averages were computed for two of the catchments: $kippt_i$ and $kitavg_i$ for the KIG catchment; and $mkppt_i$ and $mktavg_i$ for the MK catchment. Daily averages weighted by the proportion of the total number of PRISM grids in a catchment below or above 4,500 ft were computed for each catchment: $kipptwa_i$ and $kitavgwa_i$ for the KIG catchment; and $mkpptwa_i$ and $mktavgwa_i$ for the MK catchment. Daily averages of the PRISM grids within each elevation stratum in each catchment were computed: $lekippt_i$, $hekippt_i$, $lekitavg_i$, and $hekitavg_i$ for the KIG catchment; and $lemkppt_i$, $hemkppt_i$, $lemktavg_i$, and $hemktavg_i$ for the MK catchment.

Temperature and precipitation variables were transformed, rescaled, and stationarized (van den Berg et al. 2006; Montgomery et al. 2015) by first applying a $\ln(x_i + c)$ transformation (note that the *tavg* variables were not ln transformed), where x_i is the daily variable and c is a constant added to increase the minimum x_i above 1. Then, the ln transformed variables were seasonally adjusted (rescaled), and then the first difference was taken. Seasonal adjustment consisted of centering each $\ln(x_i + c)$ by subtracting from it the mean for the corresponding day of the water year across the POR. The centered variable was then divided by the standard deviation of the transformed variable for the corresponding day of the water year across the POR. The first difference was then taken as the seasonally adjusted x_i minus the seasonally adjusted x_{i-1}. The prefix *dsaln_* (*d* is for difference, *sa* is for seasonally adjusted, *ln* is for ln transformed, and _ is the *c* added prior to ln transformation) was appended to each variable name to reflect these manipulations.

Perhaps the greatest utility of the KIG accretion model to water management decision-making is during the late winter and spring seasons, when accretions tend to be largest and most variable, and when use of the accretion forecasts would be involved in decisions whether to trigger releases from UKL for flushing flows. Reasoning that the runoff response to precipitation events would likely be different when the ground is frozen (faster, more variable), a variable was constructed that tracked whether the ground was likely to be frozen or not. Air and soil temperature (2 inches depth) were downloaded for the Beatty, Oregon AgriMet weather station (https://www.usbr.gov/pn/agrimet/webarcread.html) for the period from 10/20/2004 – 12/31/2016). A threshold regression relating the 10-day trailing average of the mean daily air temperature (°F) to the daily soil temperature (°F) at a depth of 2 inches was used to identify the threshold at which this relationship changes (i.e. ground freezing threshold). The results (not shown) indicate that the freezing transition occurred when the 10-day trailing average of the mean daily air temperature was 35.2 (°F). Accordingly, the variables $lekitavg10d_i$ and $hekitavg10d_i$ were computed as the 10-day trailing average of the mean daily air temperature (°F) within the two elevation strata.

Further, because the objective was to develop models forecasting accretions based on recent conditions, precipitation was viewed from the perspective of its availability for immediate (i.e. within days) runoff. Three temperature classes were established to roughly classify this availability for runoff based on some expression of average temperature: ≤28°F was thought to be low availability because it likely fell as snow that did not rapidly melt; >28°F - ≤60°F was thought to be moderate to high availability because it likely fell as rain (or as snow that rapidly melted) and evapotranspiration was low to moderate; >60°F was thought to be low availability because evapotranspiration was moderate to high.

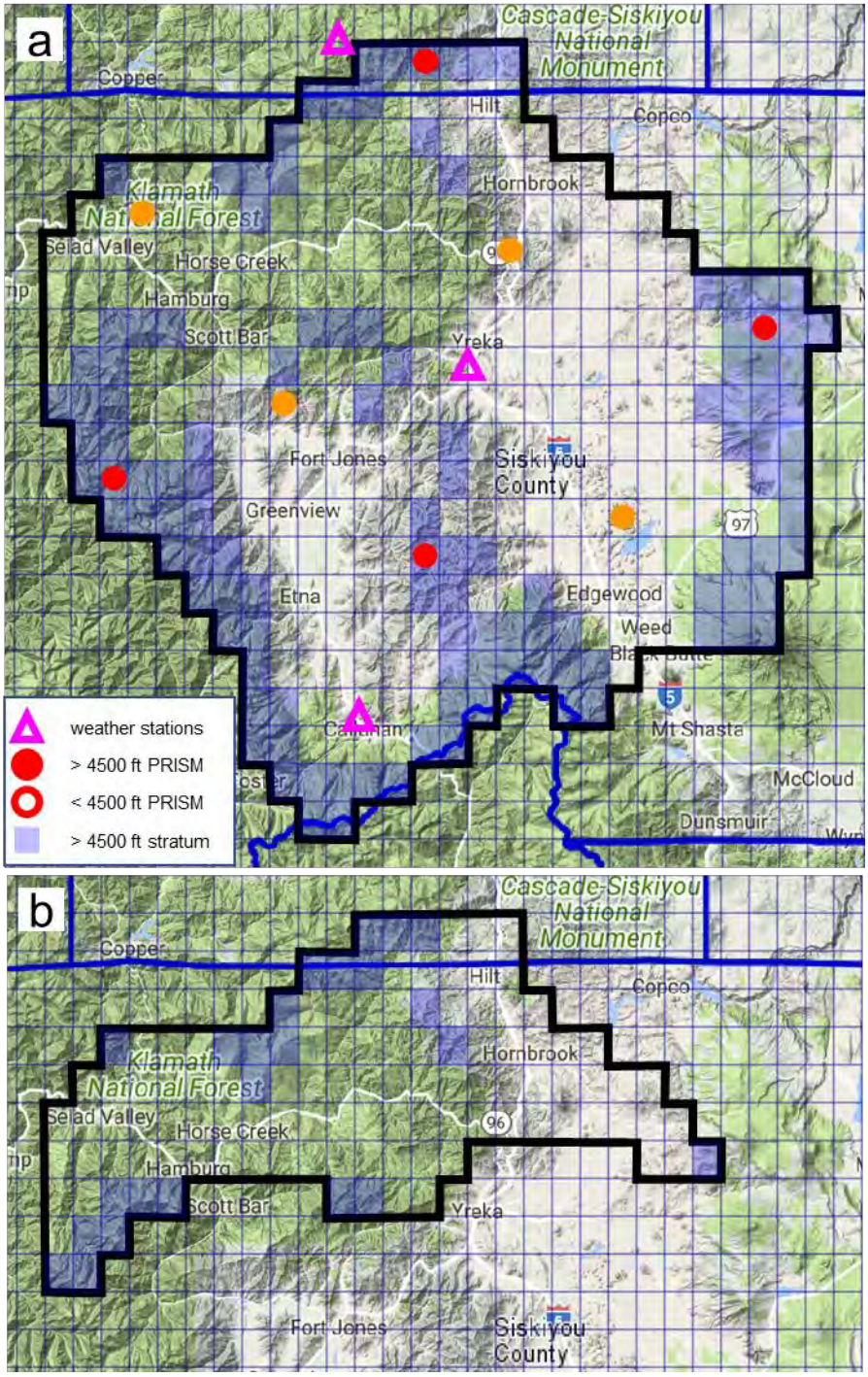


Figure A.4.3.3.6.1.3. PRISM grids and sampled grids, weather stations, and elevation strata in the MK reach used to construct climate variables appropriate to the MK catchment (a). The ungauged MK catchment (b) is the remaining area within the MK catchment after removing the Scott and Shasta river catchments.

To capture potential dynamics associated with interactions among elevation, temperature, precipitation, ground status (frozen/unfrozen), and subsequent runoff, the following series of variables were developed:

$$coldkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i \leq 28°\text{F} \\ 0 & if\ kitavgwa_i > 28°\text{F} \end{cases}$$

$$coolkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ kitavgwa_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmkippt_i = \begin{cases} dsaln1kipptwa_i & if\ kitavgwa_i > 60°\text{F} \\ 0 & if\ kitavgwa_i \leq 60°\text{F} \end{cases}$$

$$coldhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i \leq 28°\text{F} \\ 0 & if\ hekitavg_i > 28°\text{F} \end{cases}$$

$$coolhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ hekitavg_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmhekippt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg_i > 60°\text{F} \\ 0 & if\ hekitavg_i \leq 60°\text{F} \end{cases}$$

$$coldlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i \leq 28°\text{F} \\ 0 & if\ lekitavg_i > 28°\text{F} \end{cases}$$

$$coollekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 28°\text{F}\ and\ \leq 60°\text{F} \\ 0 & if\ lekitavg_i \leq 28°\text{F}\ \ or\ \ > 60°\text{F} \end{cases}$$

$$warmlekippt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg_i > 60°\text{F} \\ 0 & if\ lekitavg_i \leq 60°\text{F} \end{cases}$$

$$coollekiint_i = coollekippt_i \times dsalekitavg_i$$

$$coolkiint_i = coolkippt_i \times dsalekitavg_i$$

$$kippttavgint_i = dsaln1kipptwa_i \times dsakitavgwa_i$$

$$soilfrzheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i \leq 35.2\ °\text{F} \\ 0 & if\ hekitavg10d_i > 35.2\ °\text{F} \end{cases}$$

$$soilfrzleppt_i = \begin{cases} dsaln1lekippt_i & if\ lekitavg10d_i \leq 35.2\ °\text{F} \\ 0 & if\ lekitavg10d_i > 35.2\ °\text{F} \end{cases}$$

$$soilthwheppt_i = \begin{cases} dsaln1hekippt_i & if\ hekitavg10d_i > 35.2\ °\text{F} \\ 0 & if\ hekitavg10d_i \leq 35.2\ °\text{F} \end{cases}$$

$$soilthwleppt_i = \{dsaln1lekippt_i \quad if\ lekitavg10d_i > 35.2\ °F\ 0 \quad if\ lekitavg10d_i \leq 35.2\ °F$$

$$thwleint_i = soilthwleppt_i \times dsalekitavg_i$$

In addition to variables summarizing precipitation and temperature in various ways, an attempt was made to use data tracking snowpack dynamics. However, no NRCS SNOTEL sites with an adequate POR were located within the KIG catchment. The nearest SNOTEL site was at Fish Lake (SNOTEL 479; data download: https://wcc.sc.egov.usda.gov/reportGenerator/view_csv/customGroupByMonthReport/daily/479:OR:SNTL%7Cid=%22%22%7Cname/POR_BEGIN,POR_END/WTEQ::value), for which daily snow water equivalent data was acquired. These data were seasonally adjusted and differenced, but no ln transformation was applied; the variable was named $dsadfishswe_i$.

A.4.3.3.6.2. Flow Volume and Accretion Variables

Accretions to the KIG reach were quantified using daily inflow volume (TAF; measured at USGS gauge 11509500 below Keno Dam; variable $kenotaf_i$), outflow volume (TAF; measured at USGS gauge 11516530 below IGD [often referred to as the IGD gauge]; variable $igtaf_i$), change in combined reservoir storage volume ($kigstoretaf_i$), and travel time.

Computing accretions to the MK reach required daily flow volumes (TAF) entering the reach at the IGD gauge ($igtaf_i$) and leaving the reach at the Seiad Valley gauge (USGS 11520500; variable $seiadtaf_i$), and travel time. Isolating the portion of MK accretions from ungauged sources required daily flow volumes (TAF) measured at the Shasta River gauge (USGS 11517500; variable $shastataf_i$) and the Scott River gauge (USGS 11519500; variable $scotttaf_i$).

Travel time of water between gauges was accounted for in the estimates of daily accretions. Hourly flows at the IGD and Seiad Valley gauges were compared, and when the flow pattern at IGD was clearly discernable at Seiad Valley, the corresponding flows were used to compute the travel time in hours (Figure A.4.3.3.6.2.1a). Repeated many times, this process produced 104 measurements of travel time, which were used to develop regression equations predicting travel time based on flows measured at IGD (Figure A.4.3.3.6.2.1b) and at Seiad Valley (Figure A.4.3.3.6.2.1c) gauges. Travel time varied with flow, from about 9 hours at high flows (about 10,000 cfs at IGD; 16,000 cfs at Seiad Valley) to about 16 hours at low flows (about 900 cfs at IGD; about 1,070 cfs at Seiad Valley).

The equation estimating travel time between the IGD and Seiad Valley gauges on day *i* based on daily average flow at the IGD gauge ($igtaf_i$) is:

$$tt_igsd_ig_i = e^{-0.24311lnln\,(igtaf_i) + 2.91288},$$

where *e* is the base of the natural logarithm (2.71828).

The equation estimating travel time over the same distance, but based on the daily average flow at the Seiad Valley gauge ($seiadtaf_i$) is:

$$tt_igsd_sd_i = e^{-0.22153 lnln\,(seiadtaf_i) + 2.98041}.$$

The average of these two estimates is taken to calculate mean travel time between the two gauges:

$$tt_igsd_i = \frac{tt_igsd_ig_i + tt_igsd_sd_i}{2}$$

A similar process was used to estimate travel time between the Scott River gauge and the Seiad Valley gauge (Figure A.4.3.3.6.2.2):

$$tt_scsd_i = e^{-0.66034 lnln\,(seiadtaf_i) + 3.09763}.$$

Travel time between the Shasta River gauge and the Seiad Valley gauge was estimated in a different way. Because the Shasta River gauge is located 0.64 miles upstream of the confluence with the Klamath River, travel time was estimated as tt_igsd_i times the proportion of the distances between gauges:

$$tt_shsd_i = \frac{49.64}{61.90} tt_igsd_i$$

where 49.64 miles is the distance between the Shasta River and Seiad Valley gauges, and 61.90 miles is the distance between the IGD and Seiad Valley gauges. Distances were measured using Google Earth Pro.

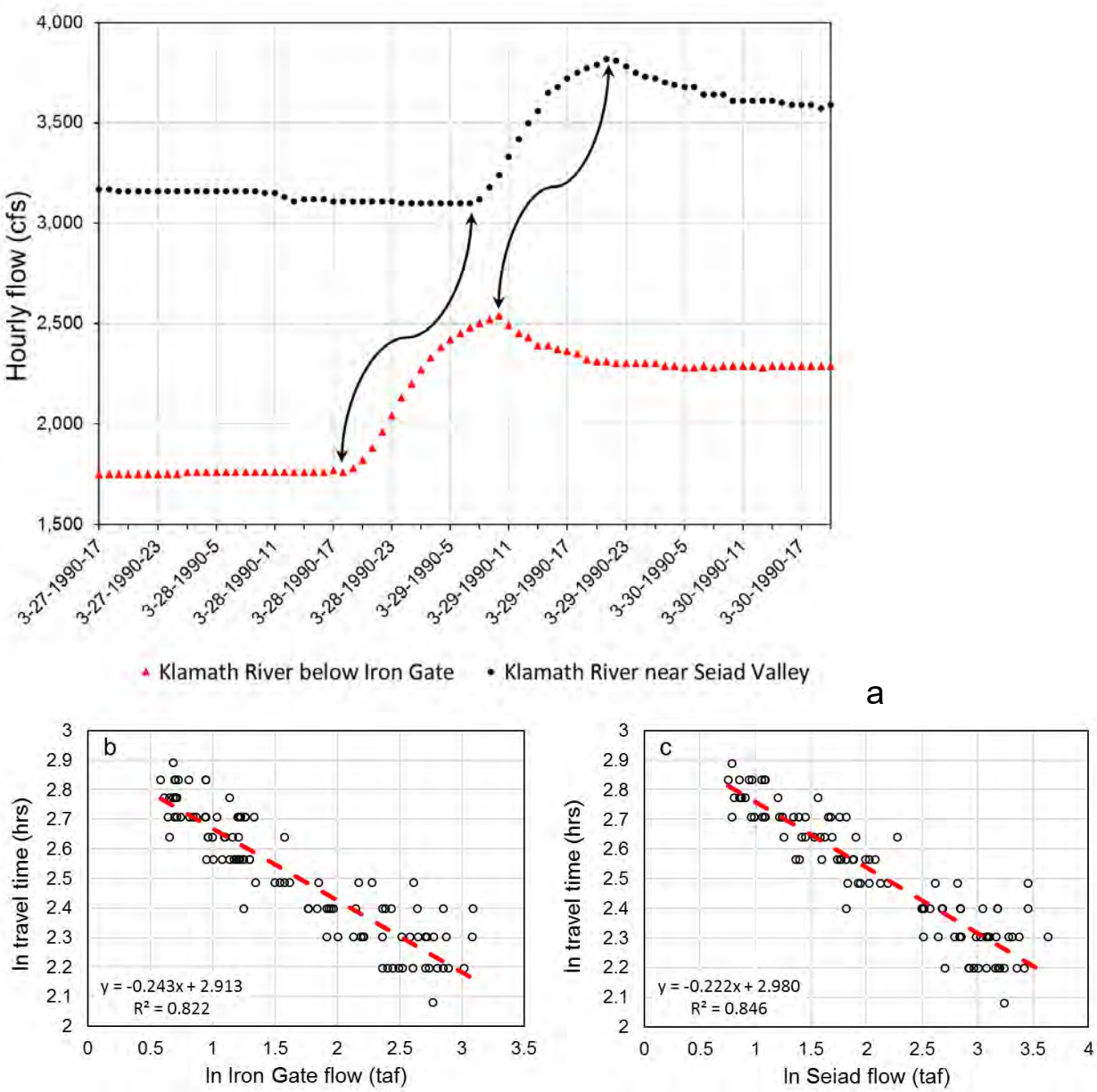


Figure A.4.3.3.6.2.1. Example of estimating travel time between the flow gauges below Iron Gate Dam and near Seiad Valley. In a, each point on a flow time series is an hourly flow measurement at one of the gauges. When the pattern of flow change at Iron Gate was clearly identifiable at Seiad Valley (indicated by the arrows), the travel time in hours was calculated. For reference, ln(9 hrs) = 2.197, and ln(18 hrs) = 2.890. Repeating this process many times (n=104) yields the measured travel times relative to flow at Iron Gate (b) and Seiad Valley (c); all values in b and c are ln transformed. Regressions (equations and dashed lines) provide the means to compute travel time as a function of flow measured at either flow gauge.

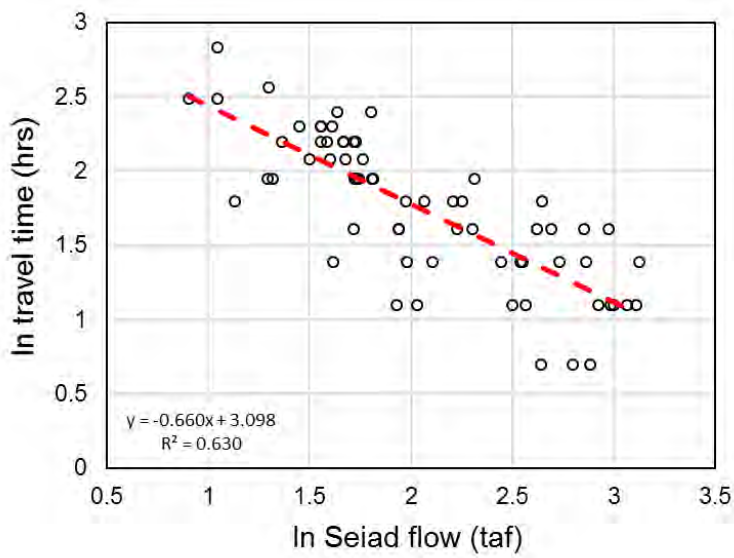


Figure A.4.3.3.6.2.2. Estimating travel time (hours) from the Scott River gauge to the Seiad Valley gauge from n=65 measurements.

Initially the same process used to estimate travel time between the IGD and Seiad Valley gauges was applied to estimate travel time through the KIG reach (between the Keno and IGD gauges). However, this approach did not work, because operations of the hydroelectric project reservoirs obscured or altered the hourly patterns of flow at IGD. Therefore, the travel time estimated between the IGD and Seiad Valley gauges was divided by the distance between them (61.90 miles), and then multiplied by the distance between the gauges at Keno and IGD (42.30 miles) to estimate travel time through the KIG reach:

$$tt_kenoig_i = \frac{tt_igsd_i}{61.90} 42.30$$

This approach assumed equivalent rates of travel through the KIG and MK reaches.

Accretions to the MK reach were computed in two ways, one that applies to the entire MK catchment, and the other based solely on the ungauged MK catchment. Accretions to the Klamath River to the MK reach based on the entire MK catchment were computed as:

$$mkawa_i = \left(\left(1 - \frac{tt_igsd_i}{24}\right) \times (seiadtaf_i - igtaf_i)\right) + \left(\frac{tt_igsd_i}{24} \times (seiadtaf_i - igtaf_{i-1})\right)$$

Because travel time between the gauges is less than a day (Figure A.4.3.3.6.2.1), accretions were computed as the average flow difference between the Seiad Valley gauge on day *i* and the IGD gauge on days *i* and *i*-1, weighted by travel time (expressed as a fraction of a day).

Accretions from the ungauged MK catchment were computed by subtracting from $mkawa_i$ the accretions from the Shasta and Scott rivers, which were computed as averages weighted by travel time in a manner similar to that for $mkawa_i$:

$$ugmkawa_i = mkawa_i - \left(\left(1 - \frac{tt_shsd_i}{24}\right) shastataf_i + \frac{tt_shsd_i}{24} shastataf_{i-1}\right) - \left(\left(1 - \frac{tt_scsd_i}{24}\right) scotttaf_i + \frac{tt_scsd_i}{24} scotttaf_{i-1}\right)$$

Computation of accretions to the KIG reach ($kigaccwa_i$) involved accounting for the daily change in storage of the combined hydroelectric reservoirs, $kigstoretaf_i$ (after gaps had been filled in that record):

$$kigacc_i = (igtaf_i - kenotaf_i) + (kigstoretaf_i - kigstoretaf_{i-1})$$

$$kigaccwa_i = \left(1 - \frac{tt_kenoig_i}{24}\right) kigacc_i + \frac{tt_kenoig_i}{24} kigacc_{i-1}$$

The time-series for $kigaccwa_i$ is used in the KBPM as the inflow arc I15, the daily accretions to the reach of the Klamath River between Keno Dam and IGD.

One final variable, an expression of KIG accretions that does not account for daily change in storage, was prepared for use as a predictor:

$$kiqdfwa_i = \left(\left(1 - \frac{tt_kenoig_i}{24}\right) \times (igtaf_i - kenotaf_i)\right) + \left(\frac{tt_kenoig_i}{24} \times (igtaf_i - kenotaf_{i-1})\right)$$

As with many of the variables previously described, the flow volume and accretion variables were also transformed with ln($x_i + c$), seasonally adjusted, and differenced, yielding the following variables: $dsalnkenotaf_i$, $dsalnigtaf_i$ (note that c=0 for the flow volume variables), $dsaln3mkawa_i$, $dsaln6ugmkawa_i$, $dsaln1kigaccwa_i$, and $dsaln3kiqdfwa_i$. Daily combined storage of the hydro reservoirs was not ln transformed ($dsakigstoretaf_i$).

A.4.3.3.6.3. Filling Gaps in the Reservoir Storage Record

Daily change in combined storage of hydroelectric reservoirs was quantified using reservoir storage data provided to Reclamation and the USFWS by PacifiCorp under a Non-disclosure Agreement. Certain aspects of the following analyses were not reported here in keeping with the terms of the Non-disclosure Agreement. After summing the daily storage of JC Boyle, Copco, and Iron Gate reservoirs into a single variable ($kigstoretaf_i$) used to compute KIG accretions, gaps in the record were apparent. Out of the 13,210 days in the period-of-record used in this analysis (10/1/1980 – 11/30/2016), 662 days were missing. The initial task was to develop a

model to fill these gaps in the $kigstoretaf_i$ time series, so that daily change in total reservoir storage could be calculated, subsequently enabling computation of daily KIG accretion.

In addition to the gaps caused by the absence of data, during some time periods $kigstoretaf_i$ patterns reflected reservoir management for reasons other than typical operations (e.g. maintenance events, emergency outages, federal agency "borrowing", etc.). Periods of atypical management were identified by reviewing re-licensing documents in the FERC eLibrary (https://www.ferc.gov/docs-filing/elibrary.asp; project P-2082) and consulting with water operations personnel at Reclamation. These periods were removed from the data (n=649) used to develop a model for filling gaps in $kigstoretaf_i$, but were retained in the final data set used to compute KIG accretions.

Methodological details were the same as for those reported in the sub-section addressing development of the KIG accretion model, so many are deferred to that description. In brief summary, 7 time-series regression models with ARMA (Autoregressive Moving Average) disturbances were developed using Stata 15 (Hyndman and Athanasopoulos 2014; Montgomery et al. 2015; StataCorp 2017; Table A.4.3.3.6.3.1). Predictive performance of each was assessed using 10-fold cross-validation (James et al. 2013); the model with the smallest mean square error (error = actual $kigstoretaf_i$ – predicted $kigstoretaf_i$) averaged across the 10 folds was used to fill the gaps in $kigstoretaf_i$ series. Overall, this approach appeared to do a reasonably good job of filling the gaps. Further details of the analysis are not presented, in keeping with the Non-disclosure Agreement with PacifiCorp.

Table A.4.3.3.6.3.1. Models evaluated for use in filling gaps in the $kigstoretaf_i$ series. The dependent variable in all models was $dsakigstoretaf_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2 (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

Variables	Model #1	Model #2	Model #3	Model #4	Model #5	Model #6	Model #7
Dsalnigtaf				0/5	0/5	0/5	0/5
Dsalnkenotaf				0/5	0/5	0/5	0/5
dsaln1kipptwa	0/5	0/5	0/4	0/5	0/5	0/3	0/3
dsaln3kiqdfwa	0/5	0/5	0/5				
Dsakitavgwa	0/2	0/2	0/1	0/2	0/2	0	0
dsaln3mkawa			0/5			0/4	0/4
dsaln1kipptwa x dsakitavgwa		0					
dsaln1kipptwa x dsaln3kiqdfwa		0					
dsalnigtaf x dsaln1kipptwa					0		0
Ar	1/3	1/3	1/3	1/2	1/2	1/3	1/3
Ma	1/2	1/2	½	1/2	1/3	1/4	¼
average MSE	0.1394	0.1395	0.1330	0.1442	0.1446	0.1411	0.1398

A.4.3.3.6.4. Modeling Accretions Between Keno and Iron Gate Dams

KIG accretions were modeled using time-series regression models with ARMA (Autoregressive Moving-average) disturbances using Stata 15 (StataCorp, 2017a; Hyndman and Athanasopoulos, 2014; Montgomery et al., 2015). This approach fitted the model:

$$y_i = x_i\beta + \mu_i \qquad \text{(structural equation)}$$

$$\mu_i = \sum_{h=1}^{p} \rho_h \mu_{i-h} + \sum_{j=1}^{q} \theta_j \epsilon_{i-j} + \epsilon_i \qquad \text{(disturbance equation)}$$

where

- y_i is the dependent variable at time *i*;
- x_i is the matrix of regressors;
- β is the vector of regressor coefficients;
- μ_i is the error associated with the structural equation;
- ρ_h is the autocorrelation parameter of order h from 1 to *p*;
- θ_j is the moving-average parameter of order *j* from 1 to *q*;
- ϵ_i is the error associated with the disturbance equation, assumed to be a white-noise process.

All variables were transformed with ln($x + c$) as appropriate, seasonally adjusted, and differenced (see prior sections detailing construction of variables). The dependent variable for each model was $dsaln1kigaccwa_i$. The eigenvalue stability condition of each model was checked, confirming the required invertibility condition of the MA process, and confirming the process to be covariance stationary (StataCorp 2017). Stationarity of *dsaln1kigaccwa* in each model was confirmed by the rejection of the null hypothesis that the variable followed a unit-root process, using the augmented Dickey-Fuller test (StataCorp 2017). Bartlett's white noise test on residuals from each model failed to reject the null hypothesis (95% confidence level) that they came from a white noise process of uncorrelated random variables having a constant mean and a constant variance (StataCorp 2017). Residuals were not normally distributed but were symmetric, so the Huber/White sandwich estimator was used to compute standard errors that are robust to symmetric non-normality in the disturbances (StataCorp 2017).

Predictive performance of each was assessed using 10-fold cross-validation (James et al. 2013; Hyndman and Athanasopoulos 2014). In this approach, the model was fitted to the data for water years 1981-1986, which was then used to predict $dsaln1kigaccwa_i$ for water years 1987-1989 (fold $k = 1$). Predicted values were converted back to the original scale of the data, and the mean square error (MSE_k) was computed for fold 1. Then the model was fitted to water years 1981-1989, used to predict $dsaln1kigaccwa_i$ for fold $k = 2$ (the next 3 water years, 1990-1992), and the MSE_k was computed (on original data scale) for fold 2. This process was repeated through fold $k = 10$ (2014-2016), and then the average MSE was computed across all 10 folds. This average MSE was used as the best estimate of the error and predictive capability of each model.

Using these techniques, 23 models were developed (Table A.4.3.3.6.4.1). Note that lags of 0 were commonly used for temperature and precipitation variables and related interactions. This indicates the expected reliance on forecasts of these variables based on products currently available from the California-Nevada River Forecast Center (https://www.cnrfc.noaa.gov/).

Attempts were made to obtain historical time-series of forecasts for these variables across the POR used for the modeling, but such data were unavailable. Therefore, historical values of temperature and precipitation were used when forecasting accretions for days 0-3. Use of perfect foresight in this way produced models that do not exhibit the same error characteristics that will be encountered when using forecasted temperature and precipitation to make daily operational decisions. Operational error will be larger than that shown in Table 2 and will need to be quantified through operational use of these models.

Model 21 had the lowest average MSE (0.077) from the cross-validation (Table A.4.3.3.6.4.1, Figure A.4.3.3.6.4.1), and was subsequently used to forecast dsaln1kigaccwai (day 0). The day 0 forecast predicts the accretion for the current day and is intended for use in making a final decision as to whether a flushing flow should be implemented on a given day. Forecasts were also needed for days *i*+1 (day 1) through *i*+3 (day 3), when forecasts would be used to guide actions that would necessarily precede release of a flushing flow (e.g. adjusting reservoir elevations to permit spill operations). However, because Model 21 included *dsaln6ugmkawa* for lags of *i*-1 and *i*-2, for which no forecasts were available, a different model had to be used for the days beyond day 0. Model 20 was selected for this purpose, because it did not include any regressors for which forecasts were unavailable, its average MSE from cross-validation was very similar to the other candidate models, and the regressor variables were very similar to those in Model 21 (Table A.4.3.3.6.4.1), which would minimize the additional effort necessary to operate using 2 models.

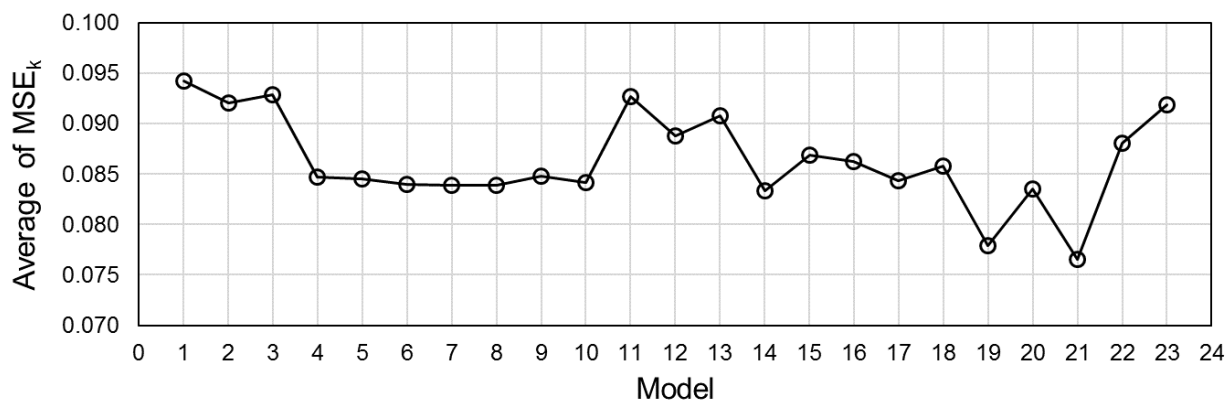


Figure A.4.3.3.6.4.1. Average of the mean square error (error = actual $kigaccwa_i$ – predicted $kigaccwa_i$) across the k=10 folds in the 10-fold cross-validation. Model 21 minimized this MSE_k, and was therefore selected as the final model.

Table A.4.3.3.6.4.1. Models evaluated for predicting KIG accretions. The dependent variable in all models was $dsaln1kigaccwa_i$. Variables included in models include autoregressive (ar) and moving average (ma) terms for errors from the structural equation. Entries show the lags of each variable used in each model. For example, 0/2 indicates use of lags *i*-0, *i*-1, and *i*-2, whereas 0 2 indicates use of lags *i*-0 and *i*-2 only (*i* = day). The model that yielded the smallest average mean square error (MSE) from 10-fold cross-validation was model 3.

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
dsadfishswe			2/5		3		3										2/5	3	3				
dsaln3kiqdfwa		2																					
dsaln1kipptwa	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7	0/7				0/7	0/7	0/7		0/7				
dsakitavgwa	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1	0/1			0/1 3	0/1 3	0/1 3		0/1				0/3
dsaln3mkawa				1/3	1/3	1/3	1/3	1/3															
dsaln1mkpptwa						0/1	0/1																
dsaln6ugmkawa									1/2	1/2				1/2					1/2		1/2		
dsahekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsalekitavg													0/3	0/3				0/3		0/3	0/3	0/3	
dsaln1kipptwa x dsakitavgwa										0 2													
coolhekippt												5 7											
warmhekippt												6											
coldlekippt											0	0/4	0/1	0/1								0/1 4	
coollekippt											0	0/6	0/4	0/1								0/7	
warmlekippt												0/5	0/5	0/1								0/5	
soilfrzheppt															0/1	0/1	0/1	0/1	0/1	0/1	0/1		
soilfrzleppt															0/1	0/1	0/1	0/1	0/1	0/3	0/1		
kippttavgint																0 3	0/1 3		0				
soilthwheppt																		6/7		6/7	6/7		
soilthwleppt																		0/5		0/5	0/5		
thwleint																				1 3	0 2		
coollekiint																						0/3	
coldkippt																							0/1 3/4
coolkippt																							0/7
warmkippt																							0/1 3/7
coolkiint																							0/3
ma	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3	1/3
average MSE	.094	.092	.093	.085	.084	.084	.084	.084	.085	.084	.093	.089	.091	.083	.087	.086	.084	.086	.078	.084	.077	.088	.092

The model 21 equation used to forecast $dsaln1kigaccwa_i$ on day 0 was (Table A.4.3.3.6.4.2):

$$\widehat{dsaln1kigaccwa_i} = \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \beta_{5,i-1}dsaln6ugmkawa_{i-1} + \beta_{5,i-2}dsaln6ugmkawa_{i-2} + \beta_{6,i-6}soilthwheppt_{i-6} + \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i}thwleint_i + \beta_{8,i-2}thwleint_{i-2} + \theta_1(dsaln1kigaccwa_{i-1} - \widehat{dsaln1kigaccwa_{i-1}}) + \theta_2(dsaln1kigaccwa_{i-2} - \widehat{dsaln1kigaccwa_{i-2}}) + \theta_3(dsaln1kigaccwa_{i-3} - \widehat{dsaln1kigaccwa_{i-3}})$$

The model 20 equation used to forecast $dsaln1kigaccwa_i$ on days 1-3, where *i* = the day being forecasted, was (Table A.4.3.3.6.4.2):

$$\widehat{dsaln1kigaccwa_i} = \beta_{1,i}dsahekitavg_i + \beta_{1,i-1}dsahekitavg_{i-1} + \beta_{1,i-2}dsahekitavg_{i-2} + \beta_{1,i-3}dsahekitavg_{i-3} + \beta_{2,i}dsalekitavg_i + \beta_{2,i-1}dsalekitavg_{i-1} + \beta_{2,i-2}dsalekitavg_{i-2} + \beta_{2,i-3}dsalekitavg_{i-3} + \beta_{3,i}soilfrzheppt_i + \beta_{3,i-1}soilfrzheppt_{i-1} + \beta_{4,i}soilfrzleppt_i + \beta_{4,i-1}soilfrzleppt_{i-1} + \beta_{4,i-2}soilfrzleppt_{i-2} + \beta_{4,i-3}soilfrzleppt_{i-3} + \beta_{6,i-6}soilthwheppt_{i-6} + \beta_{6,i-7}soilthwheppt_{i-7} + \beta_{7,i}soilthwleppt_i + \beta_{7,i-1}soilthwleppt_{i-1} + \beta_{7,i-2}soilthwleppt_{i-2} + \beta_{7,i-3}soilthwleppt_{i-3} + \beta_{7,i-4}soilthwleppt_{i-4} + \beta_{7,i-5}soilthwleppt_{i-5} + \beta_{8,i-1}thwleint_{i-1} + \beta_{8,i-3}thwleint_{i-3} + \theta_1(dsaln1kigaccwa_{i-1} - \widehat{dsaln1kigaccwa_{i-1}}) + \theta_2(dsaln1kigaccwa_{i-2} - \widehat{dsaln1kigaccwa_{i-2}}) + \theta_3(dsaln1kigaccwa_{i-3} - \widehat{dsaln1kigaccwa_{i-3}})$$

Forecasts were restored to the original measurement scale using:

$$\widehat{kigaccwa_i} = e^{\left(sd_ln1kigaccwa_{dowy}\left(\widehat{dsaln1kigaccwa_i} + saln1kigaccwa_{i-1}\right)\right) + mn_ln1kigaccwa_{dowy}} - 1$$

where

$sd_ln1kigaccwa_{dowy}$ is the standard deviation of $ln1kigaccwa$ across the POR for day of water year *dowy*;

$mn_ln1kigaccwa_{dowy}$ is the mean of $ln1kigaccwa$ across the POR for day of water year *dowy*;

e is the base of the natural logarithm (2.71828).

Table A.4.3.3.6.4.2. Coefficients and lags associated with each variable in model 21, used for day 0 forecasts of *dsaln1kigaccwa*, and model 20, used for day 1-3 forecasts of *dsaln1kigaccwa*. In the variables column, *ma* stands for the moving average component of the disturbance equation; all other variables are components of the structural equation.

		Model 21	**Model 21**	**Model 20**	**Model 20**
Variables	β	**Lag**	**Coefficient**	**Lag**	**Coefficient**
dsahekitavg	$\beta_{1,i}$	0	-0.084751935	0	-0.079570007
	$\beta_{1,i-1}$	1	-0.131145783	1	-0.135250777
	$\beta_{1,i-2}$	2	-0.09675344	2	-0.12393146
	$\beta_{1,i-3}$	3	-0.07496754	3	-0.108007704
dsalekitavg	$\beta_{2,i}$	0	0.162509412	0	0.159638178
	$\beta_{2,i-1}$	1	0.166952852	1	0.180184281
	$\beta_{2,i-2}$	2	0.084205439	2	0.121336316
	$\beta_{2,i-3}$	3	0.076453299	3	0.114166256
soilfrzheppt	$\beta_{3,i}$	0	0.052230518	0	0.056741619
	$\beta_{3,i-1}$	1	0.038355313	1	0.043526354
soilfrzleppt	$\beta_{4,i}$	0	0.167098975	0	0.160364016
	$\beta_{4,i-1}$	1	0.126016131	1	0.138847704
	$\beta_{4,i-2}$			2	0.052549174
	$\beta_{4,i-3}$			3	0.038833972
dsaln6ugmkawa	$\beta_{5,i-1}$	1	0.104267816		
	$\beta_{5,i-2}$	2	0.12480171		
soilthwheppt	$\beta_{6,i-6}$	6	0.029347092	6	0.035972385
	$\beta_{6,i-7}$	7	0.01785531	7	0.021610083
soilthwleppt	$\beta_{7,i}$	0	0.113246571	0	0.106772664
	$\beta_{7,i-1}$	1	0.081135696	1	0.103718791
	$\beta_{7,i-2}$	2	0.021968845	2	0.056118604
	$\beta_{7,i-3}$	3	0.027132767	3	0.041983045
	$\beta_{7,i-4}$	4	0.01865496	4	0.034074352
	$\beta_{7,i-5}$	5	0.018046125	5	0.02754767
thwleint	$\beta_{8,i}$	0	0.02233405		
	$\beta_{8,i-1}$			1	0.022579397
	$\beta_{8,i-2}$	2	-0.019003767		
	$\beta_{8,i-3}$			3	-0.020293628
ma	θ_1	1	-0.354124765	1	-0.338305637
	θ_2	2	-0.569710264	2	-0.562316149
	θ_3	3	0.086079682	3	0.079656475

Day 0 forecasts made with model 21 performed well in the cross-validation process (Figures A.4.3.3.6.4.2 - A.4.3.3.6.4.11). While there was a tendency to under-predict higher accretions and over-predict lower accretions, model 21 captures the pattern of accretions very well. False positives (i.e. predicting peaks that do not appear) were rare. Use of model 21 to inform final decisions triggering implementation of surface flushing flows appears likely to enhance the efficient use of stored water in UKL by piggybacking on KIG accretion events.

Day 1-3 forecasts made with model 20 do not perform as well (Figures A.4.3.3.6.4.12 - A.4.3.3.6.4.17). The tendency to under-estimate peaks and over-estimate troughs is more pronounced, and many peaks and troughs are missed entirely. This arises in part because as forecasts are made further into the future, the disturbance components of the predictive equation for which the actual accretion is unavailable (because it has not yet happened) are assumed to be zero. When forecasting day 1, $dsaln1kigaccwa_{i-1}$ is not available, and so the quantity $\theta_1(dsaln1kigaccwa_{i-1} - \widehat{dsaln1kigaccwa_{i-1}})$ is assumed to be zero. Forecasts made for day 3 assume that all 3 *ma* components of the disturbance equation are zero, and the forecasts reduce to those from the structural equation alone. Despite the lower quality of these forecasts, simulations with the KBPM have demonstrated their worth in informing preliminary decisions regarding preparation for triggering surface flushing flows. Nonetheless, future efforts to improve these forecasts could significantly enhance their utility.

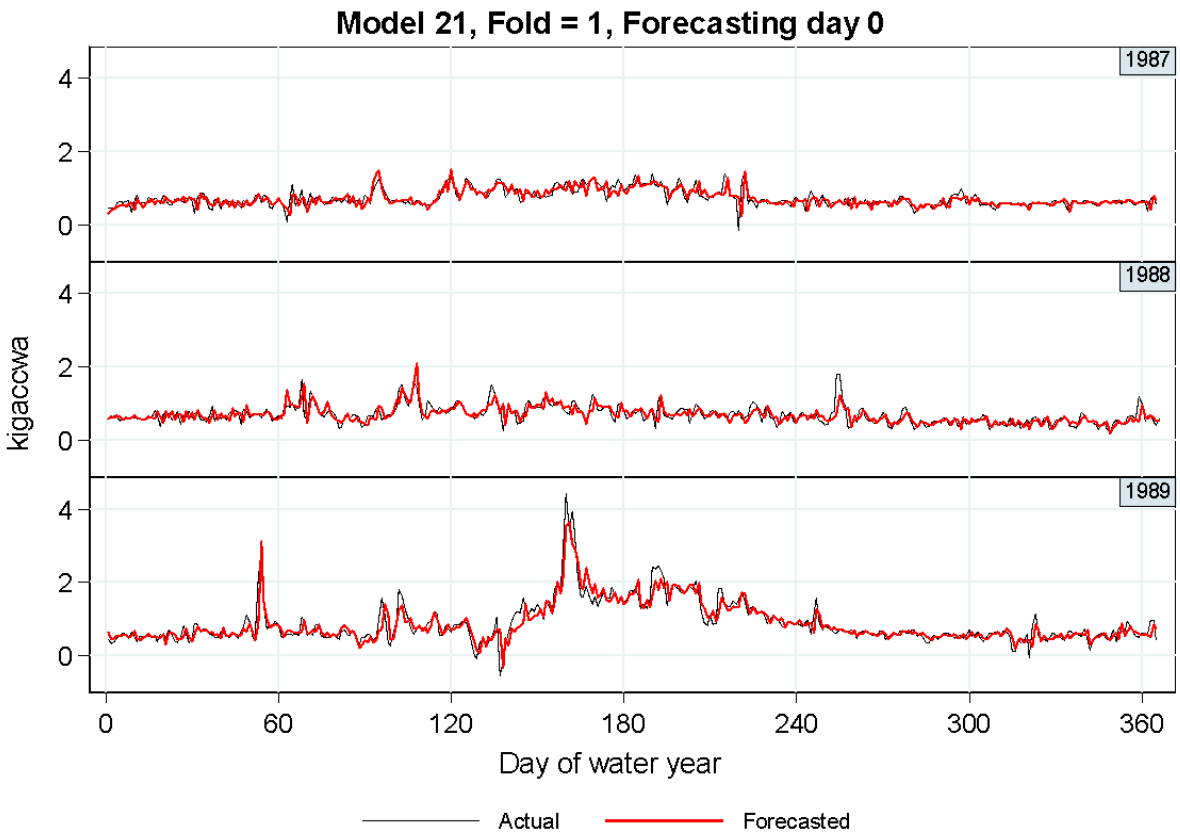


Figure A.4.3.3.6.4.2. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 1 from the 10-fold cross-validation process. The model was trained on water years 1981-1986, then used to forecast water years 1987-1989.

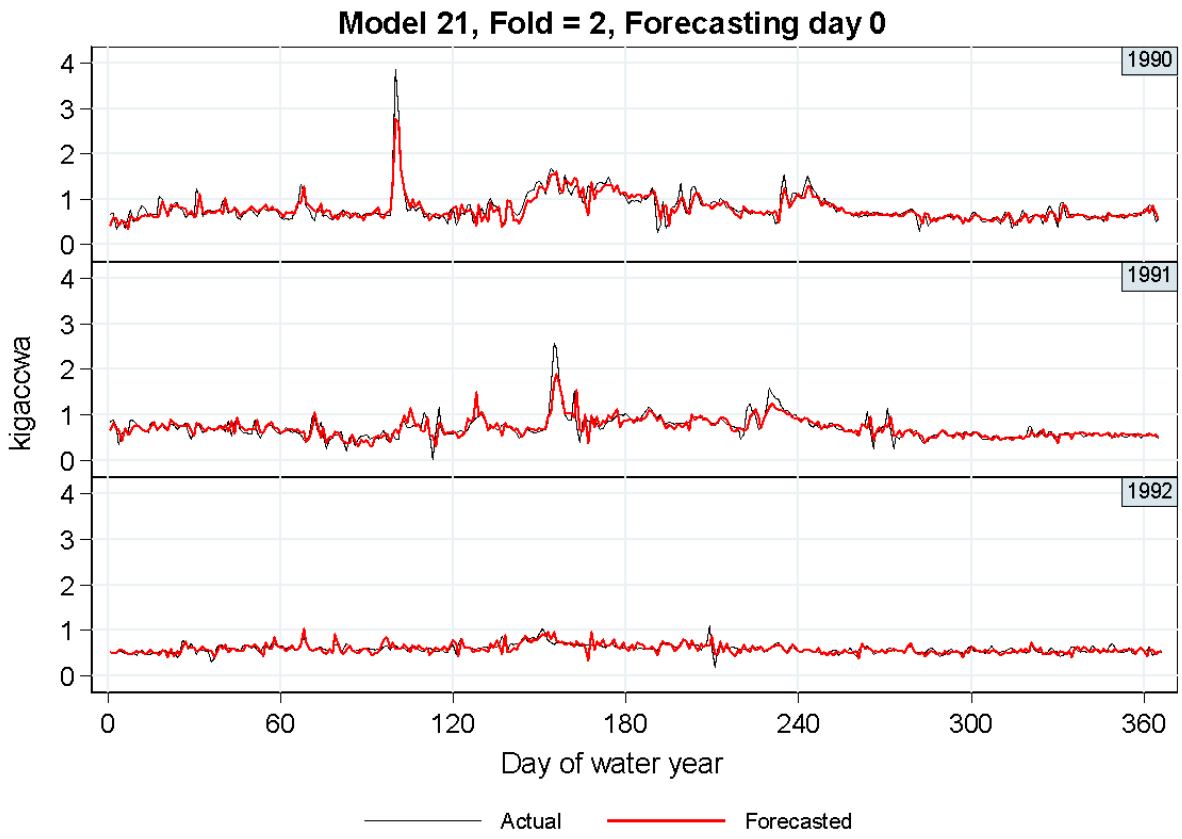


Figure A.4.3.3.6.4.3. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 2 from the 10-fold cross-validation process. The model was trained on water years 1981-1989, then used to forecast water years 1990-1992.

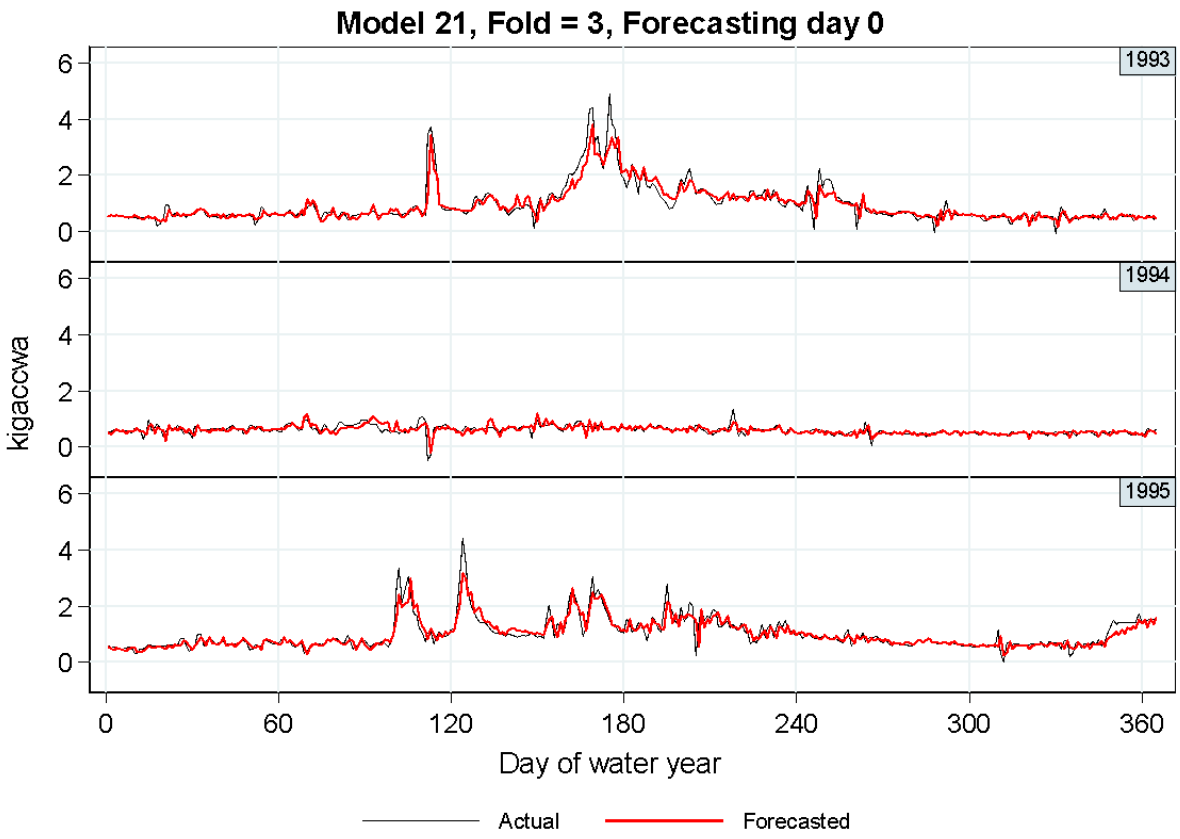


Figure A.4.3.3.6.4.4. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 3 from the 10-fold cross-validation process. The model was trained on water years 1981-1992, then used to forecast water years 1993-1995.

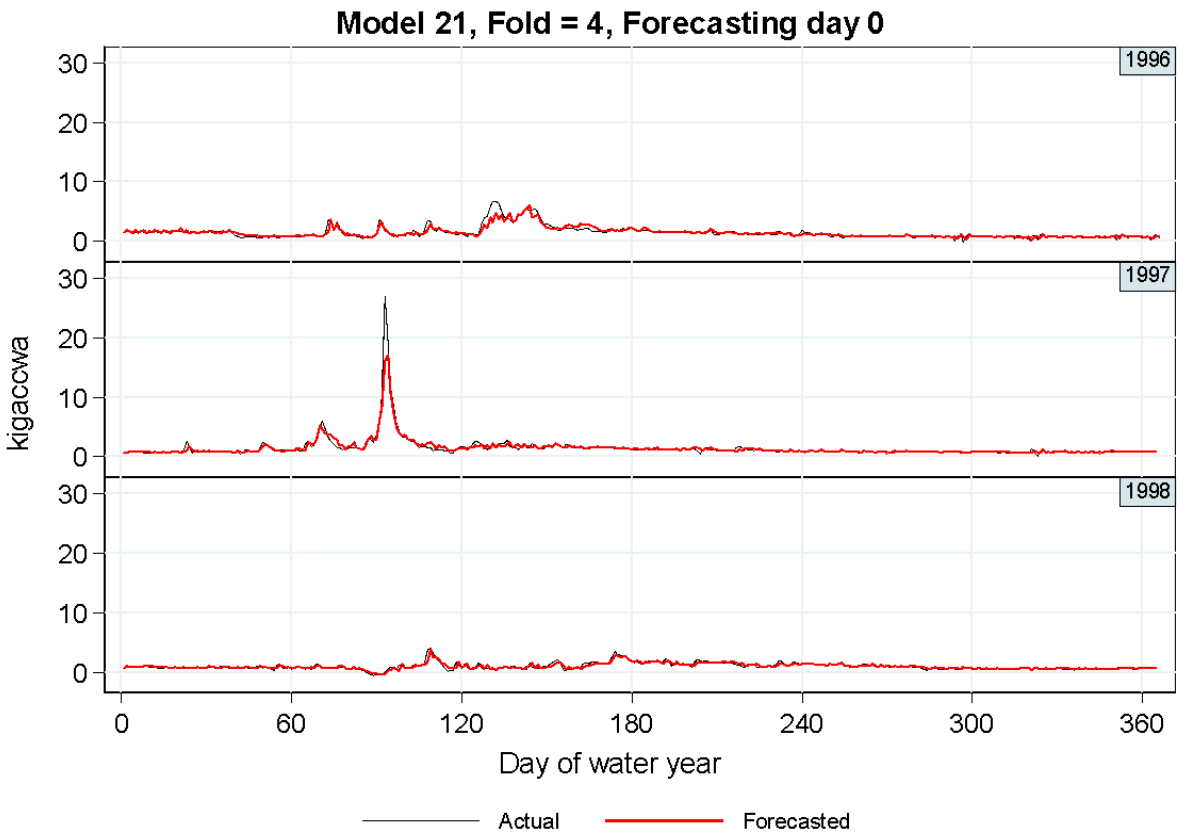


Figure A.4.3.3.6.4.5. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 4 from the 10-fold cross-validation process. The model was trained on water years 1981-1995, then used to forecast water years 1996-1998.

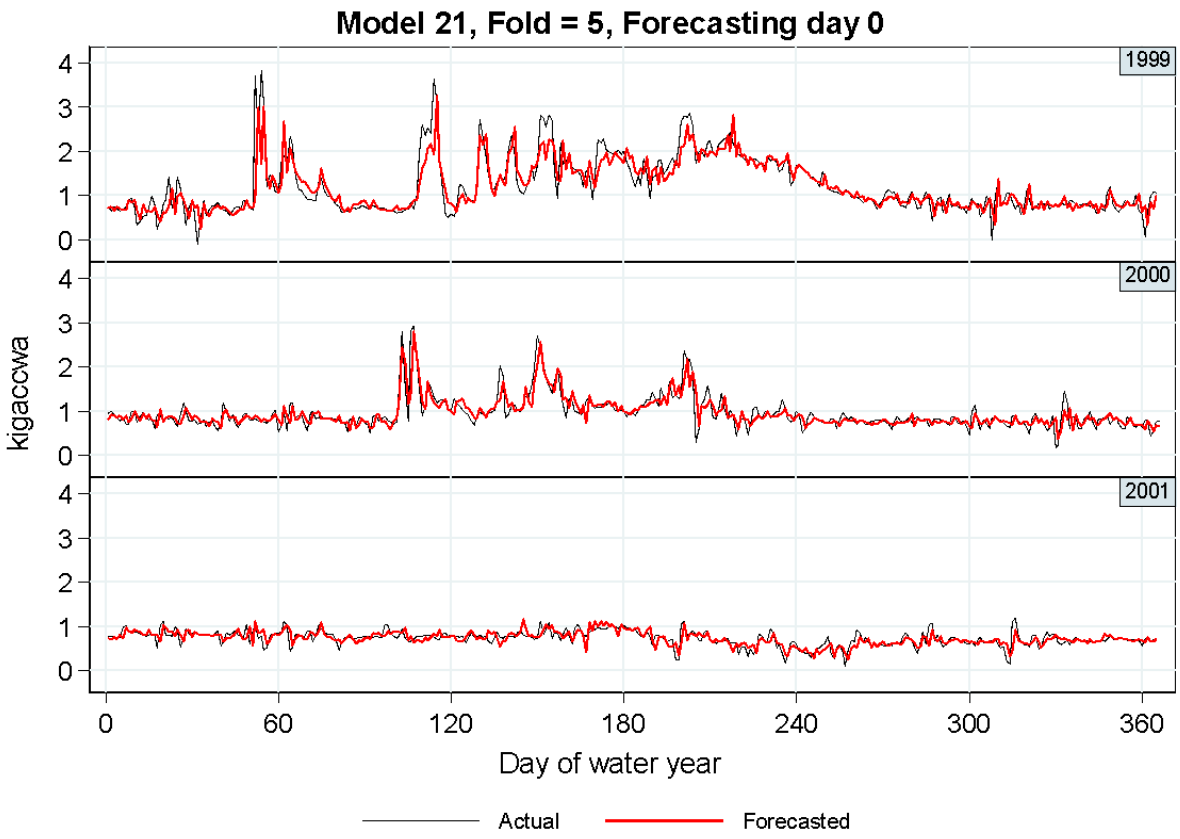


Figure A.4.3.3.6.4.6. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 5 from the 10-fold cross-validation process. The model was trained on water years 1981-1998, then used to forecast water years 1999-2001.

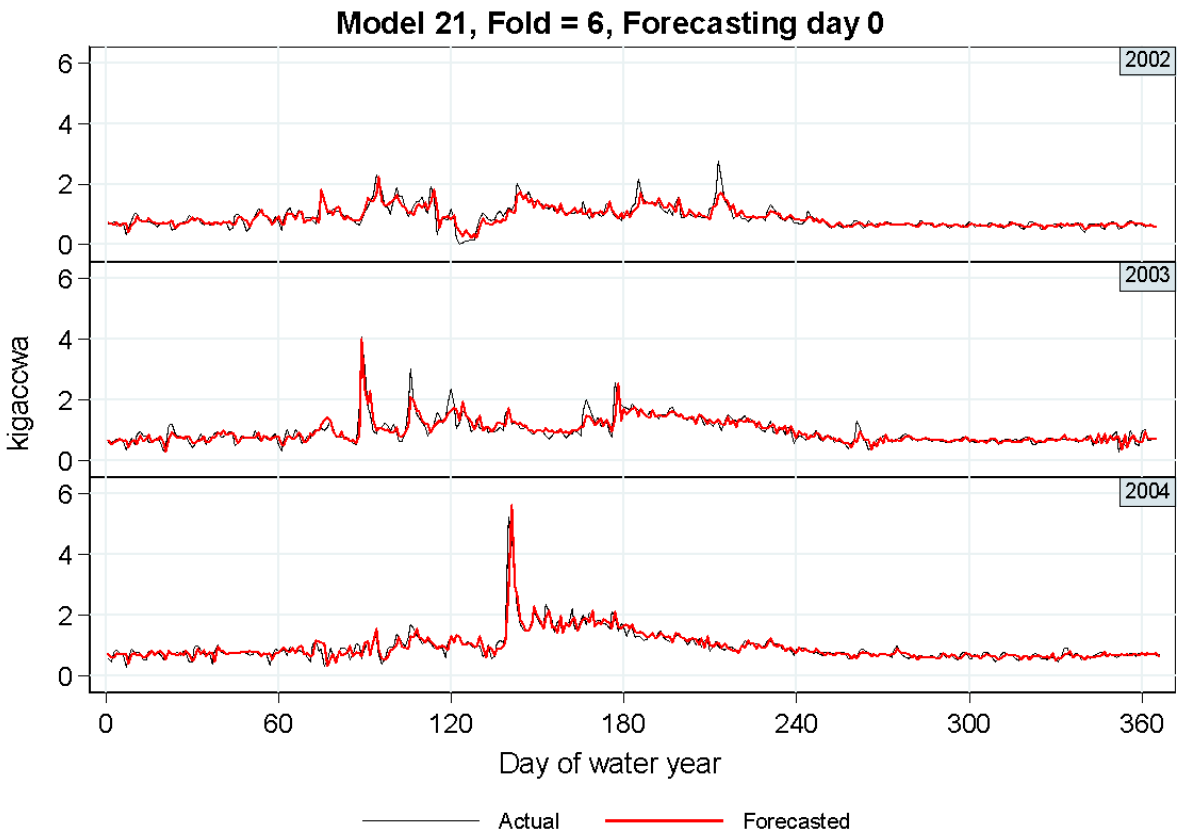


Figure A.4.3.3.6.4.7. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 6 from the 10-fold cross-validation process. The model was trained on water years 1981-2001, then used to forecast water years 2002-2004.

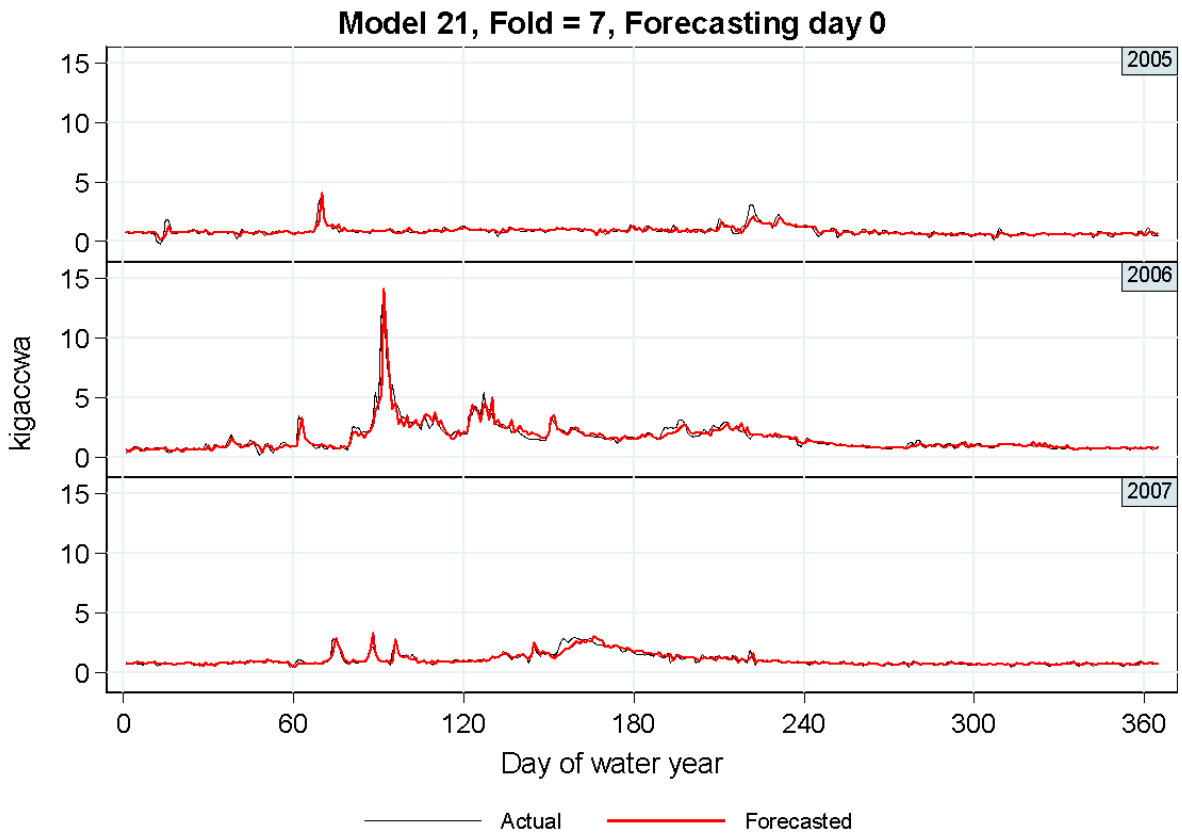


Figure A.4.3.3.6.4.8. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 7 from the 10-fold cross-validation process. The model was trained on water years 1981-2004, then used to forecast water years 2005-2007.

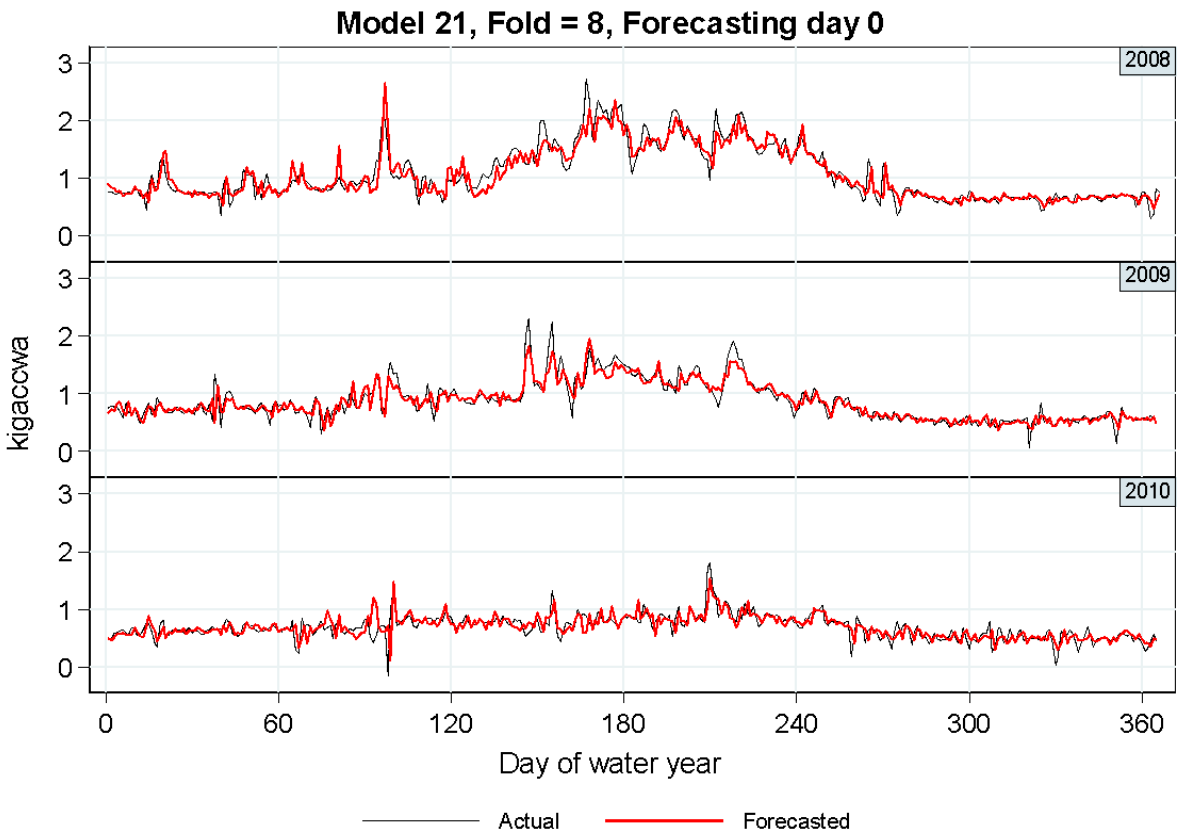


Figure A.4.3.3.6.4.9. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 8 from the 10-fold cross-validation process. The model was trained on water years 1981-2007, then used to forecast water years 2008-2010.

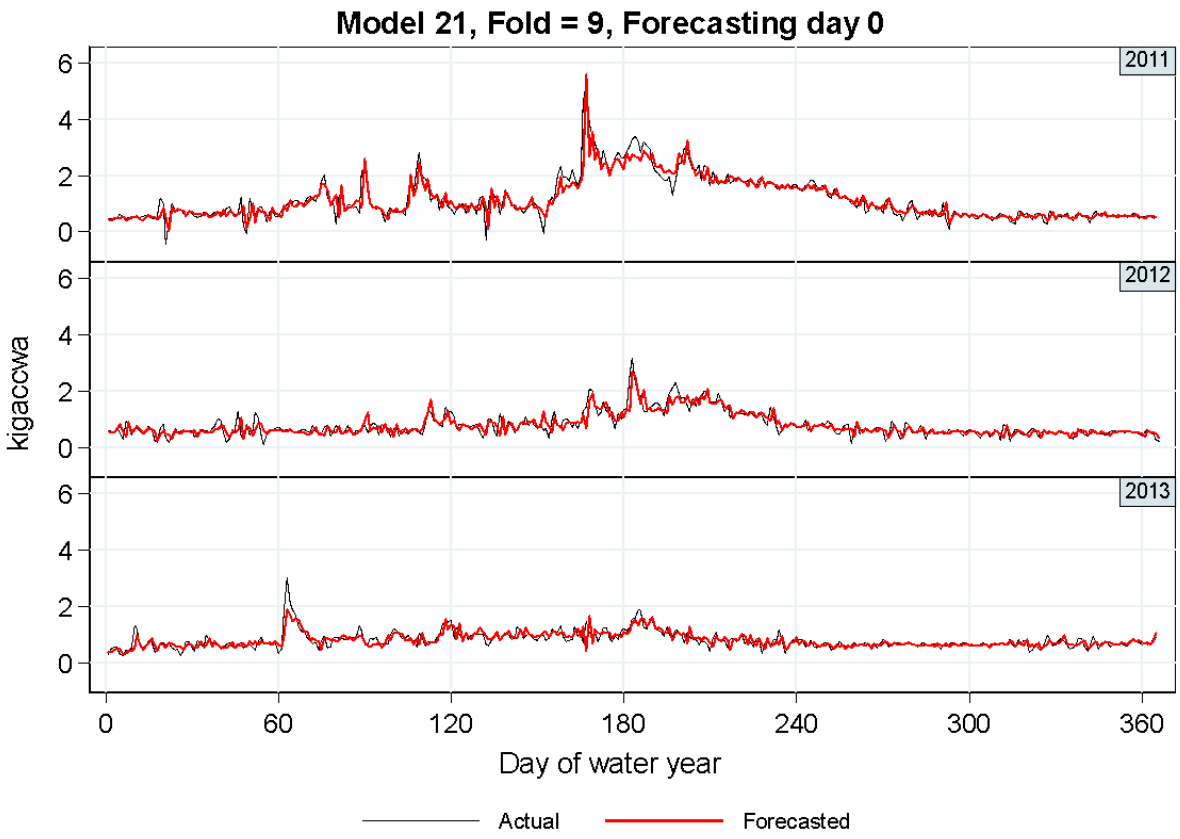


Figure A.4.3.3.6.4.10. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 9 from the 10-fold cross-validation process. The model was trained on water years 1981-2010, then used to forecast water years 2011-2013.

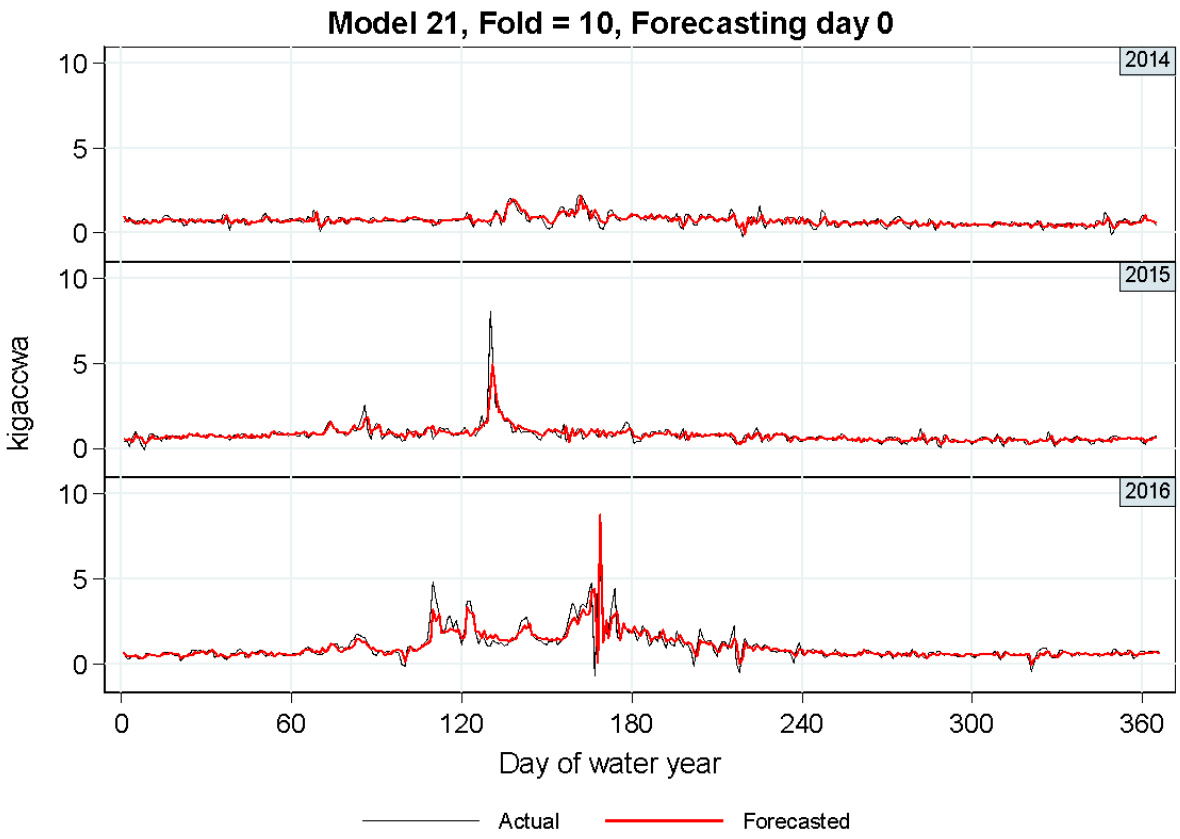


Figure A.4.3.3.6.4.11. Forecasted and actual KIG accretions for day 0 (*kigaccwa*$_i$) for fold 10 from the 10-fold cross-validation process. The model was trained on water years 1981-2013, then used to forecast water years 2014-2016.

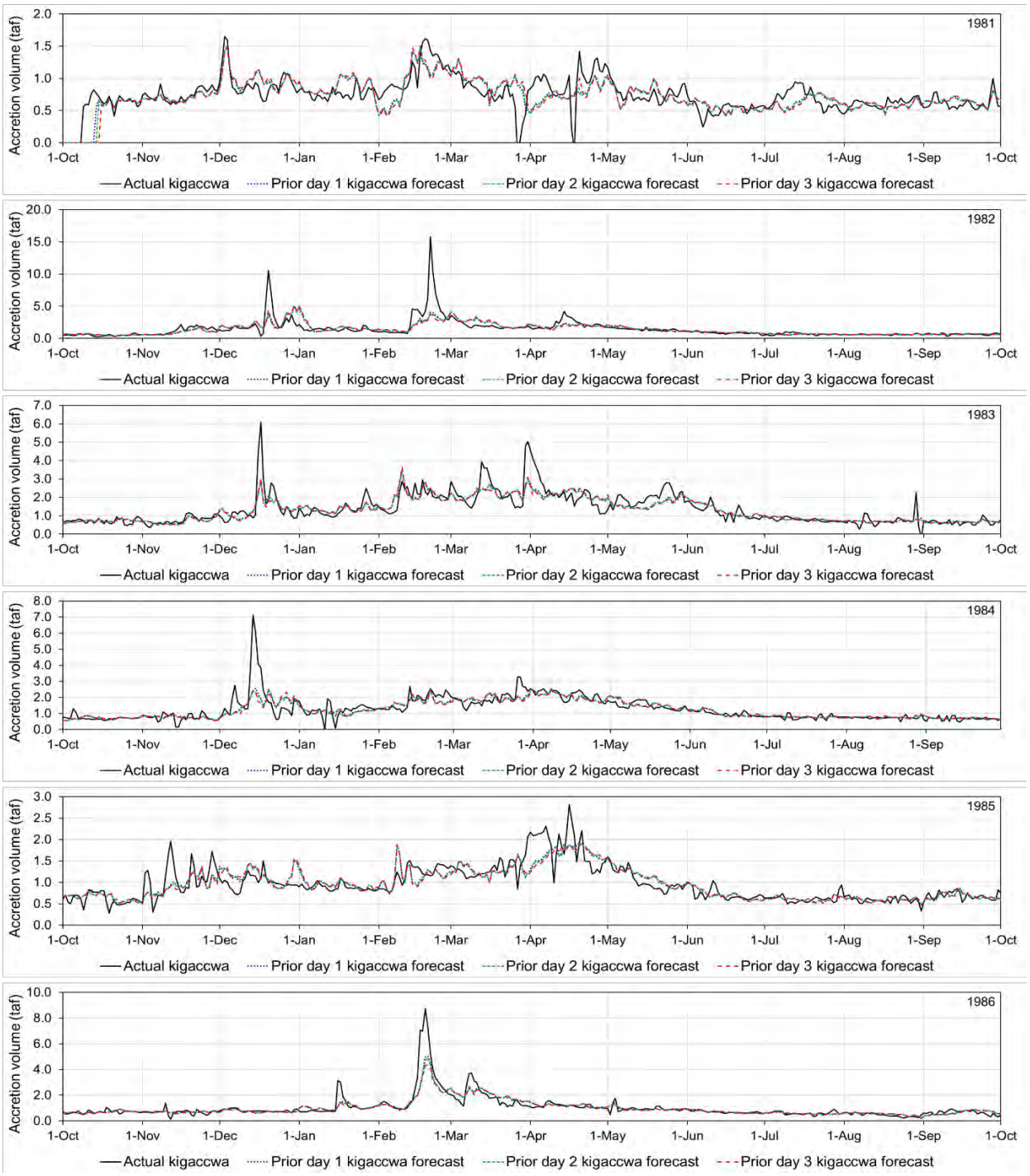


Figure A.4.3.3.6.4.12. Prior KIG accretion forecasts for water years 1981-1986 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

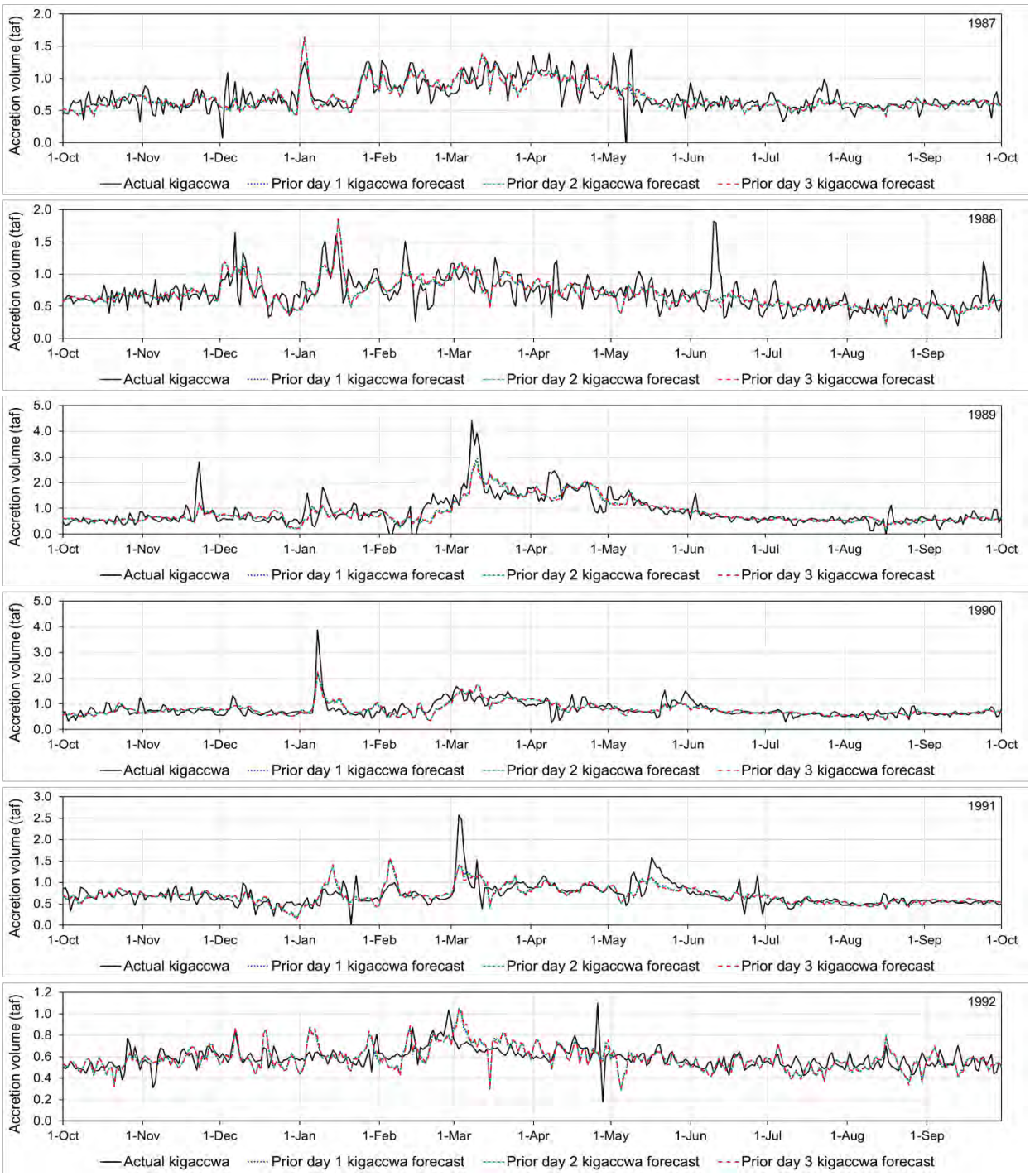


Figure A.4.3.3.6.4.13. Prior KIG accretion forecasts for water years 1987-1992 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

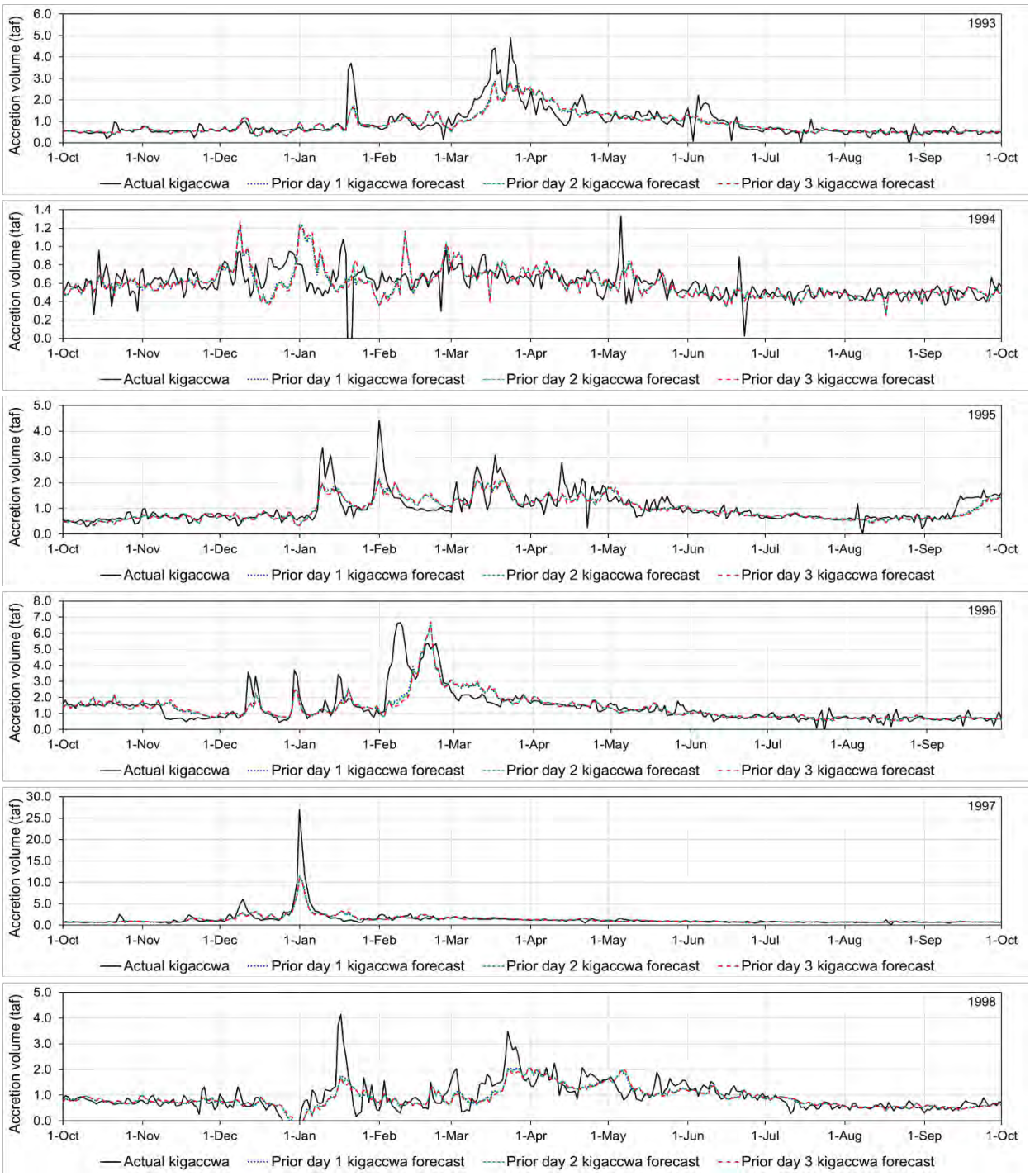


Figure A.4.3.3.6.4.14. Prior KIG accretion forecasts for water years 1993-1998 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

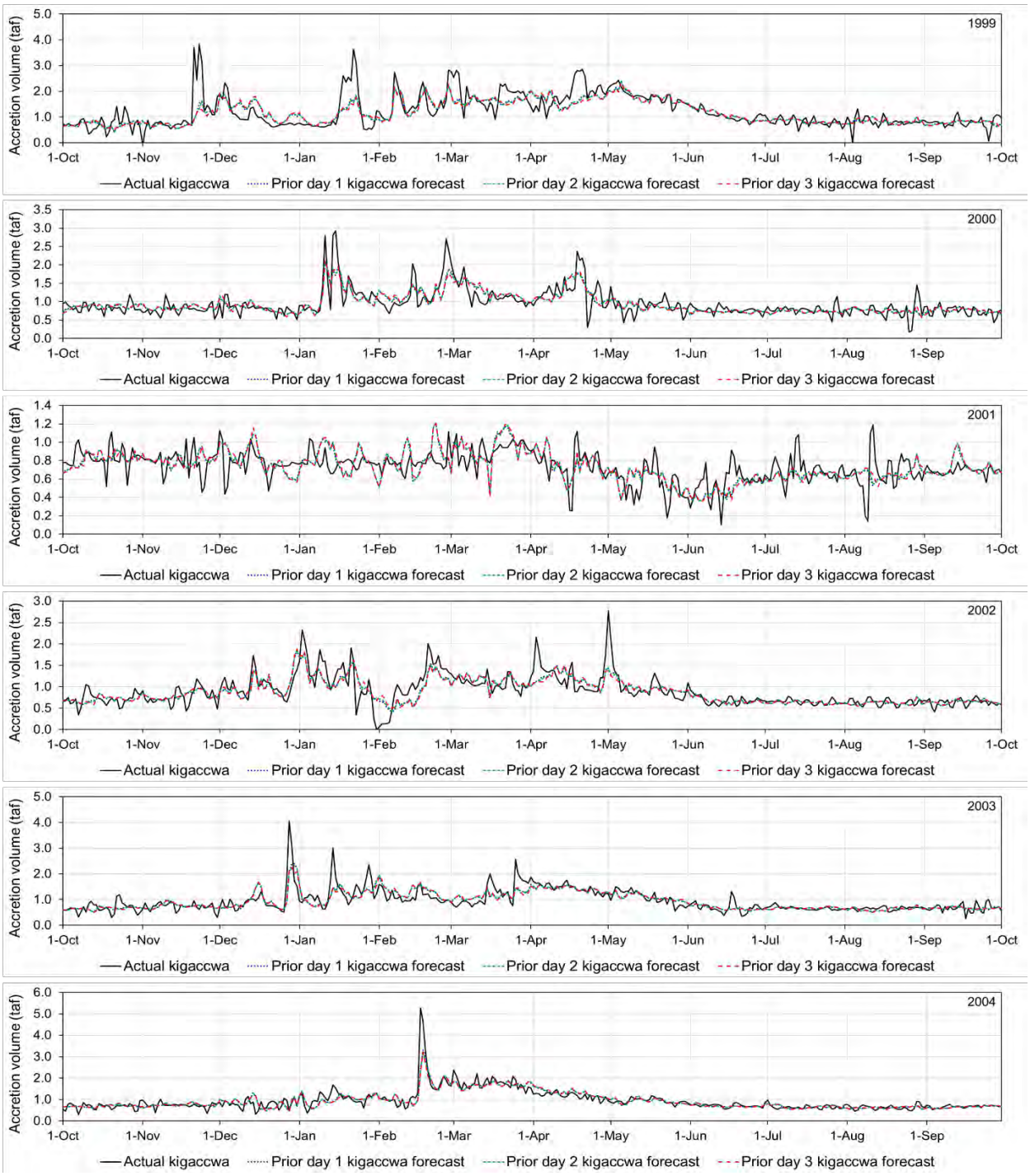


Figure A.4.3.3.6.4.15. Prior KIG accretion forecasts for water years 1999-2004 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

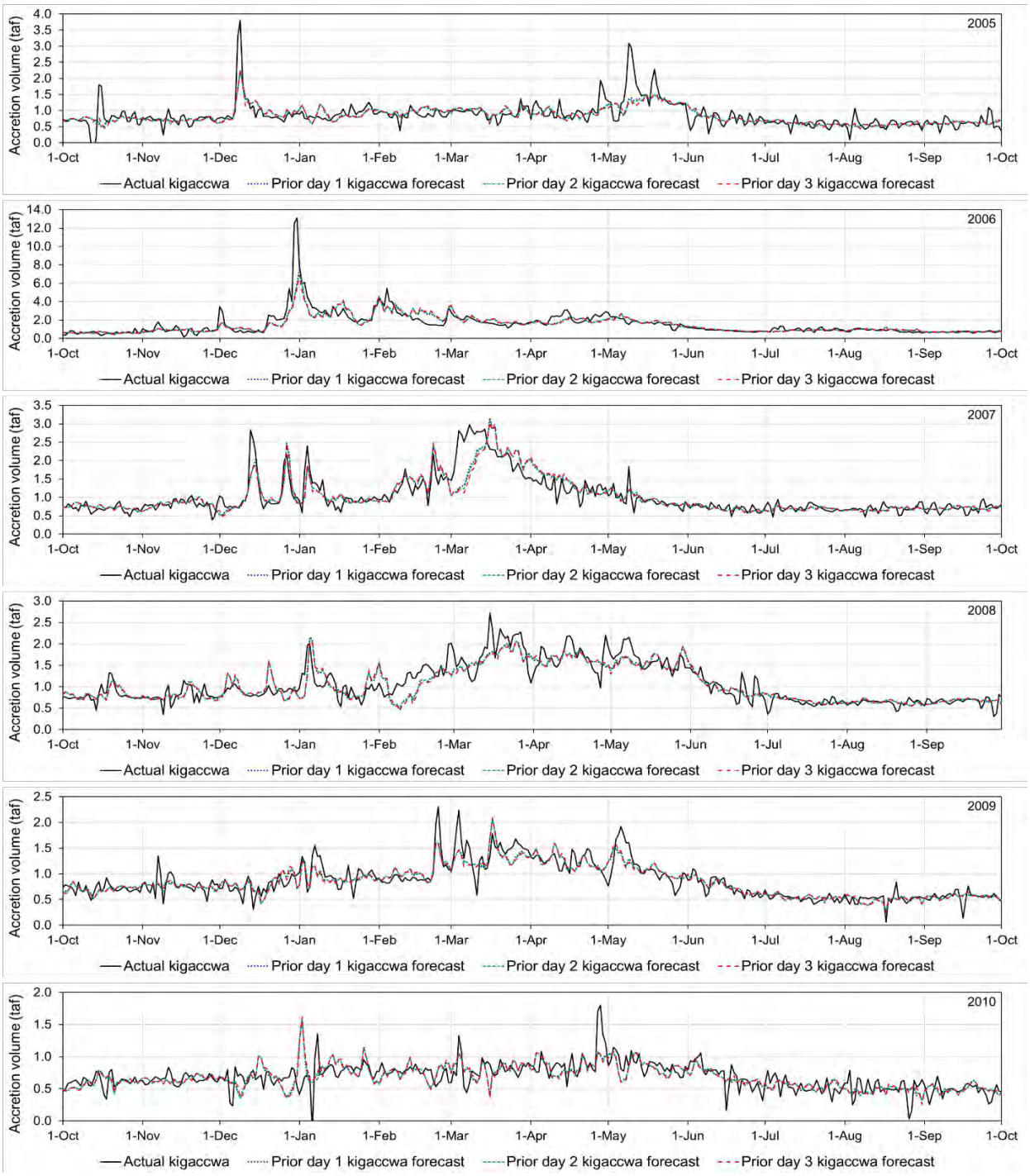


Figure A.4.3.3.6.4.16. Prior KIG accretion forecasts for water years 2005-2010 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

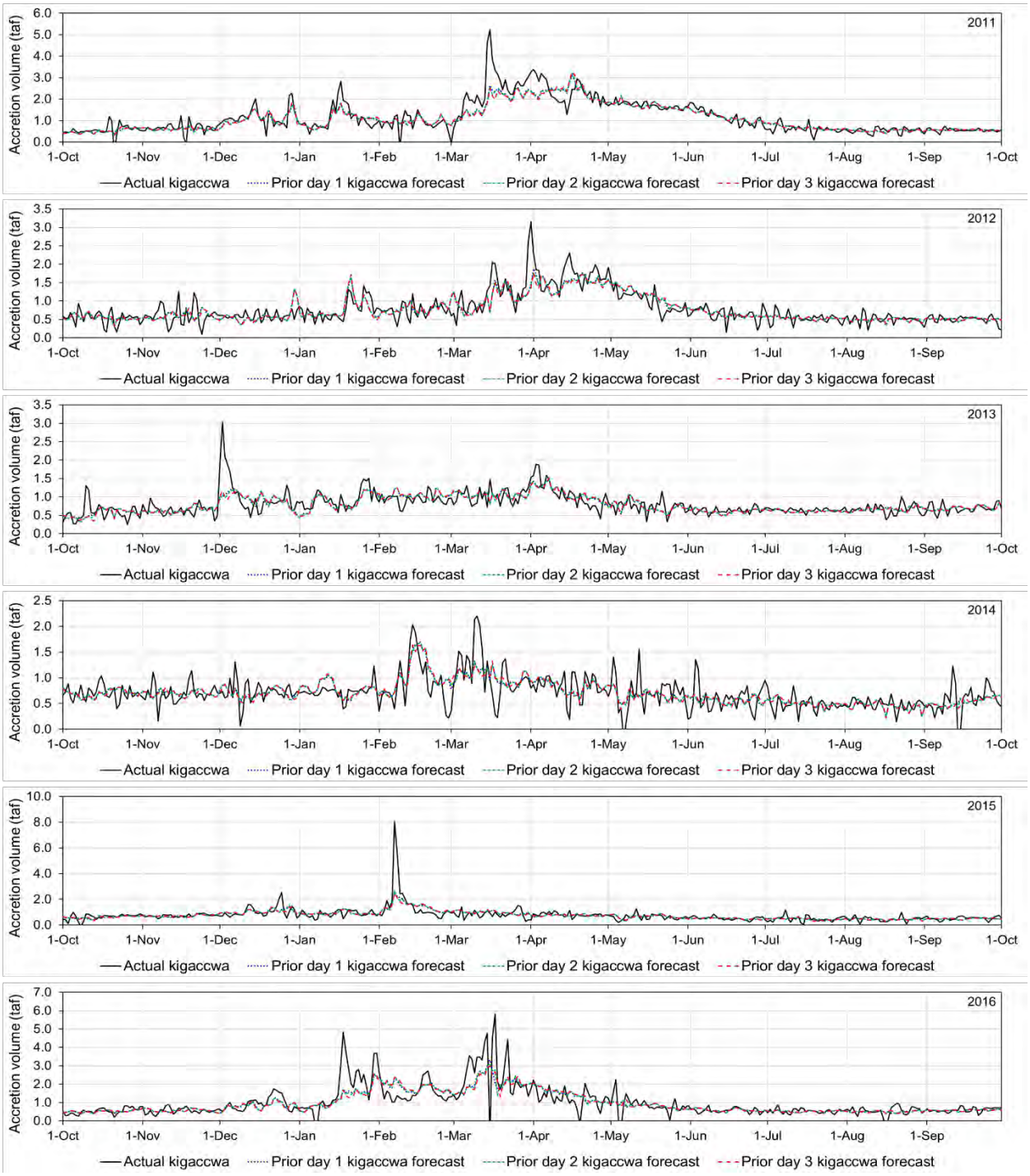


Figure A.4.3.3.6.4.17. Prior KIG accretion forecasts for water years 2011-2016 (based on model 20 fitted across all water years) compared to the actual accretions on those days.

A.4.3.3.7 Lost River Diversion Channel Inflow From Lost River

A mixture of runoff from the Lost River catchment and return flows (primarily from A Canal diversions) is diverted into the LRDC at the Lost River Diversion Dam. Data for these return flows are included in the QA/QC'ed **Daily_Project_Diversions_Final_Dec2016_corrected_Jun2017_UPDATE.xlsx** dataset.

A.4.3.3.8 Area 2 Winter Runoff

The Area A2 Winter Runoff data input (variable I131) is an error closure term for return flows from Area A2 to the Klamath River. Essentially, this term accounts for water that was introduced to or deducted from the KSD beyond that which would have been expected as a result of agriculture or LKNWR activities, or winter and spring precipitation events that may create runoff that also drains into the KSD. In addition, gage errors, changes in pumping efficiency, changes in canal dimensions and increased or decreased efficiency in area A2 water use could all contribute to this balancing term. Area A2 Winter Runoff is a state variable, meaning that these data are static and unaffected by model adjustment of A2 deliveries or F/FF pumping. It is a timeseries calculated based on the difference between measured F/FF discharge to the Klamath River and simulated return flows from KDD and Area K using the historical gauged deliveries through North and Ady canals. The model assumes no return flow from LKNWR.

These data, as well as data and formulae related to the calculation of these data, are contained in the spreadsheet named: **KDD return flow analysis 18Sep2018 version 4 FINAL.xlsx**. More detail is provided in Section A.4.4.5. In the KBPM, Area A2 Winter Runoff data are contained in the file: **PA_2020_SV.dss**.

A.4.3.3.9 Natural Resources Conservation Service Forecasts

The NRCS provided reconstructed UKL net inflow forecasts for water years 1981 through 2016 using the revised UKL net inflow data (Dunsmoor 2017b). The most recent reconstructed forecasts were completed by NRCS in October 2017. Since then, efforts to extend the period-of-record (POR) for the KBPM were impeded by NRCS ceasing the provision of certain forecast periods that were needed by the KBPM, as well as by delays in using models re-calibrated to revised UKL net inflow time series as the basis for their published forecasts. Because the published NRCS forecasts for the 2017-2019 period were still based on the un-revised UKL net inflow data, it was necessary to re-scale the 2017-2019 forecasts to be consistent with the reconstructed forecasts used for the period from 1981-2016.

Tri-Agency Hydro Team (2019: see Section E) documented the re-scaling of NRCS forecasts for the period from 2017-2019, which was done in accordance with a methodological recommendation provided by NRCS staff. For the period 1981-2016, the most recently reconstructed forecasts were called the “new” forecasts. Also available were the “old” forecasts, which included the re-constructed forecasts provided by NRCS in 2012 for the period 1981-2011, as well as the published NRCS forecasts since 2013, which NRCS confirmed were based on the same UKL net inflow data as the re-constructed forecasts provided in 2012. For each forecast period (Mar-Sep, Apr-Sep, May-Sep, and Jun-Sep), the average new:old ratio was calculated for the 1981-2016 period, which was then used to re-scale the forecasts for the 2017-2019 period as follows:

re-scaled NRCS forecast = old NRCS forecast * new:old ratio.

The forecast time series used in the KBPM for the forecast periods discussed above consist of the re-constructed forecasts provided by NRCS for the 1981-2016 period, and the re-scaled forecasts

for the 2017-2019 period. More explanation is provided in Tri-Agency Hydro Team (2019), which is included as Section E of this Appendix.

The KBPM uses the 50th percentage of exceedance forecast for UKL inflow for the months of January through June. Operationally, forecasts are provided by NRCS on the first of each month, and forecasts used in the model reflect this constraint. The March through September forecast is used on January 1, February 1, and March 1. Thereafter, forecasts for the forecast month through September are used (e.g. April – September on April 1). Spring/summer forecasted UKL net inflow is calculated in-season using the following formula:

Forecasted UKL Net Inflow = Previous month measured net inflow + Current month inflow forecast through September

The final forecast is issued and used on June 1. Further detail on use of these forecasts is discussed in Section A.4.4.

NRCS forecast reconstructions are contained in the spreadsheet: **Klamath_forecast_reconstructions_new_flow_data 13Oct2017.xlsx**. In KBPM, NRCS forecast data are contained in the file: **forecasts50pct.table**.

A.4.3.4 Model Variables

In many cases, the actual variables used in the model code have names which are not clearly descriptive of their definition. This is a function of multiple model developers, changing intentions and strategies, and general model adaptation. In order to connect the actual model code to the operations described below, please refer to Table A.4.3.4.1, which defines WRIMS variables used in the modelling of the Proposed Action with a common name (as referenced in the operations sections below) and location within the model files. Due to size, this table is located in Section A found at the end of this document.

A.4.4 Simulated Operations

A.4.4.1 Important Annual Operations

A.4.4.1.1 Upper Klamath Lake Control Logic

One of the greatest challenges identified in previous proposed actions was how to manage UKL elevations in such a way that the needs of endangered suckers in UKL are met while also providing a sure water supply to meet the needs of both threatened coho in the Klamath River and Project irrigators. While many approaches were explored, modelers ultimately created model logic that would allow flexibility in managing lake elevations while also discouraging overuse of the finite hydrologic resource, both within years and inter-annually. The UKL control logic was added to KBPM in order to control releases from UKL to the river and the Project based on UKL elevation relative to a hydrologically-dependent central tendency.

The central tendency is based on user-defined end-of-month UKL elevations which are subsequently interpolated to daily values; note that the generic central tendency end-of-month UKL elevations were arrived at through the iterative modeling process and are not intended to change during operations under this PA. This results in a generic annual hydrograph that

accounts for seasonal needs of suckers, seasonal water demand for the Klamath River and Project, and end-of-season elevations that create conditions likely to result in storage volumes appropriate to meet the next year's demands on UKL. This generic hydrograph is adjusted on a daily basis, based on a normalized 60-day trailing average of raw (i.e. not smoothed) daily net inflow to UKL (*see* section A.4.3.3.4). As the normalized 60-day trailing average of raw daily UKL net inflow approaches zero, conditions are drier and the UKL central tendency is adjusted downward. Conversely, as the 60-day trailing average of inflow approaches 1, conditions are wetter and the central tendency is adjusted upwards.

The magnitude of the daily adjustment in UKL central tendency is bounded by user-defined limits which have been tailored to meet the needs outlined above. The final result is a central tendency line that both accounts for hydrologic needs (ESA and irrigation) and accounts for the impact of seasonal hydrology in any given year. Table 4.4.1.1.1 and the equations following provide information on the generic hydrograph and the manner in which adjustments are made.

Table 4.4.1.1.1 End-of-month UKL elevations associated with the generic (i.e., unadjusted) central tendency and the lower and upper bounds within which the tendency can be adjusted, by month. The lower and upper bounds represent the limits of adjustment that can be made to the central tendency in response to hydrology.

Month	Central Tendency Base UKL Elevation (ft.)	Central Tendency Lower Bound UKL Elevation (ft.)	Central Tendency Upper Bound UKL Elevation (ft.)
October	4139.1	4138.7	4139.5
November	4139.6	4139.2	4140.0
December	4140.6	4140.2	4141.0
January	4141.6	4141.2	4142.0
February	4142.4	4142.1	4142.7
March	4142.8	4142.6	4143.0
April	4142.8	4142.6	4143.0
May	4142.4	4142.1	4142.7
June	4141.1	4140.7	4141.5
July	4140.1	4139.7	4140.5
August	4139.4	4139.0	4139.8
September	4139.1	4138.7	4139.5

Normalized 60-day average of net inflow to UKL:

Norm_uklinf_60avg = (uklinf_60avg – uklinf_min(-1)) / (uklinf_max(-1) – uklinf_min(-1))

where: uklinf_60avg = today's average of raw UKL net inflow for the past 60 days
uklinf_min(-1) = yesterday's minimum raw UKL net inflow for that day of the water year (dowy) across the POR
uklinf_max(-1) = yesterday's maximum raw UKL net inflow for that dowy across the POR

Adjustment of UKL central tendency:

Adj_uklcentral = ukltraj_central + (norm_uklinf_60avg – 0.5)

where: ukltraj_central = daily interpolated value for the central tendency
norm_uklinf_60avg = normalized 60-day average of net UKL inflow

The adjusted central tendency is used to signal the need for, and to quantify the magnitude of reduction in, releases from UKL. On any given day, if lake elevations are above the adjusted central tendency, then releases to the river or to the Project proceed unchanged from the delivery rules in the model. However, when UKL elevations are below the adjusted central tendency, Klamath River and Project (when applicable) releases are reduced by a magnitude commensurate with how far UKL is below the adjusted central tendency, which facilitates but does not force the return of UKL to a trajectory in line with the adjusted central tendency.

Release reductions occur based on a storage difference ratio. This ratio determines the magnitude of required reduction based on how far below the adjusted central tendency UKL sits; the further below the adjusted central tendency, the greater the percentage by which releases may be reduced. The storage difference ratio is updated every 5 days, meaning that an action taken on reduction (e.g., no reduction, reduction of 10%) will remain in effect for 5 days from the date of implementation. This was done to maintain operational feasibility of this approach. There are two different storage difference ratios in the model, one that is applied to Klamath River releases and one that is applied to Project releases.

LRD releases may be reduced by up to 80% from the daily calculated release and may be reduced at any time of the year; IGD minima for the Klamath River (as defined in the 2013 Biological Opinion) are still in effect and river flows cannot go below these values. Project releases may be reduced by up to 80% and these reductions can only occur to Project releases for fall/winter water deliveries, November through February, and releases to LKNWR in December through February. This reduction does not apply to the LKNWR transferred water right described in Section A.4.4.9 (additionally, see Section A.4.4.9 and in the Biological Assessment, Section 4.3.2.2.2.2 for additional information about delivery of Project Supply to LKNWR). Both storage difference ratios have an upper bound of 0, meaning that modeled releases will not increase if UKL elevations are above the adjusted central tendency. The lower bounds are -0.8 for LRD and fall/winter Project/LKNWR deliveries. The first step in calculating the storage difference ratio is to determine the volumetric difference between the current UKL elevation and the adjusted central tendency. This is done taking into account the UKL credit that has been accumulated, since this water is intended to remain in UKL (see Section A.4.4.1.2). Once this volumetric difference is determined, the ratio is created by dividing that volume by a volumetric "envelope" on UKL within which UKL may fluctuate. This envelope varies slightly throughout the year, from 20,000 AF to 60,000 AF, with intermediary values linearly interpolated. The broadest envelope (i.e., highest values) is allowed in the spring (Table 4.4.1.2.1.2), when demands on UKL are highest. As this value is used in the denominator of the storage difference ratio calculation (see below), the size of the envelope will dictate the increment by which the storage difference ratio may be applied to releases. A larger envelope value results in a more gradual implementation of adjustment before maximum adjustment is achieved; a smaller envelope value results more rapid increase in adjustment percentage as UKL elevations drop

below the central tendency. Table 4.4.1.1.2 and the following equations define the storage difference ratio:

Storage difference pre-adjustment:

Stor_diff_preadj = S1(-1) – prj_UKL_credit – adj_uklcentral_storage

where: S1(-1) = yesterday's UKL storage volume
prj_UKL_credit = accumulated credit volume in UKL (see Section A.4.4.1.2)
adj_uklcentral_storage = storage volume associated with today's adjusted central tendency

Table 4.4.1.1.2 UKL adjustment width for each day of the water year; values for intermediate days are linearly interpolated within KBPM.

Day of Water Year	UKL Adjustment Width (TAF)
1	20
124	20
152	60
212	60
227	20
366	20

Storage difference ratio:
Stor_diff_ratio = min (u_bound, max (l_bound, stor_diff_preadj / UKL_adj_width))

where: u_bound = upper bound of storage difference ratio
l_bound = lower bound of storage difference ratio
stor_diff_preadj = unadjusted storage difference ratio
UKL_adj_width = the UKL elevation "envelope" described above

It is important to note that the UKL control logic is not designed to utilize the adjusted central tendency line as a management target. Rather, it is part of an overall management scheme to ensure that needs of the UKL, Klamath River, and the Project are met in the majority of water years. The adjusted central tendency is one step in the process of setting spring/summer and fall/winter releases to the Klamath River from UKL and fall/winter releases to the Project from UKL. The other steps in this process are described in Sections A.4.4.2 and A.4.4.3.

A.4.4.1.2 Upper Klamath Lake Credit

In the 2013 BiOp, both LRDC accretions in excess of Project diversions and F/FF discharge to the Klamath River were included in the formulated IGD flow target. Both the current proposed action and the 2018 proposed action removed the IGD flow target reliance on these accretions and return flows during the irrigation season; to compensate for this, EWA will have a higher share of UKL Supply to provide IGD flows that were previously met by excess LRDC flow and F/FF pumping. These accretions and return flows will be shared between Project irrigators and UKL for mutual benefit. Irrigators can directly divert Lost River flow to the LRDC or F/FF

discharge and it does not count as a diversion of Project Supply. The LRDC flows and F/FF pumping in excess of direct diversion supports controlled IGD flow in lieu of LRD releases. This reduction in LRD release results in higher UKL storage, and the increment of higher storage is termed an Upper Klamath Lake Credit (UKL Credit).

A UKL Credit may be accrued only from March through September, while the EWA is in effect and releases at LRD and IGD are managed (i.e., not in flood operations). Flows from LRDC and F/FF must be in excess of concurrent agricultural diversions, meaning that those flows are potential irrigation water that is instead going to support IGD releases. High rainfall runoff events from the Lost River do not contribute to the UKL Credit. If UKL experiences flood spill during this time period, further UKL Credit cannot be accrued during spill; additionally, during flood control operations, UKL Credit will be considered the first UKL storage spilled.

The purpose of the UKL Credit is to hold water in UKL to facilitate the ability to establish a minimum Project Supply on April 1 with no later reduction, and the possibility of increase in subsequent May 1 and June 1 allocations. Accrual of UKL Credit ensures that there is a volume of water in UKL that can be drawn upon in the case of an early season over-forecast of seasonal inflow to UKL. However, any UKL Credit accrued in UKL above and beyond that necessary to ensure full delivery of Project Supply will remain in UKL to facilitate refill of the lake in the ensuing fall/winter period. There is no carryover of accrued UKL Credit from season to season.

UKL credit calculation:

Prj_UKL_credit = prj_UKL_credit(-1) + (C91_F_IG(-1) + C131_IG(-1) – C15_EXC(-1)) – D1(-1) – C1_AG(-1)

where: prj_UKL_credit(-1) = yesterday's UKL Credit amount
C91_F_IG(-1) = yesterday's LRDC contribution to IGD release
C131_IG(-1) = yesterday's F/FF contribution to IGD release
C15_EXC(-1) = yesterday's IGD flood release
D1(-1) = yesterday's A Canal diversion
C1_AG(-1) = yesterday's LRD release for agricultural diversion

EWA use includes the LRDC flow and F/FF discharge that goes downstream to support IGD releases in controlled flow situations.

A.4.4.2 Fall/Winter Operations

The fall/winter Project operational procedure distributes the available fall/winter UKL inflows between the following:

1. UKL
    a. Increase UKL elevation to meet ESA-listed habitat needs throughout the fall/winter period and the following spring/summer period and increase storage for spring/summer EWA releases and irrigation deliveries.
    b. This is achieved through the UKL control logic.

2. Klamath River

a. Release sufficient flow from IGD to meet ESA-listed species needs in the Klamath River downstream of IGD; this includes flows to support salmon spawning from October 1 – November 15.
b. This is achieved through the formulaic approach to calculating IGD targets.

3. Project:
    a. Klamath Drainage District (Area A2 – serviced by North Canal and Ady Canal)
    b. Lease Lands in Area K (within Area A2 – serviced by Ady Canal)
    c. LKNWR (serviced by Ady Canal)

Additionally, sufficient flood pool capacity must be maintained in UKL to protect the surrounding lake levees.

The fall/winter operations period begins on November 1 and ends on February 28/29. Note that there is often overlap between the spring/summer (see Section A.4.4.3 for details) and fall/winter operations in October and November because Area A1 and the LKNWR will likely divert a portion of the spring/summer Project Supply during these months, while EWA accounting ends on October 1. Spring/summer and fall/winter diversion accounts must be kept separate during the overlap period.

During the fall/winter season, the primary goal of operations is to refill UKL in order to support high demands on UKL in early spring, including the possibility of disease prevention/mitigation flows for the Klamath River, ensuring adequate spawning habitat for shoreline spring spawning suckers, and supporting the beginning of Project deliveries. To this end, a premium is placed on the fill rate needed to achieve a UKL elevation of 4,143 feet by the end of February. Note that this target elevation is utilized to calculate a refill trajectory that effectively refills UKL; flood control elevations will prevent UKL from reaching this elevation at the end of February (see Section A.4.4.10). In addition, KDD is provided a reserve supply of up to 28,910 AF between November 1 and February 28/29 via a state water right, and LKNWR is provided maintenance flows of up to 62 cfs/day, with a cap of 11,000 AF in total delivery volume from December through February. Both of these deliveries are subject to the UKL control logic, and so may be reduced based on hydrologic conditions. The remaining inflow to UKL is released to support Klamath River flows at IGD. IGD releases are heavily affected by the accretions downstream of Keno Reservoir. In wetter hydrologic patterns, or during periods immediately following lower-basin storms, the downstream accretions can account for a substantial portion of the flows downstream of IGD.

Following are instructions for implementing fall/winter operations.

Fall/winter releases from UKL for IGD flows are intended to support salmon spawning in October through November 15, and are determined by UKL net inflow and the fill trajectory of UKL thereafter. All KDD and LKNWR deliveries are calculated as shown below and subject the UKL control logic. No UKL credit can be accrued during the fall/winter season. Key model variables referenced throughout this document can be defined in Table A.4.3.4.1 found in Section A at the end of this document.

1. Lookup **Link_min**, which is the minimum flow release from LRD from Oct-Feb. Link River minima are only for modeling purposes and lower Link River flows may be observed in real-time operations. Note that it is operationally possible to reduce LRD flows below these flow minimums, but this requires Reclamation to conduct a fish stranding assessment below LRD (and possibly below Keno Dam). This requires additional personnel and other resources. Given these concerns, it is necessary to weigh the benefit of flows below LRD minimums against personnel and resource requirements for stranding assessments. See the Biological Assessment, section 4.3.2.2.1 for additional details.

Table A.4.4.2.1 Link River Dam minimum flow release; these discharges refer to cfs at Link River Dam, rather than the USGS gauge downstream.

Month	Link_min (cfs)
October	400
November	400
December	300
January	300
February	300

2. Determine IGD flow for the October – November 15 salmon spawning period, **IG_spawn_flow**. This flow determination begins with the lookup of **IG_spawn** flow value based on the normalized 60-day trailing average of net UKL inflow; this value is linearly interpolated between a minimum of 1000 cfs and a maximum 1200 cfs. To this base value, an additional 0 – 125 cfs may be added at intervals of about 10 days based on the 60-day trailing average of UKL net inflow and the date between October 1 and November 15; this is the **IG_spawn_inc**. On any given day during the time period:

IG_spawn_flow = IG_spawn + IG_spawn_inc

3. Calculate **Needed_fill_rate**, which is the average daily fill rate from yesterday's UKL level to attain 4143 ft. on February 28.

   Needed fill rate = (fill_target_approx_vol – S1(-1)) / (105 – (daynumDV(-1) – 47))

   where: fill_target_approx_vol = volume associated with an UKL elevation of 4143 ft. (534,502 AF);
   S1(-1) = yesterday's storage volume in UKL;
   daynumDV = the current day of the water year, numbered since October 1.

   Note: 105 is the number of days between November 16 and February 28 and 47 is the number of days from October 1 to November 16. This allows for a daily calculation of how much volume should be added to UKL between November 16 and February 28 if 4143 ft. in elevation is to be achieved.

4. Calculate **Link_release_FW**, which is the amount of water that should be released from LRD between October 1 and February 28/29 based on UKL net inflow, UKL filling trajectory, and accretions between LRD and IGD.

   a. First, **Link_release_FW_prep** is calculated, which is a release from LRD that is unadjusted by interaction with the UKL control logic. Flow releases in October –

November 15 depend on the IG_spawn_flow, which is implemented in the calculation of C15_target (see below), and so this period is omitted here. From November 16 through February, UKL net inflow is adjusted by 1.5 times the Needed_fill_rate.

November 16 – February 28/29:
Link_release_FW_prep = I1(-1) – (1.5 * Needed_fill_rate)

where: I1(-1) = yesterday's UKL net inflow

b. Then, Link_release_FW_prep is adjusted by an appropriate daily storage difference ratio, resulting in:
Link_release_FW = Link_release_FW_prep + (stor_diff_ratio5d * Link_release_FW_prep)

5. Establish **Link_max**, the maximum release possible from LRD, based on the UKL elevation. This is done by selecting the appropriate maximum release based on the associated UKL elevation from the lookup table **Link_max.table**. This value will limit how much water can possibly be released from UKL to support Klamath River, KDD, and LKNWR flows on any given day. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft, to a low of 900 cfs when UKL level is 4137.0 ft.

6. Determine the **Link_WF_target**, which is the maximum value of either Link_min or Link_release_FW.

7. Determine volumes of water needed to meet needs for KDD and LKNWR winter needs.

a. KDD has a winter water right for a volume of up to 28,910 AF. KDD daily deliveries are subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis as dictated by the UKL control logic. KDD daily deliveries (in cfs) are determined as follows:

D11_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctNorth
D12A_fw_calc_no_UKL_ctrl = min (200 cfs, KDDReserve) * pctAdy

where: KDDReserve = remaining amount of unused state water right, converted to cfs in this calculation
pctNorth = percentage of delivery to be put down North Canal, based on water year type
pctAdy = percentage of delivery to be put down Ady Canal, based on water year type

D11_fw_calc_no_UKL_ctrl and D12A_fw_calc_no_UKL_ctrl are both subject to an appropriate UKL control adjustment.

b. LKNWR can receive up to 62 cfs/day via Ady Canal from December 1 through February, up to a total volume of 11,000 AF. These deliveries are also subject to UKL control logic and can be reduced by an appropriate percentage on a daily basis.

8. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here):

Table A.4.4.2.2 Minimum Flow Below Iron Gate Dam, October to February

Month	IG_MIF (cfs)
October	1000
November	1000
December	950
January	950
February	950

9. Set **C1forC15**, the LRD release to support IGD flows. For the fall/winter period, this is equal to Link_WF_target.

10. Calculate **C15_target**, which is the targeted release at IGD. From October 1 through November 15, this target is IG_spawn_flow + stor_diff_ratio5d * IG_spawn_flow. This calculation relies upon operational values from 3 days prior (the operational delay accounted for in the model) and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values, flood control operations, and/or other facility operational emergencies and malfunctions.

    C15_target = C1forC15 + I10(-3) + I15_forecast2(-3) + (C131(-3) + max (C91_F(-3) – D11_ss_LRDC(-3) – D12A_ss_LRDC(-3) – D12B_LRDC(-3), 0))

    where: I10 = Link River Dam to Keno Dam accretions;
    I15_forecast2 = forecasted Keno Dam to Iron Gate Dam accretions;
    C131 = F/FF discharge;
    C91_F = LRDC flows toward the Klamath River;
    D11_ss_LRDC = North Canal diversion of LRDC return flow;
    D12A_ss_LRDC = Ady Canal diversion of LRDC return flow to ag;
    D12B_LRDC = Ady Canal diversion of LRDC return flow to LKNWR;
    (-3) = operational lag of three days assumed in the model.

A.4.4.3 Spring/Summer Operations

The Project irrigation season runs from March 1 through October 31, although irrigation can continue through November 15 in areas served by D91. The previous section described the fall/winter operations which are the first half of each water year. This section describes the second half of each water year, which covers the irrigation season. The irrigation season operations are controlled by defining the available UKL Supply (WRIMS variable name UKLSupply), which is computed from storage in UKL, forecasted March-September inflow, and target carryover storage. Division of this supply between the Klamath River (EWA_river) and Project (PrjSupply) is dependent on the size of UKL Supply (described below). Any UKL inflow that is not delivered or released for flow will remain in UKL as storage. All water which leaves UKL through either LRD or the A Canal is accounted for against one of these two identified volumes; this includes flood control releases with the exception of spill of UKL credit. LKNWR can receive a portion of the Project Supply or other delivery from UKL. Details for these operations are included in the sections below.

Project Supply and Environmental Water Account for Klamath River Flows
Both volumes are calculated on March 1 and April 1 with updates on May 1 and June 1. The March and April processes divide up the UKL Supply to help the irrigators and river managers plan out the spring/summer operational period. The May and June processes manage the change in supply by adjusting the volumes. The steps for determining the Project Supply and the EWA are below. Key model variables referenced throughout this section can be found in Table A.4.3.4.1 at the end of this Appendix 4-1.

1. Calculate **UKLSupply.** The UKL supply is updated on the 1st of each month March through June using the most current forecasted net inflow, the end of February storage and the end of September target. This formula is as follows (all values in TAF):

   UKLSupply = [End of February UKL Storage] + [50% exceedance forecast UKL inflow for March through September] – [End of September UKL Storage Target]

   a. The end of February UKL storage is simply the storage in UKL as determined on the last day of February. This is determined using the UKL weighted mean average elevation as determined by USGS for that date along with the elevation-storage table included as Table A.4.4. 11.1 found at the end of this Appendix.

   b. The forecasted UKL net inflow for March through September changes each month from March through June. The formulas used for this variable (called **Mar50vol** in the model code) are as follows:
      i. March = [March 1st 50% exceedance probability forecast for UKL net inflows for March through September]
      ii. April = [April 1st 50% exceedance probability forecast for UKL net inflows for April through September] + [Actual net inflows that occurred in March]
      iii. May = [May 1st 50% exceedance probability forecast for UKL net inflows for May through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April]
      iv. June = [June 1st 50% exceedance probability forecast for UKL net inflows for June through September] + [Actual net inflows that occurred in March] + [Actual net inflows that occurred in April] + [Actual net inflows that occurred in May]

   c. The **End of September UKL Storage Target** is determined each month, March through June, and is dependent on the end of September UKL central tendency (4139.1 ft), the end of September high and low central tendency increments (0.4 ft), and Mar50vol as defined above. The lowest end of September storage target is 4138.7 ft (central tendency minus the low increment) and the highest end of September storage target is 4139.5 ft (the central tendency plus the high increment). The end of September storage target equals the low target (4138.7 ft) if Mar50vol is equal to or less than the lowest Mar50vol in the simulated period of record (160,000 AF). The end of September storage target equals the high target (4139.5 ft) if Mar50vol is equal to or greater than the highest Mar50vol in the simulated period of record (1,316,258 AF). For any Mar50vol in

between 160,000 AF and 1,316,258 AF, the end of September storage target is linearly interpolated as follows:

i. Target = 4138.7 + 0.8*(Mar50vol – 160)/1156.258 when Mar50vol > 160,000 AF and Mar50vol < 1,316,258 AF.
ii. The elevation target is converted to TAF for use in the UKL supply formula with the elevation-storage table included as Table A.4.4. 11.1 found at the end of this Appendix.

2. Calculate Klamath River flow augmentation volume.

In the 2019 Biological Opinion, on April 1 when the EWA_River was above the minimum of 400,000 AF but below 575,000 AF, an additional 20,000 AF was provided to augment flows released from Iron Gate Dam during May and June. Under these specific conditions, the variable MayJuneAugment was set to a value of 20,000 AF (zero otherwise). This volume was not added to the EWA_River until July 1, because it was augmenting the normally computed daily flow, and was therefore managed to be fully expended by the end of June. Sixty percent of this volume augmented May flow releases, and 40% augmented June releases, with the daily augmentation volume distributed uniformly within each month. In the 2020 Proposed Action, this augmentation scheme was replaced by the Flexible Flow Augmentation approach.

In the Flexible Flow Augmentation approach as implemented in the KBPM, a volume of water to be dedicated to augmenting Klamath River flow from Project Supply (**PRJ_FlexAugment**) and UKL (**UKL_FlexAugment**) was specified across a range of UKL Supply from 550,000 AF to 950,000 AF (Figure A.4.4.3.1). As discussed in section A.4.4.7 *Surface Flushing Flows*, both the volume of water dedicated to flexible augmentation, and the decision whether to implement a surface flushing flow in the KBPM depended on UKL Supply on March 1 and April 1.

If March 1 UKL Supply < 815,000 AF, or if April 1 UKL Supply < 750,000 AF, then the year was categorized as SFF Status 1, a surface flushing flow was forced, and the flexible augmentation volume was specified according to Figure A.4.4.3.1-A. In these years, both UKL_FlexAugment and PRJ_FlexAugment were 10,000 AF when UKL Supply was 550,000 AF. UKL_FlexAugment was a constant 10,000 AF as UKL Supply increased to 825,000 AF, above which UKL_FlexAugment declined linearly to zero at a UKL Supply of 950,000 AF. PRJ_FlexAugment increased linearly from 10,000 AF when UKL Supply was 550,000 AF to a maximum value of 30,000 AF when UKL Supply was 650,000 AF, and remained at 30,000 AF until UKL Supply was 825,000 AF, above which it declined linearly to zero when UKL Supply was 950,000 AF. There is no augmentation when UKL Supply is greater than 950,000 AF.

If the UKL Supply on March 1 ≥ 815,000 AF and < 904,000 AF, or if the UKL Supply on April 1 ≥ 750,000 AF and < 904,000 AF, the year was categorized as SFF Status 2, a surface flushing flow was not implemented, and the flexible augmentation volume was specified according to Figure A.4.4.3.1-B. In these years, both UKL_FlexAugment and PRJ_FlexAugment were 10,000 AF across a UKL Supply range of 550,000 AF to 825,000

AF, above which both augmentation variables linearly declined to zero when UKL Supply was 950,000 AF. Also, in these years 20,000 AF of existing EWA volume was allowed to be used flexibly to further augment spring flows. Note that 904,000 AF corresponds to an EWA of 575,000 AF, which was the upper threshold for the May-June augmentation that was implemented in the 2019 Biological Opinion.

When UKL Supply ≥ 904,000 AF on March 1 or April 1 (the value on April 1 is the final determination of SFF Status and flexible augmentation), the year was categorized as SFF Status 3, an opportunistic SFF was implemented if conditions met the applicable criteria (*see* section A.4.4.7 *Surface Flushing Flows*), and the flexible augmentation volume was determined as in Figure A.4.4.3.1-A.

Finally, in years when deep flushing flows are achieved during the December through April period, it will serve as the SFF for that given water year.

PRJ_FlexAugment and UKL_FlexAugment are first computed on March 1, and then again on April 1 to determine the final volume, after which they do not change. Section A.4.4.6 describes how these augmentation volumes are disaggregated to calculate the variable **FlexFlowAdjust**, which is the amount by which daily Klamath River flow is augmented.

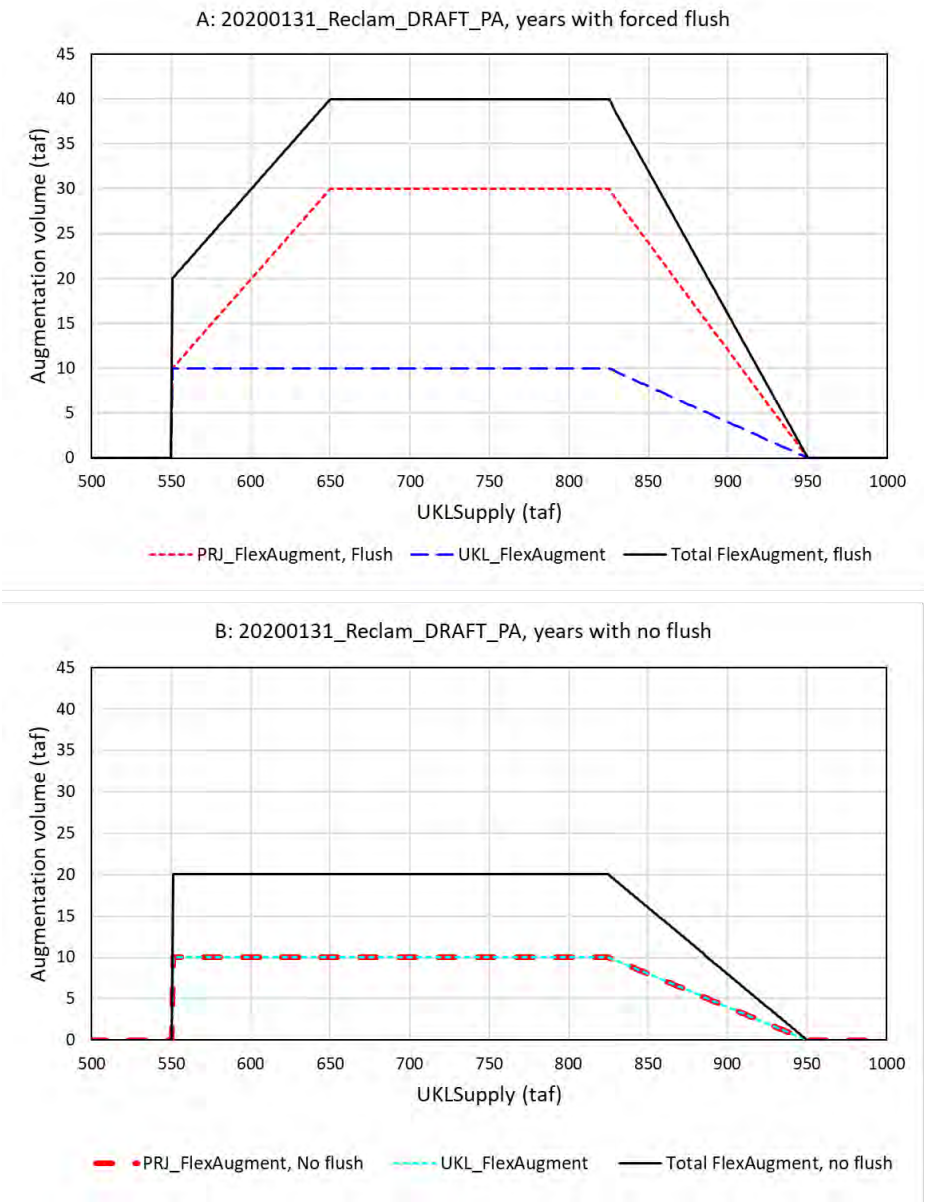


Figure A.4.4.3.1. Flexible Flow Augmentation volumes specified across a range of UKL Supply for years with a forced flush (SFF Status 1; plot A) or an opportunistic flush (SFF Status 3; plot A), and for years without a forced flush (SFF Status 2; plot B).

3. Calculate **EWA_River** as a portion of UKLSupply.

   a. When UKLSupply is greater than 1,035,000 AF, EWA_River includes all UKLSupply above the project supply maximum (UKLSupply – 350,000).

   b. When UKLSupply is less than 671,000 AF, EWA_River is at the EWA minimum of 400,000 AF. If **PRJ_FlexAugment** or **UKL_FlexAugment** exceeds zero, then the sum of the two variables is added to EWA_River on July 1, after all of the augmentation volume has been expended. Note that in SFF Status 2 years, the 20,000 AF of existing EWA that is allowed to be used flexibly during the spring is not added to EWA_River on July 1.

   c. During the months from March through June, when UKLSupply is between 671,000 AF and 1,035,000 AF, EWA_River is calculated as:

      EWA_River = 0.00029127 * UKLSupply^2 + 0.29190568 * UKLSupply + 73.17532589

   d. On July 1, the total flexible flow augmentation volume (if any) is added to the EWA_River from June:

      $EWA_River = EWA_River_{June} + PRJ_FlexAugment + UKL_FlexAugment$

   e. In even years (e.g., 2020, 2022), EWA_River is further increased by 7,000 AF to cover releases for the Yurok Boat Dance ceremony.

4. Calculate the **Project Supply.**

   a. The maximum Project Supply (**PrjSupply**) is 350,000 AF. Maximum Project Supply occurs when UKLSupply is greater than 1,035,000 AF.

   b. In the 2019 Biological Opinion, when UKLSupply was less than 1,035,000 AF, Project Supply = UKLSupply – EWA_River – 0.5*MayJuneAugment. Half of the MayJuneAugment volume was accounted for by removing it from the Project Supply, whereas the other half reduced UKL storage below what it would otherwise have been. In this 2020 PA, the Project Supply calculation has been changed to:

      PrjSupply = UKLSupply – EWA_River – PRJ_FlexAugment

   c. In May and June, Project Supply can increase or decrease, but cannot be reduced below the April 1 allocation.

   d. The final determination for Project Supply is made in June and is then fixed through the end of September.

A.4.4.4. Agricultural Water Delivery Sub-model

A.4.4.4.1. Methods

Delivery of irrigation water to agriculture during the spring/summer operational period was simulated using methods that produced realistic patterns of water delivery. Diversion data for the POR from March 1, 1980 through November 15, 2016 (Dunsmoor 2017a) was used to develop the agricultural delivery sub-model. During this time frame, the Project experienced a wide variety of conditions, including periods of essentially unconstrained diversion, periods of moderate to severe diversion constraints, and wet or dry conditions in single years and over sequences of multiple years. Of particular note are years in which regulatory actions changed irrigation patterns so substantially that the historical data was deemed to be unusable for sub-model development. Included in this category are the years 2001 (irrigation shutoff until July), 2010 (extremely late start, irrigation started in mid-May), and 2014-2015 (Ady Canal shutoff for significant portions of both summer irrigation seasons). Accordingly, these years were excluded from the data sets used to develop the sub-model. In addition, 3 test years (1991, 1998, and 2003) were randomly selected, excluded from model derivation, and reserved for evaluating the predictive capability of the final sub-model (James et al. 2013).

The sub-model was structured around 5-day periods within an irrigation water year, which extends from March 1 through the end of February and is comprised of 73 five-day periods (period 73 has 6 days in leap years; Table A.4.4.4.1.1). Period 49 ends on October 31, encompassing the season-of-use for D1, and the summer season-of-use for D11 and D12A. Period 52 ends on November 15, encompassing the season-of-use for D91.

Summing historical delivery volumes (in TAF) across the season-of-use for all 4 diversion arcs yielded what is called Total A, which represents the total water volume diverted during the spring/summer operational period from all surface water sources. In the development of these sub-models, Total A was the sum of deliveries from UKL and deliveries made from the inflow measured at the LRDC headworks at Lost River Diversion Dam.

Historical daily diversion data for years that were not excluded from model development were divided by Total A diversions for each year. The resulting proportions were multiplied by 100, and these percentages were summed within each 5-day period across periods 1-49 for diversion arcs D1, D11, and D12A, and periods 1-52 for diversion arc D91. For each diversion arc, models were fitted to these percentages of Total A diversions, which were subsequently used in the KBPM to estimate the percentage of Total A diversions to be delivered in each timestep (i.e. the irrigation pattern).

Irrigation patterns in any given 5-day period were deemed likely to be influenced by a number of factors, including precipitation, temperature, crop type and distribution, overall water availability, and prior irrigation. Crop type and distribution were eliminated from further consideration because insufficient data were available across the POR. The remaining variables were prepared for use in the sub-model development as follows.

Table A.4.4.4.1.1. Beginning and ending days of 5-day periods within the irrigation water year.

5-day period	First day	Last day		5 day period	First day	Last day		5 day period	First day	Last day
1	1-Mar	5-Mar		26	4-Jul	8-Jul		51	6-Nov	10-Nov
2	6-Mar	10-Mar		27	9-Jul	13-Jul		52	11-Nov	15-Nov
3	11-Mar	15-Mar		28	14-Jul	18-Jul		53	16-Nov	20-Nov
4	16-Mar	20-Mar		29	19-Jul	23-Jul		54	21-Nov	25-Nov
5	21-Mar	25-Mar		30	24-Jul	28-Jul		55	26-Nov	30-Nov
6	26-Mar	30-Mar		31	29-Jul	2-Aug		56	1-Dec	5-Dec
7	31-Mar	4-Apr		32	3-Aug	7-Aug		57	6-Dec	10-Dec
8	5-Apr	9-Apr		33	8-Aug	12-Aug		58	11-Dec	15-Dec
9	10-Apr	14-Apr		34	13-Aug	17-Aug		59	16-Dec	20-Dec
10	15-Apr	19-Apr		35	18-Aug	22-Aug		60	21-Dec	25-Dec
11	20-Apr	24-Apr		36	23-Aug	27-Aug		61	26-Dec	30-Dec
12	25-Apr	29-Apr		37	28-Aug	1-Sep		62	31-Dec	4-Jan
13	30-Apr	4-May		38	2-Sep	6-Sep		63	5-Jan	9-Jan
14	5-May	9-May		39	7-Sep	11-Sep		64	10-Jan	14-Jan
15	10-May	14-May		40	12-Sep	16-Sep		65	15-Jan	19-Jan
16	15-May	19-May		41	17-Sep	21-Sep		66	20-Jan	24-Jan
17	20-May	24-May		42	22-Sep	26-Sep		67	25-Jan	29-Jan
18	25-May	29-May		43	27-Sep	1-Oct		68	30-Jan	3-Feb
19	30-May	3-Jun		44	2-Oct	6-Oct		69	4-Feb	8-Feb
20	4-Jun	8-Jun		45	7-Oct	11-Oct		70	9-Feb	13-Feb
21	9-Jun	13-Jun		46	12-Oct	16-Oct		71	14-Feb	18-Feb
22	14-Jun	18-Jun		47	17-Oct	21-Oct		72	19-Feb	23-Feb
23	19-Jun	23-Jun		48	22-Oct	26-Oct		73	24-Feb	29-Feb
24	24-Jun	28-Jun		49	27-Oct	31-Oct				
25	29-Jun	3-Jul		50	1-Nov	5-Nov				

Precipitation and temperature variables were developed from data obtained from the PRISM Climate Group. PRISM (Parameter-elevation Relationships on Independent Slopes Model) is an interpolation method that estimates precipitation and temperature variables at gridded locations across the conterminous United States based on measurements from a large network of meteorological stations (Daly et al., 2008). Daily time series of maximum temperature (°F) and precipitation (inches) were downloaded (http://prism.oregonstate.edu/explorer/) for 9 randomly selected 4-kilometer grids (Figure A.4.4.4.1.1) for the period from 1/1/1981-11/30/2016. Daily data for the same variables for the period from 3/1/1980-12/31/1980 were downloaded from the National Climatic Data Center, Climate Data Online (https://www.ncdc.noaa.gov/cdo-web/) for three stations (Figure A.4.4.4.1.1): Tulelake, CA (Station USC00049053), Malin 5 E, OR (Station USC00355174), and Klamath Falls 2SSW (Station USC00354506). Mean daily maximum temperature and precipitation were computed for the Project area across either 9

PRISM grids or 3 meteorological stations for the time spans described above. Then total precipitation and average maximum temperature were computed for each 5-day period in each irrigation water year; these variables were named ppt_p and $tmax_p$, where p is the 5-day period.

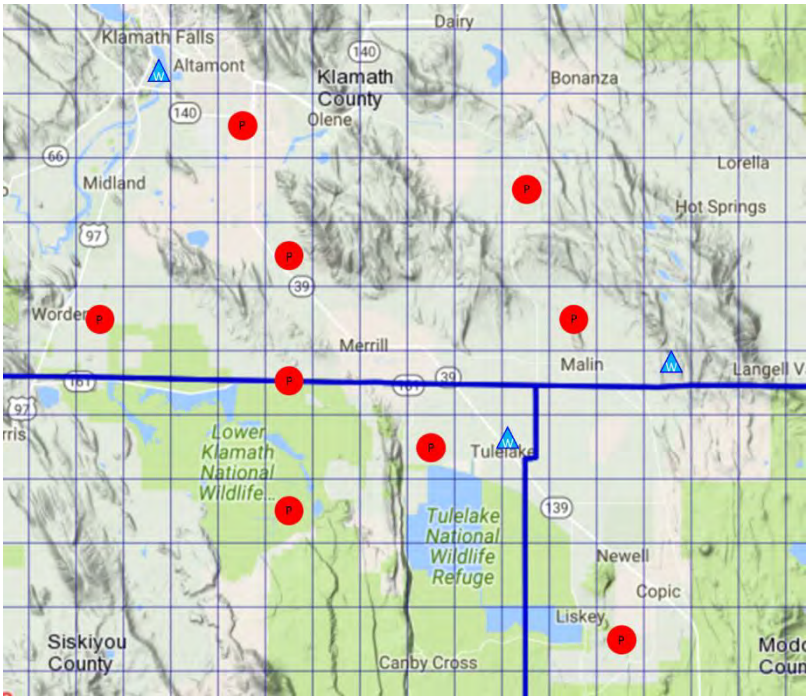


Figure A.4.4.4.1.1. PRISM grid (circles) and weather station (triangles) locations used to compute Project area precipitation and temperature variables.

In addition to using precipitation and maximum temperature variables individually, they were also combined into a single variable. Each was normalized (re-scaled to range between 0 and 1), based on the values of these variables over the period-of-record used in this analysis. For each variable, $x_{p_{norm}}$ was computed as:

$$x_{p_{norm}} = \frac{x_p - x_{p_{min}}}{x_{p_{max}} - x_{p_{min}}}$$

where p is the 5-day period, and p_{min} (p_{max}) is the minimum (maximum) value of the variable for period p across the period-of-record.

Then the normalized maximum temperature $tmax_{p_{norm}}$ was subtracted from 1, so that it ranged from warmest (0) to coolest (1) in a manner complementary to normalized precipitation $ppt_{p_{norm}}$, which ranged from driest (0) to wettest (1). These two normalized variables were combined into one, called the $ptdayindex_p$:

$$ptdayindex_p = ppt_{p_{norm}} + \left(1 - tmax_{p_{norm}}\right)$$

The $ptdayindex_p$ can range from 0 (warm and dry) to 2 (cool and wet).

Variables that summarized winter precipitation and water deliveries were also developed. Total precipitation (inches) and total water deliveries (TAF) through D11 and D12A arcs over the period from December – February preceding each irrigation water year ($cumpptwint_{y-1}$, $cumd11wint_{y-1}$, and $cumd12awint_{y-1}$, respectively) captured the influence of winter precipitation and delivery on the pattern of early season diversions. For use in models for the D11 and D12A diversion arcs, these variables were also normalized (see above; across irrigation water years instead of periods) and combined into $pdindexd11_{y-1}$ and $pdindexd12a_{y-1}$:

$$pdindexd_{_y-1} = cumpptwint_{y-1_{norm}} + cumd_wint_{y-1_{norm}}$$

where y-1 is the previous irrigation water year, and $d_$ denotes either delivery arc D11 or D12A. Finally, the variable d_taf_p is the volume (TAF) of deliveries made in each 5-day period, where $d_$ denotes either delivery arc D11 or D12A.

Anticipated differences in pattern of water use in years with restricted supplies were captured by classifying such years as being water-short, and using a dummy variable (water-short = 1, not water-short = 0) to represent this effect in the models. For model development, data on snow-water-equivalent and Total A diversions was used to classify irrigation water year-type. Daily snow-water-equivalent (SWE; inches) data was downloaded from the NRCS Report Generator site (https://wcc.sc.egov.usda.gov/reportGenerator/) for the following sites: Fish Lake, Billie Creek Divide, Fourmile Lake, Cold Springs Camp, Sevenmile Marsh, Diamond Lake, Chemult Alternative, Silver Creek, Taylor Butte, Summer Rim, Quartz Mountain, and Strawberry. The daily average SWE at these sites was computed, from which the maximum SWE for the March-April period was computed for each year. An irrigation water year was classified as water-short if the maximum SWE for March-April was less than the median of that variable for the period from 1981-2016, and if the Total A diversion was less than the median for that same time period. Irrigation water years designated as being water-short based on these criteria included: 1992, 1995, 2001, 2003, 2005, 2010, 2013, 2014, and 2015.

An information-theoretic approach coupled with model averaging techniques (Burnham and Anderson 2002; Anderson 2008) were applied to a sequence of Ordinary Least Squares (OLS) regressions (the model set) predicting the percent delivery of Total A diversions for each 5-day period and delivery arc. In this approach, multiple models were hypothesized *a priori* (the model set), and the OLS results were used to quantify and formally evaluate the relative strength of evidence for each competing hypothesis in the model set. A single, final model for each delivery arc and 5-day period was produced by averaging the model parameters across all models, weighted by the model probabilities.

Model sets were nearly identical for the diversion arcs D1 and D91 (Table A.4.4.4.1.2). Historical D1 deliveries never started before period 6 (Mar 26-30), which is why no models were applied to prior periods for D1, whereas D91 delivery models begin in period 1. D1 delivery models extend through period 49 (through Oct 31), and D91 models extend through period 52 (through Nov 15). Model sets were also nearly identical for the diversion arcs D11 and D12A (Table A.4.4.4.1.3), for which delivery models extend through period 49. Model sets were dissimilar between these pairs of arcs, however, reflecting the differences in how irrigation is managed between the areas served by these arcs.

Table A.4.4.4.1.2. Model sets for the D1 and D91 delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d_*, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (March-February) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as *β*.

Model	Model description	Model notation	Periods for D1	Periods for D91
1	delivery %	$\beta_0 + \beta_1 d_pcta_{p-1}$	7-49	2-52
2	delivery % + precipitation	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_2 ppt_{p-1}$	7-49	2-52
3	delivery % + warmth	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_3 tmax_{p-1}$	7-49	2-52
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_4 ptdayindex_{p-1}$	7-49	2-52
5	delivery % + short supply	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_5 shortdum_y$	7-49	2-52
6	delivery % + winter precipitation	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_6 cumpptwint_{y-1}$	7-18	2-18
7	winter precipitation + short supply	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_5 shortdum_y$	6	1
8	winter precipitation + (precipitation & warmth)	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_4 ptdayindex_{p-1}$	6	1
9	winter precipitation + warmth	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_3 tmax_{p-1}$	6	1
10	winter precipitation + precipitation	$\beta_0 + \beta_6 cumpptwint_{y-1} + \beta_2 ppt_{p-1}$	6	1

The arcs in Area A1 (D1 and D91) use irrigation water (nearly) exclusively during the growing season, whereas the arcs in Area A2 divert water extensively during the winter, when it is available, as well as during the growing season. Therefore, the variables influencing diversion patterns in the early periods differ between areas. In Area A1, winter precipitation and recent temperature were thought to be the most likely determinants of the delivery pattern, as modified by short supplies in some years, in the earliest period (models 7-10 in Table A.4.4.4.1.2). Similarly, the first period was thought to be influenced by delivery volume in the previous period, as well as by winter diversion volume, winter precipitation totals, or both (models 9-12 in Table A.4.4.4.1.3). Effects of winter precipitation were expected to be influential through period 18 in Area A1 (model 6 in Table A.4.4.4.1.2), and its influence coupled with that of winter diversion volume was expected to affect diversion patterns through period 18 in Area A2 (models 6-8 in Table A.4.4.4.1.3).

For the remainder of the growing season, delivery patterns in Areas A1 and A2 were thought to be influenced by the same variables, namely prior diversion, precipitation, and temperature, as modified by the effects of short supply (models 1-5 in Tables A.4.4.4.1.2 and A.4.4.4.1.3).

Period-specific variables used in models were lagged to the prior period, reflecting the potential desire to use the result of this modeling effort in operations. By lagging to previous time periods, no information is used to forecast the percent delivery of Total A diversions in period *p* that would not be available in real-time water management. The sole exception is the reliance in this analysis on the historical percentage of Total A diversion delivered through a diversion arc in the previous time period. While appropriate in terms of using the results of this analysis in the KBPM, which simulates years that have already been experienced, operationally an estimate of Total A diversions would be needed to compute the percentage of Total A diversions delivered in the prior time step. Since in this analysis these percentages were computed from historical data, Total A was known, but operationally Total A would have to be estimated, which would inject more error into the resulting estimates of delivery pattern than is present in this analysis.

Table A.4.4.4.1.3. Model sets for the D11 and D12A delivery arcs. In the model notation column, 5-day periods of the irrigation water year are denoted by *p*, and variables lagged to the prior 5-day period are denoted by the subscript *p*-1. Diversion arcs are specified by *d_*, where _ would be either 1 or 91 as appropriate to the delivery arc being modeled. Irrigation water year (Mar-Feb) is denoted by *y*, with *y*-1 referring to winter conditions in the prior irrigation water year. OLS regression coefficients are denoted as *β*.

Model	Model description	Model notation	Periods for D11 and D12A
1	delivery %	$\beta_0 + \beta_1 d_pcta_{p-1}$	2-49
2	delivery % + precipitation	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_2 ppt_{p-1}$	2-49
3	delivery % + warmth	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_3 tmax_{p-1}$	2-49
4	delivery % + (precipitation & warmth)	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_4 ptdayindex_{p-1}$	2-49
5	delivery % + short supply	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_5 shortdum_y$	2-49
6	delivery % + winter diversion	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_6 cumd_wint_{y-1}$	2-18
7	delivery % + winter precipitation	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_7 cumpptwint_{y-1}$	2-18
8	delivery % + (winter delivery & precipitation)	$\beta_0 + \beta_1 d_pcta_{p-1} + \beta_8 pdindexd_{}_{y-1}$	2-18
9	delivery volume + winter diversion	$\beta_0 + \beta_9 d_taf_{p-1} + \beta_6 cumd_wint_{y-1}$	1
10	delivery volume + winter precipitation	$\beta_0 + \beta_9 d_taf_{p-1} + \beta_7 cumpptwint_{y-1}$	1
11	delivery volume + (winter delivery & precipitation)	$\beta_0 + \beta_9 d_taf_{p-1} + \beta_8 pdindexd_{}_{y-1}$	1
12	delivery volume	$\beta_0 + \beta_9 d_taf_{p-1}$	1

OLS regressions were performed using Stata 15 software (StataCorp 2017; regress command). Individual regressions were restricted to no more than 2 variables to avoid overfitting (Babyak,

2004). After removing the excluded and test years from the analysis, sample size within each 5-day period was 29 for those models using the variable *cumpptwint* (which was not computed for 1980), and 30 for all other models. Adequacy of OLS regressions was assessed following guidance in StataCorp (2017), Sheather (2009), and Hyndman and Athanasopoulos (2014). Residual normality was evaluated graphically (Stata commands: qnorm and pnorm); serious deviation from residual normality was rare, confined mostly to the earliest 5-day periods in which 0% deliveries were common. Multicollinearity among predictor variables was evaluated using variance inflation factors (Stata command: estat vif), which never exceeded 2.3 in any of the delivery arcs. Autocorrelation plots and Durbin's alternative test for serial correlation (Stata commands: acf and estat durbinalt, respectively) assessed serial autocorrelation across years within each 5-day period; it was rarely detected. Finally, plots of residuals vs. predicted y and residuals vs. predictors were examined for inappropriate patterns reflecting heteroskedasticity or non-linearity.

Using the equations described in Burnham et al. (2011), and following the admonitions of Burnham and Anderson (2002), the following series of calculations quantified the relative performance of models used to estimate the percentage of Total A deliveries for each diversion arc, culminating in a single model-averaged predictive equation for each diversion arc in each 5-day period. Specifically, for each 5-day period (p = 1, 2, … , P), and model (m = 1, 2, … , M), the corrected Akaike Information Criterion $AIC_{c_{p,m}}$ was computed as:

$$AIC_{c_{p,m}} = -2lnL_{p,m} + 2K_{p,m} + \frac{2K_{p,m}(K_{p,m}+1)}{n_{p,m} - K_{p,m} - 1}$$

where K is the number of estimable parameters, which includes the intercept, slope parameters, and the residual variance, ln$L$ is the maximized log-likelihood of the model, and n is sample size. Then the $\Delta_{p,m}$ was computed as:

$$\Delta_{p,m} = AIC_{c_{p,m}} - AIC_{c_{p,min}}$$

where $AIC_{c_{p,m}}$ is the AIC_c for model m in 5-day period p, and $AIC_{c_{p,min}}$ is the minimum AIC_c for period p, which is to say it is the best model for that period in that it minimizes the Kullback-Leibler (K-L) information loss (see Burnham and Anderson, 2002 for a complete explanation). $\Delta_{p,m}$ directly quantifies the K-L information loss of model m relative to the best model in the model set, and so provides a valid basis for ranking models and computing Akaike weights, which were calculated as:

$$w_{p,m} = \frac{exp(-0.5\Delta_{p,m})}{\sum_{m=1}^{M} \quad exp(-0.5\Delta_{p,m})}$$

Once the Akaike weights were obtained, they were used to compute weighted averages of the OLS coefficients for each variable in the model set using:

$$\underline{\hat{\beta}}_p = \sum_{m=1}^{M} w_{p,m}\hat{\beta}_{p,m}$$

where $\underline{\hat{\beta}}_p$ is the model averaged coefficient, and $\hat{\beta}_{p,m}$ is the coefficient estimated by OLS for the *m*th model in period *p*.

To make the model-averaged prediction for each period, the Akaike weights were used to compute weighted averages of the OLS predictions of the percentage of Total A delivery for the models within each period:

$$\underline{\hat{Y}}_p = \sum_{m=1}^{M} w_{p,m}\hat{Y}_{p,m}$$

where $\underline{\hat{Y}}_p$ is the model-averaged prediction, and $\hat{Y}_{p,m}$ is the OLS estimate of *y*.

Finally, the Akaike weights were used to compute the unconditional (that is, not conditioned on any single model) standard error of the model-averaged predictions for each period using:

$$SE(\underline{\hat{Y}}_p) = \sqrt{\sum_{m=1}^{M} w_{p,m}\left(var(\hat{Y}_{p,m}) + \left(\hat{Y}_{p,m} - \underline{\hat{Y}}_p\right)^2\right)}$$

where $SE(\underline{\hat{Y}}_p)$ is the unconditional standard error of the model-averaged predictions for period *p*, $var(\hat{Y}_{p,m})$ is the variance of the OLS estimate for model *m* in period *p*, and $\hat{Y}_{p,m}$ is the OLS estimate for model *m* in period *p*.

A.4.4.4.2. Results and Discussion

Based on model ranking and error analysis procedures, details of which are provided after the results below, a final model-averaged equation predicting the percent of Total A (the total water volume diverted during the spring/summer operational period from all surface water sources) to be delivered in any given period was developed for each diversion arc:

$$\widehat{d1pcta}_p = \underline{\hat{\beta}}_{0,p} + \underline{\hat{\beta}}_{1,p}d1pcta_{p-1} + \underline{\hat{\beta}}_{2,p}ppt_{p-1} + \underline{\hat{\beta}}_{3,p}tmax_{p-1} + \underline{\hat{\beta}}_{4,p}ptdayindex_{p-1} + \underline{\hat{\beta}}_{5,p}shortdum_y + \underline{\hat{\beta}}_{6,p}cumpptwint_y$$

$$\widehat{d91pcta}_p = \underline{\hat{\beta}}_{0,p} + \underline{\hat{\beta}}_{1,p}d91pcta_{p-1} + \underline{\hat{\beta}}_{2,p}ppt_{p-1} + \underline{\hat{\beta}}_{3,p}tmax_{p-1} + \underline{\hat{\beta}}_{4,p}ptdayindex_{p-1} + \underline{\hat{\beta}}_{5,p}shortdum_y + \underline{\hat{\beta}}_{6,p}cumpptwint_y$$

$$\widehat{d11pcta}_p = \underline{\hat{\beta}}_{0,p} + \underline{\hat{\beta}}_{1,p} d11pcta_{p-1} + \underline{\hat{\beta}}_{2,p} ppt_{p-1} + \underline{\hat{\beta}}_{3,p} tmax_{p-1} + \underline{\hat{\beta}}_{4,p} ptdayindex_{p-1} + \underline{\hat{\beta}}_{5,p} shortdum_y + \underline{\hat{\beta}}_{6,p} cumd11wint_{y-1} + \underline{\hat{\beta}}_{7,p} cumpptwint_y + \underline{\hat{\beta}}_{8,p} pdindexd11_{y-1} + \underline{\hat{\beta}}_{9,p} d11taf_{p-1}$$

$$\widehat{d12apcta}_p = \underline{\hat{\beta}}_{0,p} + \underline{\hat{\beta}}_{1,p} d12apcta_{p-1} + \underline{\hat{\beta}}_{2,p} ppt_{p-1} + \underline{\hat{\beta}}_{3,p} tmax_{p-1} + \underline{\hat{\beta}}_{4,p} ptdayindex_{p-1} + \underline{\hat{\beta}}_{5,p} shortdum_y + \underline{\hat{\beta}}_{6,p} cumd12awint_{y-1} + \underline{\hat{\beta}}_{7,p} cumpptwint_y + \underline{\hat{\beta}}_{8,p} pdindexd12a_{y-1} + \underline{\hat{\beta}}_{9,p} d12ataf_{p-1}$$

Predicted values from these equations in the years used to fit the models are plotted against the historical values in Figures A.4.4.4.2.1 through A.4.4.4.2.4. The results from the model-averaged equations reproduced diversion patterns reasonably well. In Figures A.4.4.4.2.5 through A.4.4.4.2.8, the model-averaged equations were used to forecast diversion patterns in the test years, illustrating how the model-averaged equations would perform if used operationally. Again, historical diversion patterns were depicted reasonably well by the models. Summary statistics of forecast errors in the test years (Table A.4.4.4.2.1) provided further insight into potential errors associated with operational use of these models. However, the small sample size (n=3 per period) used to compute these summary statistics did not provide a comprehensive view of the forecast error structure. If used operationally, more work could be done to more thoroughly quantify likely error of these forecasts.

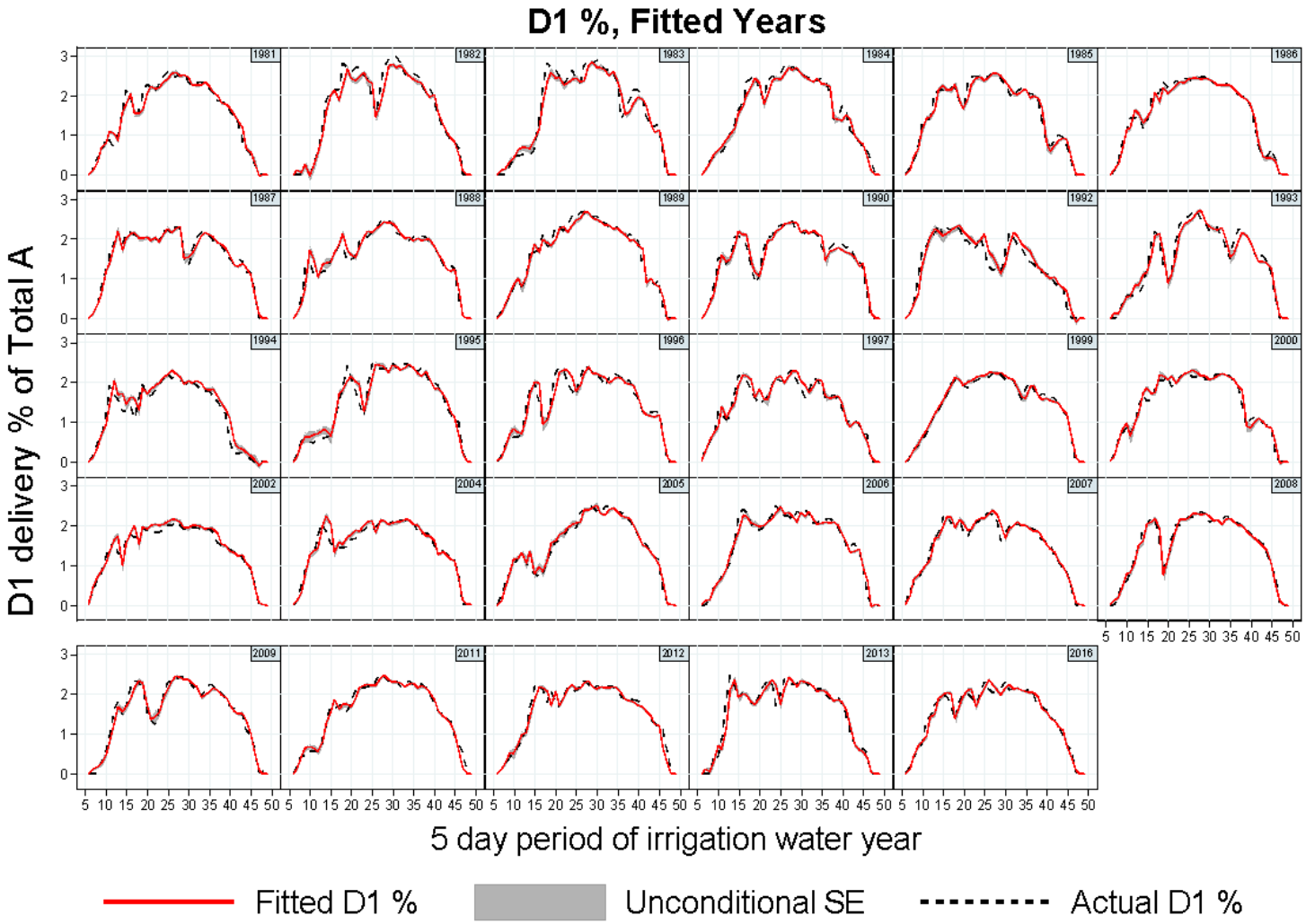


Figure A.4.4.4.2.1. Actual percent delivery of Total A diversions through diversion arc D1 compared to that predicted by the model-averaged predictive equation.

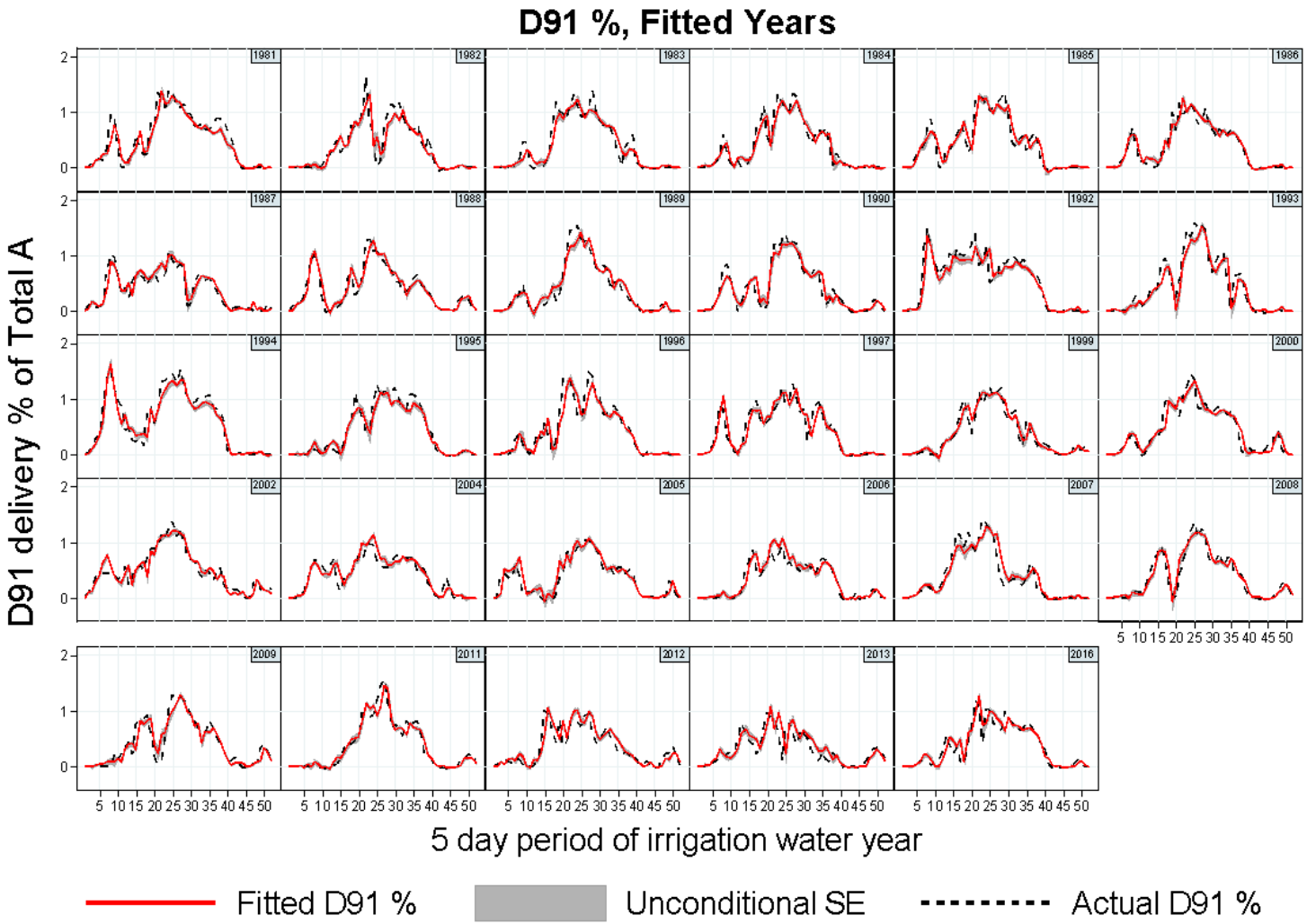


Figure A.4.4.4.2.2. Actual percent delivery of Total A diversions through diversion arc D91 compared to that predicted by the model-averaged predictive equation.

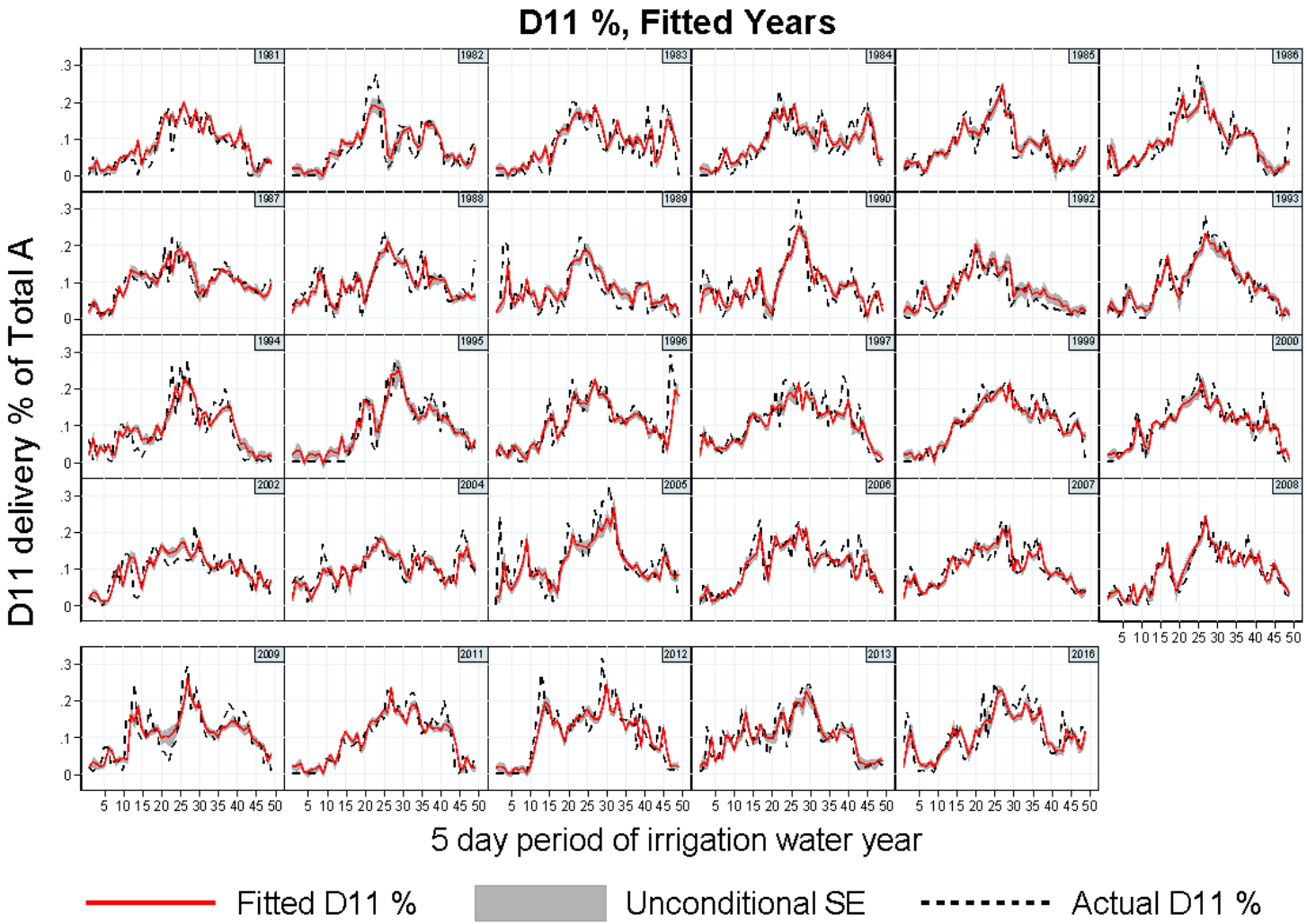


Figure A.4.4.4.2.3. Actual percent delivery of Total A diversions through diversion arc D11 compared to that predicted by the model-averaged predictive equation.

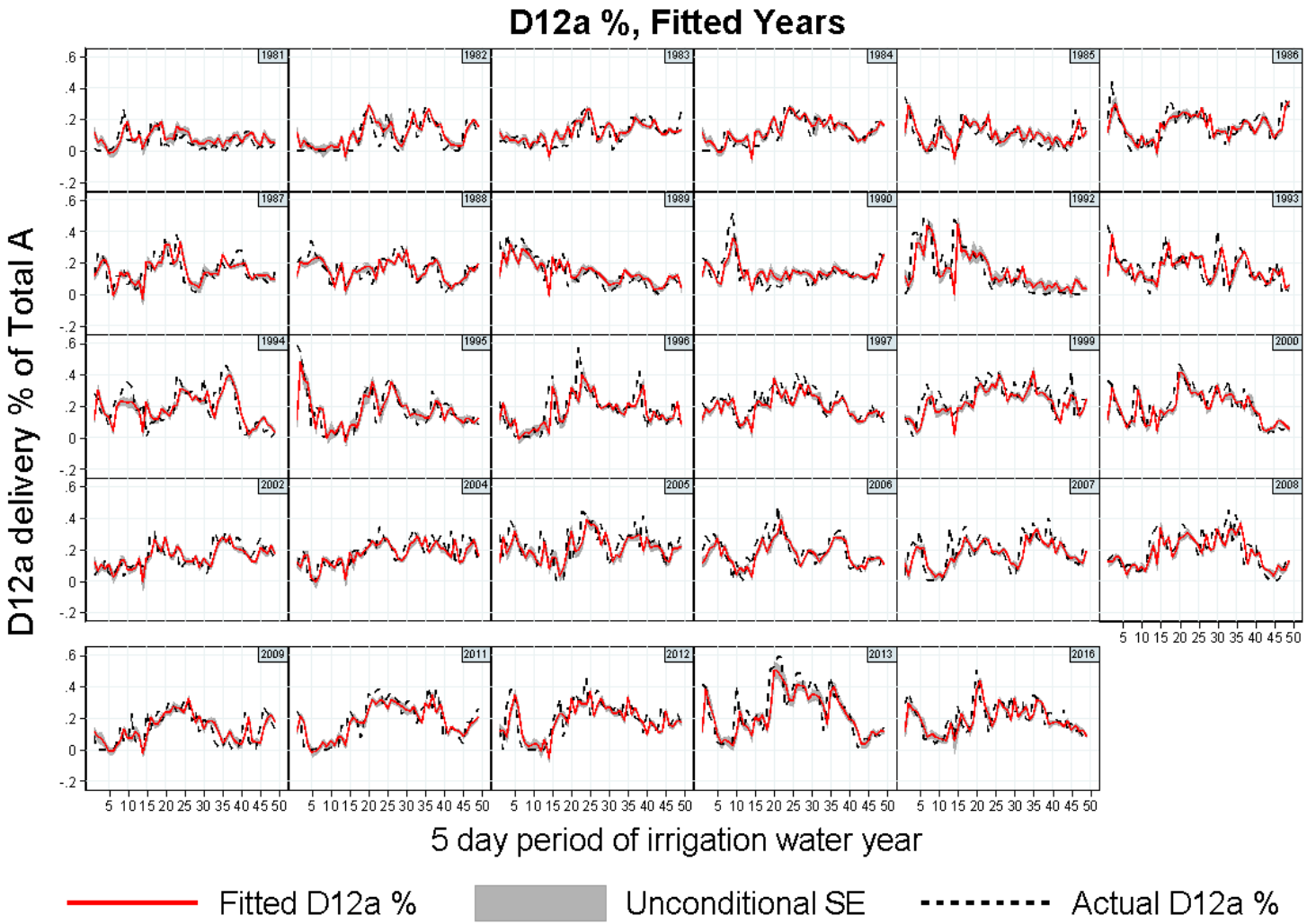


Figure A.4.4.4.2.4. Actual percent delivery of Total A diversions through diversion arc D12A compared to that predicted by the model-averaged predictive equation.

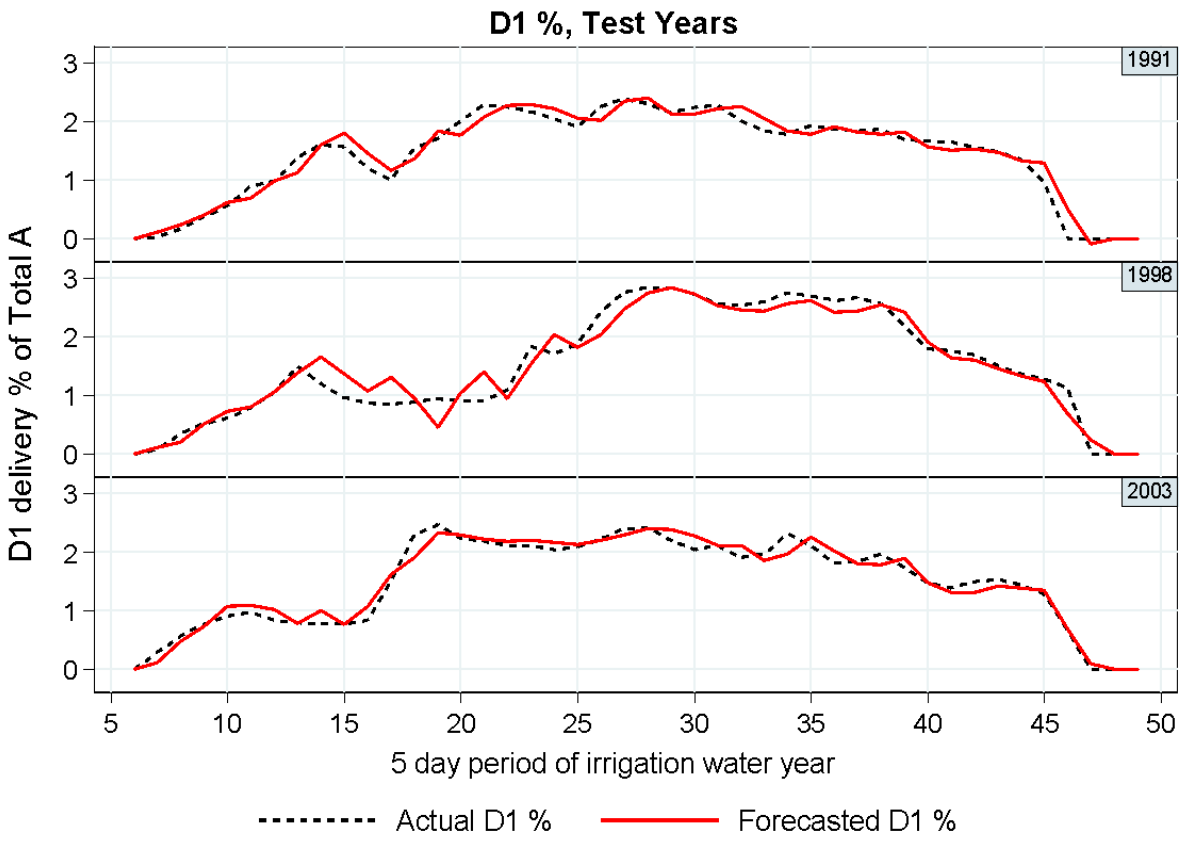


Figure A.4.4.4.2.5. Actual percent delivery of Total A diversions through diversion arc D1 compared to that forecasted by the model-averaged predictive equation in the test years.

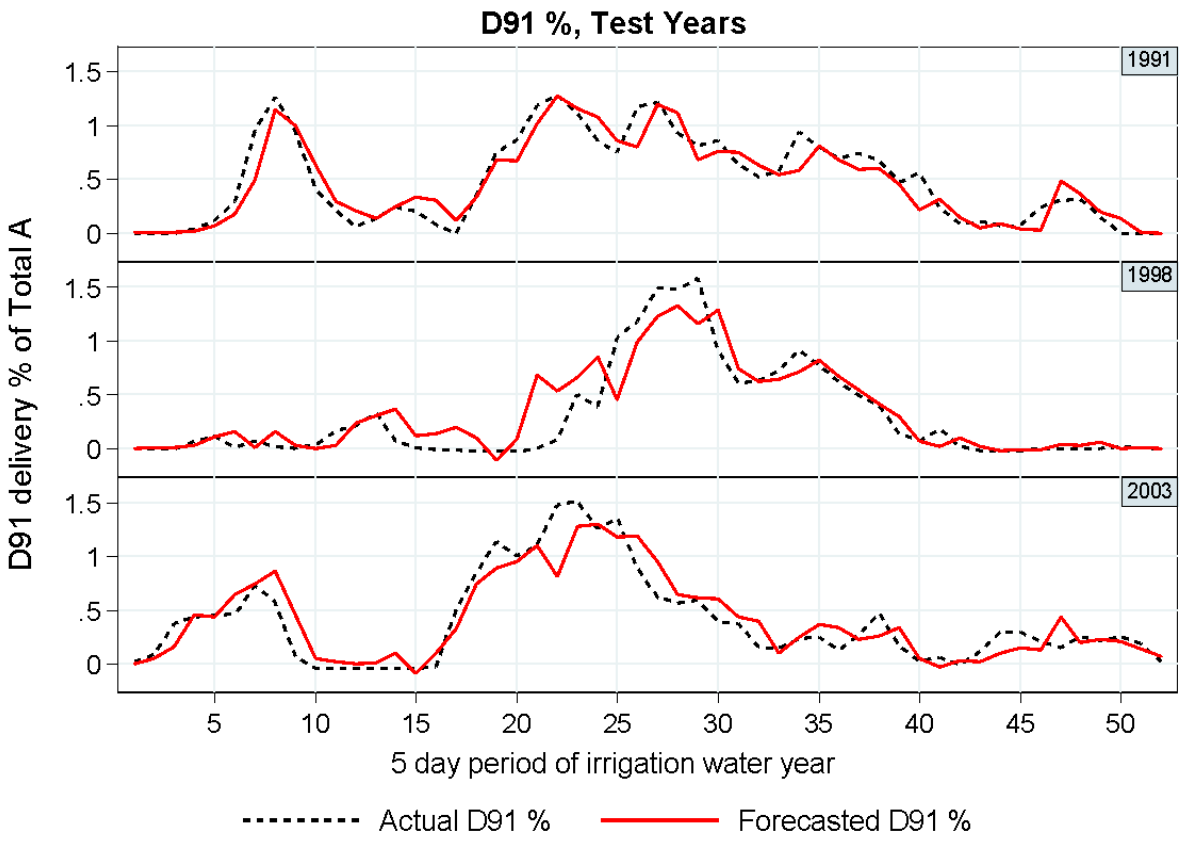


Figure A.4.4.4.2.6. Actual percent delivery of Total A diversions through diversion arc D91 compared to that forecasted by the model-averaged predictive equation in the test years.

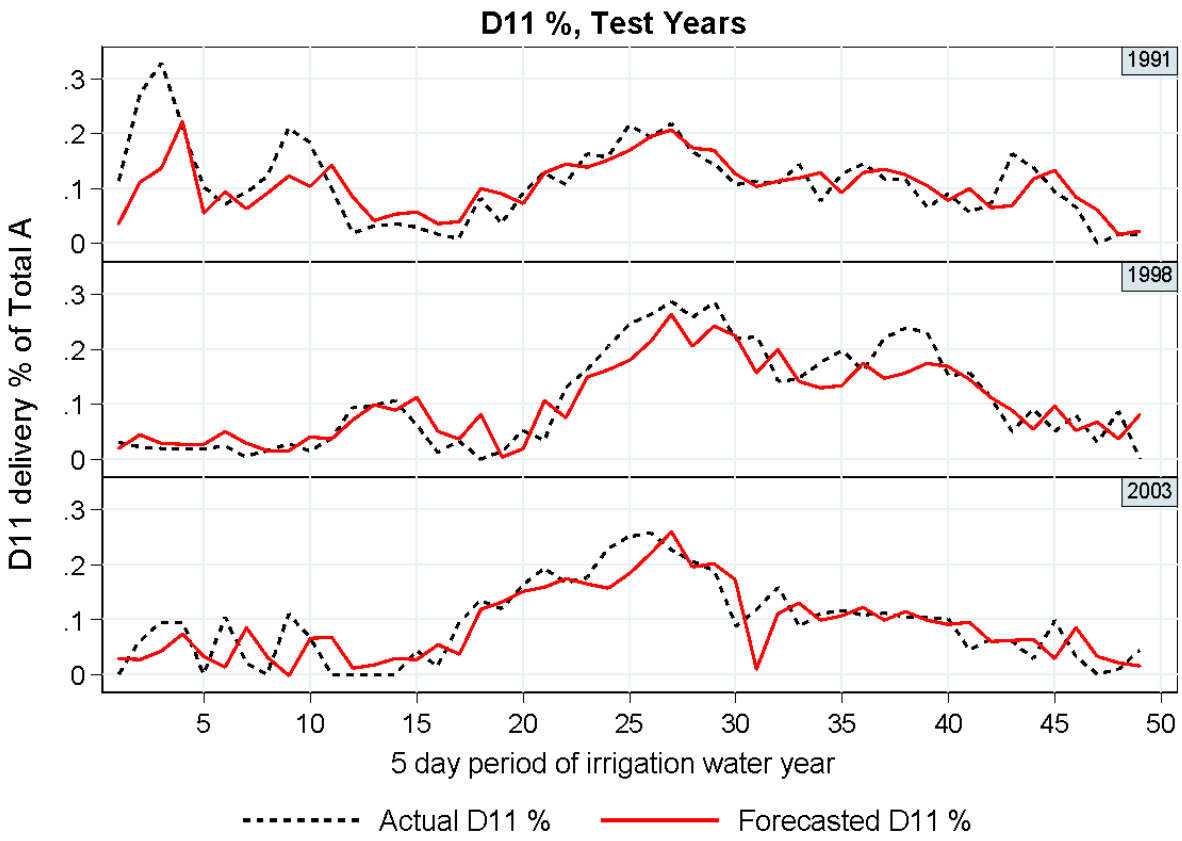


Figure A.4.4.4.2.7. Actual percent delivery of Total A diversions through diversion arc D11 compared to that forecasted by the model-averaged predictive equation in the test years.

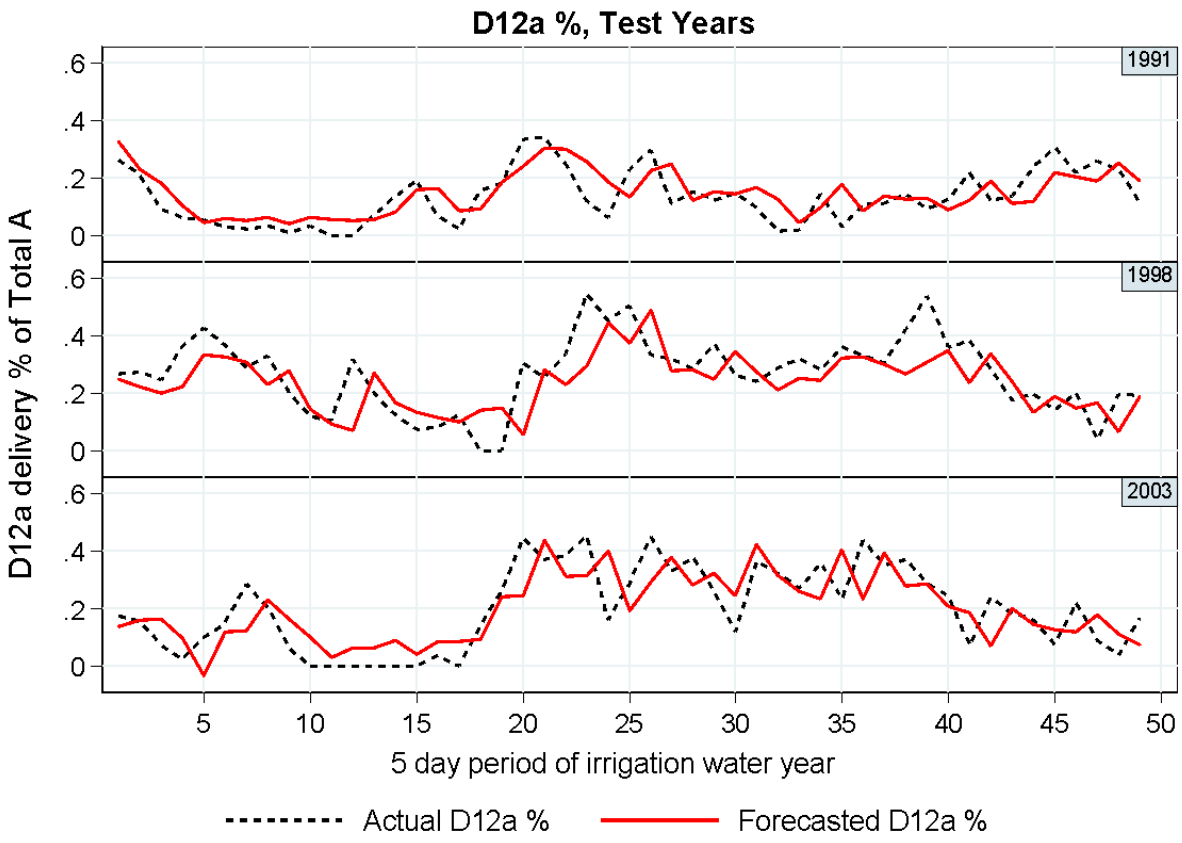


Figure A.4.4.4.2.8. Actual percent delivery of Total A diversions through diversion arc D12A compared to that forecasted by the model-averaged predictive equation in the test years.

Table A.4.4.4.2.1. Error statistics for forecasts of the percent of Total A delivery for each diversion arc in the test years (1991, 1998, and 2003). These one-step-ahead forecasts were generated using the model-averaged equations, using the historic percent of Total A diversion from the prior period as the β_1 predictor. Mean and standard deviation (sd) of forecast errors (actual delivery % - forecasted delivery %) were calculated for each 5-day period of the irrigation water year (Period). Sample size was 3 per period.

Period	d1pcta mean	d1pcta Sd	d91pcta Mean	d91pcta sd	d11pcta mean	d11pcta sd	d12apcta mean	d12apcta sd
1			0.004	0.012	0.020	0.053	-0.001	0.054
2			0.008	0.022	0.057	0.093	0.010	0.038
3			0.068	0.128	0.079	0.104	-0.045	0.080
4			0.013	0.031	0.002	0.018	0.010	0.117
5			0.026	0.020	0.002	0.041	0.079	0.061
6	-0.002	0.002	-0.071	0.168	0.014	0.066	0.014	0.037
7	0.019	0.138	0.167	0.255	-0.020	0.047	0.037	0.108
8	0.058	0.118	-0.103	0.206	0.001	0.030	0.017	0.075
9	0.008	0.034	-0.152	0.204	0.071	0.051	-0.068	0.034
10	-0.120	0.049	-0.090	0.125	0.018	0.055	-0.053	0.043
11	0.022	0.162	-0.001	0.118	-0.036	0.035	-0.025	0.033
12	-0.063	0.108	-0.075	0.060	-0.018	0.045	0.043	0.177
13	0.125	0.119	-0.008	0.037	-0.009	0.007	-0.039	0.048
14	-0.228	0.228	-0.148	0.146	-0.009	0.024	-0.027	0.073
15	-0.213	0.218	-0.068	0.099	-0.021	0.034	-0.022	0.049
16	-0.232	0.031	-0.168	0.059	-0.033	0.012	-0.059	0.032
17	-0.249	0.194	-0.047	0.206	0.007	0.046	-0.041	0.058
18	0.159	0.222	0.001	0.116	-0.027	0.049	-0.010	0.115
19	0.169	0.309	0.133	0.096	-0.020	0.032	-0.044	0.091
20	0.017	0.206	0.045	0.151	0.022	0.012	0.182	0.081
21	-0.110	0.351	-0.174	0.454	-0.012	0.055	-0.020	0.055
22	0.022	0.113	0.074	0.565	0.003	0.047	0.042	0.084
23	0.029	0.252	0.013	0.204	0.017	0.007	0.084	0.197
24	-0.209	0.103	-0.240	0.213	0.041	0.034	-0.118	0.125
25	-0.045	0.097	0.212	0.344	0.060	0.012	0.106	0.020
26	0.220	0.194	0.090	0.350	0.027	0.027	0.023	0.163
27	0.141	0.123	-0.013	0.301	0.001	0.031	-0.048	0.090
28	0.008	0.099	-0.037	0.174	0.018	0.031	0.044	0.047
29	-0.058	0.107	0.179	0.222	0.002	0.037	0.010	0.100
30	-0.041	0.172	-0.162	0.245	-0.037	0.042	-0.069	0.064
31	0.038	0.033	-0.101	0.037	0.062	0.051	-0.055	0.019
32	-0.122	0.183	-0.114	0.124	-0.004	0.053	-0.010	0.095
33	0.020	0.206	0.049	0.024	-0.003	0.035	0.018	0.046
34	0.164	0.203	0.179	0.188	0.002	0.050	0.069	0.047
35	0.018	0.150	-0.057	0.052	0.036	0.026	-0.093	0.116
36	-0.014	0.203	-0.084	0.119	-0.004	0.017	0.077	0.112
37	0.093	0.112	0.047	0.103	0.023	0.047	-0.021	0.025
38	0.095	0.079	0.088	0.117	0.021	0.053	0.088	0.068

Period	d1pcta mean	d1pcta Sd	d91pcta Mean	d91pcta sd	d11pcta mean	d11pcta sd	d12apcta mean	d12apcta sd
39	-0.178	0.061	-0.107	0.109	0.007	0.048	0.066	0.145
40	-0.005	0.110	0.105	0.206	0.002	0.016	0.028	0.016
41	0.118	0.036	0.056	0.124	-0.028	0.034	0.042	0.138
42	0.104	0.078	-0.057	0.022	0.004	0.004	0.015	0.132
43	0.061	0.053	0.040	0.069	0.018	0.068	-0.018	0.045
44	0.033	0.015	0.063	0.122	0.008	0.038	0.066	0.052
45	-0.121	0.188	0.056	0.081	-0.005	0.065	-0.003	0.077
46	-0.040	0.466	0.098	0.098	-0.015	0.040	0.057	0.043
47	-0.080	0.172	-0.170	0.121	-0.043	0.016	-0.047	0.105
48	-0.002	0.000	-0.008	0.050	0.013	0.034	0.011	0.107
49	0.000	0.001	-0.037	0.027	-0.019	0.056	0.008	0.085
50			-0.025	0.098				
51			0.011	0.028				
52			-0.017	0.030				

The discussion of how the selected formulas were used in the KBPM to simulate Agricultural deliveries is found in Section A.4.4.3 following the several tables below that provide the details of model ranking and error analysis used to select the formulas and coefficients for the four model arcs, D1, D91, D11, and D12a, shown above with the graphed results.

As expected, relative performance of models varied across 5-day periods (Tables A.4.4.4.2.1 and A.4.4.4.2.2), as determined by the relative magnitudes of the $\Delta_m$values. In both tables, results are sorted within each period by the $\Delta_m$values, so that the best performing model (lowest $AICc$) is first and the worst performing model is last. While the results in these tables provide insight into the seasonal influence of climatic and water availability factors, discussion in this regard is deferred to any potential future consideration of modifying this model approach for use in operations. For the present purpose of depicting the pattern of water deliveries in the KBPM, it is useful to note that multimodel-averaging allowed for the weighted (using w_m) influence of different regressors to affect the predicted diversion patterns in a manner that varied across diversion arcs and periods.

The end result of this process was a diversion arc-specific table of model-averaged coefficients for each variable in the model set and for each 5-day period. In any given period, regressors in models with relatively high Akaike weights (that is, $w_m\ near\ 1$) strongly influenced the $\underline{\hat{\beta}}_p$ coefficients in the final averaged model, whereas those with weights near zero had little or no influence on the coefficients (Tables A.4.4.4.2.3 through A.4.4.4.2.7. Each table was used in the KBPM as a lookup table, from which the coefficients corresponding to the appropriate diversion arc, predictor variable, and 5-day period were obtained to compute the percentage of Total A deliveries for each 5-day period.

Table A.4.4.4.2.2. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D1 and D91. Within each 5-day period, models are sorted by Δ_m (from "best" to "worst"). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m.*

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
1							7	4	100.22	-190.78	0.00	0.29
1							10	4	100.05	-190.44	0.34	0.25
1							8	4	100.01	-190.35	0.43	0.24
1							9	4	99.97	-190.27	0.51	0.23
2							1	3	69.85	-132.78	0.00	0.31
2							3	4	70.95	-132.29	0.48	0.24
2							4	4	70.79	-131.99	0.79	0.21
2							5	4	70.14	-130.68	2.09	0.11
2							2	4	70.11	-130.62	2.16	0.11
2							6	4	68.78	-127.89	4.89	0.03
3							3	4	36.01	-62.42	0.00	0.41
3							5	4	35.35	-61.10	1.32	0.21
3							4	4	35.34	-61.07	1.35	0.21
3							1	3	33.35	-59.78	2.64	0.11
3							2	4	33.74	-57.88	4.54	0.04
3							6	4	32.20	-54.73	7.69	0.01
4							4	4	53.00	-96.41	0.00	0.30
4							2	4	52.97	-96.35	0.06	0.30
4							1	3	51.25	-95.58	0.83	0.20
4							3	4	51.96	-94.33	2.08	0.11
4							5	4	51.64	-93.68	2.73	0.08
4							6	4	49.97	-90.27	6.14	0.01
5							4	4	52.18	-94.75	0.00	0.48
5							2	4	51.34	-93.09	1.67	0.21
5							3	4	50.93	-92.27	2.48	0.14

P	D1pctaM	D1pctaK	D1pctaMLL	D1pctaAIC$_c$	D1pctaΔ$_m$	D1pctaw$_m$	D91pctaM	D91pctaK	D91pctaMLL	D91pctaAIC$_c$	D91pctaΔ$_m$	D91pctaw$_m$
5							5	4	50.85	-92.09	2.66	0.13
5							1	3	48.35	-89.79	4.97	0.04
5							6	4	46.34	-83.02	11.74	0.00
6	9	4	83.49	-157.31	0.00	0.36	4	4	27.21	-44.82	0.00	0.40
6	8	4	83.38	-157.10	0.21	0.32	2	4	26.56	-43.51	1.31	0.21
6	10	4	82.72	-155.77	1.54	0.17	1	3	25.02	-43.11	1.70	0.17
6	7	4	82.62	-155.58	1.74	0.15	3	4	26.29	-42.98	1.84	0.16
6							5	4	25.03	-40.45	4.37	0.04
6							6	4	24.55	-39.43	5.39	0.03
7	1	3	35.17	-63.41	0.00	0.43	3	4	12.28	-14.96	0.00	0.67
7	5	4	35.63	-61.65	1.76	0.18	5	4	10.49	-11.38	3.58	0.11
7	3	4	35.22	-60.84	2.57	0.12	1	3	9.04	-11.15	3.80	0.10
7	4	4	35.19	-60.78	2.64	0.12	4	4	10.10	-10.61	4.35	0.08
7	2	4	35.17	-60.74	2.67	0.11	2	4	9.12	-8.64	6.32	0.03
7	6	4	34.18	-58.69	4.72	0.04	6	4	8.65	-7.64	7.32	0.02
8	2	4	26.47	-43.35	0.00	0.53	1	3	11.50	-16.07	0.00	0.38
8	4	4	25.99	-42.39	0.96	0.33	5	4	12.26	-14.92	1.15	0.21
8	1	3	23.01	-39.11	4.24	0.06	4	4	11.72	-13.83	2.24	0.12
8	3	4	23.94	-38.29	5.06	0.04	2	4	11.69	-13.79	2.29	0.12
8	5	4	23.02	-36.44	6.90	0.02	3	4	11.61	-13.63	2.44	0.11
8	6	4	22.62	-35.58	7.77	0.01	6	4	11.03	-12.39	3.68	0.06
9	4	4	11.50	-13.41	0.00	0.39	6	4	14.62	-19.57	0.00	0.37
9	2	4	10.91	-12.22	1.19	0.21	1	3	12.61	-18.31	1.27	0.20
9	3	4	10.61	-11.62	1.79	0.16	3	4	13.68	-17.77	1.81	0.15
9	1	3	9.00	-11.07	2.33	0.12	4	4	13.62	-17.64	1.93	0.14
9	6	4	9.98	-10.29	3.12	0.08	2	4	13.05	-16.50	3.07	0.08
9	5	4	9.28	-8.96	4.44	0.04	5	4	12.84	-16.09	3.48	0.06
10	2	4	9.20	-8.81	0.00	0.54	1	3	24.96	-43.00	0.00	0.29

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
10	6	4	7.91	-6.15	2.66	0.14	2	4	26.11	-42.63	0.38	0.24
10	4	4	7.84	-6.08	2.72	0.14	3	4	26.01	-42.41	0.59	0.21
10	1	3	6.26	-5.59	3.21	0.11	5	4	25.72	-41.84	1.17	0.16
10	5	4	6.54	-3.48	5.33	0.04	4	4	24.98	-40.36	2.64	0.08
10	3	4	6.27	-2.95	5.86	0.03	6	4	23.79	-37.91	5.09	0.02
11	2	4	8.70	-7.80	0.00	0.69	3	4	21.05	-32.51	0.00	0.65
11	4	4	7.32	-5.03	2.77	0.17	1	3	18.15	-29.38	3.13	0.14
11	6	4	6.11	-2.55	5.26	0.05	4	4	19.02	-28.45	4.06	0.09
11	1	3	4.63	-2.34	5.47	0.04	5	4	18.88	-28.17	4.34	0.07
11	3	4	5.46	-1.31	6.49	0.03	2	4	18.36	-27.13	5.38	0.04
11	5	4	4.76	0.07	7.88	0.01	6	4	17.14	-24.62	7.89	0.01
12	2	4	5.46	-1.33	0.00	0.79	2	4	24.40	-39.20	0.00	0.90
12	4	4	3.96	1.68	3.01	0.18	4	4	21.46	-33.32	5.89	0.05
12	5	4	1.14	7.32	8.65	0.01	1	3	19.52	-32.11	7.09	0.03
12	1	3	-0.25	7.42	8.75	0.01	5	4	20.05	-30.50	8.71	0.01
12	3	4	0.52	8.57	9.90	0.01	6	4	19.56	-29.46	9.75	0.01
12	6	4	0.04	9.59	10.92	0.00	3	4	19.53	-29.45	9.75	0.01
13	4	4	5.89	-2.18	0.00	0.75	4	4	17.91	-26.21	0.00	0.31

P	D1pctaM	D1pctaK	D1pctaMLL	D1pctaAIC$_c$	D1pctaΔ$_m$	D1pctaw$_m$	D91pctaM	D91pctaK	D91pctaMLL	D91pctaAIC$_c$	D91pctaΔ$_m$	D91pctaw$_m$
13	2	4	4.51	0.58	2.76	0.19	1	3	16.43	-25.93	0.28	0.27
13	6	4	2.29	5.08	7.26	0.02	2	4	17.31	-25.02	1.19	0.17
13	3	4	2.25	5.09	7.28	0.02	3	4	17.13	-24.67	1.54	0.14
13	1	3	0.55	5.83	8.01	0.01	5	4	16.47	-23.33	2.88	0.07
13	5	4	0.60	8.40	10.58	0.00	6	4	15.56	-21.45	4.76	0.03
14	4	4	2.96	3.68	0.00	0.70	1	3	10.01	-13.09	0.00	0.35
14	2	4	2.07	5.47	1.79	0.29	2	4	10.84	-12.07	1.02	0.21
14	3	4	-1.39	12.39	8.71	0.01	4	4	10.64	-11.69	1.41	0.18
14	1	3	-5.70	18.33	14.65	0.00	3	4	10.20	-10.79	2.30	0.11
14	6	4	-5.13	19.94	16.26	0.00	5	4	10.01	-10.42	2.67	0.09
14	5	4	-5.26	20.11	16.43	0.00	6	4	9.47	-9.27	3.82	0.05
15	5	4	5.84	-2.08	0.00	0.82	5	4	9.68	-9.75	0.00	0.62
15	2	4	3.97	1.66	3.74	0.13	2	4	8.17	-6.74	3.01	0.14
15	4	4	2.61	4.39	6.47	0.03	1	3	6.71	-6.50	3.25	0.12
15	6	4	1.84	5.99	8.08	0.01	3	4	7.06	-4.52	5.24	0.04
15	1	3	-0.96	8.85	10.93	0.00	4	4	7.01	-4.43	5.33	0.04
15	3	4	-0.85	11.30	13.39	0.00	6	4	6.94	-4.21	5.54	0.04
16	2	4	10.39	-11.18	0.00	0.91	1	3	15.42	-23.92	0.00	0.35

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
16	4	4	7.84	-6.08	5.11	0.07	2	4	16.37	-23.13	0.78	0.24
16	1	3	4.11	-1.30	9.88	0.01	3	4	15.90	-22.20	1.72	0.15
16	6	4	4.90	-0.13	11.06	0.00	5	4	15.54	-21.48	2.44	0.10
16	5	4	4.85	-0.10	11.09	0.00	4	4	15.47	-21.35	2.57	0.10
16	3	4	4.40	0.81	11.99	0.00	6	4	15.06	-20.46	3.46	0.06
17	2	4	6.18	-2.76	0.00	0.97	2	4	5.79	-1.97	0.00	0.77
17	4	4	2.74	4.11	6.87	0.03	4	4	3.85	1.89	3.87	0.11
17	3	4	-3.32	16.24	19.00	0.00	1	3	1.93	3.05	5.03	0.06
17	6	4	-3.38	16.43	19.18	0.00	6	4	2.20	5.27	7.25	0.02
17	1	3	-5.13	17.19	19.95	0.00	3	4	2.00	5.60	7.57	0.02
17	5	4	-4.99	19.59	22.34	0.00	5	4	1.96	5.68	7.65	0.02
18	3	4	2.74	4.12	0.00	0.78	3	4	9.47	-9.35	0.00	0.76
18	4	4	1.45	6.70	2.59	0.21	4	4	8.16	-6.71	2.63	0.20
18	2	4	-2.00	13.60	9.48	0.01	2	4	5.74	-1.89	7.46	0.02
18	1	3	-5.05	17.03	12.91	0.00	1	3	4.30	-1.67	7.68	0.02
18	5	4	-4.60	18.80	14.69	0.00	5	4	4.30	0.99	10.34	0.00
18	6	4	-5.25	20.16	16.04	0.00	6	4	4.06	1.54	10.89	0.00
19	2	4	5.91	-2.21	0.00	0.95	2	4	5.53	-1.45	0.00	0.58

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
19	4	4	3.06	3.49	5.70	0.05	4	4	5.18	-0.76	0.69	0.41
19	3	4	-2.72	15.05	17.26	0.00	3	4	0.95	7.69	9.15	0.01
19	1	3	-5.83	18.59	20.80	0.00	1	3	-1.92	10.77	12.22	0.00
19	5	4	-5.18	19.96	22.17	0.00	5	4	-0.66	10.92	12.37	0.00
20	2	4	9.55	-9.49	0.00	1.00	2	4	6.17	-2.73	0.00	0.91
20	4	4	3.33	2.95	12.44	0.00	4	4	3.58	2.44	5.18	0.07
20	1	3	1.25	4.42	13.91	0.00	1	3	0.76	5.39	8.13	0.02
20	3	4	1.34	6.93	16.42	0.00	5	4	1.28	7.04	9.78	0.01
20	5	4	1.27	7.05	16.55	0.00	3	4	0.78	8.03	10.77	0.00
21	2	4	12.84	-16.09	0.00	0.91	2	4	6.83	-4.05	0.00	0.86
21	4	4	10.45	-11.30	4.79	0.08	4	4	5.01	-0.43	3.62	0.14
21	1	3	5.72	-4.52	11.56	0.00	1	3	-0.44	7.81	11.86	0.00
21	3	4	6.82	-4.04	12.05	0.00	3	4	0.70	8.19	12.25	0.00
21	5	4	5.84	-2.09	14.00	0.00	5	4	-0.44	10.49	14.54	0.00
22	2	4	9.29	-8.99	0.00	0.75	5	4	2.75	4.10	0.00	0.97
22	5	4	7.76	-5.92	3.06	0.16	2	4	-1.56	12.72	8.61	0.01
22	4	4	6.63	-3.66	5.33	0.05	1	3	-3.32	13.56	9.46	0.01
22	1	3	4.66	-2.41	6.58	0.03	4	4	-2.99	15.58	11.48	0.00

P	D1pctaM	D1pctaK	D1pctaMLL	D1pctaAIC$_c$	D1pctaΔ$_m$	D1pctaw$_m$	D91pctaM	D91pctaK	D91pctaMLL	D91pctaAIC$_c$	D91pctaΔ$_m$	D91pctaw$_m$
22	3	4	4.82	-0.04	8.95	0.01	3	4	-3.30	16.19	12.09	0.00
23	2	4	20.32	-31.04	0.00	0.96	2	4	5.33	-1.07	0.00	0.67
23	4	4	17.07	-24.54	6.50	0.04	4	4	4.26	1.08	2.15	0.23
23	3	4	13.58	-17.57	13.47	0.00	1	3	1.35	4.22	5.29	0.05
23	1	3	11.65	-16.38	14.66	0.00	3	4	2.68	4.24	5.31	0.05
23	5	4	12.68	-15.76	15.27	0.00	5	4	1.45	6.71	7.78	0.01
24	2	4	11.87	-14.13	0.00	0.27	2	4	6.28	-2.96	0.00	0.85
24	1	3	10.52	-14.12	0.01	0.27	4	4	4.49	0.62	3.57	0.14
24	5	4	11.61	-13.62	0.52	0.21	1	3	-0.28	7.49	10.45	0.00
24	4	4	11.37	-13.13	1.00	0.17	5	4	1.03	7.55	10.50	0.00
24	3	4	10.63	-11.67	2.47	0.08	3	4	0.25	9.11	12.07	0.00
25	4	4	13.34	-17.09	0.00	0.38	1	3	0.30	6.32	0.00	0.48
25	2	4	13.00	-16.40	0.68	0.27	3	4	0.41	8.77	2.45	0.14
25	3	4	12.63	-15.65	1.43	0.19	4	4	0.35	8.90	2.58	0.13
25	1	3	10.85	-14.78	2.31	0.12	5	4	0.32	8.95	2.64	0.13
25	5	4	10.85	-12.10	4.98	0.03	2	4	0.30	8.99	2.68	0.13
26	2	4	16.55	-23.50	0.00	0.91	2	4	16.18	-22.77	0.00	0.40
26	4	4	14.25	-18.90	4.60	0.09	1	3	14.63	-22.33	0.44	0.32

P	D1pcta M	D1pcta K	D1pcta MLL	D1pcta AIC_c	D1pcta Δ_m	D1pcta w_m	D91pcta M	D91pcta K	D91pcta MLL	D91pcta AIC_c	D91pcta Δ_m	D91pcta w_m
26	3	4	10.57	-11.54	11.96	0.00	3	4	14.91	-20.22	2.55	0.11
26	1	3	7.59	-8.26	15.24	0.00	4	4	14.64	-19.68	3.08	0.09
26	5	4	7.65	-5.71	17.79	0.00	5	4	14.63	-19.65	3.11	0.08
27	1	3	14.79	-22.66	0.00	0.41	1	3	7.83	-8.73	0.00	0.36
27	5	4	15.41	-21.22	1.44	0.20	3	4	8.75	-7.90	0.83	0.24
27	2	4	15.21	-20.83	1.83	0.16	5	4	8.36	-7.12	1.61	0.16
27	3	4	14.97	-20.34	2.32	0.13	2	4	8.09	-6.58	2.15	0.12
27	4	4	14.79	-19.98	2.67	0.11	4	4	7.98	-6.35	2.38	0.11
28	1	3	15.92	-24.92	0.00	0.34	1	3	9.20	-11.49	0.00	0.33
28	3	4	17.13	-24.66	0.26	0.30	3	4	10.46	-11.32	0.16	0.30
28	4	4	16.57	-23.55	1.37	0.17	4	4	9.97	-10.33	1.15	0.19
28	2	4	15.99	-22.38	2.54	0.10	5	4	9.27	-8.94	2.55	0.09
28	5	4	15.95	-22.30	2.62	0.09	2	4	9.22	-8.83	2.65	0.09
29	2	4	19.05	-28.49	0.00	1.00	2	4	10.69	-11.77	0.00	0.57
29	4	4	12.72	-15.84	12.65	0.00	4	4	10.29	-10.97	0.80	0.38
29	1	3	8.73	-10.53	17.96	0.00	5	4	7.52	-5.43	6.34	0.02
29	5	4	9.73	-9.85	18.64	0.00	3	4	6.57	-3.55	8.23	0.01
29	3	4	8.84	-8.08	20.42	0.00	1	3	5.19	-3.46	8.31	0.01

P	D1pcta M	D1pcta K	D1pcta MLL	D1pcta AIC_c	D1pcta Δ_m	D1pcta w_m	D91pcta M	D91pcta K	D91pcta MLL	D91pcta AIC_c	D91pcta Δ_m	D91pcta w_m
30	5	4	22.12	-34.65	0.00	0.64	1	3	25.58	-44.23	0.00	0.38
30	2	4	20.72	-31.84	2.81	0.16	2	4	26.60	-43.61	0.62	0.28
30	1	3	19.04	-31.15	3.50	0.11	4	4	25.81	-42.01	2.22	0.12
30	4	4	19.79	-29.98	4.67	0.06	5	4	25.74	-41.89	2.34	0.12
30	3	4	19.10	-28.59	6.05	0.03	3	4	25.60	-41.61	2.62	0.10
31	3	4	20.04	-30.48	0.00	0.32	3	4	14.41	-19.21	0.00	0.32
31	4	4	20.02	-30.43	0.05	0.31	4	4	14.18	-18.76	0.45	0.26
31	1	3	18.36	-29.79	0.69	0.23	1	3	12.79	-18.66	0.55	0.25
31	5	4	18.77	-27.94	2.54	0.09	2	4	13.24	-16.88	2.33	0.10
31	2	4	18.36	-27.12	3.36	0.06	5	4	12.91	-16.21	3.00	0.07
32	1	3	29.03	-51.13	0.00	0.39	1	3	19.32	-31.73	0.00	0.35
32	2	4	29.87	-50.14	0.99	0.24	5	4	20.44	-31.28	0.45	0.28
32	3	4	29.37	-49.13	2.00	0.14	4	4	19.71	-29.81	1.91	0.13
32	5	4	29.16	-48.73	2.40	0.12	3	4	19.63	-29.66	2.06	0.12
32	4	4	29.05	-48.50	2.63	0.11	2	4	19.57	-29.53	2.19	0.12
33	2	4	25.20	-40.80	0.00	0.86	2	4	17.65	-25.70	0.00	0.72
33	4	4	22.98	-36.37	4.43	0.09	4	4	16.47	-23.35	2.36	0.22
33	1	3	20.56	-34.19	6.61	0.03	1	3	13.13	-19.33	6.38	0.03

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
33	3	4	20.78	-31.96	8.85	0.01	3	4	13.82	-18.03	7.67	0.02
33	5	4	20.59	-31.59	9.22	0.01	5	4	13.14	-16.68	9.02	0.01
34	2	4	34.81	-60.02	0.00	0.72	1	3	16.44	-25.95	0.00	0.32
34	1	3	31.85	-56.78	3.24	0.14	2	4	17.77	-25.93	0.02	0.32
34	4	4	32.44	-55.29	4.73	0.07	4	4	17.01	-24.42	1.53	0.15
34	3	4	31.88	-54.16	5.86	0.04	5	4	16.87	-24.14	1.81	0.13
34	5	4	31.88	-54.15	5.87	0.04	3	4	16.47	-23.34	2.61	0.09
35	2	4	22.71	-35.81	0.00	0.80	2	4	14.42	-19.24	0.00	0.96
35	1	3	19.28	-31.64	4.17	0.10	1	3	8.94	-10.97	8.27	0.02
35	3	4	19.82	-30.03	5.78	0.04	4	4	10.08	-10.57	8.67	0.01
35	4	4	19.39	-29.19	6.62	0.03	5	4	9.07	-8.54	10.70	0.00
35	5	4	19.38	-29.15	6.66	0.03	3	4	8.95	-8.29	10.95	0.00
36	2	4	11.39	-13.18	0.00	0.81	2	4	14.53	-19.46	0.00	0.52
36	4	4	9.44	-9.28	3.90	0.12	1	3	12.36	-17.79	1.67	0.22
36	1	3	7.11	-7.30	5.88	0.04	4	4	13.22	-16.84	2.62	0.14
36	3	4	7.53	-5.46	7.72	0.02	5	4	12.38	-15.16	4.30	0.06
36	5	4	7.13	-4.66	8.52	0.01	3	4	12.38	-15.15	4.31	0.06
37	1	3	22.09	-37.26	0.00	0.29	3	4	23.78	-37.97	0.00	0.38

P	D1pct a M	D1pct a K	D1pct a MLL	D1pct a AIC_c	D1pct a Δ_m	D1pct a w_m	D91pct a M	D91pct a K	D91pct a MLL	D91pct a AIC_c	D91pct a Δ_m	D91pct a w_m
37	4	4	23.29	-36.97	0.28	0.25	4	4	23.56	-37.51	0.46	0.30
37	3	4	23.15	-36.70	0.56	0.22	1	3	21.70	-36.47	1.50	0.18
37	2	4	22.78	-35.96	1.30	0.15	2	4	22.26	-34.92	3.05	0.08
37	5	4	22.19	-34.79	2.47	0.08	5	4	21.71	-33.81	4.15	0.05
38	2	4	20.43	-31.26	0.00	1.00	2	4	17.04	-24.47	0.00	0.63
38	4	4	14.35	-19.09	12.16	0.00	1	3	14.30	-21.68	2.79	0.16
38	1	3	12.07	-17.21	14.04	0.00	5	4	14.97	-20.35	4.12	0.08
38	3	4	12.24	-14.87	16.38	0.00	4	4	14.92	-20.23	4.24	0.08
38	5	4	12.14	-14.67	16.59	0.00	3	4	14.53	-19.46	5.02	0.05
39	2	4	21.48	-33.36	0.00	0.61	1	3	17.06	-27.20	0.00	0.46
39	4	4	20.98	-32.37	0.99	0.37	4	4	17.21	-24.83	2.37	0.14
39	3	4	17.93	-26.27	7.10	0.02	3	4	17.19	-24.79	2.41	0.14
39	1	3	14.56	-22.19	11.17	0.00	2	4	17.18	-24.77	2.43	0.14
39	5	4	14.60	-19.59	13.77	0.00	5	4	17.06	-24.52	2.68	0.12
40	2	4	13.85	-18.10	0.00	0.68	3	4	29.81	-50.01	0.00	0.40
40	4	4	12.75	-15.89	2.20	0.23	4	4	29.29	-48.98	1.04	0.24
40	3	4	11.05	-12.50	5.60	0.04	1	3	27.81	-48.69	1.33	0.20
40	1	3	9.62	-12.31	5.79	0.04	2	4	28.48	-47.36	2.65	0.11

P	D1pctaM	D1pctaK	D1pctaMLL	D1pctaAIC$_c$	D1pctaΔ$_m$	D1pctaw$_m$	D91pctaM	D91pctaK	D91pctaMLL	D91pctaAIC$_c$	D91pctaΔ$_m$	D91pctaw$_m$
40	5	4	9.62	-9.64	8.46	0.01	5	4	27.86	-46.13	3.89	0.06
41	4	4	20.21	-30.82	0.00	0.49	3	4	43.71	-77.81	0.00	0.35
41	3	4	20.13	-30.66	0.17	0.45	4	4	43.29	-76.98	0.84	0.23
41	2	4	17.72	-25.85	4.97	0.04	1	3	41.83	-76.73	1.09	0.21
41	1	3	15.34	-23.75	7.07	0.01	5	4	42.59	-75.58	2.24	0.12
41	5	4	15.56	-21.53	9.29	0.00	2	4	42.33	-75.07	2.75	0.09
42	2	4	19.10	-28.59	0.00	0.96	3	4	63.29	-116.97	0.00	0.38
42	4	4	15.78	-21.97	6.63	0.03	4	4	62.81	-116.01	0.96	0.23
42	1	3	11.70	-16.47	12.12	0.00	1	3	61.45	-115.98	0.99	0.23
42	3	4	12.57	-15.55	13.05	0.00	2	4	61.94	-114.28	2.69	0.10
42	5	4	12.41	-15.22	13.37	0.00	5	4	61.45	-113.31	3.66	0.06
43	4	4	24.22	-38.83	0.00	0.60	1	3	50.47	-94.01	0.00	0.28
43	2	4	23.63	-37.67	1.17	0.33	4	4	51.56	-93.51	0.50	0.22
43	3	4	21.94	-34.27	4.56	0.06	3	4	51.52	-93.45	0.57	0.21
43	1	3	18.38	-29.84	9.00	0.01	5	4	51.23	-92.86	1.15	0.16
43	5	4	18.40	-27.20	11.63	0.00	2	4	51.08	-92.57	1.44	0.14
44	2	4	29.85	-50.09	0.00	0.35	1	3	44.09	-81.25	0.00	0.47
44	4	4	29.75	-49.91	0.19	0.32	3	4	44.22	-78.83	2.42	0.14

P	D1pcta M	D1pcta K	D1pcta MLL	D1pcta AIC_c	D1pcta Δ_m	D1pcta w_m	D91pcta M	D91pcta K	D91pcta MLL	D91pcta AIC_c	D91pcta Δ_m	D91pcta w_m
44	1	3	27.84	-48.77	1.33	0.18	4	4	44.16	-78.73	2.53	0.13
44	3	4	28.56	-47.52	2.58	0.10	5	4	44.11	-78.62	2.63	0.13
44	5	4	28.05	-46.51	3.58	0.06	2	4	44.10	-78.60	2.65	0.13
45	2	4	21.41	-33.21	0.00	0.84	2	4	65.47	-121.34	0.00	0.32
45	4	4	19.57	-29.53	3.68	0.13	1	3	64.08	-121.23	0.11	0.30
45	1	3	15.77	-24.62	8.60	0.01	4	4	65.02	-120.45	0.89	0.20
45	3	4	16.89	-24.18	9.04	0.01	3	4	64.27	-118.94	2.40	0.10
45	5	4	15.77	-21.95	11.27	0.00	5	4	64.08	-118.57	2.77	0.08
46	1	3	6.48	-6.04	0.00	0.41	1	3	75.89	-144.86	0.00	0.41
46	3	4	7.01	-4.42	1.62	0.18	3	4	76.38	-143.15	1.70	0.17
46	4	4	6.96	-4.32	1.72	0.17	5	4	76.34	-143.08	1.77	0.17
46	2	4	6.65	-3.71	2.34	0.13	4	4	76.14	-142.68	2.17	0.14
46	5	4	6.49	-3.39	2.66	0.11	2	4	75.92	-142.23	2.62	0.11
47	1	3	20.77	-34.61	0.00	0.47	1	3	38.76	-70.59	0.00	0.48
47	2	4	20.91	-32.22	2.40	0.14	4	4	38.81	-68.01	2.57	0.13
47	4	4	20.82	-32.03	2.58	0.13	2	4	38.79	-67.99	2.60	0.13
47	5	4	20.81	-32.02	2.60	0.13	3	4	38.78	-67.97	2.62	0.13
47	3	4	20.77	-31.94	2.68	0.12	5	4	38.76	-67.91	2.68	0.13

P	D1pcta M	D1pcta K	D1pcta MLL	D1pcta AIC_c	D1pcta Δ_m	D1pcta w_m	D91pcta M	D91pcta K	D91pcta MLL	D91pcta AIC_c	D91pcta Δ_m	D91pcta w_m
48	1	3	102.51	-198.10	0.00	0.47	1	3	46.97	-87.02	0.00	0.33
48	5	4	102.69	-195.79	2.31	0.15	4	4	47.90	-86.19	0.83	0.22
48	3	4	102.57	-195.53	2.56	0.13	3	4	47.80	-85.99	1.03	0.19
48	4	4	102.55	-195.51	2.59	0.13	2	4	47.67	-85.74	1.29	0.17
48	2	4	102.53	-195.46	2.64	0.13	5	4	47.05	-84.51	2.52	0.09
49	2	4	146.32	-283.04	0.00	0.70	3	4	28.78	-47.95	0.00	0.37
49	4	4	145.16	-280.71	2.33	0.22	4	4	28.48	-47.36	0.59	0.27
49	3	4	143.59	-277.58	5.46	0.05	1	3	26.46	-46.01	1.95	0.14
49	1	3	141.79	-276.66	6.38	0.03	2	4	27.58	-45.57	2.39	0.11
49	5	4	141.85	-274.09	8.95	0.01	5	4	27.56	-45.52	2.43	0.11
50							1	3	47.02	-87.11	0.00	0.38
50							5	4	47.65	-85.70	1.41	0.19
50							2	4	47.58	-85.56	1.55	0.17
50							4	4	47.45	-85.30	1.82	0.15
50							3	4	47.13	-84.66	2.45	0.11
51							2	4	53.91	-98.22	0.00	0.38
51							4	4	53.60	-97.59	0.63	0.28
51							1	3	51.94	-96.96	1.26	0.20

P	D1pcta M	D1pcta K	D1pcta MLL	D1pcta AIC_c	D1pcta Δ_m	D1pcta w_m	D91pcta M	D91pcta K	D91pcta MLL	D91pcta AIC_c	D91pcta Δ_m	D91pcta w_m
51							3	4	52.48	-95.35	2.87	0.09
51							5	4	52.02	-94.44	3.77	0.06
52							1	3	66.60	-126.27	0.00	0.47
52							5	4	66.75	-123.90	2.37	0.14
52							3	4	66.67	-123.75	2.52	0.13
52							2	4	66.65	-123.70	2.57	0.13
52							4	4	66.60	-123.60	2.67	0.12

Table A.4.4.4.2.3. Model ranking and Akaike weights of 5-day period specific for OLS models predicting percent of Total A deliveries through diversion arcs D11 and D12A. Within each 5-day period, models are sorted by Δ_m (from "best" to "worst"). In the table below, P = 5-day period of the irrigation water year; M = model number; K = number of estimable parameters of the model; MLL = maximized log-likelihood of the model obtained from OLS output; AIC_c = corrected Akaike Information Criterion; Δ_m = difference between the AIC_c of the model with the minimum AIC_c (the best model) and the AIC_c of model *m*; w_m = Akaike weight for model *m.*

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
1	12	3	67.45	-127.98	0.00	0.86	12	3	22.56	-38.20	0.00	0.45
1	9	4	66.60	-123.53	4.45	0.09	9	4	23.31	-36.96	1.24	0.24
1	11	4	65.25	-120.83	7.14	0.02	11	4	23.09	-36.51	1.69	0.19
1	10	4	65.09	-120.50	7.47	0.02	10	4	22.54	-35.41	2.79	0.11
2	1	3	46.37	-85.81	0.00	0.37	3	4	35.46	-61.33	0.00	0.59
2	5	4	47.35	-85.10	0.71	0.26	4	4	34.19	-58.77	2.55	0.17
2	3	4	46.65	-83.71	2.10	0.13	1	3	32.60	-58.27	3.06	0.13
2	4	4	46.44	-83.29	2.53	0.10	5	4	32.89	-56.17	5.15	0.04
2	2	4	46.37	-83.15	2.66	0.10	2	4	32.70	-55.80	5.53	0.04
2	8	4	44.78	-79.89	5.92	0.02	8	4	31.51	-53.36	7.97	0.01
2	6	4	44.59	-79.51	6.30	0.02	7	4	31.49	-53.32	8.01	0.01
2	7	4	44.46	-79.25	6.56	0.01	6	4	31.44	-53.22	8.11	0.01
3	2	4	51.63	-93.67	0.00	0.36	1	3	26.65	-46.38	0.00	0.25
3	1	3	49.88	-92.85	0.82	0.24	5	4	27.98	-46.36	0.01	0.25
3	4	4	51.16	-92.71	0.95	0.22	7	4	27.58	-45.49	0.89	0.16
3	3	4	50.03	-90.46	3.20	0.07	3	4	27.20	-44.80	1.58	0.11
3	5	4	49.96	-90.32	3.34	0.07	2	4	27.01	-44.41	1.96	0.09
3	8	4	48.69	-87.72	5.95	0.02	4	4	26.66	-43.72	2.66	0.07
3	7	4	48.59	-87.51	6.16	0.02	8	4	26.18	-42.69	3.69	0.04
3	6	4	47.96	-86.25	7.42	0.01	6	4	25.79	-41.91	4.46	0.03
4	4	4	71.31	-133.03	0.00	0.34	1	3	39.72	-72.51	0.00	0.39
4	2	4	70.94	-132.29	0.74	0.23	5	4	40.24	-70.89	1.63	0.17
4	1	3	69.46	-132.00	1.03	0.20	2	4	40.04	-70.48	2.03	0.14
4	3	4	70.50	-131.39	1.63	0.15	4	4	39.80	-70.01	2.51	0.11

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
4	5	4	69.69	-129.77	3.25	0.07	3	4	39.74	-69.88	2.63	0.10
4	7	4	67.63	-125.60	7.43	0.01	8	4	38.60	-67.53	4.98	0.03
4	6	4	67.13	-124.58	8.44	0.00	6	4	38.49	-67.32	5.20	0.03
4	8	4	66.76	-123.85	9.18	0.00	7	4	38.19	-66.72	5.80	0.02
5	3	4	68.19	-126.79	0.00	0.46	5	4	37.93	-66.26	0.00	0.47
5	4	4	67.38	-125.15	1.64	0.20	1	3	35.72	-64.52	1.74	0.20
5	1	3	65.72	-124.51	2.28	0.15	3	4	36.80	-64.01	2.25	0.15
5	5	4	66.60	-123.60	3.19	0.09	4	4	35.91	-62.22	4.04	0.06
5	2	4	66.11	-122.63	4.16	0.06	2	4	35.82	-62.04	4.22	0.06
5	6	4	65.24	-120.82	5.97	0.02	6	4	35.33	-61.00	5.26	0.03
5	8	4	63.94	-118.21	8.58	0.01	8	4	34.71	-59.75	6.51	0.02
5	7	4	63.37	-117.08	9.71	0.00	7	4	34.28	-58.89	7.38	0.01
6	2	4	71.80	-133.99	0.00	0.61	5	4	33.84	-58.08	0.00	0.26
6	1	3	69.16	-131.40	2.59	0.17	1	3	32.46	-58.00	0.09	0.25
6	3	4	70.01	-130.41	3.58	0.10	6	4	33.80	-57.93	0.15	0.24
6	5	4	69.60	-129.59	4.40	0.07	2	4	32.50	-55.41	2.67	0.07
6	4	4	69.27	-128.94	5.05	0.05	3	4	32.49	-55.37	2.71	0.07
6	8	4	66.62	-123.57	10.43	0.00	4	4	32.46	-55.32	2.76	0.06
6	7	4	66.48	-123.29	10.71	0.00	8	4	31.98	-54.30	3.78	0.04
6	6	4	66.47	-123.28	10.71	0.00	7	4	31.06	-52.46	5.63	0.02
7	1	3	61.12	-115.31	0.00	0.42	4	4	42.89	-76.19	0.00	0.31
7	5	4	61.54	-113.48	1.83	0.17	2	4	42.62	-75.63	0.55	0.23
7	2	4	61.42	-113.24	2.08	0.15	1	3	41.06	-75.19	1.00	0.19
7	4	4	61.24	-112.87	2.44	0.12	3	4	42.33	-75.05	1.13	0.18
7	3	4	61.12	-112.64	2.68	0.11	5	4	41.16	-72.72	3.47	0.05
7	7	4	58.72	-107.76	7.55	0.01	7	4	40.10	-70.54	5.65	0.02
7	6	4	58.68	-107.70	7.61	0.01	6	4	39.54	-69.42	6.76	0.01
7	8	4	58.60	-107.54	7.78	0.01	8	4	39.36	-69.05	7.14	0.01

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
8	3	4	61.97	-114.34	0.00	0.33	3	4	33.19	-56.78	0.00	0.30
8	4	4	61.66	-113.71	0.63	0.24	4	4	32.93	-56.25	0.53	0.23
8	1	3	60.19	-113.46	0.88	0.21	1	3	31.51	-56.09	0.69	0.22
8	2	4	60.81	-112.01	2.33	0.10	2	4	32.10	-54.59	2.18	0.10
8	5	4	60.22	-110.84	3.50	0.06	5	4	32.05	-54.50	2.28	0.10
8	7	4	59.91	-110.15	4.19	0.04	7	4	30.41	-51.15	5.63	0.02
8	8	4	58.83	-108.00	6.34	0.01	8	4	30.25	-50.83	5.95	0.02
8	6	4	58.09	-106.51	7.84	0.01	6	4	30.07	-50.48	6.30	0.01
9	1	3	63.92	-120.92	0.00	0.29	1	3	33.81	-60.69	0.00	0.30
9	4	4	64.89	-120.19	0.73	0.20	5	4	34.99	-60.38	0.30	0.26
9	3	4	64.83	-120.05	0.87	0.19	3	4	34.39	-59.18	1.50	0.14
9	5	4	64.74	-119.88	1.04	0.17	4	4	34.29	-58.98	1.71	0.13
9	2	4	64.41	-119.23	1.69	0.12	2	4	33.98	-58.37	2.32	0.09
9	6	4	61.61	-113.55	7.37	0.01	8	4	33.18	-56.70	3.99	0.04
9	7	4	61.53	-113.40	7.52	0.01	7	4	32.71	-55.75	4.94	0.03
9	8	4	61.45	-113.24	7.68	0.01	6	4	32.49	-55.32	5.37	0.02
10	2	4	66.51	-123.42	0.00	0.36	5	4	32.23	-54.87	0.00	0.27
10	1	3	64.82	-122.71	0.71	0.25	1	3	30.76	-54.59	0.28	0.24
10	4	4	65.98	-122.37	1.05	0.21	2	4	32.05	-54.50	0.37	0.23
10	5	4	64.92	-120.24	3.18	0.07	4	4	31.58	-53.55	1.32	0.14
10	3	4	64.89	-120.17	3.25	0.07	3	4	30.78	-51.97	2.90	0.06
10	7	4	62.96	-116.24	7.18	0.01	7	4	29.75	-49.83	5.04	0.02
10	8	4	62.92	-116.17	7.25	0.01	6	4	29.69	-49.72	5.15	0.02

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
10	6	4	62.49	-115.30	8.12	0.01	8	4	29.45	-49.24	5.63	0.02
11	2	4	61.69	-113.78	0.00	0.41	1	3	39.81	-72.70	0.00	0.26
11	1	3	59.83	-112.74	1.04	0.25	7	4	40.83	-71.99	0.71	0.18
11	8	4	60.15	-110.64	3.14	0.09	2	4	40.67	-71.74	0.95	0.16
11	3	4	60.01	-110.42	3.36	0.08	4	4	40.59	-71.57	1.13	0.15
11	5	4	59.95	-110.31	3.47	0.07	3	4	40.12	-70.65	2.05	0.09
11	4	4	59.95	-110.30	3.48	0.07	5	4	39.81	-70.02	2.68	0.07
11	7	4	58.91	-108.15	5.63	0.02	6	4	39.83	-70.00	2.70	0.07
11	6	4	57.72	-105.77	8.01	0.01	8	4	38.18	-66.69	6.01	0.01
12	4	4	63.27	-116.95	0.00	0.61	3	4	37.35	-65.09	0.00	0.64
12	3	4	62.63	-115.66	1.28	0.32	4	4	35.86	-62.13	2.97	0.15
12	2	4	60.77	-111.93	5.01	0.05	1	3	34.18	-61.45	3.65	0.10
12	1	3	58.34	-109.76	7.18	0.02	5	4	34.87	-60.13	4.96	0.05
12	5	4	58.81	-108.01	8.93	0.01	2	4	34.47	-59.35	5.74	0.04
12	8	4	55.92	-102.17	14.78	0.00	7	4	32.90	-56.13	8.96	0.01
12	6	4	55.91	-102.16	14.78	0.00	8	4	32.86	-56.05	9.04	0.01
12	7	4	55.91	-102.16	14.79	0.00	6	4	32.58	-55.50	9.60	0.01
13	1	3	50.45	-93.97	0.00	0.38	7	4	38.80	-67.93	0.00	0.31

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
13	5	4	50.90	-92.20	1.78	0.16	1	3	37.24	-67.56	0.37	0.26
13	2	4	50.61	-91.62	2.35	0.12	3	4	37.81	-66.01	1.92	0.12
13	4	4	50.61	-91.62	2.35	0.12	4	4	37.58	-65.56	2.37	0.09
13	3	4	50.50	-91.40	2.57	0.11	5	4	37.42	-65.24	2.69	0.08
13	8	4	50.18	-90.69	3.29	0.07	2	4	37.25	-64.91	3.02	0.07
13	7	4	48.90	-88.13	5.84	0.02	6	4	36.87	-64.06	3.87	0.04
13	6	4	48.85	-88.02	5.95	0.02	8	4	36.37	-63.07	4.86	0.03
14	6	4	67.21	-124.76	0.00	0.62	6	4	29.07	-48.47	0.00	0.60
14	5	4	65.90	-122.20	2.56	0.17	1	3	26.16	-45.39	3.08	0.13
14	2	4	64.98	-120.35	4.41	0.07	8	4	26.75	-43.83	4.64	0.06
14	7	4	64.97	-120.26	4.50	0.07	4	4	26.71	-43.83	4.64	0.06
14	1	3	63.01	-119.10	5.66	0.04	2	4	26.63	-43.65	4.82	0.05
14	4	4	63.73	-117.85	6.91	0.02	3	4	26.57	-43.54	4.93	0.05
14	3	4	63.02	-116.44	8.32	0.01	5	4	26.46	-43.33	5.14	0.05
14	8	4	60.75	-111.83	12.94	0.00	7	4	24.99	-40.31	8.16	0.01
15	1	3	60.82	-114.71	0.00	0.41	1	3	32.39	-57.86	0.00	0.32
15	4	4	61.27	-112.94	1.77	0.17	6	4	33.13	-56.59	1.27	0.17
15	3	4	61.16	-112.72	1.99	0.15	2	4	32.97	-56.34	1.52	0.15

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
15	2	4	60.94	-112.28	2.43	0.12	4	4	32.79	-55.99	1.87	0.13
15	5	4	60.88	-112.16	2.56	0.11	3	4	32.43	-55.26	2.60	0.09
15	7	4	59.24	-108.82	5.90	0.02	5	4	32.39	-55.19	2.67	0.08
15	8	4	58.77	-107.88	6.83	0.01	7	4	31.72	-53.78	4.08	0.04
15	6	4	58.44	-107.21	7.51	0.01	8	4	31.11	-52.55	5.31	0.02
16	2	4	58.56	-107.51	0.00	0.75	2	4	32.09	-54.57	0.00	0.30
16	4	4	56.54	-103.47	4.04	0.10	5	4	31.81	-54.03	0.54	0.23
16	1	3	55.08	-103.24	4.27	0.09	1	3	30.32	-53.72	0.85	0.20
16	5	4	55.33	-101.07	6.45	0.03	4	4	31.40	-53.19	1.38	0.15
16	3	4	55.08	-100.57	6.95	0.02	3	4	30.43	-51.25	3.32	0.06
16	7	4	53.70	-97.73	9.78	0.01	7	4	29.62	-49.58	5.00	0.02
16	8	4	53.37	-97.07	10.44	0.00	6	4	29.60	-49.54	5.04	0.02
16	6	4	53.10	-96.53	10.99	0.00	8	4	29.10	-48.54	6.03	0.01
17	1	3	61.86	-116.80	0.00	0.44	1	3	37.29	-67.65	0.00	0.26
17	5	4	62.09	-114.58	2.22	0.15	4	4	38.54	-67.49	0.16	0.24
17	3	4	61.98	-114.36	2.44	0.13	2	4	38.29	-66.98	0.68	0.19
17	4	4	61.91	-114.22	2.58	0.12	3	4	38.21	-66.82	0.83	0.17
17	2	4	61.86	-114.13	2.67	0.12	5	4	37.30	-64.99	2.66	0.07

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
17	7	4	60.05	-110.42	6.37	0.02	6	4	36.43	-63.19	4.46	0.03
17	8	4	59.70	-109.74	7.06	0.01	7	4	36.01	-62.35	5.30	0.02
17	6	4	59.58	-109.50	7.30	0.01	8	4	35.73	-61.80	5.85	0.01
18	2	4	57.22	-104.83	0.00	0.59	1	3	36.43	-65.95	0.00	0.36
18	4	4	56.55	-103.51	1.32	0.31	5	4	36.84	-64.08	1.86	0.14
18	3	4	54.56	-99.52	5.31	0.04	3	4	36.59	-63.59	2.36	0.11
18	1	3	53.18	-99.45	5.38	0.04	4	4	36.47	-63.33	2.61	0.10
18	5	4	53.47	-97.35	7.48	0.01	2	4	36.44	-63.28	2.67	0.09
18	7	4	52.20	-94.74	10.09	0.00	8	4	36.46	-63.25	2.70	0.09
18	8	4	51.62	-93.58	11.25	0.00	6	4	36.24	-62.81	3.13	0.08
18	6	4	51.20	-92.74	12.09	0.00	7	4	35.16	-60.66	5.29	0.03
19	4	4	58.66	-107.72	0.00	0.54	5	4	26.89	-44.19	0.00	0.57
19	3	4	58.07	-106.55	1.17	0.30	1	3	24.70	-42.47	1.71	0.24
19	2	4	56.98	-104.37	3.36	0.10	2	4	24.75	-39.90	4.29	0.07
19	1	3	54.59	-102.27	5.46	0.04	3	4	24.72	-39.84	4.35	0.06
19	5	4	55.05	-100.50	7.22	0.01	4	4	24.70	-39.80	4.39	0.06
20	2	4	55.85	-102.10	0.00	0.76	5	4	36.20	-62.80	0.00	0.78
20	4	4	54.51	-99.43	2.67	0.20	1	3	33.01	-59.09	3.71	0.12

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
20	1	3	50.96	-95.01	7.09	0.02	2	4	33.05	-56.49	6.31	0.03
20	3	4	51.69	-93.77	8.32	0.01	4	4	33.02	-56.45	6.35	0.03
20	5	4	51.47	-93.34	8.75	0.01	3	4	33.01	-56.42	6.38	0.03
21	5	4	56.15	-102.69	0.00	0.43	5	4	37.60	-65.61	0.00	0.61
21	1	3	54.15	-101.38	1.31	0.22	1	3	35.14	-63.35	2.26	0.20
21	4	4	54.97	-100.34	2.36	0.13	2	4	35.60	-61.60	4.01	0.08
21	2	4	54.81	-100.02	2.67	0.11	4	4	35.28	-60.96	4.65	0.06
21	3	4	54.74	-99.89	2.80	0.11	3	4	35.14	-60.68	4.93	0.05
22	1	3	49.77	-92.61	0.00	0.37	1	3	27.45	-47.98	0.00	0.46
22	2	4	50.84	-92.07	0.54	0.28	5	4	27.79	-45.98	2.00	0.17
22	4	4	50.22	-90.83	1.78	0.15	3	4	27.54	-45.48	2.50	0.13
22	3	4	49.81	-90.02	2.59	0.10	4	4	27.51	-45.41	2.57	0.13
22	5	4	49.77	-89.94	2.67	0.10	2	4	27.45	-45.31	2.68	0.12
23	2	4	47.94	-86.28	0.00	0.29	1	3	27.71	-48.49	0.00	0.35
23	4	4	47.78	-85.96	0.33	0.24	2	4	28.81	-48.02	0.48	0.28
23	1	3	46.31	-85.70	0.59	0.21	5	4	28.19	-46.78	1.71	0.15
23	3	4	47.24	-84.88	1.41	0.14	4	4	28.06	-46.51	1.98	0.13
23	5	4	47.05	-84.50	1.78	0.12	3	4	27.72	-45.83	2.66	0.09

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
24	4	4	62.26	-114.93	0.00	0.57	4	4	42.17	-74.74	0.00	0.55
24	3	4	61.08	-112.56	2.37	0.18	3	4	41.70	-73.79	0.94	0.34
24	5	4	60.87	-112.13	2.79	0.14	5	4	39.65	-69.70	5.03	0.04
24	2	4	59.98	-110.35	4.57	0.06	1	3	37.93	-68.93	5.81	0.03
24	1	3	58.53	-110.14	4.79	0.05	2	4	39.21	-68.81	5.93	0.03
25	1	3	45.99	-85.05	0.00	0.37	1	3	36.51	-66.09	0.00	0.32
25	5	4	46.84	-84.09	0.97	0.23	2	4	37.42	-65.24	0.85	0.21
25	4	4	46.37	-83.14	1.91	0.14	5	4	37.40	-65.20	0.89	0.21
25	3	4	46.33	-83.05	2.00	0.14	4	4	37.15	-64.71	1.38	0.16
25	2	4	46.27	-82.95	2.10	0.13	3	4	36.71	-63.83	2.26	0.10
26	2	4	52.37	-95.15	0.00	0.50	4	4	37.68	-65.76	0.00	0.31
26	4	4	51.98	-94.35	0.80	0.34	2	4	37.32	-65.03	0.73	0.22
26	3	4	50.49	-91.39	3.76	0.08	1	3	35.89	-64.85	0.91	0.20
26	1	3	48.97	-91.01	4.14	0.06	3	4	37.21	-64.82	0.94	0.20
26	5	4	48.97	-88.33	6.82	0.02	5	4	36.21	-62.82	2.93	0.07
27	1	3	56.51	-106.09	0.00	0.32	1	3	42.66	-78.39	0.00	0.46
27	2	4	57.47	-105.35	0.74	0.22	5	4	42.97	-76.35	2.04	0.17
27	4	4	57.39	-105.18	0.91	0.21	2	4	42.71	-75.83	2.56	0.13

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
27	3	4	57.02	-104.44	1.65	0.14	4	4	42.67	-75.73	2.66	0.12
27	5	4	56.72	-103.85	2.25	0.11	3	4	42.66	-75.71	2.68	0.12
28	2	4	60.24	-110.89	0.00	0.60	1	3	37.80	-68.68	0.00	0.35
28	5	4	59.74	-109.88	1.00	0.36	2	4	38.62	-67.64	1.04	0.21
28	1	3	55.39	-103.85	7.03	0.02	5	4	38.49	-67.37	1.31	0.18
28	4	4	56.18	-102.76	8.13	0.01	4	4	38.30	-67.00	1.68	0.15
28	3	4	55.47	-101.33	9.56	0.01	3	4	38.08	-66.55	2.13	0.12
29	1	3	44.30	-81.68	0.00	0.40	1	3	40.35	-73.78	0.00	0.41
29	2	4	45.14	-80.68	1.00	0.24	3	4	41.05	-72.50	1.28	0.22
29	4	4	44.50	-79.39	2.28	0.13	4	4	40.70	-71.81	1.98	0.15
29	5	4	44.46	-79.33	2.35	0.12	5	4	40.42	-71.24	2.55	0.11
29	3	4	44.32	-79.03	2.65	0.11	2	4	40.36	-71.11	2.67	0.11
30	5	4	53.74	-97.88	0.00	0.40	4	4	33.24	-56.88	0.00	0.25
30	1	3	52.11	-97.31	0.58	0.30	1	3	31.89	-56.85	0.03	0.25
30	2	4	52.52	-95.43	2.45	0.12	2	4	33.19	-56.78	0.10	0.24
30	4	4	52.38	-95.16	2.72	0.10	3	4	32.79	-55.98	0.91	0.16
30	3	4	52.20	-94.80	3.09	0.08	5	4	32.25	-54.90	1.98	0.09
31	2	4	56.74	-103.88	0.00	0.32	2	4	40.40	-71.21	0.00	0.50

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
31	1	3	55.08	-103.23	0.64	0.23	1	3	38.23	-69.54	1.67	0.22
31	3	4	56.22	-102.84	1.04	0.19	3	4	38.97	-68.35	2.86	0.12
31	4	4	55.91	-102.22	1.66	0.14	4	4	38.71	-67.81	3.40	0.09
31	5	4	55.81	-102.02	1.85	0.13	5	4	38.54	-67.47	3.73	0.08
32	1	3	55.55	-104.17	0.00	0.40	1	3	34.36	-61.79	0.00	0.36
32	5	4	56.49	-103.38	0.80	0.27	2	4	35.18	-60.76	1.04	0.21
32	3	4	55.59	-101.57	2.60	0.11	4	4	35.09	-60.59	1.21	0.20
32	4	4	55.55	-101.51	2.66	0.11	3	4	34.70	-59.80	1.99	0.13
32	2	4	55.55	-101.50	2.67	0.11	5	4	34.36	-59.12	2.67	0.09
33	5	4	60.96	-112.33	0.00	0.61	5	4	33.58	-57.56	0.00	0.38
33	1	3	58.55	-110.18	2.15	0.21	1	3	31.99	-57.05	0.51	0.30
33	2	4	58.78	-107.95	4.38	0.07	2	4	32.41	-55.22	2.33	0.12
33	4	4	58.69	-107.77	4.56	0.06	4	4	32.37	-55.13	2.42	0.11
33	3	4	58.57	-107.53	4.80	0.06	3	4	32.10	-54.60	2.96	0.09
34	1	3	56.42	-105.92	0.00	0.44	4	4	40.39	-71.17	0.00	0.33
34	3	4	56.83	-104.07	1.85	0.17	1	3	38.73	-70.55	0.63	0.24
34	5	4	56.59	-103.57	2.35	0.14	3	4	39.85	-70.09	1.08	0.19
34	4	4	56.58	-103.56	2.36	0.13	2	4	39.66	-69.73	1.45	0.16

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
34	2	4	56.43	-103.26	2.66	0.12	5	4	38.91	-68.22	2.96	0.08
35	1	3	58.19	-109.46	0.00	0.40	1	3	35.79	-64.65	0.00	0.47
35	3	4	58.93	-108.26	1.20	0.22	3	4	35.97	-62.33	2.32	0.15
35	4	4	58.59	-107.58	1.88	0.15	2	4	35.86	-62.13	2.52	0.13
35	5	4	58.38	-107.16	2.30	0.13	4	4	35.81	-62.02	2.63	0.13
35	2	4	58.20	-106.80	2.66	0.10	5	4	35.79	-61.98	2.66	0.12
36	1	3	63.04	-119.16	0.00	0.47	1	3	43.92	-80.92	0.00	0.41
36	3	4	63.24	-116.88	2.28	0.15	3	4	44.49	-79.39	1.53	0.19
36	2	4	63.07	-116.53	2.62	0.13	4	4	44.28	-78.97	1.95	0.15
36	4	4	63.06	-116.52	2.63	0.13	5	4	44.12	-78.63	2.29	0.13
36	5	4	63.06	-116.52	2.63	0.13	2	4	44.03	-78.47	2.45	0.12
37	4	4	64.03	-118.46	0.00	0.28	1	3	37.41	-67.90	0.00	0.41
37	1	3	62.51	-118.10	0.36	0.24	5	4	38.32	-67.04	0.86	0.27
37	2	4	63.84	-118.08	0.37	0.24	2	4	37.43	-65.26	2.63	0.11
37	3	4	63.54	-117.48	0.98	0.17	3	4	37.43	-65.26	2.64	0.11
37	5	4	62.59	-115.57	2.88	0.07	4	4	37.41	-65.22	2.68	0.11
38	1	3	55.98	-105.04	0.00	0.38	5	4	41.85	-74.11	0.00	0.40
38	3	4	57.03	-104.46	0.58	0.28	1	3	40.28	-73.64	0.47	0.32

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
38	4	4	56.21	-102.81	2.22	0.12	3	4	40.61	-71.61	2.50	0.11
38	5	4	56.16	-102.72	2.32	0.12	4	4	40.34	-71.07	3.03	0.09
38	2	4	56.02	-102.43	2.60	0.10	2	4	40.31	-71.01	3.10	0.08
39	1	3	53.49	-100.06	0.00	0.44	1	3	31.19	-55.45	0.00	0.31
39	3	4	54.07	-98.54	1.52	0.20	3	4	32.52	-55.44	0.01	0.31
39	4	4	53.59	-97.57	2.49	0.13	4	4	31.92	-54.25	1.21	0.17
39	2	4	53.52	-97.43	2.63	0.12	5	4	31.55	-53.50	1.95	0.12
39	5	4	53.50	-97.40	2.66	0.12	2	4	31.39	-53.19	2.27	0.10
40	3	4	69.55	-129.50	0.00	0.35	1	3	38.97	-71.02	0.00	0.47
40	1	3	67.90	-128.87	0.63	0.25	5	4	39.24	-68.88	2.14	0.16
40	5	4	68.85	-128.09	1.41	0.17	3	4	39.01	-68.43	2.59	0.13
40	4	4	68.74	-127.88	1.62	0.15	2	4	38.98	-68.37	2.65	0.12
40	2	4	68.06	-126.52	2.98	0.08	4	4	38.97	-68.35	2.67	0.12
41	3	4	53.71	-97.83	0.00	0.88	1	3	40.27	-73.61	0.00	0.42
41	4	4	51.52	-93.45	4.38	0.10	2	4	40.72	-71.83	1.77	0.17
41	1	3	47.92	-88.92	8.90	0.01	5	4	40.60	-71.59	2.01	0.15
41	2	4	48.71	-87.82	10.01	0.01	4	4	40.47	-71.35	2.26	0.14
41	5	4	47.95	-86.31	11.52	0.00	3	4	40.28	-70.97	2.64	0.11

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
42	1	3	55.25	-103.59	0.00	0.46	1	3	36.04	-65.15	0.00	0.42
42	2	4	55.45	-101.29	2.29	0.15	3	4	36.35	-63.09	2.06	0.15
42	4	4	55.39	-101.19	2.40	0.14	4	4	36.34	-63.09	2.06	0.15
42	3	4	55.30	-100.99	2.59	0.13	5	4	36.27	-62.93	2.22	0.14
42	5	4	55.26	-100.92	2.66	0.12	2	4	36.22	-62.84	2.31	0.13
43	1	3	52.64	-98.36	0.00	0.39	1	3	49.92	-92.92	0.00	0.44
43	2	4	53.31	-97.01	1.34	0.20	2	4	50.36	-91.12	1.80	0.18
43	5	4	53.06	-96.51	1.84	0.15	4	4	50.17	-90.75	2.17	0.15
43	4	4	53.02	-96.43	1.92	0.15	3	4	49.98	-90.37	2.55	0.12
43	3	4	52.74	-95.88	2.48	0.11	5	4	49.92	-90.25	2.67	0.12
44	1	3	56.89	-106.86	0.00	0.44	1	3	41.85	-76.78	0.00	0.33
44	3	4	57.29	-104.98	1.89	0.17	3	4	42.86	-76.13	0.65	0.24
44	4	4	57.16	-104.72	2.14	0.15	4	4	42.65	-75.70	1.08	0.19
44	2	4	56.96	-104.32	2.54	0.12	2	4	42.14	-74.69	2.09	0.12
44	5	4	56.90	-104.20	2.66	0.12	5	4	42.12	-74.64	2.14	0.11
45	3	4	58.05	-106.51	0.00	0.38	5	4	42.39	-75.19	0.00	0.51
45	1	3	56.56	-106.21	0.30	0.32	1	3	40.18	-73.44	1.75	0.21
45	2	4	56.91	-104.21	2.29	0.12	2	4	40.87	-72.14	3.04	0.11

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
45	4	4	56.68	-103.77	2.74	0.10	3	4	40.79	-71.98	3.21	0.10
45	5	4	56.56	-103.53	2.98	0.08	4	4	40.18	-70.77	4.42	0.06
46	1	3	58.11	-109.30	0.00	0.45	1	3	36.01	-65.10	0.00	0.45
46	3	4	58.36	-107.12	2.17	0.15	3	4	36.42	-63.23	1.87	0.18
46	4	4	58.35	-107.09	2.20	0.15	4	4	36.11	-62.61	2.49	0.13
46	2	4	58.21	-106.82	2.47	0.13	5	4	36.07	-62.53	2.57	0.12
46	5	4	58.19	-106.78	2.51	0.13	2	4	36.02	-62.45	2.66	0.12
47	1	3	51.31	-95.70	0.00	0.44	1	3	38.14	-69.36	0.00	0.40
47	5	4	51.63	-93.65	2.05	0.16	4	4	38.68	-67.77	1.60	0.18
47	4	4	51.48	-93.36	2.34	0.14	3	4	38.67	-67.74	1.63	0.18
47	2	4	51.45	-93.31	2.40	0.13	2	4	38.39	-67.19	2.18	0.13
47	3	4	51.40	-93.20	2.50	0.13	5	4	38.16	-66.73	2.63	0.11
48	1	3	65.04	-123.15	0.00	0.40	1	3	48.88	-90.83	0.00	0.44
48	5	4	65.96	-122.31	0.84	0.26	3	4	49.33	-89.05	1.78	0.18
48	2	4	65.16	-120.71	2.44	0.12	2	4	49.03	-88.46	2.37	0.14
48	4	4	65.07	-120.55	2.61	0.11	5	4	48.92	-88.23	2.60	0.12
48	3	4	65.04	-120.48	2.68	0.11	4	4	48.90	-88.20	2.63	0.12
49	1	3	51.70	-96.47	0.00	0.47	3	4	50.02	-90.44	0.00	0.46

P	D11pcta M	D11pcta K	D11pcta MLL	D11pcta AIC_c	D11pcta Δ_m	D11pcta w_m	D12Apcta M	D12Apcta K	D12Apcta MLL	D12Apcta AIC_c	D12Apcta Δ_m	D12Apcta w_m
49	2	4	51.86	-94.12	2.36	0.14	4	4	49.71	-89.83	0.61	0.34
49	4	4	51.77	-93.94	2.54	0.13	2	4	48.41	-87.23	3.21	0.09
49	5	4	51.73	-93.86	2.62	0.13	1	3	46.61	-86.30	4.14	0.06
49	3	4	51.71	-93.83	2.65	0.13	5	4	47.80	-85.99	4.45	0.05

Table A.4.4.4.2.4. Model-averaged coefficients for predicting the percent of Total A diversion through arc D1 specific to each 5-day period of the irrigation water year.

Period	$\hat{\underline{\beta}}_{1,p}$ ***d1pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
6	0.00000	-0.00840	0.00021	-0.00316	-0.00069	0.00129	-0.00534
7	4.89474	0.00307	-0.00008	0.00071	0.00629	-0.00104	0.11349
8	1.25829	-0.67129	0.00015	-0.03989	0.00011	-0.00017	0.21523
9	0.78117	-0.41206	0.00107	-0.05936	0.00276	-0.01330	0.31869
10	1.31826	-1.48578	0.00003	-0.02144	-0.00273	-0.03078	0.15832
11	0.97914	-1.46711	0.00016	-0.03756	0.00070	-0.01120	0.25354
12	0.92898	-2.33513	0.00004	-0.04945	0.00206	-0.00060	0.36677
13	0.78099	-0.48028	0.00023	-0.32691	0.00015	0.00371	0.67261
14	0.56899	-0.93787	0.00023	-0.33477	-0.00003	0.00003	1.03871
15	0.82889	-0.28926	0.00000	-0.01456	-0.33369	0.00265	0.48421
16	0.62921	-3.75767	0.00001	-0.01883	-0.00046	-0.00029	0.81728
17	0.39790	-3.72180	0.00000	-0.01684	0.00000	0.00000	1.30555
18	0.60348	-0.02061	0.02166	-0.08892	0.00007	0.00001	-0.63705
19	0.64032	-4.47995	0.00000	-0.02919	0.00000	0.00000	0.87154
20	0.54326	-3.11626	0.00000	-0.00052	-0.00001	0.00000	0.95772
21	0.59650	-1.98105	0.00001	-0.01891	-0.00004	0.00000	0.89645

Period	$\hat{\underline{\beta}}_{1,p}$ ***d1pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
22	0.58738	-2.87929	0.00003	-0.01288	-0.03887	0.00000	0.93399
23	0.66797	-1.96561	0.00001	-0.00813	-0.00006	0.00000	0.79649
24	0.58102	-0.44357	0.00019	-0.01942	-0.02756	0.00000	0.97929
25	0.58799	-0.45708	0.00164	-0.06563	-0.00014	0.00000	0.83622
26	0.71910	-2.22443	0.00003	-0.02665	0.00000	0.00000	0.71222
27	0.79748	-0.24014	-0.00041	-0.00047	-0.01612	0.00000	0.57915
28	0.92376	-0.06480	-0.00178	0.01646	0.00162	0.00000	0.33011
29	1.09140	-2.19888	0.00000	-0.00052	0.00001	0.00000	-0.25928
30	0.85001	-0.20516	0.00004	-0.00472	0.09506	0.00000	0.30853
31	0.69106	-0.00190	-0.00276	0.04956	0.00519	0.00000	0.87585
32	0.73936	-0.20258	-0.00041	-0.00096	0.00285	0.00000	0.59554
33	0.69968	-2.95382	0.00003	-0.01589	-0.00014	0.00000	0.65606
34	0.96808	-0.81213	-0.00002	-0.00336	0.00034	0.00000	0.06084
35	0.84424	-1.21464	-0.00018	-0.00091	-0.00079	0.00000	0.31498
36	0.65902	-2.04784	0.00010	-0.02271	0.00021	0.00000	0.65816
37	0.82121	0.18396	-0.00125	0.02239	0.00220	0.00000	0.38635
38	0.92944	-1.85082	0.00000	-0.00051	0.00001	0.00000	0.07401

Period	$\hat{\underline{\beta}}_{1,p}$ ***d1pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
39	0.83461	-1.45973	0.00020	-0.11440	-0.00001	0.00000	0.26141
40	0.89172	-1.11728	0.00039	-0.05463	-0.00003	0.00000	0.04650
41	0.82994	-0.07436	0.00461	-0.09573	0.00023	0.00000	-0.21816
42	0.80064	-1.64988	0.00001	-0.00689	-0.00011	0.00000	0.19455
43	0.85920	-0.74590	0.00045	-0.10845	-0.00002	0.00000	0.10719
44	0.84725	-0.46204	0.00027	-0.02957	0.00176	0.00000	0.05451
45	0.95137	-2.44737	0.00004	-0.02037	-0.00001	0.00000	-0.00353
46	0.51954	0.07166	-0.00082	0.01570	0.00141	0.00000	0.07901
47	0.30723	-0.03814	0.00000	-0.00264	-0.00218	0.00000	-0.10126
48	-0.00078	0.00057	-0.00001	0.00014	-0.00035	0.00000	0.00247
49	0.06254	0.01281	0.00000	0.00048	0.00000	0.00000	-0.00018

Within the KBPM, these estimated percentages were multiplied by an estimate of Total A diversions to compute the diversion volume for that 5-day period, which was then divided by 5 to compute the delivery volume for each day.

Table A.4.4.4.2.5. Model-averaged coefficients for predicting the percent of Total A diversion through arc D91 specific to each 5-day period of the irrigation water year.

Period	$\hat{\underline{\beta}}_{1,p}$ ***d91pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
1	0.00000	-0.00558	0.00000	-0.00023	-0.00089	-0.00088	0.00336
2	2.36408	-0.00503	0.00027	-0.00363	-0.00096	-0.00057	-0.00163

Period	$\hat{\underline{\beta}}_{1,p}$ ***d91pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
3	1.33396	-0.00836	0.00205	-0.01564	0.01639	-0.00033	-0.07046
4	1.16868	-0.07956	0.00015	-0.00965	-0.00150	-0.00041	0.02298
5	0.99620	-0.09775	0.00037	-0.02320	-0.00653	-0.00001	0.03511
6	1.30424	-0.18141	0.00075	-0.04323	0.00029	-0.00096	0.05140
7	1.41305	-0.01239	0.00858	-0.00890	0.01628	-0.00109	-0.35941
8	1.10001	-0.05376	0.00020	-0.00583	-0.02111	-0.00378	0.08997
9	0.72463	-0.06870	0.00071	-0.01239	-0.00340	-0.07185	0.08912
10	0.66532	-0.23661	-0.00087	-0.00072	0.01005	-0.00075	0.04811
11	0.66183	-0.01409	-0.00486	0.00728	0.00574	-0.00030	0.26158
12	0.72896	-1.32435	0.00000	-0.00512	0.00075	0.00028	0.14230
13	0.83767	-0.12658	0.00064	-0.04411	-0.00142	0.00118	0.10402
14	0.66323	-0.14848	0.00038	-0.01514	-0.00036	-0.00248	0.14170
15	1.00616	-0.14127	-0.00023	-0.00493	-0.13642	-0.00009	0.11575
16	0.88618	-0.30872	-0.00054	-0.00249	-0.00364	-0.00071	0.18861
17	0.50472	-1.49939	0.00005	-0.02642	-0.00043	-0.00013	0.35678
18	0.44408	-0.03101	0.01581	-0.05887	0.00005	0.00026	-0.68761
19	0.28014	-2.06896	0.00009	-0.19401	0.00024	0.00000	0.69524

Period	$\hat{\underline{\beta}}_{1,p}$ ***d91pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
20	0.44183	-2.38322	0.00001	-0.02340	0.00081	0.00000	0.45237
21	0.35624	-2.42354	0.00002	-0.04712	0.00000	0.00000	0.74503
22	0.61450	-0.04327	0.00000	-0.00043	-0.41196	0.00000	0.54564
23	0.41989	-1.37446	0.00050	-0.05152	-0.00074	0.00000	0.62263
24	0.34829	-4.21112	0.00002	-0.06080	-0.00088	0.00000	0.81751
25	0.84271	0.00580	-0.00049	0.00549	0.00331	0.00000	0.15713
26	0.62309	-0.49588	-0.00033	-0.00122	0.00011	0.00000	0.37114
27	0.88094	-0.18408	-0.00214	0.00709	-0.01550	0.00000	0.35742
28	0.77504	-0.03044	-0.00233	0.02417	0.00300	0.00000	0.35344
29	0.59289	-1.11812	0.00010	-0.13675	0.00507	0.00000	0.30315
30	0.68944	-0.24293	-0.00007	-0.00444	0.00346	0.00000	0.20350
31	0.56705	-1.20224	-0.00338	0.04650	-0.00273	0.00000	0.52813
32	0.79052	0.07667	-0.00047	0.00745	-0.02537	0.00000	0.16817
33	0.73847	-3.12125	0.00011	-0.05552	-0.00011	0.00000	0.16800
34	0.79208	-0.41364	0.00010	-0.01248	0.00826	0.00000	0.13431
35	0.67852	-2.41290	0.00000	-0.00171	0.00020	0.00000	0.20559
36	0.61753	-0.83238	0.00007	-0.01502	0.00102	0.00000	0.19564

Period	$\hat{\underline{\beta}}_{1,p}$ ***d91pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{6,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
37	0.68822	0.10934	-0.00297	0.03617	0.00042	0.00000	0.34565
38	0.74442	-0.69261	-0.00021	-0.00857	0.00685	0.00000	0.07278
39	0.57384	-0.04460	0.00027	-0.00629	-0.00003	0.00000	0.04300
40	0.42344	-0.03909	0.00215	-0.02054	-0.00093	0.00000	-0.14205
41	0.61921	-0.03202	0.00098	-0.01080	-0.00416	0.00000	-0.10590
42	0.56841	-0.00952	0.00050	-0.00559	0.00002	0.00000	-0.03554
43	0.27155	-0.03828	0.00030	-0.00627	-0.00423	0.00000	-0.00237
44	0.89970	-0.00687	0.00009	-0.00118	0.00078	0.00000	-0.01265
45	0.48782	-0.09624	0.00004	-0.00332	-0.00013	0.00000	0.00068
46	0.44229	-0.00243	0.00007	-0.00086	-0.00151	0.00000	-0.00546
47	1.87684	-0.01012	0.00005	-0.00152	0.00003	0.00000	0.04007
48	1.09058	-0.02965	0.00031	-0.00702	0.00093	0.00000	0.01186
49	0.55530	-0.05143	0.00178	-0.02231	0.00778	0.00000	-0.04411
50	0.98108	-0.03629	0.00007	-0.00316	-0.00523	0.00000	-0.00300
51	0.62378	-0.11767	0.00014	-0.00875	-0.00048	0.00000	0.00340
52	0.40152	-0.00234	-0.00004	0.00016	0.00102	0.00000	0.00036

Table A.4.4.4.2.6. Model-averaged coefficients for predicting the percent of Total A diversion through arc D11 specific to each 5-day period of the irrigation water year.

Period	$\hat{\underline{\beta}}_{1,p}$ ***d11pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d11taf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.07301	-0.00034	0.00023	-0.00054	0.01869
2	0.81156	-0.00174	-0.00017	0.00116	0.00932	0.00000	-0.00004	-0.00012	-0.00072	0.02610
3	0.43019	0.08239	-0.00005	0.00771	-0.00059	0.00000	-0.00001	-0.00042	-0.00086	0.01621
4	0.66484	-0.03242	0.00013	-0.00603	0.00052	0.00000	0.00001	-0.00013	-0.00003	0.00668
5	0.19510	-0.00585	0.00073	-0.00399	0.00164	0.00000	0.00010	-0.00004	0.00019	-0.01749
6	0.74089	0.15853	0.00009	0.00029	0.00076	0.00000	0.00000	0.00001	0.00004	0.00484
7	0.68091	-0.02076	0.00000	-0.00080	0.00248	0.00000	0.00001	-0.00007	-0.00001	0.01494
8	0.75170	-0.01502	0.00041	-0.00515	-0.00023	0.00000	0.00001	-0.00125	-0.00047	0.00235
9	1.00361	-0.02075	0.00015	-0.00325	-0.00311	0.00000	-0.00001	0.00004	-0.00002	-0.00228
10	0.32083	-0.11076	0.00002	-0.00414	-0.00046	0.00000	0.00000	-0.00014	-0.00021	0.03806
11	0.63233	-0.09542	-0.00003	-0.00055	-0.00059	0.00000	-0.00001	-0.00072	-0.00533	0.03604

Period	$\hat{\underline{\beta}}_{1,p}$ ***d11pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d11taf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
12	0.65594	-0.01430	0.00085	-0.02756	0.00011	0.00000	0.00000	0.00000	0.00000	-0.00164
13	0.79517	-0.01189	0.00004	-0.00166	-0.00329	0.00000	-0.00006	-0.00048	-0.00533	0.02879
14	0.44772	-0.01209	0.00000	-0.00028	-0.00579	0.00000	-0.00468	0.00284	-0.00002	0.07476
15	0.82228	-0.00626	0.00009	-0.00311	0.00066	0.00000	-0.00001	0.00045	0.00035	0.02490
16	0.47569	-0.42237	0.00000	-0.00293	-0.00041	0.00000	0.00000	-0.00012	-0.00010	0.06104
17	0.83949	-0.00093	0.00006	-0.00065	-0.00152	0.00000	-0.00001	0.00028	0.00020	0.02379
18	0.06452	-0.29755	0.00008	-0.01389	0.00022	0.00000	0.00000	-0.00011	-0.00007	0.10816
19	0.41162	-0.03275	0.00066	-0.02807	0.00027	0.00000	0.00000	0.00000	0.00000	0.03074
20	0.72065	-0.32597	0.00002	-0.01170	0.00021	0.00000	0.00000	0.00000	0.00000	0.06758
21	0.60006	-0.01591	0.00009	-0.00247	-0.01668	0.00000	0.00000	0.00000	0.00000	0.06917
22	0.44099	-0.12259	0.00004	-0.00380	0.00011	0.00000	0.00000	0.00000	0.00000	0.08588

Period	$\hat{\underline{\beta}}_{1,p}$ ***d11pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d11taf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
23	0.33793	-0.08527	0.00027	-0.00852	-0.00357	0.00000	0.00000	0.00000	0.00000	0.09005
24	0.33401	-0.02003	0.00038	-0.02713	-0.00509	0.00000	0.00000	0.00000	0.00000	0.09773
25	0.23845	-0.02368	0.00016	-0.00288	-0.00829	0.00000	0.00000	0.00000	0.00000	0.12582
26	0.40076	-0.22377	0.00017	-0.01903	-0.00002	0.00000	0.00000	0.00000	0.00000	0.11464
27	0.85083	-0.12250	0.00017	-0.00589	0.00126	0.00000	0.00000	0.00000	0.00000	0.02723
28	0.47245	0.85496	0.00000	0.00030	0.01878	0.00000	0.00000	0.00000	0.00000	0.07014
29	0.72650	-0.05503	-0.00003	-0.00270	-0.00205	0.00000	0.00000	0.00000	0.00000	0.05750
30	0.69444	-0.02431	0.00004	-0.00150	0.01467	0.00000	0.00000	0.00000	0.00000	0.02297
31	0.58760	-1.75888	-0.00041	0.00480	0.00298	0.00000	0.00000	0.00000	0.00000	0.08048
32	0.77070	-0.00247	-0.00004	0.00023	-0.00731	0.00000	0.00000	0.00000	0.00000	0.02995
33	0.66535	-0.01554	0.00001	-0.00073	-0.02172	0.00000	0.00000	0.00000	0.00000	0.04518
34	0.53705	-0.00340	-0.00019	0.00148	-0.00144	0.00000	0.00000	0.00000	0.00000	0.06634

Period	$\hat{\underline{\beta}}_{1,p}$ ***d11pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d11taf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
35	0.45320	0.00214	-0.00027	0.00239	-0.00134	0.00000	0.00000	0.00000	0.00000	0.07921
36	0.65755	0.00440	0.00010	-0.00041	-0.00038	0.00000	0.00000	0.00000	0.00000	0.03655
37	0.73441	-0.09679	0.00023	-0.00667	-0.00039	0.00000	0.00000	0.00000	0.00000	0.01212
38	0.42220	-0.00349	-0.00064	0.00229	-0.00131	0.00000	0.00000	0.00000	0.00000	0.12308
39	0.54685	0.00488	0.00024	-0.00128	-0.00029	0.00000	0.00000	0.00000	0.00000	0.02126
40	0.54022	-0.00384	0.00048	-0.00279	-0.00287	0.00000	0.00000	0.00000	0.00000	0.00782
41	0.47370	-0.00237	0.00302	-0.00550	-0.00002	0.00000	0.00000	0.00000	0.00000	-0.18044
42	0.47340	-0.01208	0.00003	-0.00144	0.00027	0.00000	0.00000	0.00000	0.00000	0.03649
43	0.62588	-0.05757	0.00005	-0.00244	-0.00288	0.00000	0.00000	0.00000	0.00000	0.02007
44	0.54080	-0.01005	0.00013	-0.00174	0.00027	0.00000	0.00000	0.00000	0.00000	0.01941
45	0.98573	-0.02386	-0.00048	0.00070	-0.00002	0.00000	0.00000	0.00000	0.00000	0.03722
46	0.70021	-0.00987	0.00008	-0.00163	-0.00088	0.00000	0.00000	0.00000	0.00000	0.01247

Period	$\hat{\underline{\beta}}_{1,p}$ ***d11pcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d11taf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd11wint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd11***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
47	0.71077	-0.01267	0.00006	-0.00186	-0.00269	0.00000	0.00000	0.00000	0.00000	0.00892
48	0.61525	0.00468	0.00000	0.00039	0.00486	0.00000	0.00000	0.00000	0.00000	0.01640
49	0.82883	0.01144	-0.00002	0.00092	-0.00066	0.00000	0.00000	0.00000	0.00000	0.00889

Table A.4.4.4.2.7. Model-averaged coefficients for predicting the percent of Total A diversion through arc D12A specific to each 5-day period of the irrigation water year.

Per-iod	$\hat{\underline{\beta}}_{1,p}$ ***d12apcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d12ataf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
1	0.00000	0.00000	0.00000	0.00000	0.00000	0.18305	-0.00128	-0.00062	-0.01744	0.11927
2	0.81802	-0.00416	0.00356	-0.01294	-0.00141	0.00000	0.00000	0.00015	0.00026	-0.13215
3	0.50800	0.02508	0.00034	-0.00047	0.01952	0.00000	0.00007	-0.01538	-0.00328	0.06648
4	0.74563	-0.02448	-0.00004	-0.00113	0.00581	0.00000	0.00006	0.00026	0.00154	0.03679
5	0.94796	0.00776	0.00041	-0.00108	-0.03660	0.00000	-0.00014	0.00009	-0.00095	-0.03227
6	0.70165	0.00825	0.00004	0.00006	0.01693	0.00000	0.00171	-0.00029	0.00346	-0.01036
7	0.83783	-0.14322	0.00045	-0.01472	-0.00078	0.00000	0.00002	-0.00074	-0.00020	0.01350
8	0.71768	-0.03803	0.00096	-0.01296	-0.00424	0.00000	0.00000	-0.00065	-0.00060	-0.00151
9	0.81116	-0.02466	0.00025	-0.00375	-0.01483	0.00000	-0.00005	-0.00103	-0.00336	0.01049
10	0.47693	-0.19870	0.00003	-0.00749	0.01970	0.00000	0.00005	-0.00077	-0.00008	0.06323
11	0.52394	-0.05049	0.00011	-0.00569	0.00006	0.00000	0.00031	-0.01372	-0.00025	0.03948
12	0.53874	0.00830	-0.00306	0.00861	0.00237	0.00000	0.00000	-0.00027	-0.00032	0.21843
13	0.58993	-0.00289	0.00021	-0.00290	-0.00169	0.00000	-0.00015	0.02536	0.00115	0.04005

Per-iod	$\hat{\underline{\beta}}_{1,p}$ ***d12apcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d12ataf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
14	0.54369	-0.01630	0.00013	-0.00254	0.00176	0.00000	0.00622	-0.00014	0.00830	-0.06316
15	0.77568	-0.04073	0.00005	-0.00561	-0.00025	0.00000	-0.00116	0.00200	-0.00066	0.07246
16	0.36187	-0.28472	0.00006	-0.00882	-0.01675	0.00000	0.00008	-0.00111	-0.00006	0.12564
17	0.69767	-0.05804	0.00040	-0.01241	-0.00033	0.00000	0.00009	-0.00051	0.00020	0.04328
18	0.47018	0.00286	0.00011	-0.00074	0.00456	0.00000	0.00034	0.00058	0.00862	0.06206
19	0.22942	-0.00854	-0.00003	-0.00010	0.05956	0.00000	0.00000	0.00000	0.00000	0.15117
20	1.03382	0.00251	0.00000	0.00023	-0.07933	0.00000	0.00000	0.00000	0.00000	0.05434
21	0.76818	-0.01832	-0.00001	-0.00091	0.04779	0.00000	0.00000	0.00000	0.00000	0.04952
22	0.70908	-0.00292	0.00016	-0.00232	-0.00672	0.00000	0.00000	0.00000	0.00000	0.04407
23	0.46171	-0.12922	0.00003	-0.00435	-0.00685	0.00000	0.00000	0.00000	0.00000	0.14161
24	0.67594	0.02001	-0.00181	0.05507	0.00271	0.00000	0.00000	0.00000	0.00000	0.17308
25	0.61014	0.08799	-0.00014	0.00581	0.00959	0.00000	0.00000	0.00000	0.00000	0.09351
26	0.93549	-0.08750	0.00060	-0.01972	0.00215	0.00000	0.00000	0.00000	0.00000	-0.01883
27	0.81487	0.02788	0.00001	0.00063	0.00394	0.00000	0.00000	0.00000	0.00000	0.00657

Per-iod	$\hat{\underline{\beta}}_{1,p}$ ***d12apcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d12ataf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
28	0.76392	-0.23708	0.00017	-0.00605	-0.00737	0.00000	0.00000	0.00000	0.00000	0.02694
29	0.81036	-0.00158	-0.00052	0.00501	-0.00129	0.00000	0.00000	0.00000	0.00000	0.06148
30	0.83403	0.18065	-0.00048	0.01650	-0.00327	0.00000	0.00000	0.00000	0.00000	0.07737
31	0.62705	5.46917	0.00036	-0.00409	0.00198	0.00000	0.00000	0.00000	0.00000	0.02542
32	0.68780	-0.14152	0.00032	-0.00844	-0.00024	0.00000	0.00000	0.00000	0.00000	0.03492
33	0.77325	0.09220	-0.00014	0.00541	-0.02715	0.00000	0.00000	0.00000	0.00000	0.04019
34	0.53871	0.08192	-0.00060	0.02100	0.00147	0.00000	0.00000	0.00000	0.00000	0.11879
35	1.06332	0.01770	0.00020	-0.00100	-0.00052	0.00000	0.00000	0.00000	0.00000	0.00698
36	0.74104	-0.01487	0.00038	-0.00345	-0.00222	0.00000	0.00000	0.00000	0.00000	0.02980
37	0.73660	0.01336	0.00005	-0.00005	0.01212	0.00000	0.00000	0.00000	0.00000	0.05461
38	0.72754	0.00388	0.00023	-0.00126	-0.02137	0.00000	0.00000	0.00000	0.00000	0.02525
39	0.67850	0.02486	-0.00115	0.01003	0.00418	0.00000	0.00000	0.00000	0.00000	0.12946
40	0.58512	-0.00461	-0.00007	0.00036	0.00380	0.00000	0.00000	0.00000	0.00000	0.04039
41	0.48806	0.06198	-0.00003	0.00252	0.00390	0.00000	0.00000	0.00000	0.00000	0.06385

Per-iod	$\hat{\underline{\beta}}_{1,p}$ ***d12apcta***	$\hat{\underline{\beta}}_{2,p}$ ***ppt***	$\hat{\underline{\beta}}_{3,p}$ ***tmax***	$\hat{\underline{\beta}}_{4,p}$ ***ptdayindex***	$\hat{\underline{\beta}}_{5,p}$ ***shortdum***	$\hat{\underline{\beta}}_{9,p}$ ***d12ataf***	$\hat{\underline{\beta}}_{6,p}$ ***cumd12awint***	$\hat{\underline{\beta}}_{7,p}$ ***cumpptwint***	$\hat{\underline{\beta}}_{8,p}$ ***pdindexd12a***	$\hat{\underline{\beta}}_{0,p}$ ***constant***
42	0.85842	0.01809	-0.00018	0.00385	0.00344	0.00000	0.00000	0.00000	0.00000	0.01941
43	0.77617	0.04323	-0.00004	0.00211	0.00025	0.00000	0.00000	0.00000	0.00000	0.01957
44	0.54905	-0.03201	0.00044	-0.00596	-0.00250	0.00000	0.00000	0.00000	0.00000	0.01051
45	0.76631	-0.05339	-0.00015	-0.00012	-0.03242	0.00000	0.00000	0.00000	0.00000	0.04758
46	0.36573	-0.00601	-0.00025	0.00186	-0.00149	0.00000	0.00000	0.00000	0.00000	0.11049
47	0.50002	-0.02650	0.00032	-0.00677	-0.00074	0.00000	0.00000	0.00000	0.00000	0.05247
48	0.83936	0.01029	0.00020	-0.00061	0.00080	0.00000	0.00000	0.00000	0.00000	0.02084
49	0.84612	-0.02674	0.00136	-0.01716	0.00189	0.00000	0.00000	0.00000	0.00000	-0.05438

A.4.4.4.3. Implementing the Agricultural Water Delivery Sub-model in the KBPM

In the KBPM, the sub-model described in preceding sections has been fully implemented. For each 5-day period of the spring/summer irrigation season, the sub-model predicts the percent of Total A diversions to be delivered through each diversion arc. Several additional steps were taken within the KBPM to calculate the daily flow to be delivered through each diversion arc.

An estimate of Total A diversions was necessary in order to compute the daily diversions. Predicated on the assumption that the Project Supply will be fully used in each year, KBPM runs were iterated to obtain estimates of two variables used to estimate Total A diversions. Total seasonal diversion of return flow from the LRDC and pumps F/FF for all diversion arcs (dir_div_acc_est) was calculated from KBPM output. Also, the predicted percentages of Total A diversions from KBPM output were summed across diversion arcs for each irrigation water year, and a simple proportional adjustment (Pct_tota_adjust) was developed to correct for departures of these sums from 100%. Then the estimated Total A diversion (esttota) was calculated as:

esttota = PrjSupply_irr + dir_div_acc_est + Pct_tota_adjust * PrjSupply_irr

where PrjSupply_irr = PrjSupply - RefugeFallSupply

Daily diversions were then computed for each diversion arc by multiplying esttota by the predicted percent of Total A diversion for the appropriate 5-day period, dividing the product by 5 days, and converting the volume to cfs. D1 diversions always were comprised solely of UKL water. The other diversion arcs were split into arcs accounting for diversion of UKL water (Project Supply) as opposed to diversion of return flow.

A.4.4.5. Project Return Flows

Project return flow results from delivered water which could not be fully consumed by the Project land to which it was applied. At some times of year, return flows from irrigation are frequently mixed with runoff from precipitation or snowmelt. Return flows are considered separately for the three different irrigation areas of A1, A2 and the LKNWR (see Figure A.4.3.1.1).

Area A1 returns flow to the Lost River downstream of Harpold Dam. This return flow is accounted for through the time-series input (i.e. historical daily flow measured at LRDC headworks) of the Lost River to the Lost River Diversion Channel, or I91 in the model. Because the area between Harpold Dam and the LRDC headworks is served by D1 (A Canal) diversions, the inflows in the I91 arc were adjusted either up or down to reflect changes in A Canal diversion from what occurred historically. For example, historical I91 flow was zero for extended periods during the irrigation shutoff in 2001, whereas the KBPM simulates substantial A Canal diversion throughout 2001 under the Proposed Action. In this case, I91 flows had to be adjusted upwards to reflect the likely outcome of the Proposed Action in such a year. Conversely, simulated A Canal diversion in 1992 under the Proposed Action were much smaller than the actual diversions in that year, requiring a downward adjustment of I91 flow in the simulation.

Adjustments to LRDC inflow reflecting changed (relative to historical) A Canal diversions were made by first subtracting each 5-day period sum of simulated D1 deliveries from the historical

D1 deliveries. Multiplying this difference by 0.2, subtracting the result from I91, dividing this result by 5 days, and converting the resulting daily volume to cfs completed the adjustment. The 0.2, essentially the expected proportion of A Canal diversion expected to appear as return flow at the LRDC headworks, was selected because it produced simulated LRDC inflows of a reasonable magnitude relative to the base flow periods of other years. As a result of this process, the LRDC inflows now respond dynamically to changes in D1 diversions.

Total Area A2 return flows from the Project and Refuge lands (LKNWR and Area K) through the KSD are represented as C131 in the KBPM. Variable C131 can be further divided into return flows from the Project (return flow arc R131a) and LKNWR (return flow arc R131b), along with local runoff from the surrounding area. The Proposed Action assumes R131b to be zero, a conservative assumption reflecting the likely result of LKNWR supply reductions from the historical condition.

Agricultural return flows in R131a were simulated dynamically by a series of simple models estimating non-Refuge return flows from the F/FF pumps for different time periods throughout the year. Different models were required for different periods because of the manner with which water is managed. In Area A2, the agricultural lands are typically flooded over the winter months, pumped off in the late winter or early spring, and then irrigated through the summer and fall months. More extensive winter flood-up can be expected to incrementally reduce the irrigation demand (and the associated return flow) during the following spring and summer, and vice versa. Winter precipitation contributes to the extent of the winter flood-up, as well as the return flow volume pumped off.

All analyses were done using the 5-day periods of the irrigation water year described in Section 4.4.4.1. The irrigation water year was split into two seasons for the purpose of developing variables for use in modeling F&FF return flows. Periods 50-14 encompass the winter and spring periods when flood-up and pump-off activities are prevalent in Area A2. Periods 15-49 encompass the late spring through early fall period comprising the bulk of the growing season. Average daily precipitation (inches) and average daily maximum temperature (°F) for Area A2 were a subset of those used for the agricultural water delivery sub-model development (see section 4.4.4.1); that is, these data were from the PRISM grids in Area A2 in Figure A.4.4.4.1.1. In order to combine precipitation with diversions, average precipitation depth was converted to precipitation volume (TAF) by multiplying it by the approximate irrigated acreage within KDD (27,000 acres).

Historical daily D11 and D12A diversions into Area A2 were summed and used to quantify daily irrigation diversions into A2. Total agricultural diversion plus precipitation volume was computed for each period (variable cum_KDD_in_5d). Cumulative agricultural diversion plus precipitation volume was computed for periods 50-14 (variable cum_KDD_in_p50to14) and 15-49 (variable cum_KDD_in_p15to49); values for these two variables were held constant after the end period until the next starting period was encountered. These three variables were rescaled to be between 0 and 1 (normalized; see formula in Section A.4.4.4.1), and the prefix “norm_” was appended to each of their variable names.

Historical daily returns from the LKNWR measured at KSD at Stateline Road were subtracted from the historical daily volume pumped into the Klamath River at pumps F/FF, assuming a 1-day travel time within the KSD. These historical daily return flows absent the LKNWR returns were summed by 5-day period (variable FFFagout) and used as the dependent variable in developing the simple models used to simulate R131a in the KBPM.

Various expressions of agricultural return flow in the current period relative to combined ag diversion and precipitation as of the end of the previous period (indicated by the prefix "lag_") were calculated:

cum_KDD_in_5d_prop = (FFFagout + 1) / (lag_cum_KDD_in_5d + 1)

cum_KDD_in_p50to14_prop = (FFFagout + 1) / (lag_cum_KDD_in_p50to14 + 1)

cum_KDD_in_p15to49_prop = (FFFagout + 1) / (lag_cum_KDD_in_p15to49 + 1)

Averages by 5-day period across irrigation water year were calculated for each of these variables, denoted by the prefix "avg_".

A series of potential models estimating FFFagout was developed and evaluated based on error characteristics. For each model, error (simulated FFFagout – actual FFFagout) was summarized by 5-day period as mean error (ME), mean square error (MSE), and mean absolute error (MAE). Only the models selected for use in the KBPM are presented here. The models are:

Model_9 = max(0, avg_cum_KDD_in_5d_prop * (lag_cum_KDD_in_5d + 1) - 1)

Model_10 = max(0, model_9 + (-1 * lag_norm_cum_KDD_in_5d * model_9))

Model_11 = max(0, avg_cum_KDD_in_p50to14_prop * (lag_cum_KDD_in_p50to14 + 1) - 1)

Model_12 = max(0, model_11 + (-1 * lag_norm_cum_KDD_in_p50to14 * model_11))

Model_13 = max(0, avg_cum_KDD_in_p15to49_prop * (lag_cum_KDD_in_p15to49 + 1) - 1)

Model_14 = max(0, model_13 + (-1 * lag_norm_cum_KDD_in_p15to49 * model_13))

Model_17 = (model_11 + model_12) / 2

Model_19 = (model_9 + model_11) / 2

Model_20 = (model_9 + model_10 + model_11 + model_12) / 4

Model_22 = (model_9 + model_10 + model_11 + model_12 + model_13 + model_14) / 6

In the KBPM, R131a is computed using:

Model_11 for periods 1-9 and 62-73;

Model_19 for periods 10-32;
Model_20 for periods 33-50;
Model_22 for periods 51-55; and
Model_17 for periods 56-61.

Daily estimates of R131a were obtained by dividing each model result by the number of days in the period and converting from volume to cfs. Implementation of this logic in the KBPM makes R131a dynamically responsive to past irrigation diversions and precipitation.

Errors associated with simulating R131a (Table A.4.4.5.1) tend to be larger during the winter and early spring, tend towards overestimation during the first half of the irrigation water year, but tend towards underestimation during the last half. Note that this model structure was intended only for use in the KBPM. Real-time operational forecasts of R131a are possible and could be developed if deemed useful to operations.

Table A.4.4.5.1. Error characteristics associated with the models used to simulate R131a in the KBPM. Period is 5-day period of the irrigation water year, which begins on March 1. Error is computed as simulated minus actual FFFagout (units are TAF). ME is mean error; MSE is mean square error; and MAE is mean absolute error.

Period	ME	MSE	MAE	Period	ME	MSE	MAE
1	0.016	1.123	0.850	38	-0.151	0.121	0.285
2	0.039	1.146	0.922	39	-0.150	0.152	0.323
3	0.012	1.039	0.823	40	-0.134	0.097	0.237
4	0.010	1.531	1.008	41	-0.129	0.137	0.291
5	0.029	1.443	0.988	42	-0.089	0.087	0.232
6	0.008	1.047	0.782	43	-0.101	0.119	0.269
7	0.025	0.893	0.709	44	-0.063	0.073	0.196
8	0.015	0.960	0.765	45	-0.066	0.052	0.178
9	0.014	0.464	0.525	46	-0.046	0.031	0.129
10	0.050	0.175	0.322	47	-0.030	0.045	0.170
11	0.074	0.184	0.306	48	-0.028	0.070	0.192
12	0.068	0.211	0.334	49	-0.002	0.040	0.142
13	0.088	0.193	0.301	50	-0.069	0.042	0.141
14	0.072	0.110	0.249	51	-0.024	0.074	0.196
15	0.107	0.253	0.321	52	0.039	0.120	0.255
16	0.066	0.095	0.250	53	-0.032	0.070	0.218
17	0.093	0.160	0.287	54	-0.019	0.077	0.216
18	0.081	0.132	0.295	55	-0.031	0.117	0.220
19	0.066	0.134	0.285	56	-0.057	0.072	0.212
20	0.068	0.124	0.277	57	-0.066	0.093	0.241
21	0.079	0.163	0.332	58	-0.102	0.089	0.220
22	0.069	0.159	0.301	59	-0.096	0.122	0.260
23	0.067	0.154	0.327	60	-0.104	0.100	0.230
24	0.056	0.150	0.318	61	-0.135	0.119	0.263
25	0.050	0.164	0.334	62	0.074	0.179	0.330
26	0.059	0.142	0.291	63	0.048	0.328	0.400
27	0.077	0.154	0.311	64	0.067	0.237	0.361
28	0.075	0.153	0.311	65	0.009	0.224	0.335
29	0.066	0.104	0.262	66	-0.024	0.487	0.467
30	0.063	0.090	0.238	67	-0.021	0.581	0.537
31	0.078	0.187	0.352	68	-0.033	0.494	0.511
32	0.085	0.127	0.297	69	-0.034	0.650	0.637
33	-0.143	0.102	0.246	70	-0.028	0.846	0.735
34	-0.102	0.095	0.215	71	-0.008	0.955	0.766
35	-0.120	0.115	0.270	72	-0.006	1.140	0.886
36	-0.177	0.144	0.281	73	0.006	1.249	0.867
37	-0.199	0.119	0.281				

In past versions of the KBPM (including the original spreadsheet model, KPSIM) a variable called A2 Winter Runoff was included in determining the C131 flow. In reality, this term had little to do with runoff – it has always been an error closure term. In the present KBPM, the name A2 Winter Runoff has been dropped, although the error closure term has been retained.

This error closure term, I131, is input to the KBPM as an inflow arc, though it is comprised of both positive and negative terms. It was derived by using the model structure described above to simulate the historical FFFagout, and then subtracting the simulated FFFagout from the historical.

A.4.4.6. EWA Use in Model

The EWA is accounted for through releases for the Klamath River through LRD and releases for flood protection. The flood control releases are further described in Sections A.4.4.8 and A.4.4.10. Regardless of the intent of the release, all LRD releases that are not diverted to the Project or LKNWR are counted against the EWA. Furthermore, during IGD controlled flow conditions (e.g., minimum required flows, IGD targeted flows, ramping flows), contributions to IGD flow from LRDC and F/FF pumping are counted as EWA releases when they result in an equivalent reduction in LRD releases to support Klamath River flows. This does not happen when UKL is in flood control.

Targeted flows from March to September are the sum of a formulated LRD release, Keno Reservoir accretions, and Keno to IGD accretions. These flow targets control IGD operations when they are greater than the required minimum flows. There are two LRD release formulas for EWA use: one that applies March to June, and one that applies July to September. EWA releases in service of IGD flow targets are subject to reduction under the UKL control logic (reduction applies to LRD specifically, as described below). EWA releases in service of disease mitigation/habitat flows (as defined in Section A.4.4.7 and BA, Section 4.3.2.2.2.4), minimum required IGD flows, and IGD ramping flows are not subject to reduction under UKL control logic.

The spring/summer LRD release formulation is based on EWA allocation and UKL control logic from March 1 – September 30, and additionally accounts for UKL net inflow and forecasted March-September UKL net inflow from March 1 – June 30 (but not from July 1 – September 30, as described below). From March 1 – June 30 there is also a correction applied that accelerates EWA release if there was under-release in previous days (e.g., due to UKL control) and decelerates EWA release if there was an over-release in previous days (e.g., due to flood control or surface flushing flows). The following steps are taken to calculate the LRD Release:

1. Calculate **in_pct_Mar50vol**, used to ensure that LRD releases for IGD flows properly reflect both the UKL net inflow from the previous day and an appropriate adjustment to account for NRCS forecast error experienced through the current day. This release adjustment is calculated March through June, relying upon the Mar50vol (March 1 – June 1 monthly NRCS forecast of UKL net inflow, combined with actual net inflow since March 1). Experienced forecast error is added to the Mar50vol in order to ensure that releases are increased or decreased to account for deviations from prior UKL net inflow forecasts. In addition, a further release correction, in the form of a UKLSupply dependent quadratic equation developed from model output, is made to avoid substantial over or underspending of calculated EWA across the season. The in_pct_Mar50vol variable is calculated as follows:

   $$\text{In_pct_Mar50vol} = \max(0, I1(-1) / (\text{Mar50vol} + \text{_fcst_error}) * (1 - 0.000000029263 * \text{UKLSupply}^2 - 0.000107692714 * \text{UKLSupply} + 0.082201089297))$$

where: I1(-1) = yesterday's UKL net inflow
Mar50vol = NRCS forecast of inflow to UKL, March through September
fcst_error = 0 in March; otherwise, from April to June
[Last month's 50% exceedance UKL net inflow forecast] –
[Last month's actual UKL net inflow] –
[This month's 50% exceedance UKL net inflow forecast]
UKLSupply = calculated UKL Supply as described in section A.4.4.3

2. Calculate **FlexFlowAdjust**, which is the daily augmentation to Klamath River flow that is to be added to the river flow computed without any augmentation. The total volume (taf) available for use in augmenting river flow (if any) is PRJ_FlexAugment + UKL_FlexAugment (Figure A.4.4.3.1). In SFF Status 2 years, the 20,000 AF of flexible EWA use is also added to the augmentation. Operationally, Reclamation will coordinate as described in BA Sections 4.3.2.2.2.5 and 4.3.2.2.3 to determine the starting day, duration, and daily magnitude (including potential ramping) of flexible flow augmentation, while constraining the implementation to be within the March through June window and to not exceed the total flexible flow augmentation volume. For several reasons, it was not possible in this iteration of KBPM development to construct rules that would reliably duplicate the decision process that would operationally drive how the specified augmentation volume would be used. For example, disease dynamics have strongly influenced requests for additional flows in recent years, involving factors like concentrations of *Ceratonova shasta* actinospores of a specific genotype, observed prevalence of infection in juvenile salmon, water temperature, timing and extent of juvenile emigration of wild salmon stocks, and other considerations. At present we lack the ability to reliably simulate these factors back through the KBPM period-of-record, and so we cannot dynamically simulate these processes in the KBPM.

   Therefore, agency water management and fisheries professionals helped to develop the settings in Table A.4.4.6.1, which reproduces the EWA_Augment table used in the KBPM to dictate how the available flexible augmentation volume is managed in any given water year. In this way our best judgement was used, based on in-year consideration of available information (inflows, accretions, precipitation, disease-related information in some years, etc.), to simulate how augmentation water would be used in each year.

   Settings in Table A.4.4.6.1 for each water year specify the starting date and duration of augmentation, and whether to down-ramp flows at the end of the augmentation period, using the specified ramp rate. The volume needed to down-ramp augmentation flows is estimated dynamically near the end of the augmentation period to prevent over-spending of the total augmentation volume.

   Flow augmentation can occur in the March-June window. The daily flow augmentation quantity is computed as the variable named **FlexFlowAdjust.** When augmentation occurs in March, FlexFlowAdjust = (PRJ_FlexAugment + UKL_FlexAugment) / Duration, resulting in a uniform augmentation flow to be added to the calculated Iron Gate flow target for each day to be augmented in March. In April, augmentation volume may change due to change in UKLSupply , so FlexFlowAdjust = (PRJ_FlexAugment + UKL_FlexAugment) / (Duration – days augmented in March). As stated above, when a year is categorized as SFF Status 2,

20,000 AF of EWA volume is distributed similarly to the flexible augmentation volume, which is accomplished by adding the 20,000 AF in those years to the numerator of the FlexFlowAdjust equations.

Table A.4.4.6.1. Settings in the EWA_Augment table, which dictates how the FlexFlowAdjust variable is computed. Start month is the WY month (e.g. April = 7) when flexible augmentation (if any) begins. Start day is the day of the start month on which flexible augmentation begins. Duration is the number of days augmentation is to occur. When ramp switch is 1, at the end of the augmentation period FlexFlowAdjust reductions toward zero are constrained to not exceed the specified ramp rate. Note that augmentation occurs only in years where UKL Supply is between 550,000 TAF and 950,000 TAF (see Figure A.4.4.3.1); the specification of a start month and day in this table does not mean augmentation was provided in that given year.

WY	Start month	Start day	Duration	Ramp switch	Ramp rate
1981	7	5	64	1	50
1982	7	1	75	0	50
1983	7	1	75	0	50
1984	7	1	75	0	50
1985	7	1	75	0	50
1986	7	1	75	0	50
1987	7	1	75	0	50
1988	6	31	65	1	50
1989	7	1	75	0	50
1990	6	30	55	1	50
1991	7	13	43	0	50
1992	7	1	75	0	50
1993	7	1	75	0	50
1994	7	8	60	0	50
1995	7	1	75	0	50
1996	7	1	75	0	50
1997	7	1	75	0	50
1998	7	1	75	0	50
1999	7	1	75	0	50
2000	7	1	75	0	50
2001	7	3	58	0	50
2002	7	23	40	1	50
2003	7	1	35	0	50
2004	7	6	61	1	20
2005	7	5	36	0	50
2006	7	1	75	0	50
2007	7	20	56	0	50
2008	7	1	75	0	50
2009	7	17	50	0	50
2010	7	22	47	0	50
2011	7	1	75	0	50
2012	8	18	28	0	50
2013	7	17	60	0	50
2014	6	23	52	0	50
2015	6	26	65	0	50
2016	8	1	31	0	50
2017	7	15	61	0	50
2018	7	14	43	0	50
2019	8	7	24	0	50
2020	8	1	50	0	50

3. Determine **Link_release_ss_diff**, which is the cumulative difference between what was actually released from LRD to support IGD flows yesterday and what was expected to be released to support yesterday's IGD flow target. This variable ensures that actual LRD releases remain in line with what is calculated so that seasonal expenditure of EWA remains on track to utilize the full EWA. Link_release_ss_diff serves as a correction for previous over or under release. The calculation is as follows:

   Link_release_ss_diff = C1_River(-1) – prj_credit_spill_forEWA + prj_acc_addition_to_EWA – Link_release_SS_prep(-1) – FlexFlowAdjust + Link_release_ss_diff(-1)

   where: C1_River(-1) = that portion of yesterday's LRD release that flows out of IGD
   prj_credit_spill_forEWA = spill of the UKL credit due to flood releases
   prj_acc_addition_to_EWA = Project return flows that supported EWA release, and, therefore, count as EWA release
   Link_release_SS_prep(-1) = yesterday's calculated LRD release for IGD flow
   FlexFlowAdjust = daily flexible flow augmentation
   Link_release_ss_diff(-1) = yesterday's computation of this same variable

4. Calculate the **Link_release_SS_prep**, which is the release of UKL water at LRD to support IGD flows. As mentioned above, this flow is calculated differently through the summer. In March through June, EWA releases are predicated on UKL net inflow and are adjusted to ensure that as much EWA water is being released as is practicable while keeping EWA expenditure on track to avoid substantial over or underspending by the end of the season. This is accomplished using the in_pct_Mar50vol and Link_release_ss_diff variables described above, as well as by reserving an amount of EWA for July through September IGD flows. This reserved volume is approximately the quantity of water needed to be released from LRD to the river from July to September to meet IGD minimum flows when Keno Reservoir and Keno Dam to IGD accretions are at their historical medians (i.e., 130,000 AF). The March through June formulation is as follows:

   Link_release_ss_prep = in_pct_Mar50vol * (EWA_River – 130 TAF – Link_release_ss_diff)

   where: in_pct_Mar50vol = UKL net inflow release adjustment
   EWA_River = calculated EWA allocation
   Link_release_ss_diff = cumulative difference between actual and calculated LRD release for IGD flow

   For July through September, it is no longer necessary to make the adjustments needed in the March through June period. There is a known volume of EWA remaining, and it is all intended to be expended. Any flexible flow augmentation volume identified on April 1 is added to the EWA_River on July 1. If more UKL water is needed to support EWA minima in the July through September period than is remaining in the EWA, UKL supports the over expenditure of EWA to ensure minima are met. The July through September formula is as follows:

Link_release_ss_prep = EWA_remain_JulSep / daysinmonth

where: EWA_remain_JulSep = EWA volume remaining, adjusted for each month; July receives 35% of the remaining volume for July – September, August receives 44% of the remaining volume for August – September, and September receives what remains on September 1.

daysinmonth = the number of days in the current month

5. Determine **Link_release_SS** by adjusting Link_release_ss_prep by the appropriate storage difference ratio (UKL control logic).
6. If the formulated LRD release exceeds the maximum possible LRD release (variable Link_max is the maximum LRD release that varies with UKL surface elevation), then the maximum possible release will be made but the actual IGD flows can fall short of the target. Maximum possible releases range from a high of 8,600 cfs when UKL level is 4143.3 ft., to a low of 900 cfs when UKL level is 4137.0 ft.
7. Lookup **IGmin**, which is the minimum flow at the gauge below IGD (minima for other months not shown here). If the IGD flow target is less than the minimum flow required, then the minimum required flow is released at IGD. In months when flexible flow augmentation is occurring, FlexFlowAdjust is added to the IG_MIF in Table A.4.4.6.2.

Table A.4.4.6.2. Minimum flow below Iron Gate Dam, March through September

Month	IG_MIF (cfs)
March	1000
April	1325
May	1175
June	1025
July	900
August	900
September	1000

8. Set **C1forC15**, the LRD release to support IGD flows. For the spring/summer period, this is equal to Link_release_SS.
9. Calculate **C15_target**, which is the targeted release at IGD. This calculation relies upon operational values from 3 days prior, the operational delay accounted for in the model, and a forecast of accretions from 3 days prior. Operationally, IGD releases may vary from those calculated here due to real-time accretion values and flood control operations. Releases are not allowed to exceed a specified maximum (IG_max) during the July-September period. Values for IG_max vary with EWA_River, ranging from 1000-1500 cfs in July, 1050-1250 cfs in August, and 1100-1350 cfs in September.

C15_target = min(IG_max, C1forC15 + I10(-3) + I15_forecast2(-3)) + FlexFlowAdjust

where: I10 = LRD to Keno Dam (Keno Reservoir) accretions;
I15_forecast2 = forecasted Keno Dam to IGD accretions;
(-3) = operational lag of three days assumed in the model;
FlexFlowAdjust = daily flexible flow augmentation.

A.4.4.7. Surface Flushing Flows

In addition to normal UKL releases to support IGD flows during the spring/summer period, the PA implements a surface flushing flow between March 1 to April 15 based on criteria outlined below.

The decision whether to implement a surface flushing flow is made on March 1st, and then again on April 1st, based on UKL Supply, as follows:

1. On March 1:
    a. If the calculated UKL Supply is less than 815,000 AF (SFF Status 1), a surface flushing flow will be implemented in March if needed.
    b. If the calculated UKL Supply is greater than or equal to 815,000 AF and less than 904,000 AF (SFF Status 2), a surface flushing flow will not be implemented in March.
    c. If the calculated UKL Supply is greater than or equal to 904,000 AF (SFF Status 3), an opportunistic surface flushing flow may be implemented when applicable criteria (discussed below) are met.
    d. SFF Status determined on March 1 remains unchanged through March 31.
2. On April 1, if no surface flushing flow was triggered in March then:
    a. If the calculated UKL Supply is less than 750,000 AF (SFF Status 1), a surface flushing flow will be forced.
    b. If the calculated UKL Supply is greater than or equal to 750,000 AF and less than 904,000 AF (SFF Status 2), a surface flushing flow will not be implemented.
    c. If the calculated UKL Supply is greater than or equal to 904,000 (SFF Status 3), an opportunistic surface flushing flow may be implemented when applicable criteria (see below) are met.
    d. SFF Status determined on April 1 remains unchanged through June 30.

Spring/summer IGD flow targets are determined as described in Section A.4.4.6 on a daily basis. However, between March 1 and April 15, a surface flushing flow may replace the daily formula for a three-day period under certain conditions (longer if ramping is used). In some years a manual trigger date operation, in which the starting date for the surface flushing flow is specified in a lookup table, overrides the surface flushing flow triggers described below. This manual trigger date operation was intended to better simulate how operators would likely trigger surface flushing flows. The manual trigger operation was used in 1987, 1990, 2001-2003, 2009, 2010, 2012, 2013, 2015, 2018, and 2019. In all cases the manual operation triggered surface flushing

flows later than the aforementioned criteria would have done. Operationally, Reclamation will decide when to trigger surface flushing flows as described in BA Section 4.3.2.2.2.4 *Disease Mitigation Flows*.

In years that are SFF Status 1, the surface flushing flow is triggered in the KBPM when the following criteria are met:

1. The date is between March 1 and April 15;
2. There is sufficient head behind LRD, and accretions between LRD and IGD, to produce 6,030 cfs for 72 hours at IGD; and
3. The previous day's UKL elevation is greater than 4,142.4 feet.
4. If all three criteria above are not met by April 15, and no surface flushing flow has occurred, then on April 15 a surface flushing flow was forced. Under such conditions, it is possible that 6030 cfs for three days will not be attained because of insufficient head behind LRD, insufficient accretions between LRD and IGD, or both.

In years that are SFF Status 3, an opportunistic surface flushing flow is triggered in the KBPM when the following criteria are met:

1. The date is after February 28 (or February 29 in leap years) but earlier than April 16;
2. There is sufficient discharge capacity at LRD and accretions between LRD and IGD, to produce 6,030 cfs for 72 hours at IGD;
3. The previous day's UKL water surface elevation is greater than 4,142.4 feet; and
4. The previous day's IGD flow is greater than 3,999 cfs.

Implemented surface flushing flows are subject to ramping rates (see A.4.4.11). Flows which meet the KBPM criteria of a surface flushing flow, but happen outside of the March 1 to April 15 window, will not satisfy model requirements of a surface flushing flow unless the flow was produced by the manual trigger date operation. All surface flushing flow releases are counted against the EWA.

Model conditions on a surface flushing flow are described below. These releases replace normal IGD minimum flows when they are triggered, effectively forcing the model to produce a three-day, 6,030 cfs flow at IGD with attendant releases from LRD. At the end of the three-day period, normal calculation of Link River release resumes.

1. Determine **Link_max_DG1**, which is a conservative estimate of the maximum release from LRD in the months of March and April. The flow estimate is made conservative via a reduction in yesterday's UKL elevation by 0.3 ft., which has the effect of lowering the maximum assumed release. This is to ensure that there is sufficient head to meet the required flow even as UKL levels are dropping over the three-day release. The reduced UKL elevation is used to select a release value from the table **Link_max.table** in KBPM. Intermediary values are linearly interpolated.

2. Calculate **I15_proj_3day**, an average of forecasted Keno Dam to IGD accretions for the next three days. These accretion values are based on the accretion forecast model described in Section A.4.3.3.6. This variable, along with Link_max_DG1, will be used to determine if hydrologic conditions will exist for the next three-day period that would support a surface flushing flow.

   I15_proj_3day = (I15_forecast0 + I15_forecast1 + I15_forecast2) / 3

   where: I15_forecast0 = Keno Dam to IGD accretion forecast for today
   I15_forecast1 = Keno Dam to IGD accretion forecast for tomorrow
   I15_forecast2 = Keno Dam to IGD accretion forecast for 2 days from today

3. Set **DG1_daycount**, a counter that will begin when a surface flushing flow is triggered and ensure that the flow does not exceed the three-day period prescribed in the model.

4. Determine **DG1_supply**, which is a variable that will replace the IG_min if a flushing flow is triggered. The value of this variable is 6,030 cfs, except in the case of a forced flushing flow in which conditions do not allow for release of this magnitude. In this case, maximum LRD releases will be made to create the highest possible IGD flows achievable for three days. Conditions which trigger a flushing flow are described above.

   5. Once a surface flushing flow has been triggered during the March 1 to April 15 time period in a given water year, the model will not try to produce the surface flushing flow again in that water year.

A.4.4.8. EWA and Flood Control Releases

Flood control releases occur any time UKL elevation exceeds the allowable flood control elevation under normal operations criteria (discussed further in Section A.4.4.10). During the irrigation season, these releases typically occur March through May in average to wet years, but can occur at any time of year depending on the rate of snow melt, fall and winter inflow, and carry over storage in UKL.

When releases are made for flood control, they are counted against the EWA and factored into future EWA releases. In some cases, the flood control releases can be so large that the remaining EWA volume would not be considered adequate to provide acceptable Klamath River fish habitat for the remainder of the spring/summer period.

In order to protect against this scenario, a measure was added to ensure that the remaining EWA was enough to accommodate the minimum fish needs. This protection is considered whenever the total flood control releases have exceeded 22% of EWA_River by June 1. This measure ensures a certain volume of remaining EWA each month according to the following criteria:

1. If the total flood control releases that have occurred by June 1 exceed 22% of the EWA on June 1, then the remaining EWA is reset to 25% of the total June 1st EWA.

2. If the total flood control releases that have occurred by July 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 18% of the total EWA.

3. If the total flood control releases that have occurred by August 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 13% of the total EWA.

4. If the total flood control releases that have occurred by September 1 exceed 22% of the EWA (as calculated on June 1), then the remaining EWA is reset to 7% of the total EWA.

It is unlikely that spills will continue after June, however the potential for this does occur in very wet years where UKL remains full throughout the spring. The model results show that, when following this management plan, flood control releases do not occur in any year in the period of record after June.

A.4.4.9. LKNWR Operations

Water delivery to LKNWR is modeled in the KBPM in four distinct time periods: April through September delivery of a water right transferred from Upper Klamath National Wildlife Refuge (UKNWR; see the Biological Assessment, Section 4.3.2.2.8 for additional details); June through July delivery of UKL water; August through November delivery of Project Supply (see the Biological Assessment, Section 4.3.2.2.2.2 for additional details); and December through February delivery of winter maintenance flow. Reclamation, USFWS, and Project irrigators are currently undertaking a process to develop a shortage sharing agreement (per the 2017 memo from Deputy Secretary of the Interior Connor) to distribute a portion of Project Supply to LKNWR; as this process is on-going, this Biological Assessment will not include specific information regarding LKNWR deliveries from Project Supply between August and November. See the Biological Assessment, Section 4.3.2.2.2.2 for additional context and details regarding this process.

There is no provision for delivery to LKNWR in the month of March. All modeled delivery of water to LKNWR occurs through the Ady Canal. Additional water may be made available to LKNWR from the D Plant pumps, but this water is not modelled in the KBPM nor considered within the scope of this action. However, it is Reclamation's assumption that D Plant water, if and when delivered, will be utilized on LKNWR, unless the water is necessary to meet other legal obligations of the Project.

1. Delivery of the transferred water right occurs from April 1 through September 30. This water right, transferred from its original place of use at UKNWR, is for a daily flow of up to 30.3 cfs, which is the determined consumptive use volume of the transferred right. This flow is delivered on a daily basis in the model and is not subject to reduction via the UKL control logic. Delivery of this transferred water right is only available if Sevenmile Creek is not regulated to a senior water right (i.e., the Project); the portion of the original UKNWR water right on the Wood River was not considered here given that the Wood River is often regulated to the Klamath Tribes' Time Immemorial water right and therefore not available for transfer. See the Biological Assessment, Section 4.3.2.2.8 for additional details regarding this transferred water right.

2. Delivery of UKL water to LKNWR in the June 1 through July 31 period is conditioned on the following:

    a. The refuge has no target delivery in June through July if Project Supply is less than 350 TAF, which is considered a full supply in this Proposed Action.

    b. In June through July, if the Project has a full supply and if UKL elevation is above the threshold level denoted in Table A.4.4.9.1, then LKNWR can receive a daily delivery equal to the monthly demand, also in Table A.4.4.9.1, converted to cubic feet/second and divided by the number of days in the month. These deliveries are conditioned on UKL elevation remaining above the threshold for the month; if UKL drops below this threshold, deliveries will cease. Deliveries in these months of UKL water do not count against Project Supply nor do they affect delivery of the aforementioned transferred water right.

Table A.4.4.9.1. Monthly LKNWR demand and UKL elevation threshold which condition LKNWR deliveries.

Mo nth	Refuge Demand (TAF)	UKL Threshold (ft)
June	5.94	4142.5
July	6.93	4141.5

3. The details regarding delivery of Project Supply to LKNWR have not yet been established. As mentioned above, Reclamation, USFWS, and Project irrigators are currently undertaking a process to determine what portion of Project Supply is appropriate for delivery to LKNWR between August 1 and November 30; those details are not yet available. See the Biological Assessment, Section 4.3.2.2.2.2 for additional details regarding this process.

4. A maintenance flow is made available to LKNWR in the months of December through February. This flow is intended to allow LKNWR managers to receive water during a time of decreased demand from other users in order to manage their resources for the Spring-Summer season when demand from other users is highest and less water is made available to the refuge. Flows during this time period are capped at 62 cfs/day, or a total of up to 11,000 AF for the December through February period. These flows are subject to reduction via UKL control logic on a daily basis.

A.4.4.10. Flood Control Operations

Flood control operations are implemented in order to protect the infrastructure surrounding UKL. The modeled flood control operations were developed to mimic realistic flood control operations; however real-time management (i.e., professional judgement) will also be used in order to ensure safety and appropriate water management within UKL. The modeled operations manage the water during winter and early spring in a manner that prevents UKL from filling too early and remaining at or near full pool for several months in wetter years. The modeled flood control operations attempt to balance liability risk with risks associated with diminished water supplies for the Project, LKNWR, and the Klamath River. Actual flood control releases will be

made at the discretion of Reclamation and PacifiCorp (the operator of LRD) in coordination with USFWS and National Marine Fisheries Service.

Outline of Flood Control Operations
The general process of flood control consists of spilling water from UKL when necessary to prevent elevations from increasing above flood pool elevations, which change throughout the year in response to inflow forecasts and experienced hydrology. Flood pool elevation is calculated each day to create a smooth UKL operation, allowing UKL to fill by the end of March in drier years and by the end of April in wetter years.

The flood control elevations (termed "threshold" by the model language included below) are determined through the following process:

1. The UKL flood control elevation is set at 4141.4 ft. in September and October and then is steadily increased from 4141.4 ft. to 4141.8 ft. from November 1 through December 31. In most years, there are no flood control releases during these months.

2. From January 1 through April 30, the UKL flood control elevations are determined based on the forecasted inflow and the day of the month. The NRCS UKL net inflow forecast is used to determine the end of month flood control elevation each month (using Table A.4.4.10.1 below) and the daily flood control elevation is linearly interpolated between the current end of month elevation and the previous month's end of month flood control elevation.

    a. The distinction between wet conditions and dry conditions in Table A.4.4.10.1 is made based on the NRCS March through September 50% exceedance probability forecast for UKL net inflow volume issued in January, February and March. The forecast issued in March is used for both March and April. If the forecasted March through September net UKL inflow is greater than 710,000 AF, the year is considered wet; the water year is considered dry if the forecasted net inflow is equal to or less than 710,000 AF.

    b. The daily flood control elevation is calculated using the equation below:

Current Threshold = [Yesterday's threshold value] + ([This month's threshold] – [Last month's threshold]) / [Number of days in the month]
Note: The threshold will not decrease from day to day.

3. The UKL flood control elevations remain at the April 30 level from May 1 through August 31.

Table A.4.4.10.1. UKL flood control elevations for the last day of each month under relatively dry or wet conditions.

Month	Dry Condition Elevation (ft) (Forecast ≤ 710 TAF)	Wet Condition Elevation (ft) (Forecast > 710 TAF)
October	4141.4	4141.4
November	4141.6	4141.6
December	4141.8	4141.8
January	4142.3	4142.0
February	4142.7	4142.4
March	4143.1	4142.8
April	4143.3	4143.3

A.4.4.11. Flow Ramping

Flow ramping at IGD

The target ramp down rates at IGD are as follows:

- When IGD flows are greater than 4,600 cfs: decreases in flows of no more than 2,000 cfs per 24-hour period, and no more than 500 cfs per six-hour period.

- When IGD flows are greater than 3,600 cfs but equal to or less than 4,600 cfs: decreases in flows of 1,000 cfs or less per 24-hour period, and no more than 250 cfs per six-hour period.

- When IGD flows are greater than 3,000 cfs but equal to or less than 3,600 cfs: decreases in flows of 600 cfs or less per 24-hour period, and no more than 150 cfs per six-hour period.

- When IGD flows are above 1,750 cfs but equal to or less than 3,000 cfs: decreases in flows of 300 cfs or less per 24-hour period, and no more than 125 cfs per four-hour period.

- When IGD flows are 1,750 cfs or less: decreases in flows of 150 cfs or less per 24-hour period and no more than 50 cfs per two-hour period.

Upward ramping is not restricted.

The KBPM includes only the very crude representation of PacifiCorp reservoir storage and operations necessary to implement the operations described in this appendix. Therefore, the model is only able to adjust LRD releases to attempt to comply with the ramping rate restrictions assumed. In addition, LRD releases cannot necessarily be adjusted to comply with the ramping rate restrictions if unregulated flows (i.e., flood releases) are present at LRD or IGD.

Table A.4.4.11.1 Elevation storage-area for Upper Klamath Lake.

Active Storage (TAF)	Elevation (ft.)	Area (acres)
0.000	4136.0	66,109
6.610	4136.1	66,321
13.255	4136.2	66,461
19.914	4136.3	66,579
26.585	4136.4	66,701
33.255	4136.5	66,824
39.929	4136.6	66,927
46.633	4136.7	67,007
53.344	4136.8	67,082
60.062	4136.9	67,155
66.775	4137.0	67,228
73.488	4137.1	67,299
80.228	4137.2	67,371
86.975	4137.3	67,443
93.730	4137.4	67,514
100.478	4137.5	67,584
107.227	4137.6	67,654
114.002	4137.7	67,725
120.785	4137.8	67,798
127.576	4137.9	67,880
134.367	4138.0	68,080
141.175	4138.1	68,349
148.023	4138.2	68,467
154.882	4138.3	68,572
161.751	4138.4	68,674
168.616	4138.5	68,775
175.486	4138.6	68,877
182.385	4138.7	68,979
189.295	4138.8	69,083
196.215	4138.9	69,187
203.133	4139.0	69,294
210.054	4139.1	69,404
217.007	4139.2	69,516
223.971	4139.3	69,635
230.998	4139.4	70,809
238.182	4139.5	72,984
245.526	4139.6	74,049
252.971	4139.7	74,672
260.471	4139.8	75,180

Active Storage (TAF)	Elevation (ft.)	Area (acres)
268.021	4139.9	75,668
275.608	4140.0	76,225
283.247	4140.1	76,843
290.968	4140.2	77,454
298.756	4140.3	78,156
306.618	4140.4	78,963
314.552	4140.5	79,878
322.574	4140.6	80,890
330.725	4140.7	81,982
338.987	4140.8	83,098
347.359	4140.9	84,174
355.819	4141.0	85,167
364.364	4141.1	86,055
373.018	4141.2	86,839
381.746	4141.3	87,519
390.535	4141.4	88,088
399.359	4141.5	88,549
408.216	4141.6	88,921
417.133	4141.7	89,231
426.078	4141.8	89,491
435.047	4141.9	89,705
444.018	4142.0	89,880
452.996	4142.1	90,031
462.015	4142.2	90,166
471.047	4142.3	90,292
480.090	4142.4	90,405
489.127	4142.5	90,508
498.165	4142.6	90,607
507.240	4142.7	90,703
516.324	4142.8	90,798
525.417	4142.9	90,891
534.502	4143.0	90,982
543.587	4143.1	91,071
552.707	4143.2	91,164
561.838	4143.3	91,265
570.974	4143.4	91,376
580.110	4143.5	91,486

Appendix 4 Section A: Model Variables

Table A.4.3.4.1. Model Variables (note that *cfs_taf or *taf_cfs in a formula denotes conversion to new units; (-1) in formula refers to yesterday's value for a given variable; "Total A" refers to sum of delivery volumes for arcs D1, D11, D12A, and D91 or A Canal, North Canal, Ady Canal for agriculture, and Miller Hill/Station 48, respectively).

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
A2FW	Winter water right for A2 diversions	Winter water right for A2 diversions, set to 28.910 taf.	-	Definitions.wresl
adj_endhi	Variable used to compute adj_uklcentral	Set to 0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_endlow	Variable used to compute adj_uklcentral	Set to -0.5. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
adj_intercept	Variable used to compute adj_uklcentral	Computed as: adj_endhi - norm_inf_hi * adj_slope	adj_intercept_	UKLThresholds.wresl
adj_slope	Variable used to compute adj_uklcentral	Computed as: (adj_endhi - adj_endlow) / (norm_inf_hi - norm_inf_low)	adj_slope_	UKLThresholds.wresl
Apr50	April NRCS forecast	April NRCS 50% exceedence forecast for total April-September UKL net inflow.	-	Definitions.wresl
avg_cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop	Average cum_KDD_in_5d_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_5d_prop_	AgRefOps.wresl
avg_cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop	Average cum_KDD_in_p15to49_prop by 5-day period across irrigation water years.	avg_cum_KDD_in_p15to49_prop_	AgRefOps.wresl
avg_cum_KDD_in_p50to14_prop	Average cum_KDD_in_p50to1	Average cum_KDD_in_p50to14_prop	avg_cum_KDD_in_p50to14_prop_	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
	4_ prop	by 5-day period across irrigation water years.		
C1	Link River Dam Release	Total Link River flow released out of Link River Dam from Upper Klamath Lake.	C1	Channel-table.wresl
C1_AG	Link Ag release	Link release to support Ag and refuge diversions at Station 48, Miller Hill, North Canal and Ady Canal	C1_AG	Channel-table.wresl
C1_EXC	Link excess release	Link release in excess of minimum flow requirement and needs of Ag and refuge diversions. Likely due to UKL flood control spill or Iron Gate flow requirements.	C1_EXC	Channel-table.wresl
c1_EXCcumdv	Cumulative C1_EXC releases	Cumulative volume released through the C1_EXC arc beginning on March 1.	c1_EXCcumdv	SeasonalSupply.wresl
C1_MIF	Link MIF requirement	Portion of Link release made to support the Link minimum instream flow requirement.	C1_MIF	Channel-table.wresl
C1_River	Link river release	Portion of Link release that flows out of Iron Gate Dam. This is accounted for as an EWA release from March to September.	C1_River	Channel-table.wresl
C13	Keno Dam Release	Release at Keno Dam on the Klamath River.	C13	Channel-table.wresl
C131	Klamath Straits Drain flow (or Pumping Plant F/FF)	Return flows and runoff from the A2 area and LKNWR that	C131	Channel-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		are pumped through pumping plant F/FF.		
C131_IG	F/FF pumping to Iron Gate	F/FF pumping that flows out Iron Gate. This is accounted for as an EWA release from March to September when Iron Gate is under controlled flow (minimum, target, or ramping).	C131_IG	Channel-table.wresl
C131_PRJ	F/FF pumping to project	F/FF pumping that is re-diverted by the project at Station 48, Miller Hill, North Canal or Ady Canal.	C131_PRJ	Channel-table.wresl
C15	Iron Gate Dam flow	Flow downstream of Iron Gate Reservoir on the Klamath River.	C15	Channel-table.wresl
C15_EXC	Iron Gate excess flow	Flow in excess of all requirements (MIF, TARG, and RAMP) caused by UKL and/or Iron Gate reservoir flood spill.	C15_EXC	Channel-table.wresl
C15_MIF	Iron Gate MIF requirement	Portion of Iron Gate flow needed to meet minimum instream flow requirement.	C15_MIF	Channel-table.wresl
C15_RAMP	Iron Gate ramping flow	Increment of Iron Gate flow above MIF and TARG needed to support flow ramping requirements.	C15_RAMP	Channel-table.wresl
C15_TARG	Iron Gate target flow	Increment of Iron Gate flow above minimum required	C15_TARG	Channel-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		needed to meet Iron Gate target flow.		
C15target	Daily Iron Gate flow target	Daily Iron Gate flow target.	C15target_	UKLReleases.wresl
C15target_prep1	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-1) + I10(-1) + I15_forecast1(-1).	C15target_prep1_	UKLReleases.wresl
C15target_prep2	Variable used to determine whether Iron Gate Reservoir should be filled to spillway	This is a C15 target used to determine whether Iron Gate must be filled to spillway elevation to hit a flow target above 1700 cfs. Computed as: C1forC15dv(-2) + I10(-2) + I15_forecast2(-2).	C15target_prep2_	UKLReleases.wresl
C1forC15	Daily target releases from UKL for setting Iron Gate targets	Daily target releases from UKL for setting Iron Gate targets. During October-February, set equal to Link_WF_target. During March-September, set equal to Link_release_SS.	C1forC15dv	UKLReleases.wresl
C91	Lost River Diversion Channel	LRDC flow to the Klamath River (+) or from the Klamath River (-).	C91	Channel-table.wresl
cum_KDD_in_5d_	Total KDD_indv volume by 5-day period	KDD_indv volume summed within each 5-day period of the irrigation water year.	cum_KDD_in_5d_	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
cum_KDD_in_p15to49_	Cumulative volume input to KDD for periods 15 through 49	Cumulative volume input (diversion and precipitation) to KDD for periods 15 (May 10) through 49 (October 31).	cum_KDD_in_p15to49_	AgRefOps.wresl
cum_KDD_in_p50to14_	Cumulative volume input to KDD for periods 50 through 14	Cumulative volume input (diversion and precipitation) to KDD for periods 50 (November 1) through 14 (May 9).	cum_KDD_in_p50to14_	AgRefOps.wresl
Cum_Ppt	Cumulative daily Project-area precipitation	Cumulative daily precipitation (in) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Ppt_	AgForecast.wresl
Cum_Tmax	Cumulative daily Project-area maximum temperature	Cumulative daily maximum air temperature (°F) since March 1 through each 5 day period of the irrigation water year for the Project area	Cum_Tmax_	AgForecast.wresl
CumAg_ss_Del	Cumulative spring-summer ag diversions from UKL	Cumulative volume of surface water diverted for ag use under spring-summer operations from UKL from March through November.	CumAg_ss_DelDV	SeasonalSupply.wresl
CumAg_ss_Div	Cumulative spring-summer ag diversions from all surface water sources	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of water from UKL, non-UKL water from LRDC, and F/FF return flow.	CumAg_ss_DivDV	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
CumAgLRDC_ss_Del	Cumulative spring-summer ag diversion from LRDC and F/FF returns	Cumulative volume of surface water diverted for ag use under spring-summer operations from March through November, including diversion of non-UKL water from LRDC, and F/FF return flow.	CumAgLRDC_ss_ DelDV	SeasonalSupply.w resl
cumd11wint	Prior winter D11 diversions	Cumulative total D11 diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd11wint_	AgForecast.wresl
cumd12awint	Prior winter D12A diversions	Cumulative total D12A diversions within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumd12awint_	AgForecast.wresl
cumI15	Cumulative volume of Keno-to-Iron Gate accretions	Cumulative volume (taf) of accretions to the Keno-to-Iron Gate reach of the Klamath River beginning Oct 1.	cumI15_	FallWinterRiverOp s. wresl
cumpptwint	Cumulative winter precipitation	Cumulative Prj_Ppt within each irrigation water year from period 56 (December 1) through period 73 (the end of February).	cumpptwint_	AgForecast.wresl
CumRefDeliv_fw_DV	Cumulative fall-winter deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from December-February.	CumRefDeliv_fw_ DV	SeasonalSupply.w resl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
CumRefDeliv_ss_DV	Cumulative spring-summer deliveries to the Refuge from UKL	Cumulative delivery of UKL water through D12B to the Refuge from March-November.	CumRefDeliv_ss_ DV	SeasonalSupply.w resl
D1	A Canal Deliveries	A Canal project deliveries to area A1	D1	Delivery-table.wresl
D1_5d_	Daily simulated D1 volume	Simulated volume diverted into D1 on the current day.	D1_5d_	Definitions.wresl
D1_5d_Cum_	Total simulated D1 volume for five_day_period	Total simulated volume diverted into D1 in each five_day_period.	D1_5d_Cum_	Definitions.wresl
D1_act_	Daily actual D1 volume	Historic (actual) volume diverted into D1 on the current day.	D1_act_	Definitions.wresl
D1_act_5d_Cum_	Total actual D1 volume for five_day_period	Total historic (actual) volume diverted into D1 in each five_day_period.	D1_act_5d_Cum_	Definitions.wresl
D1_const	Constant for D1 deliveries as percent of Total A	Model-averaged constant for D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_cumpptwint	Coefficient for cumpptwint influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_l1_d1pcta	Coefficient for D1 deliveries as percent of Total A	Model-averaged coefficient for D1 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D1_l1_ppt	Coefficient for Prj_Ppt influence on D1	Model-averaged coefficient for the influence of Prj_Ppt	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
	deliveries as percent of Total A	(lagged to the previous 5-day period) on D1 deliveries as percent of Total A.		
D1_l1_ptdayindex	Coefficient for ptdayindex influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_l1_tmax	Coefficient for Mean_Tmax influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_pcta_reg_	Forecasted D1 delivery percent of Total A	Forecasted D1 delivery percent of Total A for the current 5-day period.	D1_pcta_reg_	AgForecast.wresl
D1_RealPCTA	Historical D1 delivery as percent of Total A	Historical daily D1 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year.	D1_RealPCTA_	AgForecast.wresl
D1_shortdum	Coefficient for shortdum influence on D1 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D1 deliveries as percent of Total A.	-	AgForecast.wresl
D1_calc	D1 delivery target from ag delivery sub-model	D1 delivery target from ag delivery sub-model, set equal to D1calc_reg during March - November, otherwise is 0.	D1calcdv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D1calc_reg	Forecast of daily D1	Forecast of daily delivery (cfs) through the D1 arc.	D1calc_reg_	AgForecast.wresl
D11	North Canal Deliveries	North Canal Project Deliveries to area A2	D11	Delivery-table.wresl
D11_const	Constant for D11 deliveries as percent of Total A	Model-averaged constant for D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_cumd11wint	Coefficient for cumd11wint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd11wint on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_cumpptwint	Coefficient for cumpptwint influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_fw_calc	Fall-winter component of D11calc	D11calc for November-February, otherwise 0.	D11_fw_calcdv	AgRefOps.wresl
D11_fw_calc_no_ UKL_ctrl	D11 winter release calculation without UKL control	D11 winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctNorth.	D11_fw_calc_no_ UKL_ctrldv	AgRefOps.wresl
D11_l1_d11pcta	Coefficient for D11 deliveries as percent of Total A	Model-averaged coefficient for D11 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D11_l1_d11taf	Coefficient for prior period D11 delivery volume influence on	Model-averaged coefficient for the influence of prior period D11 delivery volume	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
	D11 deliveries as percent of Total A	on D11 deliveries as percent of Total A.		
D11_l1_ppt	Coefficient for Prj_Ppt influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_ptdayindex	Coefficient for ptdayindex influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_l1_tmax	Coefficient for Mean_Tmax influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_pcta_reg_	Forecasted D11 delivery percent of Total A	Forecasted D11 delivery percent of Total A for the current 5-day period.	D11_pcta_reg_	AgForecast.wresl
D11_pdindexd11	Coefficient for pdindexd11 influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd11 on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_RealPCTA	Historical D11 delivery as percent of Total A	Historical daily D11 diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D11_RealPCTA_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D11_shortdum	Coefficient for shortdum influence on D11 deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D11 deliveries as percent of Total A.	-	AgForecast.wresl
D11_ss_calc	Spring-summer component of D11calc	D11calc for March-October, otherwise 0.	D11_ss_calcdv	AgRefOps.wresl
D11calc	Diversion target for D11	Diversion target for D11. Set equal to D11calc_reg during March - October. Otherwise computed as: D11_fw_calc_no_UKL_ctrl + stor_diff_ratio5d * D11_fw_calc_no_UKL_ctrl.	D11calcdv	AgRefOps.wresl
D11calc_reg	Forecast of daily D11	Forecast of daily delivery (cfs) through the D11 arc.	D11calc_reg_	AgForecast.wresl
D12	Ady Canal flow	Ady Canal flow to either Area A2 (including the Area K lease lands) or the Lower Klamath National Wildlife Refuge	D12	Delivery-table.wresl
D12A	Ady Canal Ag Flow	Ady Canal flow to project in Area A2	D12A	Delivery-table.wresl
D12a_const	Constant for D12A deliveries as percent of Total A	Model-averaged constant for D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_cumd12awint	Coefficient for cumd12awint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumd12awint on D12A deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12a_cumpptwint	Coefficient for cumpptwint influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_fw_calc	Fall-winter component of D12Acalc	D12Acalc for November-February, otherwise 0.	D12a_fw_calcdv	AgRefOps.wresl
D12A_fw_calc_no_UKL_ctrl	D12A winter release calculation without UKL control	D12A winter release calculation without UKL control, computed as the minimum of either (200 cfs or KDDReserve * taf_cfs) * pctAdyag.	D12a_fw_calc_no_UKL_ctrldv	AgRefOps.wresl
D12a_l1_d12apcta	Coefficient for D12A deliveries as percent of Total A	Model-averaged coefficient for D12A deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D12a_l1_d12ataf	Coefficient for prior period D12A delivery volume influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of prior period D12A delivery volume on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ppt	Coefficient for Prj_Ppt influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_l1_ptdayindex	Coefficient for ptdayindex influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D12a_l1_tmax	Coefficient for Mean_Tmax influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_pcta_reg_	Forecasted D12A delivery percent of Total A	Forecasted D12A delivery percent of Total A for the current 5-day period.	D12a_pcta_reg_	AgForecast.wresl
D12a_pdindexd12a	Coefficient for pdindexd12a influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of pdindexd12a on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12a_RealPCTA	Historical D12A delivery as percent of Total A	Historical daily D12A diversion volume percentage of Total A deliveries (Mar-Oct) summed within each 5-day period of the irrigation water year	D12a_RealPCTA_	AgForecast.wresl
D12a_shortdum	Coefficient for shortdum influence on D12A deliveries as percent of Total A	Model-averaged coefficient for the influence of shortdum on D12A deliveries as percent of Total A.	-	AgForecast.wresl
D12A_ss_calc	Spring-summer component of D12Acalc	D12Acalc for March-October, otherwise 0.	D12a_ss_calcdv	AgRefOps.wresl
D12Acalc	Diversion target for D12A	Diversion target for D12A. Set equal to D12Acalc_reg during March - October. Otherwise computed as: D12A_fw_calc_no_UKL_ctrl +	D12acalcdv	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		stor_diff_ratio5d * D12A_fw_calc_no_UKL_ctrl.		
D12acalc_reg	Forecast of daily D12A	Forecast of daily delivery (cfs) through the D12A arc.	D12acalc_reg_	AgForecast.wresl
D12B	Ady Canal Refuge Flow	Ady Canal flow to the Lower Klamath National Wildlife Refuge	D12B	Delivery-table.wresl
D12Bcalc	Delivery target for D12B (LKNWR)	Delivery target for D12B (LKNWR), computed without UKL control.	D12Bcalcdv	AgRefOps.wresl
D12Bcalc_Supply Table	Component of LKNWR delivery computation	Component of LKNWR delivery computation. Computed as Monthly_RemainRefugeFallSupply * RefugeFallRelDist/daysinmonth * taf_cfs.	D12Bcalc_Supply Table_	AgRefOps.wresl
D12Bcalc_UKL	Deliveries to LKNWR from UKL	Delivery target for D12B (LKNWR), computed with UKL control.	D12Bcalc_UKLdv	AgRefOps.wresl
D91	Station 48/Miller Hill Deliveries	Lost River Diversion Channel Project deliveries through the Station 48 diversion and Miller Hill Pumping Plant	D91	Delivery-table.wresl
D91_const	Constant for D91 deliveries as percent of Total A	Model-averaged constant for D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_cumpptwint	Coefficient for cumpptwint influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of cumpptwint on D91 deliveries as percent of Total A.	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
D91_l1_d91pcta	Coefficient for D91 deliveries as percent of Total A	Model-averaged coefficient for D91 deliveries as percent of Total A from the previous 5-day period.	-	AgForecast.wresl
D91_l1_ppt	Coefficient for Prj_Ppt influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Prj_Ppt (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_ptdayindex	Coefficient for ptdayindex influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of ptdayindex (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_l1_tmax	Coefficient for Mean_Tmax influence on D91 deliveries as percent of Total A	Model-averaged coefficient for the influence of Mean_Tmax (lagged to the previous 5-day period) on D91 deliveries as percent of Total A.	-	AgForecast.wresl
D91_pcta_reg_	Forecasted D91 delivery percent of Total A	Forecasted D91 delivery percent of Total A for the current 5-day period.	D91_pcta_reg_	AgForecast.wresl
D91_RealPCTA	Historical D91 delivery as percent of Total A	Historical daily D91 diversion volume percentage of Total A deliveries (Mar-Nov 15) summed within each 5-day period of the irrigation water year.	D91_RealPCTA_	AgForecast.wresl
D91_shortdum	Coefficient for shortdum influence on	Model-averaged coefficient for the influence of shortdum	-	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
	D91 deliveries as percent of Total A	on D91 deliveries as percent of Total A.		
D91calc	D91 delivery target from ag delivery sub-model	D91 delivery target from ag delivery sub-model, set equal to D91calc_reg during March - November, otherwise is 0.	D91calcdv	AgRefOps.wresl
D91calc_reg	Forecast of daily D91	Forecast of daily delivery (cfs) through the D91 arc.	D91calc_reg_	AgForecast.wresl
daynum	Day of water year	Day 1 is October 1, incremented by 1 each day thereafter.	daynumDV	Definitions.wresl
daysinprevmo	Days in previous month	Number of days in the previous month.	-	Definitions.wresl
dg1_compliance	Surface flushing flow compliance	Set to a value of 1 within a year once a surface flushing flow has been implemented and achieved; otherwise set to 0.	dg1_compliance_	Definitions.wresl
DG1_compliance_ threshold	Surface flushing flow compliance threshold	Minimum flow threshold for determination if a surface flushing flow has already occurred during December to April. Set at 5,000 cfs. This is not the flow target for a forced surface flushing flow.	-	Operations_Switch es. wresl
DG1_supply	Minimum flow target below Iron Gate Dam to implement surface flushing flow	Minimum flow target below Iron Gate Dam to implement surface flushing flow.	DG1_supply_	FallWinterRiverOp s. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
DG1_target	Surface flushing flow target	Surface flushing flow target. Set to 6,030 cfs.	-	Operations_Switches. wresl
dir_div_acc_est	Total diversion of return flows	Total seasonal diversion of return flow from the LRDC and pumps F&FF for all diversion arcs.	-	AgForecast.wresl
dowy	Day of water year	Day of water year: October 1 is day 1, September 30 is day 365 (366 in leap years).	dowy_	FallWinterRiverOps. wresl
DT	Distribution type	Distribution type of year based on Mar-50. Set to: 1 when Mar50 ≤ 420 taf; 2 when Mar50 is between 420-510 taf; 3 when Mar50 is between 510-690 taf; 4 when Mar50 ≥ 690 taf.	-	Definitions.wresl
EOS_hiinc	September increment above unadjusted UKL central tendency	Maximum allowable increment above the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOS_lowinc	September increment below unadjusted UKL central tendency	Maximum allowable increment below the unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl
EOScent_lvl	September unadjusted UKL central tendency	Unadjusted UKL central tendency for the end of September.	-	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
EOStgt_lvl	End-of-September UKL storage target level	End-of-September UKL storage target level.	EOStgt_lvl_	Res_Reqs.wresl
EOStgtsto	End-of-September UKL storage target volume	End-of-September UKL storage target volume. UKL active storage volume associated with EOStgt_lvl.	EOStgtstodv	Res_Reqs.wresl
esttota	Estimated Total A delivery	Estimated Total A delivery for an irrigation water year, including diversions of UKL water and diversions of return flows.	esttota_	AgForecast.wresl
EWA_remain_Jul Sep	EWA volume for release in each summer month	EWA volume to be released in each month from July-September. In July, this volume is 35% of EWAremain on July 1. In August, it is 44% of EWAremain on August 1. In September, it is remaining EWA volume.	EWA_remain_Jul Sep_	UKLReleases.wresl
EWA_River	Environmental water account	Allocation from UKLSupply for use by the Klamath River.	EWA_Riverdv	SeasonalSupply.wresl
EWA_threshold	surface flushing flow EWA threshold	EWA threshold for mandatory surface flushing flow release. Set to 575 TAF. If EWA is less than this threshold, a surface flushing flow must be released sometime between March 1st and April 15th	-	Operations_Switches. wresl
EWAmin	Minimum EWA	Minimum volume for the Environmental Water Account, set to 400 TAF.	EWAmin_	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
EWARemain	Remaining EWA	Volume of EWA remaining, computed on the first day of each month (starting March 1) as: max(EWARemainMinimum, EWA_River - EWAUseddv(-1)). Its value remains constant throughout the remainder of each month.	EWARemainDV	SeasonalSupply.wresl
EWARemain Minimum	EWA remain minimum	Minimum EWA volume to retain for use in June-September period to ensure that sufficient EWA volume remains to cover summer period in years when flows through C1_EXC arc are above a specifed proportion of the EWA volume. That is, when c1_EXCcumdv(-1)≥(0.22*EWA_River), EWARemainMinimum is computed each month as: 0.25*EWA_River in June; 0.18*EWA_River in July; 0.13*EWA_River in August; and 0.07*EWA_River in September.	EWARemain Minimumdv	SeasonalSupply.wresl
EWAUseddv	EWA used	Volume of Link River Dam releases accounted for as EWA water. Computed as: March 1: C1_MIF*cfs_taf+C1_EXC*cfs_taf After March 1: EWAUsedDV(-	EWAUseddv	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		1) + C1_MIF*cfs_taf + C1_EXC*cfs_taf - prj_credit_spill_forEWA*cfs_taf + prj_acc_addition_to_EWA*cfs_taf.		
excluded_dum	Dummy variable for excluded years	Set to 1 for years when historical diversions were altered from normal seasonal patterns by regulatory action to an extent warranting their removal from model development. Excluded years were 2001, 2010, 2014, and 2015.	excluded_dum_	AgForecast.wresl
Fcst_error	Forecast error	Tracking the approximate real-time forecast error, computed first day of the month April-June. On April 1: Mar50 - (Apr50 + LastMonthInf). On May 1: Apr50 - (May50 + LastMonthInf). On June 1: May50 - (Jun50 + LastMonthInf).	Fcst_error_	Definitions.wresl
Feb50	February NRCS forecast	February NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
fill_target_approx	UKL fill target	Elevation (ft) targeted for filling UKL by February 28. Set to 4143.0 ft, this is a soft target, the system is not	-	FallWinterRiverOps. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		forced to hit the target. Used beginning on November 16.		
fill_target_approx_ vol	UKL fill target volume	Active storage volume (TAF) at the elevation of the fill_target_approx.	-	FallWinterRiverOp s. wresl
five_day_period	Five-day period of the irrigation water year	Five-day periods begining March 1, ending at the end of February. Period 73 has 6 days in leap years.	five_day_period_	Definitions.wresl
FlexFlowAdjust	Daily flow augmentation	Daily augmentation to Iron Gate releases that may occur during Mar-Jun in years when PRJ_FlexAugment and UKL_FlexAugment volumes are above zero.	FlexFlowAdjust_	SeasonalSupply.w resl
Flood50fc	UKL net inflow forecasts used in flood operations	NRCS 50% exceedence forecasts for total Mar-Sep UKL net inflow made in Jan-Mar, and total Apr-Sep UKL net inflow forecast made in April.	-	Res_Reqs.wresl
I1	UKL net inflow - smoothed	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus releases through A Canal and Link River Dam). This input timeseries was smoothed to minimize fluctuations due to wind effects on lake levels.	I1_	Inflow-table.wresl
I1_raw	UKL net inflow - raw data	Net Inflow into Upper Klamath Lake (calculated as the change in storage plus	I1_raw_	Inflow-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		releases through A Canal and Link River Dam). This is added as a raw value and does not smooth out significant fluctuations caused by wind effects on lake level.		
I10	Lake Ewauna accretions	Lake Ewauna Accretions - difference between historical flows released out of Link River Dam minus known diversions and the measured flow upstream of Keno Reservoir. Diversions include LRDC which may flow into the Klamath River as an inflow.	I10_	Inflow-table.wresl
I131	Area 2 return flow closure term	Input timeseries that is the difference between actual return flows minus modeled return flows based on actual deliveries, precipitation and temperature.	I131_	Inflow-table.wresl
I15	Keno to Iron Gate accretions	Keno to Iron Gate accretion timeseries developed with historical mass balance from Keno Dam to the flow gage below Iron Gate Dam.	I15_	Inflow-table.wresl
I15_d0d3_total	Total 4-day forecasted Keno-to-Iron Gate accretion volume	Forecasted Keno-to-Iron Gate accretion volume summed across forecasts for day 0 (current day) through day 3.	I15_d0d3_total_	FallWinterRiverOps. wresl
I15_FORECAST0	Iron Gate accretion 0 day forecast	Forecast of today's Keno to Iron Gate accretion.	-	Inflow-table.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
I15_FORECAST1	Iron Gate accretion 1 day forecast	Forecast of tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST2	Iron Gate accretion 2 day forecast	Forecast of day after tomorrow's Keno to Iron Gate accretion.	-	Inflow-table.wresl
I15_FORECAST3	Iron Gate accretion 3 day forecast	Forecast of Keno to Iron Gate accretions three days from now.	-	Inflow-table.wresl
I15_proj_3day	Projected 3-day average daily volume of Keno-to-Iron Gate accretions	Average daily Keno-to-Iron Gate accretion volume forecasted for days 0-2.	I15_proj_3day_	FallWinterRiverOps. wresl
I15_wyAvgVol	Water year average Keno-to-Iron Gate accretion volume	Average accretion volume (TAF) to the Keno-to-Iron Gate reach of the Klamath River from October 1 to the current day.	I15_wyAvgVol_	FallWinterRiverOps. wresl
I91	LRDC at Wilson	Flow diverted at Wilson Dam into the Lost River Diversion Channel. The flow is a combination of flow from the Lost River (timeseries input) and return flows from Area 1 (dynamically determined from a return flow model).	I91_	Inflow-table.wresl
I91_D1Adjust	Adjusted I91	Historical I91 adjusted by I91_reduce.	I91_D1Adjust_	Definitions.wresl
I91_HIST	Historical flow measured at LRDC headworks	Historical diversion into the LRDC, measured at the headworks at Wilson Dam.	I91_HIST_	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
I91_IG	LRDC inflow to Iron Gate Dam flow	Flow into the LRDC from Wilson Dam that contributes to Iron Gate flow (not diverted by the project).	I91_IG	Inflow-table.wresl
I91_PRJ	LRDC inflow diverted by project	Flow into the LRDC from Wilson Dam that is diverted by the Klamath Project at Station 48, Miller Hill, North Canal, or Ady Canal.	I91_PRJ	Inflow-table.wresl
I91_reduce	Adjustment for I91	Volume by which the historical I91 arc needs to be adjusted to account for changes in D1 deliveries.	I91_reduce_	Definitions.wresl
IG_max	Maximum Iron Gate flow July-September	Maximum flow target below Iron Gate Dam in July-September. Used to constrain C15_target. IG_max is interpolated based on EWA_River between 320 taf and 1500 taf (IG_max constant below 320 taf or above 1500 taf). IG_max varies between 1000-1500 cfs in July; 1050-1250 cfs in August; and 1100-1350 cfs in September.	IG_max_	UKLReleases.wresl
IG_ramp_flow	Ramped Iron Gate flow	Computed as C15(-1) - IG_ramp_rate.	IG_ramp_flow_	UKLReleases.wresl
IG_ramp_rate	Iron Gate ramp rate	Computes down-ramp rates for Iron Gate: If C15(-1) < 1750 cfs + 150 cfs, then IG_ramp_rate = 150 cfs	IG_ramp_rate_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		If C15(-1) < 3000 cfs + 300 cfs, then IG_ramp_rate = 300 cfs If C15(-1) < 3600 cfs, then IG_ramp_rate = 600 cfs If C15(-1) ≥ 3600 cfs .and. c15(-1) < 4000, then IG_ramp_rate = c15(-1) - 3000 cfs If C15(-1) ≥ 4000 cfs .and. c15(-1) < 4600, then IG_ramp_rate = 1000 cfs Otherwise IG_ramp_rate = min(2000 cfs, c15(-1) - 3600 cfs)		
IG_spawn	Initial fall spawning flow below Iron Gate Dam	Initial flow specified on Oct 1 for fall spawning flows below Iron Gate Dam. Selected by interpolation between 1000 and 1200 cfs based on norm_uklinf_60avg.	IG_spawn_	FallWinterRiverOp s. wresl
IG_spawn_flow	Spawning flow at below Iron Gate Dam	Final flow specified for the fall spawning period (October 1-November 15) below Iron Gate Dam. Computed by adding the appropriate IG_spawn_inc variables to IG_spawn.	IG_spawn_flow_	FallWinterRiverOp s. wresl
IG_spawn_inc_ Nov1	Final incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows November 1-15 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOp s. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
IG_spawn_inc_ Oct12	First incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 12-21 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOp s. wresl
IG_spawn_inc_ Oct22	Second incremental increase of fall spawning flow at Iron Gate	Flow increment added to fall spawning flows October 22-31 below Iron Gate Dam. Selected by interpolation between 0 and 125 cfs based on norm_uklinf_60avg.	-	FallWinterRiverOp s. wresl
IGmin	Minimum flow below Iron Gate Dam	Establishes the minimum flow required below Iron Gate Dam. When surface flushing flows have been triggered, this is set to the value of the DG1_Supply. When Boat Dance flows have been triggered, this is set to 1700 cfs. Otherwise it is set to the established monthly minimum flows.	IGmin_	FallWinterRiverOp s. wresl
in_pct_Mar50vol	UKL net inflow percent of forecasted/realized net inflow	Used to establish Link River Dam release targets during March-June, which are subsequently used to establish targets at Iron Gate.	in_pct_Mar50vol_	UKLReleases.wres l
intercept_4dTrigger_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: upper_4dTrigger_mult -	intercept_4dTrigger_mult_	FallWinterRiverOp s. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		upper_I15_wyAvg_mult * slope_4dTrigger_mult.		
irr_WY	Irrigation water year	The irrigation water year extends from March 1 through the end of February. Its value is the same as that for the calendar year for March - December.	-	AgForecast.wresl
Jan50	January NRCS forecast	January NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Jun50	June NRCS forecast	June NRCS 50% exceedence forecast for total June-September UKL net inflow.	-	Definitions.wresl
KDD_indv	Input of diversion and precipitation volume into KDD	Daily total volume of D11, D12A, and KDD_ppt_acft, combined.	KDD_indv	AgRefOps.wresl
KDD_ppt	Average daily precipitation in Area A2	Average daily precipitation (in) for 3 PRISM grids in Area A2.	-	AgRefOps.wresl
KDD_ppt_acft	Precipitation volume in KDD area	KDD_ppt converted to a volume (taf), assuming 27,000 acres in KDD.	-	AgRefOps.wresl
KDDOctFebDV	Running total of winter deliveries to KDD	Running total of November - February deliveries through D11 and D12A (does not include October, despite the variable name).	KDDOctFebDV	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
KDDReserve	Amount of KDD winter water right remaining unused	Amount of KDD winter water right remaining unused, computed as A2FW - KDDOctFebDV(-1) during November - February.	KDDResDV	AgRefOps.wresl
Keno_min	Minimum Keno Dam release	Minimum release (cfs) from Keno Dam.	Keno_min_	FallWinterRiverOps. wresl
l_bound	Lower bound of stor_diff_ratio	Lower bound of stor_diff_ratio, set to -0.8.	-	UKLThresholds.wresl
L1_D11taf	Simulated D11 delivery volume total for prior 5-day period	Simulated D11 delivery volume total for prior 5-day period.	L1_D11taf_	AgForecast.wresl
L1_D12ataf	Simulated D12A delivery volume total for prior 5-day period	Simulated D12A delivery volume total for prior 5-day period.	L1_D12ataf_	AgForecast.wresl
lag_norm_cum_ KDD_in_5d	Normalized cum_KDD_in_5d_	Normalized cum_KDD_in_5d_, from the previous 5-day period.	lag_norm_cum_KDD_in_5d_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p15to49	Normalized cum_KDD_in_p15to49_	Normalized cum_KDD_in_p15to49_, from the previous 5-day period.	lag_norm_cum_KDD_in_p15to49_	AgRefOps.wresl
lag_norm_cum_ KDD_in_p50to14	Normalized cum_KDD_in_p50to14_	Normalized cum_KDD_in_p50to14_, from the previous 5-day period.	lag_norm_cum_KDD_in_p50to14_	AgRefOps.wresl
LastMonthInf	Last month's UKL net inflow volume	Total volume of UKL net inflow (taf) for previous month.	LastMonthInfdv	Definitions.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
Link_max	Maximum acheivable release from Link River Dam	Maximum achievable release from Link River Dam based on a stage-discharge curve, ranging from 900 cfs when UKL elevation is 4137.0 ft to 8600 cfs when UKL elevation is 4143.3 ft.	Link_max_	FallWinterRiverOps. wresl
Link_max_DG1	Maxmimum Link River Dam release used for DG1_supply calculation	Expression of the maximum Link River Dam release for use in calculating the DG1_supply. Computed as the Link_max associated with yesterday's UKL elevation minus 0.3 ft. This 0.3 ft buffer reduces the likelihood of triggering a surface flushing flow that cannot be attained.	Link_max_DG1_	FallWinterRiverOps. wresl
Link_min	Minimum Link River Dam release	Minimum release (cfs) from Link River Dam.	Link_min_	FallWinterRiverOps. wresl
Link_release_FW	Fall-winter flow release target for Link River Dam	Flow release target for Link River Dam for October-February. Computed as Link_release_FW_prep reduced (when appropriate) by the product of the stor_diff_ratio5d and Link_release_FW_prep.	Link_release_FW_	FallWinterRiverOps. wresl
Link_release_FW_ prep	Calculated release target for Link River Dam	Initial flow release target for Link River Dam for October-February. From October - November 15, computed as IG_spawn_flow minus	Link_release_FW_ prep_	FallWinterRiverOps. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		accretions and measured return flows plus diversions. From November 16 through February, computed as yesterday's UKL net inflow minus the Needed_fill_rate multiplied by 1.5.		
Link_release_SS	Link River Dam release target, with UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, with UKL control.	Link_release_SSdv	UKLReleases.wresl
Link_release_ss_diff	Difference between actual and expected Link River Dam releases	Cumulative difference between what was actually released from Link River Dam to support Iron Gate Dam flows yesterday and what was expected to be released to support yesterday's Iron Gate flow target.	Link_release_ss_diff_	UKLReleases.wresl
Link_release_SS_prep	Link River Dam release target, without UKL control, during spring-summer	Calculated release of UKL water at Link River Dam for March-September, without UKL control.	Link_release_SS_prep_	UKLReleases.wresl
Link_WF_target	Target release for Link River Dam during fall-winter period	Link River Dam release target for October - February. Computed as the maximum of either Link_min or Link_release_FW.	Link_WF_target_	FallWinterRiverOps.wresl
LinktoIG_Delay	Iron Gate flow target delay	Delay between scheduling the Iron Gate flow target and implementing the target.	-	Operations_Switches.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		Delay is currently set at 3 days.		
lower_4dTrigger_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 2.2.	-	FallWinterRiverOp s. wresl
lower_I15_wyAvg_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 0.7.	-	FallWinterRiverOp s. wresl
Mar1_EWA_	EWA_River on March 1	EWA_River on March 1.	Mar1_EWA_	UKLThresholds.wr esl
Mar50	March NRCS forecast	March NRCS 50% exceedence forecast for total March-September UKL net inflow.	-	Definitions.wresl
Mar50vol	Combined forecasted/experience d UKL net inflow	Always applicable to the March-September period, this is the NRCS 50% exceedence forecast for UKL net inflow looking forward plus the experienced UKL net inflow since March 1.	Mar50voldv	Definitions.wresl
May50	May NRCS forecast	May NRCS 50% exceedence forecast for total May-September UKL net inflow.	-	Definitions.wresl
Mean_Tmax	Mean daily Project area maximum temperature	Mean daily Tmax (°F) for the Project area from nine randomly selected PRISM grids, averaged within iwy 5 day periods of the irrigation water year	Mean_Tmax_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
model_10	KDD return flow model 10	KDD return flow model 10.	model_10_	AgRefOps.wresl
model_11	KDD return flow model 11	KDD return flow model 11. S	model_11_	AgRefOps.wresl
model_12	KDD return flow model 12	KDD return flow model 12.	model_12_	AgRefOps.wresl
model_13	KDD return flow model 13	KDD return flow model 13. S	model_13_	AgRefOps.wresl
model_14	KDD return flow model 14	KDD return flow model 14.	model_14_	AgRefOps.wresl
model_17	KDD return flow model 17	KDD return flow model 17.	model_17_	AgRefOps.wresl
model_19	KDD return flow model 19	KDD return flow model 19.	model_19_	AgRefOps.wresl
model_20	KDD return flow model 20	KDD return flow model 20. S	model_20_	AgRefOps.wresl
model_22	KDD return flow model 22	KDD return flow model 22.	model_22_	AgRefOps.wresl
model_9	KDD return flow model 9	KDD return flow model 9.	model_9_	AgRefOps.wresl
Monthly_RemainRefugeFallSupply	RemainRefugeFallSupply on first day of the month	During August - November, RemainRefugeFallSupply on the first day of the month.	Monthly_RemainRefugeFallSupply_	AgRefOps.wresl
Needed_fill_rate	Needed UKL fill rate	For any day between November 16 and February 28, this is the average UKL fill rate needed to reach the fill_target_approx elevation (4143.0 ft) by February 28.	Needed_fill_rate_	FallWinterRiverOps. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
norm_inf_hi	Variable used to compute adj_uklcentral	Upper end of the norm_uklinf_60avg, set to 1. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_inf_low	Variable used to compute adj_uklcentral	Lower end of the norm_uklinf_60avg, set to 0. Used to compute adj_uklcentral.	-	UKLThresholds.wresl
norm_uklinf_60avg	Normalized 60-day trailing average of UKL net inflow	60-day trailing average of UKL net inflow re-scaled (normalized) to be between 0 and 1.	norm_uklinf_ 60avgDV	UKLThresholds.wresl
normcumd11	Normalized cumd11wint	Re-scaled cumd11wint (between 0 and 1).	normcumd11_	AgForecast.wresl
normcumd12a	Normalized cumd12awint	Re-scaled cumd12awint (between 0 and 1).	normcumd12a_	AgForecast.wresl
normcumpptwint	Normalized cumpptwint	Re-scaled cumpptwint (between 0 and 1).	normcumpptwint_	AgForecast.wresl
normMar50vol	Normalized Mar50vol	Normalized (re-scaled to be between 0 and 1) Mar50vol across all months and years in the POR.	normMar50vol_	Res_Reqs.wresl
normppt	Normalized Prj_Ppt	Re-scaled Prj_Ppt (between 0 and 1), for use in calculating the ptdayindex.	normppt_	AgForecast.wresl
normpptc	Normalized Cum_Ppt	Re-scaled Cum_Ppt (between 0 and 1), for use in calculating the ptindex.	normpptc_	AgForecast.wresl
normtmax	Normalized Mean_Tmax	Re-scaled Mean_Tmax (between 0 and 1), for use in	normtmax_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		calculating the ptdayindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.		
normtmaxc	Normalized Cum_Tmax	Re-scaled Cum_Tmax (between 0 and 1), for use in calculating the ptindex. Subtracted from 1 to flip the scale, so that increasingly warm conditions move towards 0.	normtmaxc_	AgForecast.wresl
Pct_tota_adjust	Proportional adjustment for percentage of Total A	An adjustment factor applied to estimates of percentage of Total A summed across all diversion arcs, to ensure that they sum to 1 for each irrigation water year.	-	AgForecast.wresl
pctAdyAg	Historical D12A as percent of Area A2 diversion	Historical D12A delivery as percentage of Area A2 total delivery. Used to compute D12A deliveries during November-February.	-	AgRefOps.wresl
pctNorth	Historical D11 as percent of Area A2 diversion	Historical D11 delivery as percentage of Area A2 total delivery. Used to compute D11 deliveries during November-February.	-	AgRefOps.wresl
pdindexd11	Index of winter precipitation and winter D11 deliveries	Index combining winter precipitation and winter D11 delivery volume:	pdindexd11_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		normcumpptwint + normcumd11.		
pdindexd12a	Index of winter precipitation and winter D12a deliveries	Index combining winter precipitation and winter D12a delivery volume: normcumpptwint + normcumd12a.	pdindexd12a_	AgForecast.wresl
prj_acc_addition_to_EWA	Combined LRDC and F/FF EWA release contribution	Calculation of yesterday's LRDC accretions and F/FF pumping that counted as an EWA release and therefore adds to the UKL credit.	prj_acc_addition_to_EWA_	Project_IG_release_ credit.wresl
prj_credit_spill_ forEWA	Spill of UKL credit	Yesterday's spill of accumulated UKL credit. This does not count as an EWA release.	prj_credit_spill_forEWA_	Project_IG_release_ credit.wresl
PRJ_FlexAugment	Project share of flexible flow augmentation volume	Volume in addition to EWA_River that is removed from Project Supply and used to augment Klamath River flow.	PRJ_FlexAugment_	SeasonalSupply.wresl
Prj_Ppt	Average daily Project-area precipitation	Mean daily precipitation in inches for the Project area from nine randomly selected PRISM grids, averaged within 5-day periods of the irrigation water year	Prj_Ppt_	AgForecast.wresl
prj_UKL_credit	UKL credit	Accumulated credit in UKL due to LRDC accretion and F/FF pumping contribution to EWA release	prj_UKL_credit_	Project_IG_release_ credit.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
PrjPpt_max	Maximum Prj_Ppt for period of record	Maximum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_max_	AgForecast.wresl
PrjPpt_min	Minimum Prj_Ppt for period of record	Minimum value of Prj_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Prj_Ppt to be between 0 and 1, for use in calculating the ptdayindex.	PrjPpt_min_	AgForecast.wresl
PrjPptCum_max	Maximum Cum_Ppt for period of record	Maximum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_max_	AgForecast.wresl
PrjPptCum_min	Minimum Cum_Ppt for period of record	Minimum value of Cum_Ppt for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Cum_Ppt to be between 0 and 1, for use in calculating the ptindex.	PrjPptCum_min_	AgForecast.wresl
PrjSupply	Project supply	Allocation from UKLSupply for use by the Project irrigators.	PrjSupplydv	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
PrjSupply_Apr1	Project supply on April 1	Project supply computed on April 1 as min(Projectmax, UKLsupply - EWA_River).	PrjSupply_Apr1_	SeasonalSupply.wresl
PrjSupply_irr	Project supply for irrigation	Allocation from UKLSupply for use by the Project, computed as max(0., PrjSupply - RefugeFallSupply).	PrjSupply_irrdv	SeasonalSupply.wresl
PrjSupply_irr_Apr1min	Project supply for irrigation on April 1	Allocation from UKLSupply for use by the Project on April 1, computed as max(0., PrjSupply_Apr1 - RefugeFallSupplyApr1min).	PrjSupply_irr_Apr1mindv	SeasonalSupply.wresl
Proj_full_check	Project full supply check	Set to 1 when Project supply is at its maximum. Set to 1 when either UKLsupply - EWA_River > Projectmax or UKLsupply > 1035; set to zero otherwise.	Proj_full_check_	SeasonalSupply.wresl
projectmax	Maximum allocation of UKL water for Project use	Maximum allocation of UKL water for Project use, set to 350 TAF.	projectmaxdv	Definitions.wresl
ptdayindex	Precipitation-temperature index	The sum of normppt and normtmax for a 5-day period of the irrigation water year. Values near zero indicate warm, dry conditions; values near 1 indicate cool, wet conditions.	ptdayindex_	AgForecast.wresl
ptindex	Cumulative precipitation-temperature index	The sum of normpptc and normtmaxc for a 5-day period of the irrigation water year. Values near zero indicate	ptindex_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		warm, dry conditions; values near 1 indicate cool, wet conditions.		
R131a	Return flow from KDD	Return flow from KDD.	R131a	Return-table.wresl
R131b	Return flow from LKNWR	Return flow from LKNWR. Set to 0.	R131b	Return-table.wresl
RefugeFallCumulDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 1.0 in August, 0.84 in September, 0.60 in October, and 0.20 in November.	RefugeFallCumulDist_	AgRefOps.wresl
RefugeFallRelDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Computed as RefugeFallSupplyDist / RefugeFallCumulDist during August - November.	RefugeFallRelDist_	AgRefOps.wresl
RefugeFallSupply	Refuge Fall Supply		RefugeFallSupply_	SeasonalSupply.wresl
RefugeFallSupplyApr1min	Refuge Fall Supply on April 1	Refuge Fall Supply on April 1.	RefugeFallSupplyApr1min_	SeasonalSupply.wresl
RefugeFallSupplyDist	Component of LKNWR delivery computation	Variable used to compute D12B deliveries. Set to 0.16 in August, 0.25 in September, 0.40 in October, and 0.20 in November.	RefugeFallSupplyDist_	AgRefOps.wresl
RemainRefugeFallSupply	Remaining LKNWR fall supply	Remaining LKNWR fall supply. August - November, it is computed as the RefugeFallSupply on August 1, and as max(0., RemainRefugeFallSupply_(-	RemainRefugeFallSupply_	AgRefOps.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		1) - max(0.,D12b(-1)-transfer_diversion)*cfs_taf) thereafter.		
Rfg_month_dem	Monthly demand volume for LKNWR	Monthly demand volume (TAF) for LKNWR.	-	AgRefOps.wresl
Rfg_PrjSupPct	Refuge percentage of Project supply	Percentage of Project Supply set aside for LKNWR use in August – November.	Rfg_PrjSupPct_	SeasonalSupply.wresl
Rfg_PrjSupPctmin	Refuge percentage of Project supply on April 1	The Rfg_PrjSupPct computed based on PrjSupply_Apr1.	Rfg_PrjSupPctmin_	SeasonalSupply.wresl
S1	UKL storage	Storage in UKL as modeled through the mass balance of UKL net inflow, Link releases, and A Canal diversions.	S1	Reservoir-table.wresl
S15	Iron Gate storage	This is a simplistic representation of Iron Gate storage in order to replicate necessary fill to the Iron Gate spillway to make releases greater than 1,700 cfs over the spillway.	S15	Reservoir-table.wresl
S15_proj	Projected storage in Iron Gate Reservoir at end of today	Projected storage in Iron Gate Reservoir at end of today, computed as: min(S15level4, C13_MIF1(-1)*cfs_taf + I15_forecast0*cfs_taf + S15(-1) - max(IGmin, C15target)*cfs_taf).	S15_proj_	UKLReleases.wresl
S15target	Iron Gate Reservoir storage target	Set to 53 TAF (volume at spillway elevation) when	S15target_	UKLReleases.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		C15target > 1700 cfs or when stage1_trigger_ = 1; otherwise set to 51 TAF. Used to fill Iron Gate Reservoir to spillway elevation before C15target flows requiring spill.		
S1yestelev	UKL elevation	Elevation of UKL water surface measured at the end of yesterday. In the model, this is determined using the calculated storage (S1) in the storage-elevation lookup table.	S1yestelevdv	Reservoir-table.wresl
sb	Step-back	Variable used in lag functions to "step-back", or lag, to the last day of the previous five_day_period.	sb_	Definitions.wresl
shortdum	Water-short-year indicator	Dummy variable used in forecasting models to indicate when water supply is substantially less than irrigation demand. When UKLSupply < 836 TAF, this variable is set to 1, indicating water-short conditions. It is zero otherwise.	shortdum_	AgForecast.wresl
slope_4dTrigger_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Computed as: (upper_4dTrigger_mult - lower_4dTrigger_mult) /	slope_4dTrigger_ mult_	FallWinterRiverOp s. wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		(upper_I15_wyAvg_mult - lower_I15_wyAvg_mult).		
SSdaynum	Day of spring-summer season	Day 1 is March 1, incremented by 1 each day thereafter.	SSdaynumDV	Definitions.wresl
stage1_trigger	Trigger to fill Iron Gate Reservoir to spillway elevation	Triggers the filling of Iron Gate Reservoir to its spillway elevation in anticipation of releases from UKL for a surface flushing flow. It is triggered when (I15_d0d3_total(-1) - (I15_wyAvgVol(-1) * 4.)) ≥ (I15_wyAvgVol(-1) * (slope_4dTrigger_mult * I15_wyAvgVol(-1) + intercept_4dTrigger_mult)	stage1_trigger_	FallWinterRiverOps. wresl
stor_diff_ratio	Daily storage difference ratio	Daily expression of the storage difference ratio, which is used in UKL control logic.	stor_diff_ratio_	UKLThresholds.wresl
stor_diff_ratio5d	Storage difference ratio for 5-day period	5-day period expression of the storage difference ratio, which is used in UKL control logic. For each 5-day period, it is set to the value of stor_diff_ratio on day 1 of the 5-day period.	stor_diff_ratio5d_	UKLThresholds.wresl
stor_diff_ratio5d_ag	Storage difference ratio for refuge	The storage difference ratio computed for each 5-day period that is applied to D12B (Refuge) diversions. Despite the name, it is not applied to	stor_diff_ratio5d_ag_	SeasonalSupply.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		ag diversions. It is the same as stor_diff_ratio5d but is not allowed to drop below -0.5 or to go above 0.		
switch_acc_AddToTarget	Iron Gate Target augmentation switch	Conditional variable that equals 1 when LRDC accretions and F/FF pumping augment Iron Gate calculated target. Equals 0 when they do not augment Iron Gate calculated target. In current proposed action this variable equals 1 from October to February and 0 from March to September.	-	Project_IG_release_ credit.wresl
Tmax_max	Maximum Mean_Tmax for period of record	Maximum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_max_	AgForecast.wresl
Tmax_min	Minimum Mean_Tmax for period of record	Minimum value of Mean_Tmax for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Mean_Tmax to be between 0 and 1, for use in calculating the ptdayindex.	Tmax_min_	AgForecast.wresl
TmaxCum_max	Maximum Tmax_Cum for period of record	Maximum value of Tmax_Cum for a given 5-day	TmaxCum_max_	AgForecast.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.		
TmaxCum_min	Minimum Tmax_Cum for period of record	Minimum value of Tmax_Cum for a given 5-day period across all irrigation water years in the period of record. Used to re-scale (normalize) Tmax_Cum to be between 0 and 1, for use in calculating the ptindex.	TmaxCum_min_	AgForecast.wresl
transfer_diversion	Refuge transfer	Input of 11 TAF of transfer from UKL refuge to Lower Klamath Lake refuge uniformly distributed on a daily basis from April through September	refuge_transfer	Operations_Switches. wresl
u_bound	Upper bound of stor_diff_ratio	Upper bound of stor_diff_ratio, set to 0.	-	UKLThresholds.wresl
UKL_adj_width	stor_diff_ratio denominator	Specifies the volume in the denominator of the stor_diff_ratio.	-	UKLThresholds.wresl
UKL_FlexAugment	UKL share of flexible flow augmentation volume	Volume contributed from UKL to augment Klamath River flow.	UKL_FlexAugment_	SeasonalSupply.wresl
UKL_flood_lvl	Maximum UKL monthly level	Maximum allowable UKL level for each month. Set to 4143.1 ft for all months	S1_maxL_dv	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		except April (4143.2 ft), and May and June (4143.3 ft).		
UKL_flood_sto	Year-round threshold storage for UKL flood releases	Year-round threshold storage for UKL flood releases, set equal to UKL_release_sto during Oct-Apr, otherwise set to UKL_flood_sto1. This is the final determination of the UKL flood release storage threshold in the KBPM.	S1_maxS_dv	Res_Reqs.wresl
UKL_flood_sto1	Maximum UKL monthly storage volume	Maximum allowable UKL level for each month: active storage volume associated with UKL_flood_lvl.	-	Res_Reqs.wresl
UKL_min_lvl	Minimum UKL monthly level	Minimum allowable UKL level for each month. Set to 4137.0 ft in all months.	S1_minL_dv	Res_Reqs.wresl
UKL_min_sto	Minimum UKL monthly storage volume	Minimum allowable UKL storage volume for each month: active storage volume associated with UKL_min_sto.	S1_minS_dv	Res_Reqs.wresl
UKL_release_level_som_use	UKL flood release level at start of month	Computed as: max(UKL_release_lvl_som, UKL_release_thresh_(-day)), where (-day) is the last day of the previous month.	UKL_rels_lvl_som_ use_	Res_Reqs.wresl
UKL_release_lvl	Year-round threshold level for UKL flood releases	Year-round threshold storage for UKL flood releases. This is the UKL level associated with UKL_flood_sto, and is the final determination of the	UKL_release_lvl_dv	Res_Reqs.wresl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
		UKL flood release threshold level in the KBPM.		
UKL_release_lvl_ eom	UKL flood release level at end of month	UKL flood release level at end of month.	UKL_release_lvl_ eom_	Res_Reqs.wresl
UKL_release_lvl_ som	UKL flood release level at start of month	UKL flood release level at start of month.	UKL_release_lvl_ som_	Res_Reqs.wresl
UKL_release_sto	Oct-Apr threshold storage for UKL flood releases	Threshold storage volume for UKL flood releases during Oct-Apr period, when it is set equal to UKL_release_thresh_sto. It set to zero in other months.	-	Res_Reqs.wresl
UKL_release_thresh	UKL flood release threshold level	UKL level above which flood releases occur.	UKL_release_thresh_	Res_Reqs.wresl
UKL_release_thresh_sto	UKL flood release threshold storage volume	UKL volume above which flood releases occur. This is the UKL active storage volume associated with UKL_release_thresh.	-	Res_Reqs.wresl
UKL_rfg_up_thresh	UKL refuge upper threshold	During June-July, UKL level thresholds above which the Refuge can receive a daily delivery equal to the monthly demand, if the Project has a full supply. Set to 4142.50 ft in June, and 4141.50 ft in July.	UKL_rfg_up_thresh_	SeasonalSupply.w resl
UKLsupply	UKL supply	Supply identified in UKL as available to meet needs in the river, Refuge, and Project.	UKLSupplydv	SeasonalSupply.w resl

Variable Name in Model code	Common Name	Definition	Output Variable Name	Model File of Initial Definition
ukltraj_central	UKL central tendency base	Unadjusted UKL central tendency.	ukltraj_central_	UKLThresholds.wresl
ukltraj_high	Upper bound to adjusted UKL central tendency	Upper bound to adjusted UKL central tendency.	ukltraj_high_	UKLThresholds.wresl
ukltraj_low	Lower bound to adjusted UKL central tendency	Lower bound to adjusted UKL central tendency.	ukltraj_low_	UKLThresholds.wresl
upper_4dTrigger_ mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 3.	-	FallWinterRiverOps. wresl
upper_I15_wyAvg_mult	Variable used to compute stage1_trigger	Variable involved in computation of stage1_trigger. Set to 1.6.	-	FallWinterRiverOps. wresl

Appendix 4 Section B: Proposed Action Model Output Graphs

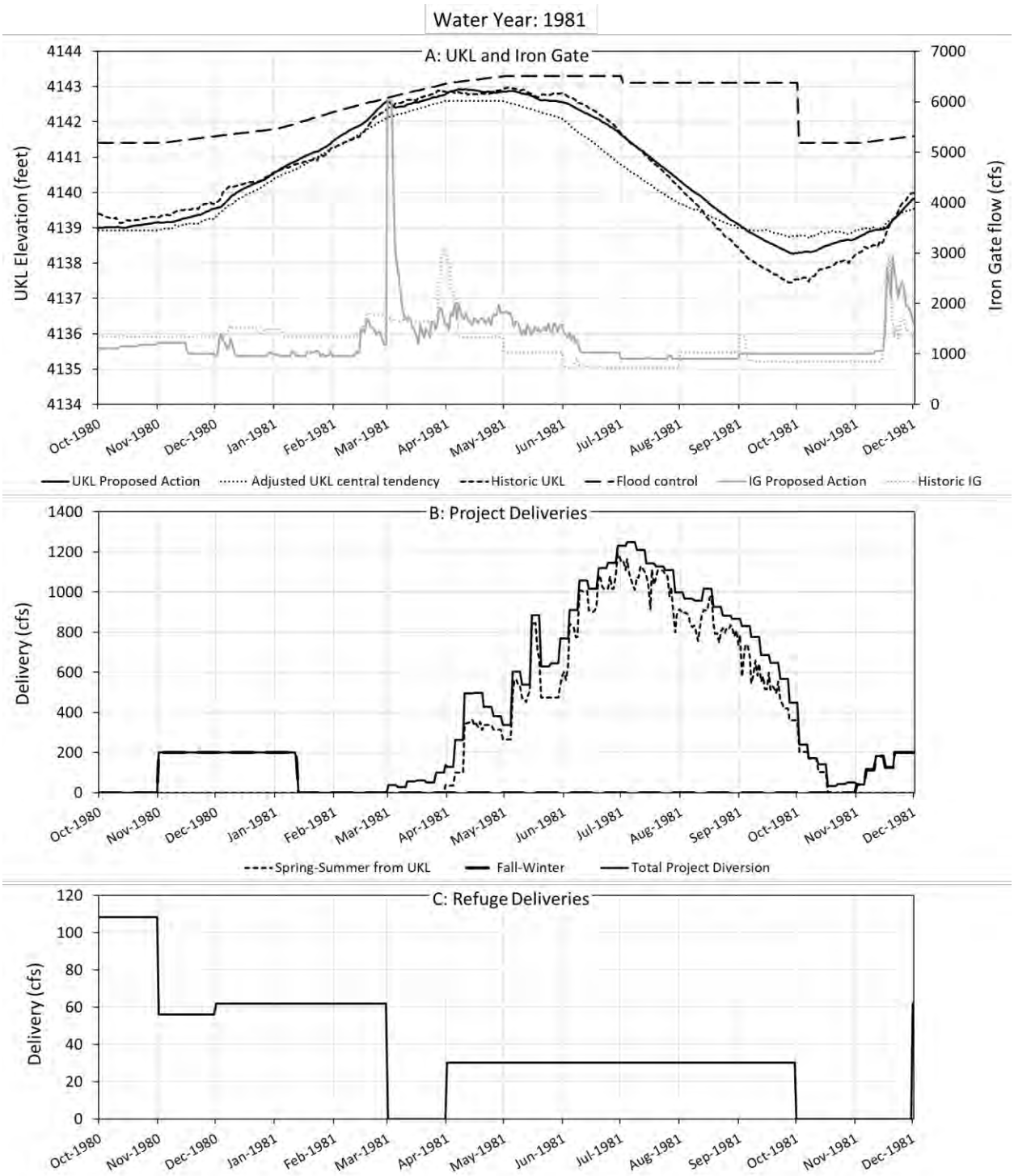


Figure B1. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1981.

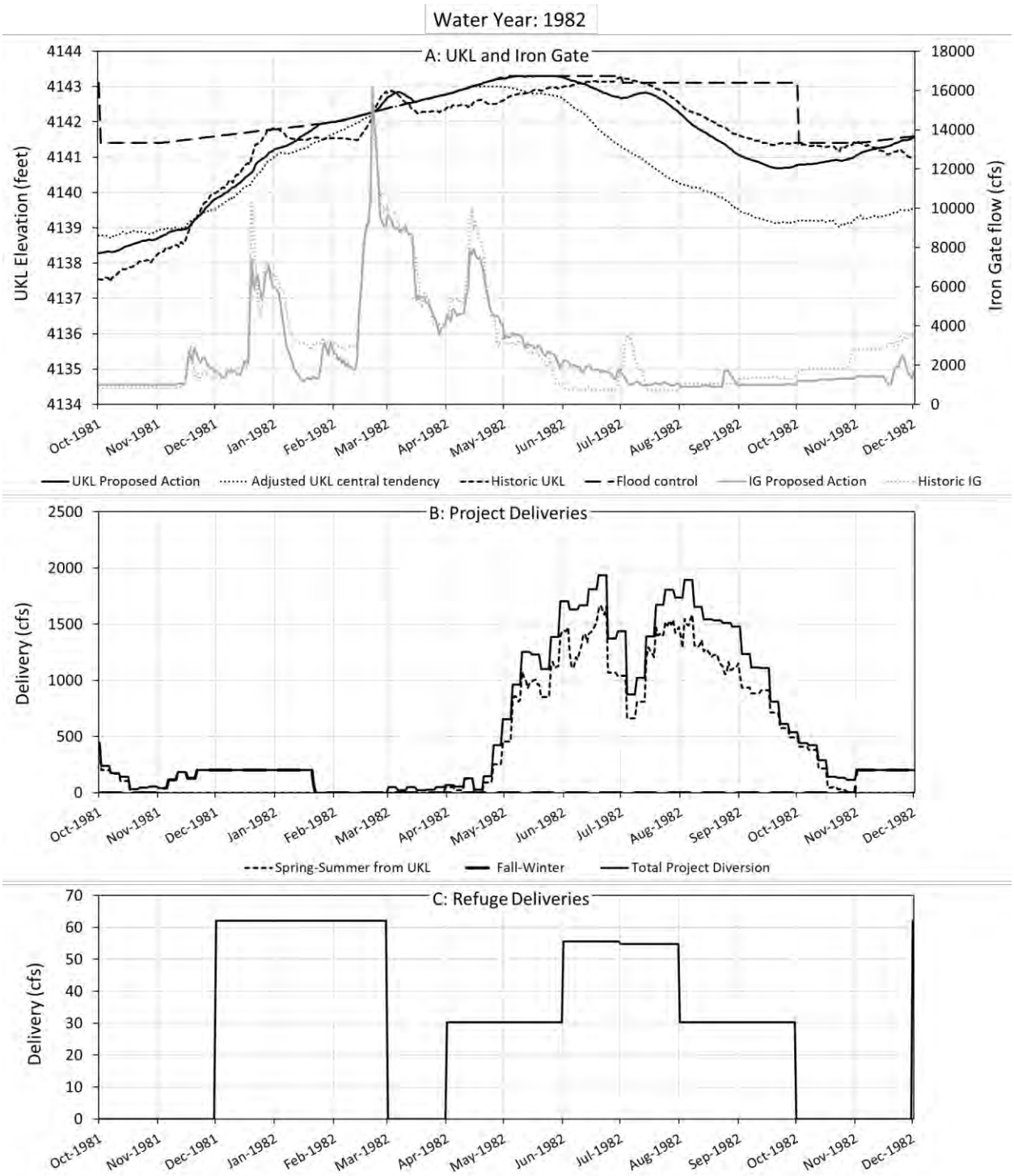


Figure B2. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1982.

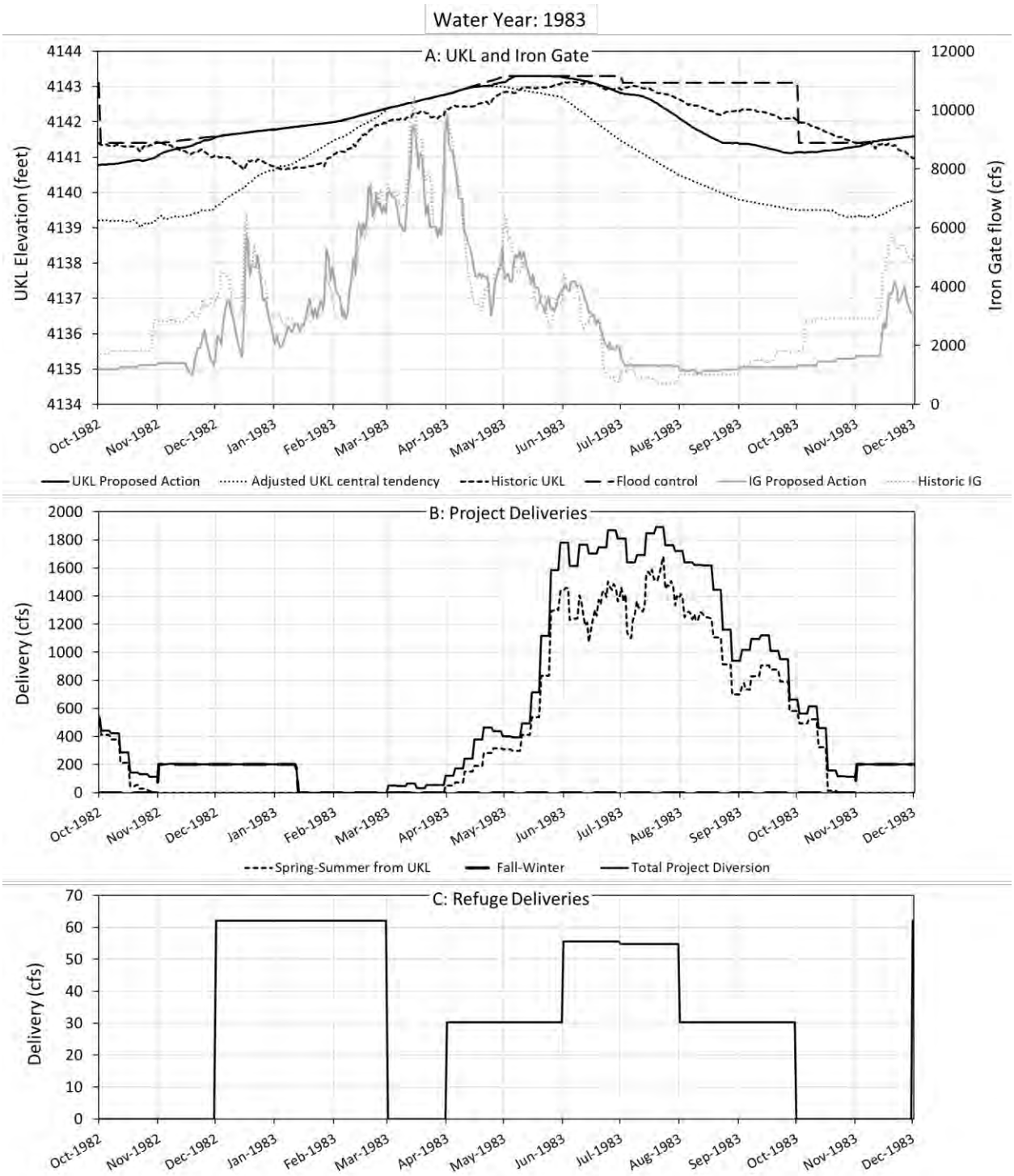


Figure B3. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1983.

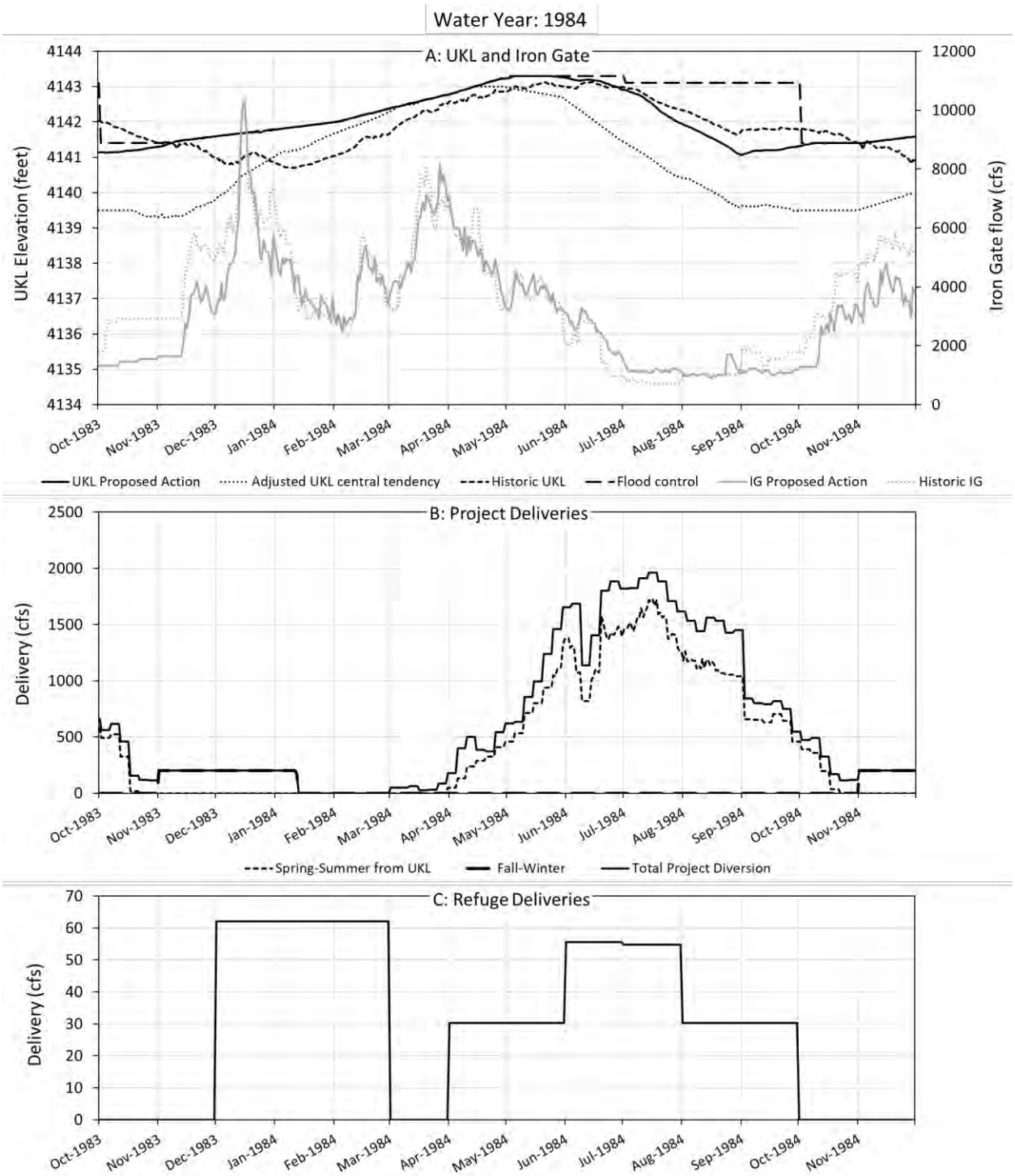


Figure B4. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1984.

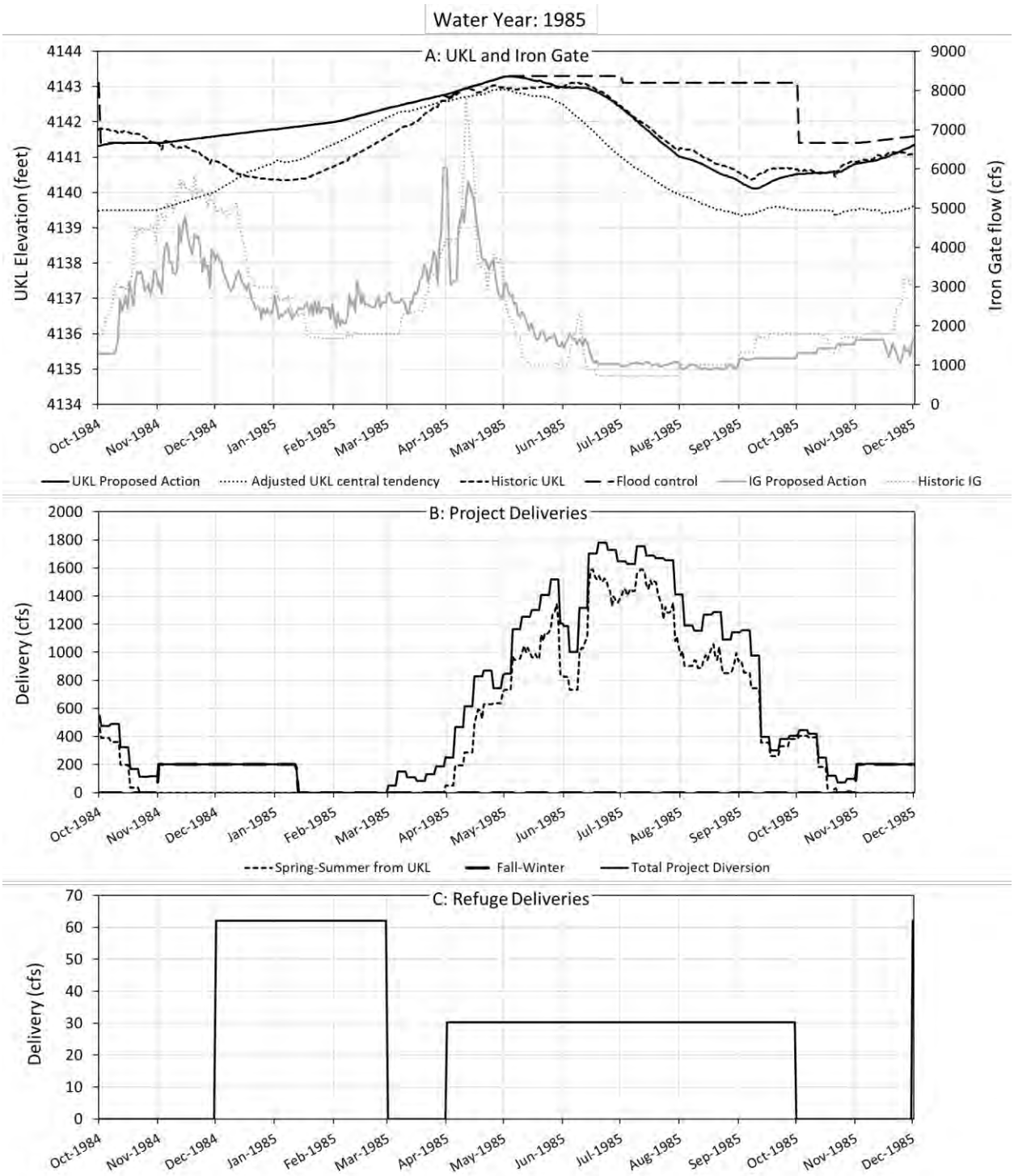


Figure B5. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1985.

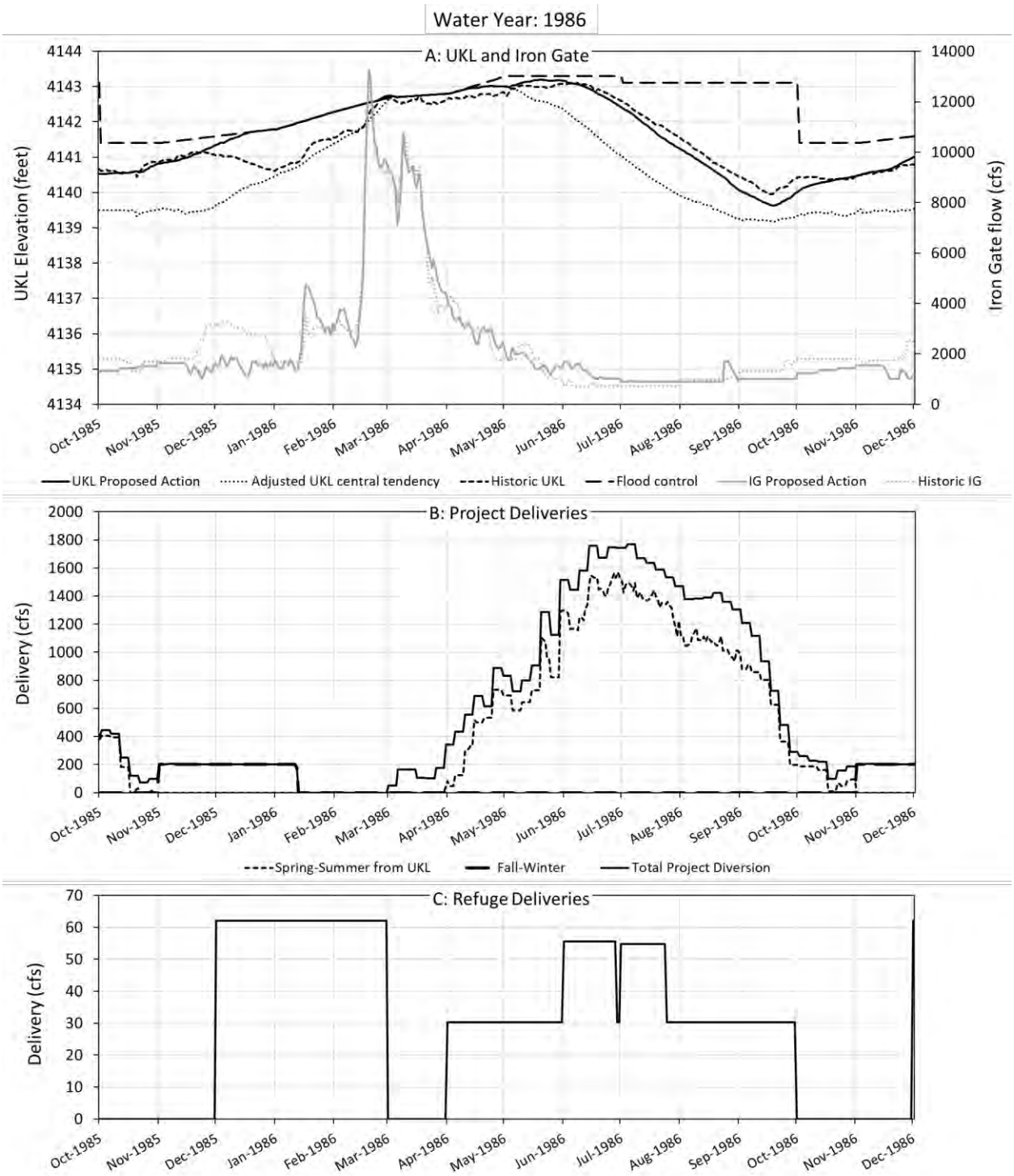


Figure B6. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1986.

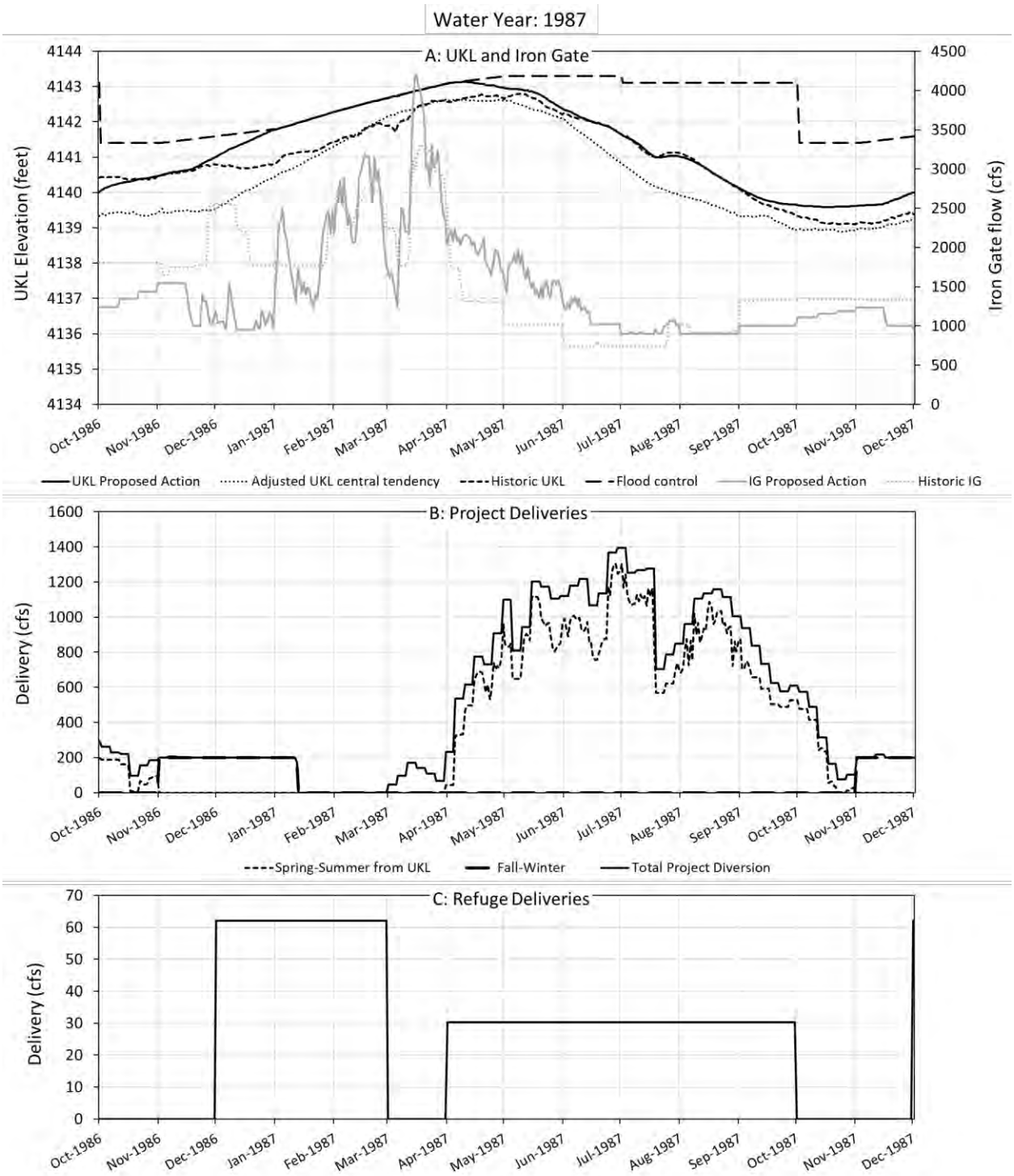


Figure B7. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1987.

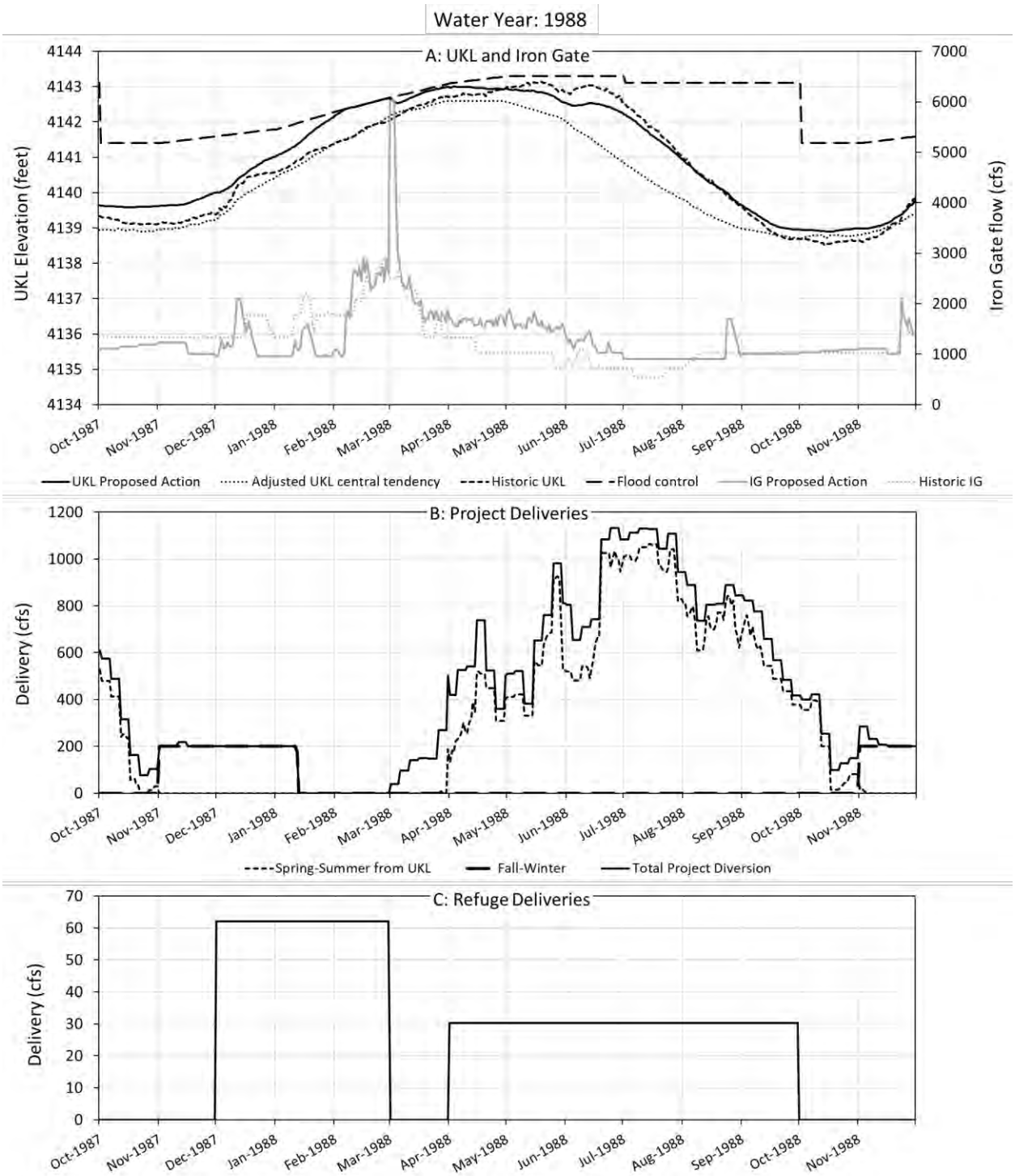


Figure B8. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1988.

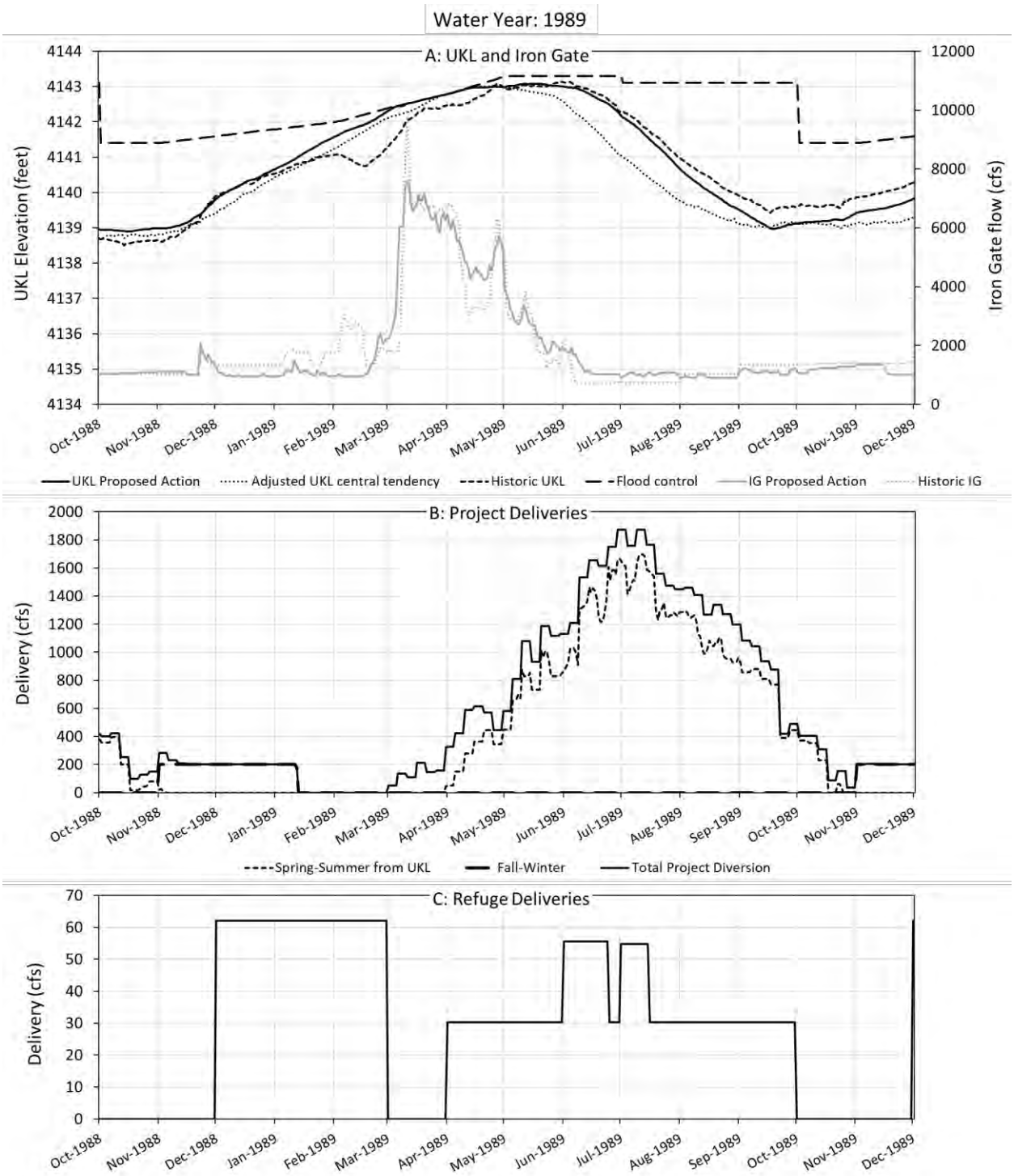


Figure B9. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1989.

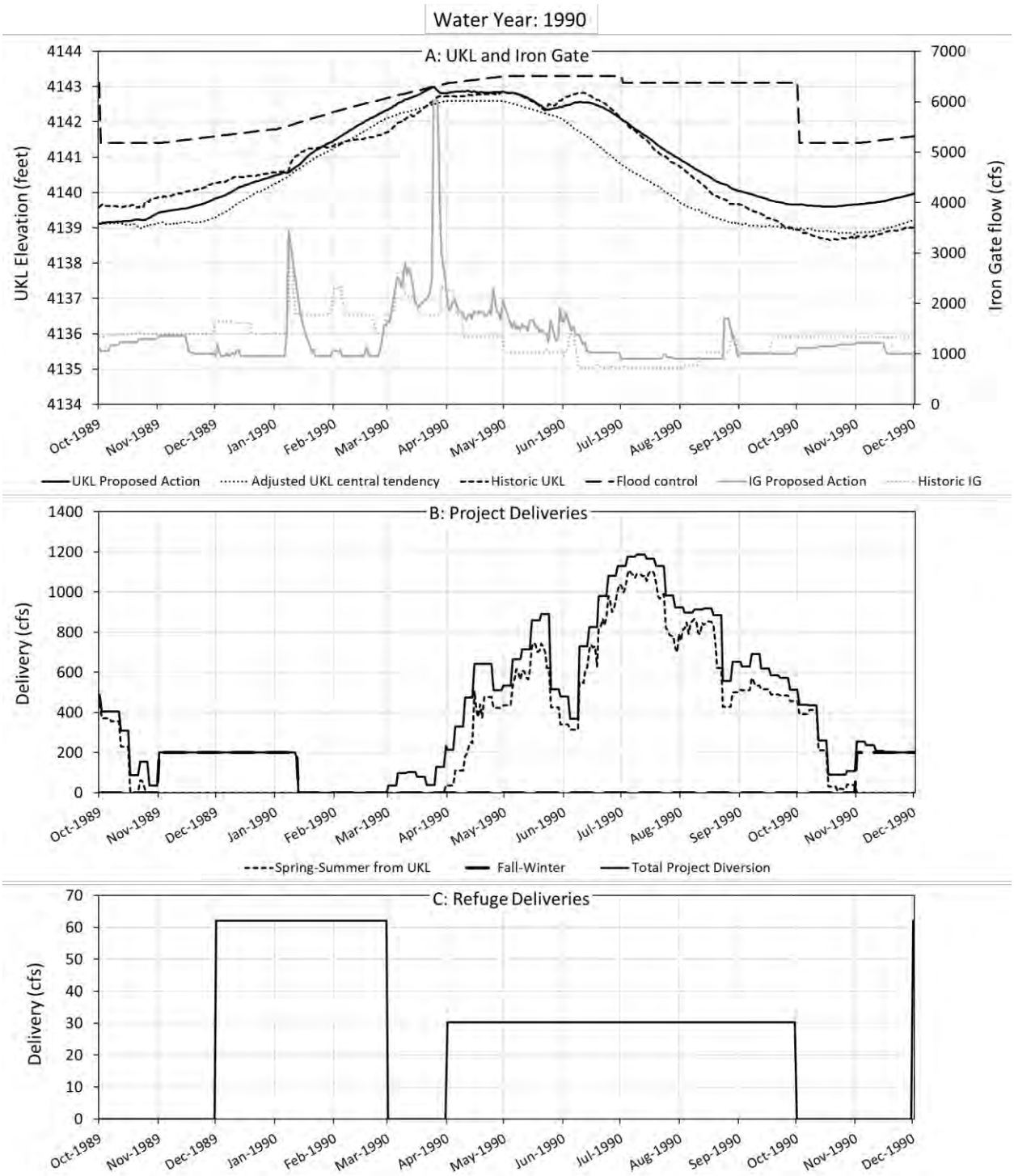


Figure B10. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1990.

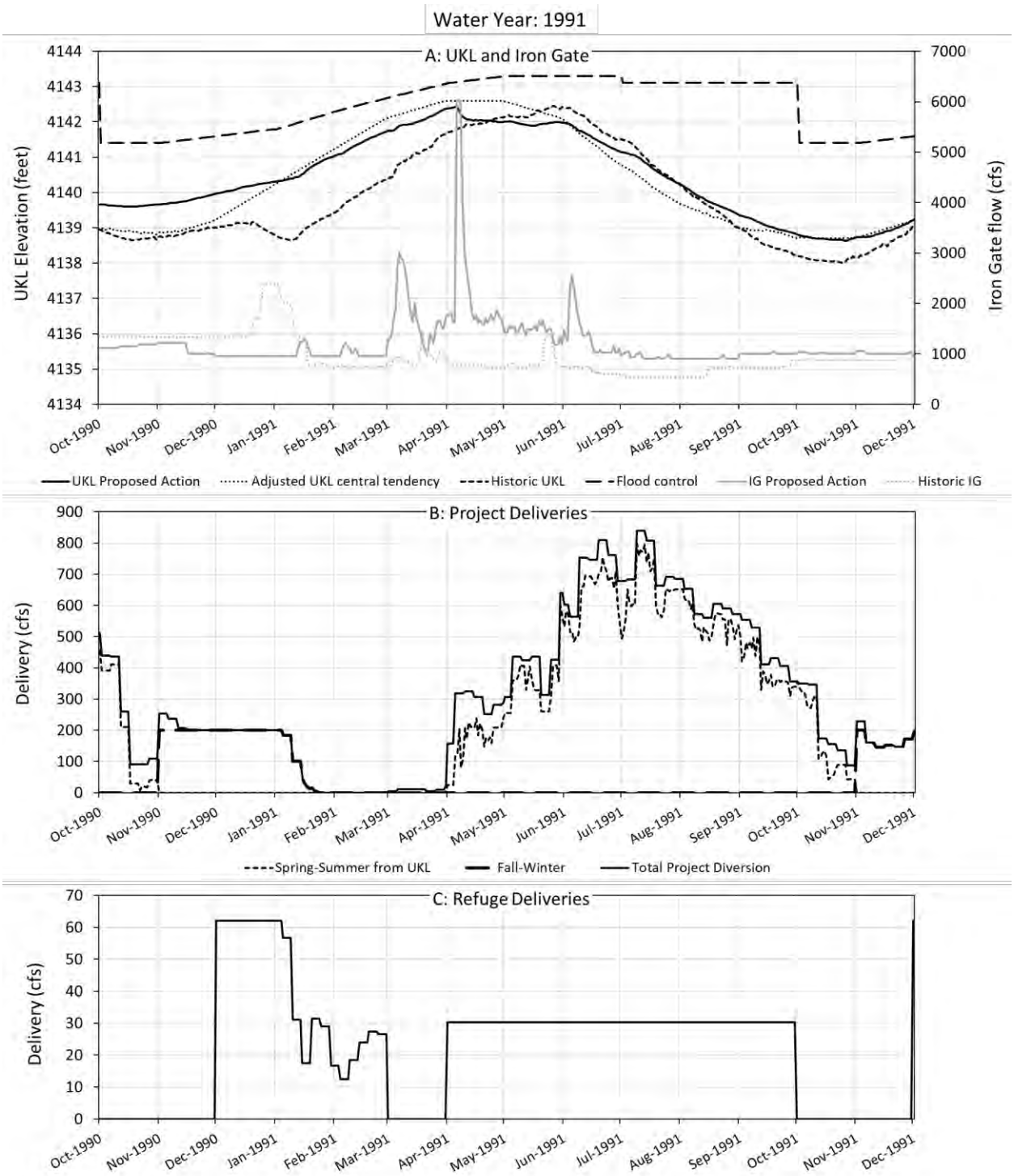


Figure B11. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1991.

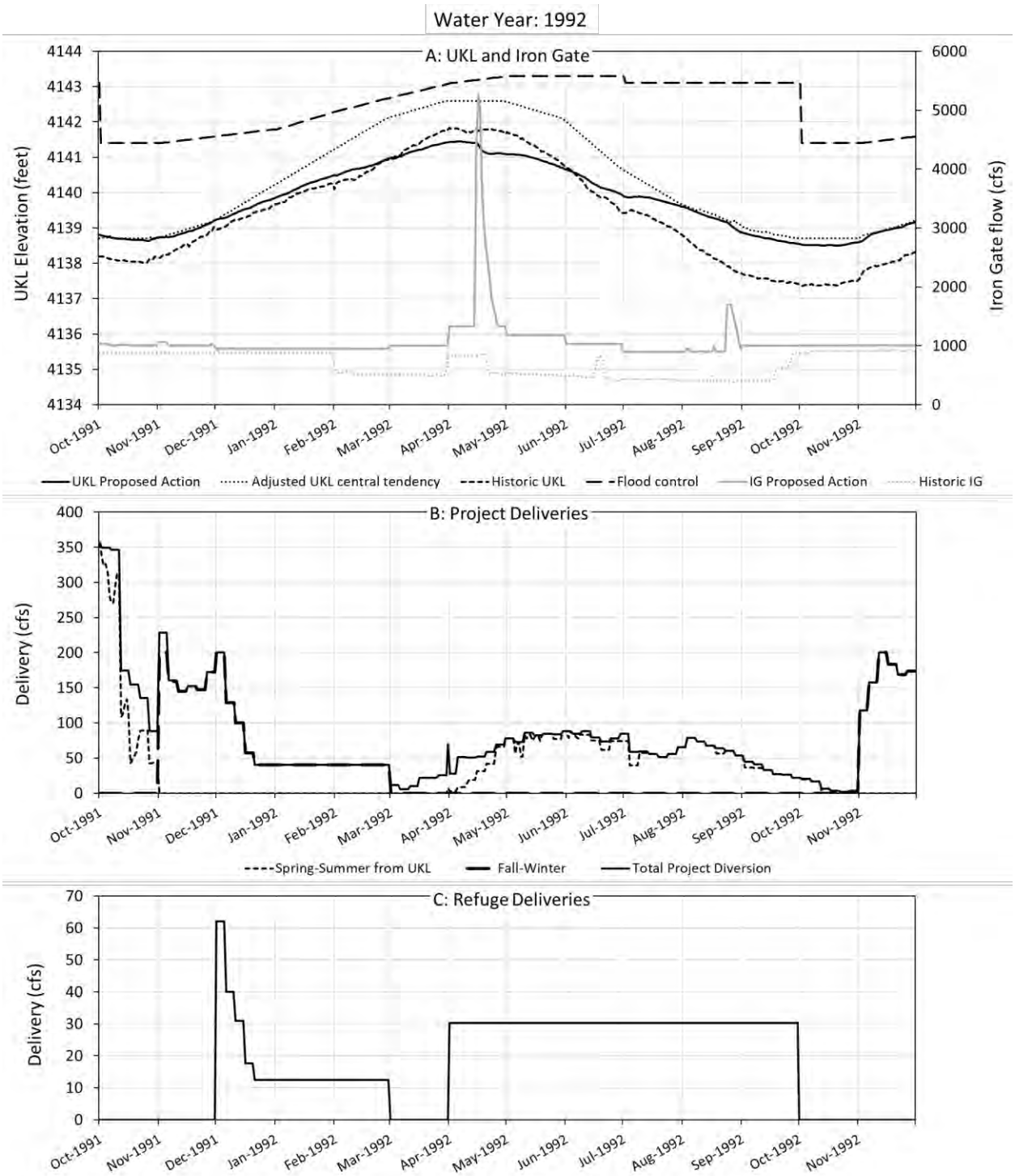


Figure B12. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1992.

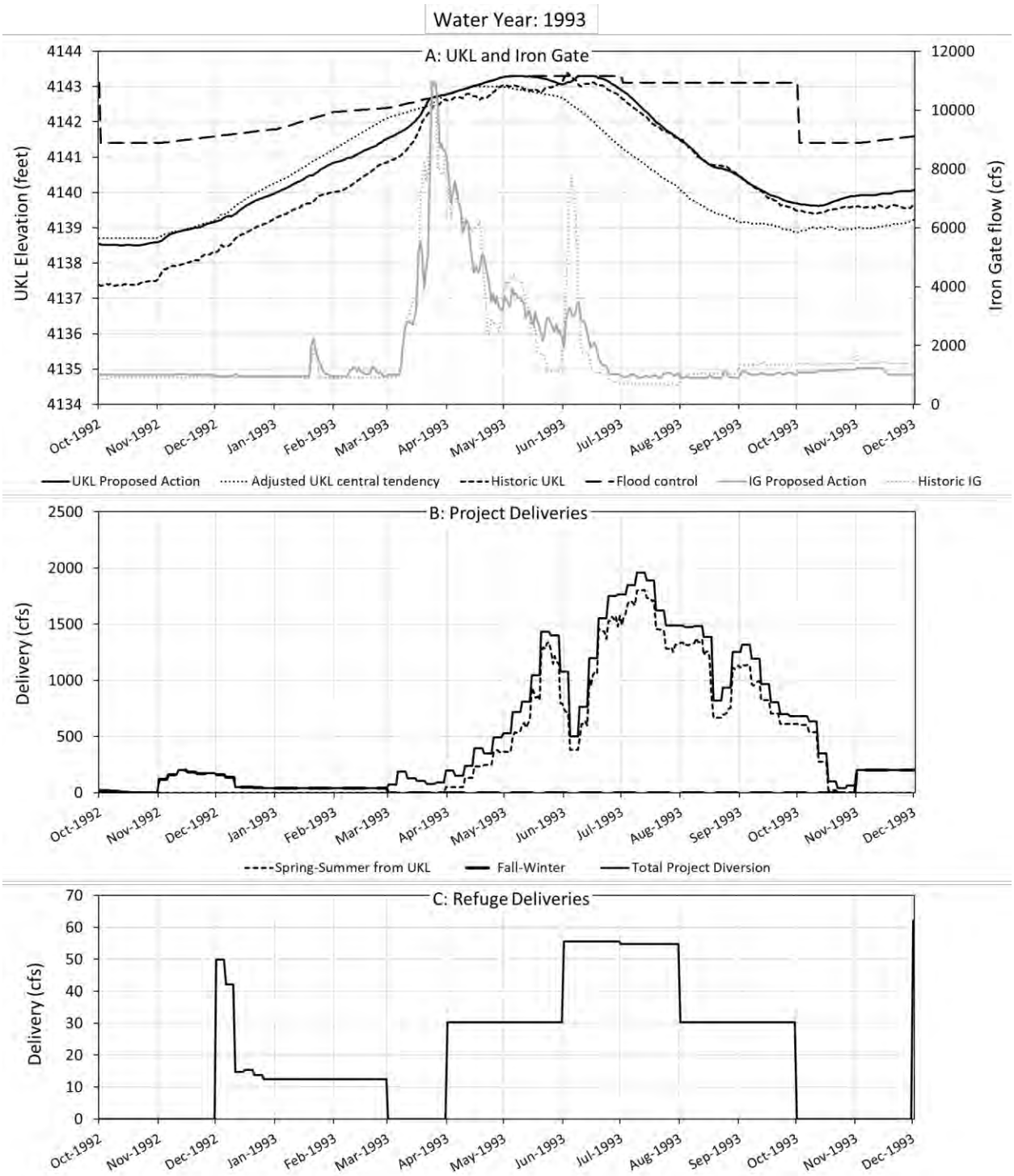


Figure B13. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1993.

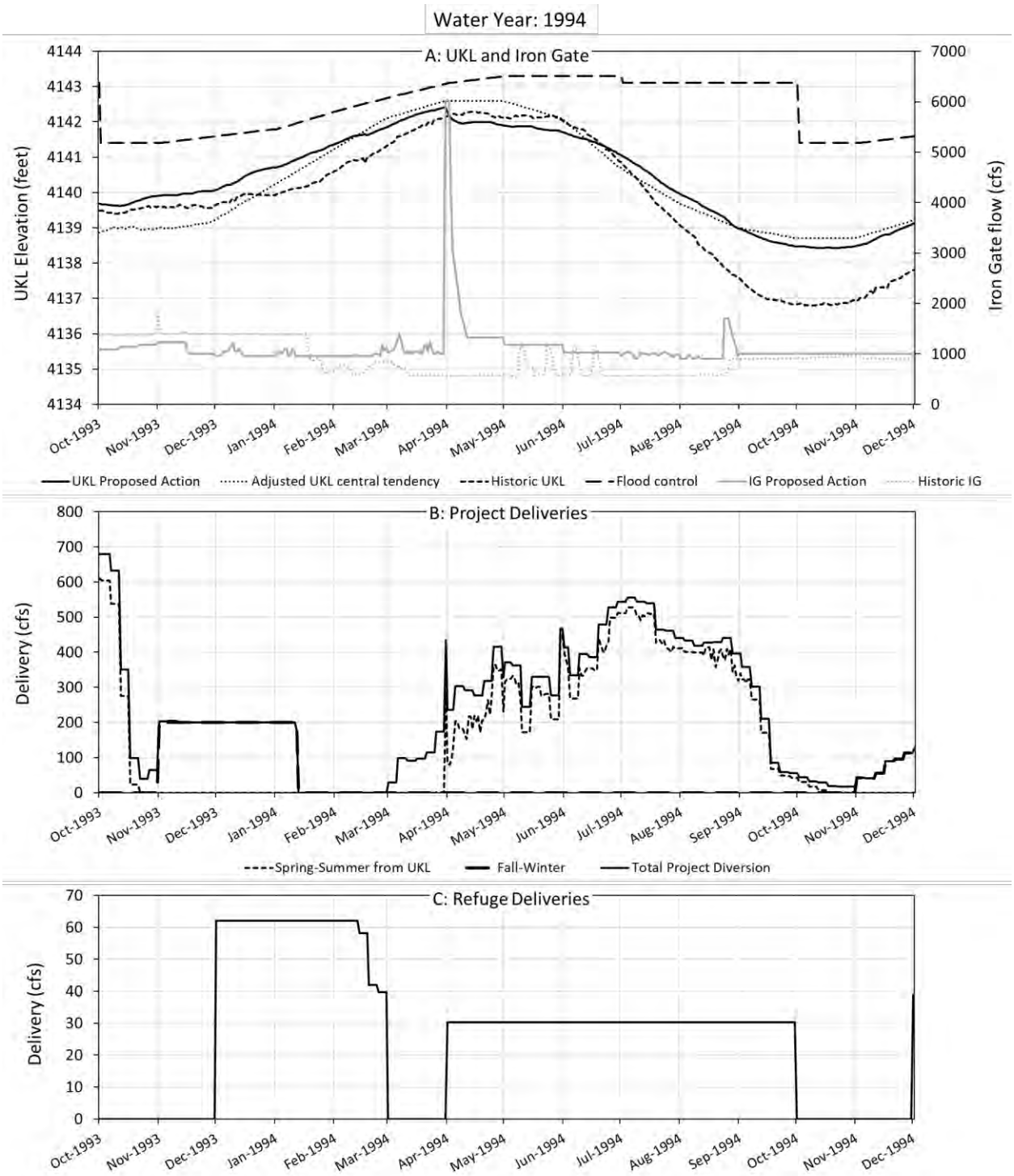


Figure B14. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1994.

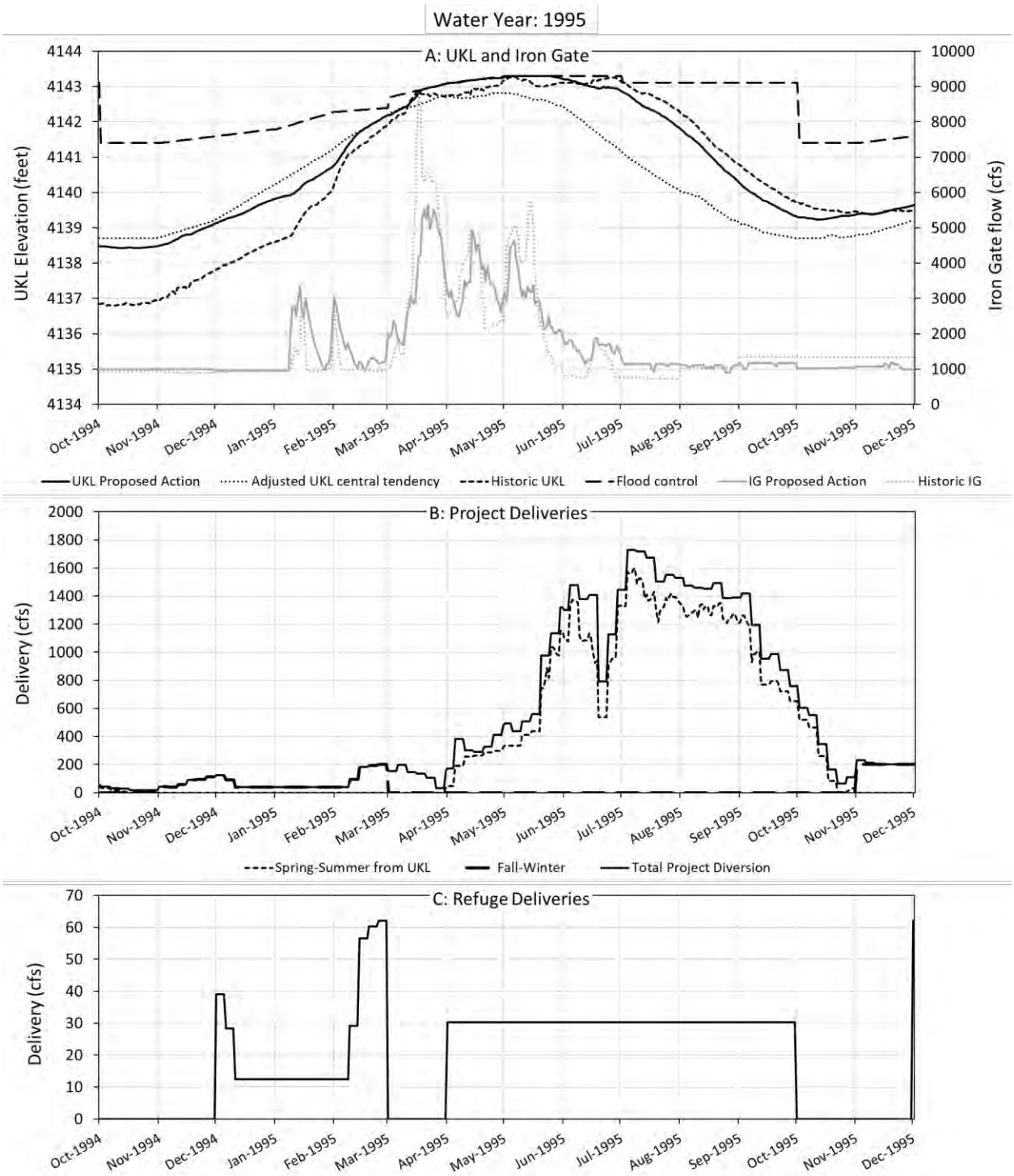


Figure B15. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1995.

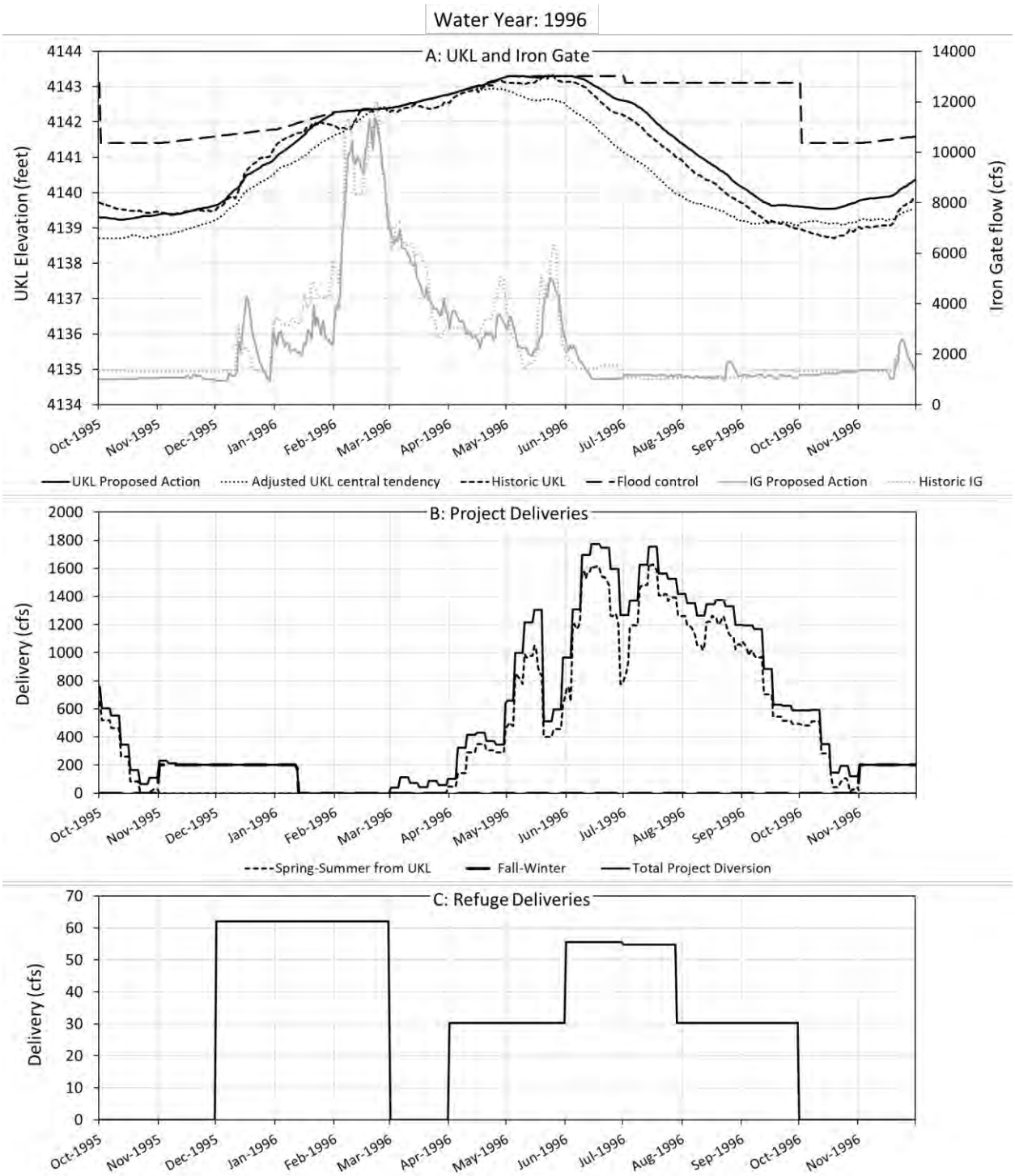


Figure B16. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1996.

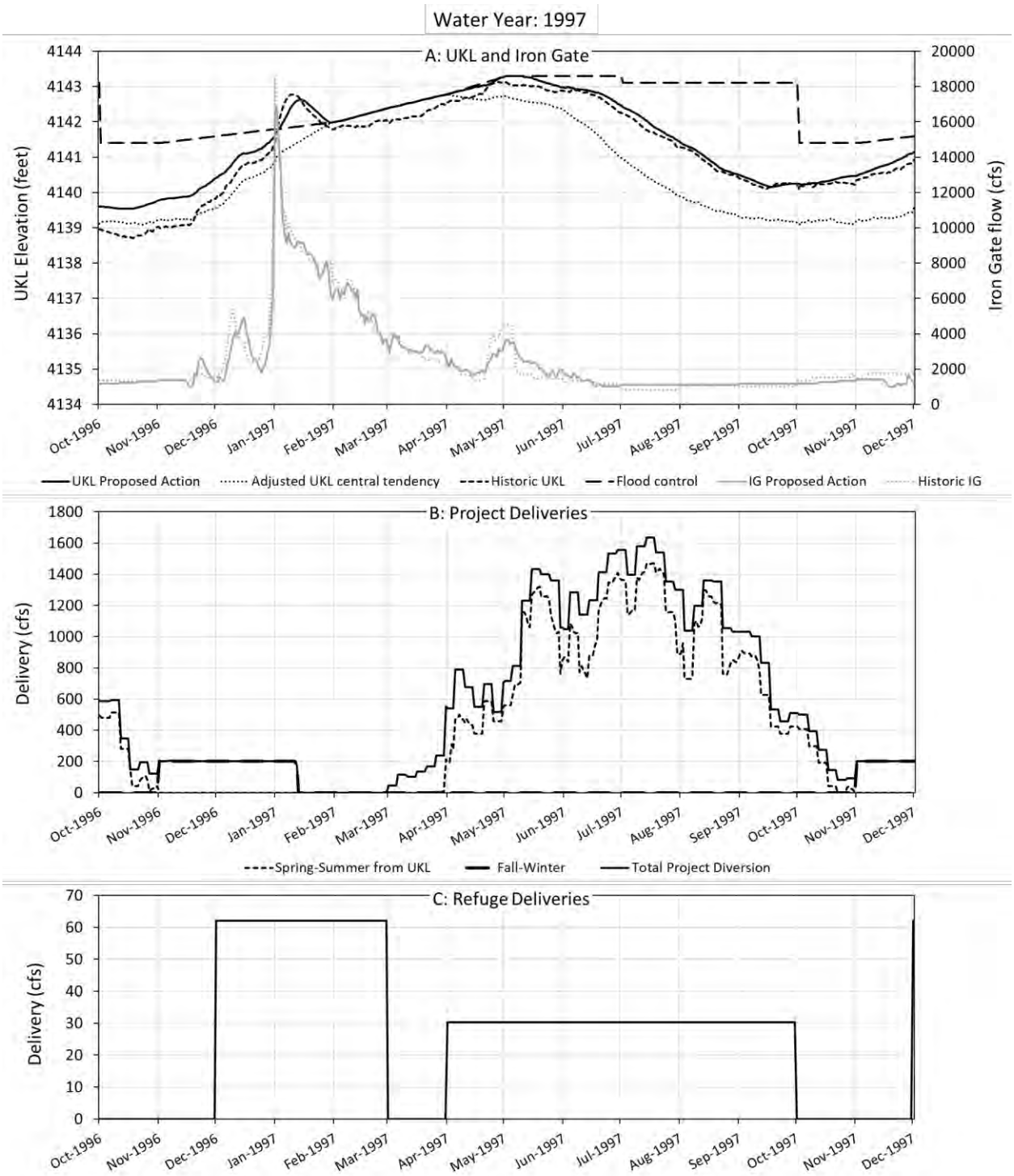


Figure B17. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1997.

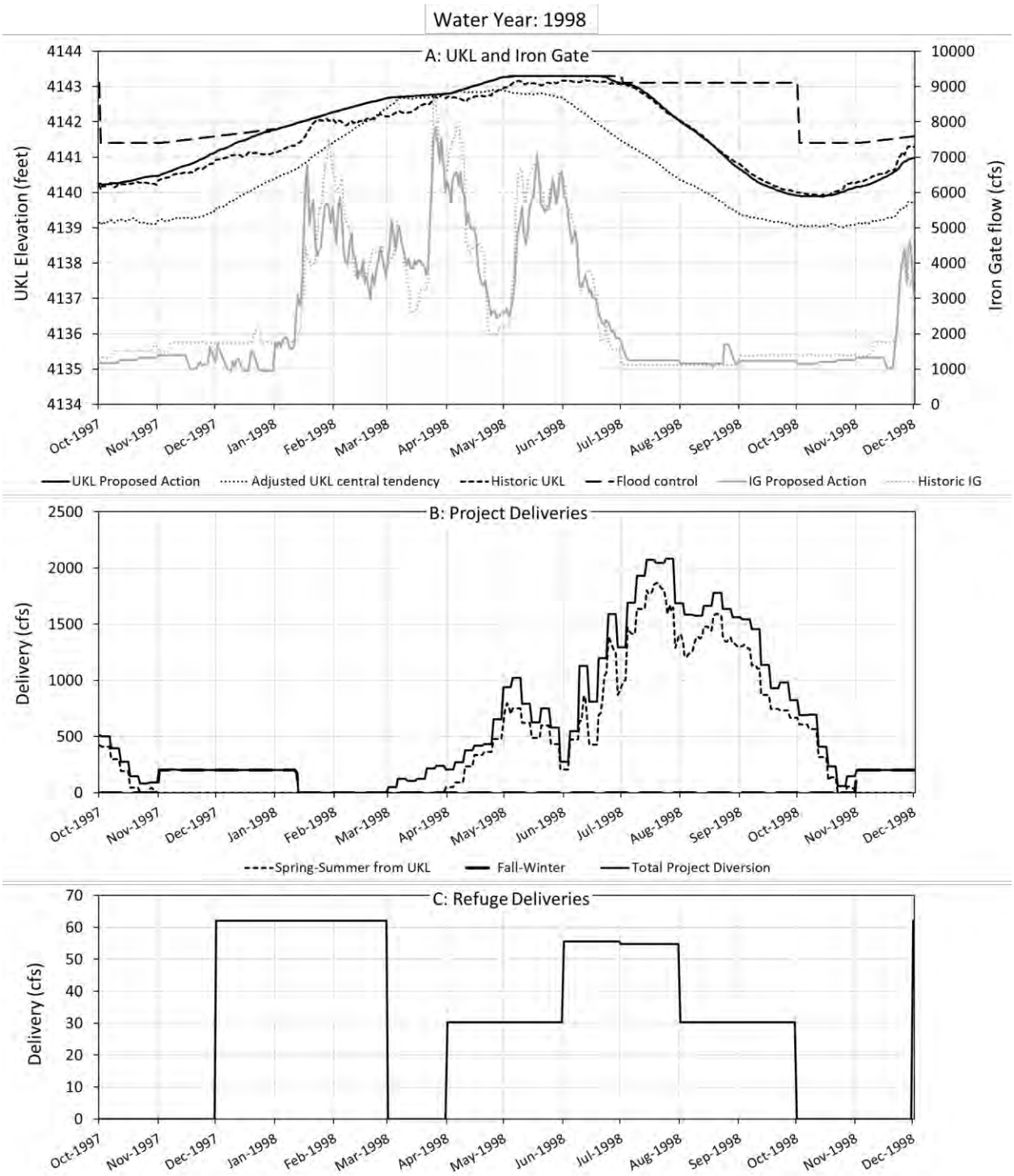


Figure B18. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1998.

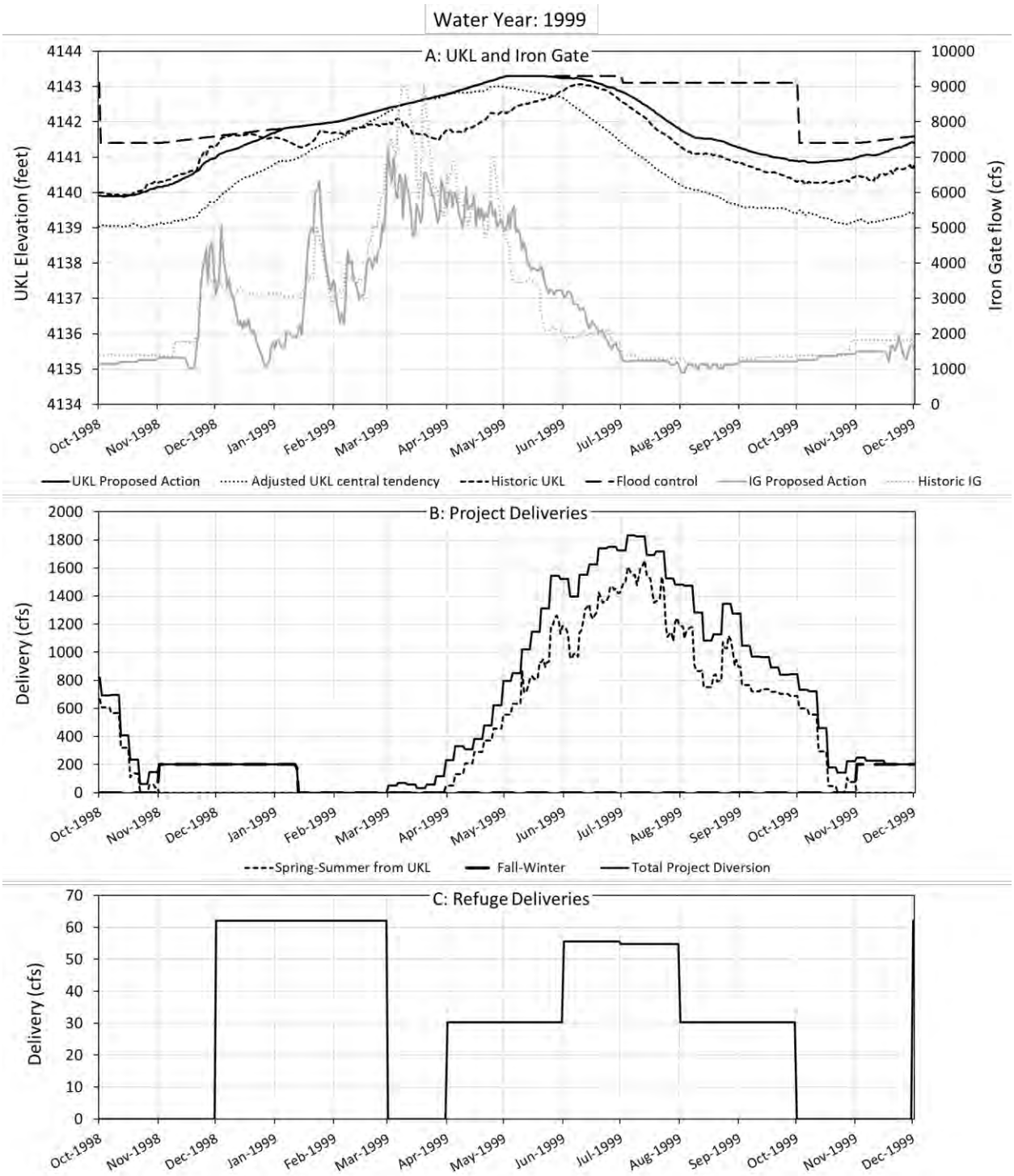


Figure B19. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 1999.

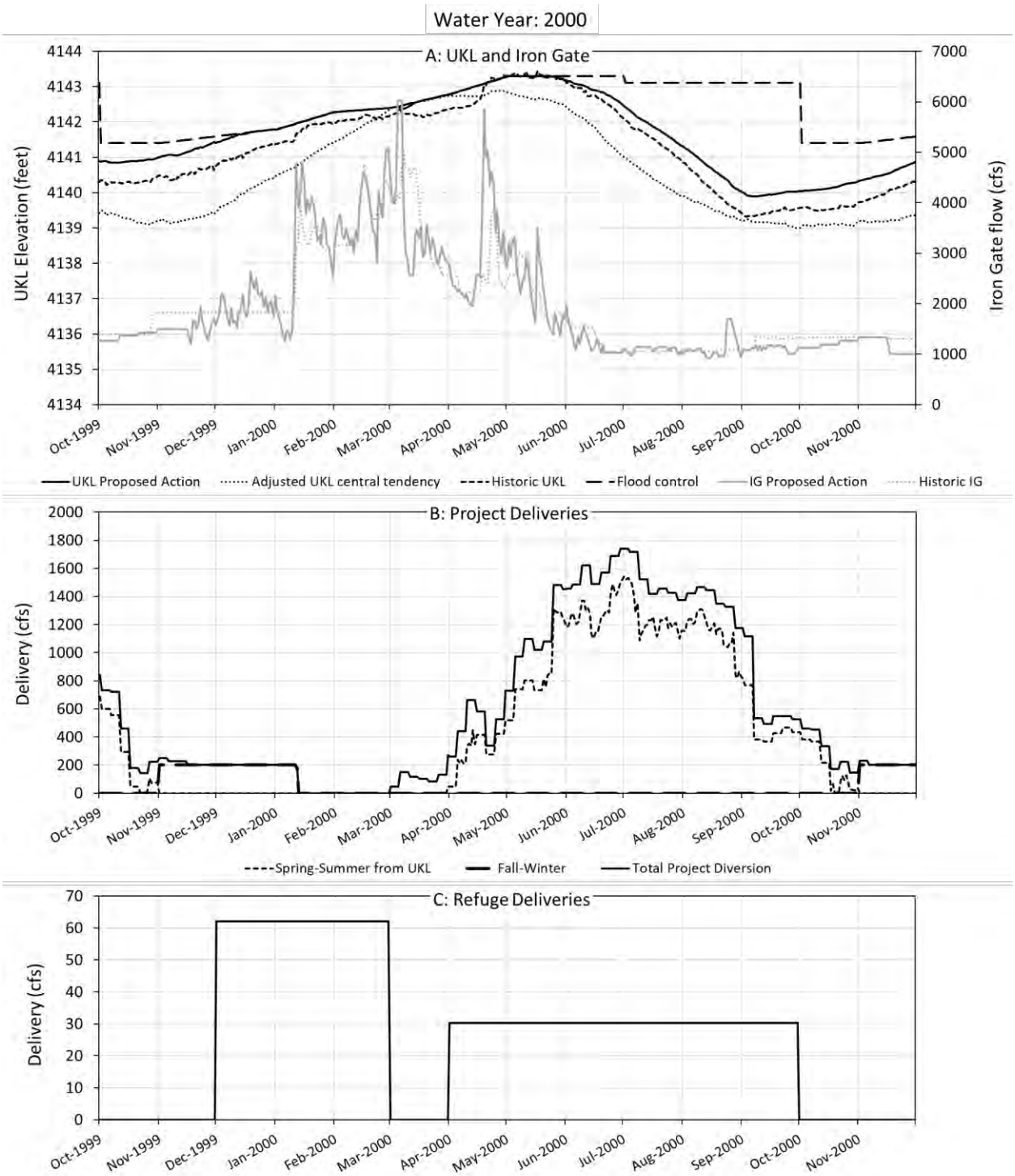


Figure B20. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2000.

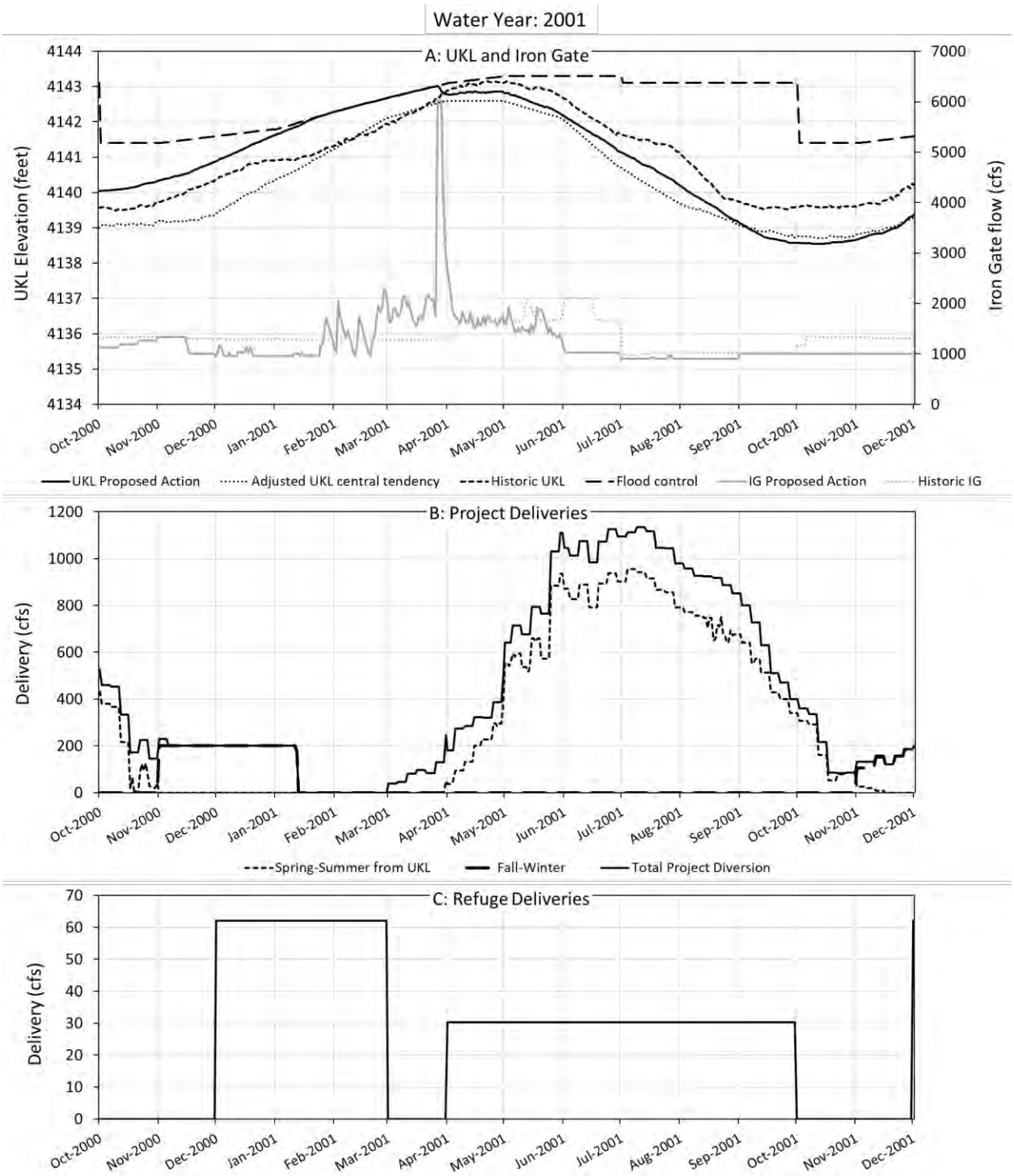


Figure B21. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2001.

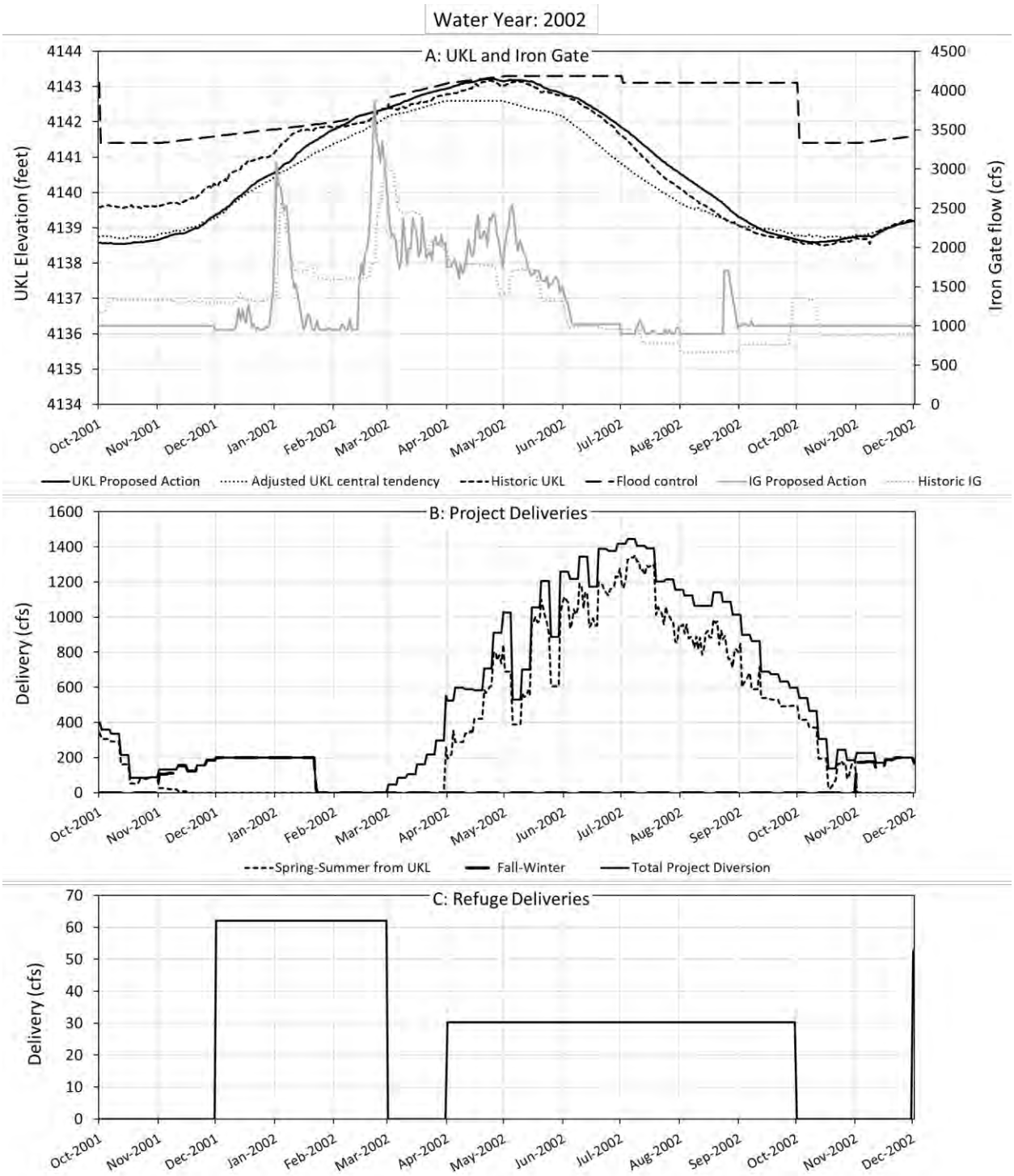


Figure B22. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2002.

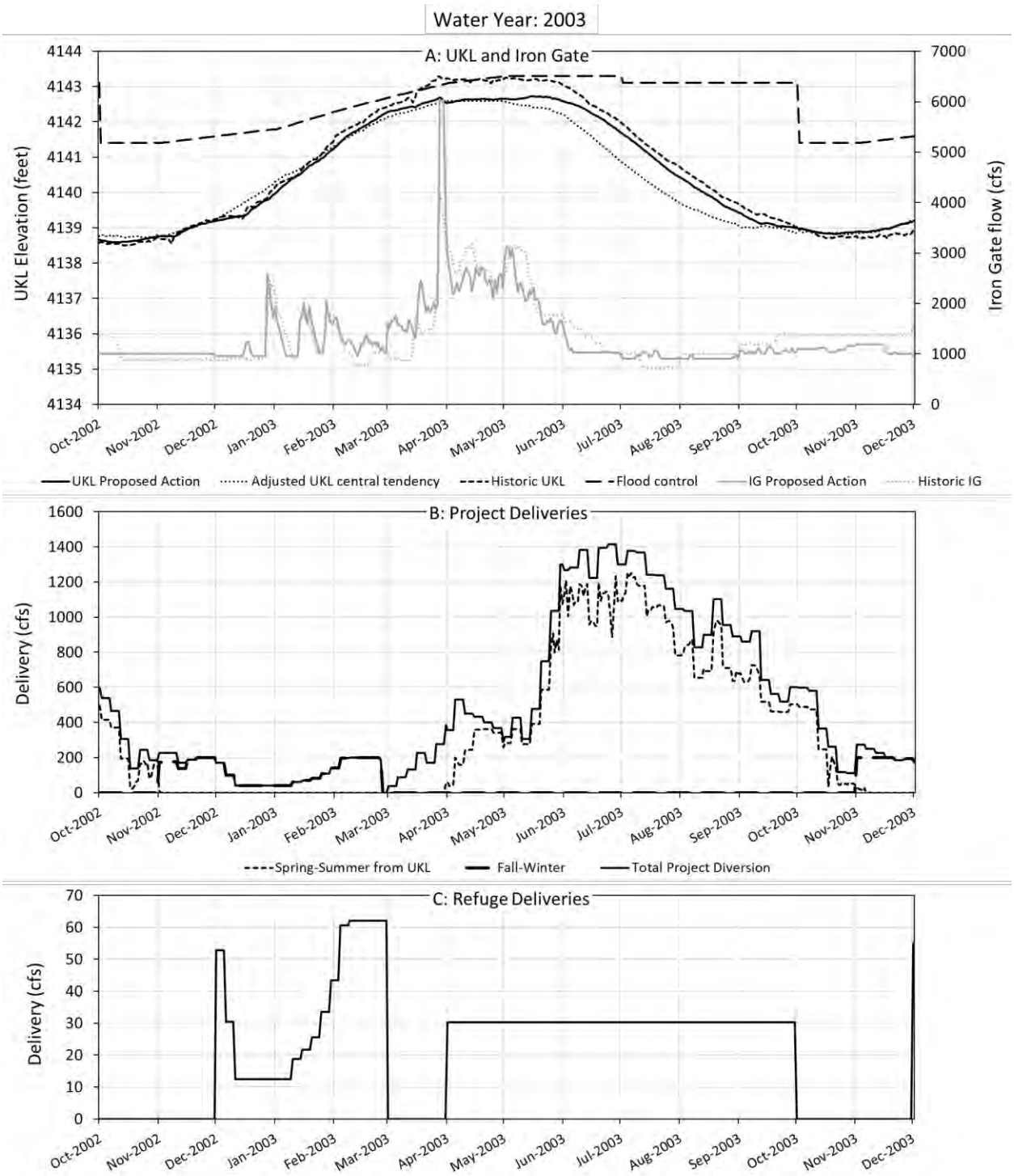


Figure B23. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2003.

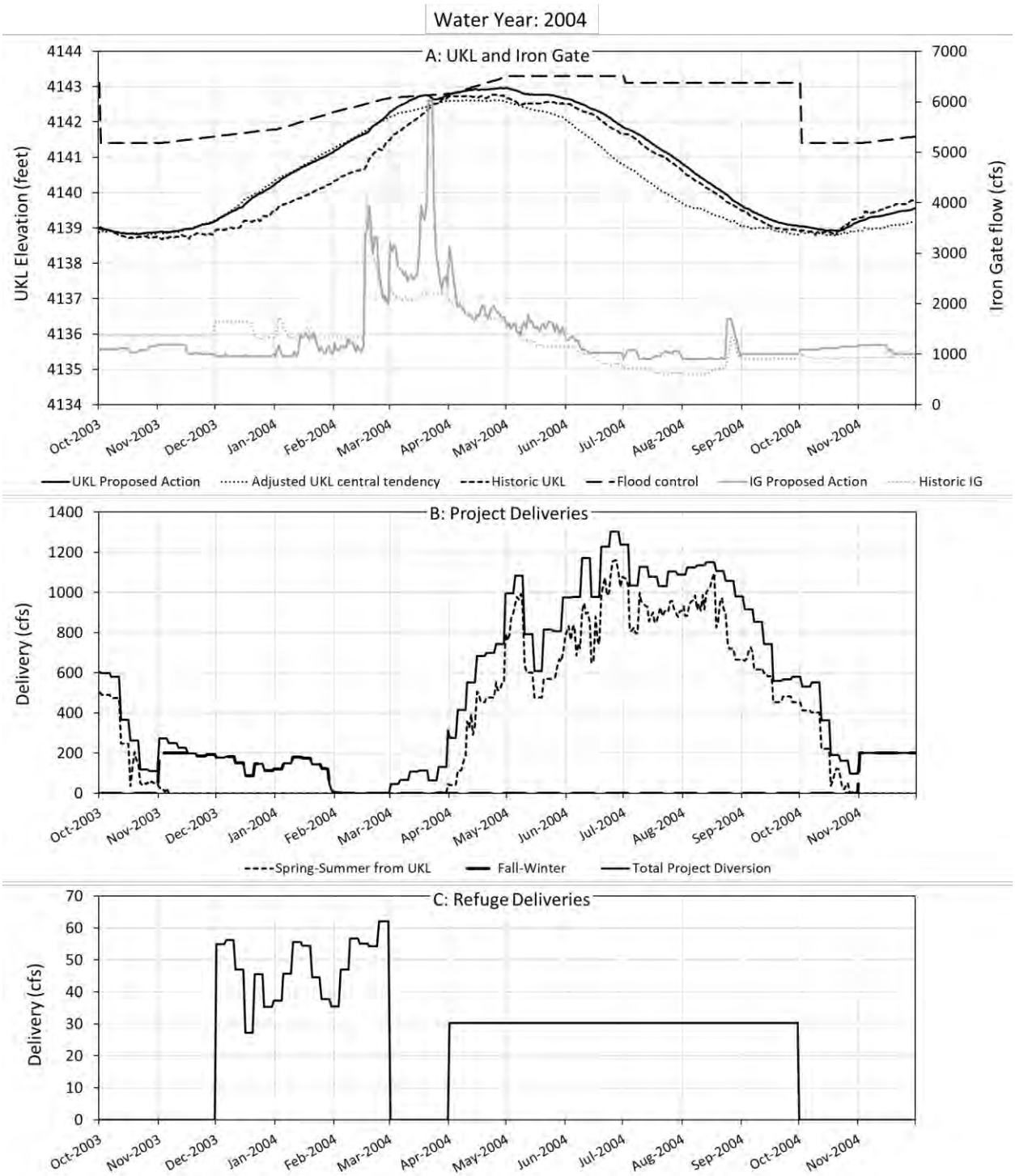


Figure B24. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2004.

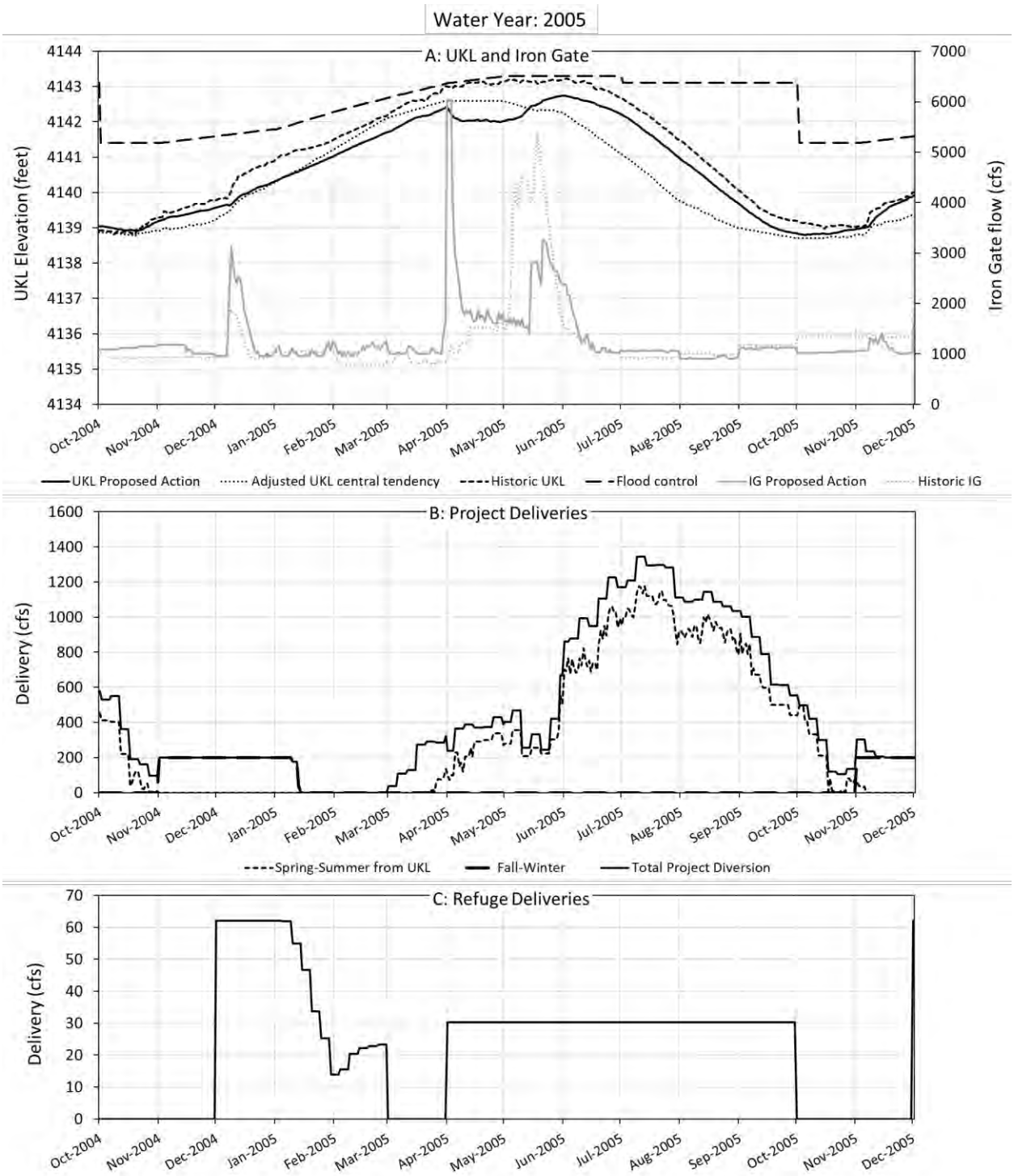


Figure B25. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2005.

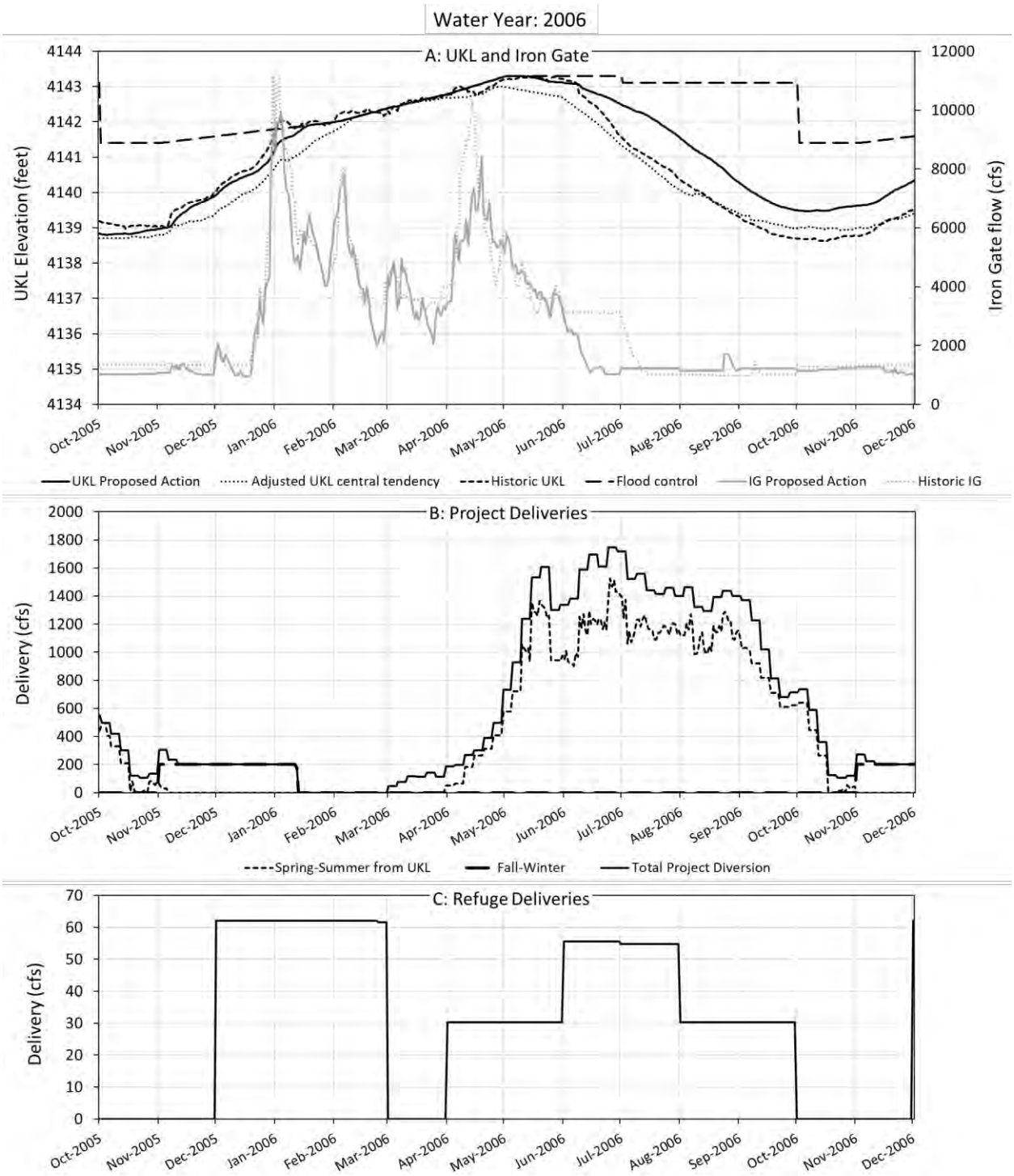


Figure B26. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2006.

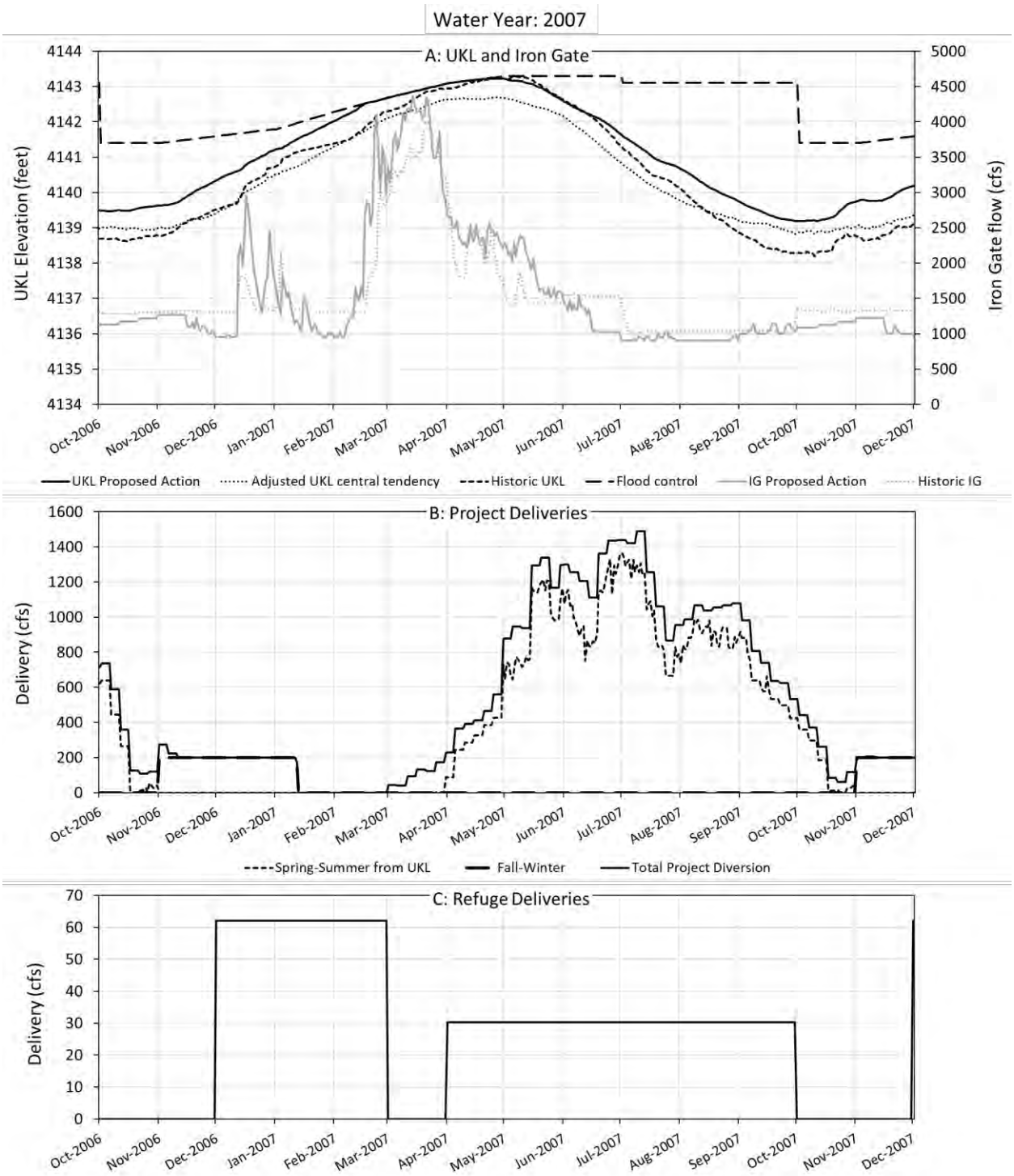


Figure B27. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2007.

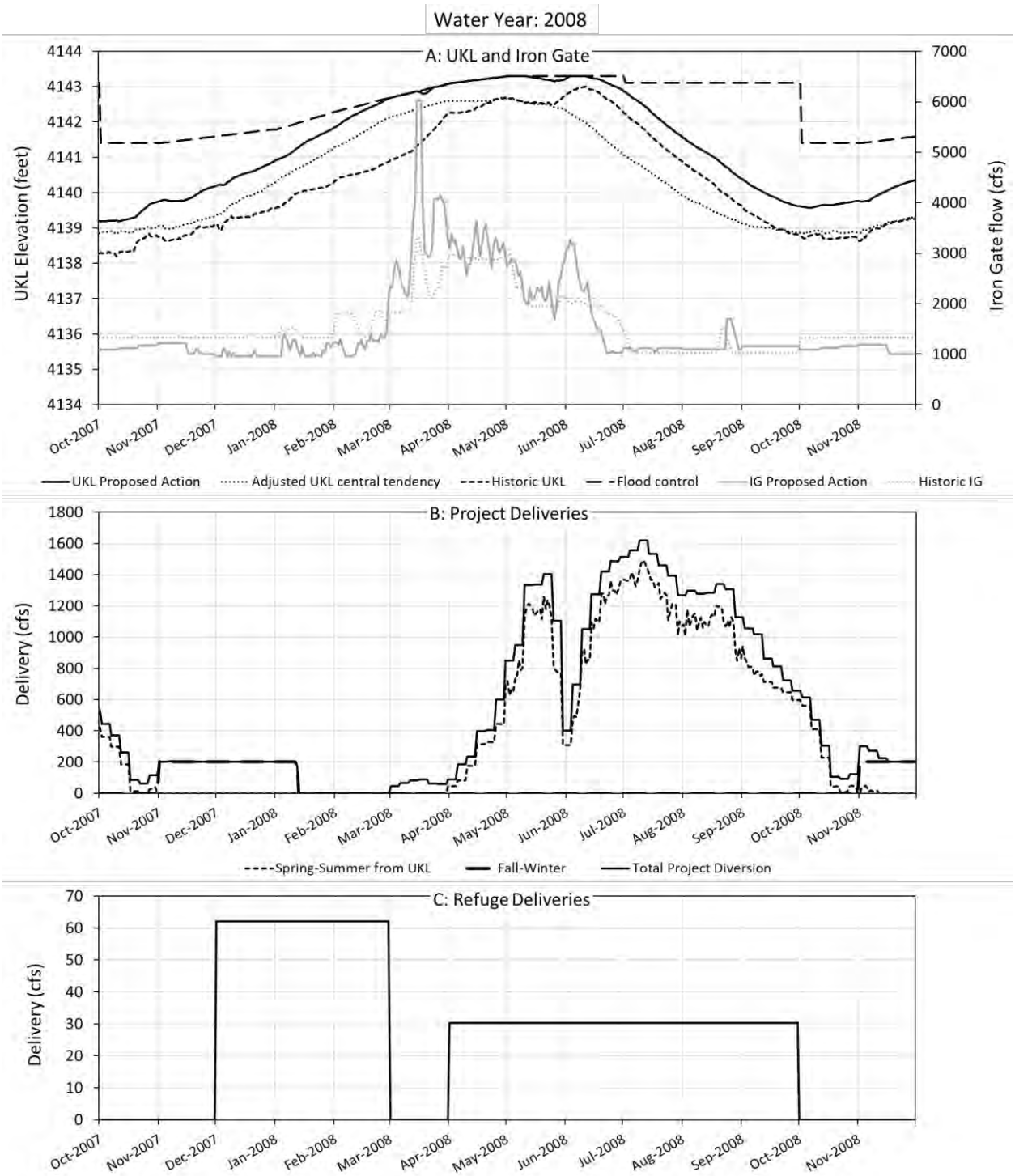


Figure B28. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2008.

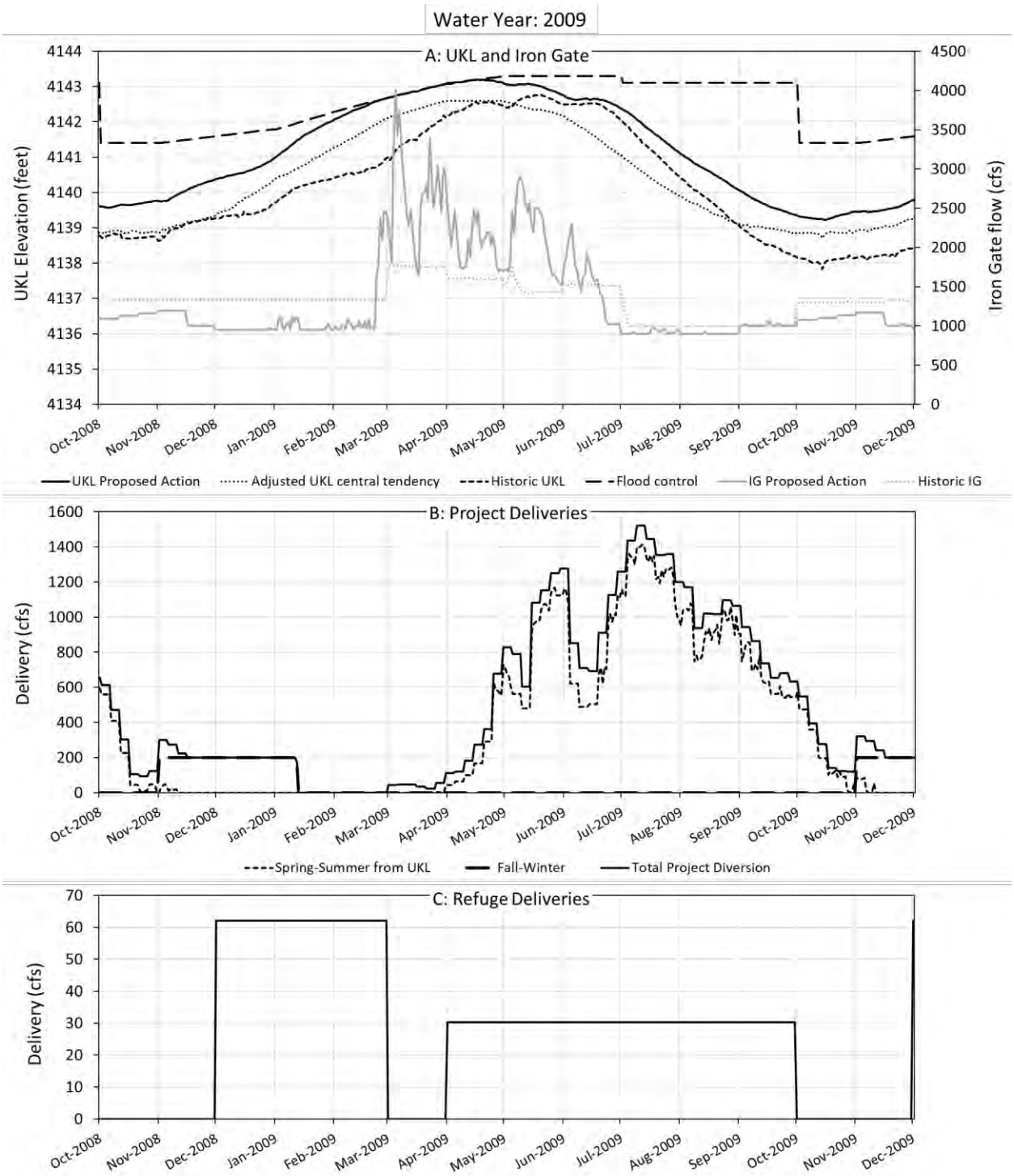


Figure B29. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2009.

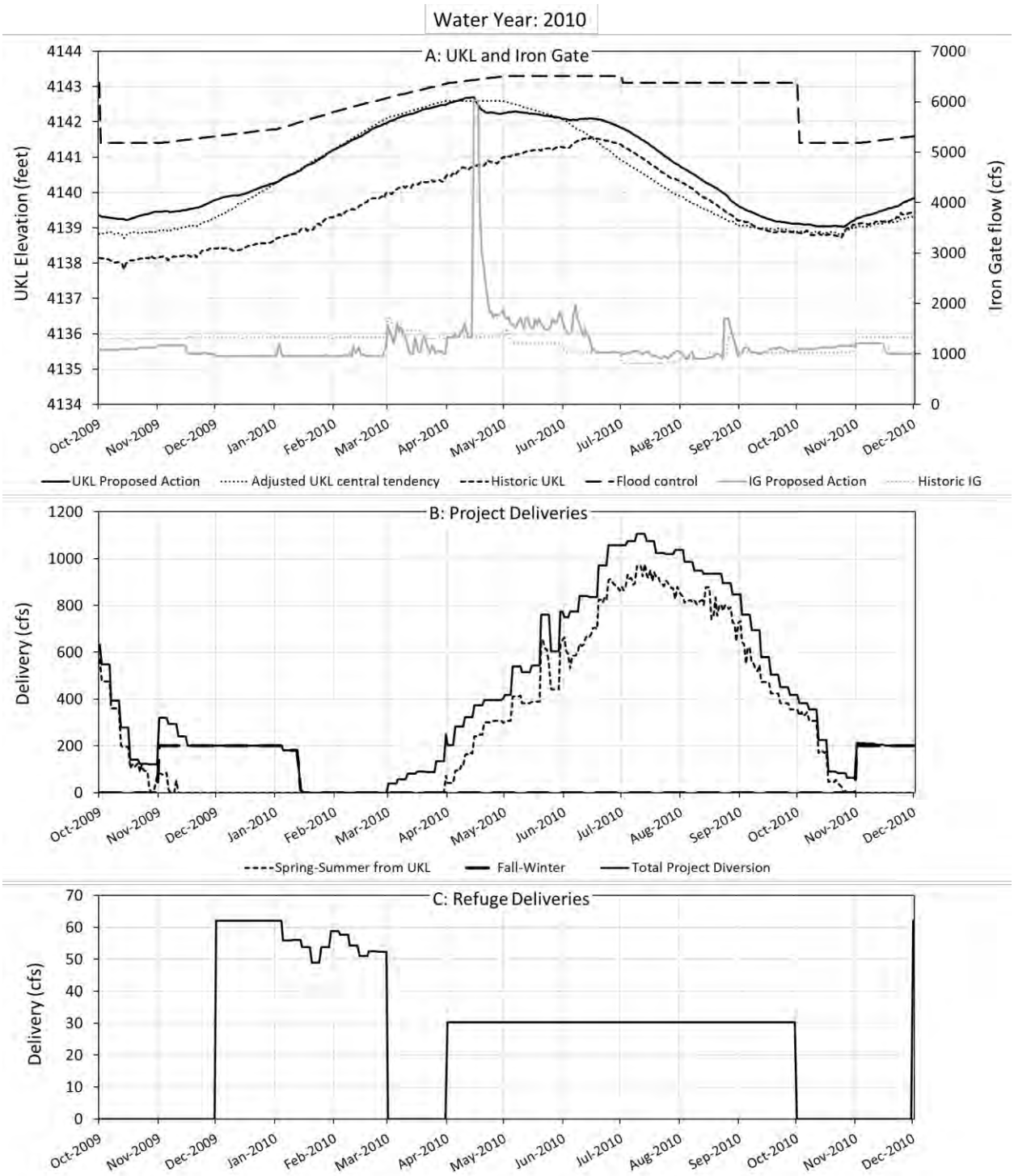


Figure B30. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2010.

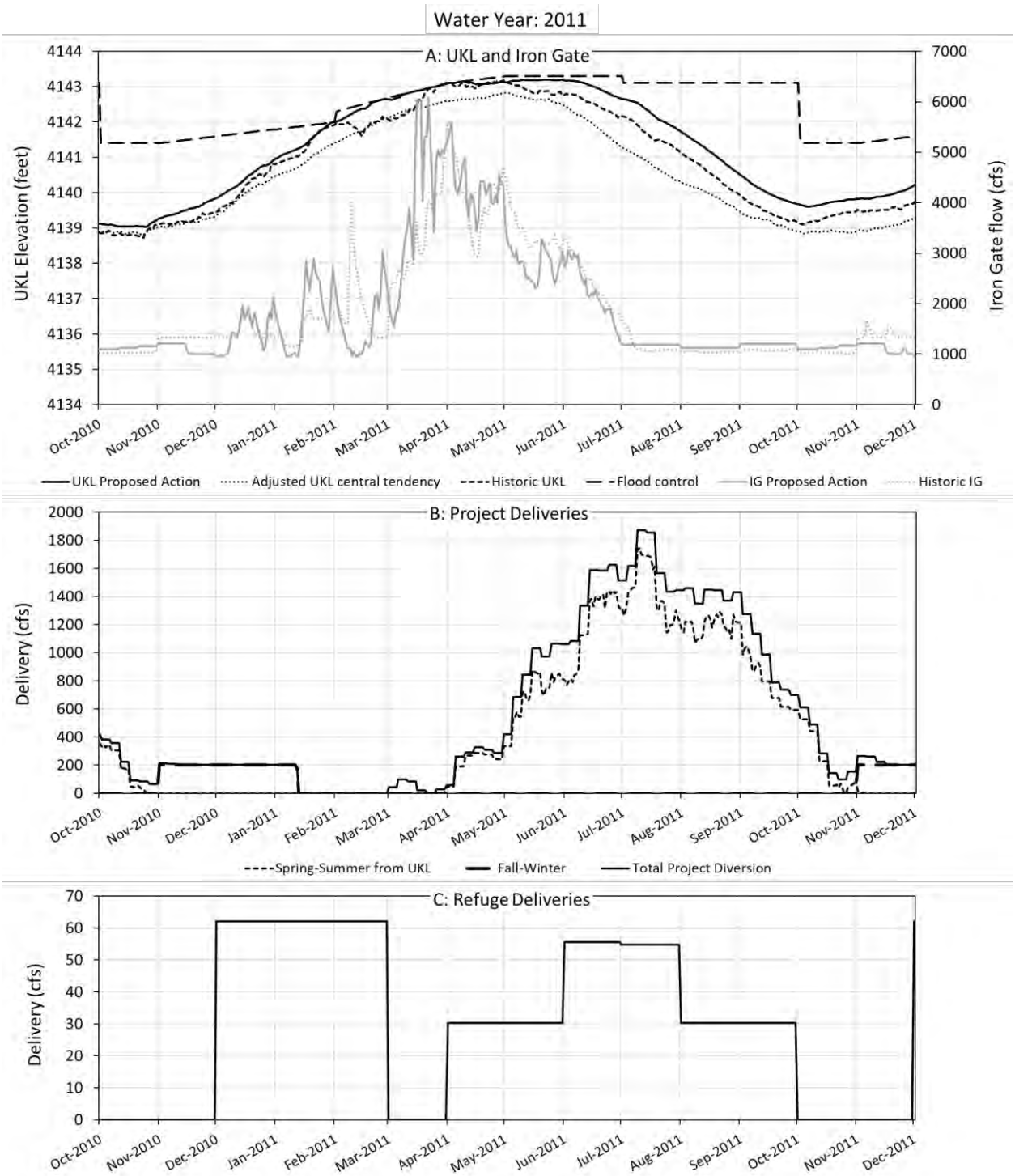


Figure B31. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2011.

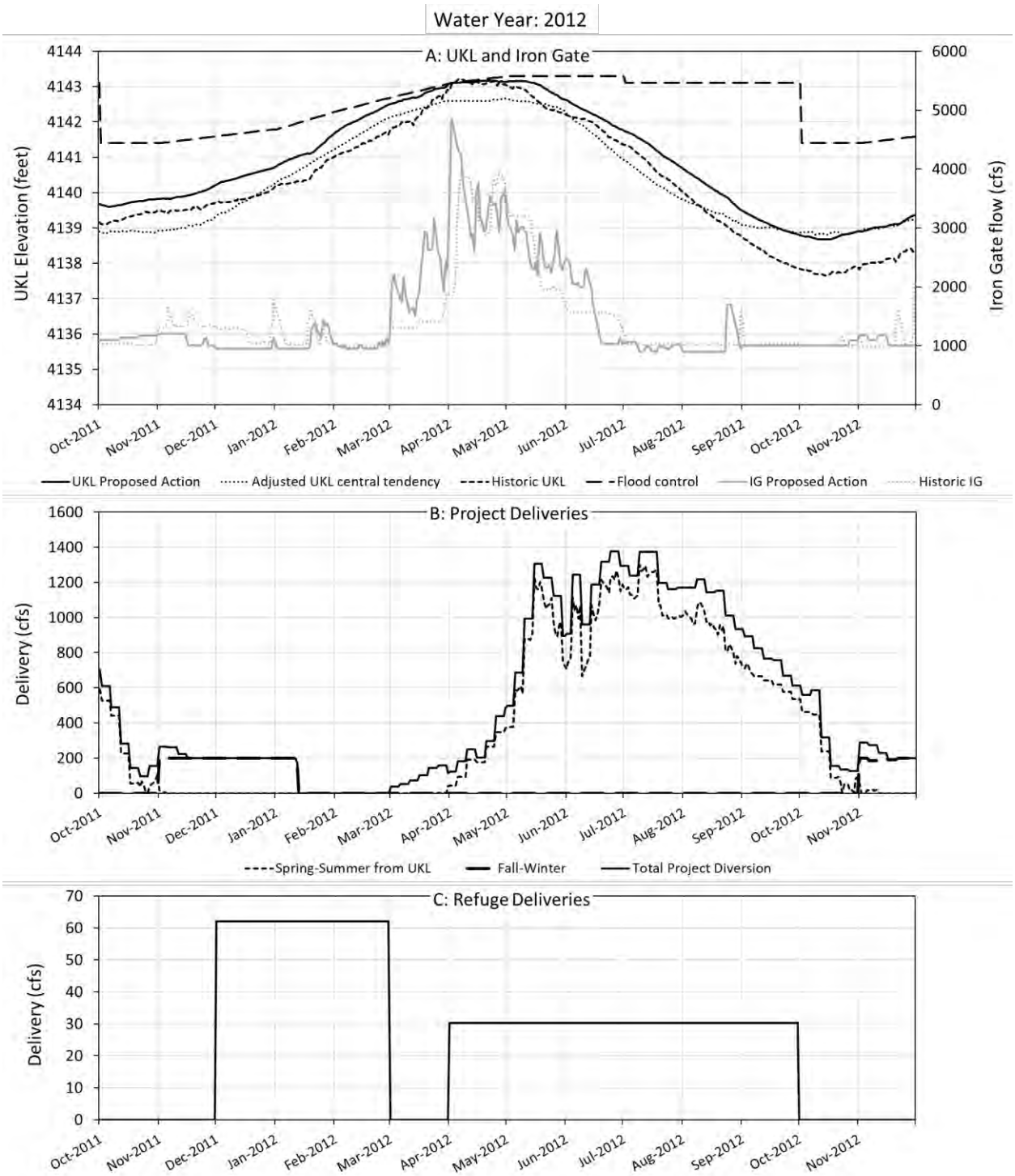


Figure B32. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2012.

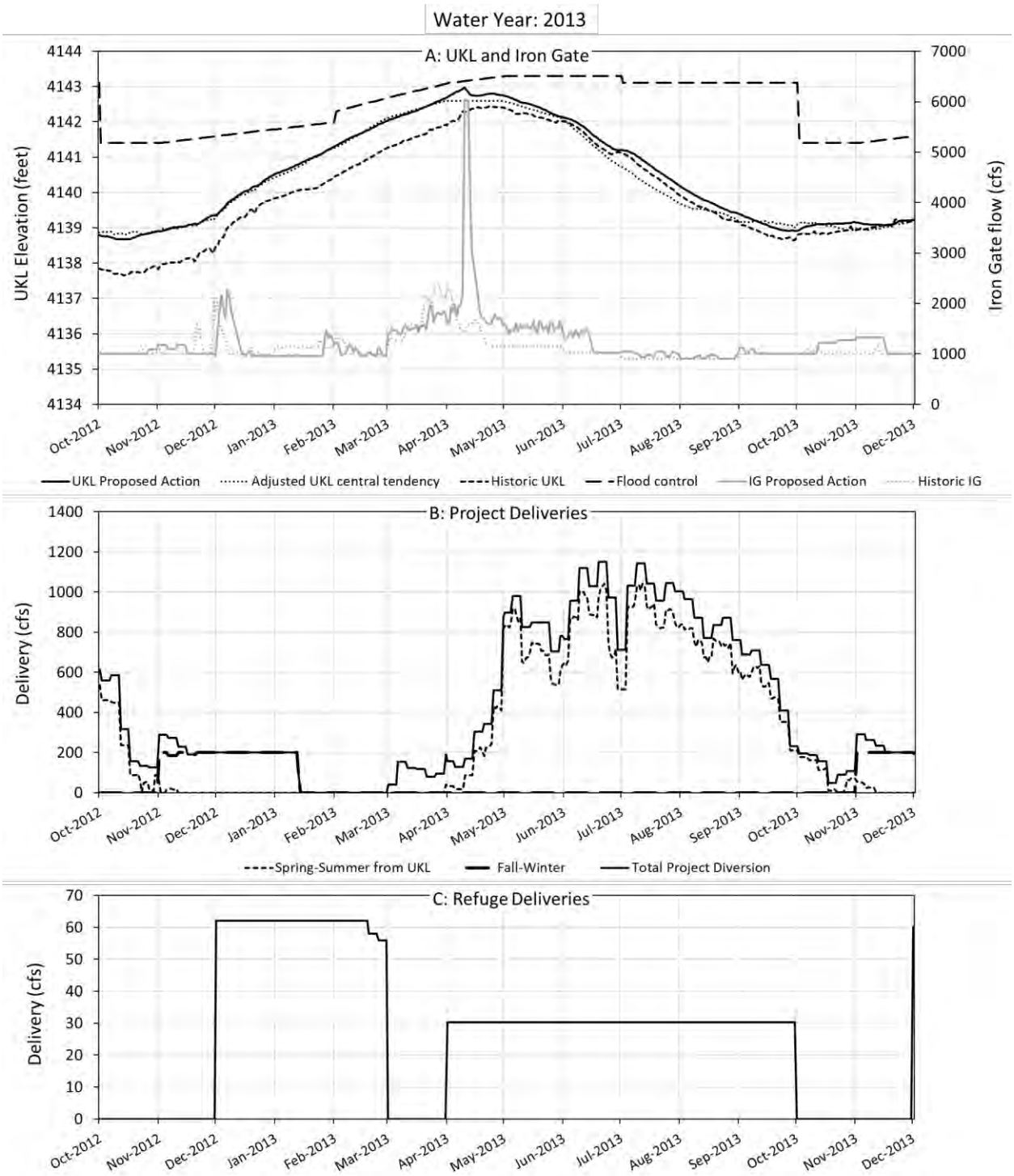


Figure B33. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2013.

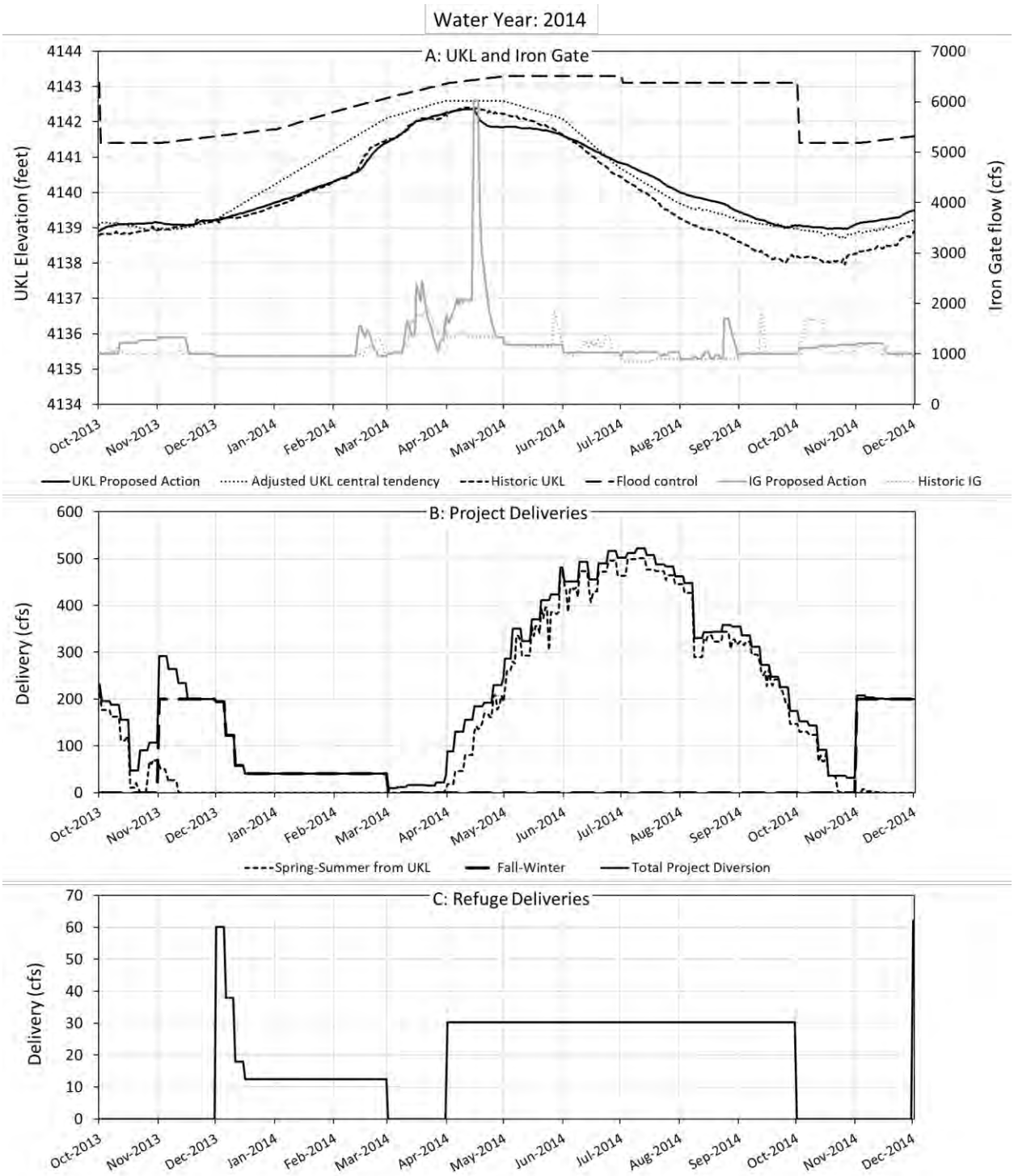


Figure B34. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2014.

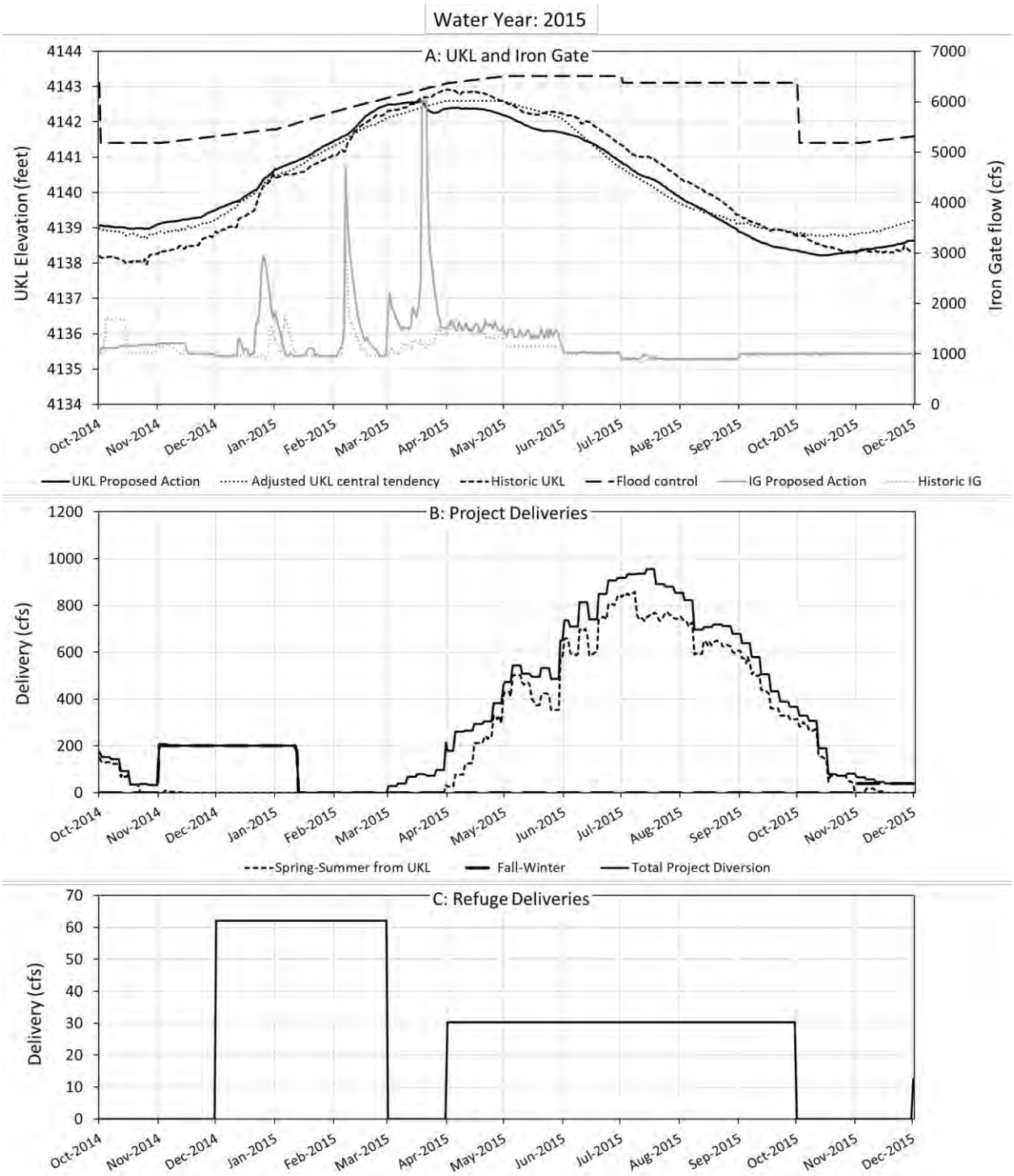


Figure B35. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2015.

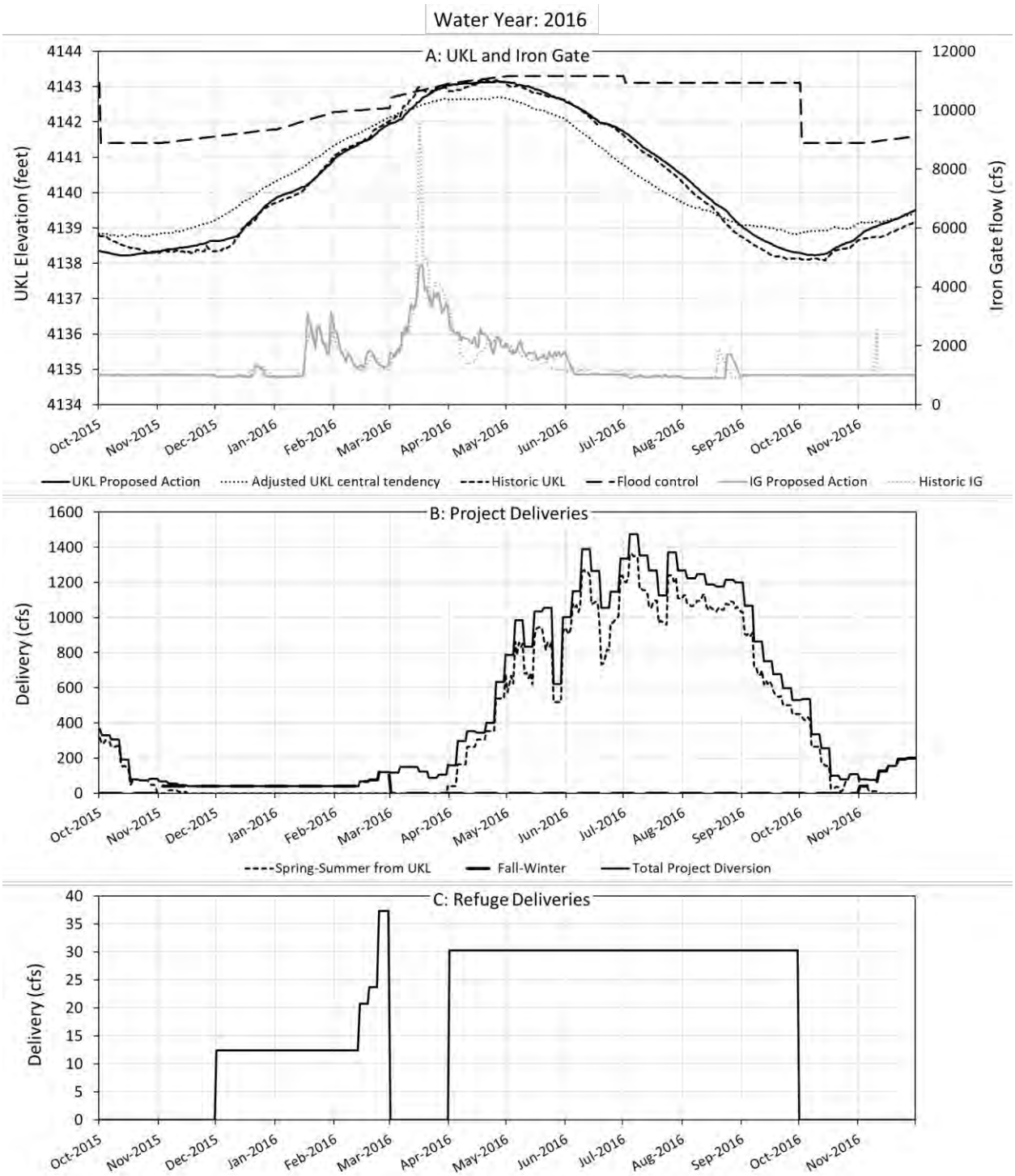


Figure B36. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2016.

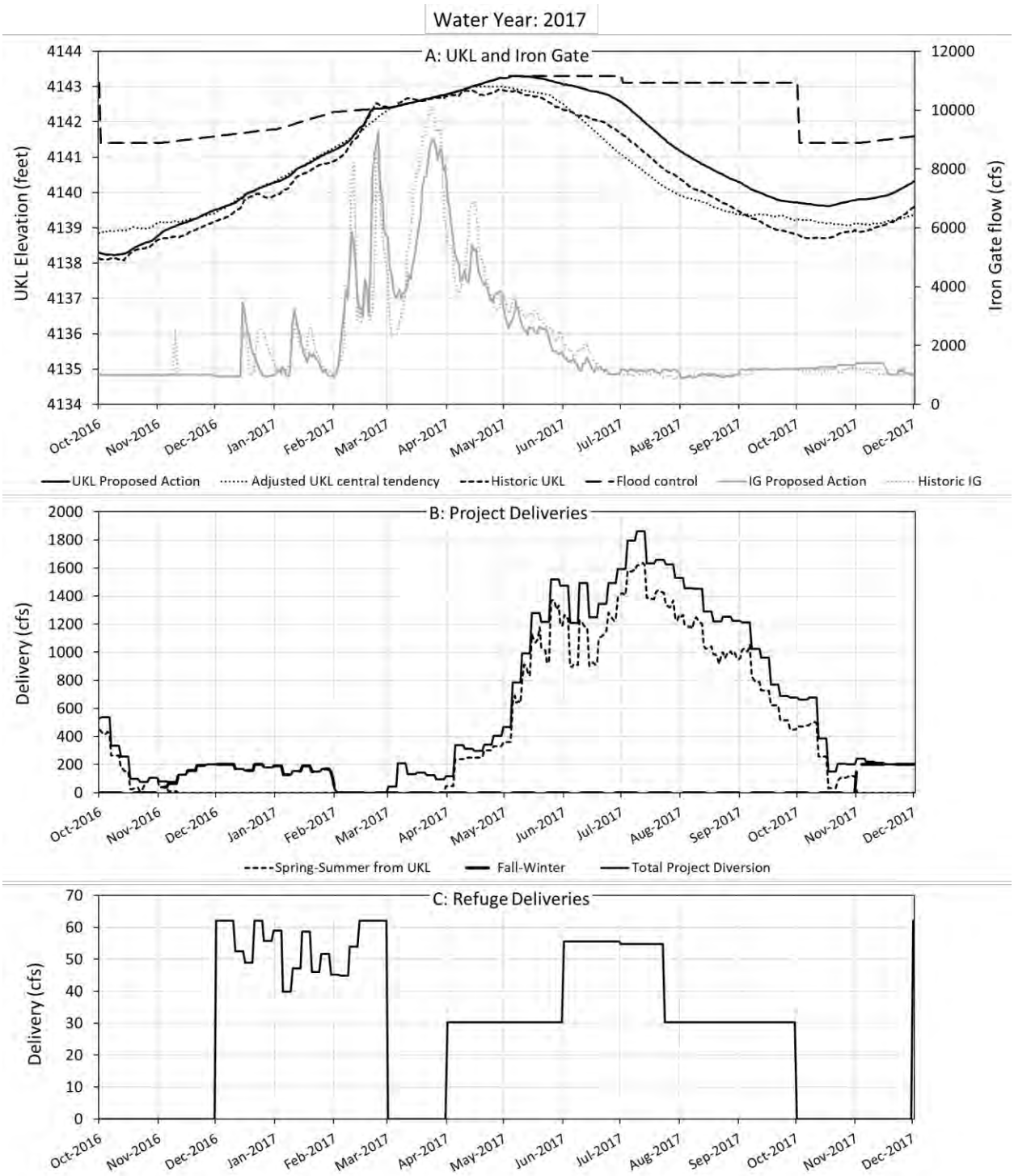


Figure B37. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2017.

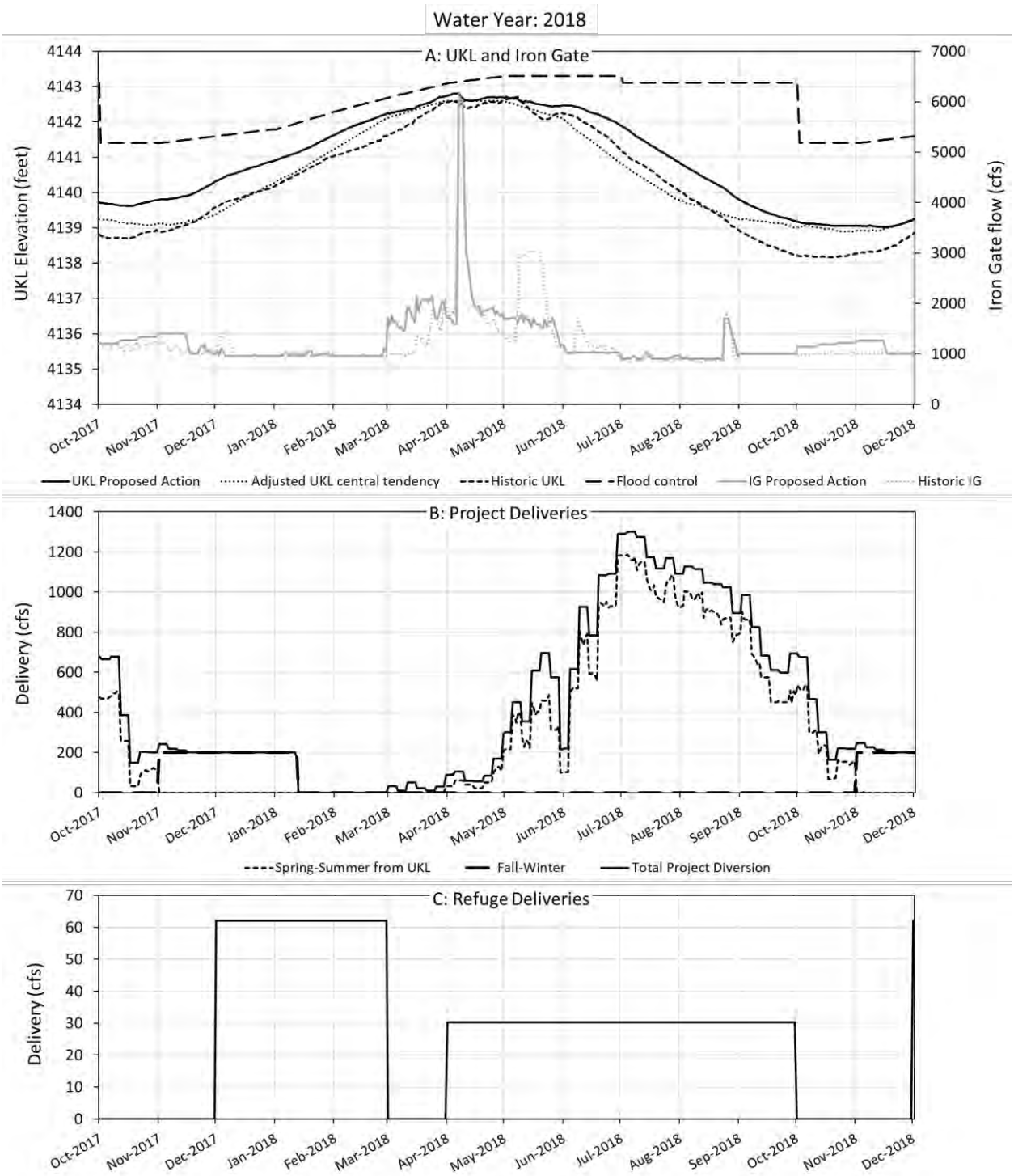


Figure B38. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2018.

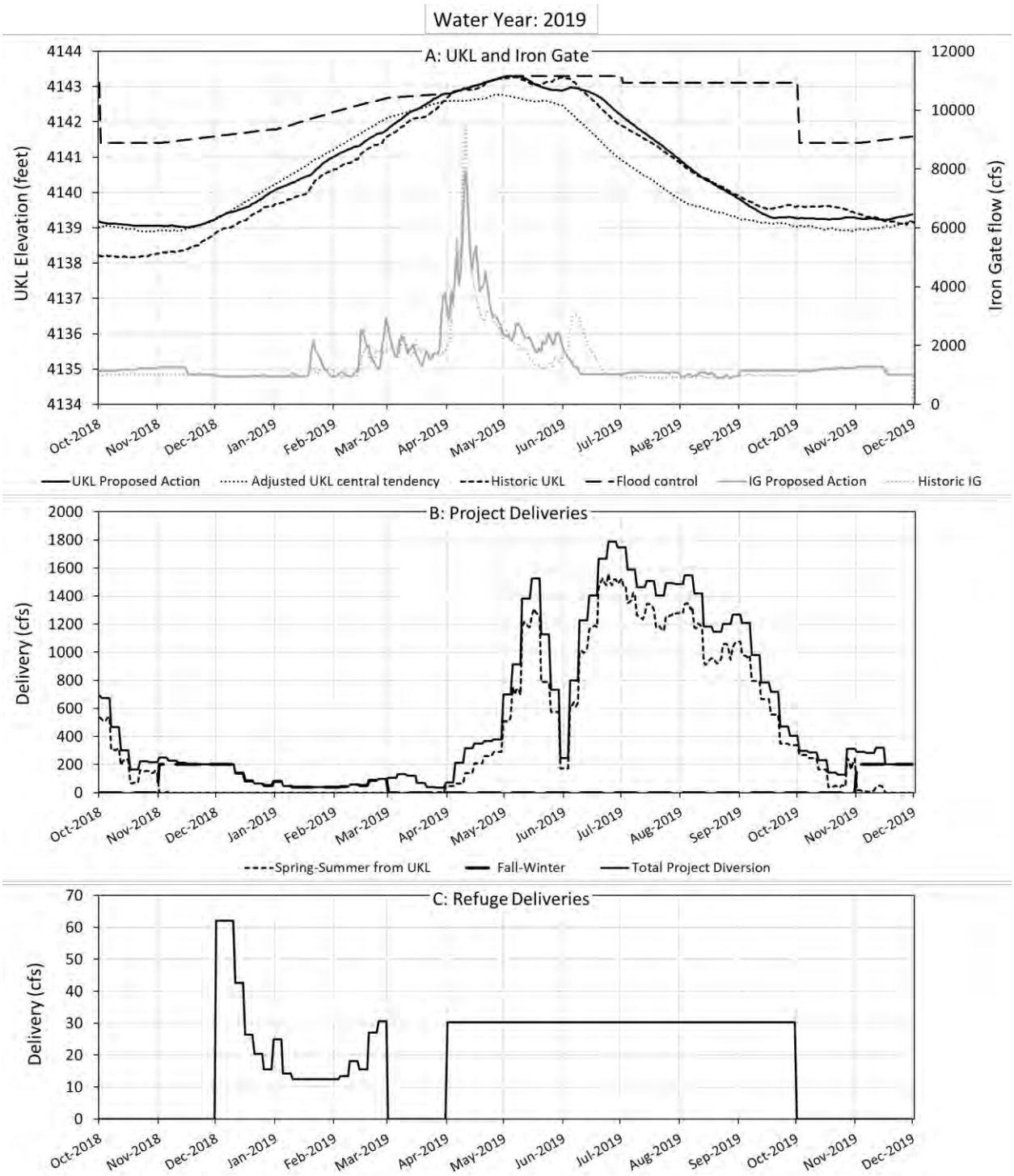


Figure B39. Proposed Action simulation results from the KBPM for Upper Klamath Lake and the Klamath River below Iron Gate Dam (A), Project irrigation diversions (B), and Refuge diversions via the Ady Canal (C) for water year 2019.

Appendix 4 Section C: LKNWR Historical Deliveries

Table C1. Historical Deliveries to Lower Klamath National Wildlife Refuge (LKNWR).

Water Year	Ady Canal Deliveries to LKNWR	D Plant Deliveries to LKNWR	Total Deliveries to LKNWR
1981	26.1	67.7	93.8
1982	10.1	120.4	130.4
1983	9.8	111.5	121.4
1984	10.4	119.9	130.3
1985	21.1	102.6	123.6
1986	20.9	103.6	124.6
1987	18.7	95.6	114.2
1988	17.2	93.8	110.9
1989	24.2	100.5	124.7
1990	22.7	95.7	118.4
1991	32.2	76.6	108.8
1992	14.7	41.0	55.6
1993	30.8	88.9	119.7
1994	35.5	49.9	85.4
1995	24.1	86.1	110.3
1996	32.7	115.4	148.0
1997	22.8	85.7	108.5
1998	21.0	97.2	118.2
1999	14.9	113.1	128.0
2000	20.9	79.5	100.3
2001	19.3	23.8	43.1
2002	38.4	77.3	115.7
2003	21.0	61.5	82.4
2004	46.2	51.3	97.5
2005	33.7	65.7	99.4
2006	23.2	112.3	135.5
2007	44.2	32.3	76.4
2008	27.2	54.9	82.0
2009	46.3	33.6	79.9
2010	6.6	10.0	16.6
2011	47.8	20.1	67.9
2012	38.0	14.5	52.5
2013	18.3	24.8	43.1
2014	7.0	12.4	19.4
2015	4.7	13.7	18.4
2016	24.4	22.1	46.5
2017	33.4	32.8	66.2
2018	25.5	16.2	41.6
2019	25.3	30.1	55.4
Average 1981-2019	24.6	65.5	90.1

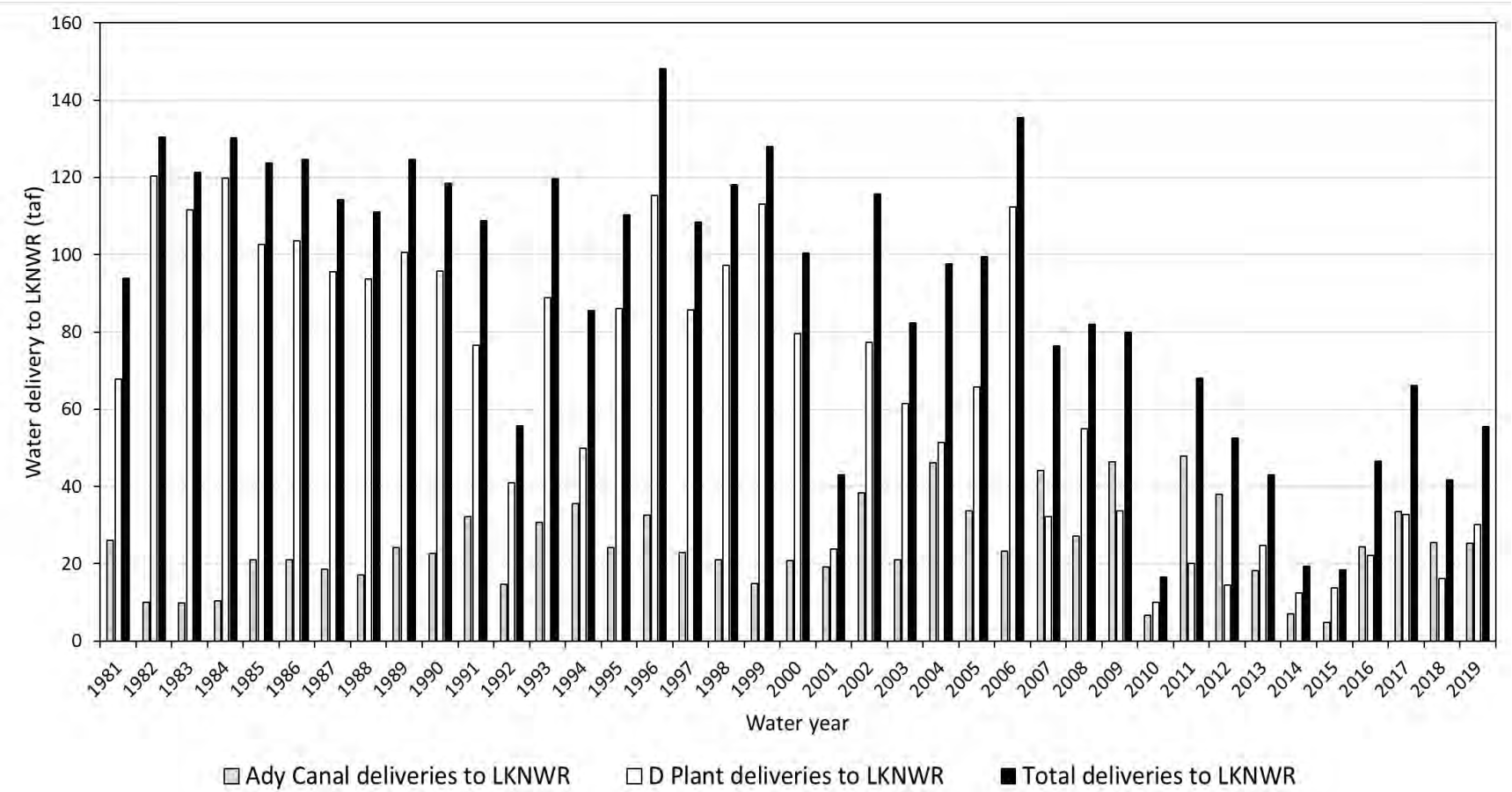


Figure C1. Historical deliveries to LKNWR by water year for the 39-year period of record (WY 1981-2019) considered in the Proposed Action. Deliveries are graphed as those delivered through Ady Canal (i.e. direct diversion from the Klamath River), D Plant pumping (i.e. deliveries made from Tule Lake Sumps), and total delivery through both delivery arcs.

Appendix 4 Section D: Clear Lake Reservoir and Gerber Reservoir Water Supply Forecast Models

Table D1. Clear Lake Reservoir Operational Forecast Model. Example of the Clear Lake Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4,531.01	228,000	21,640	5	328	125	228,000	21,640	4,531.01
2-May	4,531.00	227,780	21,640	5	328	125	227,780	21,640	4,531.00
3-May	4,530.99	227,560	21,600	5	327	125	227,560	21,600	4,530.99
4-May	4,530.98	227,350	21,600	5	327	125	227,350	21,600	4,530.98
5-May	4,530.97	227,130	21,600	5	327	125	227,130	21,600	4,530.97
6-May	4,530.95	226,700	21,600	5	327	125	226,700	21,600	4,530.95
7-May	4,530.94	226,480	21,600	5	327	165	226,480	21,600	4,530.94
8-May	4,530.92	226,050	21,600	5	327	165	226,050	21,600	4,530.92
9-May	4,530.90	225,620	21,600	5	327	188	225,620	21,600	4,530.90
10-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
11-May	4,530.86	224,760	21,560	5	327	188	224,760	21,560	4,530.86
12-May	4,530.82	223,900	21,560	5	327	377	223,900	21,560	4,530.82
13-May	4,530.79	223,260	21,510	5	326	377	223,260	21,510	4,530.79
14-May	4,530.77	222,820	21,510	5	326	377	222,820	21,510	4,530.77
15-May	4,530.73	221,960	21,510	5	326	377	221,960	21,510	4,530.73
16-May	4,530.69	221,110	21,460	5	325	377	221,110	21,460	4,530.69
17-May	4,530.67	220,680	21,460	5	325	377	220,680	21,460	4,530.67
18-May	4,530.65	220,250	21,460	5	325	377	220,250	21,460	4,530.65
19-May	4,530.62	219,610	21,460	5	325	377	219,610	21,460	4,530.62
20-May	4,530.60	219,180	21,460	5	325	377	219,180	21,460	4,530.60

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
21-May	4,530.57	218,540	21,420	5	325	377	218,540	21,420	4,530.57
22-May	4,530.54	217,900	21,420	5	325	377	217,900	21,420	4,530.54
23-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
24-May	4,530.51	217,250	21,420	5	325	377	217,250	21,420	4,530.51
25-May	4,530.53	217,680	21,420	5	325	198	217,680	21,420	4,530.53
26-May	4,530.58	218,750	21,420	5	325	0	218,750	21,420	4,530.58
27-May	4,530.60	219,180	21,460	5	325	0	219,180	21,460	4,530.60

Table D2. Gerber Reservoir Operational Forecast Model. Example of the Gerber Reservoir operational forecast model from May 2018.

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
1-May	4832.89	84,833	3,538	38	54	71	84,833	3,538	4,832.89
2-May	4832.86	84,722	3,535	75	66	71	84,722	3,535	4,832.86
3-May	4832.84	84,648	3,533	75	66	71	84,648	3,533	4,832.84
4-May	4832.81	84,537	3,531	75	66	95	84,537	3,531	4,832.81
5-May	4832.78	84,426	3,528	75	66	143	84,426	3,528	4,832.78
6-May	4832.74	84,278	3,524	75	66	143	84,278	3,524	4,832.74
7-May	4832.68	84,056	3,519	75	66	214	84,056	3,519	4,832.68
8-May	4832.61	83,797	3,512	75	66	214	83,797	3,512	4,832.61
9-May	4832.55	83,575	3,507	75	66	214	83,575	3,507	4,832.55
10-May	4832.48	83,318	3,500	75	65	214	83,318	3,500	4,832.48
11-May	4832.4	83,030	3,493	75	65	214	83,030	3,493	4,832.40
12-May	4832.32	82,734	3,486	75	65	226	82,734	3,486	4,832.32
13-May	4832.24	82,444	3,478	75	65	226	82,444	3,478	4,832.24
14-May	4832.17	82,189	3,472	75	65	262	82,189	3,472	4,832.17
15-May	4832.09	81,894	3,464	75	65	262	81,894	3,464	4,832.09
16-May	4832.01	81,606	3,457	75	65	262	81,606	3,457	4,832.01
17-May	4831.95	81,385	3,451	75	65	262	81,385	3,451	4,831.95

Date	Actual Elevation (Feet)	Actual Volume (Acre-Feet)	Actual Area (Acres)	Projected Inflow (Acre-Feet)	Projected Evaporation and Seepage (Acre-Feet)	Releases (Acre-Feet)	Modeled Volume (Acre-Feet)	Modeled Area (Acres)	Modeled Elevation (Feet)
18-May	4831.88	81,128	3,445	75	64	262	81,128	3,445	4,831.88
19-May	4831.79	80,804	3,437	75	64	262	80,804	3,437	4,831.79
20-May	4831.72	80,552	3,430	75	64	262	80,552	3,430	4,831.72
21-May	4831.64	80,264	3,423	75	64	262	80,264	3,423	4,831.64
22-May	4831.57	80,012	3,416	75	64	262	80,012	3,416	4,831.57
23-May	4831.49	79,724	3,409	75	64	262	79,724	3,409	4,831.49
24-May	4831.43	79,508	3,403	75	64	262	79,508	3,403	4,831.43
25-May	4831.44	79,544	3,404	75	64	139	79,544	3,404	4,831.44
26-May	4831.5	79,760	3,410	75	64	0	79,760	3,410	4,831.50
27-May	4831.52	79,832	3,412	75	64	0	79,832	3,412	4,831.52

Appendix 4 Section E: Re-scaling NRCS forecasts of net inflow into Upper Klamath Lake

Technical Memorandum

To: Bureau of Reclamation, Klamath Basin Area Office

U.S. Fish and Wildlife Service, Klamath Falls Fish and Wildlife Office

National Marine Fisheries Service, Klamath Branch Office

From: Tri-Agency Hydro Team

Date: March 29, 2019

Re: Re-scaling NRCS forecasts of net inflow into Upper Klamath Lake

Forecasts of net inflow into Upper Klamath Lake (UKL) made by the Natural Resources Conservation Service (NRCS) have for decades been integral components of planning models used to develop Proposed Actions upon which subsequent Biological Opinions were based. Because NRCS forecasting models had changed over the course of the 30-year period-of-record being simulated in the 2013 Proposed Action (which was the basis for the 2013 Biological Opinion), and many revisions had been made to correct data sets used to compute UKL net inflow, modern NRCS forecasting models were used to re-construct UKL net inflow forecasts over the prior 30 years. Using such re-constructed forecasts made simulations of water management decision structures over the previous 30 years more relevant to evaluating likely outcomes of implementing those decision structures in the future. Further, subsequent NRCS forecasts of UKL net inflow were calibrated to the revised UKL net inflow time series that emerged from the 2013 Proposed Action development.

As the 2018 Proposed Action was developed, multiple adjustments to data sets (including significant changes to the elevation-capacity curve in UKL) were made that changed the time series of UKL net inflow over the 1981-2016 period-of-record considered in the Proposed Action (Dunsmoor 2017a; Reclamation 2018a). As was done in the 2013 Proposed Action, NRCS staff re-constructed the past UKL net inflow forecast time series using the current NRCS forecast models and the revised UKL net inflow time series. The Klamath Basin Planning Model (KBPM) used to develop the 2018 Proposed Action used these re-constructed UKL net inflow forecasts.

Agencies developing the 2018 Proposed Action intended that NRCS would begin issuing its published forecasts based on the revised UKL net inflow time series when implementation of the 2019 Biological Opinion began. For a variety of reasons not pertinent to this Technical Memorandum, the shift by NRCS to forecasts based on the revised UKL net inflow time series will not be made until 2020. As a result, in order for operations in 2019 to be consistent with the 2018 Proposed Action, it is necessary to re-scale the published NRCS UKL net inflow forecasts.

Methods and Results

NRCS staff were consulted regarding methods for re-scaling. The recommendation we received from NRCS was to: "…calculate the ratios of new to old long-term average flows for the forecast periods in the April, May, and June forecasts, and then multiply all five NRCS exceedance forecast values by the respective ratio" (D. Garen, personal communication March 28, 2019). We followed this recommendation for the 50% exceedance forecasts, because they are the only forecasts used in the KBPM and in operations.

Seasonal UKL net inflow volume totals corresponding to forecast periods were computed for each year in the time series currently in use by NRCS (old), and for the time series used to develop the 2018 Proposed Action (new). Average inflow volumes were computed for the old and new data sets for each forecast period and were then used to compute the new-to-old inflow ratio, which is equal to the new average volume divided by the old average volume (Table 1).

As described above, two sets of re-constructed forecasts are available: those provided by NRCS in 2012 for the period 1981-2011 (the "old" forecasts), and those provided by NRCS in 2017 for the period 1981-2016 (the "new" forecasts). NRCS confirmed that forecasts published from 2013 to the present were based on the UKL net inflow data coinciding with the old forecasts (D. Garen, personal communication March 28, 2019). We assume that the forecasts published for 2012 were based on UKL net inflow time series pre-dating the revisions made in the 2013 Biological Opinion, and therefore we omit them from this analysis.

New (re-scaled) NRCS forecasts were computed as:

new NRCS forecast = old NRCS forecast * new:old inflow ratio

To facilitate comparisons, new and old forecasts are shown in Table 2, and in Figure 1.

If the Tri-Agency Hydro Team and the action agency (Reclamation) agree with this approach, we assume that the new-to-old inflow ratio will be used to adjust published NRCS forecasts in 2019. New NRCS forecasts would then be used in operations under the Proposed Action. Similarly, we assume that the new NRCS forecasts will be used in extending the KBPM from 2017-2019 as needed for operations under the Proposed Action.

References

Dunsmoor, L. K. 2017. Review and update of Upper Klamath Lake net inflow estimates. Technical Memorandum CRC-2-2017 to the Federal Hydro Team from Confluence Resource Consulting.

Reclamation. 2018. Final Biological Assessment; the effects of the proposed action to operate the Klamath Project from April 1, 2019 through March 31, 2029 on Federally-listed Threatened and Endangered species. US Department of the Interior, Bureau of Reclamation.

Table 1. Total UKL net inflow volume totals currently used by NRCS (old) compared to those used in the 2018 Proposed Action (new). For each forecast period, new-to-old inflow ratio = new average volume / old average volume. Units are thousands of acre-feet (taf).

	Mar-Sep UKL net inflow		Apr-Sep UKL net inflow		May-Sep UKL net inflow		Jun-Sep UKL net inflow	
Year	Old, Current NRCS (taf)	New, 2018 PA (taf)	Old, Current NRCS (taf)	New, 2018 PA (taf)	Old, Current NRCS (taf)	New, 2018 PA (taf)	Old, Current NRCS (taf)	New, 2018 PA (taf)
1981	388.192	366.269	280.529	255.144	184.454	158.283	108.084	83.169
1982	1005.248	994.348	720.958	713.134	478.659	469.252	280.933	268.553
1983	1223.771	1223.989	895.226	892.731	636.813	630.622	402.574	394.127
1984	1140.051	1140.831	838.967	833.091	592.718	584.651	348.882	339.576
1985	787.544	779.262	620.883	605.009	372.326	353.781	252.754	233.984
1986	868.124	850.485	533.452	516.127	358.569	339.752	224.579	203.914
1987	534.085	519.134	367.721	347.7	258.836	238.191	177.754	160.229
1988	418.796	402.542	295.493	274.213	202.027	178.556	134.33	112.181
1989	878.468	868.712	575.993	556.957	325.857	303.263	168.123	144.065
1990	445.474	431.831	312.165	291.051	211.145	189.011	138.258	117.458
1991	352.451	348.45	248.124	233.823	169.848	152.226	94.558	74.95
1992	233.872	222.549	159.353	140.676	91.933	74.117	63.855	54.535
1993	967.766	961.351	678.514	658.232	410.559	386.928	225.991	200.775
1994	273.514	254.346	192.898	167.262	123.14	97.731	73.616	49.222
1995	726.845	712.33	522.883	502.42	354.562	330.507	183.797	160.297
1996	814.589	796.772	587.234	567.528	395.366	371.303	199.609	175.229
1997	662.466	648.847	499.285	481.819	331.112	309.133	198.507	178.468
1998	975.442	960.304	754.542	735.203	567.784	546.326	305.14	282.135
1999	1040.052	1027.319	805.481	794.202	537.294	522.19	310.59	290.786
2000	740.042	723.171	549.918	531.521	344.744	319.195	196.018	171.985
2001	353.859	338.805	241.46	219.271	158.595	134.704	99.547	79.085
2002	457.801	438.677	332.455	310.493	206.319	182.416	114.511	92.86
2003	484.355	474.347	360.99	344.856	232.095	215.15	119.042	102.548
2004	460.484	459.119	308.158	297.454	200.493	189.278	115.228	103.443
2005	463.583	454.378	366.189	350.822	286.986	269.859	109.419	90.874
2006	929.945	917.206	762.148	746.039	471.219	451.306	225.642	203.698
2007	532.933	526.49	354.283	343.457	222.982	209.119	129.565	117.472
2008	620.188	623.985	479.133	472.869	316.876	306.69	171.885	159.047
2009	504.938	507.524	378.393	371.83	285.246	276.087	156.128	144.523
2010	420.246	422.643	326.316	328.453	236.767	234.796	153.673	149.219
2011	813.971	808.304	627.467	614.267	441.907	428.099	264.146	251.488
2012	530.237	566.09	411.03	426.525	249.865	254.978	127.385	129.666
2013	411.335	415.096	297.136	294.842	187.188	180.624	126.888	121.466
2014	337.05	339.015	225.55	224.46	147.585	141.579	106.055	101.149
2015	291.839	293.794	198.462	194.995	143.503	141.122	92.486	90.744
2016	506.76	506.882	310.514	303.539	196.843	186.671	117.077	107.728
2017	889.536	873.25	594.391	574.831	363.142	348.377	203.288	194.73
2018	437.161	434.488	326.871	319.165	225.522	216.415	143.634	136.097
Mean	629.553	621.919	456.331	443.053	303.181	287.429	175.357	159.776
new-to-old inflow ratio		0.987875		0.970903		0.948043		0.911147

Table 2. UKL net inflow forecasts from current NRCS models (old), forecasts re-constructed in 2017 (new), and the estimated new forecast using the new:old inflow ratio. Units are thousands of acre-feet (taf).

	Mar-Sep forecast, 50% exceedence			Apr-Sep forecast, 50% exceedence			May-Sep forecast, 50% exceedence			Jun-Sep forecast, 50% exceedence		
Year	Old forecast (taf)	New forecast (taf)	Estimated new forecast (taf)	Old forecast (taf)	New forecast (taf)	Estimated new forecast (taf)	Old forecast (taf)	New forecast (taf)	Estimated new forecast (taf)	Old forecast (taf)	New forecast (taf)	Estimated new forecast (taf)
1981	446	397	441	348	308	338	231	193	219	139	113	127
1982	1016	890	1004	792	744	768	467	432	443	258	250	235
1983	1029	1026	1016	959	985	931	608	656	576	348	346	317
1984	941	879	929	649	636	630	467	445	443	275	234	251
1985	810	795	801	562	535	546	401	340	380	193	165	176
1986	671	782	663	562	558	546	321	298	304	180	173	164
1987	500	545	494	331	349	322	184	170	175	104	91	95
1988	499	503	493	282	262	274	186	187	176	123	111	112
1989	771	744	762	682	650	663	458	375	434	253	192	230
1990	406	395	401	281	258	273	177	142	168	116	88	106
1991	158	160	156	232	255	225	150	187	142	92	93	83
1992	323	297	319	195	178	190	132	111	125	88	69	80
1993	862	946	852	591	612	573	416	455	394	200	190	182
1994	401	395	396	199	187	193	141	136	134	96	68	88
1995	580	587	573	532	529	516	367	404	348	202	203	184
1996	828	735	818	578	523	561	381	357	361	223	197	203
1997	902	901	891	559	517	543	367	376	348	196	200	178
1998	875	825	864	657	583	638	461	381	437	356	298	324
1999	1145	1070	1132	770	747	747	540	468	512	271	212	247
2000	827	868	817	549	517	533	380	303	360	203	164	185
2001	438	407	433	238	176	231	210	190	199	131	89	119
2002	605	693	597	410	468	398	235	256	223	114	120	104
2003	411	426	406	322	305	312	244	291	232	135	139	123
2004	677	731	669	389	378	377	222	197	210	120	105	109
2005	438	456	433	288	274	279	193	202	183	136	139	124
2006	980	963	968	768	755	746	503	529	477	243	250	221
2007	560	531	553	356	335	346	228	204	216	133	115	121
2008	703	692	694	512	524	497	334	289	316	188	158	171
2009	520	515	514	395	365	384	293	221	278	174	130	159
2010	467	510	461	303	319	294	205	236	194	119	130	109
2011	716	625	708	649	616	630	456	401	432	307	281	280
2012	335		331	400		388	320		303	175		159
2013	550	520	543	290	294	282	165	191	156	83	118	76
2014	275	241	272	220	202	214	135	141	128	64	91	58
2015	295	316	291	186	192	181	130	144	123	100	124	91
2016	565	587	558	430	445	417	240	204	228	143	145	130
2017	890		879	615		597	425		403	225		205
2018	355		351	285		277	195		185	134		122
2019	735		726									

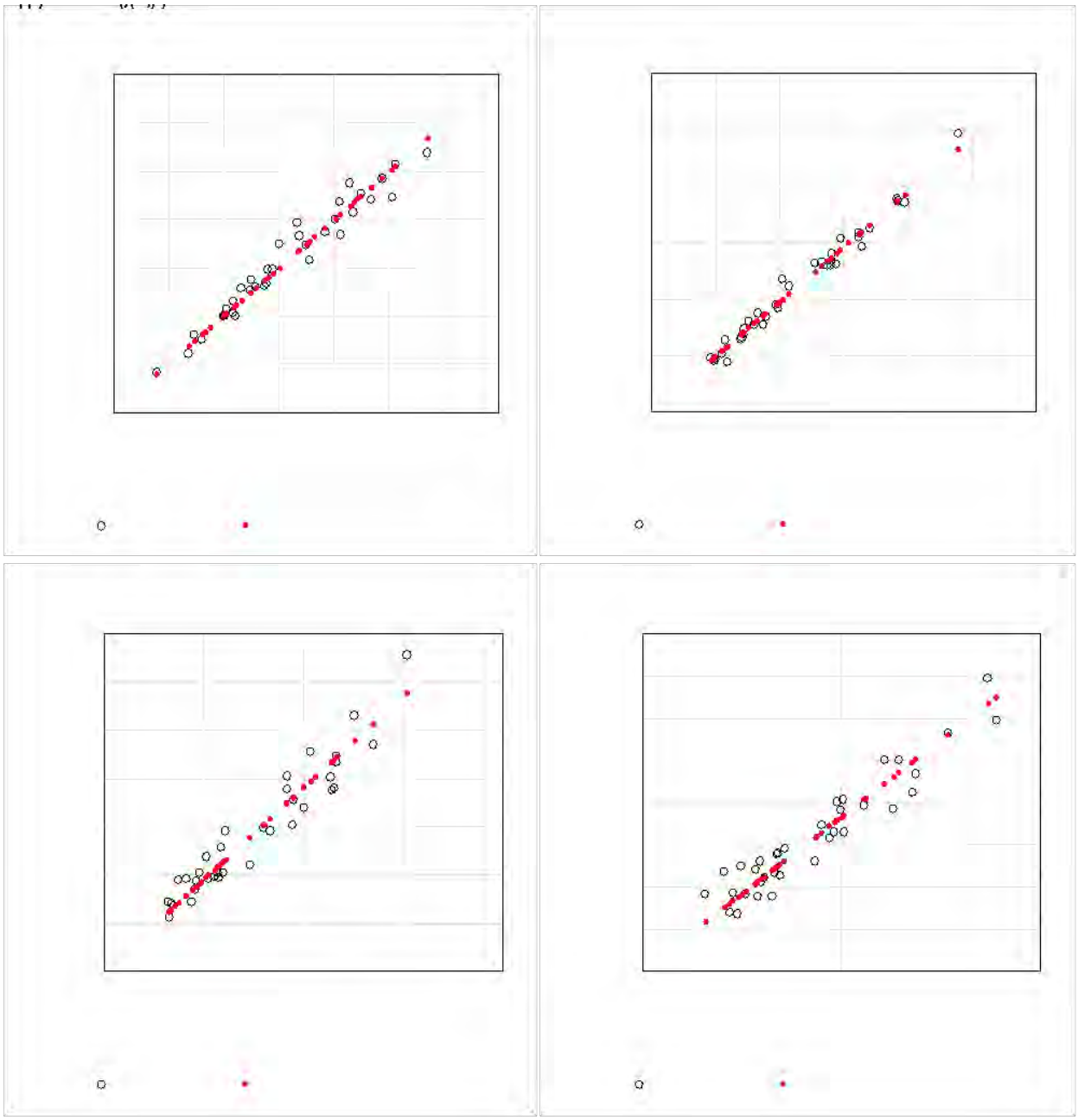


Figure 1. New UKL net inflow forecasts superimposed on scatter plots of old vs. new forecasts by forecast period. Units are thousands of acre-feet (taf).

Appendix 8: Klamath Coho Salmon Effects Analysis Tables and Figures

Source: Unless otherwise state, figures and tables developed by Mount Hood Environmental. data provided by USGS and Reclamation.

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Table A8-1. Daily average IGD exceedance flows estimated for the Proposed Action, 1980-2019.

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	1000	1000	950	950	950	1000	1456	1175	1025	900	900	1000
90%	1000	1000	950	950	950	1213	1598	1346	1025	900	900	1000
85%	1000	1000	950	950	950	1517	1680	1438	1025	900	900	1000
80%	1000	1000	950	950	950	1628	1731	1484	1025	900	900	1000
75%	1037	1000	950	950	993	1726	1802	1524	1025	909	900	1000
70%	1073	1000	950	950	1037	1870	1884	1569	1025	940	900	1000
65%	1088	1000	950	976	1103	2032	2032	1611	1025	966	900	1000
60%	1109	1014	950	1018	1171	2207	2177	1655	1025	989	900	1000
55%	1127	1067	950	1062	1259	2430	2382	1733	1025	1011	908	1000
50%	1135	1130	955	1152	1438	2659	2565	1857	1113	1037	933	1024
45%	1148	1184	1003	1290	1732	2956	2822	2038	1223	1049	951	1074
40%	1162	1208	1068	1444	2079	3227	3098	2238	1319	1060	981	1114
35%	1177	1223	1197	1634	2441	3658	3430	2395	1401	1080	1029	1142
30%	1191	1263	1396	1922	2717	4030	3848	2587	1504	1101	1090	1150
25%	1221	1319	1648	2328	3120	4453	4314	2823	1648	1122	1099	1159
20%	1254	1375	1882	2624	3620	5366	4628	3045	1795	1145	1120	1168
15%	1273	1410	2277	3121	4159	6030	5211	3311	2048	1176	1143	1196
10%	1325	1639	2934	3991	5153	6504	5613	3777	2377	1228	1178	1214
5%	1427	2527	4142	5562	7395	7783	6112	4453	2991	1250	1550	1225

Table A8-2. Daily average IGD exceedance flows estimated for the Without Action, 1980 2019.

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	633	983	1224	1463	1603	1723	1668	1427	882	552	362	425
90%	747	1063	1328	1550	1835	1948	1905	1612	1093	686	502	520
85%	813	1125	1408	1652	1942	2095	2018	1768	1201	769	566	573
80%	876	1166	1467	1759	2007	2232	2140	1861	1296	844	616	615
75%	911	1220	1520	1859	2059	2339	2253	1939	1412	908	658	652
70%	947	1258	1570	1929	2139	2438	2356	2039	1522	979	702	695
65%	983	1303	1623	1985	2237	2546	2497	2168	1629	1059	751	730
60%	1016	1338	1678	2032	2322	2652	2675	2298	1739	1135	803	762
55%	1058	1376	1736	2097	2421	2772	2849	2480	1858	1210	854	809
50%	1109	1417	1803	2170	2517	2934	3013	2714	2031	1303	931	858
45%	1147	1456	1858	2236	2603	3154	3224	2942	2219	1400	1002	922
40%	1209	1503	1943	2324	2702	3362	3490	3120	2386	1516	1086	975
35%	1265	1550	2004	2448	2831	3641	3851	3313	2566	1622	1149	1054
30%	1348	1601	2072	2607	2997	3876	4169	3562	2721	1749	1230	1140
25%	1410	1659	2198	2755	3214	4090	4508	3755	2864	1902	1323	1237
20%	1483	1720	2314	2964	3546	4484	4857	4019	3039	2066	1426	1315
15%	1549	1797	2657	3247	4298	5164	5351	4453	3385	2300	1549	1433
10%	1623	1893	3018	3758	5093	5740	5742	4712	3748	2533	1730	1602
5%	1795	2359	3741	4527	6150	6228	6119	5105	4230	2863	1971	1810

Table A8-3. Difference between Proposed Action and Without Action daily average IGD exceedance flows, 1980 – 2019.

Exceedance	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
95%	367	17	-274	-513	-653	-723	-212	-252	143	348	538	575
90%	253	-63	-378	-600	-885	-735	-307	-266	-68	214	398	480
85%	187	-125	-458	-702	-992	-578	-338	-331	-176	131	334	427
80%	124	-166	-517	-809	-1,057	-604	-409	-377	-271	56	284	385
75%	126	-220	-570	-909	-1,066	-613	-451	-415	-387	0	242	348
70%	126	-258	-620	-979	-1,103	-568	-472	-470	-497	-39	198	305
65%	105	-303	-673	-1010	-1,134	-515	-465	-557	-604	-94	149	270
60%	93	-324	-728	-1014	-1,151	-445	-498	-643	-714	-146	97	238
55%	69	-309	-786	-1035	-1,162	-342	-467	-747	-833	-199	54	191
50%	26	-287	-848	-1018	-1,079	-275	-448	-857	-918	-266	2	166
45%	1	-272	-855	-946	-872	-199	-402	-904	-996	-351	-51	152
40%	-47	-295	-875	-880	-623	-135	-392	-882	-1067	-456	-105	138
35%	-88	-327	-807	-814	-390	17	-421	-918	-1165	-542	-120	89
30%	-157	-338	-676	-685	-280	154	-322	-975	-1217	-648	-140	10
25%	-189	-340	-550	-427	-93	363	-195	-932	-1216	-780	-224	-78
20%	-229	-346	-432	-340	74	882	-229	-974	-1244	-921	-306	-147
15%	-276	-387	-380	-126	-139	866	-140	-1141	-1337	-1,124	-406	-237
10%	-298	-254	-84	233	59	764	-130	-935	-1371	-1,305	-552	-388
5%	-368	168	402	1035	1245	1555	-7	-652	-1240	-1,613	-421	-585

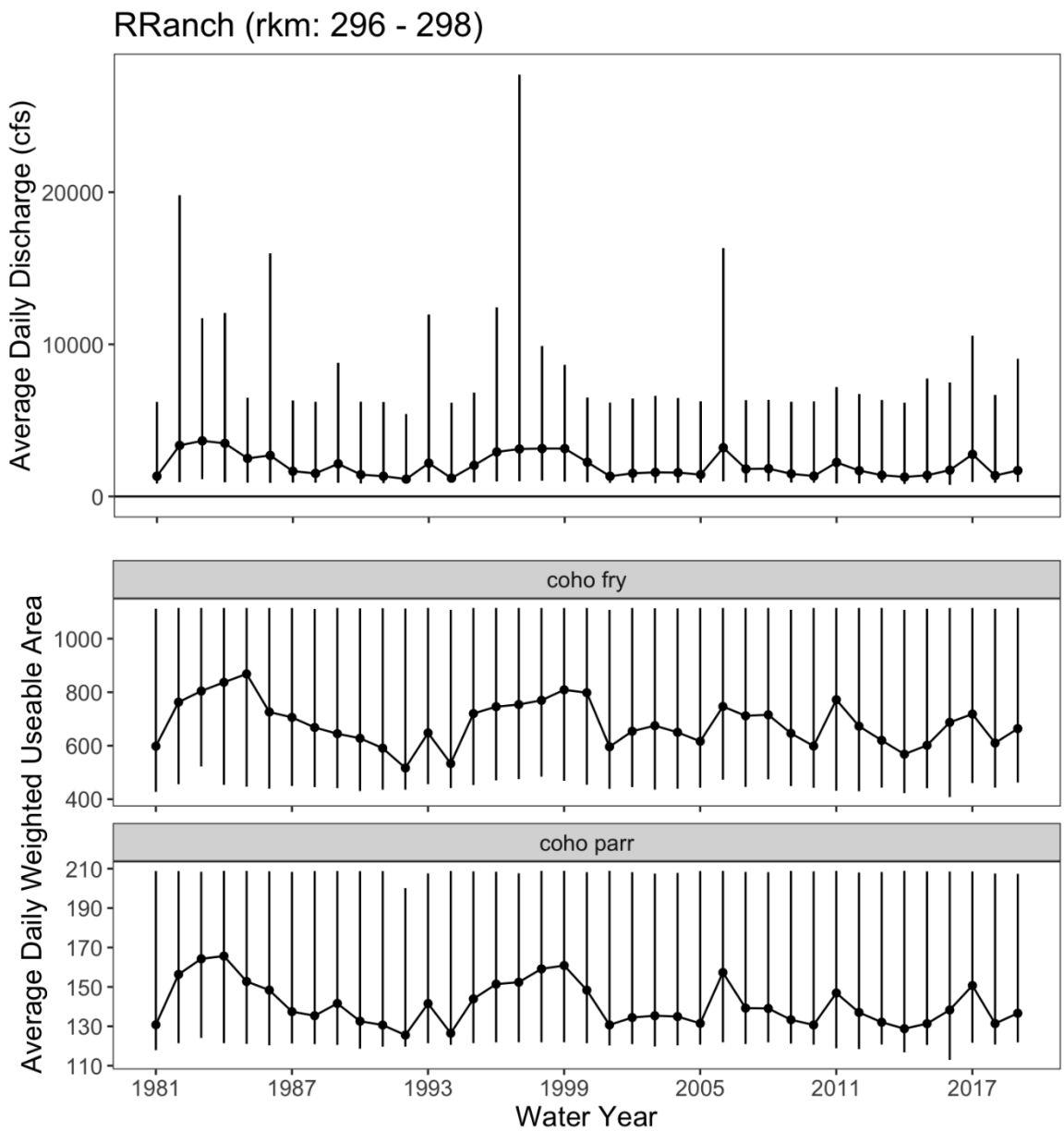

Figure A8-1. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the RR Ranch study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values

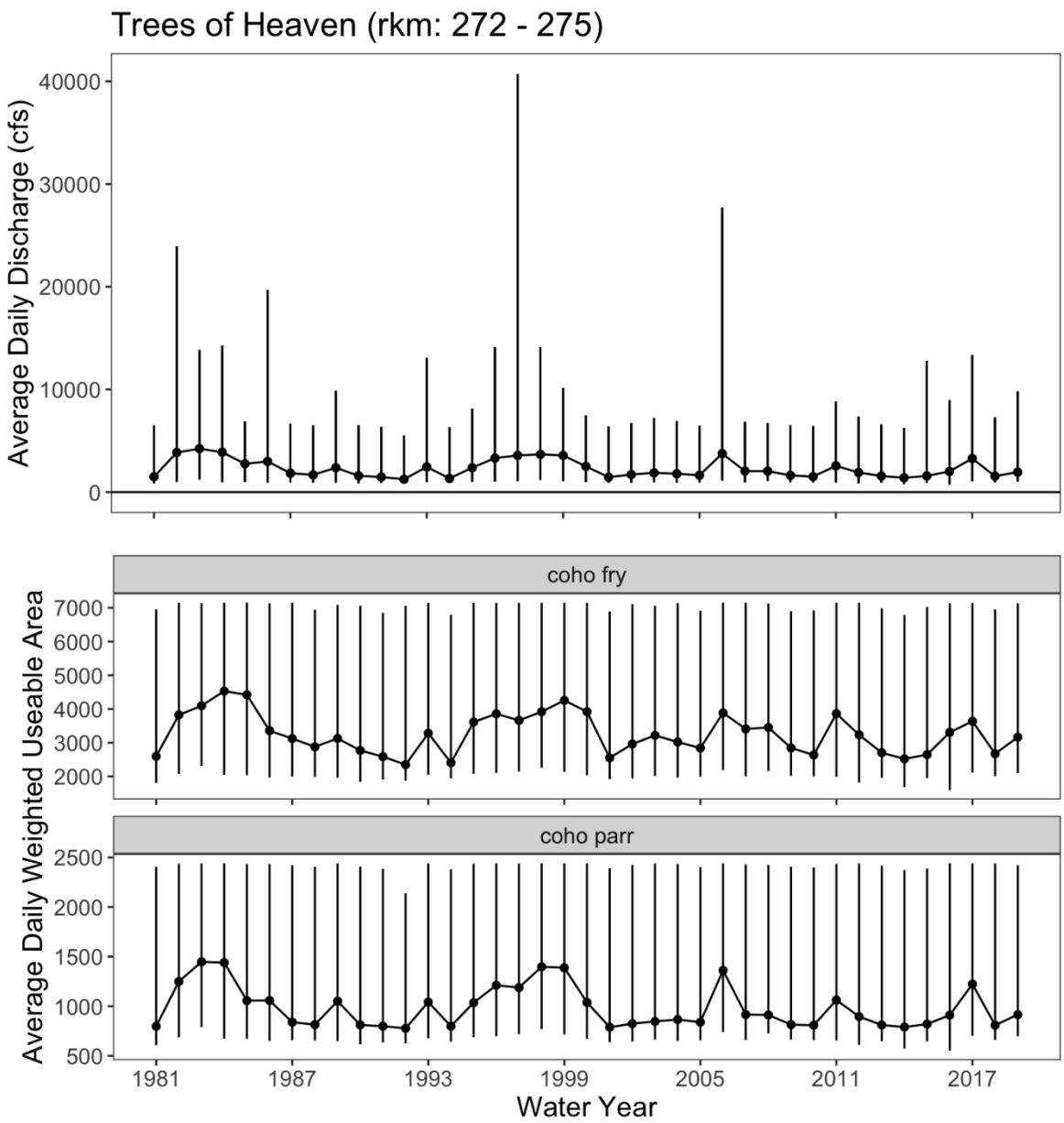

Figure A8-2. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Trees of Heaven study site (rkm 272.8937 – 275.0743) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

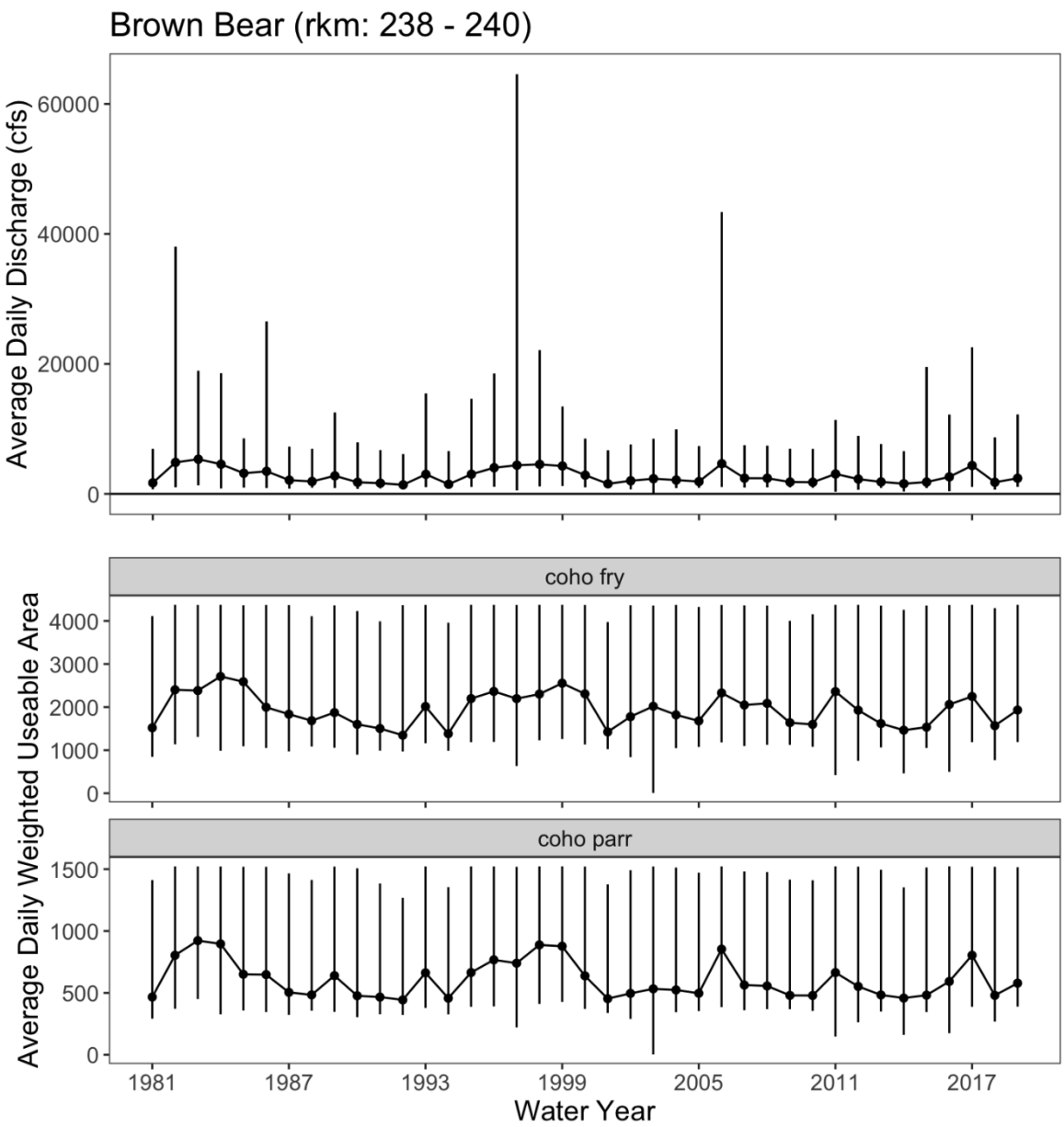

Figure A8-3. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Brown Bear study site (rkm 238.7011 – 240.1118) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

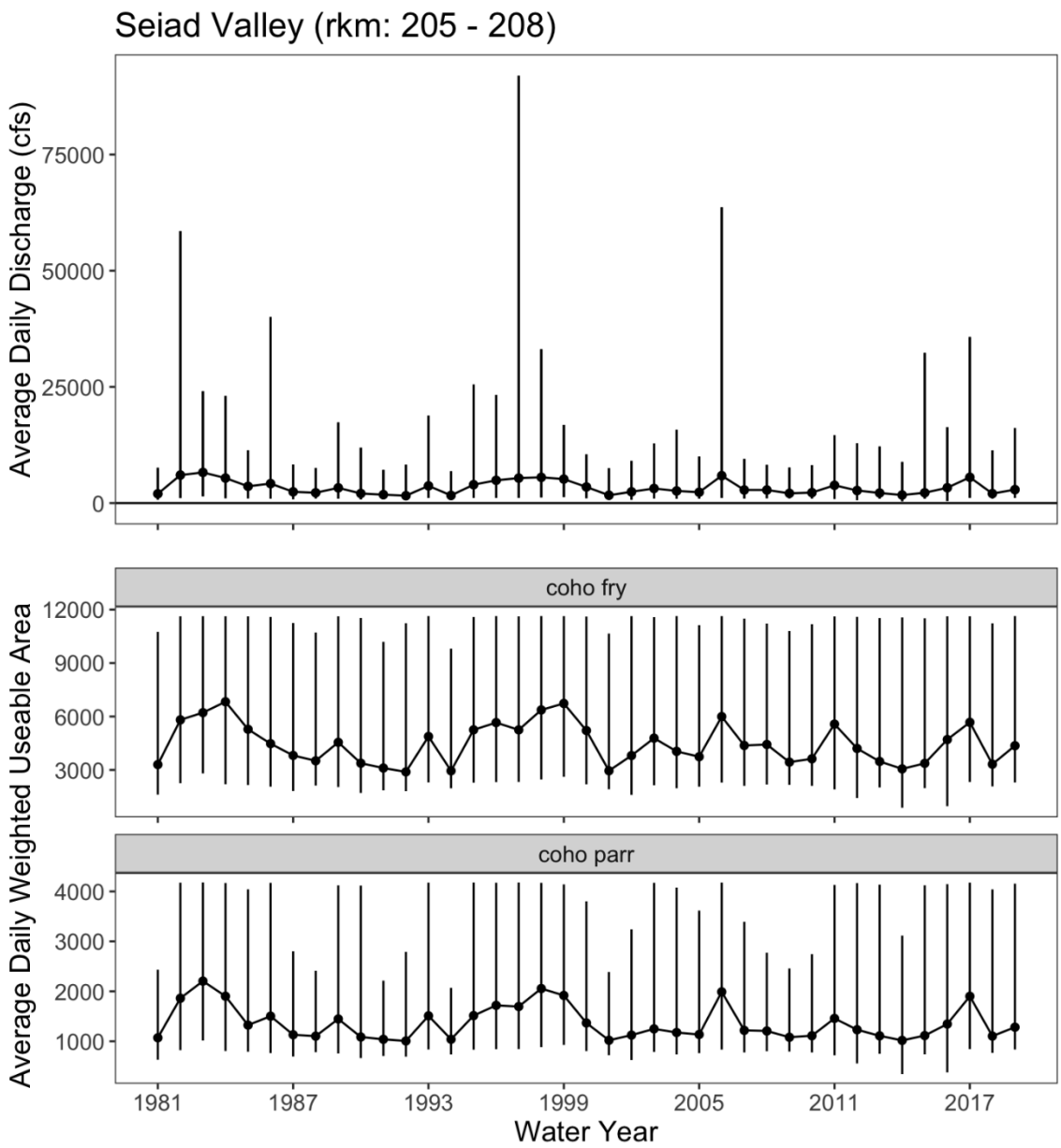

Figure A8-4. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Seiad Valley study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

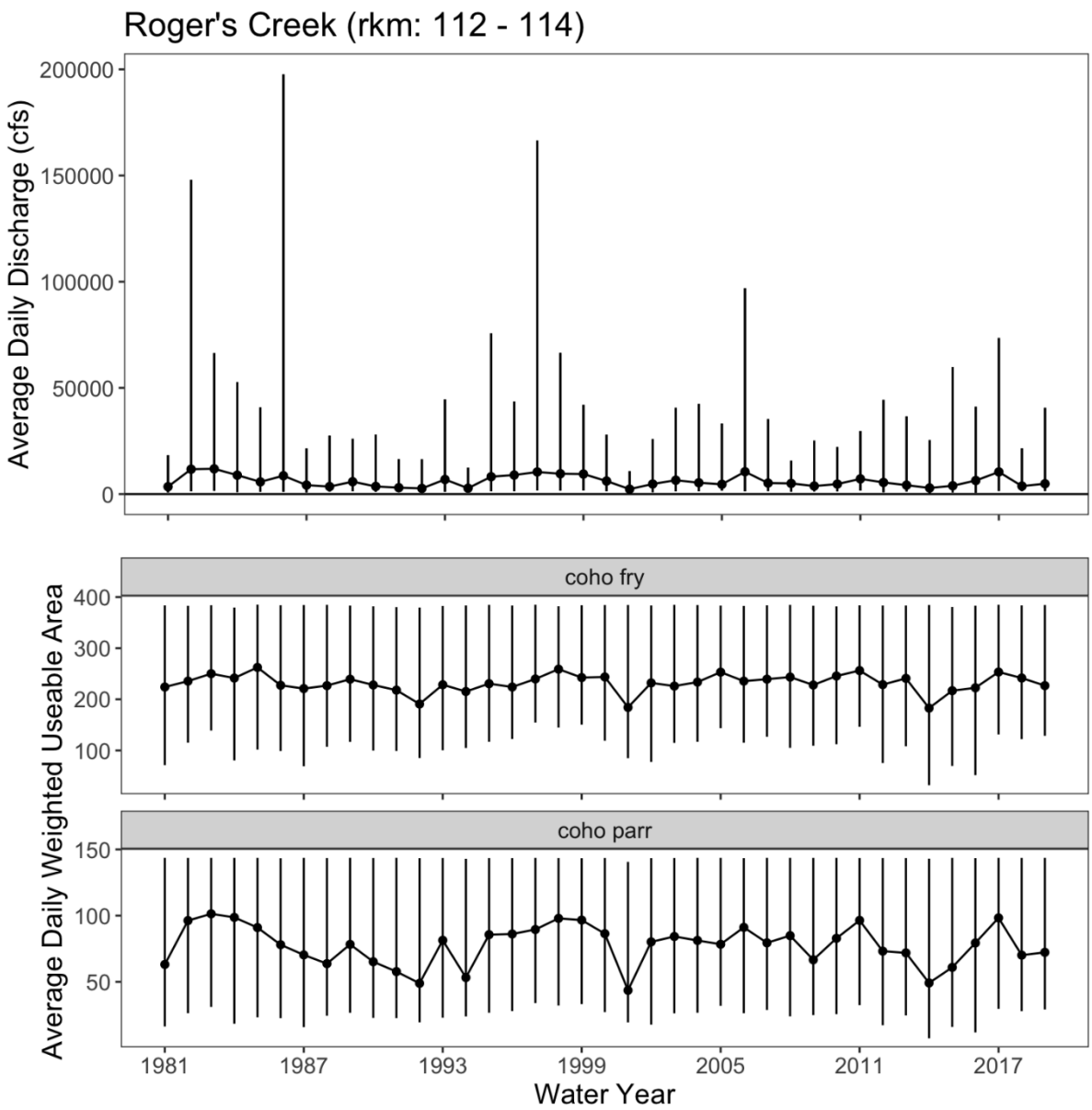

Figure A8-5. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Roger's Creek study site (rkm 112.6402 – 114.4836) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

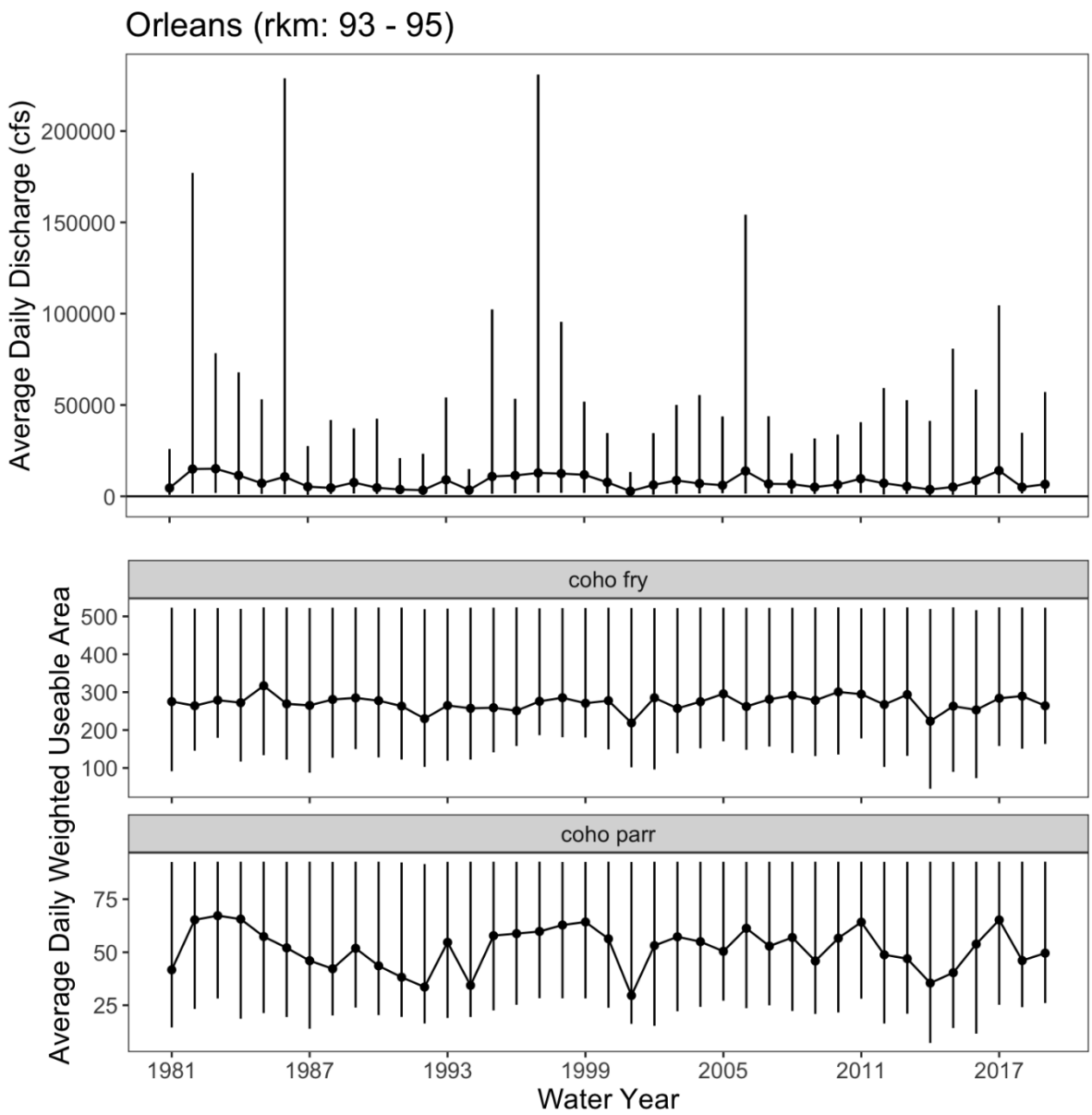

Figure A8-6. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Orleans study site (rkm 93.8881 – 95.4474) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

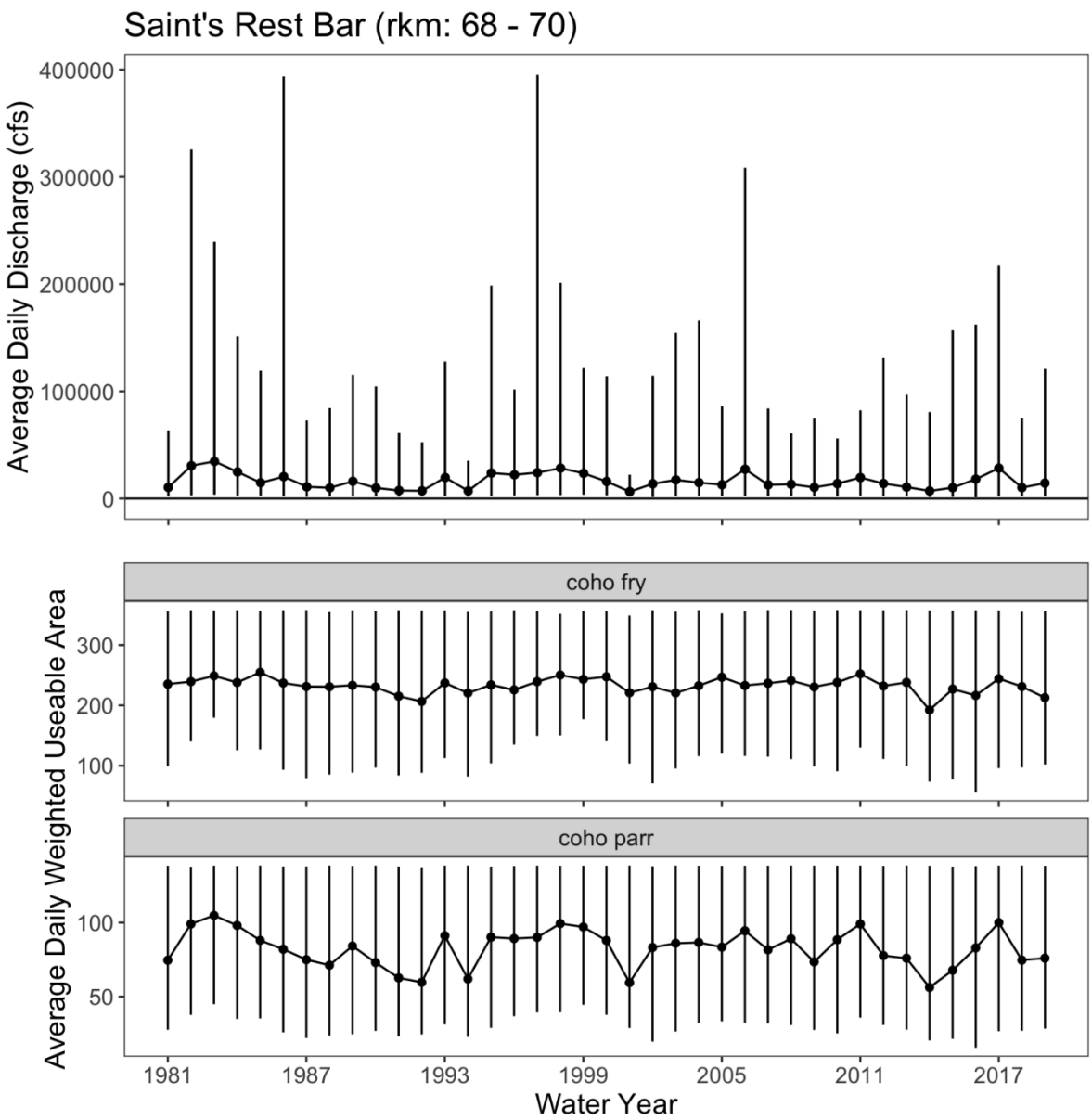

Figure A8-7. Average daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Saint's Rest Bar study site (rkm 68.7235 – 70.3264) as a result of the Proposed Action for all water years (October 1 – September 30) included in the POR. Whiskers indicate modeled maximum and minimum values.

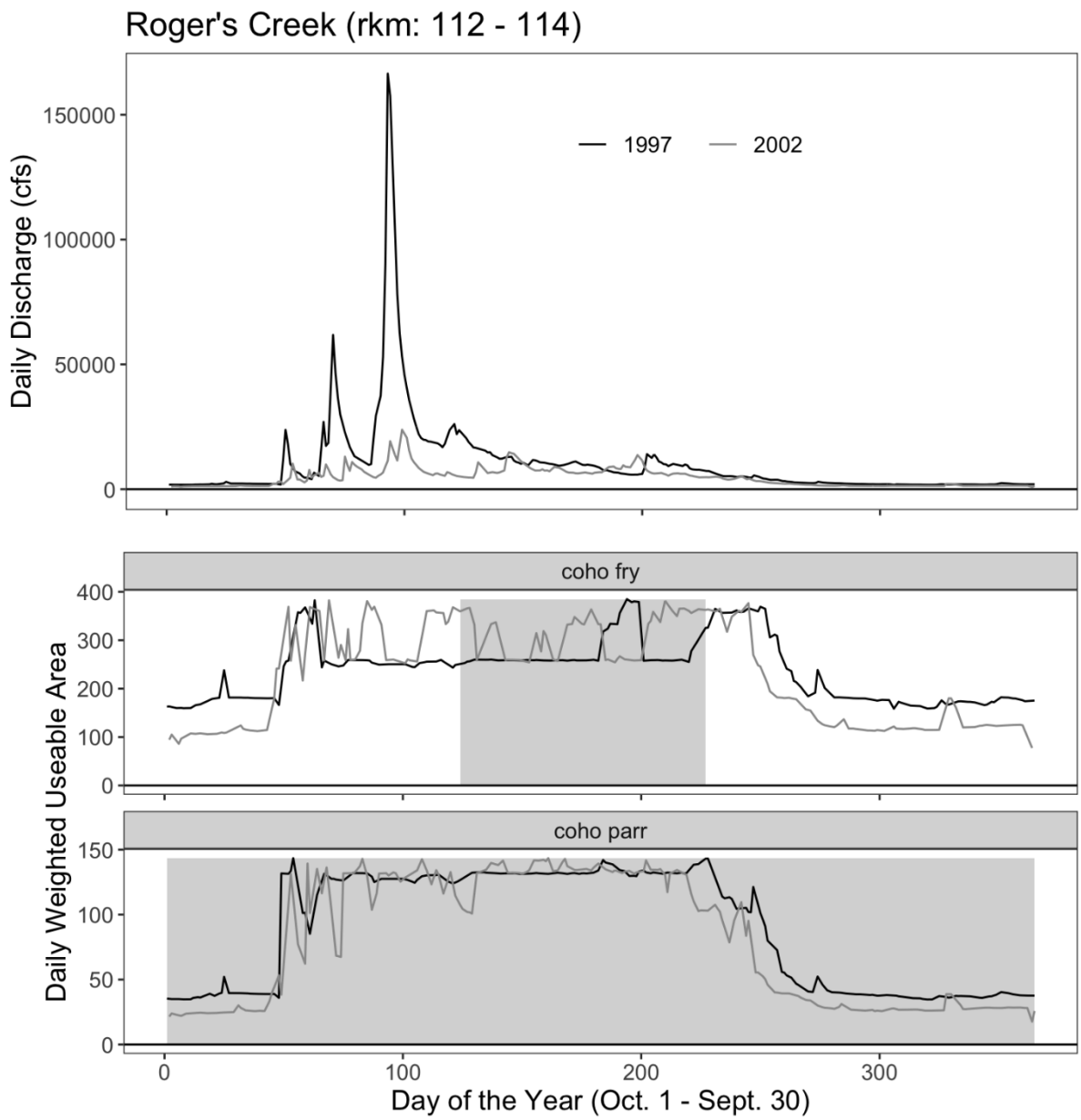

Figure A8-8. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the RRanch study site (rkm 296.7472 – 298.003) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

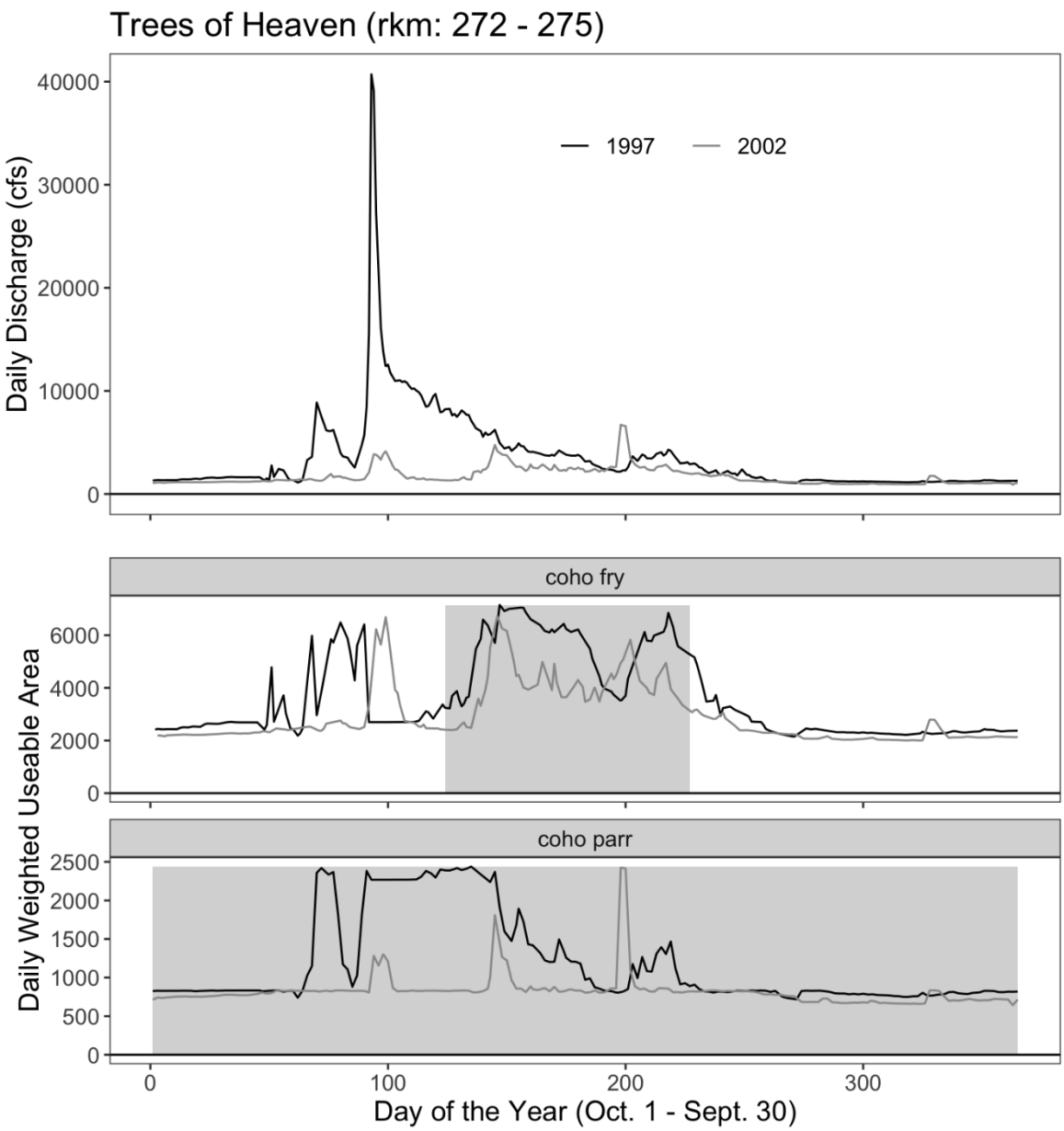

Figure A8-9. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Trees of Heaven study site (rkm 272.8937 – 275.0743) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

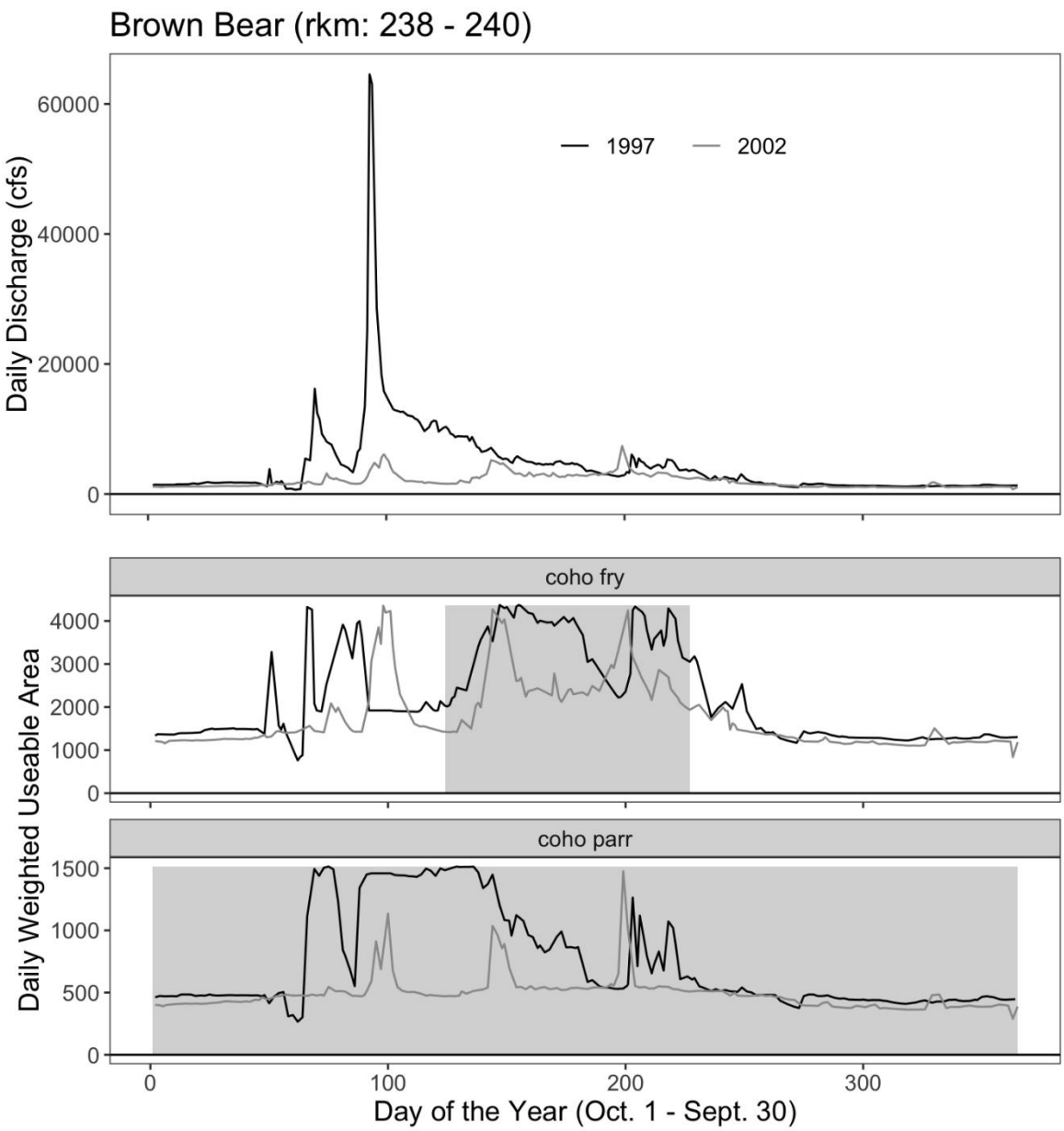

Figure A8-10. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Brown Bear study site (rkm 2238.7011 – 240.1118) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

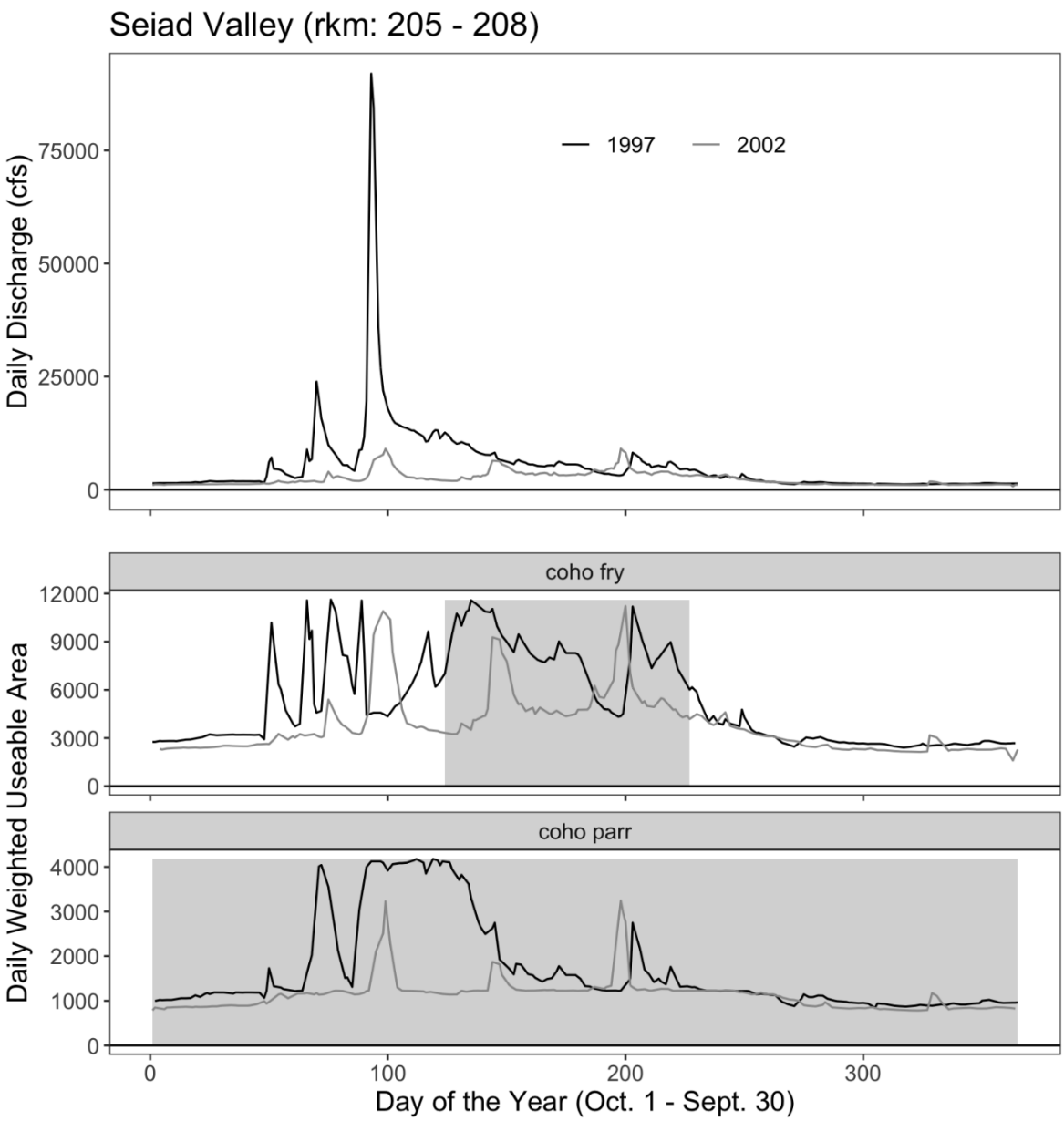

Figure A8-11. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Seiad Valley study site (rkm 205.8206 – 208.0594) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

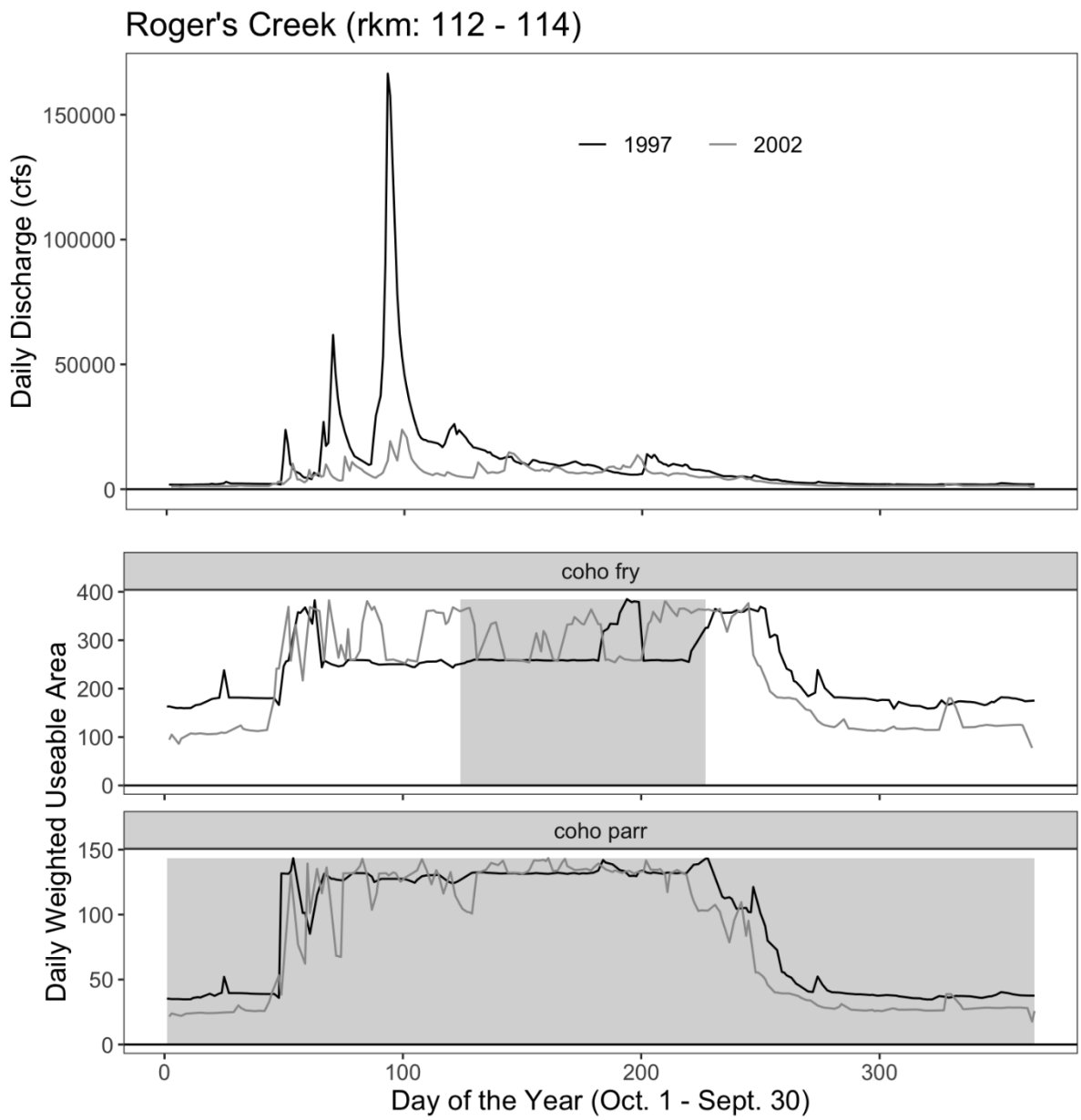

Figure A8-12. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Roger's Creek study site (rkm 112.6402 – 114.4836) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

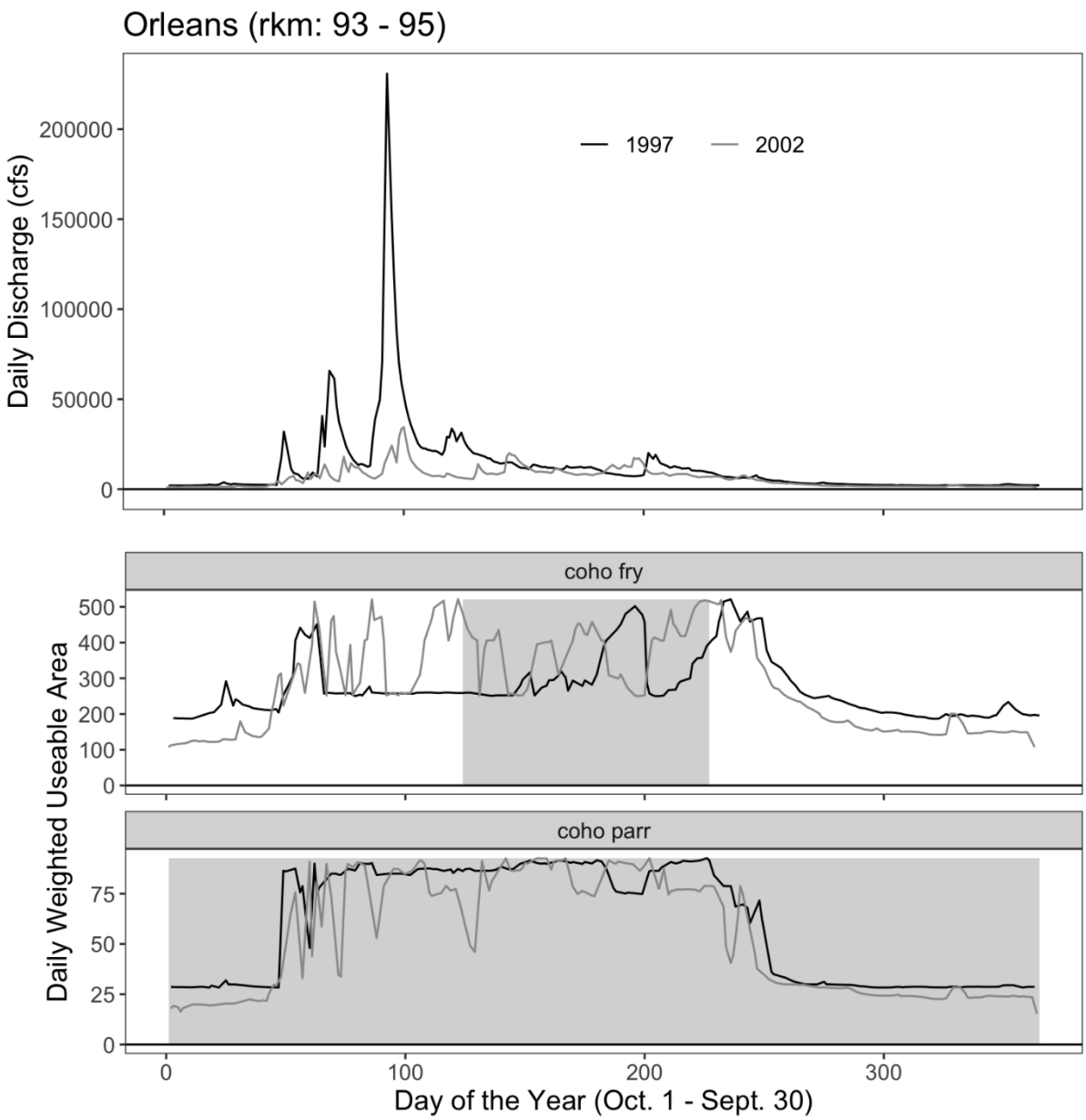

Figure A8-13. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Orleans study site (rkm 93.881 – 95.4474) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

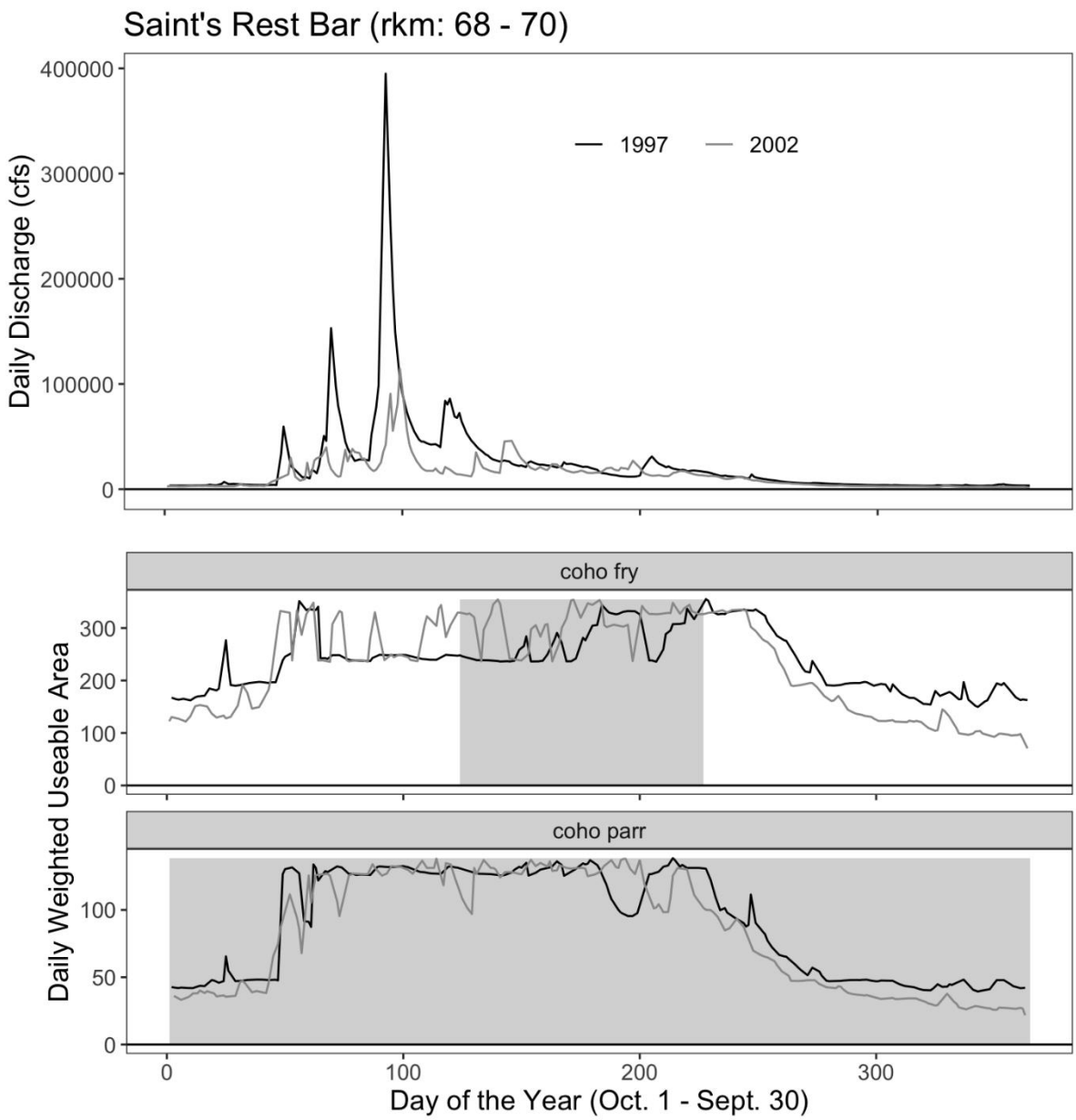

Figure A8-14. Daily discharge (top panel) and corresponding weighted useable area (WUA) for coho parr (bottom panel) and fry (middle panel) modeled at the Saint's Rest Bar study site (rkm 68.7235 – 70.3264) as a result of the Proposed Action for water years 1997 (wet) and 2002 (dry). Shaded areas indicate the timing of presence of each life stage in the main stem Klamath River.

Table A8-4. A comparison of daily average Klamath River water temperatures at Iron Gate Dam modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2017. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
1980	7.9	8.7	13.5	15.8	18.7	20.8	18.3	14.6	7.9	8.7	13.5	15.8	18.7	20.8	18.3	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	7.4	10.1	13.2	16.6	20.0	21.6	19.7	14.7	7.4	10.1	13.2	16.6	20.0	21.6	19.7	14.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1982	6.6	7.4	13.4	17.2	19.4	20.7	18.5	12.8	6.6	7.4	13.4	17.2	19.4	20.7	18.5	12.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1983	8.1	7.7	11.9	18.5	19.2	20.5	18.3	13.3	8.1	7.7	11.9	18.5	19.2	20.5	18.3	13.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1984	7.5	9.0	12.6	17.2	20.4	21.6	18.7	12.5	7.5	9.0	12.6	17.2	20.4	21.6	18.7	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1985	6.0	11.6	14.0	17.0	20.9	21.5	17.4	12.5	6.0	11.6	14.0	17.0	20.9	21.5	17.4	12.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1986	9.8	11.4	12.5	17.7	20.7	21.7	19.2	12.2	9.8	11.4	12.5	17.7	20.7	21.7	19.2	12.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1987	7.2	10.4	14.8	18.2	20.7	20.5	19.0	15.4	7.2	10.4	14.8	18.2	20.7	20.5	19.0	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1988	8.0	11.4	12.9	15.7	19.6	21.7	19.6	15.2	8.0	11.4	12.9	15.7	19.6	21.7	19.6	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1989	6.3	11.1	14.1	17.5	19.8	20.6	17.8	13.6	6.3	11.1	14.1	17.5	19.8	20.6	17.8	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1990	5.9	11.8	14.6	15.8	19.7	21.8	18.8	14.2	5.9	11.8	14.6	15.8	19.7	21.8	18.8	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1991	6.5	9.1	11.3	15.1	18.9	20.9	19.7	16.1	6.5	9.1	11.3	15.1	18.9	20.9	19.7	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1992	6.9	10.9	15.1	18.7	20.8	21.8	19.8	15.4	6.9	10.9	15.1	18.7	20.8	21.8	19.8	15.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1993	6.6	9.2	13.8	16.8	18.7	20.0	18.3	14.4	6.6	9.2	13.8	16.8	18.7	20.0	18.3	14.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1994	6.4	9.6	13.5	17.1	20.5	21.7	19.2	14.9	6.4	9.6	13.5	17.1	20.5	21.7	19.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1995	8.0	9.1	12.6	16.7	19.9	20.9	18.7	14.3	8.0	9.1	12.6	16.7	19.9	20.9	18.7	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1996	7.2	11.0	13.3	16.7	20.6	21.8	18.9	14.3	7.2	11.0	13.3	16.7	20.6	21.8	18.9	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1997	7.6	10.5	13.8	17.3	19.6	21.7	19.8	14.8	7.6	10.5	13.8	17.3	19.6	21.7	19.8	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1998	7.0	7.5	11.4	14.9	20.6	22.9	21.1	15.2	7.0	7.5	11.4	14.9	20.6	22.9	21.1	15.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1999	5.8	7.4	11.0	15.8	20.1	21.3	19.6	15.8	5.8	7.4	11.0	15.8	20.1	21.3	19.6	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2000	6.7	10.5	12.6	16.7	20.5	22.1	19.3	15.0	6.7	10.5	12.6	16.7	20.5	22.1	19.3	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2001	6.9	9.5	13.3	18.4	20.7	22.0	20.7	16.2	6.9	9.5	13.3	18.4	20.7	22.0	20.7	16.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2002	7.4	10.2	12.8	16.9	21.6	22.5	20.4	15.5	7.4	10.2	12.8	16.9	21.6	22.5	20.4	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2003	8.0	9.5	10.9	17.7	21.9	23.2	20.8	16.3	8.0	9.5	10.9	17.7	21.9	23.2	20.8	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2004	7.8	11.2	13.6	16.7	20.6	22.6	20.2	15.6	7.8	11.2	13.6	16.7	20.6	22.6	20.2	15.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
2005	7.6	10.6	12.8	15.6	19.6	22.6	20.2	14.9	7.6	10.6	12.8	15.6	19.6	22.6	20.2	14.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2006	5.3	8.3	15.3	18.0	21.9	22.1	18.8	14.1	5.3	8.3	15.3	18.0	21.9	22.1	18.8	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2007	6.8	11.4	13.6	18.2	21.0	21.5	19.1	13.7	6.8	11.4	13.6	18.2	21.0	21.5	19.1	13.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2008	5.9	9.3	14.3	17.4	22.0	21.8	19.2	14.8	5.9	9.3	14.3	17.4	22.0	21.8	19.2	14.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2009	6.7	10.4	14.8	19.4	21.7	21.7	19.4	14.6	6.7	10.4	14.8	19.4	21.7	21.7	19.4	14.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2010	7.2	9.5	12.7	16.9	21.3	21.9	18.4	15.5	7.2	9.5	12.7	16.9	21.3	21.9	18.4	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2011	5.8	9.2	12.7	16.1	20.7	22.2	20.2	15.7	5.8	9.2	12.7	16.1	20.7	22.2	20.2	15.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2012	5.8	9.4	15.5	17.8	20.9	21.9	19.5	16.1	5.8	9.4	15.5	17.8	20.9	21.9	19.5	16.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2013	6.5	11.4	16.0	18.9	21.7	21.5	19.6	14.2	6.5	11.4	16.0	18.9	21.7	21.5	19.6	14.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2014	8.4	12.0	16.4	19.3	22.3	22.0	19.3	15.8	8.4	12.0	16.4	19.3	22.3	22.0	19.3	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2015	9.3	12.0	15.9	20.0	22.4	20.9	18.7	15.8	9.3	12.0	15.9	20.0	22.4	20.9	18.7	15.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2016	7.7	12.4	15.7	19.0	20.2	21.4	19.2	15.0	7.7	12.4	15.7	19.0	20.2	21.4	19.2	15.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2017	7.2	10.2	14.7	19.3	21.9	22.3	19.9	14.3	7.2	10.2	14.7	19.3	21.9	22.3	19.9	14.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ave.	**7.1**	**10.1**	**13.6**	**17.3**	**20.6**	**21.6**	**19.3**	**14.7**	**7.1**	**10.1**	**13.6**	**17.3**	**20.6**	**21.6**	**19.3**	**14.7**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Min.	**5.3**	**7.4**	**10.9**	**14.9**	**18.7**	**20.0**	**17.4**	**12.2**	**5.3**	**7.4**	**10.9**	**14.9**	**18.7**	**20.0**	**17.4**	**12.2**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Max.	**9.8**	**12.4**	**16.4**	**20.0**	**22.4**	**23.2**	**21.1**	**16.3**	**9.8**	**12.4**	**16.4**	**20.0**	**22.4**	**23.2**	**21.1**	**16.3**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**

[1] Historical Temperature (℃)
[2] Proposed Action Temperature (℃)
[3] Temperature (℃) Difference

Table A8-5. A comparison of daily average Klamath River water temperatures at rivermile 174.0 (just below the confluence with the Shasta River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
1980	8.4	10.1	14.6	17.5	20.8	21.2	18.2	14.0	8.4	10.1	14.6	17.5	20.8	21.2	18.2	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	8.2	11.5	14.9	18.7	21.5	22.2	19.4	13.5	8.1	11.4	14.5	18.3	21.3	22.2	19.4	13.6	0.0	0.2	0.4	0.4	0.2	0.0	0.0	-0.1
1982	7.0	8.1	14.5	18.8	20.8	21.2	18.2	12.5	7.0	8.1	14.4	18.1	20.7	21.2	18.1	12.4	0.0	0.0	0.2	0.6	0.1	0.0	0.1	0.1
1983	8.6	8.5	13.1	19.2	20.4	20.9	18.2	13.2	8.6	8.5	13.1	19.1	20.1	20.8	18.2	13.1	0.0	0.1	0.0	0.1	0.3	0.0	0.0	0.1
1984	8.0	9.6	13.6	18.3	21.9	21.9	18.5	12.1	8.0	9.6	13.6	18.0	21.6	21.9	18.4	12.1	0.0	0.0	0.0	0.2	0.3	0.0	0.1	0.1
1985	6.5	12.2	15.2	18.8	22.3	21.7	17.0	12.2	6.4	12.2	14.9	18.5	22.0	21.7	16.9	12.2	0.1	-0.1	0.3	0.3	0.3	0.0	0.1	0.0
1986	10.2	12.0	14.1	19.8	21.9	22.3	18.3	12.2	10.2	12.0	14.0	19.2	21.7	22.3	18.1	12.2	0.0	0.0	0.1	0.6	0.1	0.0	0.2	0.0
1987	7.8	11.9	16.2	20.0	21.4	21.3	18.8	15.0	7.9	11.6	15.8	19.6	21.4	21.3	18.8	15.0	0.0	0.3	0.4	0.4	0.1	0.0	0.0	0.0
1988	8.7	12.3	14.3	17.6	21.8	22.2	19.3	14.7	8.6	12.1	13.9	17.2	21.4	22.2	19.3	14.7	0.1	0.2	0.4	0.4	0.4	0.0	0.0	0.0
1989	6.8	11.8	14.9	19.4	21.3	20.9	17.8	13.1	6.7	11.7	14.9	19.0	21.1	20.9	17.8	13.1	0.1	0.1	0.0	0.4	0.3	0.0	0.0	0.0
1990	7.1	12.9	15.5	18.1	21.5	22.2	18.9	13.6	6.9	12.8	15.3	17.6	21.3	22.2	18.9	13.6	0.2	0.1	0.2	0.4	0.2	0.0	0.0	0.1
1991	7.4	10.8	13.2	17.2	21.6	21.8	19.9	15.4	7.1	10.1	12.7	16.5	20.8	21.6	19.9	15.4	0.3	0.7	0.5	0.7	0.7	0.2	0.0	0.0
1992	9.4	12.7	18.0	20.5	22.8	22.9	19.4	14.6	8.6	11.9	16.8	19.9	22.1	22.5	19.5	14.7	0.9	0.8	1.2	0.6	0.7	0.5	-0.1	0.0
1993	7.6	9.9	14.8	18.3	20.4	20.7	18.4	14.0	7.6	9.9	14.6	18.1	20.1	20.7	18.5	14.0	0.0	0.1	0.2	0.3	0.3	0.0	0.0	0.0
1994	8.8	11.8	15.7	19.3	22.6	22.4	19.3	14.0	8.2	10.7	15.2	18.8	22.0	22.2	19.2	14.0	0.6	1.0	0.5	0.5	0.6	0.2	0.0	0.0
1995	8.5	9.9	14.0	18.3	21.6	21.5	18.9	13.8	8.5	9.8	13.8	17.9	21.2	21.5	18.9	13.7	0.0	0.1	0.2	0.4	0.4	0.0	0.0	0.1
1996	7.7	11.6	14.2	18.1	22.2	22.4	18.7	13.8	7.8	11.7	14.2	18.2	22.1	22.4	18.6	13.8	0.0	0.0	0.1	-0.1	0.1	0.0	0.0	0.0
1997	8.4	11.4	15.3	18.6	21.3	22.2	19.6	14.2	8.4	11.4	15.1	18.6	21.0	22.2	19.6	14.1	0.1	0.0	0.2	0.0	0.3	0.0	0.0	0.1
1998	7.9	8.7	12.2	16.6	22.3	23.5	20.8	14.4	7.9	8.7	12.3	16.6	22.2	23.5	20.8	14.3	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.1
1999	6.3	8.2	12.4	17.1	21.2	21.5	19.6	15.3	6.4	8.3	12.1	17.0	21.3	21.5	19.6	15.3	-0.1	0.0	0.3	0.1	-0.1	0.0	0.0	0.0
2000	7.5	11.5	13.9	18.6	21.6	22.6	19.1	14.3	7.5	11.4	14.0	18.7	21.6	22.6	19.1	14.2	0.0	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
2001	8.2	10.4	15.0	19.2	21.8	22.6	20.3	15.3	7.8	10.4	15.1	19.6	21.9	22.7	20.3	15.2	0.4	0.0	-0.1	-0.4	-0.1	-0.1	0.0	0.2
2002	8.0	11.2	14.2	18.8	23.0	22.9	20.1	14.4	8.0	11.2	14.1	18.8	22.9	22.8	20.1	14.4	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0
2003	9.1	10.2	12.7	19.3	23.2	23.2	20.4	15.6	8.8	10.2	12.8	19.6	23.1	23.2	20.4	15.5	0.2	0.0	-0.1	-0.3	0.1	0.0	0.0	0.1
2004	9.1	12.2	15.0	18.7	22.4	23.0	19.7	14.3	8.8	12.2	14.9	18.5	22.0	22.9	19.7	14.4	0.3	0.0	0.1	0.2	0.4	0.1	0.0	-0.2
2005	9.1	11.6	13.8	17.4	21.6	23.1	19.7	14.1	9.0	11.4	14.1	17.3	21.4	23.1	19.6	14.0	0.1	0.2	-0.3	0.1	0.2	0.0	0.0	0.1
2006	5.9	9.1	16.1	18.9	22.9	22.4	18.7	13.4	6.0	9.1	16.1	19.5	22.9	22.4	18.7	13.4	0.0	0.0	0.0	-0.6	0.0	0.0	0.0	0.1

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
2007	7.7	12.1	15.2	19.2	22.1	22.1	18.8	13.1	7.7	12.1	15.0	19.4	22.2	22.1	18.9	13.0	0.0	0.1	0.2	-0.2	-0.1	0.0	0.0	0.1
2008	6.8	10.0	15.3	18.6	22.9	22.3	19.3	14.1	6.6	10.0	15.2	18.7	22.9	22.3	19.3	14.0	0.2	0.0	0.1	-0.1	0.0	0.0	0.0	0.1
2009	7.6	11.5	16.2	20.1	23.1	22.3	19.5	13.9	7.4	11.4	15.9	20.2	23.1	22.3	19.5	13.8	0.2	0.2	0.3	-0.1	0.0	0.0	0.0	0.1
2010	8.2	10.6	14.1	18.7	22.8	22.3	18.4	14.6	8.2	10.3	13.9	18.5	22.7	22.3	18.4	14.7	0.0	0.3	0.2	0.2	0.1	0.0	0.0	-0.1
2011	6.5	9.8	13.4	17.2	21.7	22.8	20.1	14.6	6.5	9.8	13.5	17.3	21.7	22.8	20.1	14.6	0.1	0.0	-0.1	-0.1	0.0	0.0	0.0	-0.1
2012	6.7	10.5	16.3	18.7	22.0	22.6	19.5	15.1	6.5	10.4	16.3	18.7	22.0	22.6	19.5	15.1	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
2013	7.6	12.6	17.1	20.2	23.2	21.9	19.3	13.5	7.5	12.4	16.9	20.1	23.1	21.9	19.3	13.6	0.0	0.2	0.2	0.1	0.1	0.0	0.0	-0.1
2014	9.5	13.2	17.6	20.5	23.6	22.5	19.3	15.1	9.5	12.9	17.7	20.5	23.5	22.5	19.4	15.1	0.0	0.3	0.0	0.0	0.1	0.0	0.0	0.0
2015	10.5	13.1	17.0	21.6	23.3	21.8	18.8	15.1	10.2	13.0	16.9	21.6	23.3	21.8	18.8	15.1	0.4	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2016	8.3	13.5	17.0	20.3	21.6	22.2	18.9	14.0	8.4	13.4	16.9	20.4	21.5	22.2	18.9	14.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
2017	7.8	10.9	15.7	20.5	23.1	22.9	19.5	13.6	7.8	10.9	15.9	20.5	23.0	22.9	19.5	13.6	0.0	0.0	-0.1	0.0	0.1	0.0	0.0	-0.1
Ave.	**8.0**	**11.1**	**14.9**	**18.9**	**22.0**	**22.2**	**19.1**	**14.0**	**7.9**	**10.9**	**14.8**	**18.7**	**21.9**	**22.1**	**19.1**	**14.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.0**	**0.0**	**0.0**
Min.	**5.9**	**8.1**	**12.2**	**16.6**	**20.4**	**20.7**	**17.0**	**12.1**	**6.0**	**8.1**	**12.1**	**16.5**	**20.1**	**20.7**	**16.9**	**12.1**	**-0.1**	**-0.1**	**-0.3**	**-0.6**	**-0.1**	**-0.1**	**-0.1**	**-0.2**
Max.	**10.5**	**13.5**	**18.0**	**21.6**	**23.6**	**23.5**	**20.8**	**15.6**	**10.2**	**13.4**	**17.7**	**21.6**	**23.5**	**23.5**	**20.8**	**15.5**	**0.9**	**1.0**	**1.2**	**0.7**	**0.7**	**0.5**	**0.2**	**0.2**

[1] Historical Temperature (℃)
[2] Proposed Action Temperature (℃)
[3] Temperature (℃) Difference

Table A8-6. A comparison of daily average Klamath River water temperatures at rivermile 136.8 (just below the confluence with the Scott River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
1980	8.4	10.5	14.6	17.3	22.5	21.9	18.7	13.9	8.4	10.5	14.6	17.3	22.5	21.9	18.7	13.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
1981	8.4	12.1	15.1	20.5	23.4	22.9	19.6	13.4	8.4	11.9	15.3	19.3	22.7	23.1	19.8	13.6	0.0	0.2	-0.2	1.1	0.7	-0.3	-0.2	-0.2
1982	7.0	8.3	14.4	18.2	21.7	21.8	18.4	12.5	7.0	8.3	14.4	18.3	21.2	21.9	18.3	12.4	0.0	0.0	0.0	-0.1	0.5	-0.2	0.1	0.1
1983	8.4	8.7	13.7	18.2	19.5	21.2	18.4	13.2	8.4	8.7	13.6	18.4	19.8	21.6	18.4	13.1	0.0	0.1	0.0	-0.3	-0.3	-0.4	0.0	0.1
1984	8.2	9.8	13.7	18.3	23.1	22.4	18.8	12.1	8.2	9.8	13.7	18.3	22.9	22.5	18.8	12.0	0.0	0.0	0.0	0.0	0.2	-0.1	0.0	0.1
1985	6.9	12.4	15.1	20.0	23.8	22.4	17.3	12.2	6.7	12.5	15.2	19.4	22.8	22.4	17.3	12.2	0.1	-0.1	-0.1	0.6	1.0	0.0	0.0	0.0
1986	10.2	11.9	14.1	21.0	23.0	23.0	18.4	12.4	10.1	11.9	14.3	20.3	22.6	23.3	18.2	12.4	0.1	0.0	-0.1	0.7	0.4	-0.2	0.3	0.0
1987	7.9	12.4	16.3	21.3	22.5	22.3	19.1	15.0	8.0	12.2	16.6	20.6	22.2	22.4	19.0	15.0	0.0	0.2	-0.3	0.7	0.3	-0.1	0.2	0.0
1988	8.9	12.2	14.1	17.9	23.7	22.9	19.7	14.7	8.8	12.3	14.4	17.4	22.6	23.0	19.7	14.7	0.1	0.0	-0.3	0.5	1.0	0.0	0.0	0.0
1989	7.0	12.4	15.0	20.2	22.7	21.6	18.4	13.2	6.9	12.2	15.0	19.6	21.7	21.7	18.3	13.1	0.1	0.2	0.0	0.6	1.0	-0.1	0.0	0.0
1990	7.7	13.5	15.1	19.0	23.5	23.1	19.5	13.6	7.5	13.4	15.4	18.1	22.7	23.0	19.5	13.6	0.2	0.1	-0.3	0.9	0.8	0.1	0.0	0.0
1991	7.5	11.4	13.7	18.4	23.9	23.1	20.5	15.5	7.5	10.7	13.4	17.5	22.1	22.5	20.4	15.6	0.1	0.7	0.2	0.9	1.8	0.6	0.1	-0.1
1992	10.5	12.7	19.4	22.3	24.7	24.8	19.7	14.7	9.2	12.4	18.5	20.8	23.4	23.5	19.9	14.8	1.2	0.2	0.9	1.5	1.3	1.3	-0.2	-0.1
1993	8.3	10.1	14.5	18.0	21.3	21.4	19.1	14.2	8.4	10.1	14.5	17.9	20.6	21.6	19.0	14.2	-0.1	0.0	0.0	0.2	0.7	-0.3	0.1	0.0
1994	9.7	12.8	16.5	21.0	25.0	23.7	19.7	14.1	8.8	11.7	16.3	19.5	23.2	23.1	19.7	14.1	0.8	1.1	0.2	1.5	1.8	0.5	0.0	0.0
1995	8.3	10.0	14.1	17.7	22.2	22.2	19.5	13.9	8.3	10.0	14.0	17.7	22.1	22.5	19.6	13.7	0.1	0.0	0.1	0.0	0.1	-0.3	0.0	0.1
1996	8.0	11.4	14.4	19.2	23.2	23.2	19.0	13.7	8.1	11.4	14.3	18.9	23.7	23.3	19.0	13.8	-0.1	0.0	0.0	0.3	-0.5	-0.1	0.0	0.0
1997	8.9	11.5	16.5	19.7	22.8	22.7	19.8	14.1	8.8	11.5	16.2	19.4	22.6	22.8	20.0	14.0	0.1	0.0	0.3	0.3	0.1	-0.1	-0.2	0.1
1998	8.2	9.3	12.5	17.1	23.1	24.5	21.2	14.1	8.1	9.3	12.5	17.1	23.0	24.4	21.2	14.0	0.1	0.1	0.0	0.0	0.1	0.1	0.0	0.1
1999	6.6	8.9	13.2	17.7	22.4	22.6	20.2	15.2	6.7	8.9	12.9	17.6	22.6	22.4	20.3	15.2	-0.1	0.0	0.3	0.1	-0.1	0.2	-0.1	0.0
2000	7.8	11.9	14.5	19.4	22.3	23.3	19.5	14.1	7.8	11.9	14.6	19.5	22.7	23.4	19.5	14.1	0.0	0.0	0.0	0.0	-0.4	-0.1	0.0	0.0
2001	9.0	11.2	16.6	20.3	22.9	23.4	20.7	15.4	8.5	11.1	16.8	20.4	23.2	23.6	20.7	15.3	0.5	0.0	-0.2	-0.1	-0.3	-0.2	0.0	0.0
2002	8.1	11.9	14.6	19.4	24.4	24.0	20.5	14.5	8.1	11.8	14.6	19.4	24.1	23.8	20.6	14.5	0.0	0.0	0.1	0.1	0.3	0.3	-0.1	0.0
2003	8.8	10.0	13.6	20.6	24.4	23.7	21.0	15.6	8.7	10.0	13.7	20.5	24.0	23.7	20.8	15.6	0.0	0.0	-0.1	0.1	0.4	0.0	0.1	0.0
2004	10.1	12.3	15.1	19.7	24.3	24.2	20.1	14.3	9.7	12.2	15.0	19.3	23.1	23.9	20.1	14.3	0.4	0.0	0.1	0.5	1.2	0.3	-0.1	0.0
2005	9.4	11.4	14.3	17.7	22.9	23.9	20.1	14.0	9.4	11.5	14.4	17.6	22.4	24.0	20.0	13.8	0.0	0.0	-0.2	0.1	0.5	-0.2	0.1	0.2

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
2006	6.1	9.5	16.3	19.1	23.8	23.1	19.1	13.4	6.2	9.5	16.3	19.3	24.2	23.4	19.3	13.4	0.0	0.0	0.0	-0.2	-0.4	-0.3	-0.2	0.0
2007	8.1	12.4	16.1	20.5	23.0	22.8	19.2	12.9	8.1	12.3	15.9	20.5	23.1	23.0	19.3	12.9	0.0	0.1	0.2	0.0	-0.1	-0.2	-0.1	0.1
2008	7.3	10.5	14.2	19.0	23.6	23.0	19.8	13.9	7.0	10.5	14.2	19.0	23.5	22.9	19.9	13.9	0.2	0.0	0.0	0.0	0.1	0.1	-0.1	0.1
2009	8.0	12.1	16.0	20.8	24.3	23.2	20.0	13.9	7.8	11.9	15.9	20.7	24.3	23.3	20.1	13.8	0.2	0.2	0.1	0.1	0.0	-0.1	-0.1	0.1
2010	8.5	10.5	13.2	16.1	23.5	23.1	18.8	14.3	8.5	10.3	13.2	16.3	23.1	23.1	18.8	14.5	0.0	0.2	0.0	-0.2	0.4	0.0	0.0	-0.2
2011	6.7	9.7	13.0	16.1	21.4	23.3	20.3	14.4	6.6	9.7	13.0	16.0	21.5	23.8	20.5	14.5	0.1	0.0	0.0	0.1	-0.1	-0.5	-0.2	-0.1
2012	6.8	10.9	16.1	19.2	22.9	23.5	20.1	15.0	6.6	10.9	16.1	19.0	23.2	23.7	20.1	15.0	0.1	0.0	0.0	0.1	-0.2	-0.2	0.0	0.0
2013	8.3	12.9	17.3	21.1	24.8	22.7	19.7	13.6	8.2	12.8	17.2	21.3	24.4	22.7	19.7	13.7	0.0	0.2	0.1	-0.2	0.4	0.0	0.0	0.0
2014	9.7	13.7	18.8	21.8	25.2	23.5	19.8	15.2	9.7	13.4	18.9	21.6	24.6	23.5	19.8	15.2	0.0	0.3	-0.1	0.2	0.7	0.1	0.0	0.0
2015	10.9	13.7	18.2	22.6	24.7	22.9	19.3	15.2	10.6	13.6	18.0	22.7	24.7	22.8	19.3	15.2	0.3	0.1	0.2	0.0	0.1	0.1	0.0	0.0
2016	8.4	13.7	16.4	21.0	22.6	23.3	19.4	13.5	8.5	13.6	16.4	20.7	22.4	23.3	19.4	13.5	0.0	0.1	0.0	0.3	0.2	0.0	0.0	0.0
2017	8.0	10.7	14.6	19.3	23.9	23.6	19.8	13.6	8.1	10.7	14.5	19.2	24.2	23.6	19.8	13.6	-0.1	0.0	0.1	0.1	-0.4	0.0	-0.1	0.0
Ave.	**8.3**	**11.4**	**15.1**	**19.4**	**23.2**	**23.0**	**19.5**	**14.0**	**8.2**	**11.2**	**15.1**	**19.1**	**22.9**	**23.0**	**19.6**	**14.0**	**0.1**	**0.1**	**0.0**	**0.3**	**0.3**	**0.0**	**0.0**	**0.0**
Min.	**6.1**	**8.3**	**12.5**	**16.1**	**19.5**	**21.2**	**17.3**	**12.1**	**6.2**	**8.3**	**12.5**	**16.0**	**19.8**	**21.6**	**17.3**	**12.0**	**-0.1**	**-0.1**	**-0.3**	**-0.3**	**-0.5**	**-0.5**	**-0.2**	**-0.2**
Max.	**10.9**	**13.7**	**19.4**	**22.6**	**25.2**	**24.8**	**21.2**	**15.6**	**10.6**	**13.6**	**18.9**	**22.7**	**24.7**	**24.4**	**21.2**	**15.6**	**1.2**	**1.1**	**0.9**	**1.5**	**1.8**	**1.3**	**0.3**	**0.2**

[1] Historical Temperature (℃)
[2] Proposed Action Temperature (℃)
[3] Temperature (℃) Difference

Table A8-7. A comparison of daily average Klamath River water temperatures at rivermile 62.5 (just below the confluence with the Salmon River) modeled under the Proposed Action and historical conditions, averaged by month for March – October 1981 – 2014. Negative numbers in the columns reporting differences refer to a reduction in temperature under the Proposed Action, relative to those under historical conditions.

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
1980	8.2	10.5	13.8	16.4	21.7	22.4	18.8	14.0	8.2	10.5	13.8	16.4	21.7	22.4	18.8	14.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1
1981	8.4	11.6	15.1	19.7	23.3	23.6	19.7	13.0	8.4	11.4	14.9	19.7	23.0	23.3	19.8	13.2	0.0	0.2	0.2	0.0	0.3	0.3	0.0	-0.2
1982	7.2	8.4	13.8	17.4	20.7	22.2	18.4	12.9	7.2	8.4	13.9	17.5	20.7	22.1	18.5	12.8	0.0	0.0	-0.1	-0.1	-0.1	0.1	0.0	0.0
1983	8.4	8.9	13.6	17.1	18.7	21.5	18.6	13.5	8.4	8.9	13.6	17.3	18.8	21.4	18.6	13.6	0.0	0.0	0.0	-0.2	-0.1	0.1	0.0	-0.1
1984	8.6	9.7	13.2	17.3	22.3	22.7	18.9	12.2	8.6	9.7	13.2	17.2	22.4	22.6	19.0	12.2	0.0	0.0	0.0	0.1	-0.1	0.0	-0.1	0.1
1985	7.0	12.2	14.5	19.5	23.6	22.6	17.5	12.8	7.0	12.3	14.4	19.5	23.6	22.6	17.5	12.8	0.1	-0.1	0.0	0.0	0.0	0.0	0.0	0.0
1986	10.3	11.6	13.5	20.5	22.4	23.8	18.0	13.1	10.2	11.6	13.5	20.4	22.5	23.8	17.8	13.2	0.1	0.0	0.0	0.1	-0.1	0.0	0.2	-0.1
1987	7.9	12.4	16.5	20.4	22.4	23.2	19.3	15.1	7.9	12.2	16.3	20.6	22.5	23.2	19.2	15.2	0.0	0.2	0.2	-0.2	0.0	0.0	0.1	-0.1
1988	8.9	11.9	13.8	16.7	23.1	23.4	20.0	15.0	8.7	11.8	13.7	16.9	22.9	23.2	19.9	15.0	0.2	0.1	0.0	-0.1	0.2	0.1	0.1	0.0
1989	7.3	12.7	14.5	19.4	22.0	22.2	18.8	13.5	7.3	12.6	14.5	19.4	22.1	22.2	18.9	13.5	0.1	0.2	-0.1	0.0	-0.1	0.0	-0.1	0.0
1990	8.4	13.5	14.7	17.4	23.6	23.3	19.8	13.8	8.3	13.3	14.6	17.6	23.4	23.3	19.9	13.9	0.2	0.2	0.0	-0.2	0.2	0.1	0.0	0.0
1991	7.6	11.0	13.4	17.8	24.0	23.4	21.3	15.6	7.4	10.7	13.3	17.6	23.3	23.1	21.1	15.7	0.2	0.3	0.1	0.2	0.7	0.4	0.1	0.0
1992	11.1	12.8	19.4	22.0	24.3	25.0	20.4	14.9	10.7	12.7	19.0	21.7	23.9	24.1	20.3	14.9	0.4	0.1	0.5	0.3	0.4	0.9	0.1	-0.1
1993	9.0	10.1	14.1	17.3	20.6	22.3	19.5	14.4	9.1	10.1	14.2	17.1	20.6	22.3	19.7	14.5	-0.1	0.0	-0.1	0.1	-0.1	0.0	-0.2	0.0
1994	10.2	12.6	16.0	20.3	25.4	23.9	20.2	13.7	9.9	12.0	16.0	20.2	24.8	23.5	20.2	13.8	0.3	0.6	0.1	0.1	0.6	0.4	0.0	-0.1
1995	8.2	10.0	13.8	16.9	21.9	22.5	19.9	14.0	8.2	10.0	13.8	16.9	21.8	22.4	20.0	14.1	0.1	-0.1	0.0	0.0	0.1	0.1	-0.1	-0.1
1996	8.3	11.1	14.0	18.5	23.8	23.7	19.2	13.9	8.4	11.0	14.0	18.4	23.7	23.6	19.2	14.0	-0.1	0.1	0.0	0.1	0.1	0.1	-0.1	-0.1
1997	9.2	11.4	16.5	19.3	22.5	23.2	20.1	14.2	9.1	11.3	16.3	19.3	22.6	23.1	20.1	14.1	0.1	0.1	0.2	0.0	-0.1	0.0	0.0	0.1
1998	8.6	9.6	12.6	17.1	22.5	24.1	21.0	14.1	8.5	9.5	12.6	17.2	22.5	24.0	21.1	14.1	0.1	0.1	0.0	0.0	0.0	0.0	-0.1	0.0
1999	6.8	9.5	13.1	17.2	21.8	22.3	20.3	15.2	7.0	9.5	13.0	17.1	21.9	22.4	20.5	15.1	-0.1	0.0	0.1	0.1	0.0	0.0	-0.1	0.0
2000	8.1	12.1	14.4	19.8	22.8	23.8	19.6	14.1	8.1	12.2	14.5	19.9	22.7	23.7	19.7	14.2	0.0	-0.1	-0.1	-0.1	0.1	0.1	-0.1	-0.1

Year	[1]Mar.	[1]Apr.	[1]May	[1]Jun.	[1]Jul.	[1]Aug.	[1]Sep.	[1]Oct.	[2]Mar.	[2]Apr.	[2]May	[2]Jun.	[2]Jul.	[2]Aug.	[2]Sep.	[2]Oct.	[3]Mar.	[3]Apr.	[3]May	[3]Jun.	[3]Jul.	[3]Aug.	[3]Sep.	[3]Oct.
2001	9.8	11.1	17.2	20.2	24.5	24.3	20.9	15.2	9.1	11.1	17.5	21.0	24.5	24.2	20.9	15.0	0.6	0.1	-0.3	-0.8	0.0	0.1	0.0	0.1
2002	8.0	12.2	13.9	19.5	24.6	24.1	20.6	14.1	8.0	12.2	13.9	19.5	24.7	24.0	20.7	14.2	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1
2003	8.7	9.3	12.4	18.7	23.9	23.6	20.8	15.6	8.6	9.3	12.4	18.7	24.0	23.7	20.8	15.7	0.1	0.0	0.0	0.0	-0.1	0.0	0.0	0.0
2004	10.8	11.1	13.5	18.6	23.7	24.0	20.0	13.7	10.4	11.1	13.5	18.6	23.6	24.0	20.0	13.9	0.3	0.0	0.0	-0.1	0.1	0.0	0.0	-0.2
2005	10.3	10.7	14.0	16.5	23.3	24.4	19.8	13.9	10.2	10.7	14.1	16.5	23.2	24.4	19.7	13.9	0.1	-0.1	-0.1	0.0	0.1	0.0	0.0	0.0
2006	6.5	9.8	16.3	18.3	23.6	23.0	19.3	13.3	6.5	9.9	16.3	18.3	23.6	22.9	19.3	13.3	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0
2007	8.2	11.2	16.0	20.2	23.9	23.6	19.6	13.1	8.1	11.3	15.8	20.4	23.9	23.6	19.6	13.1	0.0	-0.1	0.2	-0.2	0.0	0.0	0.0	0.0
2008	7.5	10.1	14.5	18.0	23.0	23.3	20.0	13.9	7.4	10.1	14.5	18.1	23.1	23.2	20.1	13.9	0.1	0.0	0.1	-0.1	-0.1	0.0	-0.1	0.0
2009	8.0	11.0	15.3	19.9	25.0	23.7	20.4	13.6	8.0	11.0	15.2	19.9	25.1	23.7	20.5	13.6	0.1	0.0	0.0	-0.1	0.0	0.0	0.0	0.0
2010	8.3	9.4	11.1	14.4	21.8	22.9	18.9	14.1	8.3	9.3	11.2	14.4	21.9	22.8	18.9	14.2	0.0	0.0	-0.1	-0.1	-0.2	0.0	0.0	0.0
2011	7.0	9.4	11.7	13.9	19.8	23.6	20.8	14.0	6.9	9.4	11.4	13.8	19.8	23.5	20.8	14.0	0.0	0.0	0.2	0.2	0.0	0.1	0.0	-0.1
2012	6.8	9.9	14.5	17.7	22.8	23.9	20.3	14.6	6.7	9.9	14.6	17.6	22.8	23.9	20.3	14.6	0.1	0.0	-0.1	0.0	0.1	0.0	0.0	0.0
2013	8.2	11.6	16.0	21.1	25.5	22.9	19.6	13.2	8.2	11.6	16.1	21.1	25.4	22.9	19.6	13.2	0.1	0.0	0.0	0.1	0.0	0.0	0.0	-0.1
2014	10.1	12.7	17.7	22.1	25.5	24.0	20.3	15.0	10.1	12.5	17.8	22.3	25.8	24.1	20.2	15.0	0.0	0.2	0.0	-0.2	-0.3	0.0	0.0	0.0
2015	10.8	13.5	17.9	23.8	25.0	23.1	19.6	15.2	10.5	13.3	17.8	23.8	25.2	23.4	19.6	15.2	0.3	0.1	0.1	0.0	-0.2	-0.2	0.0	0.0
2016	8.6	12.0	15.2	20.4	23.5	24.0	19.6	12.8	8.6	12.0	15.2	20.4	23.5	24.1	19.6	12.8	0.0	0.0	0.0	0.0	0.0	-0.1	0.0	0.0
2017	8.0	10.1	12.7	17.5	23.5	24.0	19.6	13.4	8.1	10.1	12.5	17.3	23.5	24.0	19.6	13.4	0.0	0.0	0.3	0.1	0.0	0.0	0.0	0.0
Ave.	**8.5**	**11.0**	**14.6**	**18.7**	**23.1**	**23.3**	**19.7**	**14.0**	**8.4**	**11.0**	**14.6**	**18.7**	**23.0**	**23.3**	**19.7**	**14.0**	**0.1**	**0.1**	**0.0**	**0.0**	**0.0**	**0.1**	**0.0**	**0.0**
Min.	**6.5**	**8.4**	**11.1**	**13.9**	**18.7**	**21.5**	**17.5**	**12.2**	**6.5**	**8.4**	**11.2**	**13.8**	**18.8**	**21.4**	**17.5**	**12.2**	**-0.1**	**-0.1**	**-0.3**	**-0.8**	**-0.3**	**-0.2**	**-0.2**	**-0.2**
Max.	**11.1**	**13.5**	**19.4**	**23.8**	**25.5**	**25.0**	**21.3**	**15.6**	**10.7**	**13.3**	**19.0**	**23.8**	**25.8**	**24.4**	**21.1**	**15.7**	**0.6**	**0.6**	**0.5**	**0.3**	**0.7**	**0.9**	**0.2**	**0.1**

[1] Historical Temperature (℃)
[2] Proposed Action Temperature (℃)
[3] Temperature (℃) Difference