Long-Term Operation – Biological Assessment

Appendix AB-I – Old and Middle River Flow Management

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Appendix I Old and Middle River Flow Management

I.1 Introduction

This appendix analyses the management of exports for Old and Middle River (OMR) reverse flows to reduce entrainment stressors on winter-run and spring-run Chinook salmon, steelhead, and Delta smelt.

Within the area of the Sacramento–San Joaquin Delta (Delta) affected by exports, survival and behavior of fish depend, in part, on actions by many parties, including the United States Department of the Interior, Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR), the State Water Resources Control Board, in-Delta diverters, flood projects, and non-project upstream releases. Export operations at the C.W. Bill Jones Pumping Plant and Harvey O. Banks Pumping Plant are anticipated to entrain fish into the central and south Delta. The Central Valley Project (CVP) operates the Tracy Fish Collection Facility and the State Water Project (SWP) operates the Skinner Delta Fish Protection Facility (collectively "Salvage Facilities") to monitor entrainment and salvage fish before they reach the pumps. The effectiveness of capturing and the survival of fish through salvage (salvage efficiency) can be high for salmonids, but very low or zero for smelt. Net flows in Old and Middle Rivers provide a surrogate for how exports influence hydrodynamics in the Delta. Negative flow rates in Old and Middle Rivers indicate a net direction towards export facilities, and positive flow rates indicate a net direction towards exiting the Delta from the South Delta. The management of exports for Old and Middle Rivers reverse flows, in combination with other environmental variables, can minimize or avoid adverse effects on the migration of fish and reduce or avoid entrainment at the export facilities.

I.2 Initial Alternatives Report

An Initial Alternative Report (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT)* developed potential options for the long-term operation of the CVP and SWP to inform alternative formulation by seeking the bounds of potential decisions and a contrast between approaches. Initial alternative options generally considered flow actions, non-flow actions, and the use of real-time information. Management questions, analyses, and findings provided information for further evaluation in the public draft Environmental Impact Statement (EIS) alternatives.

I.2.1 Management Questions

Reclamation's management questions for the formulation of an alternative include:

Should the onset of OMR management be based on real-time conditions, or does a fixed schedule based on the historical migration timing protect species with limited impacts on water supply?

How does the magnitude of different OMR restrictions change the relative risk of species entrainment at the export facilities and in the central and/or south Delta?

How does the duration of temporary OMR restrictions change the entrainment of species within the influence of export facilities?

Does an offramp of OMR management based on real-time conditions protect species and improve water supply performance, or does a fixed schedule protect species with limited impacts on water supply?

What is the effect of different levels of near- and far-field entrainment on population viability?

I.2.2 Initial Analyses

Reclamation solicited input for the knowledge base paper, Old and Middle River Reverse Flow Management – Smelt, Chinook Salmon, and Steelhead Migration and Survival.

Reclamation completed an exhaustive literature and data review to consider on-ramp and offramp strategies for Old and Middle River reverse flow management. It evaluated loss and entrainment processes and mechanisms using various relationships between loss and operational and environmental covariates.

Reclamation conducted Delta Simulation Model II (DSM2) simulations for Initial Alternative 1, Initial Alternative 2, Initial Alternative 3, followed by Particle Track Model (PTM) models for two types of particle behaviors: larval and adult fish. It also used these DSM2 simulations to model juvenile salmonid survival under a broad range of OMR reverse flow conditions. Model assumptions and results of these initial alternatives are summarized in 1 of Appendix AB-I (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT)*.

I.2.3 Initial Findings

Should the onset of OMR management be based on real-time conditions, or does a fixed schedule based on the historical migration timing protect species with limited impacts on water supply?

Monitoring data indicate that >5% of winter-run sized Chinook salmon have passed real-time Delta entry or salvage much more frequently than a calendar-based schedule starting January 1st (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT); Section 9.4)* See:

- At Knights Landing, 5% of fish observed occurred as early as September 16, with 17 of 19 (89%) years showing >5% of passage before January 1
- In the Sacramento Trawl, >5% of fish observed there occurred as early as October 8, with 22 of 25 (88%) years showing >5% of passage before January 1

- At Chipps Island 5% of fish observed in monitoring are detected as early as December 6, with 9 of 25 (36%) years showing >5% passage before January 1
- The triggers for an integrated early winter pulse protections were observed as early as December 7 in the past 25 years, with 3 of 6 (50%) years when these triggers were exceeded occurring before January 1
- Onset of OMR management based on >5% salvage occurred as early as December 6 (prior to the 2009 National Marine Fisheries Service (NMFS) Biological Opinion), with 9 of 25 (36%) years showing >5% passage before January 1

Using a fixed schedule based on the historical migration timing for Delta entry at Knights Landing or Sacramento Trawl rather than one based on real-time conditions may reduce OMR management flexibility prior to January 1 (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Section 9.4)*

A schedule based on >5% presence at Chipps Island or salvage rather than a fixed January 1 onset may increase OMR management impacts on winter-run Chinook salmon entrainment

How does the magnitude of different OMR restrictions change the relative risk of species entrainment at the export facilities and into the central and/or south Delta?

Delta PTM under varying OMR conditions: range of particle fates and particle export fates (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling)*

Under most circumstances in December, the overall percentage of particles entrained at the export facilities varies by OMR flow condition specified by a sensitivity analysis.

- As OMR reverse flow decreases, the percentage of particles entrained at the exports incrementally decreases (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling, Figure I.1-2)*.
- The percentage of particles that exit the Delta decreases as the OMR reverse flow condition incrementally increases (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling, Figure I.1-10)*.

Under most circumstances in December, regions close to the export facility (Central Delta) observed varying percentage of particles entrained at the export facilities or passing Chipps Island regardless of OMR flow conditions. This result is different compared to regions further away from the export facilities (Sacramento River) (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling, Figure I.1-6)*.

Overall, the location of particle injection can provide limits on the entrainment and residence times of particles.

- As OMR flow decreases, the percentage of particles entrained at the exports or exiting Chipps overlap (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling; I.2.2 Results)*.
- The percentage of particles that are entrained is different than the percent of particles exiting the Delta for regions further away (Sacramento River vs Central Delta) (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 1: Delta Particle Tracking Modeling; I.2.2 Results)*.

Delta PTM under varying OMR conditions: conclusions

No Action Alternative (NAA) particle entrainment at exports is most similar to the OMR flow condition of -5,000 cfs in December

NAA particle entrainment is between the OMR flow condition of -4,000 cfs and -5,000 cfs in January and February

NAA particle entrainment is similar to the OMR flow condition of -3,000 cfs in March

Zone of Influence

Gaussian Kernel Density Estimation (KDE) plots used to assess the effect of pumping for varying OMR flow conditions and proportional overlap maps illustrate the estimated effects of pumping under a range of OMR flow conditions (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 2:Zone of Influence Analysis; I.3.4.2 Velocity KDE Plots; I.3.4.3 Zone of Influence Maps)*.

Multiple factors affect the proportional overlap and velocity differential values (e.g., proximity to the pumps, orientation of flow relative to the pumps, influence of riverine flow, preexisting flow and/or velocity patterns).

Increasingly negative OMR flows increase the spatial extent of the zone of influence 0.75 contour in a nested manner for the months of March through June. This pattern does not hold in earlier months (January and February) (*LTO 2021 Consultation Initial Alternatives Appendix I – OMR 20220127 DRAFT; Attachment 2:Zone of Influence Analysis; I.3.4.4 Contour Maps)*.

Biological implications of varying OMR flow conditions are not reflected in results because the water velocity threshold that alters fish movements is unknown.

Does the duration of temporary OMR restrictions change the entrainment of species within the influence of export facilities?

Based on the expanded salvage autocorrelation analysis and other studies (Tillotson et al. 2022), it seems likely that a change in fish observations in salvage due to changes in OMR would not be instantaneous and may take up to seven days.

It is unclear how long temporary OMR restrictions based on species loss triggers need to be for re-routing fish out of the central and south Delta. We have no evidence that the duration of a temporary OMR restriction changes farfield effects. To reduce routing of fish species into the interior Delta requires a proactive approach.

Does an offramp of OMR management based on real-time conditions protect species and improve water supply performance, or does a fixed schedule protect species with limited impacts on water supply?

Real-time fish monitoring data indicates 100% of winter-run Chinook salmon and steelhead have exited the Delta earlier than June 30 (calendar-based offramp)

Temperature-based offramp criteria at Mossdale and Prisoner Point are met by June 30th in some years, but not all.

- In the years since 2012, the Mossdale temperature-based offramp criteria was not met in 2017 and was not reached in 2019 until July 15th
- The Prisoner's Point temperature record began in 2020. In the years 2020 – 2022, the Prisoner's Point temperature-based offramp criteria was met in each year

Using a fixed schedule based on the historical migration timing for Delta exit at Chipps Island rather than a June 30 offramp may increase OMR management flexibility with similar fish protection

A schedule-based temperature criteria rather than a real-time fishery monitoring offramp may increase water supply impacts without benefiting steelhead entrainment protection

What is the effect of different levels of near- and far-field entrainment on population viability?

There is not a tool to evaluate this.

I.2.4 Subsequent Considerations

Subsequent review of the PTM in the Initial Alternatives Report for larval smelt found that the injection point of particles was more significant than OMR at -5,000 cfs or more positive on the amount of entrainment at the facilities. Particles entering the Delta from the San Joaquin region arrive at the facility in similar large quantities regardless of OMR level. Particles entering the Delta from the Sacramento Region arrive at the facilities in similar quantities regardless of OMR level. For central Delta injection points, variation across OMR -3,000 cfs to -7,000 cfs results in a change of ~10% in fish arriving at the facilities or exiting the Delta.

The Salmon Scoping Team Report found juvenile salmon and steelhead survival in different regions of the Delta is variable. The Salmonid Scoping Team found a relationship between inflow and survival, but did not find a relationship between OMR and through-Delta survival. At OMR levels less than -5,000 cfs where the changes in hydrodynamics as a result of exports are small relative to tides and inflow, the effects on survival are small. Inflow, tides, and export hydrodynamics vary by region within the Delta. The influence of exports on fish survival depends on the hydraulic footprint of the facilities. Results for the Delta Passage Model for Sacramento origin fish also found survival to be linked to inflows, not OMR between -3,000 cfs and -7,000 cfs. Additional analyses were done to review outmigration period protection for steelhead by evaluating weekly and seasonal loss, presence of steelhead, and environmental variables influencing steelhead presence and loss.

I.3 Public Draft EIS Scenarios

Under the National Environmental Policy Act, Reclamation compares action alternatives to a “no action” alternative. Under the Endangered Species Act, Reclamation’s discretionary actions over an environmental baseline determine the effects on listed species. No single environmental baseline to evaluate the effects under the Endangered Species Act (ESA) or impacts under NEPA. ESA requires a comparison to the environmental baseline which is informed by ROR and Alt 1. NEPA requires a comparison to NA.

I.3.1 Exploratory 1

No OMR restrictions, no exports, Delta Cross Channel (DCC) gate closed.

I.3.2 Exploratory 3

No OMR restrictions, no Delta exports, DCC gate closed.

I.3.3 No Action

OMR restrictions per 2020 Record of Decision (ROD) and 2020 Incidental Take Permit (ITP), Delta exports, DCC gate operations per 2020 ROD, D-1641 outflow.

I.3.4 Alternative 1 - WQCPs

D-1641 export/inflow (E/I) ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. No OMR restriction, no additional DCC gate fish protection closures.

I.3.5 Alternative 2 – Multi-Agency Consensus

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, additional DCC gate fish protection closures.

I.3.5.1 Winter-Run Early Season Loss Threshold

Genetically confirmed winter-run Chinook salmon have been observed in the Delta during the months of November and December (Brandes et al. 2021), though November and December observations of genetically verified winter-run Chinook salmon at the salvage facilities have not occurred in over a decade (Kevin Reece, personal communications). In the 2020 ITP for the SWP, a static daily loss threshold for winter-run sized Chinook salmon and larger fish was set for the months of November and December to reduce entrainment of these early migrating fish towards the pumping facilities (ITP 2020). These daily thresholds were loss of 6 juvenile winter-run sized Chinook salmon or larger at the salvage facilities for November, and 26 juvenile winter-run sized Chinook salmon or larger for December. These November and December thresholds were determined based on data of winter-run sized or larger juvenile Chinook salmon, and as such, were not necessarily based on true genetic winter-run Chinook salmon (Harvey et al. 2014). To calculate these thresholds in the ITP, historical salvage daily data with zero

Chinook salmon observations were also removed and the November loss threshold was based on data from a single date in November of 2010 in which two juvenile Chinook Salmon were observed at salvage. There was no consideration as to how these thresholds link back to the winter-run Chinook salmon population number and the portion of these larger Chinook salmon that are true genetic winter-run. To develop limits that are more responsive to interannual changes in juvenile production or population, November-December winter-run Chinook salmon data from upstream of the Delta can potentially be used. Furthermore, as with the annual loss threshold, new genetic markers can be used to produce genetic information of salvaged Chinook salmon in near real-time during the months of November and December.

Research has been conducted looking into loss of Chinook salmon and other populations of native estuarine species to diversions in the San Francisco Bay-Delta and to the State and Federal fish facilities. Jahn and Kier (2020) concluded estimates of loss to diversions and the fish facilities may not reliable and recommend both an improvement to currently existing loss estimation equations and studies (e.g., predation near the fish facilities) to increase accuracy and precision of estimates. Alternative 2 was developed using the California Department of Fish and Wildlife (CDFW) (2020) calculation method for loss.

I.3.5.2 Winter-Run Total Annual Loss Threshold

The purpose of the total annual loss threshold is to avoid loss exceeding a level that may impact the number of juveniles existing the Delta and potentially affecting the number of adults returning to spawn. This threshold is a fraction of the juvenile production estimate calculated by NMFS annually. It is uncertain whether the level of facility loss may affect through Delta survival, but it is hypothesized that higher mortality associated with interior routing of juvenile salmonid, predation, and poor habitat that influence rearing, sheltering, and outmigrating juvenile salmonids are reflected by the magnitude of facility loss. Thus, it is hypothesized total annual loss is an indicator of overall entrainment effects on juvenile outmigration survival.

I.3.5.3 Steelhead Loss Threshold

The purpose of steelhead loss threshold is to avoid loss exceeding a level that may impact the number of juveniles existing the Delta and potentially affecting the number of adults returning to spawn. The is uncertainty about what level of loss may be appropriate to protect abundance, life history diversity, and distribution.

A hypothesis that weekly distributed loss threshold may reduce impacting juvenile steelhead outmigration was examined. Weekly proportions of Delta entrance at Sacramento and San Joaquin monitoring locations and exit at Chipps Island were examined (Table I-1).

Table I-1. Water years 2017 through 2021 historical cumulative percent presence of genetically verified winter-run Chinook salmon entering the Delta (Sherwood Harbor Trawl and Mossdale Trawl), exiting the Delta (Chipps Island Trawl), remaining to pass Chipps Island (100% minus exiting the Delta), and present in the Delta (entering the Delta minus exiting the Delta). Data are grouped by week starting on January 1st, with steelhead presence in monitoring occurring before January 1st included in the first week of the cumulative presence.

Week	Cumulative % based on Mossdale and Sac counts entering the Delta	Historical Cumulative exiting the Delta	Historical Remaining to Pass Chipps	Historical Present In Delta
1/1-1/7	1%	1%	99%	0%
1/8-1/14	2%	1%	99%	1%
1/15-1/21	3%	3%	97%	1%
1/22-1/28	4%	3%	97%	2%
1/29-2/4	7%	4%	96%	3%
2/5-2/11	10%	8%	92%	2%
2/12-2/18	14%	11%	89%	3%
2/19-2/25	17%	13%	87%	4%
2/26-3/4	19%	18%	82%	2%
3/5-3/11	20%	21%	79%	-1%
3/12-3/18	23%	23%	77%	0%
3/19-3/25	24%	28%	72%	-4%
3/26-4/1	25%	35%	65%	-10%
4/2-4/8	31%	40%	60%	-9%
4/9-4/15	37%	47%	53%	-10%
4/16-4/22	48%	52%	48%	-3%
4/23-4/29	57%	59%	41%	-3%
4/30-5/6	65%	66%	34%	0%
5/7-5/13	81%	79%	21%	2%
5/14-5/20	88%	86%	14%	2%
5/21-5/27	94%	93%	7%	1%
5/28-6/4	98%	96%	4%	3%
6/5-6/11	99%	97%	3%	1%
6/12-6/18	100%	100%	0%	0%

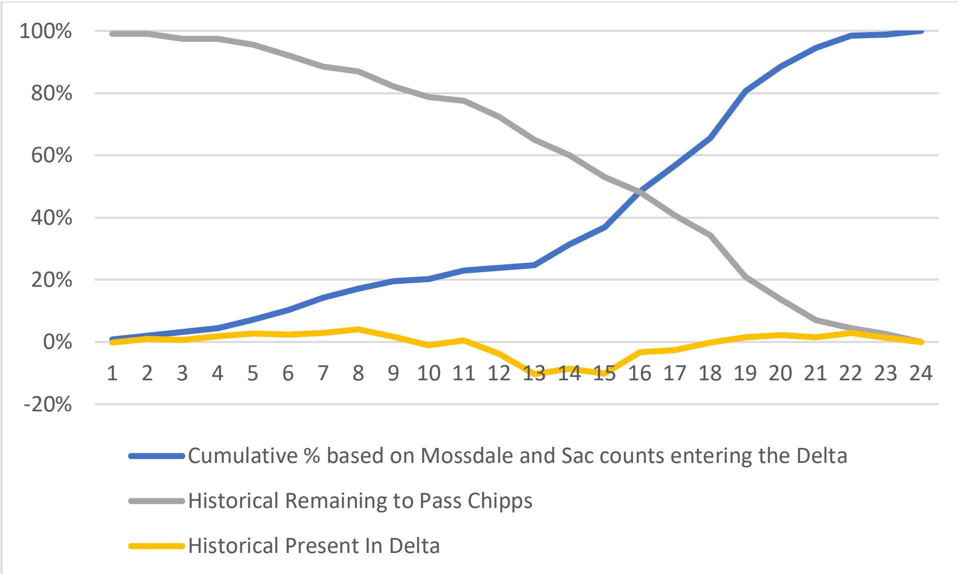

Figure I-1. Cumulative percent of juvenile steelhead entering, exiting, and present in the Delta

When the proportion of the outmigration period that is present in the Delta is considered (Figure I-1), periods where more fish have left the Delta than are reported remaining the Delta results in a negative presence in the Delta. This suggests that juvenile steelhead salvage and loss management cannot be based on our monitoring of the outmigration period in the Delta. Since steelhead outmigration does not seem to be reflected. To evaluate other potential drivers of steelhead salvage, weekly loss across 2009-2019 was looked at (Figure I-2).

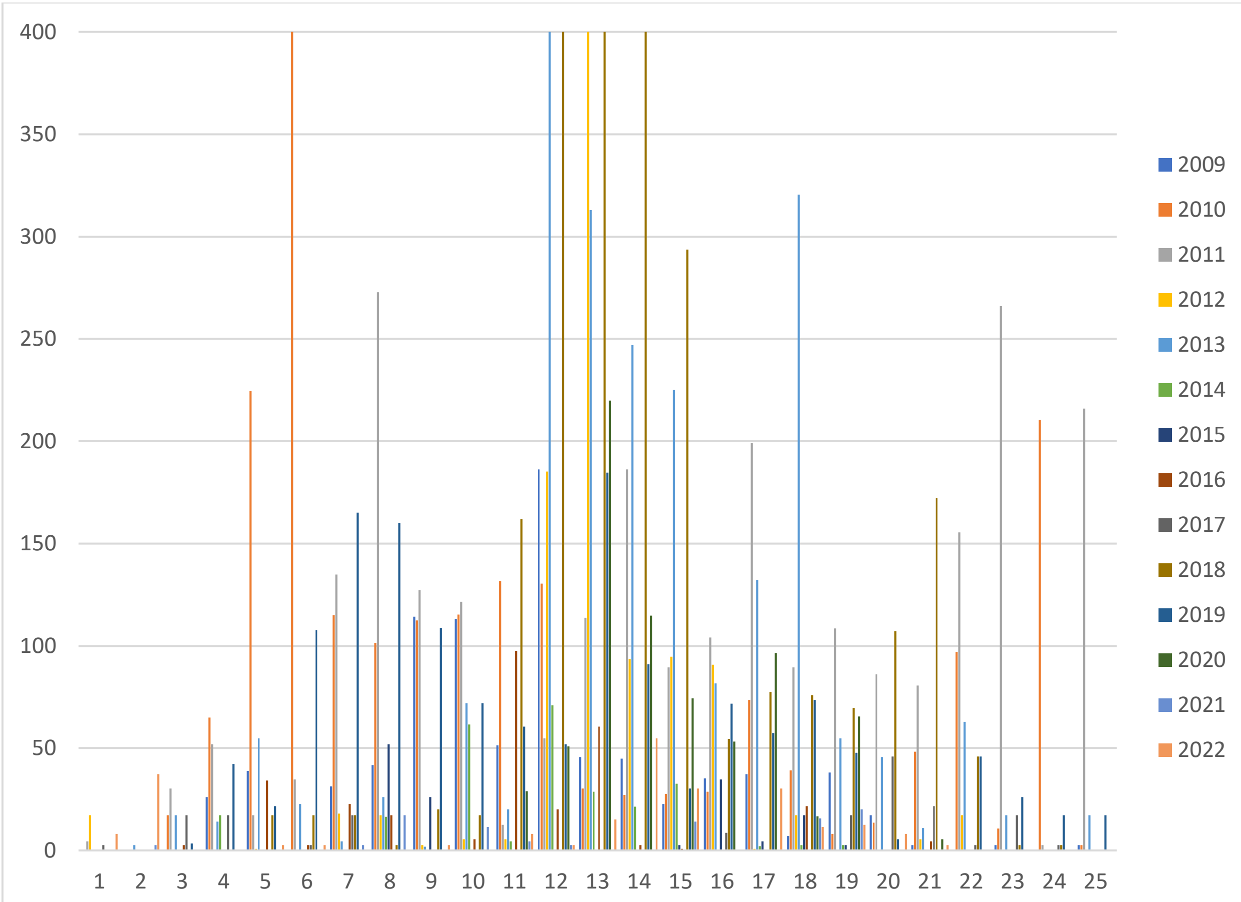

Figure I-2. Steelhead loss by Julian Week

Although steelhead salvage is greatest and less variable in the middle of their outmigration period, there can be moderate-to-high loss early and late in the period.

There is not a clear pattern between presence in the Delta and loss. This could be due to sampling and/or outmigration behavior and long migration and rearing times in Delta, but we have limited information about these hypotheses. We assume steelhead are not sampled as well in trawls as Chinook salmon, but all trawls likely catch steelhead equally. We know that steelhead do spend longer migrating through the Delta than juvenile Chinook, but do not know how this would result in affecting salvage patterns. To consider other factors influencing the loss of steelhead, we looked at if annual loss may be related to other correlations. We hypothesized current and previous water year indices may be indicative of steelhead abundance. For instance, higher water year indices may support better temperatures and flows for rearing survival and winter releases for outmigration survival. Loss generally followed the 2-year water year type rolling average, which suggests that estimated loss may be related to conditions when fish are rearing and outmigrating and not the week during the outmigration window (Figure I-3). If this is the case, weekly steelhead loss minimization may provide similar protection to distributed loss thresholds during the outmigration window of steelhead.

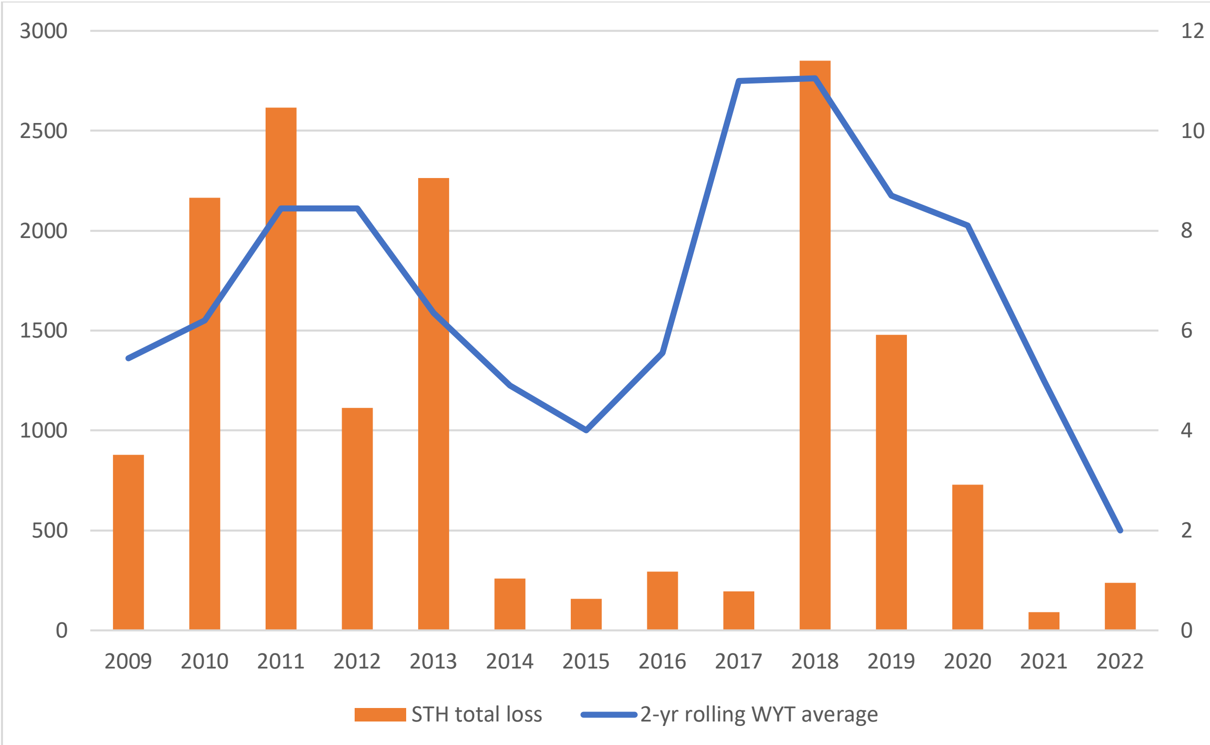

Figure I-3. Average of current and previous Sacramento River index and annual steelhead loss

I.3.6 Alternative 3 – Modified Natural Flow Hydrograph

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, Additional DCC gate fish protection closures. Spring Delta outflow following D-1641 and consistent with modeling for storage requirements.

I.3.7 Alternative 4 – Reservoir Flexibility

D-1641 E/I ratio, DCC gate closures, 30-day San Joaquin River I:E ratio of 1:1. OMR restriction based on environmental surrogate and fish salvage criteria, Additional DCC gate fish protection closures.

I.4 Performance Metrics

Performance metrics describe criteria that can be measured, estimated, or calculated relevant to informing trade-offs for alternative management actions. Additional performance metrics were considered in the Initial Alternatives Report; however, only the performance metrics below were included to evaluate the effects of Delta operations. Performance metrics include measures or estimates related to water supply, NEPA Resource Areas, and fish. These performance metrics are associated with methods that are available, accessible, peer-reviewed, repeatable, and transparent which are further described in the Methods Section.

I.4.1 Fish Performance Metrics

Salmonids: Winter-run and Spring-run Chinook salmon, Steelhead

- Routing probability into Delta Cross Channel, Georgiana Slough, Sutter/Steamboat Slough, Sacramento and San Joaquin Rivers
- Survival probability to Chipps Island
- Estimated seasonal loss
- Predicted seasonal salvage
- Estimated first entrainment date (useful for on-ramping to OMR)
- Zone of entrainment

Delta smelt

- Estimated Larval Entrainment Risk
- Population Growth Rate
- Zone of entrainment

Longfin Smelt

- Estimated Larval Entrainment Risk
- Zone of entrainment

I.4.2 Water Supply

Water supply performance metrics include:

- South of Delta agricultural deliveries (average and critical/dry years)
- San Joaquin River Exchange and Settlement Contracts and Central Valley Project Improvement Act (CVPIA) Refuge deliveries
- Frequency of when OMR is controlling exports

I.4.3 NEPA Resource Areas

Considerations under the National Environmental Policy Act will include changes in multiple resource areas. Key resources are anticipated to include surface water supply, water quality, groundwater resources, power, aquatic resources, terrestrial biological resources, regional economics, land use and agricultural resources, recreation, cultural resources, socioeconomics, environmental justice, and climate change.

I.5 Methods Selection

Reclamation solicited input from agencies and interested parties for the knowledge base paper *Old and Middle River Reverse Flow Management – Smelt, Chinook Salmon, and Steelhead Migration and Survival*, which is included as Attachment XX. Knowledge base papers compile potential datasets, literature, and models for analyzing potential effects from the operation of the CVP and SWP on species, water supply, and power generation. From the knowledge base papers, Reclamation and DWR organized the best available information for evaluating the impacts of OMR management as described below:

I.5.1 Literature

I.5.1.1 History of OMR and Outflow Effects by Regulatory Regime

1950s – early 1970s: Onset of CVP Operations

The C.W. "Bill" Jones Pumping Plant was constructed from 1947 to 1951. The Tracy Fish Collection Facility (TFCF) was constructed shortly there-after. The facility was completed in 1956 and operations began in 1957. During this era, regulatory mandates required changes to TFCF operations including the 1957 Memorandum of Agreement, Water Right Decision (D-) D-990, and D-1275. During the 1960s, exports primarily served as delivery for agriculture during the summer months.

1957 Memorandum of Agreement: Reclamation and the U.S. Fish and Wildlife Service (USFWS) entered an agreement in 1957, before TFCF came online, which lasted two years. During these two years, the agreement's intent was to evaluate TFCF operations and provide monthly progress reports including biological phases of the program.

D-990: D-990 was adopted in February of 1961. During the early 1960's, this Water Right Decision did not provide guidance on export rates. Protections were in place for operations of Shasta and Keswick Dam (D-990, page 42) but no fish-related flow requirements at the Delta pumping facilities.

D-1275: D-1275 was adopted in May of 1967. This Water Right Decision did not provide criteria for protections for listed species at the Delta pumping facilities.

1978: Water Right Decision D-1485

Unlike the 1960s, during the 1970s exports began to occur year-round and were increasing in volume. D-1485 was the first Water Right Decision to consider monthly Delta outflow, pumping, and protections for fish and wildlife at and near the Delta pumping facilities. D-1485 was adopted in 1978 to establish water quality standards, including flows to be maintained for the protection of fish and wildlife, imposed as a condition to all of the CVP and SWP permits. The two documents adopted by the State Board (a water quality control plan and a water right decision) represent a unified effort by the Board to develop and implement under its full authority a single comprehensive set of water quality standards to protect beneficial uses of Delta water supplies (D-1485, page 6).

1990s & Early 2000s" CVPIA, D-1641, CALFED

By the early 1990s, agreements were in place allowing the CDFW to monitor TFCF salvage operations providing further monitoring of fish. During this era, requirements were set to address standards for fish and wildlife protection with written intent to restore the Bay-Delta ecosystem and improve water management. Among these requirements was consideration of the export rate restriction standard (E/I ratio). The CVPIA passed mandating changes in CVP management specifically for "protection, restoration, and enhancement of fish and wildlife" (Section (b) (4) of CVPIA). There was organization of Federal and State agencies through CALFED. State Water Resources Control Board Decision D-1641 outlined a long-term plan, incorporating seasonal and water-year specific criteria, to limit pumping to protect juvenile Chinook salmonids.

CVPIA: In 1992, Congress included fish and wildlife actions through the CVPIA. Physical improvements to facilities (e.g., fish recovery and protections) and management practices were among the included mitigations. After implementation of D-1641 (discussed below), the Department of Interior Decision on Implementation of Section 3406(b)(2) of the CVPIA increased export curtailment and directly reduced exports by the CVP for fishery management.

CALFED: CALFED was organized in 1994, a partnership between Federal and State agencies with management and regulatory responsibilities in the Delta. The lead CALFED agencies released a Final Programmatic Environmental Impact Statement/Environmental Impact Report and the Preferred Alternative on July 21, 2000. This was followed by the signing of the ROD on August 28, 2000, which formally approved a long-term plan to restore the Bay-Delta ecosystem and improve water management.

D-1641: In 2000, through adoption of D-1641, the SWP and CVP were mandated to comply with the objectives in the 1995 Bay-Delta Plan. The requirements in D-1641 address standards for fish and wildlife protection, M&I water quality, agricultural water quality, and Suisun Marsh salinity. D-1641 also authorizes SWP and CVP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. An important component of D-1641 was the export/inflow (E/I) ratio, an export rate restriction standard, generally occurring during winter and spring months when hydrologic conditions are such that exports are not supported by reservoir storage releases. Another important component of D-1641 was the month-long San Joaquin River pulse flow requirement and CVP-SWP export limitation with the intent to improve river flows and reduce export potential for outmigrating juvenile salmonids from the San Joaquin River watershed. The Vernalis Adaptive Management Program (VAMP) was developed because of technical and legal disagreements over the spring pulse requirements.

Environmental Water Account: Fishery management agencies (USFWS, National Oceanic and Atmospheric Administration, and California Department of Fish and Game [CDFG]) and action agencies (Reclamation, DWR) shared responsibility in implementing and managing the Environmental Water Account. Management agencies were responsible for recommending biological judgement on the operations of the SWP and CVP to provide benefits to the Bay-Delta system.

Late 2000s & 2010s: 2008/2009 RPAs

USFWS and NMFS issued Biological Opinions (BiOp) in 2008 and 2009, respectively, for the operation of TFCF to minimize take of listed species. The fishery management agencies recognized operations of the CVP and SWP were likely to adversely modify critical habitat for listed species and jeopardize some species' continued existence. Protections were put in place including controlling the OMR flows. The NMFS 2009 BiOp included measures implemented specific to entrainment of salmonids and green sturgeon, and management actions for listed fish protections.

2009 BiOp: The 2009 NMFS BiOp suggested reasonable and prudent alternatives (RPAs) to enable the project to move forward in compliance with the ESA. There were six actions to be taken in the Delta Division (p. 630), two of which were directly related to the history of OMR: *Action IV.2* and *IV.3*. This suite of actions incorporated studies and a refined understanding of the relationships between inflows, exports, and native fish distribution and behavior. OMR management was "dialed in" and measures were put in place specific to entrainment risk.

Action IV.2 reads "Control the net negative flows toward the export pumps in Old and Middle rivers to reduce the likelihood that fish will be diverted from the San Joaquin or Sacramento River into the southern or central Delta." Within Action IV.2 Delta Flow Management there were a suite of three actions directed related to informing OMR and entrainment: *Action IV.2.1* San Joaquin River Inflow to Export Ratio (SJR I:E, p. 641), *Action IV.2.2* Six-Year Acoustic Tag Experiment (p. 645), and *Action IV.2.3* Old and Middle River Flow Management (p. 648). The suite of actions within Action IV.2 were developed to provide Delta flow management through the lens of protecting listed native fish.

Action IV.2.1 San Joaquin River Inflow to Export Ratio was developed to reduce vulnerability of emigrating Central Valley (CV) steelhead within the lower San Joaquin River. This sub-action increased the inflow to export ratio to include greater net downstream flows to enhance likelihood of survival to Chipps Island. The underlying rationale for Action IV.2.1 came from coded-wire tagged (CWT) Chinook smolt survival estimates from the VAMP experiments to spring flows to provide benefit salmonids (Chinook and steelhead).

Action IV.2.2 Six-Year Acoustic Tag Experiment was developed to quantify proportional causes of mortality to tagged steelhead smolts outmigrating from the San Joaquin basin (flows, exports, project- and non-project-related effects). The implementation of this 6-year study yielded results that were used in the development of the 2020 ROD and 2020 ITP. The study was designed to allow exports to vary in relation to inflows from the San Joaquin River to test varying flow to export ratios.

Action IV.2.3 Old and Middle River Flow Management was developed to reduce vulnerability of listed fish within the lower Sacramento and San Joaquin rivers to entrainment into the Delta fish collection facilities. Combined exports were managed to provide for a flow in OMR of -5,000 cfs, tidally filtered over 14-days between January 1 and June 15. A 5-day running average was set to be no more than 25% more negative than the targeted requirement flow for the 14-day average (NMFS 2009, p. 648). PTM simulations and results from acoustic tagging studies were used to craft protections for fish.

2008 BiOp: The USFWS 2008 BiOp included measures implemented specific to entrainment of Delta smelt, and management actions for listed fish protections.

Action 1: Adult Migration and Entrainment (First Flush) is a fixed duration action that was developed to protect pre-spawning adult delta smelt from entrainment during the first flush, and to provide advantageous hydrodynamic conditions early in the migration period. The action occurs during two time-periods (December 1 to December 20 and after December 20) and calls for limiting exports so that the average daily OMR flow[6] is no more negative than -2,000 cfs for a total duration of 14 days, with a 5-day running average no more negative than -2,500 cfs (within 25 percent).

Present Day: 2019 RPMs, 2020 ROD & 2020 ITP

Currently, continued measures are in place to provide protections for listed fish and to minimize the amount or extent of incidental take including OMR management. Reclamation's 2020 Proposed Action via the 2020 ROD and DWR's 2020 ITP both include "OMR Management" sections with subsections to on-ramp and off-ramp along with real-time limits (e.g., 2020 Proposed Action Single-Year Loss thresholds 4.10.5.1.2 Additional Real-Time OMR Restrictions and Performance Objectives; 2020 ITP 3.5 Salmonid Cumulative Entrainment Loss Thresholds).

2019 BiOp: The 2019 NMFS BiOp suggests reasonable and prudent measures (RPMs) to minimize the impact of the amount or extent of incidental take. The 2019 BiOp calls for one RPM in the Bay-Delta Division directly related to the history of OMR (p. 817), RPM 5. *RPM 5* reads "Reclamation and DWR shall minimize the impact of the amount or extent of incidental take of listed species during operations of the Bay-Delta Division". In conjunction with RPM 5, the 2019 BiOp has section *8.6.9 Old and Middle River Flow Management* which calls for seasonal operations that "maximizes exports while minimizing entrainment of fish and protecting critical habitat" (p. 476).

Data from the Six Year Acoustic Tag Experiment (NMFS 2009 BiOp) refined understanding of the relationship of flows and entrainment. Studies on migration through Sacramento-San Joaquin Delta providing data on how Delta inflow affects survival to define relationship of Freeport flow and survival but also routing on migratory success. The Delta Passage model was used to integrate operational effects to understand the influence of survival based on operating scenarios. The Winter-Run Chinook Salmon Life Cycle Model (WRLCM) was used to estimate survival of emigrating WR to Chipps that have reared in different Sac River habitats. The STARS model estimated the relationship between Sacramento inflows on reach-specific parameters such as travel time, survival, and routing.

2020 ROD/Proposed Action and 2020 ITP:

4.10.5.10 OMR Management (2020 Proposed Action, page 4-66) and *3.1 OMR Management* (2020 ITP, page 22), in combination with other environmental variables, was implemented to minimize or avoid the entrainment of fish in the Delta salvage facilities. Operations attempted to maximize exports by incorporating real-time monitoring of environmental and fish parameters into decisions to management of OMR. Actions in OMR Management include "First Flush" and "Salmonids Presence" to guide the onset of the OMR Management season, real-time restrictions, and performance objects during the OMR Management season (e.g., single year loss thresholds for salmonids, turbidity bridge avoidance for smelt), Storm -related OMR flexibility, and criteria for off ramping the OMR Management season (e.g., by date, fish presence, or environmental conditions)

I.5.1.2 Winter-Run and Spring-Run Chinook Salmon

Studies have shown that juvenile outmigrants from the Sacramento River experience higher survival when riverine inflows are higher (Kjelson et al 1982, Buchanan et al 2021, 2017). Also, studies have shown that juvenile outmigrants from the Sacramento River experience lower survival when they route through the central and south Delta instead of remaining in the mainstem Sacramento River, which is hypothesized to be linked to CVP and SWP diversion rates (Brandes and McLain 2001, Newman and Brandes 2010). A negative correlation between water exports and survival probabilities have been demonstrated, although the mechanism is not well documented (Newman and Brandes 2010). The reversed tidal flows in the central and south Delta due to the pumping facilities is hypothesized to slow outmigration for juvenile Chinook salmon towards the ocean, which may reduce survival due to the unfavorable Delta habitat conditions (high densities of predators, lower density of food, and suboptimal water quality). Another hypothesis is that juvenile Chinook salmon may experience a diminished ability to navigate out of the south Delta due to confusing navigational cues from altered hydrology and water quality gradients, the highly altered channel network configuration, and impairments to sensory systems from contaminants (Windell et al. 2017).

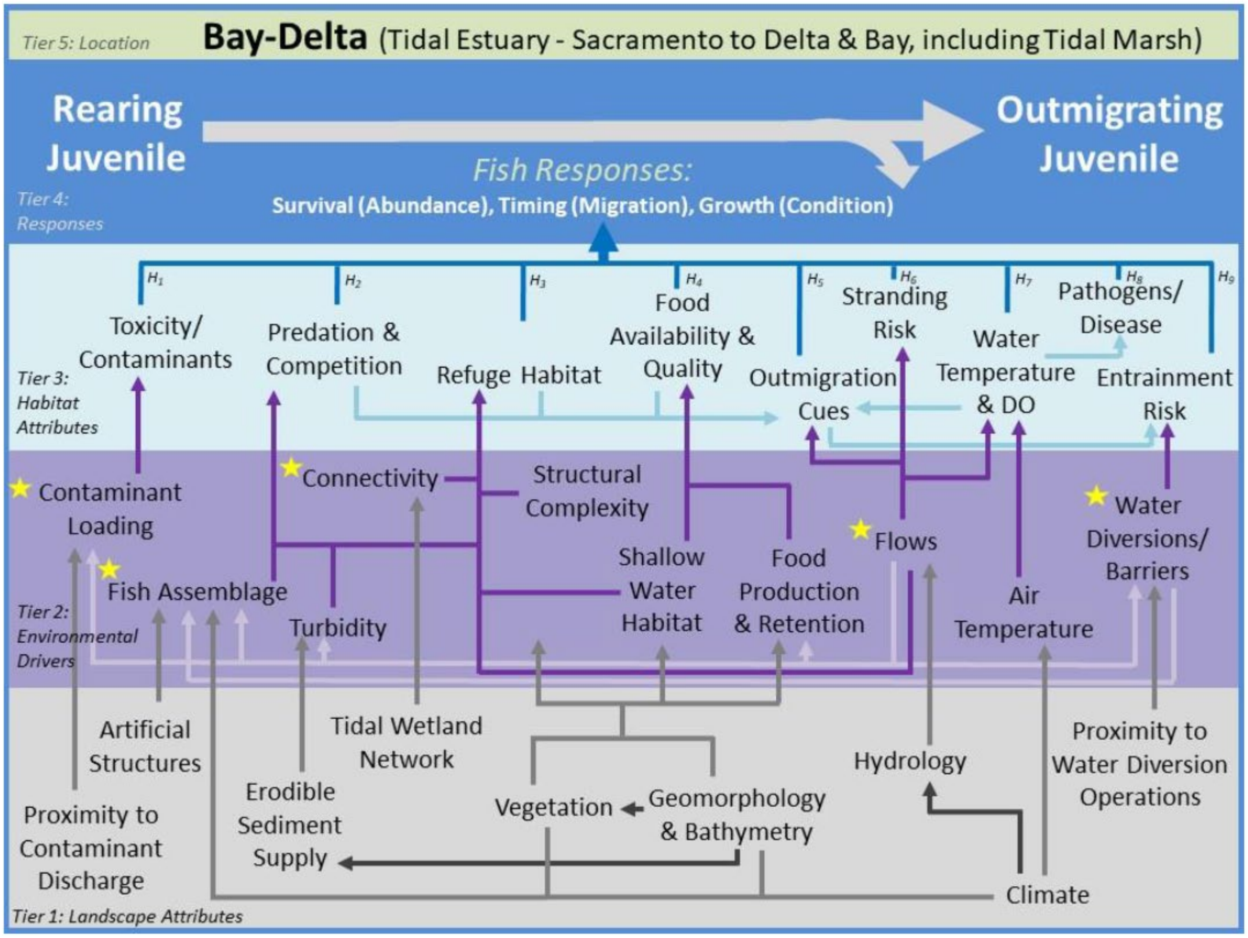

Figure I-4. Conceptual model of winter-run Chinook Salmon in the Bay-Delta (Windell et al. 2017)

I.5.1.3 Delta Smelt

The operation of the CVP and SWP pumping plants can potentially entrain Delta smelt in all post-hatch life stages. Upon hatching, Delta smelt begin a pelagic larval life stage and are distributed primarily by water current direction due to minimal swimming ability. Flows due to the operations of the CVP and SWP may entrain these early life stages into lower quality habitats in the South Delta or as loss at the facilities. Delta smelt become more proficient at swimming at approximately 20 mm (Wang 2007) and are assumed to seek out suitable habitat with turbid water (>12 Formazin Nephelometric Units [FNU]), suitable water temperatures (< 25˚C), and low salinity (< 6 psu). The subadult Delta smelt rear until the fall when inflows and turbidity from seasonal rains initiate a migration to the low salinity zone (<0.2 ppt) where they stage until moving upstream into freshwater to spawn. The increases in inflows and turbidity that initiate migration may increase the likelihood of entraining adults if they migrate into the central and south Delta toward the CVP and SWP pumping plants. After the initial migration, Delta smelt are hypothesized to remain in areas of high turbidity, and CVP and SWP operations are adjusted to minimize turbidity in the south Delta. Delta smelt adults typically do not live long after spawning and two-year-old adults are rare.

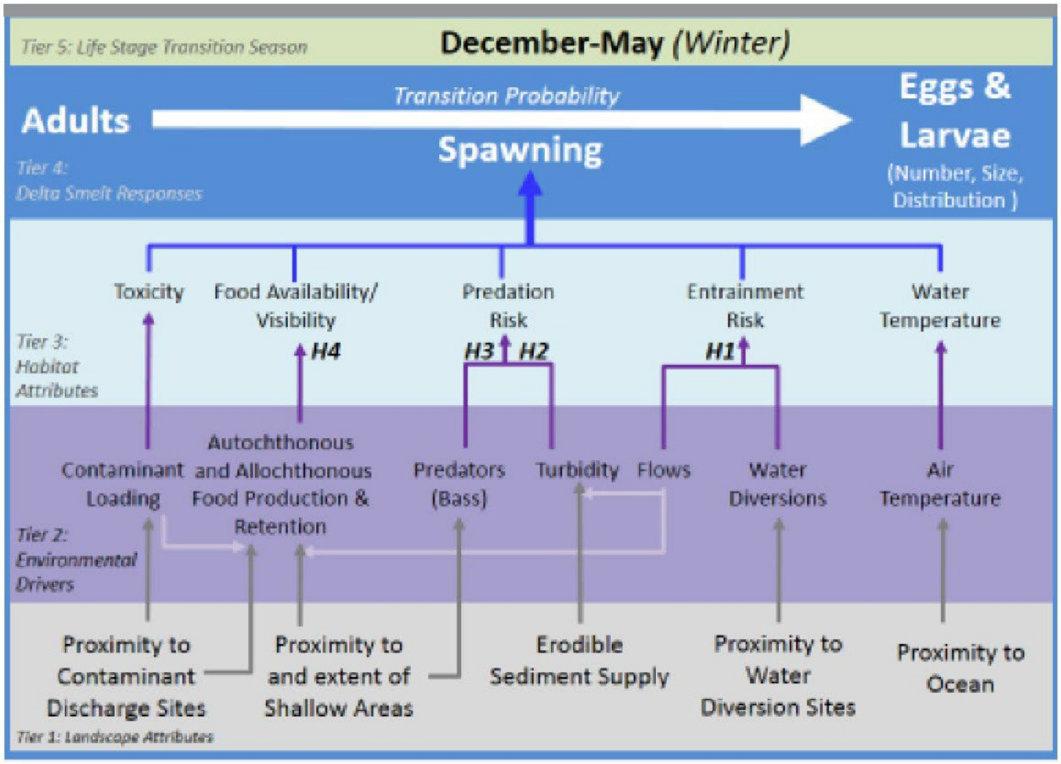

Figure I-5. Conceptual model of Delta Smelt in the Delta (Baxter et al. 2015)

I.5.1.4 Longfin Smelt

The operation of the CVP and SWP pumping plants can potentially entrain longfin smelt in post-hatch life stages. The Delta pumps can directly entrain longfin smelt into the facilities, resulting in salvage, or influence flows in OMR, which can route LFS to sub-optimal habitats within the Delta. Spawning locations have been estimated using field observations of gravid females and yolk-sac larvae (Grimaldo et al. 2017; Lewis et al. 2019), and through particle-tracking modeling (Gross et al. 2022) to suggest spawning extends farther seaward than previously estimated (Moyle 2002). Based on these studies, longfin smelt appear to spawn in the low-salinity zone where brackish and freshwaters meet (Grimaldo et al. 2017:11), in tidal wetlands of South San Francisco Bay (Lewis et al. 2020:3), and in San Pablo and lower South Bay during wet years (Grimaldo et al. 2020:10). Longfin smelt migrate from areas of high salinity to either brackish or fresh water for spawning from winter to the spring, and spawn by the spring (Rosenfield 2010:4; Lewis et al. 2019:5). Since longfin smelt can spawn farther seaward than previously thought, entrainment from the SWP and CVP pumps do not appear to have a substantial effect on the population (Gross et al. 2022:189). Kimmerer and Gross (2022:2741) indicate that larval abundance is not related to outflow effects, and that the relationship of longfin smelt with freshwater flow may be more important after March/ early larval development. The spatial distribution of these larvae reflects the year-to-year variation in the geographic location of the low-salinity zone (Dege and Brown 2004, Fig. 3, p. 57; Grimaldo et al. 2020, Fig. 6, p. 10). Within the low-salinity zone and adjacent waters, larvae have been commonly collected in both littoral (nearshore) and pelagic (offshore) habitats. Upon hatching, the larvae may swim toward the water surface which would facilitate relatively rapid seaward transport (CDFG 2009a, p. 8).

However, it is not clear that such a behavior would facilitate retention in the low-salinity zone, especially when Delta outflow is high (Kimmerer et al. 2014, Fig. 5, p. 910). Modeling by Gross et al. (2022) found early stage longfin smelt larvae would be rapidly transported seaward and suggests larval longfin smelt undergo from a passive to directional behavior transition which may include tidal vertical migration and depth seeking behavior to retain position in the LSZ.

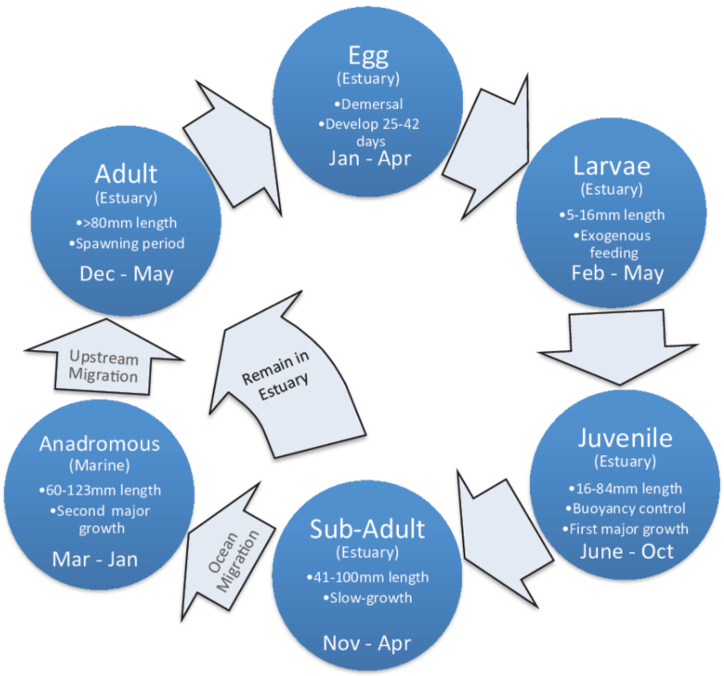

Figure I-6. Life cycle of longfin smelt, adapted from the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) Conceptual Models. Source: Merz et al. 2013

I.5.1.5 Steelhead

Steelhead, or *Oncorhynchus mykiss* expressing anadromous life history, pass through the Delta as they outmigrate towards the Pacific Ocean. However, unlike Chinook salmon, the age at which steelhead conduct their outmigration may vary by multiple years. Steelhead are also iteroparous and may pass through the Delta more than twice (juvenile outmigration and return as adults) within their lifetime (Moyle 2002). In the Delta, there are many pathways that outmigrating steelhead may take to reach the Pacific Ocean. Delta inflow, tidal flows, and diversions influence outmigrating steelhead route selection by altering hydrodynamics around channel junctions along the lower San Joaquin River (Anchor QEA 2022). These changes in flows can attract fish entering the Delta out of the San Joaquin River (with low-moderate survival) into the interior Delta (with extremely low survival) and pumping facilities (with low-moderate survival; Buchanan et al. 2021). Thus, changes in the flow regime due to inflow and diversions can have effects on route selection and ultimately survival (Figure I-7).

Additionally, the duration of the migration, and therefore timing of ocean entry, are also likely impacted by water management in the Delta through changes in the flow patterns and route selection of outmigrating juveniles. Assuming *O. mykiss* smolts travel time in the Delta is comparable to juvenile Chinook salmon, we would expect a rapid migration during periods of high flow entering the Delta. Oppositely, under low flow conditions, we would expect slower outmigration for *O. mykiss* smolts.

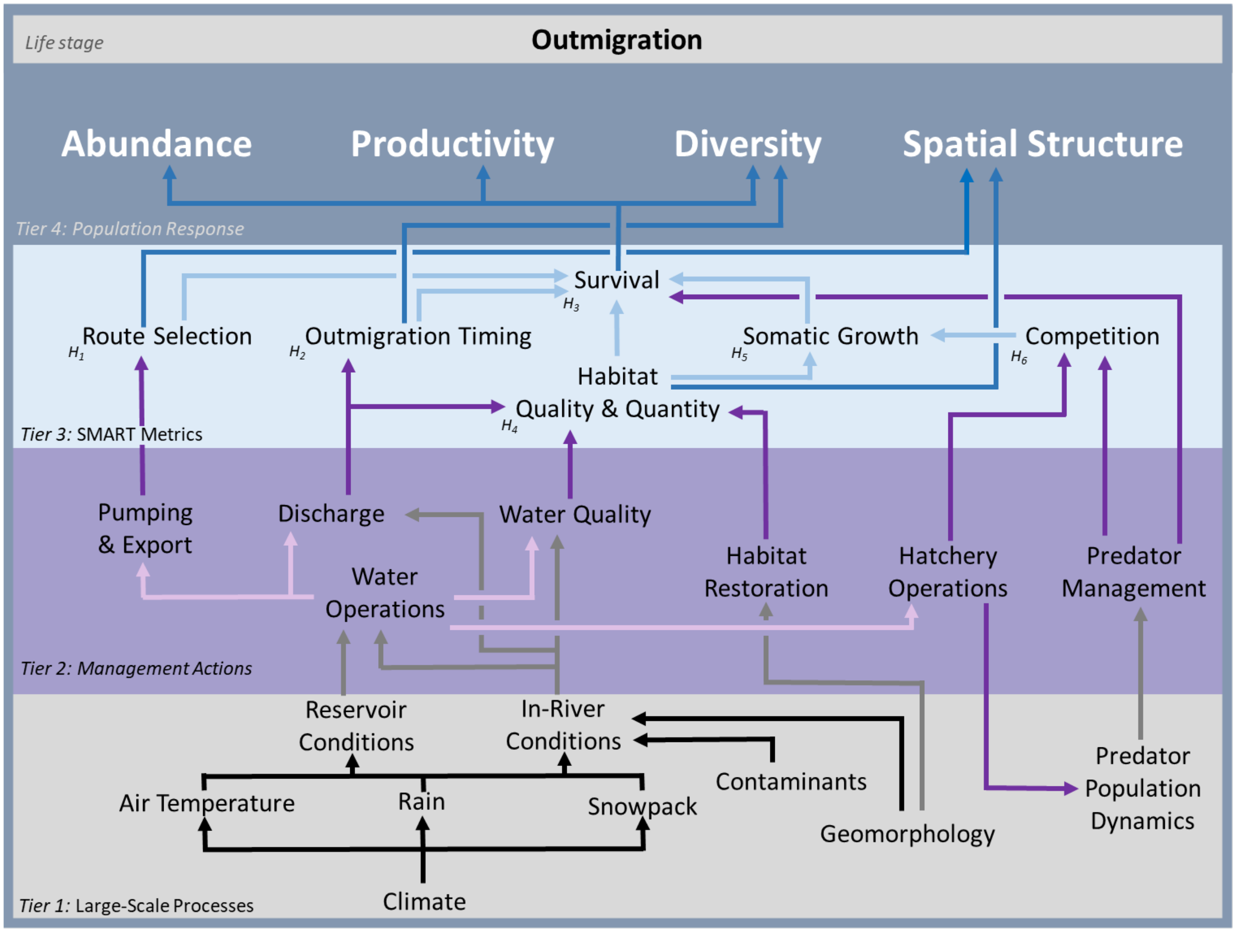

Figure I-7. Steelhead smolt outmigration conceptual model linking large-scale processes to management actions, SMART metrics, and desired population responses (i.e., VSP criteria) from Beakes et al. (2022)

I.5.1.6 Green Sturgeon

Green sturgeon (*Acipenser medirostris*) is an anadromous species, spawning in the upper Sacramento River from January through November. Juveniles outmigrate from the Sacramento River to the Delta through San Francisco Bay starting in late August; however, juveniles are present in the central Delta in all months, except January (Miller et al. 2020). Subadults are in the Delta and San Francisco Bay in all months, with greater presence from April through October (Miller et al. 2020; Colborne et al. 2022).

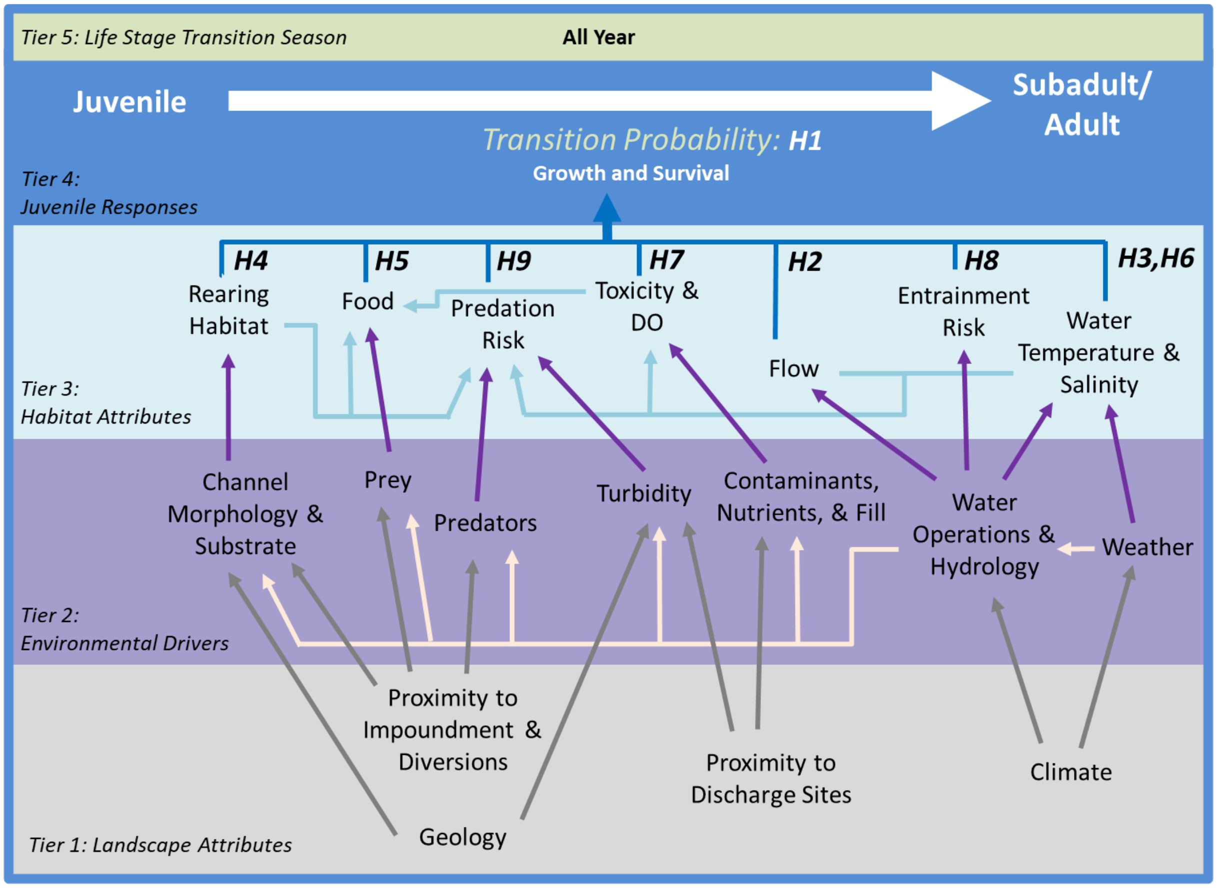

Figure I-8. Conceptual model of Green Sturgeon juvenile to subadult transition in the Delta

I.5.2 Datasets

Entrainment stressors on federally-listed native fish species are influenced by multiple factors, including hydrology, water quality, facilities operations, and fish population abundance and distribution. Monitoring of hydrodynamics, water quality, and fish populations has been ongoing for over forty years for some datasets and covers the full spatial extent of the Bay-Delta. These data, in the following plots serve as a foundation to illustrate patterns of interannual variability in historical hydrology and exports and trends in water quality. They also provide data and visualizations of trends in Federally listed native fish population abundances, distribution, and losses to the CVP and SWP facilities.

Presented in this section are three themes of empirical data: Bay-Delta hydrodynamics, Bay-Delta water quality parameters, and Bay-Delta fish observations for Federally listed native fish species. Hydrodynamics datasets (Section 5.2.1, *Hydrodynamics*) include five decades of Delta inflow and SWP and CVP exports, 1970 – 2021. Water quality parameters (Section 5.2.2, *Water Quality Parameters*) include monitoring data for turbidity, flow, salinity, and temperature at locations throughout the Bay-Delta representing a broad spatial and temporal range. Fish observations (Section 5.2.3, *Fish Observations in Salvage*) include Delta Smelt abundance indices and estimates from multiple surveys and loss at the SWP and CVP fish facilities for

Federally listed salmonids (natural and CWT), Delta smelt, and green sturgeon and state of California listed longfin smelt. Delta migration timing is documented in Appendix AB-C, *Species Spatial and Temporal Domains*.

While some datasets include data gaps or shorter sampling efforts than others, overall a large body of historic monitoring data within the Bay-Delta is available. These data sets, in conjunction with modeled data (i.e., CalSim 3, DSM2, USRDOM), serve as inputs for models that can be used to understand and predict the effects of CVP and SWP operations on environmental conditions and fish distributions and loss. Each data set is incorporated into one or multiple lines of evidence used to inform conclusions about both the magnitude and direction of differences among alternatives regarding Delta hydrology and listed native fish populations abundance and loss at state and federal facilities.

I.5.2.1 Hydrodynamics

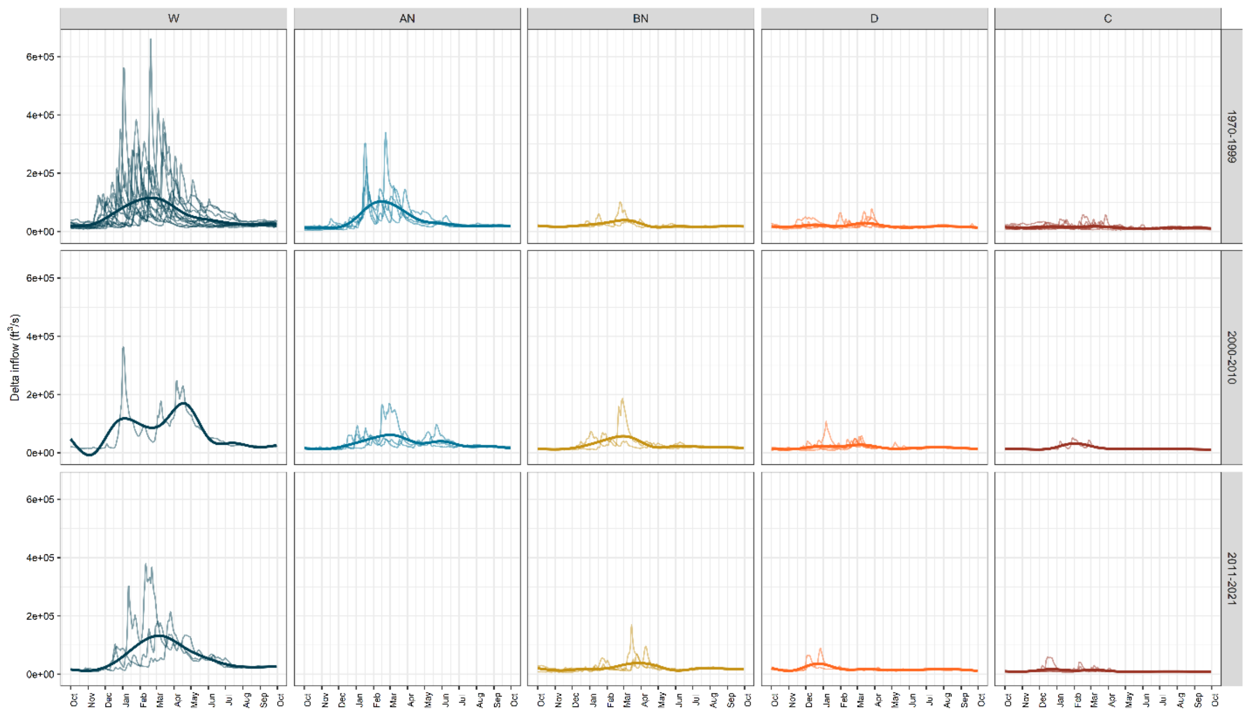

Figure I-9. Daily Delta inflow data from DAYFLOW (https://data.cnra.ca.gov/dataset/dayflow) from 1970 to 2021 by water-year type (W: Wet, AN: Above Normal, BN: Below Normal, D: Dry, C: Critical) and time periods (1970-1999: pre-D-1641 and CALFED era, 2000-2010: D-1641 and CALFED era, 2011-2021: post-2008/2009 Biological Opinions). Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

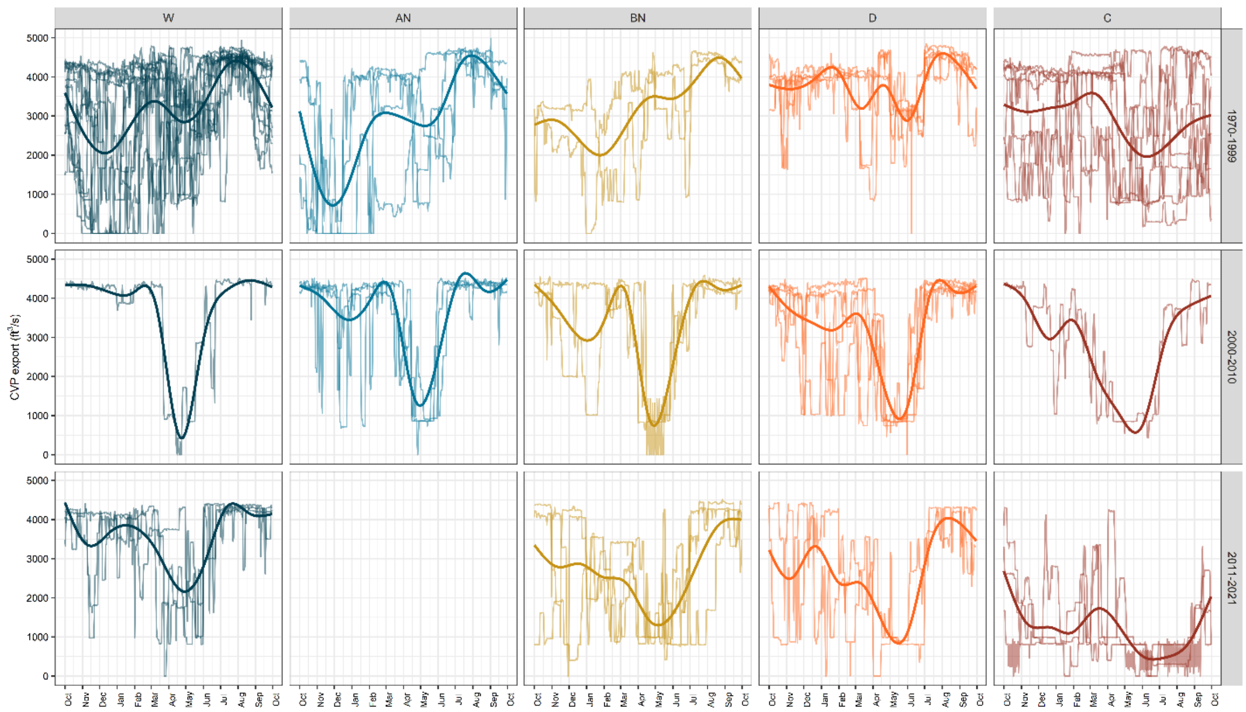

Figure I-10. Central Valley Project Delta export data from DAYFLOW (https://data.cnra.ca.gov/dataset/dayflow) from 1970 to 2021 by water-year type (W: Wet, AN: Above Normal, BN: Below Normal, D: Dry, C: Critical) and time periods (1970-1999: pre-D-1641 and CALFED era, 2000-2010: D-1641 and CALFED era, 2011-2021: post-2008/2009 Biological Opinions). Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

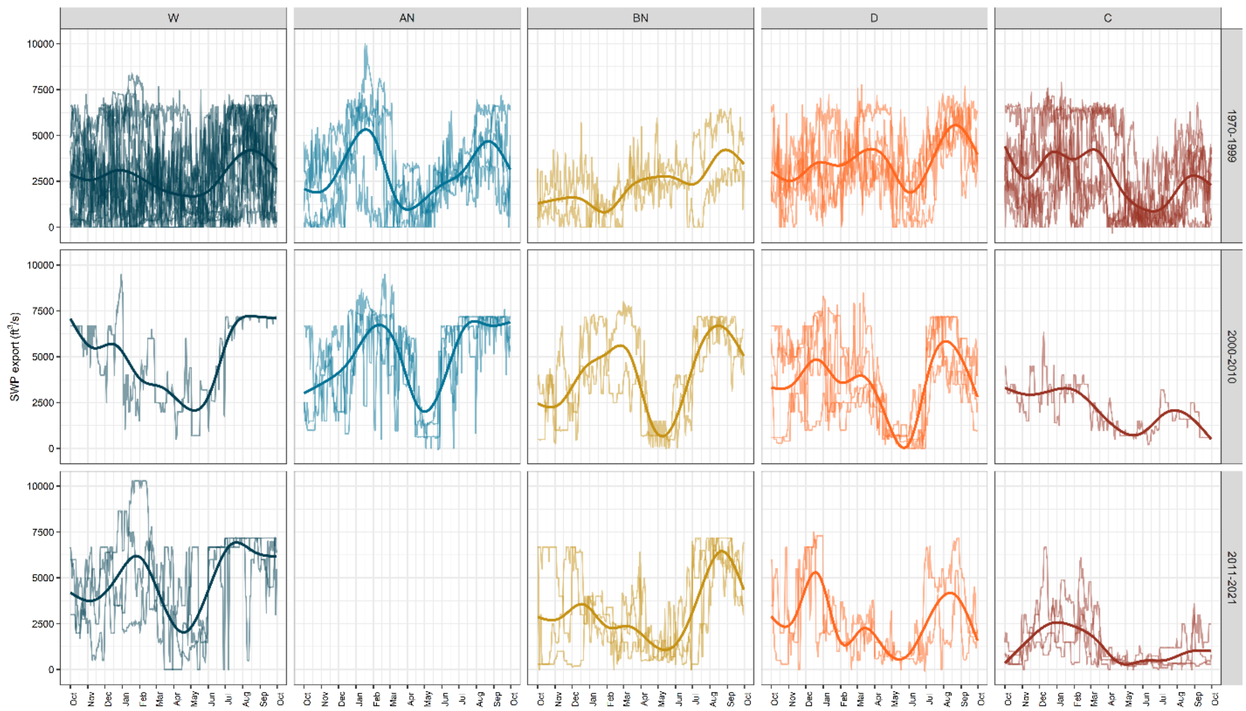

Figure I-11. State Water Project Delta export data from DAYFLOW (https://data.cnra.ca.gov/dataset/dayflow) from 1970 to 2021 by water-year type (W: Wet, AN: Above Normal, BN: Below Normal, D: Dry, C: Critical) and time periods (1970-1999: pre-D-1641 and CALFED era, 2000-2010: D-1641 and CALFED era, 2011-2021: post-2008/2009 Biological Opinions). Each thin line represents a water year within a category and bolded line represents the LOESS smoothed trend line in each category's dataset (which may include multiple water years).

I.5.2.2 Water Quality Parameters

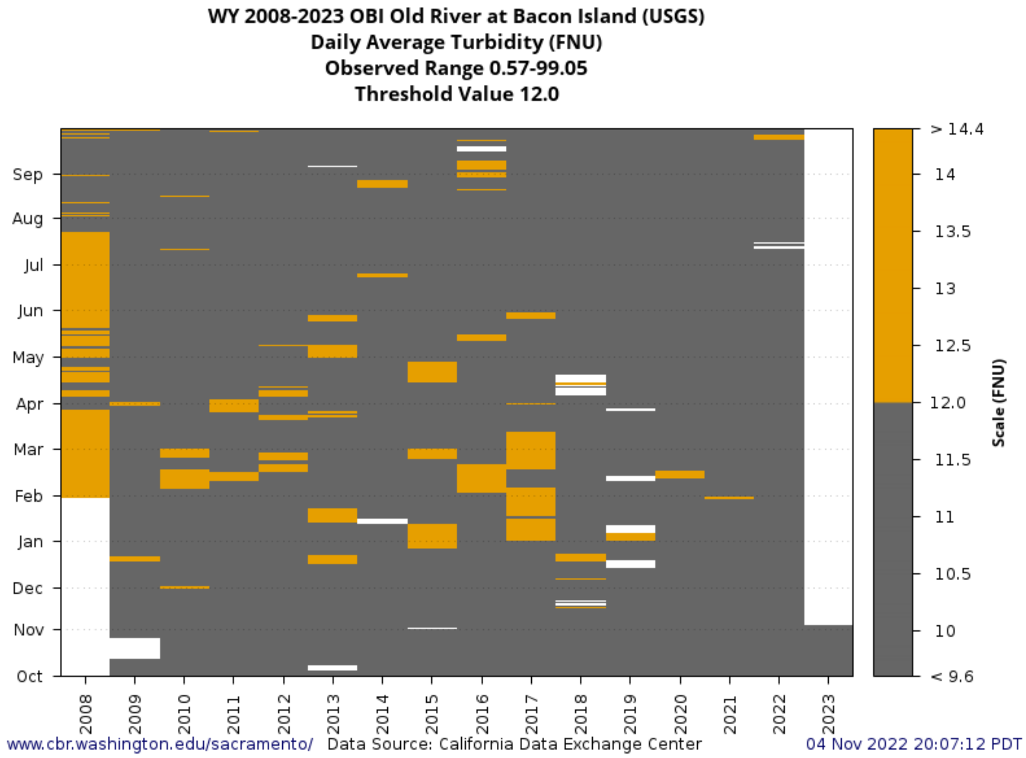

Figure I-12. Daily average turbidity (FNU) values observed at Old River at Bacon Island, water years 2008 – 2023. Gray shading represents turbidity values below a 12.0 FNU threshold, orange shading represents turbidity values above a 12.0 FNU threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

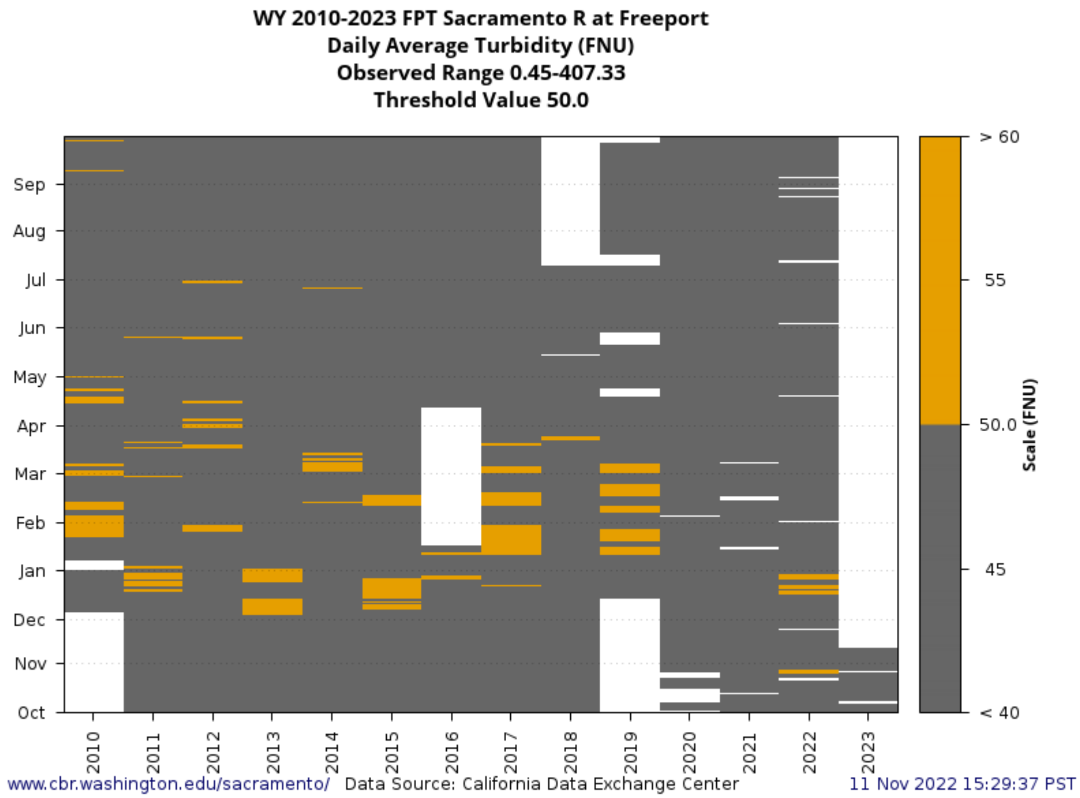

Figure I-13. Daily average turbidity (FNU) values observed at Sacramento River at Freeport, water years 2010 – 2023. Gray shading represents turbidity values below a 12.0 FNU threshold, orange shading represents turbidity values above a 12.0 FNU threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

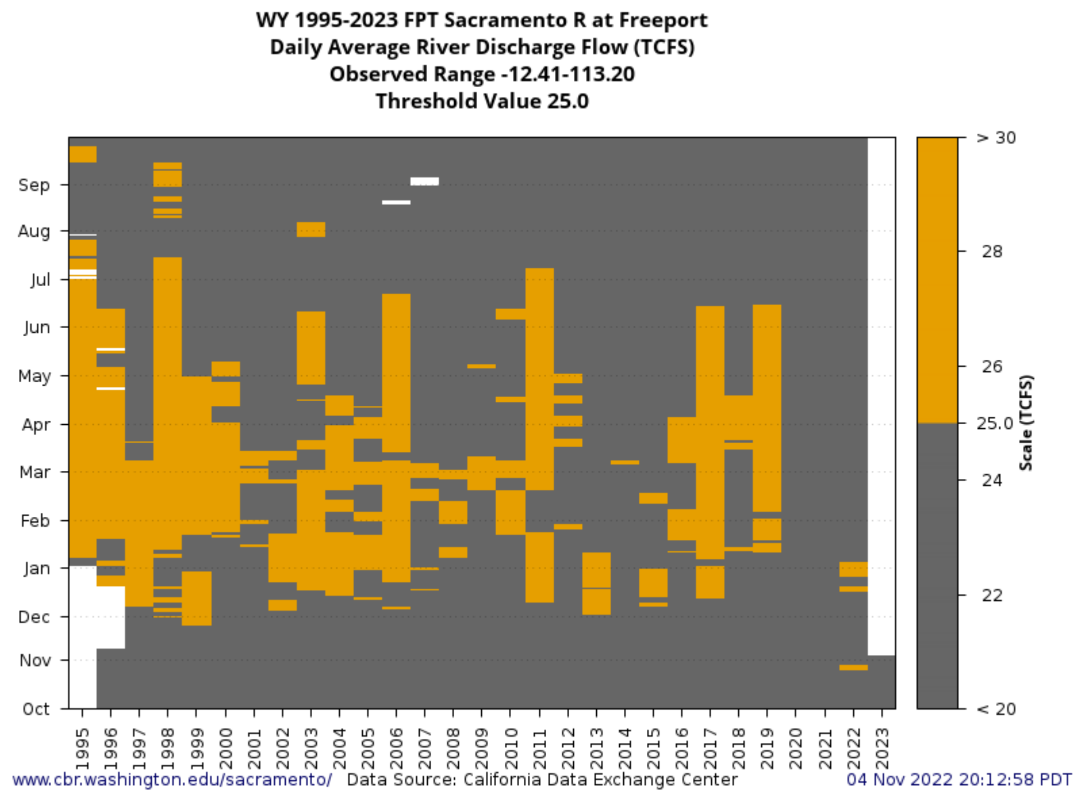

Figure I-14. Daily average river discharge flow (TCFS) values observed at Sacramento River at Freeport, water years 1995 – 2023. Gray shading represents flow values below a 25.0 TCFS threshold, orange shading represents flow values above a 25.0 TCFS threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

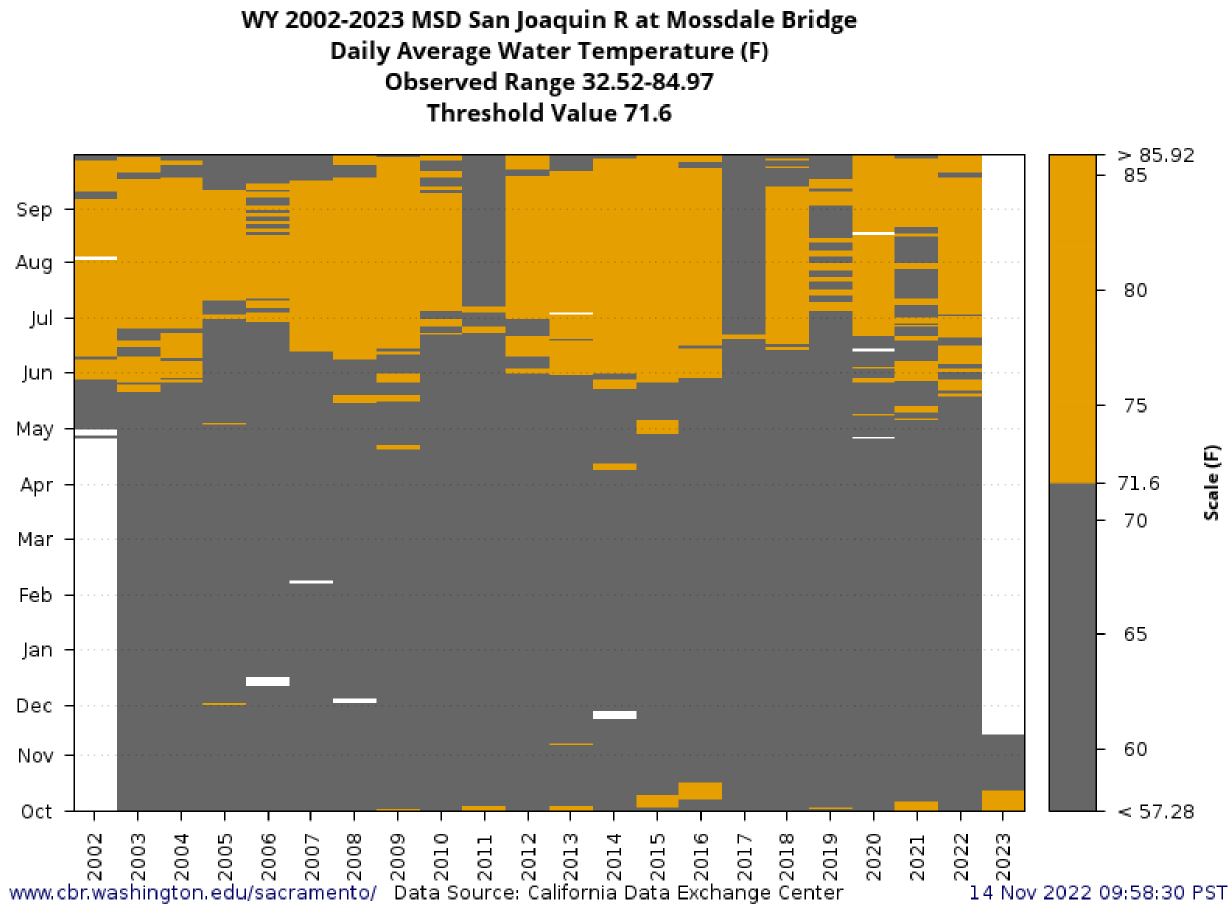

Figure I-15. Daily average water temperature (F) values observed at San Joaquin River at Mossdale Bridge, water years 2002– 2023. Gray shading represents temperature values below a 71.6 F threshold, orange shading represents temperature values above a 71.6 F threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

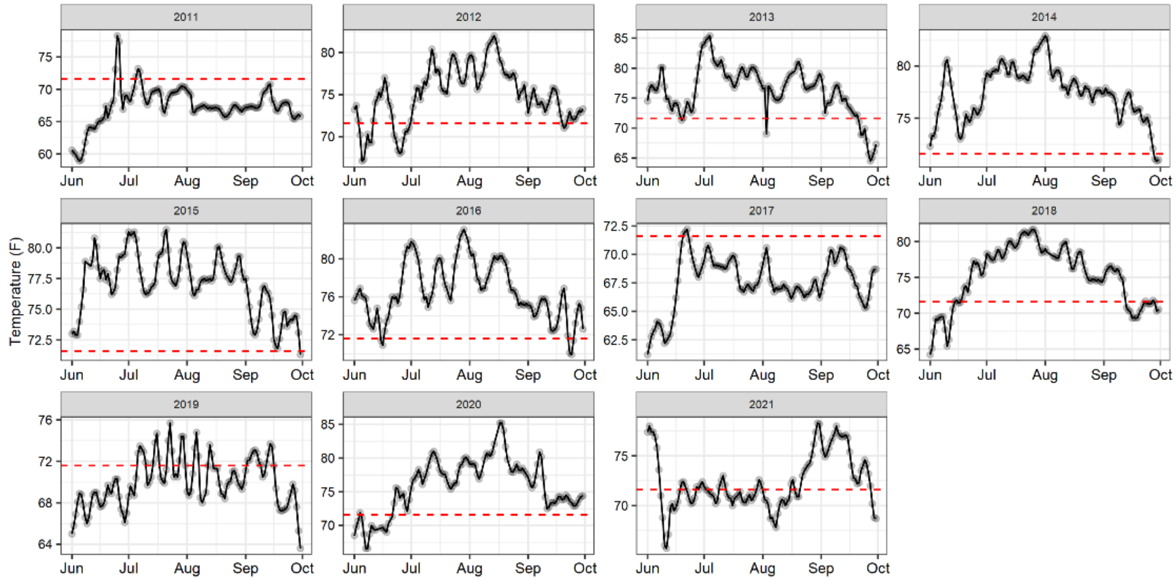

Figure I-16. Daily average water temperature (F) values observed at Mossdale station (CDEC station "MSD") for water years 2011-2021. The red dashed line represents a temperature threshold of 71.6°F.

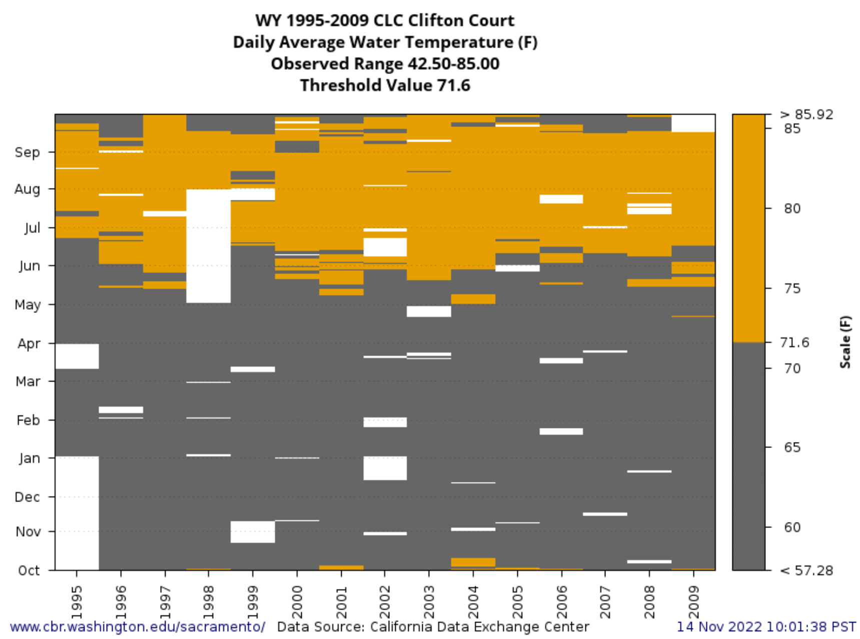

Figure I-17. Daily average water temperature (F) values observed at Clifton Court, water years 1995– 2023. Gray shading represents temperature values below a 71.6 F threshold, orange shading represents temperature values above a 71.6 F threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

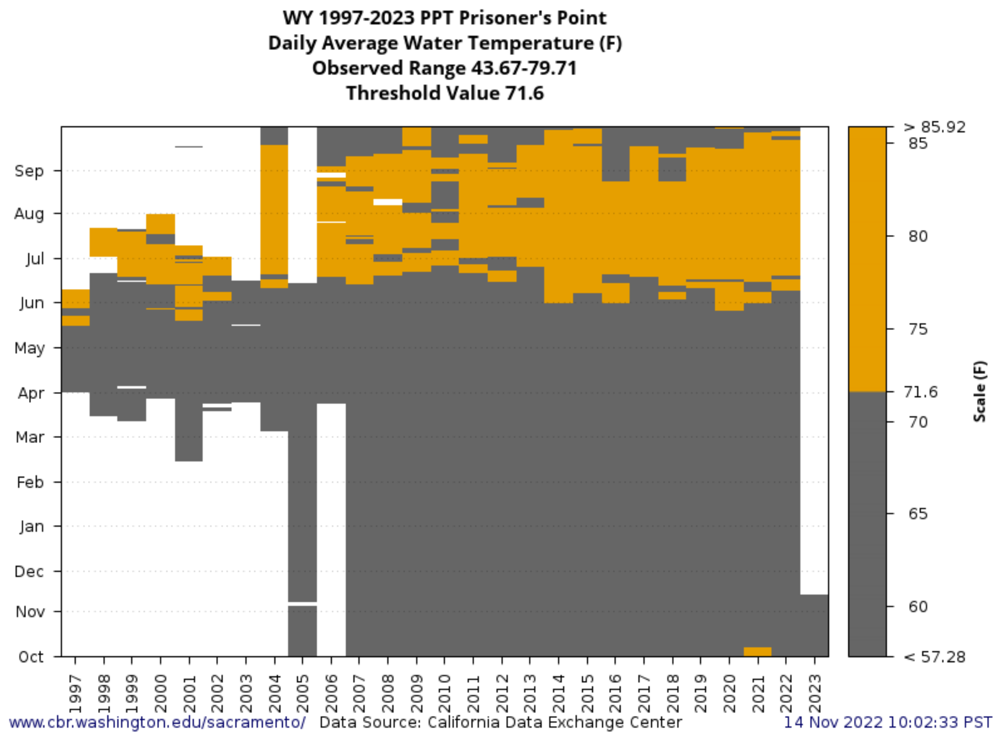

Figure I-18. Daily average water temperature (F) values observed at Prisoner's Point, water years 1997 – 2023. Gray shading represents temperature values below a 71.6 F threshold, orange shading represents temperature values above a 71.6 F threshold. Data and figures available online at SacPAS (https://www.cbr.washington.edu/sacramento/).

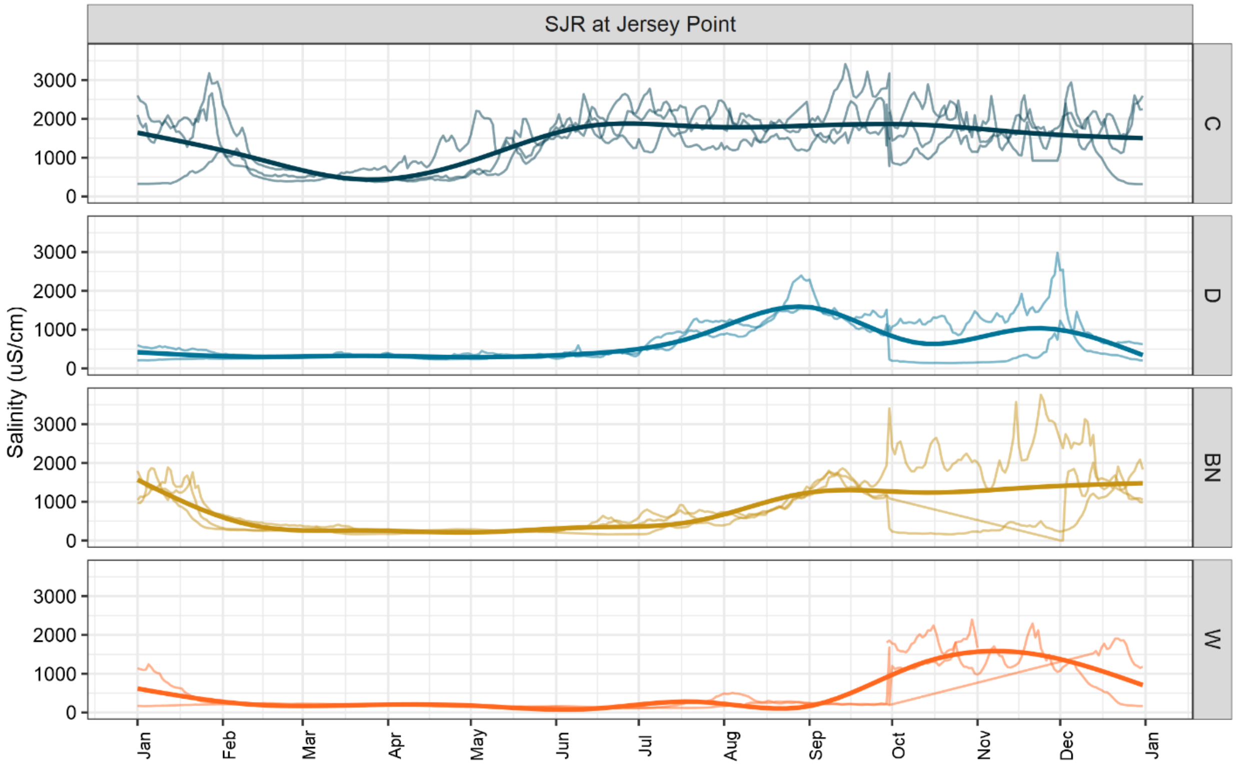

Figure I-19. Daily average salinity (uS/cm) observed at Jersey Point (SJJ), 2009-2021. Event data downloaded from CDEC then averaged. Minor QA/QC applied (Filtered between 0 and 10,000µS/cm; minor outlier removal).

I.5.2.3 Fish Observations in salvage

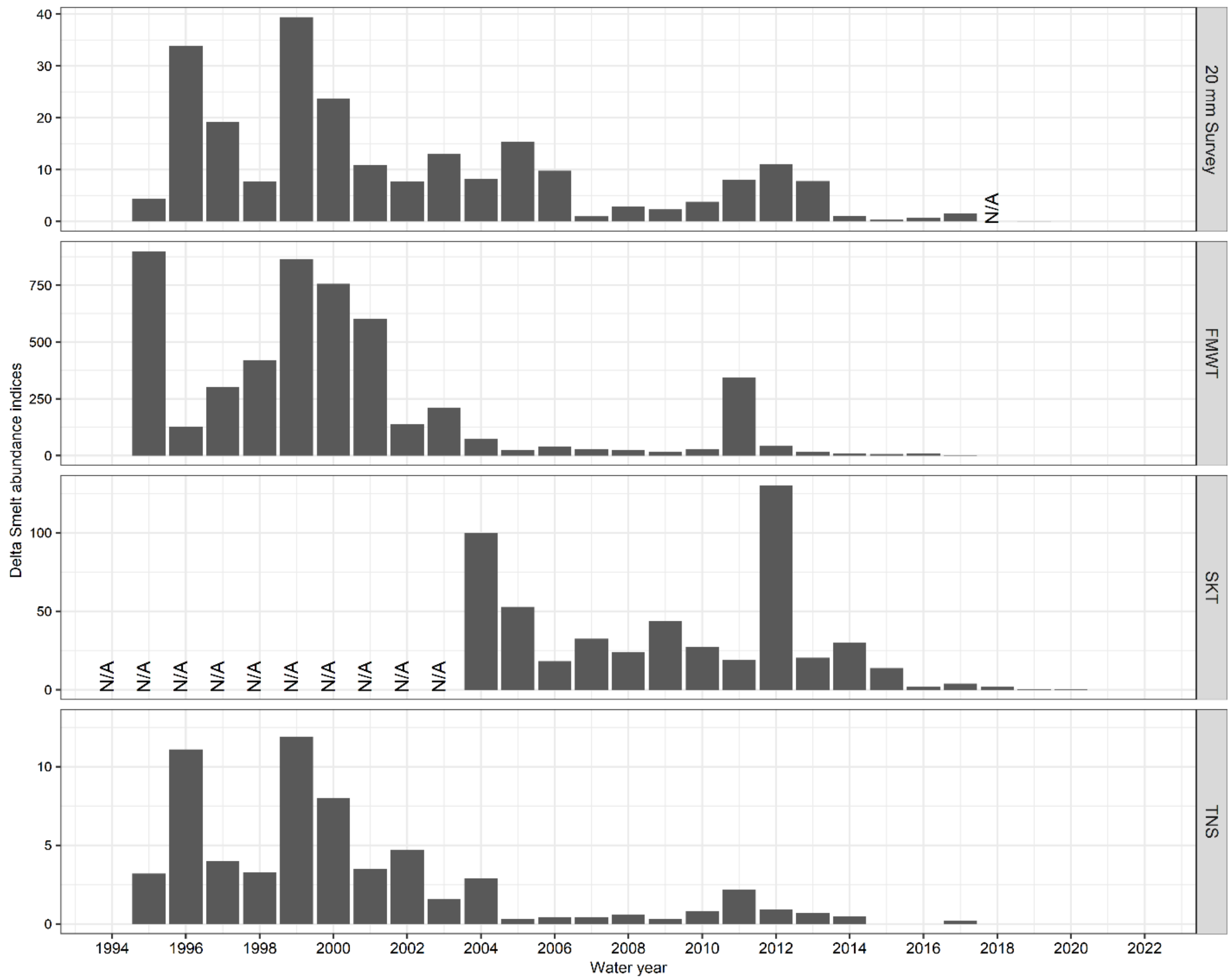

Figure I-20. Indices of Delta smelt abundance from long-running fish surveys in the Delta. From top to bottom: 20-mm larval Delta smelt survey (20 mm Survey), Fall Midwater Trawl survey (FMWT), Spring Kodiak Trawl survey (SKT), and Summer Townet Survey (TNS). For more information on each survey, see Tempel et al. (2021).

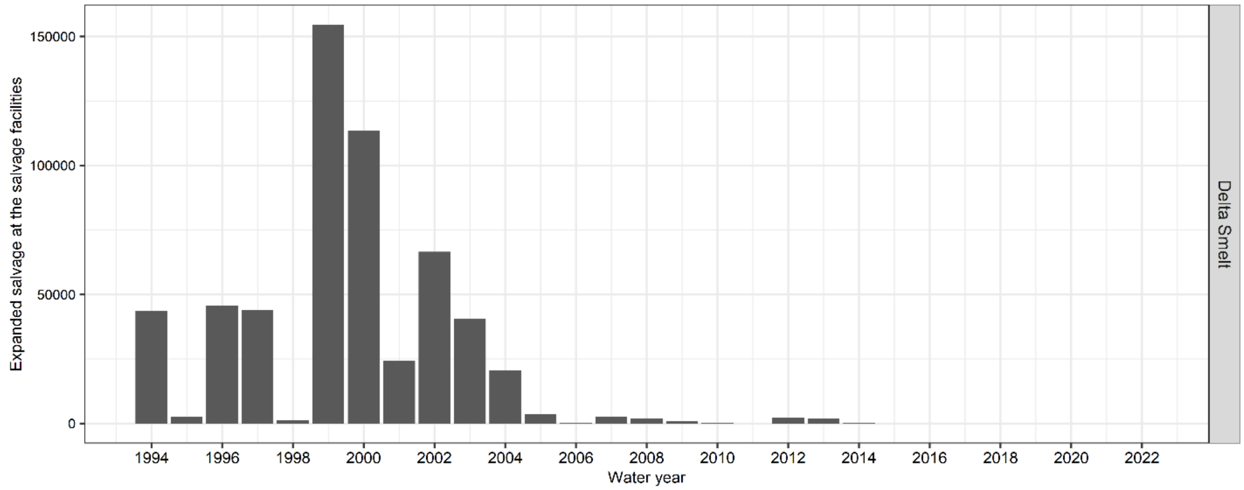

Figure I-21. Annual Delta smelt expanded salvage numbers at the CVP and SWP export facilities from 1994 – 2022

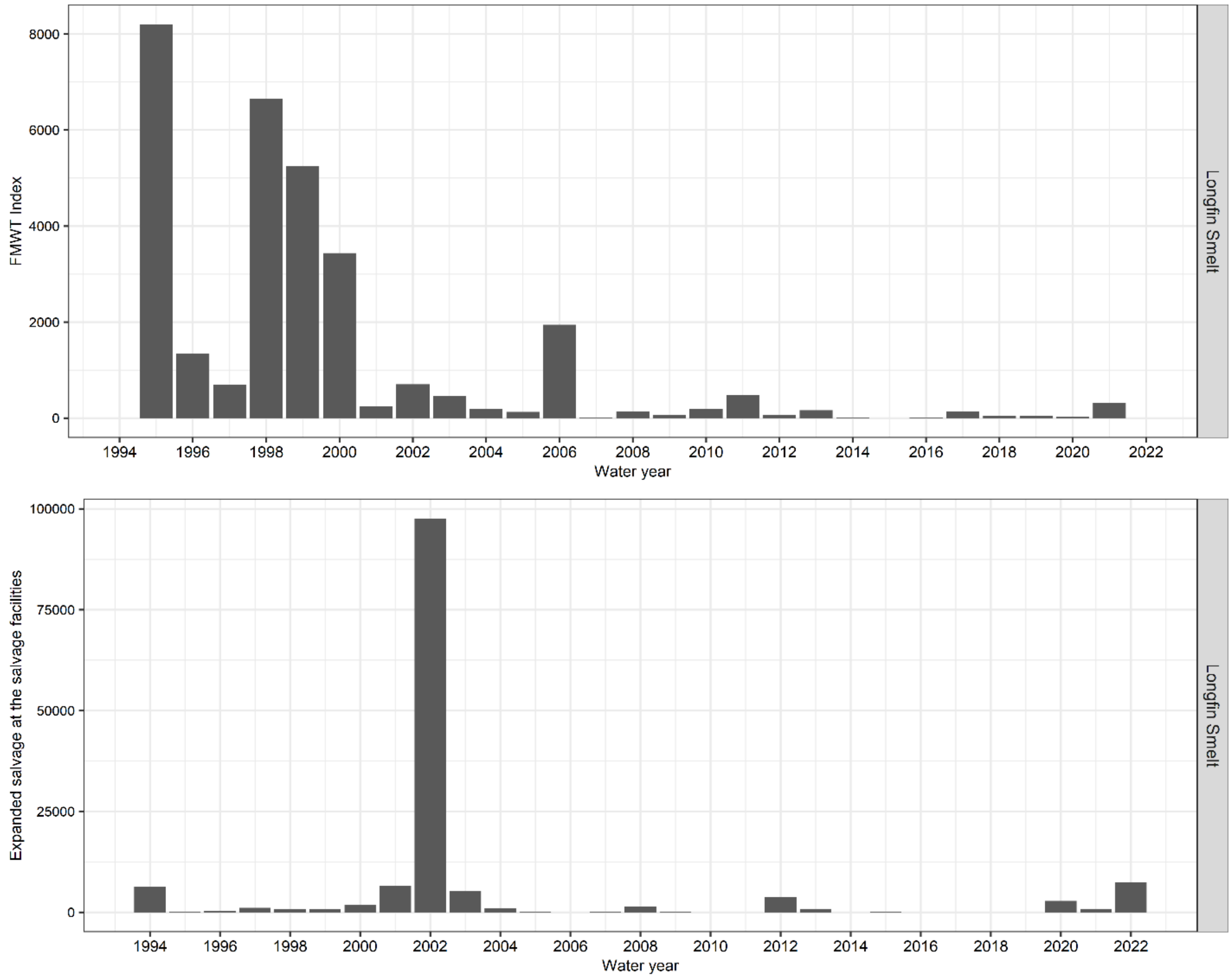

Figure I-22. Longfin smelt abundance index time series from Fall Midwater Trawl survey (FMWT) (top) and total annual Longfin smelt expanded salvage numbers at the CVP and SWP export facilities (bottom) from 1994 – 2022

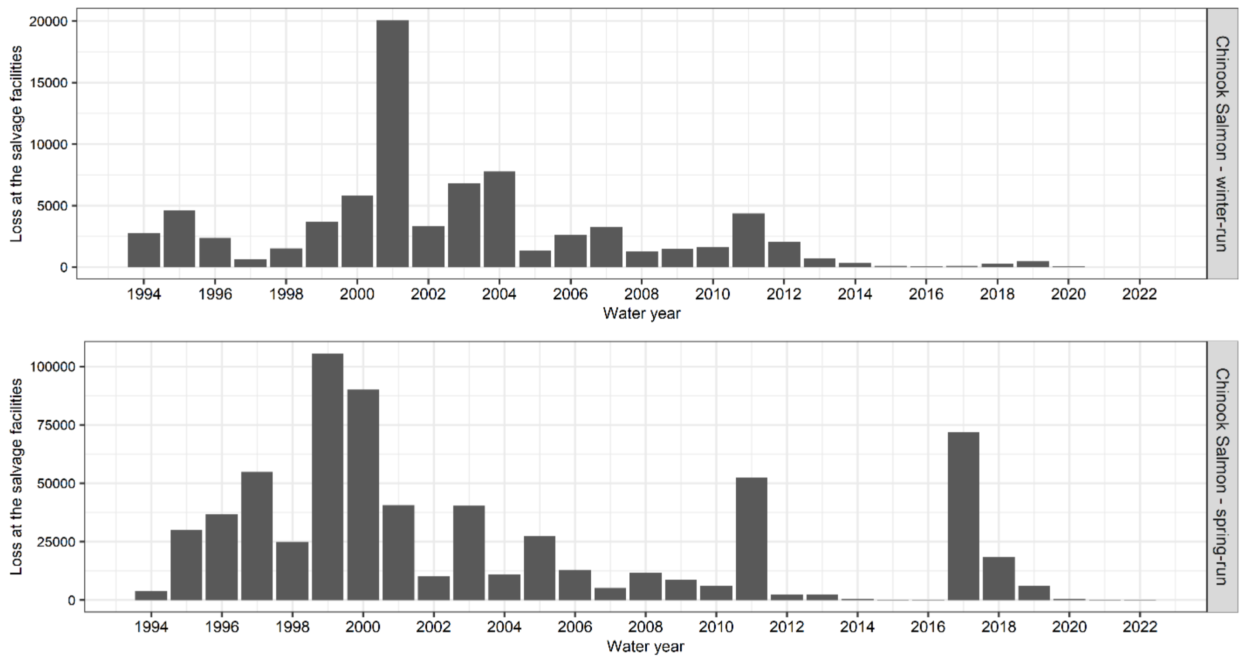

Figure I-23. Summary of Chinook salmon metrics related to OMR management. Top: Annual total loss of unclipped winter-run length-at-date Chinook salmon at the CVP and SWP export facilities from 1994-2022. Bottom: Annual total loss of unclipped spring-run length-at-date Chinook salmon at the CVP and SWP export facilities from 1994-2022.

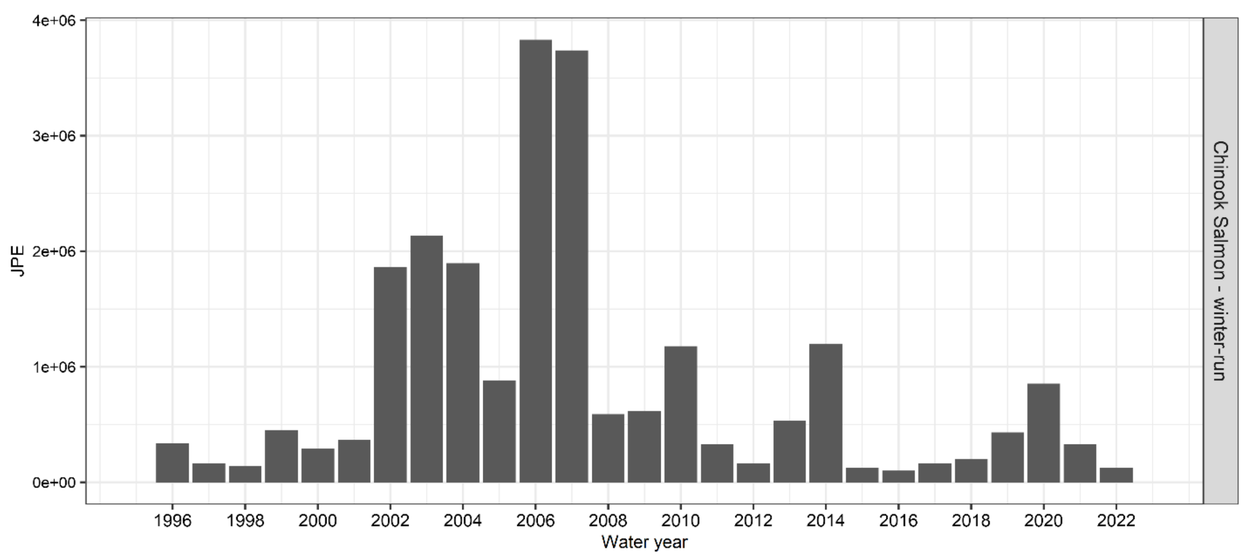

Figure I-24. Annual winter-run Chinook salmon juvenile production estimates (JPE) from 2009-2022

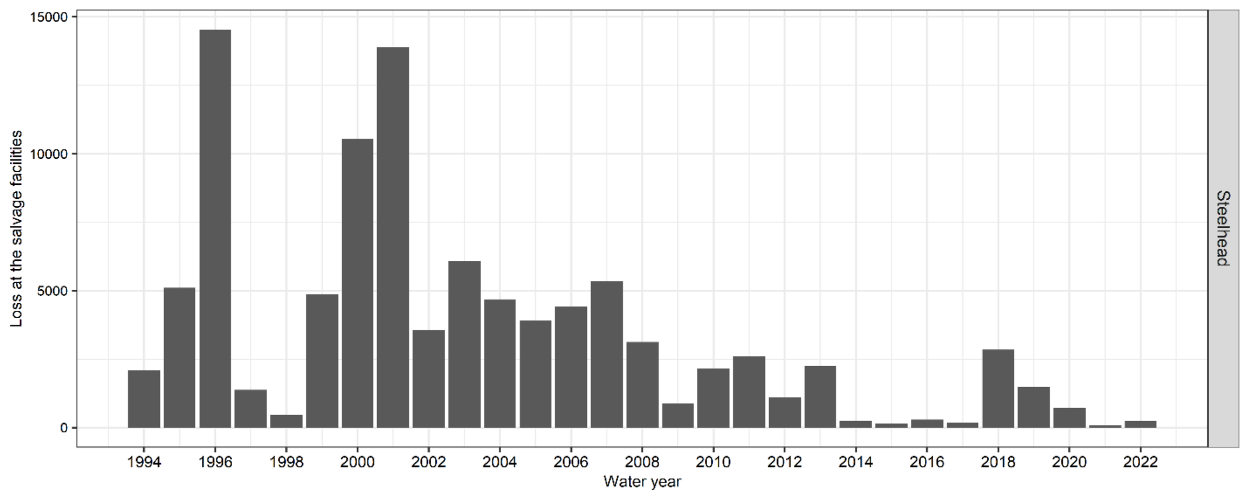

Figure I-25. Annual total loss of unclipped Steelhead/Rainbow Trout at the CVP and SWP export facilities from 1994-2022

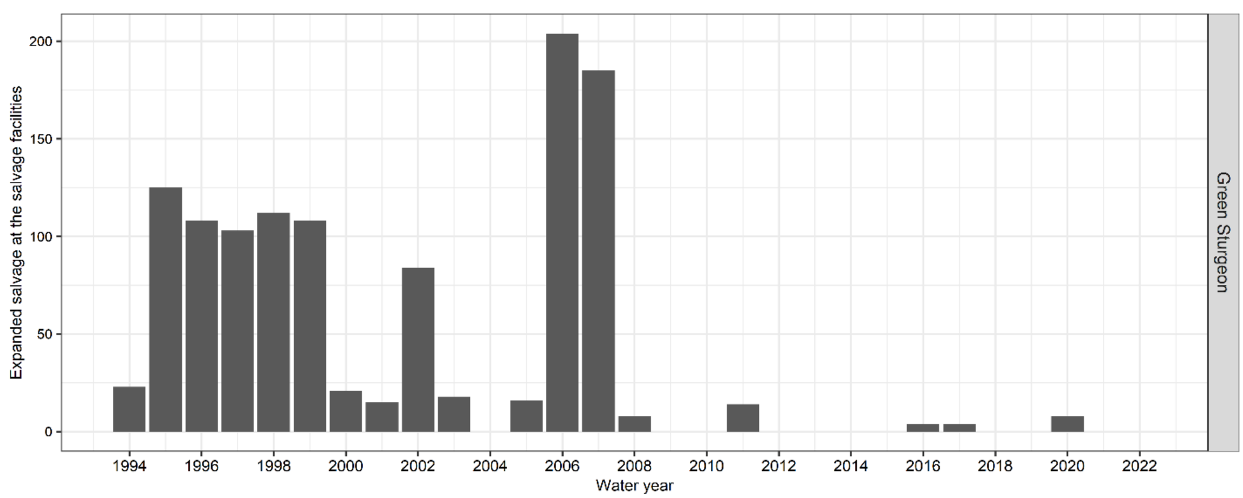

Figure I-26. Annual Green sturgeon expanded salvage numbers at the CVP and SWP export facilities from 1994 – 2022

I.5.2.4 Loss of Coded-wire tagged salmonids

Between 2009 and 2022, 369 batches of Sacramento River basin CWT fall-run (n = 311) and late fall-run (n = 58) Chinook salmon were released at Coleman National Fish Hatchery (Table I-2). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to almost 30% (2018) (Table I-2).

Table I-2. CWT information for Sacramento River basin tagged fall-run and late fall-run Chinook salmon, 2009 – 2022

	Groups with Observed Salvage	Total Number CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT groups Salvaged, Non-Zero (min, max)
2009		34	0.0	
2010		27	0.0	
2011		27	0.0	
2012	10	36	27.8	0.096 (0.009 - 0.281)
2013	3	13	23.1	0.073 (0.047 - 0.121)
2014	1	14	7.1	0.005 (0.005 - 0.005)
2015		1	0.0	
2016	1	29	3.4	0.244 (0.244 - 0.244)
2017		29	0.0	
2018	7	24	29.2	0.015 (0.003 - 0.065)
2019	1	31	3.2	0.323 (0.323 - 0.323)
2020	1	34	2.9	0.029 (0.029 - 0.029)
2021	6	41	14.6	0.013 (0.006 - 0.024)
2022	1	29	3.4	0.048 (0.048 - 0.048)

Between 2009 and 2020, 27 batches of American River basin CWT fall-run Chinook salmon from Nimbus Fish Hatchery were released at a few locations along the American River (Table I-3). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 66.7% (2012) (Table I-3).

Table I-3. CWT information for American River basin tagged fall-run Chinook salmon, 2009 – 2020

	Groups with Observed Salvage	Total Number CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT groups Salvaged, Non-Zero (min, max)
2009		1	0	
2010		1	0	
2011		1	0	
2012	2	3	66.7	0.003 (0.003 - 0.004)
2013		3	0	
2016		4	0	
2017		4	0	
2018		2	0	
2019		4	0	
2020	1	4	25	0.016 (0.016 - 0.016)

Between 2009 and 2022, 62 batches of Feather River basin CWT spring-run (n = 55) and fall-run (n = 7) Chinook salmon from Feather River Hatchery were released at a few locations along the

Feather River (Table I-4). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 50% (2018) (Table I-4).

Table I-4. CWT information for Feather River basin tagged spring-run and fall-run Chinook salmon, 2009 – 2022

	Groups with Observed Salvage	Total Number CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT groups Salvaged, Non-Zero (min, max)
2009		5	0	
2010		1	0	
2011		2	0	
2012		2	0	
2013		1	0	
2014		4	0	
2015		7	0	
2016		6	0	
2017		10	0	
2018	1	2	50	0.032 (0.032 - 0.032)
2019		9	0	
2020	1	7	14.3	0.010 (0.010 - 0.010)
2021		4	0	
2022		2	0	

Between 2011 - and 2023, 40 batches of San Joaquin River basin CWT spring-run (n = 39) and fall-run (n = 1) Chinook salmon from Feather River Hatchery and the San Joaquin River Conservation Hatchery were released at a few locations along the San Joaquin River (Table I-5). The percentage of release groups from each year which had fish observed in the Delta fish collection facilities ranged from 0% to 100% (2011, 2016, 2017, 2018. and 2021) (Table I-5).

Table I-5. CWT information for San Joaquin River basin tagged spring-run and fall-run Chinook salmon, 2011 – 2023

	Groups with Observed Salvage	Total Number CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT groups Salvaged, Non-Zero (min, max)
2011	1	1	100	0.325 (0.325 - 0.325)
2014		1	0	
2015		1	0	
2016	2	2	100	7.021 (1.127 - 12.914)
2017	3	3	100	7.715 (6.701 - 7.672)
2018	4	4	100	3.888 (1.069 - 7.730)
2019	4	7	57.1	2.432 (0.080 - 3.595)
2020	7	10	70.0	2.362 (0.155 - 4.393)
2021	4	4	100	0.374 (0.003 - 0.615)
2022	2	5	40.0	0.028 (0.015 - 0.042)

	Groups with Observed Salvage	Total Number CWT Groups	Percent of Groups with Observed Salvage	Average Percent of CWT groups Salvaged, Non-Zero (min, max)
2023	1	2	50	0.016 (0.016 - 0.016)

I.5.3 Models

Numerous quantitative models can be used to evaluate the environmental impacts of the CVP and SWP on listed fishes. A standardized set of criteria was applied to identify the suite of models used in our effects analysis. The necessary criteria include: 1) models are accessible and model output can be reproduced by an independent party, 2) model structure is well documented including model assumptions, 3) model functions are responsive to changing operations such as flow, and 4) model output informs performance metrics. In addition, models also preferably include: 1) focus on target species and/or run-timing group, 2) data collected after 2008, 3) an open and participatory development process, and 4) recent application in regulatory context (e.g., Biological Assessment, BiOps).

I.5.3.1 Salvage Models

Salvage Density Model Documentation (NMFS 2019 Biological Opinion, Appendix C)

Input data and preprocessing: Historic monthly export data and expanded salvage data for all species were used for water years 1994 – 2020. The combined datasets were used as basic estimates of fish density (fish salvaged / volume of water exported) multiplied by simulated export data for the 1922 – 2021 (CalSim3) CALSIM modeling period to assess differences between scenarios. The use of expanded salvage estimates has a known associated statistical error caused by the expansion of subsamples. This statistical error has not been accounted for in the current salvage-density method though this is consistent with analyses using these data. The method assumes a linear relationship between entrainment and export flows due to a lack of information on how salvage would increase with increasing flows. The method does not account for spatial distribution of fish populations. Juvenile Chinook were assigned a race using length at date (LAD) method. There is a large overlap in size distributions among races which can lead to false race assignments and LAD has been shown to be inaccurate for both winter-run and spring-run Chinook salmon when compared with genetic identification assignment. Salvage by race should be interpreted with caution.

Normalization to population size: Salvage and loss data were normalized where possible (e.g., winter-run Chinook salmon estimates normalized by juvenile production estimate (JPE)) to account for population abundance. No normalization occurred for spring-run Chinook salmon, fall- / late fall-run Chinook salmon, steelhead, or green sturgeon.

Salvage index calculation: For each species at each month at each facility, density (fish / TAF) was calculated as total monthly loss or expanded salvage for the facility divided by total monthly volume of exported water. Assuming a linear relationship between entrainment and flow may be an oversimplification so the method “functions as a description of changes in export flows weighted by seasonal changes in salvage density of covered species.” Mean monthly entrainment indices for each month of each water year type is calculated as salvage or loss density multiplied by CALSIM modeled export value for the same month for all years with the same water year type.

This method can be used to compare the salvage index calculated from one export scenario to another and relies on historical salvage data to estimate changes in entrainment at the SWP/CVP export facilities providing a description of "changes in export flows weighted by seasonal changes in salvage density of covered species."

Machine Learning

A new model to predict winter-run Chinook salmon occurrence at the salvage facilities is currently being developed by Jeremy Gaeta (CDFW), Trinh Nguyen (CDFW), and Brian Mahardja (Reclamation). This model (hereinafter, Salvage Machine-Learning Tool) takes a machine learning approach (extreme gradient boosting dropout multiple additive regression trees) to predict winter-run Chinook salmon salvage as a function of various potential environmental drivers. Whereas previously developed machine learning salvage prediction tool (Tillotson et al. 2022) can estimate the number of winter-run Chinook salmon with high accuracy after salvage has occurred, the Salvage Machine-Learning Tool is designed to predict winter-run Chinook salmon occurrence prior to any salvage (one-week and three-week ahead models are currently being refined) and, thus, may be useful for on-ramping of OMR management season.

The Salvage Machine-Learning Tool can be used to evaluate the seasonal loss and first entrainment date performance metrics for winter-run Chinook salmon. This model can incorporate daily flow data from the Sacramento and San Joaquin Rivers as well as export level values from the pumping facilities (combined). CALSIM output is in a monthly timestep and because using the same value across all days within the month for the Salvage Machine-Learning Tool may yield highly biased or misleading results, Reclamation will not use this model for evaluating different OMR alternatives.

Tillotson et. Al 2022

Tillotson et al. (2022) developed a hurdle quantile regression forest model that predicts winter-run Chinook salmon and natural CV steelhead numbers at the salvage facilities one week in advance. This model was built to be a risk forecasting tool that can inform adjustments of water export in the Delta based on real-time conditions. This model is currently accessible through SacPAS and provides a robust and conservative estimate of entrainment risk, as overpredictions were uncommon in the testing dataset. However, because the previous week's entrainment loss was found to be the strongest predictor for the model, it complicates the use of this model for evaluating alternatives. A fish behavior component or model that predicts fish response to changing environmental conditions will likely be required in order to properly estimate expected salvage numbers across alternatives. Because there is currently no means to incorporate such effect in the model, Reclamation will not use this model for evaluating different OMR alternatives.

Negative binomial model of loss

To evaluate potential changes to the number of LAD winter-run and spring-run Chinook salmon salvaged at the CVP and SWP pumping facilities based on the alternatives, Reclamation analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation.

I.5.3.2 Hydrodynamic Models

DSM2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model for the Sacramento / San Joaquin Delta, developed by DWR. The state and federal agencies, through the Salmon Monitoring Team (SaMT), model impacts of OMR scenarios associated with changes in operations of the Delta projects on behavior of sheltering, migrating, foraging, and rearing salmonids. DSM2 can simulate flows, velocities, and stage, and these data can be used to compare differences in flow conditions reflecting distinct inputs (i.e., no exports, specific inflows), which allows for visualizing the zone of influence of different releases and diversions in Delta regions. Reclamation conducted a DSM2 scenario sensitivity exercise. This was a collaboration between Reclamation and DWR's operations modeling teams to determine what difference in OMR flows resulted in differences in distribution of velocities and flow. Kolmogorov-Smirnov test statistic results demonstrated that if the difference in modeled OMR scenarios is less than 500 cfs (possibly even less than 1,000 cfs), then a comparison of DSM2 model runs outputs are not different. This finding is likely due to the dominant control of velocity, flow, and stage due to tides.

UnTRIM Bay-Delta Model

UnTRIM is a three-dimensional hydrodynamic model developed for San Francisco Bay-Delta boundary conditions used to test hypotheses and evaluate impacts of varying management actions, climate scenarios, and hydrology. The model provides predictions of water level, tidal flows, current speed, and salinity. Use of an unstructured mesh grid at varying resolutions allows for individual cells to be wetted and dried in both horizontal and vertical directions by solving Navier-Stokes equations in the horizontal plane. Varying grid size allows for flexibility in a single model: localized model predictions while still incorporating estuary-wide hydrodynamics. The model incorporates high-resolution bathymetric data varying from 10-meter to 90-meter resolution within different Bay regions (e.g., San Pablo Bay derived from 30-meter, Suisun Bay derived from 10-meter). Calibration includes water level, flow, and salinity observations from San Francisco Bay and Sacramento-San Joaquin Delta (Casulli and Zanolli 2002, MacWilliams et al 2015). Model calibration and validation show UnTRIM provides accurate predictions of flow, stage, and salinity.

RMA Bay-Delta Model

RMA Bay-Delta model is a two-dimensional hydrodynamic model developed for the San Francisco Bay-Delta and includes one-dimensional representations of some Delta and Suisun March channels in a single model (MacWilliams et al. 2016). The model provides predictions of flow, velocity, depth, electrical conductivity, residence time, and particle tracking. Flexibility in grid size allows for flexibility and ability to represent different scenarios. Bathymetric inputs are updated as new bathymetry data becomes available. Calibration includes observed stage, flow, and salinity time series data from San Francisco Bay locations.

I.5.3.3 Salmonid Delta Survival and Routing

This study (Buchanan et al. 2021) investigated factors influencing survival of acoustically telemetered juvenile hatchery *O. mykiss* from 2011 to 2016. Juvenile steelhead survival through Delta varied considerably both within years and between years. In general, survival through the San Joaquin route was greater than survival through the Old River Route, but not notably so. Survival was higher for the SJR route compared to the Old River Route for 16 of 19 release groups; however, the differences were sometimes very small and not statistically significant when year, barrier status, and fork length were accounted for. It would be expected that if the San Joaquin route was the superior route, then a positive effect on survival would have been observed by fish using this route.

Low steelhead survival was observed through the Turner Cut route. One would expect that entering the interior Delta at Turner Cut junction would lower survival by increasing risk of entrainment into the water export facilities. 67% of the fish that used Old River route entered the facilities compared to only 8 percent of the fish that took the SJR at the head of Old River. While increased entrainment into the facilities was observed for *O. mykiss* using the OR route markedly lower survival was not observed. This study did not find a relationship between exports and survival head of OR to Chipps. A complete range of exports was not evaluated (around 6100 cfs).

STARS

The Survival, Travel time, and Routing Simulation (STARS) model is an individual-based simulation that predicts fish parameters (survival, travel time, entrainment) of juvenile salmonids migrating through the Delta. The fish parameters are related to movement of individual acoustically tagged late-fall and winter-run Chinook salmon connected to daily data (DCC gate status and Sacramento River flow at Freeport). The implementation of the simulation model currently available for use is calibrated to acoustically tagged late-fall fish released from 2007 to 2011. Data inputs to the model can be obtained by assigning monthly CalSim output to daily values within each month. Results are for individuals in cohorts, or fish who enter the model's "system" daily at Freeport. The use of the STARS model can inform the migrating behavior of juvenile salmonids (i.e., route selection) and total survival in the Delta. It is constructed to understand the space outside the interior Delta, but interpolation could be used to identify possible behavior of fish once they take a specific route away from the Sacramento River (i.e., Delta Cross Channel or Georgiana Slough). STARS provides overall survival and travel time, route-specific survival and travel time, and proportion of fish on a daily timestep that would use individual migration pathways or routes. An application of the STAR models run in real time is available here: https://oceanview.pfeg.noaa.gov/shiny/FED/CalFishTrack/. The code and supporting document are available from USGS (Russ Perry, USGS, Personal Communication). The model structure and assumptions are documented in peer-reviewed literature (Perry et al. 2018). Model development is not currently open and participatory.

The STARS model can be applied to assess the performance metric of routing probability for winter-run Chinook salmon and possibly also spring-run Chinook salmon. The STARS model was applied to the 2019 NMFS BiOp.

DPM

The Delta Passage Model (DPM) is based on migratory pathways and reach-specific mortality as Chinook Salmon smolts travel through a simplified network of reaches and junctions. The biological functionality of the DPM is based on releases of acoustically tagged Chinook salmon performed between 2007 and 2017. The current model is based on acoustically tagged winter run, spring run, fall run and late fall–run individuals (≥ 80 mm) released in the upper reaches of the Sacramento River and within the Delta. These releases are primarily comprised of hatchery fish. However, wild spring and fall run are included in the dataset. These releases cover a wide range of environmental conditions, including extreme drought in 2014 and 2015 and high flow years. Uncertainty is explicitly modeled in the DPM by incorporating environmental stochasticity and estimation error whenever available. The major model functions in the DPM are as follows: 1) delta entry timing, which models the temporal distribution of smolts entering the Delta for each race of Chinook salmon, 2) fish behavior at junctions, which models fish movement as they approach river junctions, 3) migration speed, which models reach-specific smolt migration speed and travel time, 4) route-specific survival, which models route-specific survival response to non-flow factors, 5) flow-dependent survival, which models reach-specific survival response to flow, and 6) export-dependent survival, which models survival response to water export levels in the interior Delta reach. The DPM model can be used to assess the survival of smolts from Delta entry to Chipps Island performance metrics for winter-run or spring-run Chinook salmon. Model documentation for previous iterations of the model is available in an accompanying report (Cavallo et al. 2011). The model was applied in the NMFS 2019 BiOp. Model development and current application is not fully open and participatory.

The DPM operates on a daily timestep using simulated daily average flows and south Delta exports as model inputs. Water movement through the Delta as input to the DPM is derived from daily (tidally averaged) flow output produced by the hydrology module of the Delta Simulation Model II (DSM2- HYDRO; <http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/>) or from CalSim -II.

PTM

The particle tracking model (PTM) component of DSM2 computes the location of an individual particle at any time step within a channel based on velocity, flow and water level information provided by HYDRO. The longitudinal movement is based on transverse and vertical velocity profiles computed from mean channel velocity provided by HYDRO. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. PTM is publicly available from DWR at CADWRDeltaModeling/dsm2: Delta Simulation Model 2 (github.com).

ECO-PTM

The ecological particle tracking model (ECO-PTM) was developed by DWR, in collaboration with USGS, and applies to juvenile Chinook Salmon migration. Currently built upon data from acoustically tagged late fall–run Chinook salmon (2006 – 2014), the ECO-PTM estimates routing through Georgiana Slough, Delta Cross Channel route, the Sutter / Steamboat slough complex, or remaining in the Sacramento River. Development of the model is still ongoing and currently focused on the south Delta. This model was recently used in evaluating the biological effects of the spring 2022 Temporary Urgency Change Petition (TUCP), and code is available from DWR at https://data.cnra.ca.gov/dataset/ecological-particle-tracking-model-eco-ptm.

ECO-PTM can be used to evaluate survival, travel time, and routing probabilities, and thus apply to the seasonal loss and zone of entrainment performance metrics for winter-run and spring-run Chinook salmon. This model can incorporate CalSim or DSM2 data as model input. Development of this model is in progress.

I.5.4 Life Cycle Models

I.5.4.1 Winter-Run Chinook Salmon Life Cycle Model (WRLCM)

The Winter-Run Chinook Salmon Life Cycle Model (WRLCM) is a spatially and temporally explicit stage-structured simulation model that estimates the number of winter-run Chinook salmon at each geographic area and timestep for all stages of their lifecycle. The first version of the WRLCM was developed in 2014. In 2015, the WRLCM underwent a model review by the Center for Independent Experts, which contributed to improvements in more recent versions of the model. See: https://oceanview.pfeg.noaa.gov/wrlcm/intro.

In the 2019 NMFS BiOp, the WRLCM uses the Newman model (Newman 2003), which is a nonlinear hierarchical juvenile Chinook salmon Delta survival model that incorporates biotic covariates, environmental covariates, and random effects. Covariates include fish length, log transformed median river flow during the outmigration period, water salinity, river water temperature and hatchery water temperature at release, magnitude of the tide, median volume of exports during the outmigration period, DCC gate position, and water turbidity. The enhanced Particle Tracking Model (ePTM) has been developed to improve the Lifecycle Model (LCM) estimates for survival effects from Delta flows.

The Newman model compares survival of juvenile hatchery coded-wire-tagged (CWT) fall-run Chinook salmon released upstream (lower Sacramento River, cities of Sacramento Courtland and Ryde) and downstream (west of Chipps Island) of the Delta. Releases represent two scenarios where fish either had to transit the Delta or not before reaching the ocean. The relative difference in survival between release groups (upstream: CWT recoveries from Chipps Island midwater trawl; upstream and downstream: CWT recoveries from commercial and recreational fisheries) allows for delta-specific survival estimates. The Newman model results are based on environmental data from 1979 – 1995. The model is developed using fall-run hatchery Chinook released in April and May (later than winter-run peak outmigration). Model results should be considered as an assumption of how smolt survival rates vary with changes in scenarios.

The ePTM was developed as joint collaboration between the University of California, Santa Cruz and National Marine Fisheries Service's Southwest Fisheries Science Center. It is a data-driven model of juvenile salmonid migration through the Delta built off of behavioral fish decisions based on local environmental variables. The model uses acoustically tagged late fall–run Chinook salmon data with plans to use fall-run Chinook salmon in the future. It is currently still in development but has a downloadable, working version at GitHub: The ePTM Version 2.0 (https://github.com/cvclcm/ePTM_v2). Attempts to use the model for the LCM were limited by documentation and program versioning.

I.5.4.2 Oncorhynchus Bayesian Analysis (OBAN)

The winter-run Chinook salmon Oncorhynchus Bayesian Analysis (OBAN) model has been developed from the conceptual life cycle model of winter-run Chinook salmon and coded into Windows-based software with graphic output capability. The Bayesian estimation of model coefficients was coded into WinBUGS. The software finds a statistical "best fit" to empirical trends by matching model predictions to empirically observed juvenile and adult abundances. The model is capable of fitting any number of abundance data sources and estimating any number of coefficient values to find the best statistical prediction. This model code is not available for Reclamation's use, so it does not inform the initial alternative analyses.

I.5.4.3 CVPIA Winter-run and Spring-run Life Cycle Models

CVPIA SIT DSM life cycle models can be used to compare natural production and demographic rates of Winter-run and Spring-run Chinook Salmon. The CVPIA SIT DSM models were developed by the CVPIA Science Integration Team (SIT) as part of a Structured Decision Making process, and the models, as implemented in R, are open source and publicly available. See: https://cvpia.scienceintegrationteam.com/cvpia-sit/resources/dsm-r-packages. Analyses using a version of the DSMs have been published (Peterson and Duarte 2020). These models can incorporate CalSim flow and HEC-5Q temperature data from the Sacramento River and tributaries. The original purpose of these DSMs was to compare outcomes of different restoration scenarios, but they would also be appropriate for comparisons of different flow and temperature scenarios. These models can inform multiple performance metrics for Chinook salmon, including Delta routing and survival probabilities.

I.5.4.4 Delta smelt Individual Based Model

Delta Smelt Individual Based Model (IBM) can potentially be used to evaluate the population growth, entrainment mortality, and survival probability between life stages for Delta smelt (Rose et al. 2013a, 2013b). However, some key issues precluded the use of the Delta Smelt IBM by Reclamation. The Delta Smelt IBM would not be able to directly incorporate any flow variables from CalSim into the simulation aside from OMR, whereas the Delta Smelt Life Cycle Model (Smith et al. 2021; see below) contains a summer Delta outflow component. Delta Smelt IBM-simulated movement is also not mechanistic. Relevant to this application for OMR management, the entrainment submodel lacks any effect causing simulated fish to occupy the San Joaquin River or South Delta, such as turbidity.

I.5.4.5 Delta Smelt Life Cycle Model (2021 version)

Polansky et al. (2020) developed a stage-structured state-space life cycle model for Delta Smelt. State-space models are useful as ecological modeling tool because they allow separate descriptions of state and observation processes and because they permit integration of disparate data sets. This Delta Smelt life cycle model was later expanded from four to seven different life stages and to include a component that describes the entrainment process into the Delta export facilities (Smith et al. 2021). This model produces expected values for larval recruitment and survival at the subsequent life stages. The best model in Smith et al. (2021) also used OMR values at a monthly scale and therefore, CalSim output for the alternatives can be directly incorporated into the analysis. As such, Reclamation can use this model to calculate expected annual population growth rate (λ). The metric of interest will be geometric mean of λ for a specified time period (e.g., 1995-2015), which will be compared across alternatives.

I.6 Lines of Evidence

From the full list of quantitative models outlined above (9.3 Models), a subset of tools was selected to evaluate the environmental impacts of the CVP and SWP operations on listed fishes. These tools are included as lines of evidence. Additionally, observations from the literature and datasets can be incorporated to understand management concepts regarding OMR effects on fish and the environment as lines of evidence.

I.6.1 First Flush Conditions

The frequency of first flush conditions are summarized below with additional detail and statistics reported in Appendix AB-I.A First Flush Conditions. Results will provide an evaluation of the first flush criteria for the Proposed Action and each of the alternatives.

First flush conditions, when flows and turbidity in the Delta initially increases occurs in winter when large precipitation events occur within the Sacramento and San Joaquin River basins. These conditions are the cue for the seasonal prespawn migration of adult Delta Smelt to reach tidal freshwater habitats where they spawn in later months (Bennet 2005). The reduction of exports by the CVP and SWP was hypothesized to reduce entrainment of migrating adult Delta Smelt (Grimaldo et al 2009). After the first flush event, adult Delta smelt show little movement (Polansky et al 2018).

Under the 2020 ROD, first flush conditions were contained in the Integrated Early Winter Pulse Protection (IEWPP) action in which Reclamation and DWR would reduce exports for 14 consecutive days so that the 14-day averaged OMR index for the period will not be more negative than -2,000 cfs, in response to “First Flush” conditions in the Delta. The IEWPP could be triggered between December 1 and January 31 when the follow environmental criteria occurs:

- Running 3-day average of the daily flows at Freeport is greater than 25,000 cfs; and
- Running 3-day average of the daily turbidity at Freeport is 50 Nephelometric turbidity units (NTU) or greater; or
- Real-time monitoring indicates a high risk of migration and dispersal into areas at high risk of future entrainment.

The Proposed Action includes a First Flush Action as the start of OMR management, similar to the First Flush Action in the 2020 ROD. During the Proposed Action’s First Flush Action, Reclamation and DWR will reduce CVP and SWP exports for 14 consecutive days, anytime between December 1 and the last day of February, to maintain a 14-day average OMR index no more negative than -2,000 cfs within three days of when the following criteria are met:

- Three-day running average of daily flows at Freeport is greater than, or equal to, 25,000 cfs, and
- Three-day running average of daily turbidity at Freeport is greater than, or equal to, 50 FNU

These conditions were exceeded in WY2022 and WY2023. Analysis of historical water quality and flow data between WY2010 and WY2021 showed that these conditions were exceeded in WY2019, WY2017, WY2014, and WY2012. (See Attachment I.A. for historical analysis of water quality and frequency of first flush conditions). OMR South Delta Turbidity Sources, Conditions, and Frequency of Delta Smelt Adult, Larvae and Juvenile Entrainment Protection

The frequency of alternative South Delta entrainment protection criteria is summarized below with additional detail and statistics reported in Appendix I.X OMR South Delta Turbidity Sources for Delta Smelt Adult, Larvae and Juvenile Entrainment Protection Attachment. Results will provide an evaluation of the OMR management related to turbidity for the Proposed Action and each of the alternatives.

Under the 2020 Record of Decision (ROD), injury and mortality of adult, larval, and juvenile Delta smelt are anticipated to be minimized due to active real-time management of OMR flow and turbidity in the south Delta:

Adult protection: During the winter and early spring, after a First Flush event or February 1 (whichever comes first) net negative OMR flows are held at levels no more negative than a 14-day averaged OMR of -2000 cfs, for at least 5 days, when turbidity at the Bacon Island monitoring station (OBI) is a daily average of 12 NTU or greater.

Juvenile/Larval protection: On or after March 15 of each year, if QWEST is negative and larval or juvenile delta smelt are within the entrainment zone of the pumps based on real-time sampling of spawning adults or young of year life stages, Reclamation and DWR will manage exports to limit entrainment of larval and juvenile delta smelt. When secchi depth in the south Delta is less than 1m, Reclamation will operate to OMR no more negative than -3500 cfs. When secchi depth in the south Delta is greater than 1m, Reclamation and DWR and DWR will operate to OMR no more negative than -5000 cfs.

Entrainment protections under the Proposed Action include:

Adult protection: If after a First Flush Action and until larval and juvenile protections are applicable, Reclamation and DWR propose to manage exports to maintain daily average turbidity in Old River at Bacon Island (OBI) at a level of less than 12 FNU. If the daily average turbidity at Bacon Island cannot be maintained less than 12 FNU, Reclamation and DWR will manage exports to achieve an OMR no more negative than -2,000 cfs until the daily average turbidity at Bacon Island drops below 12 FNU. However, if five consecutive days of OMR less negative than -2,000 cfs do not reduce turbidity at Bacon Island below 12 FNU in a given month, Reclamation and will instead operate to OMR no more negative than -3,500 cfs until OBI less than 12 FNU.

Juvenile/Larval protection: Larval and juvenile Delta smelt protections start when larval or juvenile delta smelt are detected withing the entrainment zone based on real-time sampling of spawning adults or young of year life stages, Reclamation and DWR will restrict exports to OMR no more negative than -5,000 cfs. When the secchi depth in the south Delta is less than 1 meter, as determined by weekly monitoring, Reclamation and DWR will restrict exports to OMR no more negative than -3,500 cfs.

The purpose of these actions is to minimize entrainment risk to Delta smelt in the Old and Middle River Corridor and South Delta, since these regions are associated with low-quality habitat, high predation risk, and can lead to salvage at export facilities.

Analysis of historical turbidity data indicates that between WY 2012 and 2023, turbidity bridge conditions were met in eight years under the 2020 ROD and in six years under the Proposed Action (Appendix I. OMR South Delta Turbidity Sources for Delta Smelt Adult, Larvae and Juvenile Entrainment Protection Attachment; Figure 1, Table 1).

Analysis of historical secchi depth and dayflow data indicates that between WY 2010 and 2019, larval and juvenile protection conditions were met in seven years under the 2020 ROD (Appendix I. OMR South Delta Turbidity Sources for Delta Smelt Adult, Larvae and Juvenile Entrainment Protection Attachment; Figure 2), and in all years under the Proposed Action (Appendix I. OMR South Delta Turbidity Sources for Delta Smelt Adult, Larvae and Juvenile Entrainment Protection Attachment; Figure 3).

I.6.2 Adult Delta Smelt Salvage Off-ramp Analysis

In the Proposed Action, adult Delta smelt protection off-ramp criteria include when San Joaquin River flows at Vernalis are greater than 10,000 cfs, the Adult Delta Smelt Entrainment Protection Action (Turbidity Bridge) is offramped. While offramped, the OMR Index will be managed to no more negative than –5,000 cfs on a 14-day average. The Adult Delta Smelt Entrainment Protection Action (Turbidity Bridge) would be immediately reinstated when San Joaquin River flows at Vernalis drop below 8,000 cfs.

USFWS (2008) included an off-ramp criterion that required Rio Vista flow at 100,000 cfs and Vernalis flow at 10,000 cfs. Adult Delta Smelt salvage can remain high even with high Rio Vista flows when Vernalis flow remained low, likely because OMR is influenced largely by San Joaquin River instead of Sacramento River. This is observed in the data, and although adult salvage between January and March has been low since 2008 (Figure I-27), it follows similar trends from prior to 2008 (Figure I-28) in relationship to Sacramento and San Joaquin rivers inflow. Sacramento River at Rio Vista flow was proxied from DAYFLOW by summing Yolo Bypass flow and Sacramento River flow at Freeport. San Joaquin River flow at Vernalis was acquired directly from DAYFLOW variable SJR.

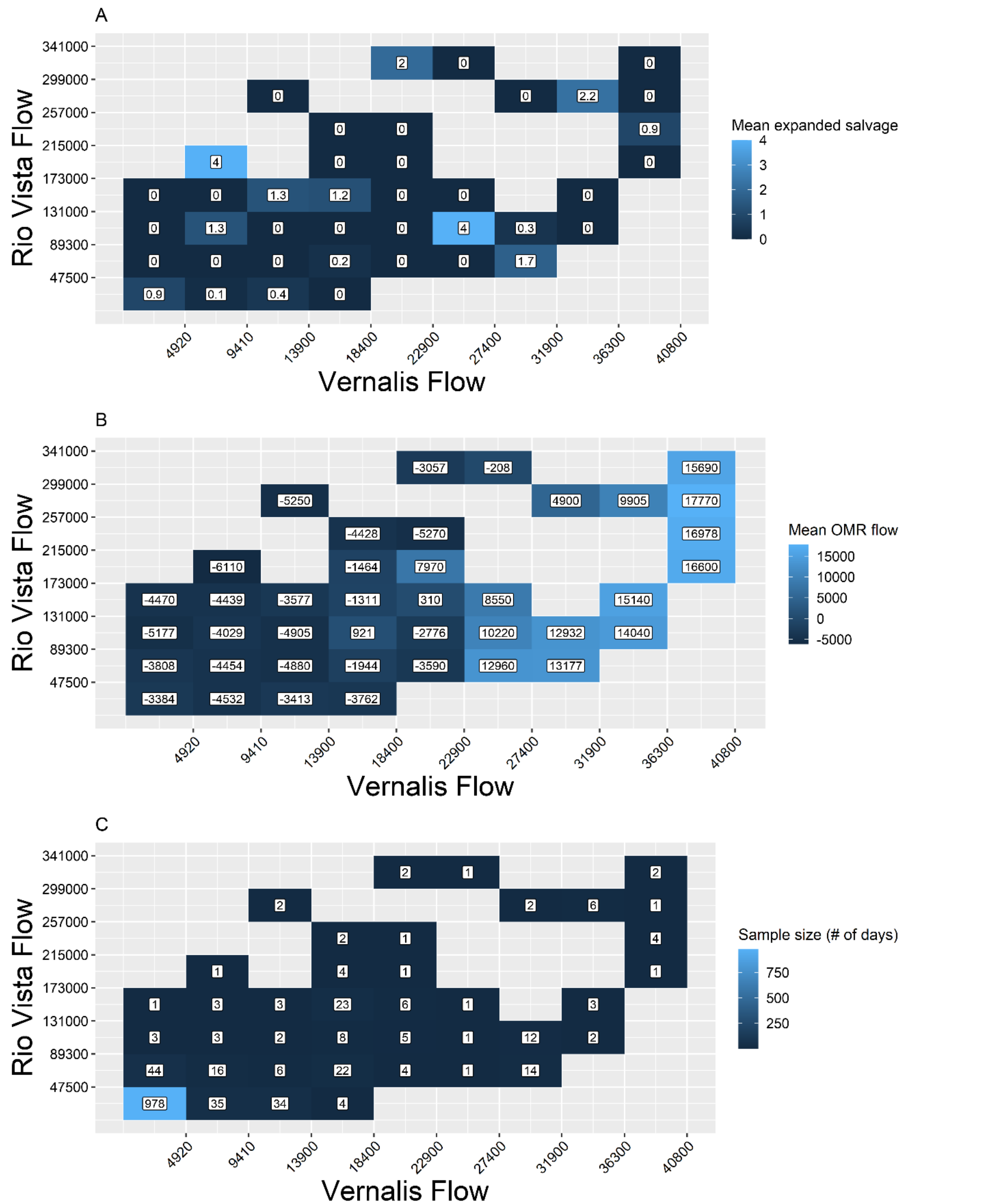

Figure I-27. Mean daily Delta Smelt expanded salvage data (A), mean OMR flow (B), and sample size/number of days (C) binned by Sacramento River flow at Rio Vista and San Joaquin River flow at Vernalis flow values. Data shown came from January-March months from <u>2008 to 2022</u>.

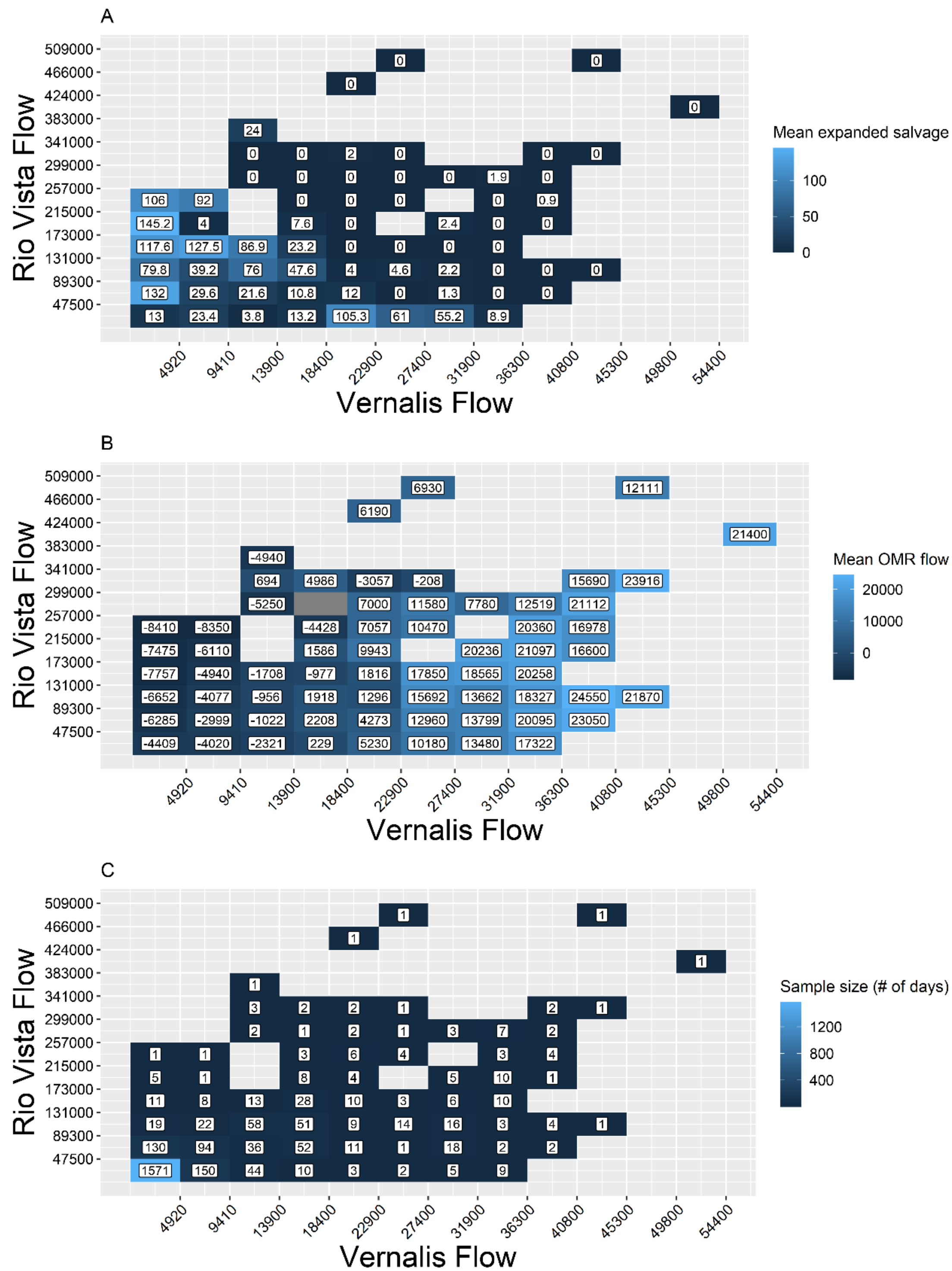

Figure I-28. Mean daily Delta Smelt expanded salvage data (A), mean OMR flow (B), and sample size/number of days (C) binned by Sacramento River flow at Rio Vista and San Joaquin River flow at Vernalis flow values. Data shown came from January-March months from 1993 to 2022.

I.6.3 Use of genetic data for OMR Management

Genetic data have been collected from Chinook salmon captured within the Delta and the Central Valley for over two decades. Through this genetic information, it is now well understood that the length-at-date (LAD) criteria used to assign Chinook salmon to runs are flawed and can be highly inaccurate (Harvey et al. 2014, Johnson et al. 2017). As such, using LAD criteria do not accurately describe the effects of CVP and SWP on listed Chinook salmon runs (i.e., winter-run and spring-run). However, it has been commonly used to assign Chinook salmon runs in surveys, studies, and regulatory context due to its practicality (ITP 2020, 2020 BiOps), as processing for genetic analysis can be costly and time intensive. Reclamation and DWR have demonstrated that rapid genetic protocol to report run assignment of salvaged Chinook salmon within two days can be done (Reclamation Letter 2019). Through this process, if salvaged LAD winter-run or spring-run Chinook salmon triggered pumping reductions, but were later discovered to be not genetically ESA listed ESUs, then these pumping restrictions will be rescinded. Through recent advancements in genetic technology, genetic assay that produces results in near real-time (i.e., hours) at a low cost is now a possibility (Baerwald et al. 2023). In WY 2023, the genetic methods and field procedures to identify runs of Chinook salmon within hours is being piloted, and it should be available as part of the 2021 Consultation. This use of genetic data can replace the inaccurate LAD criteria for identifying Chinook salmon runs at the salvage facilities and be used for more effective OMR management to protect winter-run and spring-run Chinook salmon populations.

In the Proposed Action, genetic identification of juvenile salmon will be implemented to improve accuracy of OMR management including winter-run Chinook salmon early migration protection, annual threshold, and weekly distributed loss threshold real-time adjustment for OMR management.

I.6.4 Historical, Presence-Based, and Model-Based OMR On-Ramp Analysis

The frequency of alternative OMR management on-ramp strategies is summarized below with additional detail and statistics reported in Attachment I.X OMR Historical, Presence Based, and Model-Based OMR On-ramp analysis.

One component to consider regarding OMR flow management is when to initiate the OMR management season (when OMR flow is managed to be more positive than what would normally be operated for if fish species of concern were not an issue). Results will provide an evaluation of the on-ramp criteria for the Proposed Action and each of the alternatives.

I.6.4.1 Calendar-Based

Under the 2020 ROD, OMR flow no more negative than -5,000 cfs is initiated if after January 1 more than 5% of any salmonid species are determined to be present in the Delta by the SaMT. Unless preceded by a First Flush Action for Delta smelt, January 1 has typically been the start date for OMR management season. As such, the 2020 ROD has a combination of calendar-based and presence-based starting criteria for OMR management season. An alternative for OMR management may be using a fixed earlier or later calendar (date-based) start for OMR management or in combination with other on-ramping criteria as described below.

Under the Proposed Action, OMR flows no more negative than -5,000 cfs is initiated by January 1. Between 2009-2022, 5% of the total LAD winter-run Chinook salmon were salvage prior to January 1 in 4 of 13 years.

I.6.4.2 Presence-Based

In the 2020 ROD, OMR management at no more negative than -5,000 cfs is initiated after January 1 when the SaMT has determined that more than five percent of any salmonid species are present in the Delta. Although the percentage of salmonid distribution as determined by the SaMT can be somewhat subjective, they often rely on real-time monitoring data. In lieu of forming a team of salmonid experts to determine start dates for OMR flow management season, historical data from commonly used salmonid surveys can be used to identify dates when five percent of each species are believed to have entered the Delta. This was done by calculating the date at which five percent of winter-run Chinook salmon total catch has been reached for the water year (as winter-run Chinook salmon is typically the taxon that initiates OMR management season for salmonids). Note that LAD criteria were used to define winter-run Chinook salmon (Fisher 1992). Water year type based on the Sacramento Valley and in water years when it occurred the date at which the turbidity and flow conditions were met to trigger IEWPP are included.

I.6.4.3 Model-Based

Models with the ability to forecast salvage events of winter-run Chinook salmon have been produced (Tillotson et al. 2022), and more are being developed (see 10.9 Winter-run Chinook Salmon Salvage Machine-Learning Tool). Because winter-run Chinook salmon is typically the species that initiates the OMR management season, these predictive models can be used to on-ramp the OMR management season. Complex machine learning models may be able to incorporate complex information and various interacting factors that determine the timing and number of winter-run Chinook salmon entering the Delta. For example, date of first model-predicted entrainment event or certain probability of salvage can be used to initiate the start of OMR management at -5,000 cfs OMR flow or other thresholds.

I.6.5 Historical, Environmental Surrogate, and Calendar-Based OMR Offramp Analysis

The frequency of alternative OMR management on-ramp strategies is summarized below with additional detail and statistics reported in Attachment I.X OMR Offramp Analysis. Results will provide an evaluation of the off-ramp criteria for the Proposed Action and each of the alternatives. The final variable component to consider is the offramp criteria for OMR flow management season. Warm conditions during late-summer and fall would presumably preclude Delta smelt and salmonids from the south Delta and the vicinities of the CVP and SWP pumping facilities. As such, the 2020 ROD and ITP have a combination of criteria that would signify the end of OMR management. These criteria include those based on real-time monitoring data (temperature threshold and SaMT distribution estimates) and a calendar-based cut-off (e.g., June 30).

I.6.5.1 Presence-Based

Under the 2020 ROD, OMR management may end when more than 95 percent of salmonids have migrated past Chipps Island, as determined by the SaMT.

I.6.5.2 Temperature-Based

Salmonids: Under the 2020 ROD, OMR management may also end after daily average water temperatures at Mossdale exceed 72.0°F (22°C) for 7 days during June (the 7 days do not need to be consecutive). Under the new Proposed Action, OMR management may end when daily mean water temperatures at Mossdale (MSD) and Prisoner's Point (PPT) have exceeded 72.0°F (22.2°C) for 7 non-consecutive days. Mossdale temperature exceeded 72.0°F (22°C) and Prisoner's Point temperature exceeded 72.0°F (22°C) for 7 non-consecutive days prior to June 30 in 6 of 11 years (2011-2021).

Delta Smelt: Under the 2020 ROD, OMR management may end when the daily mean water temperature at Clifton Court Forebay reaches 77°F (25°C) for 3 consecutive days. This criterion occurred prior to June 30 in 8 of 11 years.

Under the new Proposed Action, Adult Delta Smelt Entrainment Protection Action ends when the three-day continuous average water temperature at Jersey Point or Rio Vista reaches 53.6°F (12°C).

I.6.5.3 Calendar-Based

Under the 2020 ROD, OMR management may end June 30 (for Delta smelt and Chinook salmon) or June 15 (for steelhead) if real-time criteria have not been met. In addition, Turbidity Bridge Avoidance is offramped under the 2020 ROD when a ripe or spent female was detected or April 1, whichever is first.

Historical data from water year 2010 to water year 2021 was used to identify the date when 95% of each salmonid species of interest exited the Delta, based on Chipps Trawl. This date was compared to June 30 and the temperature exceedance date to determine when OMR management to reduce entrainment would end. Historical data were also used to identify the data when temperature offramp criteria would occur under the new Proposed Action.
Historical data indicate that in all years between 2011-2021, date when 100% salmonids were past Chipps Island occurred sooner than the date when temperature criteria were met, and both criteria typically (in all years but 2019) occurred prior to June 30 (Appendix I. OMR Offramp Analysis Attachment; Table 1).

Historical data indicate that in all years between 2011-2021, the date when adult Delta smelt entrainment protection met temperature criteria was consistently earlier than April 1, the date specified in the 2020 ROD. Meanwhile, the date when temperatures met OMR management season offramp temperature criteria was usually earlier than the calendar date threshold of June 30.

I.6.6 Winter-run Chinook Salmon Salvage Machine-Learning Tool

This section will summarize results from Attachment I.A. Winter-run Chinook salmon Salvage Machine Learning Tool. Results will provide an evaluation of the seasonal loss and first entrainment date performance metrics for winter-run Chinook salmon for the Proposed Action and applicable alternatives.

A new model to predict winter-run Chinook salmon occurrence at the salvage facilities is currently being developed by Jeremy Gaeta (CDFW), Trinh Nguyen (CDFW), and Brian Mahardja (Reclamation). This model (hereinafter, Salvage Machine-Learning Tool) takes a machine learning approach (extreme gradient boosting dropout multiple additive regression trees) to predict winter-run Chinook salmon salvage as a function of various potential environmental drivers. Whereas previously developed machine learning salvage prediction tool (Tillotson et al. 2022) can estimate the number of winter-run Chinook salmon with high accuracy after salvage has occurred, the Salvage Machine-Learning Tool is designed to predict winter-run Chinook salmon occurrence prior to any salvage (one-week and three-week ahead models are currently being refined) and, thus, may be useful for on-ramping of OMR management season (Section 4.2). The model can incorporate daily flow data from the Sacramento and San Joaquin Rivers as well as export level values from the pumping facilities (combined).

I.6.7 Volumetric Influence Analysis

This section will summarize results from Attachment I.Y. Volumetric Influence. Results will provide an evaluation of the maximum potential hydrodynamic influence of exports for the Proposed Action and each of the alternatives.

This modeling exercise serves as a low resolution analysis of operations under different alternatives to provide context for the scale of exports relative to patterns of Net Delta Outflow Index. It is intended to be foundational to more complex models that address more nuanced topics.

Under all alternatives the sum of monthly mean exports of CVP and SWP does not exceed 4% of Net Delta Outflow Index.

I.6.8 Delta Export Zone of Influence

This section will summarize results from Attachment I.Y. Zone of Influence. This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of the area hydrodynamically influenced by exports for each of the alternatives.

I.6.9 Flow into Junctions

This section will summarize results from Attachment I.Y Flow into Junctions. This line of evidence was not used in the Initial Alternative Report. Results will provide an evaluation of the fraction of flows entering junctions that may be hydrologically altered under different pumping conditions created by the CVP and SWP exports facilities for each of the alternatives.

I.6.10 Particle Tracking/Fate Modeling

This section will summarize results from Attachment I.Y. Particle Tracking/Fate Modeling This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of the area hydrodynamically influenced by exports for the Proposed Action and each of the alternatives.

I.6.11 ECO-PTM

This section will summarize results from Attachment I.Y. ECO-PTM. This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of through Delta survival influenced by exports for the Proposed Action and each of the alternatives.

I.6.12 STARS Model

This section will summarize results from Attachment I.Y. This line of evidence was used in the Initial Alternative Report. Results will provide an evaluation of juvenile salmonid through-Delta survival and routing probability for the Proposed Action and each of the alternatives.

Reclamation analyzed monthly CALSIM 3 flows for each alternative to evaluate long-term operations (e.g., releases, exports, and DCC gate closures) effects on juvenile salmonids migrating through the Delta. Using inflow groups, through-Delta survival, travel time through the Delta, and probability of entering the interior Delta was described.

Describe difference between NAA and alternative's estimated td survival and probability of interior Delta entrance by inflow group.

[Bar chart with inflows groups on X, estimated value of Y.]

[Alternative way could be to look at it by WYT.]

I.6.13 Negative binomial model loss simulation

This section summarizes results from Attachment I. Negative Binomial Model. This line of evidence was not used in the Initial Alternative Report. Results provide an evaluation of potential changes to the predicted number of LAD winter-run Chinook salmon, LAD spring-run Chinook salmon, and steelhead salvaged at the Delta fish collection facilities (Jones and Banks) combined for each of the alternatives. Modeled predictions should not be treated as predictions of future entrainment.

Reclamation analyzed historical salvage data via negative binomial regression. Negative binomial regression requires estimation of a dispersion parameter rather than assuming the variance is equal to the mean. In doing so, negative binomial regression can account for overdispersion, which is common in ecological data (e.g., the salvage dataset), as well as reduce the likelihood of biased coefficient estimation. The final model variables, by species / run, are as follows:

LAD winter-run Chinook salmon: month, Sacramento Trawl Catch, Exports (combined), San Joaquin River flow

LAD spring-run Chinook salmon: month, San Joaquin River flow, Exports (combined)

Steelhead: month, Exports (combined)

I.6.13.1 LAD Winter-run Chinook salmon

Across all alternatives except EXP1 and EXP3, the highest predicted salvage of LAD winter-run Chinook salmon occurred in March followed by February, in all water year types. This may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. Predicted average salvage values in Table I-6, below, are calculated for all water year types using the months developed for the model: December through April.

The greatest predicted salvage of LAD winter-run Chinook salmon occurred during Above Normal and Wet water year types for all alternatives (Table I-6). Within both Above Normal and Wet water year types, the greatest predicted salvage occurred under Alternative 1 and the lowest predicted salvage occurred under Alt3 (Table I-6). Predicted average monthly salvage had a wide range among water year types (e.g., 28 Alt1 Above Normal compared with 7 Alt1 Critical) but a narrower range within water year types (e.g., Critical Alt1 7 compared with 2 Alt3) (Table I-6).

The lowest predicted salvage of LAD winter-run Chinook salmon occurred during Dry and Critical water year types for all alternatives and NAA (Table I-6). Within Dry water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt2 without TUCP Delta VA, Alt 2 without TUCP All VA, and Alt3 (Table I-6). Within Critical water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt3 (Table I-6).

The average monthly exports by water year type (WYT) could explain trends in salvage of LAD winter-run Chinook salmon among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four components of Alt2, Alt4). The months of highest predicted winter-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, *Seasonal Operations*, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-6. Predicted average monthly salvage of juvenile winter-run Chinook salmon at the Delta fish collection facilities by water year type December through April

Water year type	NAA	Alt1	Alt2wTUCP woVA	Alt2wo TUCP woVA	Alt2 woTUCP DeltaVA	Alt2woTUCP AllVA	Alt3	Alt4
Wet	13	25	15	15	14	14	6	16
Above Normal	8	28	9	8	6	6	8	9
Below Normal	6	22	6	6	5	5	6	7
Dry	5	16	5	5	4	4	4	5
Critical	4	7	3	3	3	3	2	4

I.6.13.2 LAD Spring-run Chinook salmon

Across all alternatives except EXP1 and EXP3, the highest predicted salvage of LAD spring-run Chinook salmon occurred between March and May, depending on water year type. This may reflect the months when the largest proportion of the juvenile spring-run Chinook salmon population are expected to be in the Delta. Predicted average salvage values in Table I-7, below, are calculated for all water year types using the months developed for the model: March through June.

The greatest predicted salvage of LAD spring-run Chinook salmon occurred during Wet water year types for all alternatives (Table I-7). Within Wet water year types, the greatest predicted salvage occurred under Alt4 and the lowest predicted salvage occurred under Alt3 (Table I-7). Predicted average monthly salvage had a wide range among water year types (e.g., 2,212 Alt4 Wet compared with 36 Alt4 Critical) but a narrower range within water year types (e.g., Critical Alt1 41 compared with 18 Alt3) (Table I-7).

The lowest predicted salvage of LAD spring-run Chinook salmon occurred during Dry and Critical water year types for all alternatives and NAA (Table I-7). Within Dry water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt3 (Table I-7). Within Critical water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt3 (Table I-7).

The average monthly exports by WYT could explain trends in salvage of LAD spring-run Chinook salmon among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four components of Alt2, Alt4). The months of highest predicted spring-run Chinook salvage at the facilities temporally coincides with when the largest proportion of the juvenile spring-run Chinook salmon population is expected to be in the Delta.

Generally, across all water year types, combined monthly OMR flows become slightly more positive or consistent from March through May (Chapter 4, Figure 66). Monthly Sacramento River flows below Keswick Dam, across all water year types, decreases from February through April after increasing since November, and begins to increase in May through the summer months (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-7. Predicted average monthly salvage of juvenile spring-run Chinook salmon at the Delta fish collection facilities by water year type March through June.

	NAA	**Alt1**	**Alt2wTUCPwoVA**	**Alt2woTUCPwoVA**	**Alt2woTUCPDeltaVA**	**Alt2woTUCPAllVA**	**Alt3**	**Alt4**
Wet	1615	1906	2183	2188	1959	1940	209	2212
Above Normal	115	292	224	223	121	120	55	226

	NAA	Alt1	Alt2wTUCPwoVA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA	Alt3	Alt4
Below Normal	134	278	207	205	167	168	65	201
Dry	48	88	63	63	50	50	23	63
Critical	30	41	36	35	35	35	18	36

I.6.13.3 Steelhead

Across all alternatives except EXP1 and EXP3, the highest predicted salvage of steelhead occurred in February or march, depending on water year type. This may reflect the months when a large proportion of the juvenile steelhead population are expected to be in the Delta. Predicted average salvage values in Table I-8, below, are calculated for all water year types using the months developed for the model: December through June.

The greatest predicted salvage of steelhead occurred during Wet water year types for all alternatives (Table I-8). Within Wet water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt3 (Table I-8). Predicted average monthly salvage had a wide range among water year types (e.g., 5,428 Alt1 Wet compared with 632 Alt1 Critical; (Table I-8).

The lowest predicted salvage of steelhead occurred during Dry and Critical water year types for all alternatives and NAA (Table I-8). Within Dry water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt2 without TUCP Delta VA (Table I-8). Within Critical water year types, the greatest predicted salvage occurred under Alt1 and the lowest predicted salvage occurred under Alt3 (Table I-8).

The average monthly exports by WYT could explain trends in salvage of steelhead among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four components of Alt2, Alt4). The months of highest predicted steelhead salvage at the facilities temporally coincides with when the largest proportion of the juvenile steelhead population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to February through late fall into winter (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). Monthly Stanislaus River flows below Goodwin Dam, across all water year types, increase from November to February before decreasing in March (Chapter 4, Figure 42). This increase of flows in the Sacramento River cues juveniles to outmigrate from the upper Sacramento River through the mainstem. This increase of flows in the Stanislaus River cues juveniles to outmigrate through the San Joaquin River. Fish are present in the South Delta if they become entrained into the Central and Interior Delta at junctions like Georgiana Slough or the Delta Cross Channel, from the Sacramento River route, or at junctions like Head of Old River, from the San Joaquin River route.

Table I-8. Predicted average monthly salvage of juvenile steelhead at the Delta fish collection facilities by water year type December through June

	NAA	Alt1	Alt2wTUCPwoVA	Alt2woTUCPwoVA	Alt2woTUCPDeltaVA	Alt2woTUCPAllVA	Alt3	Alt4
Wet	3145	5428	4287	4286	3917	3844	1024	4375
Above Normal	921	3909	1298	1248	947	915	948	1478
Below Normal	718	2857	838	832	679	680	620	871
Dry	339	1732	342	342	277	278	278	401
Critical	218	632	209	194	190	191	120	253

I.6.14 OMR-salvage density model loss simulation

This section summarizes results from Attachment I. OMR-salvage density model loss simulation. This line of evidence was not used in the Initial Alternative Report. Results provide an evaluation of potential changes of estimated seasonal loss of LAD winter-run Chinook salmon, genetic winter-run Chinook salmon, LAD spring-run Chinook salmon, and steelhead salvaged at each of the Delta fish collection facilities (Jones and Banks) independently for each of the alternatives. Modeled predictions should not be treated as predictions of future entrainment.

I.6.14.1 LAD Winter-Run Chinook salmon

Across the alternatives except EXP1 and EXP3, the highest values of predicted average monthly loss of LAD winter-run Chinook salmon was estimated were in March followed by February at both Banks and Jones facilities which may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. There are no exports in EXP1 and EXP3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-9 and Table I-10, below, are calculated using the months where predicted loss is non-zero.

The **greatest** predicted loss at Banks across all months with predicted non-zero average monthly loss of LAD winter-run Chinook salmon occurred during Below Normal and Wet water year types for all alternatives (Table I-9). Within both Below Normal and Wet water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-9). Predicted average monthly loss at Banks had a wide range among water year types (e.g., 584 Alt1 Below Normal compared with 19 Alt1 Critical) but a narrower range within water year types (e.g., Critical Alt1 19 compared with 13 Alt2c) (Table I-9). The **lowest** predicted loss at Banks across all months with predicted non-zero average monthly loss occurred during Dry and Critical water year types for all alternatives and NAA (Table I-9). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-9). Within Critical water year types, the greatest predicted loss occurred under Alt1 and the lowest predicted loss occurred under Alt3 and Alt4 (Table I-9). Alt1 predicted loss ranged from 584 to 19 in Below Normal and Critical water year types, respectively (Table

I-9). Alt3 predicted loss ranged from 271 to 16 in Below Normal and Critical water year types, respectively (Table I-9).

The **greatest** predicted loss at Jones across all months with predicted non-zero average monthly loss of LAD winter-run Chinook salmon occurred during Below Normal water year type for all alternatives (Table I-10). Within Below Normal water year type, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-10). Predicted average monthly loss at Jones had a wide range among water year types (e.g., 135 Alt1 Below Normal compared with 9 Alt1 Critical) but a narrower range within water year types (e.g., all scenarios except Alt3 in Critical had predicted loss 8 or 9) (Table I-10). The **lowest** predicted loss at Jones across all months with predicted non-zero average monthly loss occurred during Dry and Critical water year types for all alternatives and NAA (Table I-10). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-10). Within Critical water year types, predicted loss for all alternatives was 9 or 9 with the exception of Alt3 which was 4 (Table I-10). Alt1 predicted loss ranged from 135 to 9 in Below Normal and Critical water year types, respectively (Table I-10). Alt3 predicted loss ranged from 67 to 4 in Below Normal and Critical water year types, respectively (Table I-10).

At Banks, the average monthly exports by WYT could explain trends in loss of LAD winter-run Chinook salmon among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four versions of Alt2, Alt4). At Jones, the trend is more pronounced for Alt1 while Alt3 is more similar to the other scenarios (NAA, four versions of Alt2, Alt 4). This, in combination with lower historic salvage density at Jones could explain predicted loss at Jones less than at Banks. The months of highest predicted winter-run Chinook loss at the facilities (both LAD and genetic) temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-9. Predicted average monthly loss of **LAD WR** at **Banks** by water year type for all months with predicted non-zero average monthly loss. In W, AN, BN, and D WYTs, average across 6 months: December – May. In C WYTs, average across 5 months: December – April.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	404	548	422	424	415	414	185	434	6: Dec - May
Above Normal	266	501	271	268	242	242	214	278	6: Dec - May
Below Normal	300	584	303	294	256	260	271	316	6: Dec - May

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Dry	140	249	136	136	118	120	158	142	6: Dec - May
Critical	15	19	15	13	13	14	16	16	5: Dec - Apr

Table I-10. Predicted average monthly loss of **LAD WR** at **Jones** by water year type for all months with predicted non-zero average monthly loss. In all WYTs, average across 5 months: December – April.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	52	54	54	54	53	53	40	55	5: Dec - Apr
Above Normal	52	58	55	55	48	48	38	56	5: Dec - Apr
Below Normal	117	135	116	118	98	97	67	119	5: Dec - Apr
Dry	45	51	44	44	39	39	23	45	5: Dec - Apr
Critical	9	9	9	9	8	8	4	9	5: Dec - Apr

I.6.14.2 Genetic Winter-Run Chinook salmon

Given all the alternatives aside from EXP1 and EXP3, the highest values of predicted average monthly loss of genetic winter-run Chinook salmon estimated at Banks and Jones were in March followed by February, in all water year types, except for the Dry and Critically dry water year types. In the Dry and Critical water year types, the highest predicted loss of winter-run Chinook salmon was in April followed by March at Banks. At Jones the highest predicted loss for genetic winter-run Chinook salmon was in March, followed by December for the Dry water year type, and March followed by January for the Critically dry water year type. The timing of the predicted loss for genetic winter-run Chinook salmon at Banks and Jones may reflect the months when the largest proportion of the juvenile winter-run Chinook salmon population are expected to be in the Delta. There are no exports in EXP1 and EXP3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-11 and Table I-12, below, are calculated using the months where predicted loss is non-zero.

The **greatest** predicted loss at Banks across all months with predicted non-zero average monthly loss of genetic winter-run Chinook salmon occurred during Below Normal and Wet water year types for all alternatives (Table I-11). Within both Below Normal and Wet water year types, the **greatest** predicted loss occurred under Alt1. The **lowest** predicted loss for genetic winter-run Chinook salmon at Banks occurred under Alt3, and Alt2c, for the Wet, and Below Normal water year types, respectively (Table I-11). Predicted average monthly loss at Banks had a wide range among water year types (e.g., 179 Alt1 Wet compared with 2 Alt1 Critical) but a narrower range within water year types (e.g., Dry Alt1 31 compared with 14 Alt2c) (Table I-11). The **lowest** predicted loss at Banks across all months with predicted non-zero average monthly loss occurred during Dry and Critical water year types for all alternatives and NAA (Table I-11). Within the critically Dry water year type, predicted loss was low, and the same loss was predicted for all alternatives (Table I-11). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt2c, and Alt2d (Table I-11). Alt1 predicted loss ranged from 179 to 2 in Wet and Critically dry water year types, respectively

(Table I-11). Alt3 predicted loss ranged from 82 to 2 in Below Normal and Critical water year types, respectively (Table I-11).

The **greatest** predicted loss at Jones across all months with predicted non-zero average monthly loss of genetic winter-run Chinook salmon occurred during Below Normal water year type for all alternatives (Table I-12). Within Below Normal water year type, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3, although by just a small margin (Table I-12). Predicted average monthly loss at Jones had a somewhat narrow range among water year types (e.g., 39 Alt1 Below Normal compared with 2 Alt1 Critical) but a narrower range within water year types (e.g., all scenarios except Alt3 in Critical had predicted loss 5 or 6) (Table I-12). The **lowest** predicted loss at Jones across all months with predicted non-zero average monthly loss occurred during Wet and Critical water year types for all alternatives and NAA (Table I-12). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-12). Within the Above Normal water year types, the range of loss was very narrow, 19 to 14 for Alt1 and Alt3, respectively. Alt1 predicted loss ranged from 39 to 5 in Below Normal and Critical water year types, respectively (Table I-12). Alt3 predicted loss ranged from 22 to 2 in Below Normal and Critical water year types, respectively (Table I-12).

At Banks, the average monthly exports by WYT could explain trends in loss of genetic winter-run Chinook salmon among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four versions of Alt2, Alt4). At Banks, the trend is more pronounced for Alt1. Given the lower historic salvage density seen at Jones, the model predicted, as expected, less loss at Jones than at Banks. The months of highest predicted winter-run Chinook loss at the facilities (both LAD and genetic) temporally coincides with when the largest proportion of the juvenile winter-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-11. Predicted average monthly loss of **genetic WR** at **Banks** by water year type for all months with predicted non-zero average monthly loss. In W, AN, BN, and D WYTs, average across 6 months: December – May. For C WYT, average across 5 months: December- April.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	120	179	146	146	143	142	59	152	6: Dec - May
Above Normal	86	163	89	88	77	77	72	93	6: Dec - May
Below Normal	92	178	92	88	71	73	82	94	6: Dec - May
Dry	17	31	17	17	14	14	22	18	6: Dec - May

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Critical	2	2	2	2	2	2	2	2	5: Dec - Apr

Table I-12. Predicted average monthly loss of **genetic WR** at **Jones** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 5 months: December – April. For BN WYT, average across 4 months: December, February- April. In D, and C WYTs, average across 2 months: January, and March.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	17	17	18	17	17	17	12	18	5: Dec - Apr
Above Normal	17	19	18	18	15	15	14	19	5: Dec - Apr
Below Normal	34	39	34	35	26	25	22	35	4: Dec, Feb- Apr
Dry	22	25	22	22	18	17	13	22	2: Dec, March
Critical	6	5	5	5	5	5	2	6	2: Jan, March

I.6.14.3 LAD Spring-Run Chinook salmon

Across the alternatives except EXP1 and EXP3, depending on water year type, the highest values of predicted average monthly loss of LAD spring-run Chinook salmon estimated were in March, April, or May, for both Banks and Jones facilities, which may reflect the months when the largest proportion of the juvenile spring-run Chinook salmon population are expected to be in the Delta. There are no exports in EXP1 and EXP3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-13 and Table I-14, below, are calculated using the months where predicted loss is non-zero.

The **greatest** predicted loss at Banks across all months with predicted non-zero average monthly loss of LAD spring-run Chinook salmon occurred during Above Normal and Wet water year types for all alternatives (Table I-13). Within both Above Normal and Wet water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-13). Predicted average monthly loss at Banks had a wide range among water year types (e.g., 9463 Alt1 Wet compared with 105 Alt1 Critical) but a narrower range within water year types (e.g., Critical Alt1 105 compared with 84 NAA) (Table I-13). The **lowest** predicted loss at Banks across all months with predicted non-zero average monthly loss occurred during Dry and Critical water year types for all alternatives and NAA (Table I-13). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under the NAA (Table I-13). Within Critical water year types, the greatest predicted loss occurred under Alt1 and the **lowest** predicted loss occurred also occurred under the NAA (Table I-13). Alt1 predicted loss ranged from 9,463 to 105 in Wet and Critical water year types, respectively (Table I-13). Alt3 predicted loss ranged from 2,308 to 91 in Wet and Critical water year types, respectively (Table I-13).

The **greatest** predicted loss at Jones across all months with predicted non-zero average monthly loss of LAD spring-run Chinook salmon occurred during Wet water year type for all alternatives (Table I-14). Within the Wet water year type, the **greatest** predicted loss occurred under Alt4 and the **lowest** predicted loss occurred under Alt3 (Table I-14). Predicted average monthly loss at Jones had a wide range among water year types (e.g., 1,269 Alt4 Wet compared with 17 Alt3 Critical) as well as a wide range within water year types (e.g., 516 Alt1 to 109 Alt 3 Dry) (Table I-14). The **lowest** predicted loss at Jones across all months with predicted non-zero average monthly loss occurred during Dry and Critical water year types for all alternatives and NAA (Table I-14). Within Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-14). Within Critical water year types, the **greatest** predicted loss occurred under Alt2b, and the **lowest** predicted loss occurred under Alt3 (Table I-14). Alt1 predicted loss ranged from 1,228 to 63 in Wet and Critical water year types, respectively (Table I-14). Alt3 predicted loss ranged from 234 to 17 in Below Normal and Critical water year types, respectively (Table I-14).

At Banks, the average monthly exports by WYT could explain trends in loss of LAD spring-run Chinook salmon among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four versions of Alt2, Alt4). At Banks, the trend is more pronounced for Alt1, but the difference in predicted loss for all alternatives besides Alt3 is minimal. The predicted loss under Alt3 is notably far less than all other alternatives at both facilities. Given the lower historic salvage density at Jones, the model predicted, as would be expected, far less loss at Jones compared to Banks. The months of highest predicted spring-run Chinook loss at both facilities temporally coincides with when the largest proportion of the juvenile spring-run Chinook salmon population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-13. Predicted average monthly loss of **LAD SR** at **Banks** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 6 months: January- June. For BN WYT, average across 4 months: March- June. In D WYT, average across 3 months: March- May. In C WYT, average across 4 months: February- May.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	6,425	9463	9,347	9,334	9,110	9,125	2,308	9,181	6: Jan - June
Above Normal	2273	5677	4920	4914	3842	3801	1995	4929	6: Jan - June
Below Normal	1196	2403	2015	2043	1579	1616	1205	2010	4: March - June
Dry	900	1675	1433	1434	1043	1037	922	1442	3: March - May
Critical	84	105	95	86	86	90	91	102	4: Feb - May

Table I-14. Predicted average monthly loss of **LAD SR** at **Jones** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 7 months: December- June. For BN WYT, average across 6 months: January- June. In D WYT, average across 5 months: December, and March- June. In C WYT, average across 5 months: January- May.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	1,220	1,228	1,259	1,260	1,205	1,202	227	1,269	7: Dec - June
Above Normal	1042	1111	1062	1061	946	942	188	1067	7: Dec - June
Below Normal	674	757	700	689	606	603	234	707	6: Jan- June
Dry	472	516	468	467	410	408	109	469	5: Dec, March- June
Critical	60	63	60	64	62	62	17	61	5: Jan - May

I.6.14.4 Steelhead

Across the alternatives except EXP1 and EXP3, the highest values of predicted average monthly loss of steelhead estimated were in December, January, and February, at both Banks and Jones facilities which may reflect the months when the largest proportion of the juvenile steelhead are expected to be in the Delta. There are no exports in EXP1 and EXP3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-15 and Table I-16, below, are calculated using the months where predicted loss is non-zero.

The **greatest** predicted loss at Banks across all months with predicted non-zero average monthly loss of steelhead occurred during Wet and Dry water year types, for all alternatives (Table I-15). Within both Wet and Dry water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-15). Predicted average monthly loss at Banks had a wide range among water year types (e.g., 617 Alt1 Wet compared with 68 Alt3 Below Normal) also having a wide range within water year types (e.g., Above Normal Alt1 567 compared with 198 Alt3) (Table I-15). The **lowest** predicted loss at Banks across all months with predicted non-zero average monthly loss occurred during Below Normal and Critical water year types for all alternatives and NAA (Table I-15). Within Below Normal water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-15). Within Critical water year types, the greatest predicted loss also occurred under Alt1 and the lowest predicted loss occurred under Alt3 (Table I-15). Alt1 predicted loss ranged from 617 to 138 in Wet and Critical water year types, respectively (Table I-15). Alt3 predicted loss ranged from 222 to 68 in Wet and Critical water year types, respectively (Table I-15).

The **greatest** predicted loss at Jones across all months with predicted non-zero average monthly loss of steelhead occurred during Wet water year type for all alternatives (Table I-16). Within the Wet water year type, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-16), albeit by a small margin. Predicted average monthly loss at Jones had a somewhat narrow range among water year types (e.g., 61 Alt1 Wet to 7 Alt3 Below Normal) and a even narrower range within water year types (e.g., Above Normal Alt1 58 to 26 Alt3) (Table I-16). The **lowest** predicted loss at Jones across all months with predicted non-zero average monthly loss occurred during Below Normal and Critical water year types for all alternatives and NAA (Table I-16). Within Below Normal, and Critical water year types, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3 (Table I-16). Alt1 predicted loss ranged from 61 to 17 in Wet and Below Normal water year types, respectively (Table I-16). Alt3 predicted loss ranged from 43 to 7 in Wet and Below Normal water year types, respectively (Table I-16).

At Banks, the average monthly exports by WYT could explain trends in loss of steelhead among modeled scenarios. CalSim exports under Alt1 are consistently higher average monthly exports, particularly in Dec – Apr. CalSim exports under Alt3 often have lower average monthly exports, particularly in non-summer months. Finally, there is less variation among remaining scenarios (NAA, four versions of Alt2, Alt4). At Banks, the trend is more pronounced for Alt1 while Alt3 similarly outperforms all other alternatives at both facilities. The lower historic salvage density at Jones could explain the lower predicted loss at Jones compared to Banks. The months of highest predicted steelhead loss at the facilities temporally coincides with when the largest proportion of the juvenile steelhead population is expected to be in the Delta. Generally, across all water year types, combined monthly OMR flows become increasingly more positive from November to March through late-fall and winter into spring (Chapter 4, Figure 66.) Monthly Sacramento River flows below Keswick Dam, across all water year types, increase across the same months and seasons (Chapter 4, Figure 3). This increase of flows cues juveniles to outmigrate from the upper Sacramento River through the mainstem. Fish are present in the South Delta if they become entrained into the Central and Interior Delta through routes like Georgiana Slough or the Delta Cross Channel.

Table I-15. Predicted average monthly loss of **steelhead** at **Banks** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 4 months: December- March. For BN WYT, average across 5 months: December- April. In D WYT, average across 2 months: December- January. In C WYT, average across 5 months: December- April.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	377	617	372	372	372	373	222	351	4: Dec.- March
Above Normal	300	567	293	291	288	287	198	269	4: Dec.- March
Below Normal	81	157	78	78	77	76	68	78	5: Dec.- April
Dry	359	503	360	358	351	340	182	312	2: Dec.- Jan.
Critical	96	138	98	92	88	89	76	95	5: Dec.- April

Table I-16. Predicted average monthly loss of **steelhead** at **Jones** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 5 months: October- February. For BN WYT, average across 5 months: December- April. In D WYT, average across 2 months: December- January. In C WYT, average across 4 months: December- March.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	58	61	57	57	57	58	43	55	5: Oct - Feb

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Above Normal	49	58	52	52	52	52	26	50	5: Oct - Feb
Below Normal	14	17	14	14	14	14	7	14	5: Dec- April
Dry	42	48	43	42	41	41	18	42	2: Dec - Jan
Critical	29	35	27	29	30	30	15	29	4: Dec - March

I.6.14.5 Green Sturgeon

Across the alternatives except EXP1 and EXP3, the highest values of predicted average monthly loss of Green Sturgeon estimated were in January, March, or June depending on the water year type, and facility. The extremely low historic salvage density for Green Sturgeon at both facilities may explain the seemingly random distribution of predicted values both by facility, and by month. It should be further stated that the presence of 1-2 fish at either facility over a calendar year does not speak much to the abundance, movement, or distribution of Green Sturgeon in the Delta. There are no exports in EXP1 and EXP3; thus, predicted loss is 0 for those scenarios. Predicted average monthly loss values in Table I-17 and Table I-18, below, are calculated using the months where predicted loss is non-zero.

The **greatest** predicted loss at Banks across all months with predicted non-zero average monthly loss of Green Sturgeon occurred during Wet and Below Normal water year types for all alternatives (Table I-17). Within the Wet water year types, the **greatest** predicted loss occurred under the NAA, Alt1, all components of Alt2, and Alt4, the **lowest** predicted loss occurred under Alt3 (Table I-17). Predicted average monthly loss at Banks had a narrow range among water year types (e.g., 4 Alt1 Below Normal compared with 1, the only other value higher than zero, for all water year types, and alternatives) but a narrower range within water year types (e.g., Wet Alt1 1 compared with 0 Alt3) (Table I-17). The **lowest** predicted loss at Banks across all months with predicted non-zero average monthly loss occurred during Above Normal water year types for all alternatives and NAA (Table I-17). Within Above Normal water year types, the **greatest** predicted loss occurred under the NAA, Alt1, Alt2a, Alt2b, and Alt4, the **lowest** predicted loss occurred under Alt3, Alt2c, and Alt2d (Table I-17). Within Dry, and Critical water year types, the predicted loss for Green Sturgeon at Banks was zero for all alternatives. Alt1 predicted loss ranged from 4 to 1 in Below Normal and Wet water year types, respectively (Table I-17). Alt3 predicted loss ranged from 1 to 0 in Below Normal and all other water year types, respectively (Table I-17).

The **greatest** predicted loss at Jones across all months with predicted non-zero average monthly loss of Green Sturgeon occurred during Wet, and Above Normal water year type for all alternatives (Table I-18). Within the Wet water year type, the **greatest** predicted loss occurred under Alt1 and the NAA, the **lowest** predicted loss occurred under Alt3 (Table I-18). Similarly, under the Above Normal water year type, the **greatest** predicted loss occurred under Alt1 and the **lowest** predicted loss occurred under Alt3. Predicted average monthly loss at Jones had a narrow range among water year types (e.g., 7 Alt1 Above Normal compared with 1 Alt4 Dry) and a similar range within water year types (e.g., Above Normal Alt 1 7 to 1 Alt3) (Table I-18). The **lowest** predicted loss at Jones across all months with predicted non-zero average monthly loss occurred during the Dry water year types for all alternatives and NAA (Table I-18). Within Dry water year types, the **greatest** predicted loss occurred under the NAA, Alt1, all components of Alt2, and Alt4, with the same value predicted (1), the **lowest** predicted loss occurred under Alt3

(0) (Table I-18). Alt1 predicted loss ranged from 7 to 1 in Wet and Above Normal water year types, and Dry water year types, respectively (Table I-18). Alt3 predicted loss ranged from 4 to 1 in Wet, and Above Normal water year types, respectively (Table I-18).

The extremely low historic salvage density for Green Sturgeon at both facilities likely explains the seemingly random trends of predicted loss by water year type and across all alternatives. Distribution and movement of Green Sturgeon in the Delta and importantly, the affect to which exports and OMR flows have on their movements is not well understood. While the model predicts that decreased exports, especially in non-summer months associated with Alt3 will have decreased salvage of Green Sturgeon, actual affects will likely vary, this is due to the overlying bias in the model and data currently available.

Table I-17. Predicted average monthly loss of **GST** at **Banks** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 1 month: March. For BN WYT, average across 1 month: January. In D, and C WYTs, no predicted loss in all months.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	1	1	1	1	1	1	0	1	1: March
Above Normal	1	1	1	1	0	0	0	1	1: March
Below Normal	1	4	1	1	1	1	1	1	1: Jan.
Dry	0	0	0	0	0	0	0	0	No Fish
Critical	0	0	0	0	0	0	0	0	No Fish

Table I-18. Predicted average monthly loss of **GST** at **Jones** by water year type for all months with predicted non-zero average monthly loss. In W, and AN WYTs, average across 1 month: June. For D WYT, average across 2 months: June- July. In BN, and C WYTs, no predicted loss in all months.

	NAA	Alt1	Alt2a	Alt2b	Alt2c	Alt2d	Alt3	Alt4	Months
Wet	7	7	6	6	6	6	4	6	1: June
Above Normal	6	7	5	5	5	5	1	5	1: June
Below Normal	0	0	0	0	0	0	0	0	No Fish
Dry	1	1	1	1	1	1	0	1	2: June - July
Critical	0	0	0	0	0	0	0	0	No Fish

I.6.14.6 Fall-Run Chinook salmon

[No analysis interpreted yet]

I.6.14.7 Late Fall-Run Chinook salmon

[No analysis interpreted yet]

I.6.14.8 American Shad

[No analysis interpreted yet]

I.6.14.9 Hardhead

[No analysis interpreted yet]

I.6.14.10 Pacific Lamprey

[No analysis interpreted yet]

I.6.14.11 River Lamprey

[No analysis interpreted yet]

I.6.14.12 Largemouth Bass

[No analysis interpreted yet]

I.6.14.13 Sacramento Splittail

[No analysis interpreted yet]

I.6.14.14 Smallmouth Bass

[No analysis interpreted yet]

I.6.14.15 Spotted Bass

[No analysis interpreted yet]

I.6.14.16 Striped Bass

[No analysis interpreted yet]

I.6.14.17 White Sturgeon

[No analysis interpreted yet]

I.6.14.18 California Roach

[No analysis interpreted yet]

I.6.14.19 Threadfin Shad

[No analysis interpreted yet]

I.6.14.20 Hitch

[No analysis interpreted yet]

I.6.14.21 Starry Flounder

[No analysis interpreted yet]

I.6.15 Expanded Loss Autocorrelation Analysis

This section will summarize results from Attachment I.A Expanded Loss Autocorrelation Analysis. This line of evidence was not used in the Initial Alternative Report. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

Temporal autocorrelation is a well-known phenomenon commonly observed in time series data. As such, there are questions regarding the expected lag/response time of fish when daily loss thresholds, such as those in the 2020 ITP, are triggered and OMR is adjusted. Overall, the autocorrelation analysis indicated that autocorrelation is mostly prominent for about a week (~7 days). Because this analysis did not specifically evaluate autocorrelation during times when actions were taken (e.g., OMR shift towards a more positive or negative value), it does not provide a definitive answer on the question of response time for any particular species. Nevertheless, the results do suggest that a lagged response to water operation changes is likely and that there may be a carryover effect for roughly a week. In the Proposed Action, fish loss thresholds are thus set at a weekly or annual timescale for OMR management.

I.6.16 IOS

This section will summarize Delta survival results from Attachment F.A IOS. Estimates cane be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

I.6.17 OBAN

This section will summarize Delta survival results from Attachment F.A OBAN. Estimates cane be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

I.6.18 CVPIA SIT LCM

This section will summarize Delta survival results from Attachment F.A CVPIA SIT LCM. Estimates cane be used as a representation of entrainment risk effects. Results will provide an evaluation of OMR management fish criteria for the Proposed Action and alternatives.

I.7 Uncertainty

Hydrodynamics and effects of the CVP and SWP operations on entrainment risk is well documented. Multiple corollary and mechanistic models exists to explain individual effects. Uncertainty remains around how these individual effects, both direct and indirect, from operations, may impact ESA listed species populations.

Future studies of high value that may benefit from special studies include estimating the juvenile production of steelhead in the Delta and studies to evaluate the effect operations has on winter-run Chinook salmon and other migratory ESA listed species seasonal survival through outmigration past Chipps Island. Better understanding for the percentage of winter-run and other ESA species that are influenced by export versus inflow effects of the CVP and SWP may help to better inform Delta management efforts that use Old and Middle River flows to influence population dynamics of these species.

These special studies include:

Winter-run Chinook Salmon Delta Route Selection and Survival

Steelhead JPE and OMR Management

I.8 References

I.8.1 Printed References

Anchor QEA 2022

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I.8.2 Personal Communications

DWR, personal communications

Kevin Reece, personal communications

Russ Perry, USGS, Personal Communication