Appendix A2

June 2017

Description of the Proposed Action

Description of the Proposed Action[1]

3.1 Introduction

The CVP/SWP comprises two major inter-basin water storage and delivery systems that divert and re-divert water from the southern portion of the Delta. The CVP/SWP includes major reservoirs upstream of the Delta, and transports water via natural watercourses and canal systems to areas south and west of the Delta. The CVP also includes facilities and operations on the Stanislaus and San Joaquin Rivers. The major facilities on these rivers are New Melones and Friant Dams, respectively.

The California State Water Resources Control Board (SWRCB) permits the CVP and SWP to store water during wet periods, divert unstored water, and re-divert water that has been stored in upstream reservoirs. The CVP/SWP operates pursuant to water right permits and licenses issued by the SWRCB to appropriate water by diverting to storage or by directly diverting to use and re-diverting releases from storage later in the year. As conditions of their water right permits and licenses, the SWRCB requires the CVP/SWP to meet specific water quality, quantity, and operational criteria within the Delta. Reclamation and the California Department of Water Resources (DWR) closely coordinate the CVP/SWP operations, respectively, to meet these conditions.

The proposed action (PA) includes new water conveyance facility construction, new conveyance facility operation in coordination with operation of existing CVP/SWP Delta facilities, maintenance required monitoring and adaptive management activities. Each of these components of the PA is described in detail below. The chapter ends with a discussion of activities that may be interrelated or interdependent with the PA.s with a discussion of activities that may be interrelated or interdependent with the PA.

Table 3.1-1 identifies the proposed new facilities, identifies the existing requirements that apply to CVP/SWP facilities in the Delta region, and notes which requirements are (or are not) incorporated in the PA. As such, Table 3.1-1 clarifies which facilities and activities addressed under the 2008 U.S. Fish and Wildlife Service (USFWS) and 2009 National Marine Fisheries Service (NMFS) Biological Opinions (BiOps) will be replaced and superseded by the PA once the new facilities are operational, provided, however, that requirements listed in Table 3.1-1 may be adjusted to the extent allowed by law based on new data and/or scientific analyses, including data from the coordinated monitoring and research to be conducted under the Coordinated Science and Adaptive Management Program and real time operations, such that operations will still adequately protect listed species from jeopardy while maximizing water supplies.

[1] The Description of the Proposed Action was submitted as part of the Biological Assessment in July 2016. As a result of formal consultation with USFWS and NMFS, and as a result of DFW's issuance of The Draft Permit for Incidental Take issued under Section 2081(b) of the California Endangered Species Act (2081(b) ITP), DWR and Reclamation submitted clarifications to the Proposed Action on May 5, 2017. This document reconciles other portions of the text in the Biological Assessment with those clarifications, as well as supplements the clarifications to the Proposed Action.

Table 3.1-1. CVP/SWP Facilities and Actions Included and Not Included in the Proposed Action

Topic	Action	Description	Source	Comments
Facilities and Activities Included in the PA				
New Facilities	Conveyance facilities construction	Construction, operations, and maintenance of the proposed north Delta intakes and associated conveyance facilities.	This document	
New Facilities	Head of Old River Gate construction	Construction, operations, and maintenance of the proposed head of Old River operable gate.	This document	
Real-time Operations	Real-time Decision-making	Apply real-time decision-making to assist fishery management; 2081 application specifies structure: SWG, DOSS, WOMT.	Reclamation (2008) USFWS (2008) DWR (2009), NMFS (2009)	Changes needed to incorporate operations of new facilities and corresponding changes in management structure.
Real-time Operations	NMFS IV.3	Reduce likelihood of entrainment or salvage at the export facilities	NMFS (2009)	PA operational criteria supplement this RPA.
Real-time Operations	USFWS RPA General	Smelt Working Group and Water and Operations Management Team	USFWS (2008)	WOMT coordinates with and provides recommendations to the RTO Team for the Delta operations.
Real-time Operations	NMFS 11.2.1.1	Technical Team	NMFS (2009)	Existing real-time decision making process is incorporated into the PA as described in Section 3.1.5. In addition to this process a separate real-time operations coordination team will be convened in an advisory capacity, as described in Section 3.3.3.
Real-time Operations	NMFS IV.5	Formation of Delta Operations for Salmon and Sturgeon Technical Working Group	NMFS (2009)	These technical groups are incorporated in the PA unchanged.
Barriers	Temporary Barriers	Operation of the temporary barriers project in the south Delta	Reclamation (2008)	Temporary barriers are included with regard to hydrodynamic effects, with year-to-year placement and removal subject to separate authorizations. HORB replaced by operable HOR gate.

Topic	Action	Description	Source	Comments
Barriers	Do not implement Permanent Barriers	South Delta Improvement Program—Phase I (Permanent Operable Gates)	USFWS (2008), NMFS (2009)	SDIP is not being implemented. The HOR gate is included in the PA.
Barriers	DO in Stockton Deep-Water Ship Channel	Operate HORB to improve DO in the Stockton Deep-Water Ship Channel	Reclamation (2008)	Existing aeration facility in the Stockton Deep-Water Ship Channel is not included in the PA.
Flow	CDFW Condition 5	Flow criteria, also including real-time operational considerations	CDFG (2009)	PA operational criteria supersede this condition.
Flow	Jones Pumping Plant	Permitted diversion capacity of 4,600 cfs	Reclamation (2008) USFWS (2008) NMFS (2009)	To be operated per flow criteria. Permitted diversion capacity does not allow for more water to be exported in conjunction with the operation of NDD than is permitted by the SWRCB.
Flow	Banks Pumping Plant	Diversion rates at Clifton Court intake are normally restricted to 6,680 cfs, with exceptions	Reclamation (2008) USFWS (2008) DWR (2009) NMFS (2009)	To be operated per flow criteria.
Flow	NMFS IV.2.1	San Joaquin River inflow to export ratio (and 61-day pulse flows)	NMFS (2009)	Modeling criteria of PA uses this as mechanism to meet spring outflow criteria in April and May. PA operational criteria for south Delta operations supersede this RPA action; PA operational criteria include this I:E ratio for April and May only. See Table 3.3-1.
Flow	NMFS IV.2.3	OMR flow management	NMFS (2009)	PA operational criteria incorporate all aspects of this action including salvage based triggers, and replace this RPA action. See Table 3.3-1 and Section 3.3.2.
Flow	USFWS 1	Adult migration and entrainment; first flush: limit exports so average daily OMF flow is no more negative than -2,000 cfs for 14 days, with a 5-day running average no more negative than -2,500 cfs	USFWS (2008)	

Topic	Action	Description	Source	Comments
Flow	USFWS 2	Adult migration and entrainment	USFWS (2008)	PA operational criteria incorporate and replace this RPA action.
Flow	USFWS 3	Entrainment protection of larval smelt	USFWS (2008)	PA operational criteria incorporate and replace this RPA action.
Flow	USFWS 4	Estuarine habitat during fall (provide Delta outflow to maintain average X2 for September, October, and November)	USFWS (2008)	
North Bay Aqueduct	North Bay Aqueduct Monitoring	Conduct monitoring at NBA	Reclamation (2008)	Monitoring would continue.
North Bay Aqueduct	North Bay Aqueduct Operations	Operate NBA	USFWS (2008) CDFG (2009)	No change from 2008/2009 operational constraints.
Delta Cross Channel	Delta Cross Channel Operations	Operate Delta Cross Channel	Reclamation (2008) NMFS (2009)	NMFS IV.1.2 operational criteria without any change. NMFS IV.1.1 is addressed by real-time operations. As described in Section 3.4.8, *Monitoring and Research Program*, the monitoring associated with current operations would continue.
Interior Delta Entry	Engineering solutions to reduce interior Delta entry	Reduce interior Delta entry	Reclamation (2008) NMFS (2009)	NMFS IV.1.3 is addressed in PA by Georgiana Slough non-physical barrier and HOR gate.
Tracy and Skinner Facilities	CDFW Condition 6.2	Skinner facility operations	CDFG (2009)	No change from 2009 operational constraints.
Tracy and Skinner Facilities	CDFW Condition 6.3	Skinner facility salvage operations	CDFG (2009)	No change from 2009 operational constraints.
Suisun Marsh Facilities	Suisun Marsh Salinity Control Gates	Operate Suisun Marsh salinity control gates, as described	Reclamation (2008) DWR (2009)	No change from 2009 operational constraints.
Suisun Marsh Facilities	Roaring River Distribution System	Operations	Reclamation (2008) NMFS (2009) DWR (2009)	No change from 2009 operational constraints.
Suisun Marsh Facilities	Morrow Island Distribution System	Operations	Reclamation (2008) NMFS (2009) DWR (2009)	No change from 2009 operational constraints.

Topic	Action	Description	Source	Comments
Suisun Marsh Facilities	Goodyear Slough Outfall	Operations	Reclamation (2008) NMFS (2009) DWR (2009)	No change from 2009 operational constraints.
Studies	NMFS 11.2.1.2	Research and adaptive management	NMFS (2009)	California WaterFix proposes new program.
Studies	NMFS 11.2.1.3	Monitoring programs and reporting regarding effects of CVP/SWP operations	NMFS (2009)	This work is performed by IEP with take authorization via scientific collection permits. This would continue and include any additional monitoring and reporting as required by CWF.
Studies	CDFW Condition 8	Monitoring and reporting	CDFG (2009)	No change from 2009 activities.
Other Facilities	CCWD Facilities	Operation and maintenance of CCWD facilities owned by Reclamation: the Rock Slough Intake and Contra Costa Canal	Reclamation (2008)	Rock Slough diversion is included in modeling/baseline.
Other Facilities	Clifton Court Forebay Aquatic Weed Control Program	Application of herbicide to control aquatic weeds and algal blooms in CFF	Reclamation (2008) DWR (2009)	
Facilities and Activities Not Included in the PA				
Existing Requirements	D-1641	Implement D-1641, as described	SWRCB D-1641	Incorporated into the environmental baseline. PA may include discretionary operations as allowed under the existing regulatory criteria and proposed operations criteria.
Existing Requirements	COA	Implement existing COA	P.L. 99-546	Incorporated into the environmental baseline. PA may include discretionary operations as allowed under the existing regulatory criteria and proposed operations criteria.
Existing Requirements	CVPIA	Implement CVPIA, as authorized	P.L. 102-575	Incorporated into the environmental baseline. PA may include discretionary operations as allowed under the existing regulatory criteria and proposed operations criteria.
Existing Requirements	SWRCB WRO 90-05	Implement WRO 90-05	SWRCB WRO 90-05	Incorporated into the environmental baseline.
Flow	VAMP	Vernalis Adaptive Management Plan (VAMP)	D-1641 Reclamation (2008)	VAMP has expired, per agreement.

Topic	Action	Description	Source	Comments
North Bay Aqueduct	CDFW Condition 6.4	NBA, RRDS, and Sherman Island diversions and fish screens	CDFG (2009)	Will be complete prior to start of PA.
Tracy and Skinner Facilities[2]	NMFS IV.4.1	Tracy fish collection facility improvements to reduce pre-screen loss and improve screening efficiency	NMFS (2009)	Will be completed before north Delta diversion operations begin; subject to a separate take authorization.
Tracy and Skinner Facilities	NMFS IV.4.2	Skinner fish collection facility improvements to reduce pre-screen loss and improve screening efficiency	NMFS (2009)	Will be completed before north Delta diversion operations begin; subject to a separate take authorization.
Tracy and Skinner Facilities	NMFS IV.4.3	Tracy fish collection facility and the Skinner fish collection facility actions to improve salvage monitoring, reporting, and release survival rates	NMFS (2009)	Will be completed before north Delta diversion operations begin; subject to a separate take authorization.
Studies	NMFS IV.2.2	Six-year acoustic tag experiment	NMFS (2009)	In progress.
Habitat Restoration	NMFS I.5	Funding for CVPIA Anadromous Fish Screen Program	NMFS (2009)	
Habitat Restoration	NMFS I.6.1	Restoration of floodplain rearing habitat	NMFS (2009)	Occurs in Yolo Bypass; subject to separate take authorization.
Habitat Restoration	NMFS I.6.2	Near-term actions at Liberty Island/Lower Cache Slough and Lower Yolo Bypass	NMFS (2009)	Actions already under way and will have separate take authorization.
Habitat Restoration	NMFS I.6.3	Lower Putah Creek enhancements	NMFS (2009)	Actions already under way and will have separate take authorization.
Habitat Restoration	NMFS I.6.4	Lisbon Weir improvements	NMFS (2009)	Actions already under way and will have separate take authorization.
Habitat Restoration	NMFS I.7	Reduce migratory delays and loss of salmon, steelhead, and sturgeon at Fremont Weir and other structures in the Yolo Bypass	NMFS (2009)	Occurs in Yolo Bypass; subject to separate take authorization.

[2] See Permit Resolution Log item # 4

Topic	Action	Description	Source	Comments
Habitat Restoration	USFWS 6	Habitat restoration (create or restore a minimum of 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh)	USFWS (2008)	Action is being implemented and is expected to be completed before north Delta diversion operations begin.
Habitat Restoration	CDFW Condition 7	LFS habitat restoration	CDFG (2009)	Action is being implemented and may be included in the USFWS 6 requirement above. Action is expected to be completed before north Delta diversion operations begin.
Studies	CDFW Condition 6.1	MIDS study of entrainment effects	CDFG (2009)	Study is underway and will complete prior to initiation of PA.
Other Facilities	CCWD Alternative Intake	Construction of alternative intake at Rock Slough	Reclamation (2008)	Operates under existing BiOps, incorporated into the environmental baseline.

BiOp = biological opinion
CAMT = Collaborative Adaptive Management Team
CCWD = Contra Costa Water District
CDFW = California Department of Fish and Wildlife
CESA = California Endangered Species Act
cfs = cubic feet per second
COA = Coordinated Operations Agreement
CVPIA = Central Valley Project Improvement Act
DO = Dissolved oxygen
ESA = Endangered Species Act of 1972, as amended
HOR = head of Old River
HORB = head of Old River barrier
IEP = Interagency Ecological Program
ITP = Incidental take permit
LFS = Longfin smelt
MIDS = Morrow Island Distribution System
NBA = North Bay Aqueduct
OMR = Old and Middle Rivers
RPA = Reasonable and Prudent Alternative
RRDS = Roaring River Distribution System
RTO = Real-Time Operations
SWG = Smelt Working Group
SWRCB = State Water Resources Control Board
WOMT = Water and Operations Management Team

The purpose of this BA is to evaluate the effects of the proposed action on federally listed species. The PA entails construction and operation of facilities for the movement of water entering the Delta from the Sacramento Valley watershed to the existing CVP/SWP pumping plants located in the southern Delta. The PA also entails operation of the existing and proposed new CVP/SWP Delta facilities in a manner that minimizes or avoids adverse effects on listed species, and that protects and enhances aquatic, riparian, and associated natural communities and ecosystems. The PA will maintain the ability of the CVP/SWP to deliver up to full contract amounts, when hydrologic conditions result in the availability of sufficient water, consistent with the requirements of state and Federal law and the terms and conditions of water delivery contracts held by SWP contractors and certain members of San Luis Delta Mendota Water Authority, and other existing applicable agreements.

The Proposed Action includes ongoing compliance with D-1641 (the current Bay-Delta Water Quality Control Plan), ongoing compliance with the Fall X2 RPA (FWS 2008), and a new spring outflow criterion that ensures the same spring outflow exceedance frequencies that would have occurred absent the PA. Reclamation has reinitiated consultation with FWS and NMFS on the Coordinated Long-Term Operation of the CVP and SWP (LTO). This more broadly-scoped consultation will update system-wide operating criteria for the LTO consistent with the requirements of section 7 and will be coordinated with the update of the water quality control plan.

Presentation of the PA in this biological assessment does not amount to a project approval by DWR or Reclamation. DWR must complete CEQA review, as well as compliance with several other federal and state environmental laws and regulations, before it can construct, operate or use any new facilities associated with the PA. Reclamation must complete NEPA review prior to implementing any federal actions associated with the PA. In conducting its CEQA review, and completing other environmental compliance processes, DWR may be required to modify, add, or remove elements of the PA consistent with the requirement to adopt mitigation measures and/or alternative in order to address specific environmental impacts. Consistent with the directives of CEQA, DWR may determine, at the completion of the CEQA process, to deny approval of the PA or specific elements of the PA based on any significant environmental impact that cannot be mitigated. Prior to the conclusion of formal consultation, the BA will be supplemented if substantive changes are made to the PA relevant to the analysis of listed species or designated critical habitat.

3.1.1 Guiding Principles

Future CWF actions subject to subsequent federal decisions or approvals include construction and related actions (including maintenance, mitigation and monitoring) of the NDD intakes and HOR Gate, and operations of the new CWF facilities.

Consistent with USFWS programmatic consultation under Section 7, it is anticipated that the construction-related actions subject to future federal approvals will be consulted upon as part of the Corps' Phase 2 permitting for CWF. Phase 2 permitting will be preceded by the reinitated consultation on the 2008 USFWS BiOp and 2009 NMFS BiOp. Agency decisions related to identifying the final CWF operational criteria will be made in a subsequent consultation, and Reclamation and DWR have committed to analyze and further address species effects from CWF operations at that time.

The following guiding principles are proposed to establish a framework in this programmatic consultation under which the future CWF actions will be developed to ensure both that future consultations with USFWS, and NMFS as appropriate, related to CWF actions build upon the analysis in this document as described in the consultation approach section above and that the CWF is constructed and operated in a manner that promotes the co-equal goals articulated in California's Delta Reform Act.. The principles are intended to promote (1) ecological conditions suitable for all life stages of delta smelt and (2) water supply reliability. The guiding principles are as follows:

1. Improving habitat conditions for listed species, including rearing juvenile delta smelt, which may include locating the low salinity zone in suitable areas of the estuary.
2. Operate CVP/SWP water exports in the south Delta to minimize entrainment of migrating and spawning adult delta smelt and larval/young juvenile delta smelt..
3. Promoting increased turbidity in geographical areas and during temporal windows that may be expected to increase the extent and quality of delta smelt habitat through implementation of the sediment management plan referenced in the 2017 CWF PA and through actions described in the Delta Smelt Resiliency Strategy.
4. Restoring, creating, or enhancing spawning habitat conditions through use of mitigation commitments made by Reclamation and DWR in the 2017 CWF PA and through actions described in the Delta Smelt Resiliency Strategy.
5. Promoting food production and transport into areas where habitat conditions are suitable for delta smelt.
6. Improving population-level delta smelt habitat conditions through reductions in non-native invasive species.
7. Coordinating operations of the SDDs and NDDs water facilities to limit effects to delta smelt populations from cyanobacteria blooms.
8. Implementing all actions in a manner that limits, to the maximum extent practicable, impacts to water supply and provides opportunities to recover water supplies consistent with protection of listed species.

These principles are subject to change over time where the best available scientific information indicates that such change is appropriate. In such event, the agencies will evaluate whether the change triggers the requirement to reinitiate consultation.

3.1.2 Central Valley Project

The CVP is the largest Federal Reclamation project and was originally authorized by the Rivers and Harbors Act of 1935. The CVP was reauthorized by the Rivers and Harbors Act of 1937 for the purposes of "improving navigation, regulating the flow of the San Joaquin River and the Sacramento River, controlling floods, providing for storage and for the delivery of the stored waters thereof, for construction under the provisions of the Federal Reclamation Laws of such distribution systems as the Secretary of the Interior (Secretary) deems necessary in connection with lands for which said stored waters are to be delivered, for the reclamation of arid and semiarid lands and lands of Indian reservations, and other beneficial uses, and for the generation and sale of electric energy as a means of financially aiding and assisting such undertakings and in order to permit the full utilization of the works constructed." This Act provided that the dams and reservoirs of the CVP "shall be used, first, for river regulation, improvement of navigation and flood control; second, for irrigation and domestic uses; and, third, for power." The CVP was reauthorized in 1992 through the Central Valley Project Improvement Act (CVPIA). The CVPIA modified that authorization under Rivers and Harbors Act of 1937 adding mitigation, protection, and restoration of fish and wildlife as a project purpose. Further, the CVPIA specified that the dams and reservoirs of the CVP should now be used "first, for river regulation, improvement of navigation, and flood control; second, for irrigation and domestic uses and fish and wildlife mitigation, protection and restoration purposes; and, third, for power and fish and wildlife enhancement."

CVPIA (Public Law 102-575, Title 34) includes authorization for actions to benefit fish and wildlife intended to implement the purposes of that Title. Specifically, Section 3406(b)(1) is implemented through the Anadromous Fish Restoration Program (AFRP). The AFRP objectives, as they relate to operations, are further explained below. CVPIA Section 3406(b)(1) provides for modification of the CVP Operations to meet the fishery restoration goals of the CVPIA, so long as the operations are not in conflict with the fulfillment of the Secretary's contractual obligations to provide CVP water for other authorized purposes. The U.S. Department of the Interior's (Interior) decision on Implementation of Section 3406(b)(2) of the CVPIA, dated May 9, 2003, provides for the dedication and management of 800,000 acre-feet (af) of CVP-water yield annually by implementing upstream and Delta actions. Interior manages and accounts for (b)(2) water pursuant to its May 9, 2003, decision and the Ninth Circuit's decision in *Bay Institute of San Francisco v. United States*, 66 Fed. Appx. 734 (9th Cir. 2003), as amended, 87 Fed. Appx. 637 (2004). Additionally, Interior is authorized to acquire water to supplement (b)(2) water, pursuant to Section 3406(b)(3).

A portion of the water conserved in upstream reservoirs on the Sacramento and San Joaquin Rivers and their tributaries is pumped at the C.W. "Bill" Jones Pumping Plant (Jones PP) in the Delta and delivered to the south of the Delta, the CVP service area.

Under the PA, the Jones PP will continue to fulfill its role, in conjunction with the Banks PP. Both pumping plants will also use water diverted from the Sacramento River at three new intakes located in the north Delta and conveyed to the south Delta export facilities via new tunneled and connecting conveyance, as described in Section 3.2, *Conveyance Facility Construction*. Flow criteria affecting CVP/SWP water withdrawals under the PA are described in Section 3.3, *Operations and Maintenance of New and Existing Facilities*, as are operational criteria for other CVP/SWP facilities and activities in the Delta, as well as facilities maintenance.

3.1.3 State Water Project

DWR was established in 1956 as the successor to the Department of Public Works for authority over water resources and dams within California. DWR also succeeded to the Department of Finance's powers with respect to state application for the appropriation of water (Stats. 1956, First Ex. Sess., Ch. 52; see also Wat. Code Sec. 123) and has permits for appropriation from the SWRCB for use by the SWP. DWR's authority to construct state water facilities or projects is derived from the Central Valley Project Act (CVPA) (Wat. Code Sec. 11100 et seq.), the Burns-Porter Act (California Water Resources Development Bond Act) (Wat. Code Sec. 12930-12944), the State Contract Act (Pub. Contract Code Sec. 10100 et seq.), the Davis-Dolwig Act (Wat. Code Sec. 11900-11925), and special acts of the State Legislature. Although the Federal government built certain facilities described in the CVPA, the Act authorizes DWR to build facilities described in the Act and to issue bonds. See *Warne v. Harkness*, 60 Cal. 2d 579 (1963). The CVPA describes specific facilities that have been built by DWR, including the Feather River

Project and California Aqueduct (Wat. Code Sec. 11260), Silverwood Lake (Wat. Code Sec. 11261), and the North Bay Aqueduct (Wat. Code Sec. 11270). The Act allows DWR to administratively add other units (Wat. Code Sec. 11290) and develop power facilities (Wat. Code Sec. 11295).

The Burns-Porter Act, approved by the California voters in November 1960 (Wat. Code Sec. 12930-12944), authorized issuance of bonds for construction of the SWP. The principal facilities of the SWP are Oroville Reservoir and related facilities, and San Luis Dam and related facilities, Delta facilities, the California Aqueduct including its terminal reservoirs, and the North and South Bay Aqueducts. The Burns-Porter Act incorporates the provisions of the CVPA. DWR is required to plan for recreational and fish and wildlife uses of water in connection with state-constructed water projects and can acquire land for such uses (Wat. Code Sec. 233, 345, 346, 12582). The Davis-Dolwig Act (Wat. Code Sec. 11900-11925) establishes the policy that preservation of fish and wildlife is part of state costs to be paid by water supply contractors, and recreation and enhancement of fish and wildlife are to be provided by appropriations from the General Fund.

DWR holds contracts with 29 public agencies in northern, central, and southern California for water supplies from the SWP. Water stored in the Oroville facilities, along with water available in the Delta (consistent with applicable regulations) is captured in the Delta and conveyed through several facilities to SWP contractors.

The SWP is operated to provide flood control and water for agricultural, municipal, industrial, recreational, and environmental purposes. A large portion of the water conserved in Oroville Reservoir is released to serve three Feather River area contractors, two contractors served from the North Bay Aqueduct, and pumped at the Harvey O. Banks Pumping Plant (Banks PP) in the Delta serving the remaining 24 contractors in the SWP service areas south of the Delta. In addition to pumping water released from Oroville Reservoir, the Banks PP pumps water from other sources entering the Delta.

Under the PA, the Banks PP will continue to fulfill this role, but will also use water diverted from the Sacramento River at three new intakes located in the north Delta and conveyed to the Banks PP via new tunneled and connecting conveyance, as described in Section 3.2, *Conveyance Facility Construction*. Flow criteria affecting CVP/SWP water withdrawals under the PA are described in Section 3.3 *Operations and Maintenance of New and Existing Facilities*, as are operational criteria for other CVP/SWP facilities and activities in the Delta, and facilities maintenance.

3.1.4 Coordinated Operations Agreement

The Coordinated Operations Agreement (COA) between the United States of America and DWR to operate the CVP/SWP was signed in November 1986. Congress, through Public Law 99-546, authorized and directed the Secretary of the Interior to execute and implement the COA. The COA defines the rights and responsibilities of the CVP/SWP with respect to in-basin water needs and project exports and provides a mechanism to account for those rights and responsibilities.

Under the COA, Reclamation and DWR agree to operate the CVP/SWP under balanced conditions in a manner that meets Sacramento Valley and Delta needs while maintaining their respective annual water supplies as identified in the COA. Balanced conditions are defined as periods when the two projects agree that releases from upstream reservoirs, plus unregulated flow, approximately equal water supply needed to meet Sacramento Valley in-basin uses and project exports. Coordination between the CVP and the SWP is facilitated by implementing an accounting procedure based on the sharing principles outlined in the COA. During balanced conditions in the Delta when water must be withdrawn from storage to meet Sacramento Valley and Delta requirements, 75% of the responsibility to withdraw from storage is borne by the CVP and 25% by the SWP. The COA also provides that during balanced conditions when unstored water is available for export, 55% of the sum of stored water and the unstored water for export is allocated to the CVP, and 45% is allocated to the SWP. Although the principles were intended to cover a broad range of conditions, changes implanted in subsequent the 2000 Trinity ROD, recent biological opinions (Chapter 2 *Consultation History*), a Revised SWRCB Decision 1641 (Revised D-1641) (Section 3.1.4.2 *Decision 1641 and Revised D1641*), and changes to the CVPIA were not specifically addressed by the COA. However, these variances have been addressed by Reclamation and DWR through mutual, informal agreements.

3.1.5 Delta Operations Regulatory Setting

3.1.5.1 1995 Water Quality Control Plan

The SWRCB adopted the 1995 Bay-Delta Water Quality Control Plan (1995 WQCP) on May 22, 1995, which became the basis of SWRCB Decision 1641. The SWRCB continues to hold workshops and receive information regarding processes on specific areas of the 1995 WQCP. The SWRCB amended the WQCP in 2006 (as discussed below), but, to date, the SWRCB has made no significant changes to the 1995 WQCP framework.

3.1.5.2 Decision 1641 and Revised D1641

The SWRCB has issued numerous orders and decisions regarding water quality and water right requirements for the Bay-Delta Estuary that impose multiple operations responsibilities on CVP/SWP in the Delta to meet the flow objectives in the 1995 WQCP. With D-1641 (issued December 29, 1999) and its subsequent revision (Revised D-1641, dated March 15, 2000), the SWRCB implements the objectives set forth in the 1995 WQCP, resulting in flow and water quality requirements for CVP/SWP operations to assure protection of beneficial uses in the Delta. The SWRCB also conditionally allows for changes to points of diversion (e.g., for the PA) with Revised D-1641.

The various flow objectives and export restraints are designed to protect fisheries. These objectives include specific outflow requirements throughout the year, specific export restraints in the spring, and export limits based on a percentage of estuary inflow throughout the year. The water quality objectives are designed to protect agricultural, municipal and industrial (M&I), and fishery uses, and they vary throughout the year and according to the wetness of the year (five water-year types: W, AN, BN, D, CD) classification scheme (e.g., the five water-year types using Sacramento Valley 40-30-30 Water Year Index). These flow and water quality objectives remain in effect and are subject to revision per petition process or every 3–5 year revision process set by the SWRCQB.

On December 29, 1999, SWRCB adopted and subsequently revised (on March 15, 2000) D-1641, amending certain terms and conditions of the water rights of the CVP/SWP under D1485. D-1641 substituted certain objectives adopted in the 1995 Bay-Delta Plan for water quality objectives that had to be met under the water rights of the CVP/SWP. The requirements in D-1641 address the standards for fish and wildlife protection, M&I water quality, agricultural water quality, and Suisun Marsh salinity. SWRCB D-1641 also authorizes the CVP/SWP to jointly use each other's points of diversion in the southern Delta, with conditional limitations and required response coordination plans. SWRCB D-1641 modified the Vernalis salinity standard under SWRCB Decision 1422 to the corresponding Vernalis salinity objective in the 1995 Bay-Delta Plan.

3.1.5.3 2006 Revised WQCP

The SWRCB undertook a proceeding under its water quality authority to amend the 1995 WQCP. Prior to commencing this proceeding, the SWRCB conducted a series of workshops in 2004 and 2005 to receive information on specific topics addressed in the 1995 WQCP.

The SWRCB adopted a revised WQCP on December 13, 2006. There were no changes to the Beneficial Uses from the 1995 WQCP to the 2006 WQCP, nor were any new water quality objectives adopted in the 2006 WQCP. A number of changes were made simply for readability. Consistency changes were also made to assure that sections of the 2006 plan reflected the current physical condition or current regulation. The SWRCB continues to hold workshops and receive information regarding Pelagic Organism Decline (POD), Climate Change, and San Joaquin salinity and flows, and will coordinate updates of the Bay-Delta Plan with on-going development of the comprehensive Salinity Management Plan.

3.1.5.4 Current Water Quality Control Plan Revision Process

The State Water Board is in the process of developing and implementing updates to 2006 WQCP that protect beneficial uses in the Bay-Delta watershed. This update is broken into four phases, some of which are proceeding concurrently. Phase 1 of this work, currently in progress, involves updating San Joaquin River flow and southern Delta water quality requirements for inclusion in the WQCP. Phase 2 will involve comprehensive changes to the WQCP to protect beneficial uses not addressed in Phase 1, focusing on Sacramento River driven standards. Phase 3 will involve implementation of Phases 1 and 2 through changes to water rights and other measures; this phase requires a hearing to determine the appropriate allocation of responsibility between water rights holders within the scope of the Phase 1 and Phase 2 plans. Phase 4 will involve developing and implementing flow objectives for priority Delta tributaries upstream of the Delta.

3.1.5.5 Annual/Seasonal Temperature Management Upstream of the Delta

Reclamation is required to control water temperature in the Sacramento River pursuant to State Water Board Order WR 90-5. Furthermore, per the Reasonable and Prudent Alternative (RPA) (Action Suite I.2) in the NMFS 2009 BiOp, Reclamation is required to develop and implement an annual Temperature Management Plan by May 15 each year to manage the cold water supply within Shasta Reservoir and make cold water releases from Shasta Reservoir, and Trinity Reservoir through the Spring Creek Tunnel, to provide suitable temperatures for listed species, and, when feasible, fall-run Chinook salmon, which is an important commercial fishery and a prey base for listed Southern Resident Distinct Population Segment (DPS) killer whale. Reclamation shall manage operations to achieve certain daily average water temperatures in the Sacramento River between Keswick Dam and Bend Bridge. In addition, Reclamation is required to provide the draft February forecast and initial allocations, as well as a projection of temperature management operations for the summer months to NMFS for review and evaluation under RPA Action I.2.3.

Since December 2013, state and Federal agencies that supply water, regulate water quality, and protect fish and wildlife have worked closely to manage these resources despite persistent drought conditions. As an example, in 2015 and 2016, Reclamation and NMFS adjusted the February operations forecast modeling, temperature compliance criteria, and Keswick release schedule in efforts to minimize further temperature effects. However, recent drought operations under the 2009 NMFS BiOp RPA have resulted in approximately 5.6% and 4.2% egg-to-fry survival to Red Bluff in 2014 and 2015, respectively[3]. In consideration of recent concerns with the level of protection provided by the NMFS 2009 BiOp RPA based on the very low egg-to-fry survival to Red Bluff, and new information regarding temperature tolerance during early life stages over the past few years, NMFS will work with Reclamation and other state and Federal agencies to adjust the RPA Action Suite 1.2. The adjustment will be made pursuant to the 2009 NMFS BiOp Section 11.2.1.2. *Research and Adaptive Management,* which states "After completion of the annual review, NMFS may initiate a process to amend specific measures in this RPA to reflect new information, provided that the amendment is consistent with the Opinion's underlying analysis and conclusions and does not limit the effectiveness of the RPA in avoiding jeopardy to listed species or adverse modification of critical habitat." This process is anticipated to conclude in late 2016 and may include refinements and additions to the existing annual/seasonal temperature management processes, including spring storage targets, revised temperature compliance criteria and a range in summertime Keswick release rates. The adjusted RPA Action Suite I.2 will apply to Reclamation's Shasta operations when the adjustment process is completed as described above.

3.1.6 Current Real-Time Operations

The goal for real-time decision making is to assist fishery management by minimizing potential adverse effects for listed species while meeting permit requirements and contractual obligations for water deliveries. Real-time data assessment promotes flexible operational decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. High uncertainty exists regarding real-time conditions that can change management decisions to balance operations to meet beneficial uses through 2030.

The PA does not propose changing any of the existing real-time operational processes currently in place. However, as described in Section 3.3.3 *Real-Time Operational Decision-Making Process,* an additional real-time operations process would be implemented under the PA.

[3] NMFS' March 18, 2016, response to the Bureau of Reclamation's February forecast.

Sources of uncertainty or flexibility in operations that are considered and responded to during real-time operations include the following.

Hydrologic conditions

Meteorological conditions

Tidal variability

Listed species (presence, distribution, habitat, and other factors such as ocean conditions)

Ecological conditions

3.1.7 Ongoing Processes to support Real-Time Decision Making

Real-time changes to CVP/SWP operations that help avoid and minimize adverse effects to listed species must also consider public health, safety, and water supply reliability. While Reclamation and DWR maintain their respective authorities to operate the CVP and SWP, various operating criteria are influenced by a number of real-time factors. To facilitate real-time operational decisions and fish and wildlife agency (consisting of USFWS, NMFS, and the California Department of Fish and Wildlife [CDFW]) determinations, Reclamation, DWR, and the fish and wildlife agencies have developed and refined (U.S. Bureau of Reclamation 2008; National Marine Fisheries Service 2009; U.S. Fish and Wildlife Service 2008) a set of processes to collect data, disseminate information, develop recommendations, make decisions, and provide transparency. This process consists of three types of groups that meet on a recurring basis. All of these teams review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species.

The process to identify actions to protect listed species varies to some degree among species and geographic area, but abides by the following general outline. A fisheries or operations technical team compiles and assesses current information regarding species, operational or hydrologic conditions, such as stages of reproductive development, geographic distribution, relative abundance, and physical habitat conditions. That team then provides a recommendation to the fish and wildlife agency with statutory obligation to enforce protection of the species in question, within guidelines established within the respective biological opinion or incidental take authorization. The fish and wildlife agency's staff and management review the recommendation and use it as a basis for developing, in cooperation with Reclamation and DWR, an operational response that minimizes adverse effects on listed species. In addition, certain actions may require input from the SWRCB to assess consistency with WQCP requirements or other water rights permit terms. The outcomes of protective actions that are implemented are monitored and documented, and this information informs future actions by the real-time decision-making teams.The management team is comprised of management staff from Reclamation, DWR, and the fish and wildlife agencies. The SWRCB also participates in management team meetings.

Information teams are teams that disseminate and coordinate information among agencies and stakeholders.

Fisheries and operations technical teams are comprised of technical staff from state and Federal agencies.

All of these teams review the most up-to-date data and information on fish status and Delta conditions, and develop recommendations that can be used to modify operations or criteria to improve the protection of listed species.

Table 3.1-2. Ongoing Real-Time Decision-Making Groups

CURRENT REAL TIME OPERATIONS DECISION-MAKING			
Working Group	**Description**	**Agency Lead**	**Meeting**
Water Operations Management Team (WOMT)	Existing technical work teams report weekly updates and recommendations to the WOMT, which is then used to advise USFWS, NMFS and CDFW in order to make final determinations for listed aquatic species conservation needs and water operations.	DWR	Weekly (Tuesday at 1:00PM) October–June
Water Operations Technical Work Teams			
Smelt Working Group (SWG)	A technical advisory team that provides recommendations on SWP and CVP operations to USFWS, CDFW, and WOMT pursuant to the USFWS RPA on Delta Smelt and CDFW ITP on Longfin Smelt.	FWS	Weekly (Monday at 10:00AM) December–June
Delta Operations for Salmonids and Sturgeon (DOSS)	A technical advisory team that provides recommendations on SWP and CVP operations to NMFS and WOMT pursuant to the NMFS RPA on anadromous salmonids and green sturgeon.	NMFS	Weekly (Tuesday at 9:00AM) October–June
CALFED Operations Group	Representatives from fish agencies and stakeholder groups make recommendations to SWP and CVP operations with the requirements of the SWRCB's Decision 95-6, the NMFS & USFWS biological opinions and CVPIA.	DWR	Monthly
Central Valley Project Improvement Act B2 Interagency Team (B2IT)	Discusses implementation of section 3406 (b)(2) of the CVPIA, which defines the dedication of CVP water supply for environmental purposes. It communicates with WOMT to ensure coordination with the other operational programs or resource-related aspects of project operations, including flow and temperature issues.	FWS	Weekly (Thursdays at 9:30AM)
Data Assessment Team (DAT)	Coordinates and disseminates information and data among Project and Fisheries agencies and stakeholders that are related to water project operations, hydrology, and fish surveys in the Delta.	DWR	Weekly
Delta Conditions Team (DCT)	Coordinates with scientists and engineers from the state and federal agencies, water contractors, and environmental groups to review the real-time operations and Delta conditions, including data from new turbidity monitoring stations and new analytical tools. The	FWS	Weekly (Friday at 9:30AM)

	members of the DCT provides their individual information to the SWG and/or DOSS, which can then be used to provide recommendations to WOMT.		
Sacramento River Temperature Task Group (SRTTG)	Meets initially in the spring to discuss biological, hydrologic, and operational information, objectives, and alternative operations plans to recommend a temperature control point. Once the SRTTG has recommended an operation plan for temperature control, Reclamation submits to the SWRCB an operations plan for temperature control, generally on or before June 1st each year.	USBR	Monthly (April–October)
American River Group (ARG)	Although open to the public, the ARG meetings generally include representatives from several agencies and organizations with on-going concerns and interests regarding management of the Lower American River. The ARG convenes monthly or more frequently if needed, with the purpose of providing fishery updates and reports for Reclamation to help manage Folsom Reservoir for fish resources in the Lower American River.	USBR	Monthly
Clear Creek Technical Working Group (CCTWG)	Group that identifies, prioritizes, and guides restoration opportunities on lower Clear Creek with an emphasis on anadromous fish.	USBR	Quarterly
Stanislaus Operation Group (SOG)	Action III.1.1 calls for Reclamation to create a Stanislaus Operations Group to provide a forum for real-time operational flexibility and implementation of the alternative actions defined in the RPA. This group provides direction and oversight to ensure that the East Side Division RPA actions are implemented, monitored for effectiveness and evaluated. Reclamation, in coordination with SOG, shall submit an annual summary of the status of these actions.	USBR	Monthly
Stanislaus River Forum (SRF)	New group formed to allow for stakeholder input immediately prior to the SOG discussions. Not part of the existing NMFS BiOp.	USBR	Monthly (Right before SOG)
NMFS BiOp Annual Review Group	Reclamation and NMFS will host a workshop to review the prior water years' operations and to determine whether any measures prescribed in the 2009 NMFS Biological Opinion RPA should be altered in light of information learned from prior years' operations or research.	NMFS	Annually (No later than 11/30)
5 Agency Meeting (BO RPA Implementation)	To assure close coordination and oversee the efforts of IMT on the implementation of the biological opinions governing SWP and CVP.	DWR	Monthly
Implementation Management Team (IMT)	Responsible for ensuring the regulatory compliance and implementation of the biological opinions (i.e. RPA actions).	NMFS	Monthly
Interagency Fish Passage Steering Committee (IFPSC)	To charter, and support through funding agreements, an interagency steering committee to provide oversight and technical, management, and policy direction for the Fish Passage Program.	USBR	Periodically

Sources: National Marine Fisheries Service (2009), U.S. Fish and Wildlife Service (2008).

3.1.8 Groups Involved in Real-Time Decision Making and Information Sharing

3.1.8.1.1 Water Operations Management Team

The Water Operations Management Team (WOMT) is composed of representatives from Reclamation, DWR, USFWS, NMFS, and CDFW. SWRCB participates in discussions. This management-level team was established to facilitate timely decision-support and decision making at the appropriate level. The WOMT first met in 1999, and continues to meet to make management decisions. Although the goal of WOMT is to achieve consensus on decisions, the participating agencies retain their authorized roles and responsibilities. Existing working groups/technical work teams report weekly updates and recommendations to the WOMT, which are then used to advise USFWS, NMFS and CDFW in order to make final determinations for listed aquatic species conservation needs and water operations.

Operations and Fisheries Technical Teams

Several fisheries-specific teams have been established to provide guidance and recommendations on current operations (flow and temperature regimes), as well as resource management issues. These teams include the Sacramento River Temperature Task Group, Smelt Working Group, Delta Conditions Team, Delta Operations for Salmonids and Sturgeon Workgroup, and American River Group. Each of these teams is described in more detail below. A more detailed list is provided in Table 3.1-2 above.

The Sacramento River Temperature Task Group

The Sacramento River Temperature Task Group (SRTTG) is a multiagency group formed by Reclamation pursuant to SWRCB Water Rights Orders 90-5 and 91-1, to assist with improving and stabilizing the Chinook salmon population in the Sacramento River. Annually, Reclamation develops temperature operation plans for the Shasta and Trinity divisions of the CVP. These plans consider impacts on winter-run and other races of Chinook salmon and associated Project operations. The SRTTG meets initially in the spring to discuss biological, hydrologic, and operational information, objectives, and alternative operations plans for temperature control. Once the SRTTG has recommended an operations plan for temperature control, Reclamation then submits a temperature management plan to SWRCB and NMFS, generally on or before June 1 each year.

After implementation of the operations plan, the SRTTG may report out on the results of studies and monitoring, or temperature model runs. The group holds meetings as needed, typically monthly through the summer and into fall, to recommend plan revisions based on updated biological data, reservoir temperature profiles, and operations data. Updated plans may be needed for summer operations to protect winter-run, or in fall for the fall-run spawning season. If there are any changes in the plan, Reclamation submits a supplemental report to SWRCB.

Smelt Working Group

The Smelt Working Group (SWG) consists of representatives from USFWS, CDFW, DWR, U.S. Environmental Protection Agency (USEPA), Reclamation, and NMFS. USFWS chairs the group, and a member is assigned by each agency. The SWG evaluates biological and technical issues regarding delta smelt and develops recommendations for consideration by USFWS. Since longfin smelt became a state candidate species in 2008, SWG has also developed recommendations for CDFW to minimize adverse effects on longfin smelt.

The SWG compiles and interpret the latest real-time information regarding state- and federally listed smelt, such as stages of development, distribution, and salvage. After evaluating available information, if the SWG members agree that a protective action is warranted, the SWG submits its recommendations in writing to WOMT, USFWS and CDFW.

The SWG may meet at any time at the request of USFWS, but generally meets weekly during the months of January through June, when smelt salvage at the CVP and SWP export facilities has historically occurred.

Delta Operations for Salmonid and Sturgeon Workgroup
The DOSS workgroup is a technical team with relevant expertise from Reclamation, DWR, CDFW, USFWS, SWRCB, U.S. Geological Survey (USGS), USEPA, and NMFS that provides advice to WOMT and to NMFS on issues related to fisheries and water resources in the Delta and recommendations on measures to reduce adverse effects of Delta operations of the CVP and SWP on salmonids and green sturgeon. The purpose of DOSS is to review CVP and SWP operations in the Delta and the collected data from the different ongoing monitoring programs.

Delta Condition Team
The existing SWG and WOMT advise USFWS on smelt conservation needs and water operations. In addition, a Delta Condition Team (DCT), consisting of scientists and engineers from the state and federal agencies, water contractors, and environmental groups, meet weekly to review the real time operations and Delta conditions, including data from new turbidity monitoring stations and new analytical tools such as the Delta Smelt behavior model. The members of the DCT provide their individual information to the SWG and the DOSS workgroup. Individual members of the DCT may provide, in accordance with a process provided by the WOMT, their information to the SWG or DOSS for their consideration in developing recommendations to the Project Agencies for actions to protect listed fish species.

American River Group
In 1996, Reclamation established a working group for the Lower American River, known as the American River Group (ARG). Although open to the public, the ARG meetings generally include representatives from several agencies and organizations with ongoing concerns and interests regarding management of the Lower American River. The formal members of the group are Reclamation, USFWS, NMFS, CDFW, and the Water Forum.

The ARG convenes monthly or more frequently if needed, with the purpose of providing fishery updates and recommendations for Reclamation to help manage operations at Folsom Dam and Reservoir for the protection of fishery resources in the Lower American River, and with consideration of its other intended purposes (*e.g.*, water and power supply).

3.1.9 Take Authorization Requested

The PA includes several activities that are expected to result in incidental take of federally listed species. In compliance with Section 7 of the ESA, take authorization is being requested for activities in which take is anticipated. However, some activities that may result in incidental take are not able to be authorized at this time because of lack of specific detail for effects to federally listed species. In these cases, separate incidental take authorization may be required via reinitiation of the CWF consultation, separate Section 7 consultation, or scientific collection permits.

The following timeline of actions indicates which of the actions under the PA include a request for take authorization. For clarity on the relationship of these actions to the existing biological opinions, the timeline also includes some components of operations pursuant to the USFWS (2008) and NMFS (2009) biological opinions for the operations of the CVP and SWP.

3.1.10 Construction Phase

The construction phase begins after the NEPA record of decision is issued, compliance with the Delta Reform Act is achieved, and all other necessary authorizations are obtained consistent with state and federal law; and ends when operations of the NDDs commence. During the construction phase, take authorization is requested for the following activities.

- All activities described in Section 3.2.1 *Geotechnical Exploration*.
- All activities described in Section 3.2.2 *North Delta Diversions*.
- All activities described in Section 3.2.3 *Tunneled Conveyance*.
- All activities described in Section 3.2.4 *Intermediate Forebay*.
- All activities described in Section 3.2.5 *Clifton Court Forebay*.
- All activities described in Section 3.2.6 *Connections to Banks and Jones Pumping Plants.*
- All activities described in Section 3.2.7 *Power Supply and Grid Connections.*
- All activities described in Section 3.2.8 *Head of Old River Gate.*
- All activities described in Section 3.2.9 *Temporary Access and Work Areas.*

During the construction phase, take authorization is not requested for the following activities.

- CVP/SWP operations, which will continue pursuant to the USFWS (2008) and NMFS (2009) biological opinions.
- Construction of the Georgiana Slough non-physical barrier described in Section 3.4.3.1.1.1 *Nonphysical Fish Barrier at Georgiana Slough.*
- Construction of mitigation for impacts to listed species, described in Section 3.4.3 *Restoration for Fish Species* and Section 3.4.5 *Terrestrial Species Conservation*. Once these mitigation sites have been selected, following procedures described in the cited sections, separate Section 7 consultations are expected for construction at each mitigation site.

- Mitigation site compliance monitoring effects on listed species other than valley elderberry longhorn beetle and California red-legged frog. Such monitoring will need scientific collection permits.

3.1.11 Operations Phase

The operations phase begins when operations of the NDDs commence. During the operations phase, take authorization is requested for the following activities.

- Operations of the NDDs as described in Section 3.3.2.1 *Operational Criteria for North Delta CVP/SWP Export Facilities.*
- Continued operations of south Delta CVP/SWP export facilities (i.e., operations currently covered under the USFWS (2008) and NMFS (2009) biological opinions for the operations of the CVP and SWP) as described in Section 3.3.2.2 *Operational Criteria for South Delta CVP/SWP Export Facilities.*
- Operations of the HOR gate as described in Section 3.3.2.3 *Operational Criteria for the Head of Old River Gate.*
- Operations of the Delta Cross Channel gates as described in Section 3.3.2.4 *Operational Criteria for the Delta Cross Channel Gates.*
- Operations of the Suisun Marsh facilities as described in Section 3.3.2.5 *Operational Criteria for the Suisun Marsh Facilities.*
- Operations of the North bay Aqueduct intake as described in Section 3.3.2.6 *Operational Criteria for the North Bay Aqueduct Intake.*
- Operations of the Georgiana Slough non-physical barrier as described in Section 3.4.3.1.1.1 *Nonphysical Fish Barrier at Georgiana Slough.*
- Giant garter snake habitat maintenance as described in Section 3.3.6.4 *Clifton Court Forebay and Pumping Plant* and Section 3.3.6.6 *Power Supply and Grid Connections.*

During the operations phase, take authorization is not requested for the following activities.

- All activities described in Section 3.4.3.1.1.1 *Nonphysical Fish Barrier at Georgiana Slough.* Installation and operations of this barrier are expected to be covered under a separate Section 7 consultation.
- In-water maintenance activities described in Section 3.3.6.1 *North Delta Diversions.* It is not possible, prior to final design of the facilities, to define how these activities would be performed or how often they would be needed. These activities will be addressed via consultation reinitiation or via a separate Section 7 consultation.
- In-water maintenance activities described in Section 3.3.6.4 *Clifton Court Forebay and Pumping Plant.* It is not possible, prior to final design of the facilities, to define how

these activities would be performed or how often they would be needed. These activities will be addressed via consultation reinitiation or via a separate Section 7 consultation.

- In-water maintenance activities described in Section 3.3.6.5 *Connections to Banks and Jones Pumping Plants.* It is not possible, prior to final design of the facilities, to define how these activities would be performed or how often they would be needed. These activities will be addressed via consultation reinitiation or via a separate Section 7 consultation.

- In-water maintenance activities described in Section 3.3.6.7 *Head of Old River Gate.* It is not possible, prior to final design of the facilities, to define how these activities would be performed or how often they would be needed. These activities will be addressed via consultation reinitiation or via a separate Section 7 consultation.

- Fish monitoring and studies described in Section 3.4.7 *Monitoring and Research Program.* These studies are subject to design through a collaborative process engaging the fish and wildlife agencies. The need for take authorization and any necessary Section 7 consultation will occur through that process.

- Mitigation site compliance monitoring effects on listed species other than valley elderberry longhorn beetle and California red-legged frog. Such monitoring will need scientific collection permits.

3.2 Conveyance Facility Construction

Conveyance facility construction includes the following component parts, with each discussed in a subsection to this chapter as follows:

Geotechnical exploration, Section 3.2.1.

North delta diversions construction, Section 3.2.2.

Tunneled conveyance, which will connect the intakes to the forebays, Section 3.2.3.

Intermediate Forebay (IF), Section 3.2.4.

Clifton Court Forebay, an existing structure that will be reconfigured in accordance with the new dual-conveyance system design, Section 3.2.5.

Connections to the Banks and Jones Pumping Plants, which are existing CVP/SWP export facilities, Section 3.2.6.

Power supply and grid connections, Section 3.2.7.

Head of Old River (HOR) gate, Section 3.2.8.

Temporary access and work areas, Section 3.2.9.

As part of the water right change in point of diversion process with the California State Water Resources Control Board, DWR and Reclamation are working to address the concerns of protesting legal users of water throughout the watersheds involved in either the CVP or SWP. To date, only one settlement, with Contra Costa Water District (CCWD), is complete. The CCWD settlement requires the inclusion of mitigation measures for water quality effects associated with the PA. The mitigation measures include sequenced implementation mechanisms, related to the construction, operation, and maintenance of additional facilities to transfer water to existing CCWD facilities[4]. When actions associated with implementation of the agreement are sufficiently defined to provide for analysis of potential adverse effects to listed species and critical habitat, a supplement to this BA will be provided to the Services.

A detailed description of the construction activities associated with each of these component parts is provided below. Figure 3.2-1 provides a map overview of these facilities, and Figure 3.2-2 provides a schematic diagram showing how these facilities will work with existing water-export facilities to create a modified water-export infrastructure facility for the Delta. Further design detail is provided in these following appendices: Appendices 3.A *Map Book for the Proposed Action*; 3.B *Conceptual Engineering Report, Volume 1*[5]; 3.C *Conceptual Engineering Report, Volume 2*; and 3.D *Construction Schedule for the Proposed Action*. Many of the construction techniques that will be employed during construction phase, such as cofferdams, sheet pile walls, slurry and diaphragm walls, are detailed in Appendix 3.B, *Appendix B Conceptual Level Construction Sequencing of DHCCP Intakes* (despite the title, Appendix 3.B addresses engineering techniques common to intake, shaft, and forebay construction).

Components of conveyance facility construction share common construction-related activities; for example, some of the component parts require dewatering. Table 3.2-1 identifies 11 common construction-related activities, each of which is described in greater detail in Section 3.2.10 *Common Construction-Related Activities*. In addition, all construction-related activities described in the PA will be performed in accordance with the general avoidance and minimization measures detailed in Appendix 3.F *General Avoidance and Minimization Measures* (AMMs). Specific avoidance and minimization measures (Table 3.2-2) are referred to in the following descriptions as applicable, except that *AMM-1 Worker Awareness Training* is a general AMM and is applicable to all personnel and all aspects of conveyance facility construction, and therefore will not be repeated in this description. Except where stipulated by an applicable species-specific AMM, proposed work may occur at the following times of day (see Table 3.2-1 for definitions of each term).

Clearing: Between dawn and sunset.

[4] See Attachment BO#146 for information adding the Settlement Agreement facilities to the Proposed Action and evaluating the effects of this change on listed species.

[5] Note that Appendix 3.B *Conceptual Engineering Report, Volume 1* and Appendix 3.C *Conceptual Engineering Report, Volume 2* were prepared to support engineering conceptual design as of July 1, 2015. During the preparation of this biological assessment, certain design changes were made in order to further minimize potential effects on listed species. Thus the PA described in this biological assessment differs in some particulars from the description in the appendices. Where such inconsistencies occur, the biological assessment constitutes an accurate description and represents DWR's and Reclamation's intent to perform the PA as here described.

Site work: At any time of the day or night.

Ground improvement: At any time of the day or night.

Borrow fill: At any time of the day or night.

Fill to flood height: At any time of the day or night.

Dispose spoils: At any time of the day or night.

Dewatering: At any time of the day or night.

Dredging and Riprap Placement: Between dawn and sunset when performed adjacent to or in water bodies. At any time of the day or night when performed in dry areas or in a previously-cleared area.

Barge operations: At any time of the day or night.

Landscaping: Between dawn and sunset.

Pile Driving: Between dawn and sunset.

Proposed construction-related work entails the use of equipment that may produce in-air sound at levels in excess of the local acoustic background; see the effects analysis (Chapter 6) for detailed analysis of the effects of exposure to in-air sound associated with various activities on listed species.

Several activities required for conveyance construction (e.g., dredging, pile driving, barge operations, geotechnical exploration, etc.) will result in disturbance and redistribution of sediments at and below the surface. There is a potential for some of these sediments to contain existing contaminants, and the disturbance associated with these activities could increase the risk of exposure to contaminants for listed species. Detailed sediment and contaminant characterizations of the specific areas expected to be subject to sediment disturbance are limited and do not provide enough information to support a thorough analysis of effects at this time. Examples of such studies include the maintenance dredging of Discovery Bay and the maintenance dredging of federal navigational channels in San Francisco Bay.

The former study (Central Valley Water Board 2003) considered a site near Clifton Court forebay where sediments are predominantly silt- and clay-sized, with less than 33% sand. Such sediments may be taken as representative of potential contaminants in the Clifton Court Forebay area. Contaminants detected in sediment testing included arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, zinc, tributyltin, polycyclic aromatic hydrocarbons, and organochlorine pesticides. Arsenic levels averaged 7.4 mg/kg, which is below average Sacramento-San Joaquin Delta background concentrations. All other constituents were at concentrations significantly below Human Residential and Human Industrial screening values.

The latter study (USACE and San Francisco Water Board 2014) considered a variety of federally maintained navigation channels. Although the channels are located downstream of the

Sacramento-San Joaquin Rivers confluence, the evaluated materials had predominately been transported downstream from those rivers, and at several of the tested sites primarily consisted of fine sand; thus study results are expected to be representative of contaminants likely to be found in the NDD area, where preliminary geotechnical results indicate surficial sediments that are predominately sand-sized. Sediment from the San Francisco Ship Channel was found to be 93% to 99% sand, and the analysis concluded "The total organic carbon levels in composite samples (total of two composites) ranged from 0.11 percent to 0.35 percent for samples collected in 2010. This is considered to be low, and in the highly suitable range for beneficial reuse. Throughout the years that MSC has been tested for maintenance dredging purposes, the sediment has been determined to be suitable for unconfined aquatic placement at the San Francisco Bar Channel Disposal Site (SF-8) or the Ocean Beach Demonstration Site." Testing at the Suisun Bay Channel and New York Slough found sediments to be 94% to 99% sand and concluded "Historically, the sediment has been deemed suitable for in-Bay placement at SF-9 and Suisun Bay placement site (SF-16). In 2009, confirmatory chemistry tests were run, in addition to the usual grain-size testing; these tests showed that no potential contaminant exceeded acceptable limits." Other sites yielded similar results, but are not reported here because their primary sediment source was not the Sacramento and San Joaquin rivers.

Based on these previous studies, the preliminary contaminant risk to listed species is low due to low contaminant levels in both clay/silt and sand samples, with particularly low concentrations likely in the predominately sand-sized sediments at the NDDs where exposure risk is greatest. Therefore, analysis of all actions in this PA that result in potential turbidity effects and sediment disturbance assumes a level of risk to the species from exposure to contaminants that is equivalent to the findings of the first-level sediment assessment for an initial evaluation of effects to listed fish species and their aquatic habitat. The PA also includes AMMs that are intended to specifically address the identified preliminary contaminant risk(s).

As described in Appendix 3.F, *General Avoidance and Minimization Measures*, *AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material,* to better define potential effects to listed species or aquatic habitat, and to streamline the collection and incorporation of newer information (i.e., monitoring data or site-specific baseline information), the following protocol will be followed. The action agency will work with State and Federal resource agencies with authorization and jurisdiction to identify the timeline for information gathering in relation to initiation of the specific action, but it is anticipated to be at least several months prior to the initiation of the action. At that time, DWR and Reclamation will follow the protocol below.

DWR will ensure the preparation and implementation of a pre-dredge sampling and analysis plan (SAP). The SAP will be developed and submitted by the contractor(s) as part of the water plan required per standard DWR contract specifications (Section 01570). Prior to initiating any dredging activity, the SAP will evaluate the presence of contaminants that may affect water quality from the following discharge routes.

Instream discharges during dredging.

Direct exposure to contaminants in the material through ingestion, inhalation, or dermal exposure.

Effluent (return flow) discharge from an upland disposal site.

Leachate from upland dredge material disposal that may affect groundwater or surface water.

Concentrations of the identified chemical constituents in the core samples will be screened through appropriate contaminant screening tables to ensure compliance with applicable agency guidelines.

Results of the sediment analyses and the quality guidelines screening will determine the risk associated with the disturbance of the sediment horizons by identifying specific pathways of exposure to adverse effects.

Results of the testing will be provided to all relevant State and Federal agencies for their use in monitoring or regulating the activities under consideration.

If the results of the chemical analyses of the sediment samples indicate that one or more chemical constituents are present at concentrations exceeding screening criteria, then additional alternative protocols to further minimize or eliminate the release of sediments into the surrounding water column must be implemented.

The applicant must provide to CDFW, NMFS and USFWS a plan to reduce or eliminate the release of contaminated sediment prior to the start of any actions that will disturb the sediments in the proposed construction area. Plans using a shrouded hydraulic cutterhead, or an environmentally sealed clamshell bucket may be acceptable provided that adequate supporting information is provided with the proposed plan. Plans should also include descriptions of the methods employed to treat, transport, and dispose of the contaminated sediment, as well as any resulting decant waters.

This approach incorporates the potential for take authorization to be revised at the time that effects of the action are determined to be “reasonably certain to occur” and the description of activities, existing conditions, and risk to species can be more specifically described with updated, site-specific information.

This type of approach is consistent with approaches to ESA compliance for other large-scale, long-term, repeated actions that do not have adequate site-specific and current information to support the analysis of effect of a specific future action at the time of consultation.

In Appendix 3.A *Map Book for the Proposed Action*, a detailed set of aerial photographs showing the proposed facilities and areas of both temporary and permanent impacts are presented.

Temporary impacts include impacts associated with new facility construction, but not ongoing or future facility operations. The following criteria determine whether a construction impact is temporary or permanent for the purposes of assessing effects on listed species.

For all wildlife species and Delta Smelt, impacts lasting more than 1 year (365 days) are considered permanent.

For all salmonid species and green sturgeon, impacts lasting more than 2 years are considered permanent.

Temporary impacts are not compensated for by habitat restoration; however, affected sites are restored to preconstruction conditions.

Note that Appendix 3.A does not include facilities for which the location is unknown. These unknown locations fall into three types: geotechnical exploration sites, safe haven work areas, and barge landings. Section 3.2.1 *Geotechnical Exploration* describes geotechnical exploration sites; Section 3.2.3 *Tunneled Conveyance* describes safe haven work areas; and Section 3.2.10.9 *Barge Landing Construction and Operations*, describes barge landings. See Chapter 5 *Effects Analysis for Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*, and Chapter 6 *Effects Analysis for Delta Smelt and Terrestrial Species*, for a discussion of how effects of these activities on listed species were analyzed.

Appendix 3.B[5] *Conceptual Engineering Report, Volume 1,* provides detailed descriptions and related information pertaining to conveyance facility construction. Sections of Appendix 3.B are referenced in the following subsections where appropriate. Similarly, Appendix 3.C[5] *Conceptual Engineering Report, Volume 2,* provides detailed drawings of conveyance facilities.

Appendix 3.D *Construction Schedule for the Proposed Action*, contains conveyance facility construction-related scheduling and forms the basis for statements regarding scheduling in this chapter.

Pile driving assumptions are detailed in Appendix 3.E *Pile Driving Assumptions for the Proposed Action*.

Table 3.2-1. Components of Conveyance Construction and the Common Construction Activities Used in Each

Common Construction Activity	Conveyance System Component							
	Geotechnical Exploration	Delta Intakes	Tunnels	Intermediate Forebay	Clifton Court Forebay	Connections to Banks and Jones	Power Supply and Grid Connections	Head of Old River Gate
Clearing[a]	At upland sites	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Site work[b]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ground improvement[c]	No	Yes	Shafts	Yes	Yes	Yes	Yes	No
Borrow fill[d]	No	Yes	Yes	Yes	Yes	Yes	No	No
Fill to flood height[e]	No	Yes	Yes	Yes	Yes	Yes	Yes	No
Dispose spoils[f]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Dewatering[g]	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes
Dredging and Riprap Placement[h]	No	Yes	Yes	No	Yes	Yes	No	Yes
Barge operations[i]	No	Yes	Yes	Yes	Yes	Yes	No	Yes
Landscaping[j]	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Pile Driving[k]	Yes	Yes	No	No	Yes	Yes	No	Yes

[a] Includes grubbing, clearing, and grading. Assumed to affect entire construction footprint; any areas not actually cleared are nonetheless subject to sufficiently invasive activity that their value as habitat for listed species is reduced to near zero.

[b] Includes all initial site work: Construct access, establish stockpiles and storage areas, construction electric, fencing, stormwater treatment per a SWPPP (Storm Water Pollution Prevention Plan). Occurs only on cleared sites.

[c] Includes drilling, injection of materials, installation of dewatering wells, etc. Occurs only on cleared sites.

[d] Includes excavation, dewatering (separate activity), and transport of borrow material. Occurs only on cleared sites.

[e] Includes placement of engineered fill to design flood height. Occurs only on cleared sites that previously or concurrently experience ground treatment and dewatering. Fill work meets U.S. Army Corps of Engineers (USACE) levee specifications where relevant.

[f] Includes placement of excavated, dredged, sedimentation basin, or reusable tunnel material (RTM) material on cleared sites where site work has been done.

[g] Includes dewatering via groundwater wells or by direct removal of water from excavation, as well as dewatering of excavated material; water may be contaminated by contact with wet cement or other chemicals (e.g., binders for RTM); includes dewatering of completed construction, e.g. of shafts during tunneling.

[h] Includes any work that occurs in fish-bearing waters, except that barge operations and pile driving are separately described.

[i] Includes barge landing construction; barge operations in river (e.g., to place sheetpiles); tug operations; barge landing removal.

[j] Includes placement of topsoil, installation of plant material, and irrigation and other activities as necessary until performance criteria are met. Occurs only on cleared sites.

[k] Includes work that involves vibratory and/or impact driving of piles in fish-bearing waters.

Table 3.2-2. Summary of the Avoidance and Minimization Measures Detailed in Appendix 3.F

Number	Title	Summary
AMM1	Worker Awareness Training	Includes procedures and training requirements to educate construction personnel on the types of sensitive resources in the work area, the applicable environmental rules and regulations, and the measures required to avoid and minimize effects on these resources.
AMM2	Construction Best Management Practices (BMPs) and Monitoring	Standard practices and measures that will be implemented prior, during, and after construction to avoid or minimize effects of construction activities on sensitive resources (e.g., species, habitat), and monitoring protocols for verifying the protection provided by the implemented measures.
AMM3	Stormwater Pollution Prevention Plan	Includes measures that will be implemented to minimize pollutants in stormwater discharges during and after construction related to the PA, and that will be incorporated into a stormwater pollution prevention plan to prevent water quality degradation related to pollutant delivery from action area runoff to receiving waters.
AMM4	Erosion and Sediment Control Plan	Includes measures that will be implemented for ground-disturbing activities to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities, and that will be incorporated into plans developed and implemented as part of the National Pollutant Discharge Elimination System (NPDES) permitting process for the PA.
AMM5	Spill Prevention, Containment, and Countermeasure Plan	Includes measures to prevent and respond to spills of hazardous material that could affect navigable waters, including actions used to prevent spills, as well as specifying actions that will be taken should any spills occur, and emergency notification procedures.
AMM6	Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material	Includes measures for handling, storage, beneficial reuse, and disposal of excavation or dredge spoils and reusable tunnel material, including procedures for the chemical characterization of this material or the decant water to comply with permit requirements, and reducing potential effects on aquatic habitat, as well as specific measures to avoid and minimize effects on species in the areas where RTM will be used or disposed.
AMM7	Barge Operations Plan	Includes measures to avoid or minimize effects on aquatic species and habitat related to barge operations, by establishing specific protocols for the operation of all PA-related vessels at the construction and/or barge landing sites. Also includes monitoring protocols to verify compliance with the plan and procedures for contingency plans.
AMM8	Fish Rescue and Salvage Plan	Includes measures that detail procedures for fish rescue and salvage to avoid and minimize the number of Chinook salmon, steelhead, green sturgeon, and other listed species of fish stranded during construction activities, especially during the placement and removal of cofferdams at the intake construction sites.
AMM9	Underwater Sound Control and Abatement Plan	Includes measures to minimize the effects of underwater construction noise on fish, particularly from impact pile–driving activities. Potential effects of pile driving will be minimized by restricting work to the proposed in-water work windows[6] and by controlling or abating underwater noise generated during pile driving.

[6] Proposed in-water work windows vary within the Delta:
Geotechnical exploration: August 1 to October 31; Barge landings: July 1 to August 31;.
NDDs: June 1 to October 31, except that in-water impact pile driving is limited to June 15 to September 15;
CCF and Banks/Jones Connections: July 1 to October 31;and HOR gate: August 1 to October 31.
With regard to impact pile driving, work windows for the NDD may be lengthened subject to NMFS and USFWS approval based on success of bubble curtain and real-time monitoring for fish presence (any extension would not go past October 31st). In-water activities associated with mobilization and demobilization are not subject to the work windows. In-water impact pile installation may occur outside of the work windows if performed within a dewatered cofferdam and with in-channel acoustic monitoring to verify that generated sound thresholds do not exceed the 150 dB

Number	Title	Summary
AMM10	Methylmercury Management	Design and construct wetland mitigation sites to minimize ecological risks of methylmercury production.
AMM11	Design Standards and Building Codes	Ensure that the standards, guidelines, and codes, which establish minimum design criteria and construction requirements for project facilities, will be followed. Follow any other standards, guidelines, and code requirements that are promulgated during the detailed design and construction phases and during operation of the conveyance facilities.
AMM12	Transmission Line Design and Alignment Guidelines	Design the alignment of proposed transmission lines to minimize impacts on sensitive terrestrial and aquatic habitats when siting poles and towers. Restore disturbed areas to preconstruction conditions. In agricultural areas, implement additional BMPs. Site transmission lines to avoid greater sandhill crane roost sites or, for temporary roost sites, by relocating roost sites prior to construction if needed. Site transmission lines to minimize bird strike risk.
AMM13	Noise Abatement	Develop and implement a plan to avoid or reduce the potential in-air noise impacts related to construction, maintenance, and operations.
AMM14	Hazardous Material Management	Develop and implement site-specific plans that will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities and required emergency-response procedures in case of a spill. Before construction activities begin, establish a specific protocol for the proper handling and disposal of hazardous materials.
AMM15	Construction Site Security	Provide all security personnel with environmental training similar to that of onsite construction workers, so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.
AMM16	Fugitive Dust Control	Implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust and ensure the Action commitments are appropriately implemented before and during construction, and that proper documentation procedures are followed.
AMM17	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives when these activities could affect water quality or aquatic species.

A great deal of refinement has occurred during the PA development process, enabling substantial reductions in potential impacts. These refinements are summarized in Table 3.2-3.

behavioral criterion. Apart from impact pile driving, any other work may occur within a dewatered cofferdam regardless of the timing of in-water work windows. Any extension/reduction of work windows would focus on half-month increments.

Table 3.2-3. California WaterFix Design Refinements

PA Refinement	Administrative Draft EIR/EIS (December 2012)	2013 Design Refinements	2014 Design Refinements
Water facility footprint	3,654 acres	1,851 acres	1,810 acres
Intermediate forebay size (water surface)	750 acres	40 acres	28 acres
Private property impacts	5,965 acres	5,557 acres	4,288 acres
Public lands used	240 acres	657 acres	733 acres
Number of intakes	5	3	3
Number of tunnel reaches	6	5	5
Number of launch and retrieval shaft locations	7	5	5
Agricultural impacts	6,105 acres	6,033 acres	4,890 acres

3.2.1 Geotechnical Exploration

3.2.1.1 Overview of Geotechnical Exploration

Geotechnical exploration will be used to obtain data to support the development of an appropriate geologic model, characterize ground conditions, and reduce the geologic risks associated with the construction of proposed facilities.

DWR will perform a series of geotechnical investigations along the selected water conveyance alignment, at locations proposed for facilities, and at material borrow areas. The proposed exploration is designed as a two-part program (Phases 2a and 2b) to collect geotechnical data. The two-part program will allow refinement of the second part of the program to respond to findings from the first part. The Draft Geotechnical Exploration Plan (Phase 2) provides additional details for both phases regarding the rationale, methodology, locations, and criteria for obtaining subsurface soil information and laboratory test data (Appendix 3.G *Geotechnical Exploration Plan—Phase 2*).

Sampling will occur at locations along the water conveyance alignment and at proposed facility sites. The exploration will include field and laboratory testing of soil samples. The field tests will consist of auger and mud-rotary drilling with soil sampling using a standard penetration test (SPT) barrel (split spoon sampler) and Shelby tubes; cone penetrometer testing (CPT); geophysical testing; pressure meter testing; installation of piezometers and groundwater extraction wells; dissolved gas sampling; aquifer testing; and excavation of test pits. All of these techniques, except test pit excavation and CPT, entail drilling. The field exploration program will evaluate soil characteristics and collect samples for laboratory testing. Laboratory tests will include soil index properties, strength, compressibility, permeability, and specialty testing to support tunnel boring machine (TBM) selection and performance specification.

3.2.1.2 Methods for Land-Based Exploration

The land-based portion of the proposed Phase 2a and 2b exploration will occur at approximately 1,380 geotechnical exploration locations. The exploration locations will be selected on the basis of location (as shown in Appendix 3.G, *Geotechnical Exploration Plan—Phase 2, Attachment A*) and on accessibility for truck or track-mounted drill rigs. At approximately 60 of the exploration locations, test pits will be excavated, with test pit dimensions 4 feet wide, 12 feet long, and 12 feet deep. Test pits are used to evaluate bearing capacity, physical properties of the sediments, location of the groundwater table, and other typical geologic and geotechnical parameters.

Temporary pumping wells and piezometers will be installed at intake, forebay, pump shaft, and tunnel shaft exploration locations to investigate soil permeability and to allow sampling of dissolved gases in the groundwater. Small test pits will be excavated at some locations to obtain near-surface soil samples for laboratory analysis.

At each geotechnical exploration location, DWR will implement BMPs that include measures for air quality, noise, greenhouse gases, and water quality. Direct impacts on buildings, utilities, and known irrigation and drainage ditches will be avoided during geotechnical exploration activities.

Each geotechnical exploration location will be active for a period ranging from a few hours to 12 work days, depending on exploration type and target depth. Exploration locations that involve only CPT testing and/or soil test pits will typically be active for less than 1 day (normally a crew would do two such locations per day). There will be approximately 415 sites that involve only CPT testing. The remaining exploration locations (approximately 965) involve soil borings and will be active for multiple days, with the duration of activity dependent upon the depth of the borings. The deepest borings (i.e., 300 feet) will be located at shaft locations, and will require up to 12 work days. There will be approximately 50 such locations. The remaining 365 borings will be to depths of up to 200 feet and will be located along the majority of the tunnel alignment and at other facility construction sites (i.e., the intakes, Intermediate Forebay, and facilities near Clifton Court Forebay); work at these sites will require approximately 5 work days each. After each site is explored, bored excavations will be backfilled with cement-bentonite grout in accordance with California regulations and industry standards (Water Well Standards, DWR 74-81 and 74-90). Test pits will be backfilled with the excavated material on the same day as they are excavated, with the stockpiled topsoil placed at the surface and the area restored as closely as possible to its original condition. Piezometers will be installed at some sites, and at these locations, technicians may periodically revisit the sites to collect data. Aquifer pump tests will also be performed at some sites; however, pump test activities are not expected to exceed 10 days at these sites.

3.2.1.3 Methods for Overwater Exploration

The overwater portion of the proposed Phase 2a and 2b exploration will occur at approximately 90 to 100 exploration locations. At these locations, geotechnical borings and CPTs will be drilled in the Delta waterways. The exploration locations will be selected on the basis of location (as shown in Appendix 3.G *Geotechnical Exploration Plan—Phase 2, Attachment A*), with precise site selection based upon practicability considerations such as avoidance of navigation markers and underwater cables. Approximately 30 of these locations will be in the Sacramento River to obtain geotechnical data for the proposed intake structures. An additional 25 to 35 of these locations will be at the major water undercrossings along the tunnel alignment and 30 to 35 of these locations will be at the proposed barge unloading facilities and Clifton Court Forebay (CCF) modifications. The borings and CPTs are planned to explore depths between 100 and 200 feet below the mud line (i.e., river bottom).

DWR will conduct overwater drilling only during the in-water work window[6] between the hours of sunrise and sunset. Duration of drilling at each location will vary depending on the number and depth of the holes, drill rate, and weather conditions, but activities are not expected to exceed 60 days at any one location. Overwater borings for the intake structures and river crossings for tunnels will be carried out by a drill ship and barge-mounted drill rigs.

3.2.1.4 Extent of Phase 2a Land-based and Overwater Work

Phase 2a exploration will focus on collecting data to support preliminary engineering through soil borings and CPTs at approximately 550 land-based and 43 overwater locations. Land-based explorations will be conducted for the intake perimeter berms, State Route (SR) 160, sedimentation basins, pumping plants, forebay embankments, tunnel construction and vent shafts, and other appurtenant facilities (subsequent subsections herein describe these facilities in detail). Overwater explorations will support the design of intake structures and the major water crossings along the conveyance alignment.

Phase 2a exploration for tunnel construction will entail land-based drilling approximately every 1,000 feet along the tunnel alignment. One-third of the sites will receive only soil borings, half will receive only CPTs, and one-sixth will receive both soil borings and CPTs. All of the land-based boreholes along the tunnel alignments will be fitted with piezometers. Overwater drilling is planned in Potato Slough (three sites), San Joaquin River (three sites), Connection Slough (two sites), and CCF (35 sites).

In addition, six soil borings and four CPTs will occur at each tunnel shaft or CCF pumping plant shaft site. Once drilling is completed at each shaft site, two of the boreholes will be converted into groundwater extraction wells and the other four boreholes will be converted into piezometers. Boreholes and CPTs are also proposed for the intake and pumping plant sites and SR 160. Approximately six boreholes at each of the proposed intakes will be converted into piezometers.

3.2.1.5 Extent of Phase 2b Land-based and Overwater Work

Phase 2b exploration will support final design, permitting requirements, and planning for procurement and construction-related activities. Phase 2b explorations will include soil borings, CPTs, and test pits at approximately 830 land-based and 94 overwater locations.

Phase 2b exploration for tunnel construction will entail land-based drilling for soil borings near the Phase 2a CPT locations such that a borehole (soil boring or CPT) will have been located at approximately 500-foot intervals along the entire tunnel alignment, a spacing that generally conforms to typical design efforts for tunnels like those proposed.

Similarly, Phase 2b boring will occur at the construction and ventilation shaft sites, and will also occur at the safe haven intervention sites (these types of facilities are described in Section 3.2.3 *Tunneled Conveyance*). Overwater boreholes and CPTs are planned in the Sacramento River, Snodgrass Slough, South Fork Mokelumne River, San Joaquin River, Potato Slough, Middle River, Connection Slough, Old River, North Victoria Canal, and CCF. Phase 2a and Phase 2b geotechnical exploration are summarized in Table 3.2-4.

Table 3.2-4. Planned Geotechnical Exploration

Siting	Location	Maximum Number of Exploration Sites	
		Phase 2a	Phase 2b
On land	All locations	550	880
Over-water	Sacramento River	0	30
Over-water	Snodgrass Slough	0	3
Over-water	South Fork Mokelumne River	0	3
Over-water	San Joaquin River	3	12
Over-water	Potato Slough	3	18
Over-water	Middle River	0	2
Over-water	Connection Slough	2	7
Over-water	Old River	0	6
Over-water	West Canal	0	8
Over-water	CCF	35	5

3.2.1.6 Schedule

Phase 2a and Phase 2b land-based explorations will require approximately 24 months, using six land-based drill rigs operating concurrently for 6 days per week. Land-based explorations will typically occur from April through November, and when performed in suitable habitat will conform to timing constraints for terrestrial species as specified in Section 3.4, *Conservation Measures*. Phase 2a and Phase 2b overwater explorations will require approximately 14 months, using two drill rigs operating concurrently for 6 days per week. Work will be performed within proposed in-water work windows[6]. This schedule will be expedited if possible, depending on the availability of site access, drilling contractors and equipment, permit conditions, and weather. Most of the proposed geotechnical explorations will be performed during the first 3 years of implementation. See Appendix 3.D *Construction Schedule for the Proposed Action* for further information on the conveyance facility construction schedule.

3.2.2 North Delta Diversions

The siting process featured evaluations of a wide variety of locations for north Delta diversion intakes and various configurations. Possible intake locations and configurations were considered and analyzed in terms of the availability of quantity and quality of water for the diversion, the ability to divert at each intake location, potential impacts on other nearby diverters and dischargers, fish exposure-risk to intakes, presence of fish migration corridors, potential water quality considerations, and reasonable costs estimates involved in construction and operation, among other considerations. This preliminary analysis provided information sufficient to focus on potential intake locations and assumed a diversion facility consisting of five (5) intakes with a total capacity of 15,000 cubic feet per second (cfs). Potential siting of intake locations ranged in distance as far upstream on the Sacramento River to north of the American River confluence in Sacramento County, to as far downstream as south of Steamboat Slough in Solano County. Detailed analyses of these potential intake configurations were conducted in 2010. These analyses showed that actual intake locations are primarily influenced by exposure risk for fish, and to a lesser extent, migration pathways (California Department of Water Resources et al. 2013 [Appendix 3.A]). After extensive analysis and consultation with stakeholders, in July 2012 the project proponents proposed to evaluate the construction and use of three intakes (Intakes 2, 3, and 5) located between Courtland

and Clarksburg for a total maximum pumping capacity of 9,000 cfs. This configuration and capacity was chosen because the water facilities would meet projected water supply needs. The use of three intakes was found to be sufficient to meet forecast diversion volume needs and would have lower environmental impacts compared to construction of five intakes. The intakes are designed as on-bank screens. Design and operational criteria supporting this concept included design constraints developed in collaboration with the fish and wildlife agencies (Fish Facilities Technical Team 2008, 2011), as well as minimum performance standards for bypass flows, sufficient to minimize the risk of covered fishes becoming entrained or impinged on the screens.

The intake design process also reflects a long duration of collaborative discussions between the project proponents and the fish and wildlife agencies. In 2008, the Fish Facilities Technical Team's (FFTT) preliminary draft, *Conceptual Proposal for Screening Water Diversion Facilities along the Sacramento River*, reviewed and evaluated various approaches to the screening of diversion facilities, using screen design principles offered by NMFS, CDFW, and USFWS (Fish Facilities Technical Team 2008). These principles included using designs that would comply with the following criteria.

- Be biologically protective.
- Provide a positive, physical barrier between fish and water intakes.
- Avoid the need to collect, concentrate, and handle fish passing the intake.
- Avoid bypasses that would concentrate fish numbers, increasing the risk of predation.
- Avoid off-channel systems, in order to avoid handling fish.
- Select locations that have desirable hydraulic characteristics (e.g., uniform sweeping velocities, reduced turbulence).
- Use the best available existing technology in use in the Sacramento Valley.
- Use smaller multiple intakes (as opposed to a single large intake) to enhance fish protection with operational flexibility under varying flow conditions.
- Minimize the length of intake(s) to reduce the duration of exposure to the screen surface for fish.
- Select locations on the Sacramento River as far north as practicable to reduce the exposure of delta smelt, longfin smelt, and other estuarine species.
- Avoid areas where predators may congregate or where potential prey would have increased vulnerability to predation.
- Avoid areas of existing riparian habitat.

To the extent possible, these principles have been used to guide the preliminary design of the NDD and will continue to be used as the design process continues, although it is acknowledged that site-specific constraints may not allow all of the criteria suggested in these principles to be met.

3.2.2.1 Intake Design

The PA will include construction of three intakes (Intake 2, Intake 3, and Intake 5) on the east bank of the Sacramento River between Clarksburg and Courtland, in Sacramento County, California. Intake locations and plans are shown in Figure 3-1; in Appendix 3.A *Map Book for the Proposed Action*, Sheets 1 and 2; and Appendix 3.C[5] *Conceptual Engineering Report, Volume 2,* Sheets 10 to 32, 44, and 45. The materials in Appendix 3.C include a rendering of a completed intake, as well as both overview and detail drawings for each intake site. The intakes are described in Appendix 3.B[5] *Conceptual Engineering Report, Volume 1*, Section 6.1 *Description and Site Plans*; see particularly Tables 6-1 and 6-2, which describe intake design criteria relevant to analysis of effects, such as approach and sweeping velocities and fish screen specifications, and Section 6.1.1.1 *Intake Structures*, which describes fish screen design. Other intake components are behind the fish screens and have no potential to affect listed species. Information relevant to intakes construction details is provided in Appendix 3.B, Section 6.2 *Construction Methodology*. General intake dimensions are shown in Table 3.2-5.

Table 3.2-5. Intake Dimensions

Intake	Location (river mile)	Overall Length of Structure along Sacramento River Bank (feet)	Area of Intake Construction Site (acres)	Area of Tidal Perennial Habitat (acres)	
				Temporary In-Water Work	Permanent (Intake + Wing Wall Transitions)
Intake 2	41.1	1,969	190	4.9	2.6
Intake 3	39.4	1,497	152	3.3	1.8
Intake 5	36.8	1,901	144	5.0	2.3
Total	**--**	**5,367**	**486**	**13.2**	**6.6**

Each intake can divert a maximum of 3,000 cfs of river water. Each intake consists of an intake structure fitted with on-bank fish screens; gravity collector box conduits extending through the levee to convey flow to the sedimentation system; a sedimentation system consisting of sedimentation basins to capture sand-sized sediment and drying lagoons for sediment drying and consolidation; a sedimentation afterbay providing the transition from the sedimentation basins to a shaft that will discharge into a tunnel leading to the Intermediate Forebay; and an access road, parking area, electrical service, and fencing (as shown in Appendix 3.C *Conceptual Engineering Report, Volume 2,* Sheets 11, 12, and 13).

3.2.2.2 Fish Screen Design

The intakes include fish screens designed to minimize the risk that fish or larvae will be entrained into the intakes or injured by impingement on the fish screens. The foremost design attribute achieving this purpose is to meet criteria established by the fish agencies limiting water velocities through the screen (called the approach velocity) to values substantially less than swimming speeds achievable by the fish species of concern and limiting water velocities parallel to the surface of the screen (called the sweeping velocity) to values that will allow fish to travel past the screen with minimal additional effort or risk of impingement (Fish Facilities Technical Team 2011). However, many other aspects of facility design also help determine its effects on fish, therefore the process of design has been and will continue to be subject to extensive collaborative discussions with the fish agencies. A variety of preconstruction studies are proposed to aid in refinement of the fish screen design; see Section 3.4.8 *Monitoring and Research Program*, for a listing and description of these studies.

Each screened intake will consist of a reinforced concrete structure subdivided into six individual bays that can be isolated and managed separately. Water will be diverted from the Sacramento River by gravity into the screened intake bays and routed from each bay through multiple parallel conveyance box conduits to the sedimentation basins. Flow meters and flow control sluice gates will be located on each box conduit to assure limitations on approach velocities and that flow balancing between the three intake facilities is achieved. All of the intakes will be sized at the design water surface elevation (WSE) to provide approach velocities at the fish screen of less than or equal to 0.20 feet per second (ft/s) at an intake flow rate of 3,000 cfs. The design WSE for each site has been established as the 99% exceedance (Sacramento River stage) elevation, and the maximum design WSE was established as the 200-year flood elevation plus an 18-inch allowance for sea level rise, which is a conservative estimate in the context of available forecasts (Mineart et al. 2009).

The fish screen will include screen panels and solid panels that form a barrier to prevent fish from being drawn into the intake and the traveling screen cleaning system. Fish screen design has not yet been finalized, and final design is subject to review and approval by the fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW). Design specifications for the fish screens meet Delta Smelt criteria, which require an approach velocity less than or equal to 0.2 ft/s. When coupled with equal or greater sweeping velocities, Delta Smelt impingement and screen contact are thereby minimized (Swanson et al. 2005; White et al. 2007), and therefore this standard has been adopted as a performance standard for the North Delta Diversions (Fish Facilities Technical Team 2011). The Delta Smelt approach velocity criterion is also protective of salmonids because it is well below the 0.33 ft/s approach velocity standard for Chinook salmon fry[7]. Fish screens will be provided with monitoring systems capable of verifying approach and sweeping velocity standard compliance in real time.

As currently designed, the fish screens will be a vertical flat plate profile bar type made from stainless steel with a maximum opening of 0.069 inch and porosity of 43%. Proposed fish screens dimensions are shown in Table 3.2-6. Each of the configurations shown in the table provides hydraulic performance adequate to divert up to 3,000 cfs within a design range of river flows. Each configuration achieves this with a given total area of active fish screen, but the size of the intakes is variable due to differences in screen height, and the length of the intakes incorporates unscreened refugia areas (further discussed below).

[7] The specific performance standard is: "Diversions should be designed to operate at an approach velocity of 0.33 fps to minimize screen length, however, to minimize impacts to delta smelt, the diversions should be operated to an approach velocity of 0.2 fps at night if delta smelt are suspected to be present, based on a real-time monitoring program. The diversions may be operated to an approach velocity of 0.33 fps at all other times" (Fish Facilities Technical Team 2011).

Table 3.2-6. Fish Screen Dimensions

Intake	Screen Height	Screen Width	Number of Screens	Total Length of Screens[1]
Intake 2	12.6 feet	15 feet	90	1,350 feet
Intake 3	17.0 feet	15 feet	74	1,110 feet
Intake 5	12.6 feet	15 feet	90	1,350 feet

Notes

[1] Fish screen length is shorter than structure length shown in Table 3.2-5 because structure length includes concrete approach sections and refugia.

Source: Appendix 3.C

See Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheets 16, 17, 19, 22, and 23 for illustration of the following elements of the fish screen system. Screen panels will be installed in the lower portion of the intake structure face, above a 2-foot wall against which sediment could accumulate between maintenance intervals (described in Section 3.3.6.1.2 *Sediment Removal*). Solid panels will be stacked above the screen panels in guides extending above the deck of the structure. The screen panels will be arranged in groups, with each screen bay group providing sufficient screen area for 500 cfs of diversion. There will be six separate screen bay groups per intake facility, all of which will be hydraulically independent. A log boom will protect the screens and screen cleaning systems from impact by large floating debris. Each screen bay group will have a traveling screen cleaning system. The screen cleaners will be supported by a monorail and driven by an electric motor and cable system with a cycle time of no more than 5 minutes. Flow control baffles will be located behind each screen panel and will be installed in guides to accommodate complete removal of the baffle assembly for maintenance. These flow control baffles will be designed to evenly distribute the approach velocity to each screen such that it meets the guidelines developed by the FFTT (Fish Facilities Technical Team 2011). The flow control baffle guides will also serve as guides for installing bulkhead gates (after removal of the flow control baffles) for maintenance of each screen bay group. The bulkhead gates will be designed to permit dewatering of a screen bay group under normal river conditions.

Because of the length of the screens and extended fish exposure to their influence (screens and cleaners), incorporation of fish refugia areas will be evaluated as part of next engineering design phase of the intakes, as recommended by the FFTT (Fish Facilities Technical Team 2011). Current conceptual design for the refugia would provide areas within the columns between the fish screen bay groups that would provide fish resting areas and protected cover from predators. The current design calls for a 22-foot-wide refugium between each of the six screen bay groups at each intake. Design concepts for fish refugia and studies to evaluate their effectiveness are still in development, and final refugia design is subject to review by the fish agencies (i.e., USFWS, NMFS, and CDFW). The review and final design process will incorporate lessons from the Fish Facilities Technical Team (2011) work, the current NMFS (2011) guidance for fish screens, and recent relevant projects, as applicable. Two recent examples of fish refugia design and installation include the Red Bluff Diversion fish screen and that of Reclamation District 2035, on the Sacramento River just north of Sacramento (Svoboda 2013). The Red Bluff Diversion fish screen design used a physical model study to assess hydraulic parameters such as velocity and turbulence in relation to behavior of juvenile Chinook salmon, white sturgeon, and rainbow trout. The refugia consist of flat recessed panels protected by vertical bars. Bar spacing at the entrance to each refugium was selected based on fish size, to allow entry of protected species while excluding predators. A final design was chosen to reduce velocity in the refuge while minimizing turbulence; under this design, a total of four fish refugia were constructed along 1,100 feet of screen. At the Reclamation District 2035 fish screen, an initial design included a single refuge pocket midway along the intake, which was subsequently modified to include 2-ft-long refugia between each screen panel along the intake. This fish screen also included juvenile fish habitat elements into the upstream and downstream sheet pile training walls and the sloped soil areas above the training walls, with grating materials attached to the sheet pile walls to prevent predatory fish from holding in the corrugated areas by the walls and to provide another form of refuge for small fish (Svoboda 2013). These two examples serve to illustrate the site-specific design considerations that are necessary for construction of large intakes. The effectiveness of refugia requires study (Svoboda 2013).

All fish screen bay groups will be separated by piers with appropriate guides to allow for easy installation and removal of screen and solid panels as well as the flow control baffle system and bulkheads; these features will be removable by gantry crane (Appendix 3.C *Conceptual Engineering Report, Volume 2,* Sheet 17). Piers will support the operating deck set with a freeboard of 18 inches above the 200-year flood level with sea level rise. The levee in the immediate area will be raised to provide a freeboard of 3 feet above the 200-year flood level with sea level rise. Sheet pile training walls will have a radius of 200 feet and will be upstream and downstream of the intake structures providing improved river hydraulics and vehicular access to the operating deck as well as transitioning the intake structure to the levee (Appendix 3.C, Sheets 33 and 34 show the extent of levee modifications).

3.2.2.3 Construction Overview and Schedule

The timeline for NDD construction is presented in Appendix 3.D *Construction Schedule for the Proposed Action*. The schedule is complex, with work simultaneously occurring at all major facilities for a period of years, and tunnel boring likewise occurring simultaneously at multiple sites for a period of years. During construction, the sequence of activities and duration of each schedule element will depend on the contractor’s available means and methods, definition and variation of the design, departure from expected conditions, and perhaps other variable factors.

Each intake has its own construction duration with Intakes 2, 3, and 5 each projected to take approximately 4 to 5 years. Early phase tasks to facilitate construction will include mobilization, site work, and establishing concrete batch plants, pug mills, and cement storage areas. During mobilization the contractors will bring materials and equipment to construction sites, set up work areas, locate offices, staging and laydown areas, and secure temporary electrical power. Staging, storage, and construction zone prep areas for each intake site will cover approximately 5 to 10 acres. Barges, which will be used as construction platforms for drilling rigs, cranes, etc., will be present throughout the construction period at each intake facility.

Site work consists of clearing and grubbing (discussed in Section 3.2.10.1 *Clearing*), constructing site work pads, and defining and building construction access roads (discussed in Section 3.2.9 *Temporary Access and Work Areas*) and barge access (discussed in Section 3.2.10.9 *Barge Landing Construction and Operations*). Before site work commences, the contractor will implement erosion and sediment controls in accordance with the Storm Water Pollution Prevention Plan (SWPPP) (See Appendix 3.F *General Avoidance and Minimization Measures, AMM3 Stormwater Pollution Prevention Plan*, for a detailed description). Site clearing and grubbing and site access to stockpile locations have not yet been developed, but will be subject to erosion and dust control measures as specified in the SWPPP and other permit authorizations.

Although DWR plans to use existing roads to the greatest extent possible, some new roads will be constructed to expedite construction activities and to minimize impact to existing commuters and the environment. Access roads and environmental controls will be maintained consistent with BMPs and other requirements of the SWPPP and permit documents.

Substantial amounts of engineered fill will be placed landward of the levee, amounting to approximately 2 million cubic yards at each intake site. This fill material will be used primarily in levee work, pad construction for the fills, and other placements needed to ensure that the permanent facilities are at an elevation above the design flood (i.e., a 200-year flood with additional allowance for sea level rise). The required engineered fill material will preferably be sourced onsite from locations within the permanent impact footprint, for instance from excavations to construct the sedimentation basins. Material sourced from offsite will be obtained as described in Section 3.2.10.4 *Borrow Fill*.

3.2.2.4 Levee Work

Levee modifications will be needed to facilitate intake construction and to provide continued flood management. The levee modifications are described in Appendix 3.B *Conceptual Engineering Report, Volume 1*, Section 15 *Levees*, and in Appendix 3.C, *Conceptual Engineering Report, Volume 2,* Drawings 6, 10 to 17, 19, 44, and 45. Additional information on cofferdam construction (one element of the levee work) appears in Appendix 3.B, Section 6.2.1, *General Constructability Considerations*. The Sacramento River levees are Federal Flood Control Project levees under the jurisdiction of USACE and Central Valley Flood Protection Board, and specific requirements are applicable to penetrations of these levees. Authorizations for this work have not yet been issued. All construction on these levees will be performed in accordance with conditions and requirements set forth in the USACE permit authorizing the work.

Principal levee modifications necessary for conveyance construction are here summarized. See the referenced text in Appendices 3.B and 3.C, *Conceptual Engineering Report, Volumes 1 and 2,* respectively, for detailed descriptions of the work. Appendix 3.B, Section 15.2, *Sequence of Construction at the Levee,* includes a table detailing the sequence of construction activities in levee work.

New facilities interfacing with the levee at each intake site will include the following elements.

3.2.2.4.1 Levee Widening

Levees near the intakes will be widened on the land-side to increase the crest width, facilitate intake construction, provide a pad for sediment handling, and accommodate the Highway 160 realignment. Levee widening is done by placing low permeability levee fill material on the land-side of the levee. The material is compacted in lifts and keyed into the existing levee and ground. The levee will be widened by about 250 feet at each intake site. The widened levee sections will allow for construction of the intake cofferdams, associated diaphragm walls, and levee cutoff walls within the existing levee prism while preserving a robust levee section to remain in place during construction.

SR 160 will be impacted by construction activities at each of the three intake sites. During the levee widening, the highway will be permanently relocated from its current alignment along the top of the river levee to a new alignment established on top of the widened levee aligned approximately 220 feet farther inland from the river. The location of the new permanent SR 160 alignment is shown in Appendix 3.C *Conceptual Engineering Report, Volume 2*, Drawings 13, 14, 15 and 16.

3.2.2.4.2 On-Bank Intake Structure, Cofferdam, and Cutoff Walls

The intake structure and a portion of the box conduits will be constructed inside a dual sheet pile cofferdam installed within the levee prism on the river-side (Appendix 3.C, *Conceptual Engineering Report, Volume 2,* Drawings 15, 16, 17 and 19; construction techniques are described in Appendix 3.B, *Conceptual Engineering Report, Volume 1*, Sections 6.2.1, *General Constructability Considerations*; 15.1, *Configuration of Facilities in the Levee;* and 15.2, *Sequence of Construction at the Levee.* See Section 3.2.2.5, *Pile Installation for Intake Construction*, for detail on the pile placement required for cofferdam construction). The intake structure foundation will use a combination of ground improvement (as described in Section 3.2.10.3, *Ground Improvement*) and steel-cased driven piles or drilled piers. The cofferdams will project from 10 to 35 feet into the river, relative to the final location of the intake screens, dewatering up to 5 acres of channel at each intake site. The river width varies from 475 feet at Intake 3 to 615 feet at Intake 5, so this represents 1.6% to 7.4% of the channel width.

The back wall of the cofferdam along the levee crest will be a deep slurry diaphragm cutoff wall designed for dual duty as a structural component of the cofferdam and to minimize seepage through and under the levee at the facility site; thus the cofferdam sheet piles will become permanent structural components of the intake facility. The diaphragm wall will extend along the levee crest upstream and downstream of the cofferdam and the fill pad for the sedimentation on the land-side, which will allow for a future tie-in with levee seepage cutoffs that are not part of the PA. The other three sides of the cofferdam, including a center divider wall, will be sheet pile walls. The cofferdam will include a permanent, 5-foot-thick tremie concrete seal in the bottom to aid dewatering and constructability within the enclosed work area.

Once each cofferdam is completed and the tremie seal has been poured and has cured, the enclosed area will be dewatered as described in Section 3.2.10.7, *Dewatering*, with fish rescue occurring at that time, in accordance with a fish rescue plan that has been previously approved by CDFW, NMFS, and USFWS. Preparation and requirements for fish rescue plans are described in Appendix 3.F *General Avoidance and Minimization Measures, AMM8 Fish Rescue and Salvage Plan.* Following dewatering, areas within the cofferdam will be excavated to the level of design subgrade using clam shell or long-reach backhoe before ground improvements (jet grouting and deep soil mixing) and installation of foundation piles as described below in Section 3.2.2.5, *Pile Installation for Intake Construction*.

In conjunction with the diaphragm wall, a slurry cutoff wall (soil, bentonite, and cement slurry) will be constructed around the perimeter of the construction area for the land-side facilities. This slurry wall will be tied into the diaphragm wall at the levee by short sections of diaphragm wall perpendicular to the levee. The slurry cutoff wall will overlap for approximately 150 feet along the diaphragm wall at the points of tie-in. The slurry wall is intended to help prevent river water from seeping through or under the levee during periods when deep excavations and associated dewatering are required on the land-side. By using the slurry wall in conjunction with the diaphragm wall, the open cut excavation portion of the work on the landside will be completely surrounded by cutoff walls. These walls will minimize induced seepage from the river through the levee, both at the site and immediately adjacent to the site, and serve as long-term seepage control behind the levee.

At the upstream and downstream ends of the intake structure, a sheet pile training wall will transition from the concrete intake structure into the river-side of the levee. Riprap will be placed on the levee-side slope upstream and downstream of the structure to prevent erosion from anomalies in the river created by the structure. Riprap will also be placed along the face of the structure at the river bottom to resist scour.

The cofferdam structure and the berm surrounding the entire intake construction site will provide temporary flood protection during construction; see Appendix 3.B, *Conceptual Engineering Report, Volume 1,* Section 15.3.1, *Temporary Flood Protection Features*, for a detailed explanation of how this will be accomplished.

After intake construction is complete the cofferdammed area will be flooded and underwater divers using torches or plasma cutters will trim the sheet piles at the finished grade/top of structural slab. A portion of the cofferdam will remain in place after intake construction is complete to facilitate dewatering as necessary for maintenance and repairs, as shown in Appendix 3.C, *Conceptual Engineering Report, Volume 2,* Drawing 16.

3.2.2.4.3 Box Conduits

Large gravity collector box conduits (12 conduits at each intake) will lead from the intake structure through the levee prism to the landside facilities. The box conduits will be constructed by open-cut methods after the intake portion of the cofferdam is backfilled. Backfill above the box conduits and reconstruction of the disturbed portion of the levee prism will be accomplished using low-permeability levee material in accordance with USACE specifications.

3.2.2.5 Pile Installation for Intake Construction

Structural properties of the sediment at the construction site are a principal consideration in determining the effort required for pile installation. See Appendix 3.B, Section 6.2.2, *Intake Structure and Sediment Facilities Geotechnical,* for a description of geotechnical findings at each intake site. Generally, sediments at the intake sites consist of a surficial layer of soft to medium stiff, fine-grained soils to a depth of approximately 20 to 30 feet below ground surface; underlain by stratified stiff clay, clayey silt, and dense silty sand to the depth of the soil borings.

See Section 3.2.10.11, *Pile Driving*, for a general description of how pile driving will be performed. Table 3.2-7 summarizes proposed pile driving at the intake sites, including the type, size, and number of piles required, as well as the number of piles driven per day, the number of impact strikes per pile, and whether piles will be driven in-water or on land (source: Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*). Table 3.2-7 specifies 42-inch steel piles for the intake foundations; however, depending on the findings of the geotechnical exploration, it may be feasible to replace some or all of those steel piles with cast-in-drilled-hole (CIDH) foundation piles. The CIDH piles are installed by drilling a shaft, installing rebar, and filling the shaft with concrete; no pile driving is necessary with CIDH methods. Use of concrete filled steel piles will involve vibratory or impact-driving hollow steel piles, and then filling them with concrete. Table 3.2-7 assumes that all piles will be driven using impact pile driving, but the design intent is to use impact pile driving only for placement of the intake structure foundation piles. All other piles will be started using vibratory pile driving and driving will be completed using impact pile driving. Based on experience during construction of the Freeport diversion facility, it is expected that approximately 70% of the length of each pile can be placed using vibratory pile driving, with impact driving used to finalize pile placement. In-water pile driving will be subject to abatement, hydroacoustic monitoring[9], and compliance with timing limitations as described in Appendix 3.F, *General Avoidance and Minimization Measures*, *AMM9 Underwater Sound Control and Abatement Plan*.

Table 3.2-7. Pile Driving for Intake Construction

Feature	On-land or In-water	Pile Type/ Sizes	Total Piles	Number of Pile Drivers in Concurrent Use	Piles/ Day	Strikes/ Pile	Strikes/ Day
Intake Cofferdam – Intakes 2, 3, and 5	In-water	Sheet pile	2,500	4	60	210	12,600
Intake Structure Foundation – Intake 2	In-water	42-inch diameter steel	1,120	4	60	1,500	90,000
Intake Structure Foundation – Intake 3	In-water	42-inch diameter steel	850	4	60	1,500	90,000
Intake Structure Foundation – Intake 5	In-water	42-inch diameter steel	1,120	4	60	1,500	90,000
SR-160 Bridge (Realignment) at Intake	On-land	42-inch diameter steel	150	2	30	1,200	36,000
Control Structure at Intake	On-land	42-inch diameter steel	650	4	60	1,200	72,000
Pumping Plant and Concrete Sedimentation Basins at Intake	On-land	42-inch diameter steel	1,650	4	60	1,200	72,000

Sheet piles will be installed in two phases starting with a vibratory hammer and then switching to impact hammer if refusal is encountered before target depths. Sheet pile placement for cofferdam installation will be performed by a barge-mounted crane equipped with vibratory and impact pile-driving rigs. Foundation pile placement within the cofferdammed area may be done before or after the cofferdammed area is dewatered. If it is done after the cofferdammed area is dewatered and the site is dry, a crane equipped with pile driving rig will be used within the cofferdam. If done before the cofferdam is dewatered, pile driving will be performed by a barge-mounted crane positioned outside of the cofferdam or a crane mounted on a deck on top of the cofferdam. In-water pile driving will be subject to abatement (e.g., use of a bubble curtain), hydroacoustic monitoring, and compliance with timing limitations as described in Appendix 3.F, *General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan*.

At the conclusion of construction, the intake facilities will be landscaped, fenced, and provided with security lighting as described in Section 3.2.10.10, *Landscaping and Associated Activities*.

3.2.3 Tunneled Conveyance

Although conceptual proposals for north Delta diversions of water for the CVP/SWP have been discussed since at least the early 1960s[10], the earlier proposals all relied upon canal designs that

[9] For more on corrective measures, thresholds, and responses to underwater noise see Permit Resolution Log, item #33.
[10] See Draft EIR/EIS Appendix 3.A (California Department of Water Resources et al. 2013) for a detailed description of the historical development of the tunneled conveyance concept.

would have resulted in extensive and unacceptable adverse impacts on both the human and natural environment in the Delta.

In 2009, however, the project proponents selected a pipeline and tunnel-based system as the preferred basis of design for conveyance of water from the North Delta Diversions to the CVP/SWP export facilities. The initial tunneled conveyance design, analyzed in the draft EIR/EIS for the PA (U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, National Marine Fisheries Service, and California Department of Water Resources 2013), had pump stations sited at each of the intakes, and somewhat smaller tunnels, north of the IF, compared to the PA.

Subsequent value engineering studies revealed that if the tunnels were made larger, then a gravity-feed system would work, allowing elimination of the pump stations at the intakes and their replacement with a consolidated pump station at the CCF. This design change reduced overall electricity consumption associated with operations of the PA, with a concomitant reduction in greenhouse gas generation (for electric power production). It also eliminated the need for new, permanent high-voltage electrical transmission lines serving the new intakes, and thereby eliminated the potential bird strike and other adverse effects associated with those transmission lines (although temporary transmission lines are still needed, to power TBMs and provide other construction electricity).

3.2.3.1 Design

The conveyance tunnels will extend from the proposed intake facilities (Section 3.2.2 *North Delta Diversions*) to the North Clifton Court Forebay (NCCF). The tunneled conveyance includes the North Tunnels, which consist of three reaches that connect the intakes to the IF; and two parallel Main Tunnels, connecting the IF to the NCCF. Final surface conveyance connecting the NCCF to the existing export facilities is described in Section 3.2.6 *Connections to the Banks and Jones Pumping Plants*. The water conveyance tunnels will be operated with a gravity feed system, delivering to a pumping station located at the NCCF.

Each tunnel segment will be excavated by a TBM. This technique largely limits surface impacts on those associated with initial geotechnical investigations on the TBM route (Section 3.2.1 *Geotechnical Exploration*), surface facilities located at the TBM launch and reception shafts (this section), the disposition of material excavated by the TBMs (Section 3.2.10.6 *Dispose Spoils*), the provision of electric power to the TBM (Section 3.2.7 *Power Supply and Grid Connections*), and points where the TBM cutterhead may need to be accessed for repair or maintenance (Section 3.2.3.3.5 *Intermediate Tunnel Access*). Water quality impact potential is associated with dewatering procedures and construction stormwater disposition at the TBM launch and reception surface facilities, and would be addressed via relevant minimization measures described in Section 3.2.10.7 *Dewatering*, and relevant AMMs (Appendix 3.F *General Avoidance and Minimization Measures, AMM3 Stormwater Pollution Prevention Plan, AMM4 Erosion and Sediment Control Plan*, and *AMM5 Spill Prevention, Containment, and Countermeasure Plan*). TBMs also have the potential to generate subsurface effects due to the sound produced by TBM excavation, which can be detected by sensitive receptors such as green sturgeon.

The TBM launch facilities will be relatively large and active construction sites because they are continuously active during a TBM tunnel drive, when they will provide the only surface access to the tunnel. Thus they will require stockpiles of materials used by the TBM, will provide access to the TBM for its operation and maintenance, and will receive all materials excavated by the TBM. Conversely, TBM reception facilities will be used to recover the TBM at the end of its drive, and thus have a smaller footprint and a more limited operating scope. Table 3.2-8 summarizes all of the proposed tunnel drives, identifying launch and reception shafts, tunnel lengths, and tunnel diameters. Appendix 3.B *Conceptual Engineering Report*, *Volume 1*, Figure 11-1, shows this information on a map. Note that Bouldin Island and the IF will be the primary tunneling sites; the IF will be the launch point for 25.1 miles of two 40-foot tunnels and 4.8 miles of a 28-foot tunnel, while Bouldin Island will be the launch point for four, 40-foot tunnels with a total length of 25.4 miles. Bacon Island will be the launch point for two, 40-foot tunnels with a total length of 16.6 miles, while Intake 2 will be a relatively small site, acting as launch point for one 28-foot tunnel that will be 2.0 miles long.

For a detailed explanation of the tunneling work, see Appendix 3.B *Conceptual Engineering Report, Volume 1,* Sections 3.1 *Proposed Alignment and Key Components*, 3.2 *Reach Descriptions*, and 11.0 *Tunnels*; Sections 11.2.5 *Tunnel Excavation Methods* and 11.2.6 *Tunnel Support*, in particular, detail the process of tunneling. Briefly[11], tunneling will be performed by a TBM, which is a very large and heavy electrically-powered machine that will be launched from the bottom of a launch shaft, and will tunnel continuously underground to a reception shaft. The cutterhead of the TBM will be hydrostatically isolated from the remainder of the machine, so that the inside of the tunnel will be dry and at atmospheric pressure. As the TBM proceeds, precast concrete tunnel lining sections will be assembled within the TBM to produce a rigid, water-tight tunnel lining. Typically very little dewatering will be needed to keep the interior of the tunnel dry. A electrically-powered conveyor will carry excavated material from the TBM back to the launch shaft, where a vertical conveyor will carry the material to the surface for disposal (Section 3.2.10.6 *Dispose Spoils*). A narrow-guage railway may be installed in the tunnel with a diesel locomotive, or rubber wheeled diesel engine trucks may be used to carry workers, tunnel lining segments, and other materials from the launch shaft to the TBM.

A map book showing all of the tunnel drives is presented in Appendix 3.A *Map Book for the Proposed Action*. Design drawings showing tunnel routing, design of the shaft structures, and layout of the surface facilities at launch and reception sites appear in Appendix 3.C *Conceptual Engineering Report*, *Volume 2*; see Drawings 44 to 54, showing the tunnel routing and all associated areas of surface activity. A detailed project schedule, showing periods of tunneling and associated activities, is given in Appendix 3.D *Construction Schedule for the Proposed Action*. Each TBM launch or retrieval shaft will require barge access for equipment and materials; see Section 3.2.10.9 *Barge Landing Construction and Operations,* for further information. Avoidance and minimization measures (AMMs) to be implemented during construction work at all surface facilities supporting the tunneling work appear in Appendix 3.F *General Avoidance and Minimization Measures*, and are referenced below as appropriate.

[11] An excellent video summarizing how a TBM tunnels through soft sediment is available at https://www.youtube.com/watch?v=qx_EjMlLgqY. Neither the contractor nor the project depicted in the video has any relationship to the proposed action, but the type of machine used and the procedures depicted are very similar to those that would occur under the proposed action.

Table 3.2-8. Tunnel Drive Summary

Reach	Launch Shaft	Reception Shaft	Inside Diameter (ft)	Length (miles)
1	Intake 2	Intake 3 junction structure	28	1.99
2	IF inlet	Intake 3 junction structure	40	6.74
3	IF inlet	Intake 5	28	4.77
4 (west tunnel)	IF	Staten Island	40	9.17
4 (east tunnel)	IF	Staten Island	40	9.17
5 (west tunnel)	Bouldin Island	Staten Island	40	3.83
5 (east tunnel)	Bouldin Island	Staten Island	40	3.83
6 (west tunnel)	Bouldin Island	Bacon Island	40	8.86
6 (east tunnel)	Bouldin Island	Bacon Island	40	8.86
7 (west tunnel)	NCCF	Bacon Island	40	8.29
7 (east tunnel)	NCCF	Bacon Island	40	8.29

3.2.3.2 Schedule

Appendix 3.D *Construction Schedule for the Proposed Action*, provides scheduling information for tunneling activities. The TBM launch shafts will be most active, producing RTM on a nearly continuous basis, for the following time periods:

CCF: May 2020 to February 2025

Bouldin Island: October 2020 to May 2025

IF: May 2021 to October 2026

Intake 2: October 2021 to July 2025

Overall, the peak period of activity will be from October 2020 to April 2025. Considering time required to prepare each site, as well as time required to stabilize and restore RTM storage areas, each site will remain active throughout essentially the whole period of construction (2018 to 2030). Since the CCF, IF, and Intake 2 are essential components of the conveyance system, these sites will remain permanently active. The Bouldin Island site, however, will close following attainment of revegetation and restoration objectives for the associated RTM storage areas, although a small permanent tunnel access shaft will remain.

3.2.3.3 Construction

Launch shaft sites (IF, Bouldin, NCCF, and Intake 2) are shown in Appendix 3.C *Conceptual Engineering Report*, *Volume 2*, Drawings 56, 50, 76, and 11, respectively. Reception shaft sites (Intake 3, Intake 5, Staten Island, and Bacon Island) are similar in design. Appendix 3.C, Drawings 69 to 73 show typical work area and finished construction plans for paired tunnel shafts.

3.2.3.3.1 Shaft Site Facilities

Facilities at launch shaft sites will include a concrete batch plant and construction work areas including offices, parking, shop, short-term segment storage, fan line storage, crane, dry houses, settling ponds, daily spoils piles, temporary RTM storage, electrical power supplies, air, water treatment, and other requirements. There will also be space for slurry ponds at sites where slurry wall construction is required. Work areas for RTM handling and permanent spoils disposal will also be necessary, as discussed in Section 3.2.10.6 *Dispose Spoils*. Facilities at reception shafts will be similar but more limited, as there will be no need for a concrete batch plant or for RTM storage.

3.2.3.3.2 Shaft Site Preparation

Shaft site preparation is detailed in Appendix 3.B *Conceptual Engineering Report, Volume 1,* Section 11.2.1 *Advance Works Contracts*. During shaft site preparation, vehicular access will be established and electrical service will be provided via temporary transmission line (see Section 3.2.7 *Power Supply and Grid Connections*). The shafts will be located on pads elevated to above the 200-year flood elevation; fill will be placed to construct these pads and to preload the ground to facilitate settling. The site will be fenced for security and made ready for full construction mobilization. Due to the pervasive nature of these activities, all surface disturbance associated with construction at each shaft site will occur very early during the period of activity at each site; the entire site footprint will be disturbed and will remain so for the duration of construction activity.

3.2.3.3.2.1 Access Routes

Access routes for each shaft site are shown in Appendix 3.A *Map Book for the Proposed Action*, and in Appendix 3.C *Conceptual Engineering Report, Volume 2*, Drawings 44 to 54. These sources also depict the footprint for new permanent access roads, which will be a feature of every shaft site. SR 160 provides access to the intakes and their associated shafts, but for all other shafts (including atmospheric safe haven access shafts, discussed in Section 3.2.3.3.5 *Intermediate Tunnel Access*), access roads will be constructed. Those roads will be permanent features except at atmospheric safe haven access shafts, where they will be temporary.

3.2.3.3.2.2 Fill Pads

Permanent conveyance facilities (intakes, permanent shaft sites, IF, and CCF facilities) must be sited at elevations that are at minimal risk of flooding; see Appendix 3.B *Conceptual Engineering Report, Volume 1,* Section 3.5 *Flood Protection Considerations* for a detailed discussion of this issue. This means that the facilities will require fill pads with a top surface elevation of approximately 25 feet to 35 feet, depending upon location (Appendix 3.B, Table 3-4). These sites are currently near or below sea level, so substantial fill volumes will be needed, the placement of which will cause consolidation settlement of underlying delta soils at the construction sites. The shafts at the IF are an exception; these will initially be constructed at near existing site grades, and final site grades will be established in conjunction with final IF inlet and outlet facilities. The permanent elevated pad perimeters are assumed to extend to 75 feet from the outside of the shafts to facilitate heavy equipment access for maintenance and inspection. As the existing ground elevations are significantly lower than the final planned elevations, the pad fills will slope down to the adjacent existing site grades at an inclination of between 3 horizontal to 1 vertical (3H to 1V) to 5H to 1V.

Due to the soft ground conditions expected at the construction sites, it will also be necessary to improve existing sites to support heavy construction equipment, switchyards, transformers, concrete and grout plants, cranes and hoists, TBMs, and water treatment plants. See Section 3.2.10.3 *Ground Improvement*, for discussion of how this will be achieved.

Preliminary estimates suggest 8 to 10 feet of consolidation settlement can be expected from the placement of shaft pad area fills. Pre-loading of the existing pad and placement of vertical wick drains, spaced at 5 feet on center to a depth of 60 feet, will be used to achieve soil consolidation through vertical relief of excess pore water pressure in the compressible soils. It is expected that all but approximately 12 inches of the total settlement will occur within 1 year following pad placement. Thus pad construction will significantly precede other work at the shaft site; at the IF, for instance, earthwork will begin 2.5 years prior to ground improvement, and will then be followed by a 9-month period of ground improvement, before the site will be ready for mobilization.

Construction of the pad fills will require substantial amounts of material, which will be sourced from borrow sites; see Section 3.2.10.4 *Borrow Fill,* for further discussion.

3.2.3.3.3 Shaft Construction

During mobilization, construction manpower, stockpiles of materials, and needed equipment will be stationed at the construction site.

Shaft construction procedures are described in Appendix B *Conceptual Engineering Report, Volume 1,* Section 11.2.3 *Shaft Construction*, and here summarized. Shafts are circular in plan with a 100-foot diameter for 28 foot tunnels and a 113-foot diameter for 40-foot tunnels. These minimum sizes are constrained by the equipment needs to launch and retrieve the TBM from the bottom of the shaft.

Final design of shafts is not complete, but the basic objective is to use concrete construction methods to create a watertight shaft sufficiently strong to resist hydrostatic pressure within the delta sediments. This will be done by constructing a concrete cylinder prior to removing the sediment from the structure. Potential construction methods include overlapping concrete caisson walls, panel walls, jet-grout column walls, secant piles walls, slurry walls, precast sunken caissons, and potentially other technologies. In the areas where TBMs enter and exit, a special break-in/break-out section will be constructed as an integral part of the shaft.

Shaft bottoms will be stabilized to resist uplift associated with external hydrostatic pressures, during both excavation and operation. It may be necessary to pretreat ground at the shaft area from the surface to the bottom of the shaft to control blowouts during excavation of the shaft. Concrete working slabs capable of withstanding uplift will be required at all shaft locations to provide a stable bottom and a suitable working environment. To place the bottom slab, the shaft will be excavated to approximately 30 to 50 feet below the invert level of the tunnel, and a concrete base will be placed underwater using tremie techniques. It is expected that this will be an unreinforced mass concrete plug to withstand ground water pressure, with optional relief wells to relieve uplift pressure during tunnel construction. The launch and reception of the TBMs will require that large openings be created in the shaft walls. To maintain structural stability, it will be necessary to provide additional structural support. This will be provided by a reinforced concrete buttress or frame structure within the shaft.

Dewatering will be required during shaft construction and operation, and will be performed as described in Section 3.2.10.7 *Dewatering*. Dewatering of sediments surrounding the shaft may be needed during construction, depending upon the construction method selected. Dewatering will also be needed during excavation within the shaft, following placement of the tremie seal, and continuously thereafter until completion of construction work within the shaft.

3.2.3.3.4 Tunnel Excavation

The tunnel excavation procedure is described in Appendix 3.B *Conceptual Engineering Report, Volume 1,* Sections 11.2.5 *Tunnel Excavation Methods*, to 11.2.8 *Logistics*. Tunnel excavation will occur entirely underground and thus will entail no surface impacts, apart from those associated with the TBM launch and reception shafts (discussed above) and the construction access shafts (discussed below). Tunnel dewatering needs will be minor, compared to those associated with shaft construction, and are discussed above. Disposition of material excavated during tunnel construction is addressed in Section 3.2.10.6 *Dispose Spoils.*

3.2.3.3.5 Intermediate Tunnel Access

In the event that maintenance, inspection, or repair of the TBM cutterhead will be needed, contractors will be able to access their equipment either from inside the TBM or from the surface using construction access shafts. Such access points are termed "safe havens" because they constitute points where humans can work on the outside of the TBM in conditions of comparative safety.

Access to the cutterhead from inside the TBM will occur at a "pressurized safe haven intervention." It will be a "pressurized" safe haven because compressed air will be used to create a safe work area; the air pressure will exclude sediment and water from the excavation. Consequently humans in the work area will be subject to risks similar to those experienced by SCUBA divers: they will have a limited time during which they can safely work in the excavation, and must undergo a long and potentially dangerous decompression process when they leave the work area. In order to minimize that risk, surface-based equipment is commonly used to inject grout into the sediments surrounding the work area, minimizing the risk that the excavation will collapse and allowing workers to work in a less highly pressurized environment. Pressurized safe haven interventions will be constructed by injecting grout from the surface to a point in front of the TBM, or by using other ground improvement techniques such as ground freezing. Once the ground has been stabilized by one of these techniques, the TBM will then bore into the treated area. Surface equipment required to construct the safe haven intervention site will include a small drill rig and grout mixing and injection equipment, and facilities to control runoff from dewatering (dewatering, if required, will be performed as described in Section 3.2.10.7 *Dewatering*). Disturbance at the site is expected to be limited to an area of approximately 100 feet by 100 feet. The surface drilling and treatment operation will typically take about 8 weeks to complete. Once complete, all equipment will be removed and the surface features reestablished. To the greatest extent possible, established roadways will be used to access the intervention sites. If access is not readily available, temporary access roads will be established.

Access to the cutterhead from the surface, referred to as an "atmospheric safe haven interventions," will require construction of a shaft. These construction access shafts will not require pad construction to elevate the top of the shaft to above the 200-year flood level. At these sites, a shaft roughly equal to the diameter of the TBM cutterhead will be excavated to tunnel depth. Approximately 3 acres will be required at each of these locations to set up equipment, construct flood protection facilities, excavate/construct the shaft, and set up and maintain the equipment necessary for the TBM maintenance work. It is anticipated that all work associated with developing and maintaining these shafts will occur over approximately 9 to 12 months. At the completion of the TBM maintenance at these sites, the TBM will mine forward, and the shaft location will be backfilled. Dewatering at construction access shafts, if required, will be performed as described in Section 3.2.10.7 *Dewatering*. Drilling muds or other materials required for drilling and grouting will be confined on the work site and such materials will be disposed of offsite at a permitted facility. Disturbed areas will be returned to preconstruction conditions by grading and appropriate revegetation (in most cases, returning the site to use as cropland).

Final determination of the number and siting of shaft locations will depend upon determinations by the tunnel construction contractor(s). Moreover, it is likely that final siting of both pressurized and atmospheric safe haven intervention sites will not occur until after geotechnical explorations are completed, as information from those explorations is needed to determine the appropriate spacing for safe haven intervention sites (TBM cutterhead wear rates depend partly upon the types of material being tunneled). Table 3.2-9 shows the number of safe haven interventions expected to be associated with each tunnel, based upon current understanding of site conditions.

Table 3.2-9. Expected Safe Haven Interventions

Reach	Length (miles)	Number of Safe Haven Interventions	
		Pressurized	Atmospheric
1	1.99	1	1
2	6.74	5	1 to 3
3	4.77	3	1 to 2
4 (twin tunnel)	9.17	7	1 to 4
5 (twin tunnel)	3.83	2	1
6 (twin tunnel)	8.86	7	1 to 4
7 (twin tunnel)	8.29	6	1 to 3

Both pressurized and atmospheric safe haven intervention sites will be located to minimize impacts on sensitive terrestrial and aquatic habitats. Because intervention sites are not determinable at this time, potential effects on species are estimated using a conservative analysis, as detailed in in Appendix 6.B *Terrestrial Effects Analysis Methods*.

3.2.3.4 Landscaping

As at the Delta intakes, the construction phase at both permanent and temporary shaft sites will conclude with landscaping and the installation of safety lighting and security fencing, which will be performed as described in Section 3.2.10.10 *Landscaping and Associated Activities*.

3.2.4 Intermediate Forebay

The IF will receive water from the three North Delta Diversions and discharge it to the twin tunneled conveyance to CCF. When first proposed, the IF was a much larger facility (750 acres) and was located in an environmentally sensitive location, on private land adjacent to the Stone Lakes National Wildlife Refuge. Subsequent hydraulic design of the conveyance system that locates the pumping plants at CCF allows the IF to be located on a DWR-owned parcel of land. The IF footprint is a water surface area of 54 acres at maximum water elevation.

3.2.4.1 Design

Appendix 3.A *Map Book for the Proposed Action*, Sheet 5, shows the IF, access routes, and related facilities in the area. Appendix 3.C *Conceptual Engineering Report, Volume 2,* Drawings 55 to 68, show an artist's concept of the completed forebay, as well as drawings showing the complete forebay and various design details. Appendix 3.B *Conceptual Engineering Report, Volume 1,* Section 14 *Forebays*, provides detail on the design, construction and operations of the IF; see particularly Sections 14.1. (description and site plan), 14.2. (construction methodology), 14.2.4 (embankment completion), 14.2.6 (spillway), and 14.2.8 (inlet and outlet structures). Section 5.3.1 *Intermediate Forebay Size Evaluation*, describes the basis for design sizing of the IF. Proposed construction will comply with avoidance and minimization measures identified in Appendix 3.F *General Avoidance and Minimization Measures*.

The IF, located on Glannvale Tract, will store water between the proposed intake and conveyance facilities and the main tunnel conveyance segment. The IF provides an atmospheric break in the deep tunnel system and buffer volume for the upstream intake sites and the downstream CCFPP. This buffer provides make-up water and storage volume to mitigate transients generated as a result of planned or unplanned adjustments of system pumping rates. The IF also facilitates isolating segments of the tunnel system, while maintaining operational flexibility. Thus each tunnel, into and out of IF, can be hydraulically isolated for maintenance, while maintaining partial system capacity.

The IF will have a capacity of 750 acre feet (af) and an embankment crest elevation of +32.2 feet, which meets Delta Habitat Conservation and Conveyance Program (DHCCP) flood protection standards (i.e., a 200-year flood with provision for sea level rise). Current ground surface elevation at the site averages +0 feet. The WSE varies between a maximum elevation of +25 feet and a minimum elevation of -20 feet. The IF will include an emergency spillway and emergency inundation area to prevent the forebay from overtopping. This spillway will divert water during high flow periods to an approximately 131-acre emergency inundation area adjacent to and surrounding the IF. From the IF, water will be conveyed by a gravity bypass system through an outlet control structure into a dual-bore 40-foot-diameter tunnel that runs south to the CCF. The IF will serve to enhance water supply operational flexibility by using forebay storage capacity to regulate flows from the intakes to the CCF.

3.2.4.2 Schedule

The principal dates for construction of the IF are shown in Table 3.2-10.

Table 3.2-10. Summary Construction Schedule for the Intermediate Forebay

Description	Start[a]	End[a]	Duration
Contract management, supervision, administration, temporary facility operations, and delivery of construction supplies	7/1/2026	7/11/2031	61 months
Earthworks	7/1/2026	12/25/2029	42 months
Inlet & outlet ground improvements	12/28/2028	10/12/2030	23 months
Inlet & outlet site work	9/27/2029	4/12/2030	8 months
Operate concrete batch plant; inlet & outlet concrete work	3/27/2030	4/11/2031	13 months
Inlet & outlet gates, mechanical & electrical work	12/25/2030	7/11/2031	7 months

[a] Dates given in this table assume a Record of Decision date of 1/1/2018 and a construction end date of 7/11/2031.

3.2.4.3 Construction

Construction of the IF entails first excavating the embankment areas down to suitable material. A slurry cutoff wall is then emplaced to a depth of -50 feet to eliminate the potential for piping or seepage beneath the embankment. The embankment is then constructed of compacted fill material.

Inlet and outlet shafts (which also serve as TBM launch shafts as described in Section 3.2.3 *Tunneled Conveyance*) are then constructed. Then the interior basin is excavated to design depth (-20 feet), and the spillway is constructed. All excavations are expected to require dewatering, and dewatering is expected to be continuous throughout construction of the IF; see Section 3.2.10.7 *Dewatering*, for further discussion of how this will be achieved. Ground improvement (described in Section 3.2.10.3 *Ground Improvement*) may be needed beneath structures, depending upon the outcomes of the geotechnical explorations described in Section 3.2.1 *Geotechnical Exploration*.

The IF will have a surface footprint of 243 acres, all of which is permanent impact (under current conditions, the area is a vineyard). Approximately 1 million cubic yards (cy) of excavation and 2.3 million cy of fill material are required for completing the IF embankments. Much of the excavated material is expected to be high in organics and unsuitable for use in embankment construction and requires disposal (see Section 3.2.10.6 *Dispose Spoils*).

Construction of the IF embankments and tunnel shaft pans will require substantial volumes of engineered fill. The required fill material will preferably be sourced onsite from locations within the permanent impact footprint. Material sourced from offsite will be obtained as described in Section 3.2.10.4, *Borrow Fill*.

As at the Delta intakes, the construction phase at the IF will conclude with landscaping and the installation of safety lighting and security fencing, which will be performed as described in Section 3.2.10.10 *Landscaping and Associated Activities*.

3.2.5 Clifton Court Forebay

3.2.5.1 Design

Functionally, the facilities at CCF are proposed to receive water from north Delta and south Delta sources, and to deliver that water into the CVP/SWP. In order to accomplish this dual function, the existing forebay will be divided into two halves, North CCF (NCCF) and South CCF (SCCF). The NCCF will received screened water from the new river intakes, while the SCCF will continue to receive flows from the existing Old River intake gate on CCF. The NCCF will be designed to accommodate hydraulic surges and transitions related to short-term (typically less than 24 hours) differences in the rate of water delivery to NCCF and the rate of export by the CVP/SWP pumps. The NCCF will also be the site for a pump station, the operations of which form the primary control and constraints on the rate of water diversion through the river intakes (although that rate is also subject to control at the river intakes). Collective operations of these facilities will be coordinated through an operations center sited at the NCCF pump station. The SCCF will continue to operate as under current conditions. To minimize environmental impacts, the proposed size of the CCF and its appurtenant facilities have been optimized consistent with the overall design goal of the PA to achieve diversion rates at the North Delta Diversions not exceeding 9,000 cfs, and to achieve overall CVP/SWP water export rates consistent with existing authorizations for those facilities, subject to operational and regulatory constraints detailed in Section 3.3 *Operations and Maintenance of the New and Existing Facilities*.

Maps and drawings depicting the CCF and its spatial relationship to other elements of the PA are shown in the Appendices. Appendix 3.A *Map Book for the Proposed Action*, Sheet 13, shows the CCF, access routes, and related facilities in the area. Appendix 3.C *Conceptual Engineering Report*, *Volume 2*, Drawing 2, provides an overview of the CCF facilities in relation to the rest of the conveyance facilities, and Drawing 54 provides a site-scale view of the proposed facilities at CCF. Drawing 74 shows an artist's concept of the completed CCF pumping plant, and Drawings 75 to 78 show details of the proposed pumping plant. Drawing 82 is a detailed overall CCF site plan, and Drawings 85 to 87 provide sectional views of the proposed embankments that contain the CCF. Drawings 90 and 91 provide plan and section views of the proposed spillway from the NCCF into Old River.

Detailed information on design of the proposed facilities at CCF is given in Appendix 3.B[5] *Conceptual Engineering Report, Volume 1*. Sections 4.4.6 *Clifton Court Forebay Pump Plant (CCFPP) Operations*; 4.4.7 *North Clifton Court Forebay Operations*; and 4.6 *Implications of Modified Pipeline/Tunnel Clifton Court Option on Current SWP and CVP Operations*, describe how the CCF pump plant and the NCCF will be operated to support overall conveyance system functions. Section 7, *CCF Pumping Plant*, describes the design and construction of the CCF pumping plant, while the north and south CCF and their construction methodology are described in Sections 14.1.2 *North Clifton Court Forebay*; 14.1.3 *South Clifton Court Forebay*; 14.2.2 *General Excavation for the NCCF and SCCF*; 14.2.3 *General Excavation for the Existing South Embankment of Clifton Court Forebay*; 14.2.5 *New Clifton Court Forebay Embankment*; 14.2.6 *New Spillway and Stilling Basin*; and 14.2.8 *New Forebay Structures*. Construction will comply with avoidance and minimization measures identified in Appendix 3.F *General Avoidance and Minimization Measures*.

Construction at CCF will also include connections to the existing Banks and Jones pumping plants. Design and construction of those connections are described in Section 3.2.6 *Connections to Banks and Jones Pumping Plants*.

The overall schedule[12] for activities at CCF is shown in Appendix 3.D *Construction Schedule for the Proposed Action*; see drawings in Appendix 3.C, *Conceptual Engineering Report, Volume 2*, for locations of the referenced structures. Four major elements of the proposed construction will occur in the CCF area: tunneling, the CCPP, the modifications to the current CCF to create a North and South CCF, and connections to the Banks and Jones pumping plants.

Tunneling (Reach 7) will start from the CCPP construction site and will excavate north to Bacon Island, as described in Section 3.2.3 *Tunneled Conveyance*; RTM from the tunnels will be disposed near CCF as described in Section 3.2.10.6 *Dispose Spoils*. Tunneling activity will begin 47 months after project start (scheduled to occur in January; the start year depends upon the date of project authorization and the time needed to prepare contract specifications and issue contracts) and will proceed continuously for 61 months.

The CCPP will be constructed at the northeast corner of the CCF complex and includes the shafts used to launch the TBMs. Construction will start at the CCPP will begin 36 months after project start and will proceed continuously for 100 months.

CCF work will occur throughout the site, and will be continuously active from 84 months after project start until 147 months after project start. Apart from startup activities (access improvement, mobilization, etc.), embankment and canal work will continue from 90

[12] For more information on timing of activities at CCF, see Attachment BO#9.

months to 130 months after project start. Work on control structures and spillways will occur from 108 months to 144 months after project start.

3.2.5.1.1 Clifton Court Pumping Plant

Each of the two units at CCPP will have a design pumping capacity of 4,500 cfs and will include 4 large pumps (1,125 cfs capacity) and 2 smaller pumps (563 cfs capacity). One large pump at each plant will be a spare. Each pumping plant will be housed within a building and will have an associated electrical building. The pumping plant buildings will be circular structures with a diameter of 182 feet and each will be equipped with a bridge crane that will rotate around the building and allow for access to the main floor for pump removal and installation. The total site for the pumping plants, electrical buildings, substation, spillway, access roads, and construction staging areas is approximately 95 acres. The main floor of the pumping plants and appurtenant permanent facilities will be constructed at a minimum elevation of 25 feet to provide flood protection. The bottom of the pump shafts will be at an elevation of approximately -163 feet, though a concrete base slab, shaft lining, and diaphragm wall will be constructed to deeper levels (to an elevation of -275 feet). A control room within an electrical building at the pumping facility site will be responsible for controlling and monitoring the communication between the intakes, pumping plants, and the Delta Field Division Operations and Maintenance Center, DWR Headquarters, and the Joint Operations Center.

A 230 kV transmission line and associated 230Kv–115kV substation used during construction will be repurposed and used to power the pumping plants at the CCF location during operations. The repurposed substation will provide power to a new substation that will convert power from 115kV to 13.8kV. This substation will then include 13.8 kV feeder lines to a proposed electrical building to distribute the power to the major loads including the main pumps, dewatering pumps, and 13.8kV to 480V transformers.

3.2.5.1.2 Clifton Court Forebay

SWP pumps operate primarily during off-peak electrical usage hours, which minimizes electricity costs and makes optimal use of available generating capacity. Thus the current CCF is sized to accommodate the hydraulic differential generated by the difference between a fairly constant rate of flow into the Forebay, but a highly variable rate of discharge into the export canal. Under the PA, the CCF will be divided into two separate but contiguous forebays: North Clifton Court Forebay (NCCF) and South Clifton Court Forebay (SCCF). The NCCF will be sized to meet the hydraulic needs of balancing water entry from the North Delta Diversions with discharge via the CVP/SWP export pumps. Since NCCF will receive the flow from the Delta Intakes, this will be water that has passed through the Delta Intake fish screens and is therefore expected to contain no fish. The SCCF will continue to meet the needs of SWP export pumps taking in south Delta water; as such it will function as a replacement for the current CCF, and thus must be enlarged south in order to maintain its current size while still accommodating he creation of the NCCF. SCCF will consist of the southern portion of the existing CCF, with expansion to the south into Byron Tract 2.

The CCF will be expanded by approximately 590 acres to the southeast of the existing forebay. The existing CCF will be dredged, and the expansion area excavated, to design depths of -8 feet for the north cell (the NCCF) and -10 feet for the south cell (the SCCF). A new embankment will be constructed around the perimeter of the forebay, as well as an embankment dividing the forebay into the NCCF and the SCCF. The tunnels from the Sacramento River intakes will enter the CCPP at the northeastern end of the NCCF, immediately south of Victoria Island, and flows will typically enter the NCCF via pumping (unpumped gravity flow will be feasible when the Sacramento River is at exceptionally high stages; see Appendix 3.B, *Conceptual Engineering Report, Volume 1*, Section 7.1.3.2, *Pumping Hydraulics*, for detailed discussion of hydraulic constraints on gravity-driven vs. pumped operations).

3.2.5.1.3 Clifton Court Forebay Technical Team

Modifications to CCF constitute one of the most complex aspects of the PA. Recognizing that design of these modifications is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have determined that ongoing collaborative efforts will be needed to ensure that the final design and construction procedures for CCF minimize effects on listed species. Accordingly, representatives from each of these agencies will participate in a Clifton Court Forebay Technical Team (CCFTT). The CCFTT will convene upon initiation of formal consultation for the PA and will meet periodically until DWR completes final design for the proposed CCF modifications (a time period expected to be at least two years). The CCFTT will be charged with the following duties:

- Based on construction information presented by DWR, review and make recommendations regarding phasing of CCF construction for the benefit of listed and unlisted fish or for water quality. In considering any options for phasing, the CCFTT will consider preliminary costs and constructability.

- Based on construction information presented by DWR, review and make recommendations regarding appropriate techniques for dewatering, fish rescue, and fish exclusion during in-water work. Dewatering and fish rescue will be needed for all cofferdam work at CCF, and fish exclusion will be needed for dredging. In considering these techniques, the CCFTT will consider preliminary costs and constructability.

- Develop performance criteria and study programs to evaluate critical issues in CCF operations. One such issue is changes to predation patterns in the SCCF, which may have significantly deeper water depths, different residence times, and more exposure of mineral substrates, compared to the current CCF. Other operational issues may also be identified by the CCFTT.

- Identify and describe near-term research/monitoring needs, if any, to reduce key uncertainties prior to construction.

- Prepare draft and final reports summarizing CCFTT recommendations. The final report must be provided no less than 8 months prior to DWR's completion of final design, so that recommendations can be incorporated into those construction contract documents.

CCFTT recommendations will be reviewed by the five agencies for consideration. Adopted recommendations will be incorporated to CCF final design. DWR will abide by monitoring provisions and other measures sufficient to demonstrate implementation of these recommendations.

3.2.5.2 Construction

3.2.5.2.1 Clifton Court Pumping Plant

3.2.5.2.1.1 Overview

A detailed account of CCPP construction appears in Appendix 3.B[5] *Conceptual Engineering Report, Volume 1,* Section 7.2 *Construction Methodology*. In general, construction of the CCPP will follow the procedures described for tunnel shaft construction in Sections 3.2.3.3.1 *Shaft Site Facilities*; 3.2.3.3.2 *Shaft Site Preparation*; and 3.2.3.3.3 *Shaft Construction*. The CCPP shafts will be larger in inside diameter (150 feet instead of 113 feet) than most shafts serving 40-foot tunnel bores due to the design needs of the pumping plant. As shown in Appendix 3.C *Conceptual Engineering Report, Volume 2,* Drawings 75 and 76, the appurtenant facilities will be more extensive than at most tunnel shaft sites, including a permanent electrical substation, two electrical buildings, and an office/storage building, as well as temporary facilities for storage, staging, construction electrical, and water treatment (for stormwater). All of these facilities will be sited on the CCF embankment, at the design flood elevation (i.e., a 200-year flood with provision for sea level rise) of 25 feet.

3.2.5.2.1.2 Site Access

Vehicular site access during construction will use existing roads: from the east, from Byron Highway via Clifton Court Road and the Italian Slough levee crest road or the NCCF embankment crest road. Access from the south will be from the Byron Highway via NCCF embankment crest road and West Canal levee crest road. Barge access will also be needed, for transport of heavy TBM sections and other very large equipment and materials, and possibly for transport of bulk materials (fill material or excavated material). Barge access will be from the West Canal using a proposed barge unloading facility. See Section 3.2.10.9 *Barge Landing Construction and Operations*, for further discussion of the use, design, and construction of barge landings. Proposed barge traffic and landing facilities are also generally described in Appendix 3.B[5] *Conceptual Engineering Report, Volume 1,* Section 23.3.

3.2.5.2.1.3 Cofferdam and Fill Work

A sheet pile cofferdam will be placed to enclose the portion of the CCPP fill pad adjoined by water (Appendix 3.C[5] *Conceptual Engineering Report, Volume 2,* Drawings 75 and 83; however note that, as detailed below, the design has been modified to dewater NCCF prior to CCPP construction; thus no sheet pile cofferdam will be placed in the portions of the CCPP fill pad adjoining the NCCF). Sheet pile placement for cofferdam installation will be performed by a barge-mounted crane and/or a crane mounted on the existing levee, equipped with vibratory and impact pile-driving rigs.

The general approach to pile driving, including minimization measures to be used, is described in Section 3.2.10.11, *Pile Driving*. Assumptions for pile driving are given in Appendix 3.E, *Pile Driving Assumptions for the Proposed Action*, which addresses the number, type and size of piles required, as well as the number of piles driven per day, the number of impact strikes per pile, and whether piles will be driven in-water or on land (piles driven to construct the cofferdam will all be "in-water"). Sheet piles will be driven starting with a vibratory hammer, then switching to an impact hammer if refusal is encountered before target depths. In-water pile driving will be subject to abatement, hydroacoustic monitoring, and compliance with timing limitations as described in Appendix 3.F, *General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan*.

Fill pad construction will then proceed within the dewatered area, as described in Section 3.2.3.3.2.2, *Fill Pads*, including fill placement, compaction, and ground improvement.

3.2.5.2.1.4 Dewatering

Dewatering and water treatment associated with cofferdam installation will be as described in Section 3.2.10.7, *Dewatering*. This procedure includes fish removal as prescribed in Appendix 3.F, *General Avoidance and Minimization Measures, AMM8 Fish Rescue and Salvage Plan*.

Extensive dewatering will be required during construction of the CCPP shafts. Dewatering will be performed as described in Section 3.2.3.3.3, *Shaft Construction*. Other construction activities with the potential to affect listed species are described below, in the discussion of how CCF embankments and related facilities will be constructed.

3.2.5.2.2 Clifton Court Forebay

Please refer to Attachment BO#9 for a description of proposed construction at CCF[14].

3.2.5.2.2.1 Embankments

[section deleted, replaced by Attachment BO#9]

Phased Construction at Clifton Court Forebay

[section deleted, replaced by Attachment BO#9]

An emergency spillway will be constructed in the NCCF east side embankment, south of the CCPP fill pad. The spillway will be sized to carry emergency overflow (9,000 cfs, the maximum inflow from the North Delta Diversions) to the Old River, so a containment area will not be necessary.

The shallow foundation beneath this structure must be improved to prevent strength loss and seismic settlement. The ground improvement (Section 3.2.10.3, *Ground Improvement*) will be to elevation -50.0 feet within the footprint of the structure and beyond the structure by a distance of approximately 25 feet. The work will be performed within the sheet pile installed for embankment filling under construction Phase 6.

3.2.6 Connections to Banks and Jones Pumping Plants

3.2.6.1 Design

Under existing conditions, the Jones PP draws water from the Old River and West Canal via an approach canal that originates at the Tracy Fish Collection Facility, near the southeast corner of the CCF. The Banks PP draws water from the CCF via an approach canal that originates at the southwest corner of the CCF, at the Skinner Delta Fish Protective Facility. The PA entails no changes to the Tracy or Skinner fish facilities.

[14] For more information on construction activities, see Permit Resolution Log items #127, #128, #129, #130 and #131

The new system configuration allows both the Banks PP and the Jones PP to draw water from existing sources and/or from the NCCF. See Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheet 82, for a drawing showing the following:

The Jones PP will continue to draw water from the Middle River via the existing canal. A new control structure will be installed downstream of the Tracy Fish Collection Facility.

The Jones PP will also be able to draw water from the NCCF via a new canal on the south side of SCCF that connects with the existing Jones PP approach canal. A new control structure will be installed just upstream of the connection.

The Banks PP will continue to draw water from the CCF (which will become part of the SCCF) via the Skinner Delta Fish Protective Facility, but a new control structure will be installed between the SCCF and the fish facility.

The Banks PP will also be able to draw water from the NCCF via the same canal used by the Jones PP. That canal will fork near the southwest corner of SCCF; the east branch will go toward the Jones PP, and the south branch will enter a control structure and then connect with the existing Banks PP approach canal.

The new system configuration will require, in addition to the canals and control structures mentioned above, two new siphons, shown in Appendix 3.C *Conceptual Engineering Report, Volume 2,* Sheets 83 and 84. One siphon will convey NCCF water beneath the SCCF outlet canal. The second siphon will convey NCCF water to the Banks PP underneath the Byron Highway and the adjacent Southern Pacific Railroad line. Siphons are proposed because the water level in the canals is higher than the level of either the railroad or the highway. Each siphon will have a control structure fitted with radial gates at the inlet, to regulate upstream WSE and flow through the siphons. In order to isolate a siphon for repairs and inspections, stop logs will also be provided at the downstream end of the siphon barrel.

Control structures, fitted with radial gates, will also be located at the end of the new approach channels to control the amount of flow delivered to Jones PP and Banks PP.

For further detail on the design and configuration of these connections, see the material in the following appendices:

Appendix 3.A *Map Book for the Proposed Action*, Sheet 13, provides a photo-aerial map view of the proposed system configuration changes.

Appendix 3.B *Conceptual Engineering Report, Volume 1*, Section 4 *Conveyance System Operations*, describes the existing and proposed facilities and the hydraulic constraints on their operations.

Appendix 3.B *Conceptual Engineering Report, Volume 1*, Section 10 *Culvert Siphons—Shallow Crossings*, describes the siphons and their construction.

Appendix 3.B *Conceptual Engineering Report, Volume 1*, Sections 14.1.2 *North Clifton Court Forebay*; 14.1.3 *South Clifton Court Forebay*; 14.2.7 *New Approach Canals to Banks and Jones Pumping Plants*; and 14.2.9 *Banks and Jones Channel Control Structures* describe design and construction of various elements of the Banks and Jones connections. Further details appear in Sections 24.4.3.4 *Canals (Approach Canals to Jones and Banks Pumping Plants)* and 24.4.3.5 *Culvert Siphons*.

Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheets 82 to 84, are drawings showing the proposed canals, siphons, and control structures.

3.2.6.2 Construction

3.2.6.2.1 NCCF Canal

The new canal delivering water from the NCCF to the Banks PP and Jones PP will originate at NCCF Siphon 1, which will convey water from the NCCF under the existing CCF outlet. The canal will run due south for 2,700 feet, where it will fork; the south fork will pass through Siphon 2 and then join the existing Banks PP approach canal at a location downstream of the existing Skinner Delta Fish Protective Facility. The east fork will parallel the Byron Highway on its north side for 4,900 feet, where it will join the existing Jones PP approach canal at a location downstream of the existing Tracy Fish Collection Facility (Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheet 82).

As with SCCF, the embankment crest elevation for the NCCF canal is +24.5 feet, which includes considerations for flood levels and sea-level rise. The canal invert is -5 feet at Siphon 1, dropping gradually to meet the existing invert depths at the points where it connects to the existing Banks and Jones approach canals. The ground beneath the canal will be subject to ground improvement (Section 3.2.10.3 *Ground Improvement*) to depth -50 feet. The canal will be excavated and its embankments constructed using the same procedure described in Section 3.2.5.2.2.1 *Embankments*. That procedure will entail cofferdam installation to provide a dry work area, in places where construction will be contiguous with waters of the state. The canal adjoins fish-bearing waters, and entails pile driving in or near those waters, for approximately 800 feet along the Banks PP approach canal upstream of the Skinner Delta Fish Protective Facility. Apart from this section, construction pile driving associated with the Banks and Jones connections will not occur in or near fish-bearing waters.

3.2.6.2.2 NCCF Siphon 1 (Beneath SCCF Outlet)

NCCF Siphon 1 will convey water from the NCCF beneath the existing CCF outlet (which will become the SCCF outlet) and into the NCCF canal, leading to the Banks PP and Jones PP approach canals (Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheet 82). The siphon will be 1,500 feet long and will consist of 3 concrete box culverts, each 23 feet wide and 23 feet tall, with a total conveyance capacity of 15,000 cfs, matching the combined pumping capacity of the Banks PP plus the Jones PP and providing maximum operational flexibility for drawdown of the forebay. It will be provided with radial gates at the inlet, and it will have provision for stop logs at the outlet, enabling dewatering of each culvert if necessary for maintenance.

The siphon will be supported on a pile foundation, and will be constructed within a cofferdam erected in the CCF outlet channel. Concrete structures will be cast-in-place. The CCF outlet channel is a fish-bearing water, so cofferdam installation is subject to timing, noise abatement, and other constraints as identified in Section 3.2.10.11 *Pile Driving*, and in Appendix 3.F *General Avoidance and Minimization Measures*, *AMM9 Underwater Sound Control and Abatement Plan*. Foundation pile driving, if required, will occur within a dewatered cofferdam and thus will not be an in-water activity. Dewatering of the cofferdam will occur as described in Section 3.2.10.7, *Dewatering,* and will require compliance with Appendix 3.F, *AMM8 Fish Rescue and Salvage Plan*.

The siphon will be constructed in two phases, each phase lasting approximately one year. In the first phase, a temporary cofferdam will be constructed approximately halfway along the length of the siphon and then the area will be dewatered and excavated to the desired lines and grade. Half of the total length of the culvert siphon will be constructed inside the cofferdam, temporarily plugged, and backfilled to the desired waterway bottom configuration. During the second phase, the cofferdam will be re-installed across the other half of the siphon, the area will be dewatered, and the remainder of the siphon will be constructed and backfilled.

The siphon structure footprint will be as shown in the map book (Appendix 3.A *Map Book for the Proposed Action*, Sheet 13). The area of impact will be up to 250 feet wide. A 15-acre area will be required for construction staging, also as shown in the map book.

3.2.6.2.3 NCCF Siphon 2 (Beneath Byron Highway)

NCCF Siphon 2, which will pass beneath Byron Highway and the adjacent Southern Pacific Railroad line, will be of the same basic design as NCCF Siphon 1, but will be smaller, consisting of 2, 23-foot-square box culverts with a total flow capacity of 10,300 cfs; the siphon will be 1,000 feet long.

Construction of NCCF Siphon 2 will be as described above for NCCF Siphon 1, except that no cofferdam will be needed, no fish-bearing waters will be affected, construction will occur within one year, and reroutes of the Byron Highway and the SPRR will be needed during construction. These reroutes will occur within the temporary impact areas shown in the map book (Appendix 3.A *Map Book for the Proposed Action*, Sheet 13). The excavation will require dewatering as described in Section 3.2.10.7, *Dewatering*, and the footprint of the construction work and staging areas will be as shown in the map book (Appendix 3.A, Sheet 13).

3.2.6.2.4 Canal Control Structures

Four canal control structures will be constructed (shown in Appendix 3.C[5] *Conceptual Engineering Report*, *Volume 2*, Sheet 82):

- Old River/Jones PP canal control structure.
- NCCF/Jones PP canal control structure.
- NCCF/Banks PP canal control structure.
- SCCF/Banks PP canal control structure.

Two of these will be constructed in the existing Banks PP and Jones PP approach canals, and the others will be constructed in the forks of the new NCCF canal that lead to the Banks PP and Jones PP approach canals. Use of these control structures will enable operational decisions about how much water to divert to each PP from each water source (i.e., north or south Delta waters). Control structure designs are shown in Appendix 3.C, Sheets 88 and 89. Note that the design in Appendix 3.C has been revised to site the control structure shown just upstream of the Skinner Fish Facility. The control structure will instead be sited downstream of the facility. As such, all control structures will be sited in non-fish-bearing waters and will be located downstream of fish-bearing waters.

Structures will be cast-in-place concrete structures with ground improvement (Section 3.2.10.3 *Ground Improvement*) used for foundation work. Footprints for construction will range from 476 by 200 feet (Old River/Jones PP canal structure) to 656 by 422 feet (NCCF/Banks PP canal structure); in each case, the footprint will lie within the area otherwise occupied by the canal itself.

3.2.7 Power Supply and Grid Connections

The PA as originally envisioned entailed new pumping plants at each of the new North Delta Diversions, which would have required long runs of high-voltage (250 kV) electrical transmission lines powerlines to establish grid connections. Those powerlines transmission lines resulted in substantial adverse effects on covered listed species due to construction, maintenance, and bird strike potential of the operational lines. Redesign to eliminate the intake pumping plants has greatly reduced the electrical demand of the operating project. During construction, the PA will rely primarily upon electrical power sourced from the grid via temporary transmission lines to serve the TBMs and other project components. Use of diesel generators or other portable electrical power sources will be minimized due to the adverse air quality impacts of onsite power generation. Once operational, the largest power consumption will be for the pumping plant at CCF, where a grid connection will be available nearby. The intakes and IF will have relatively low operational power demands, which will be met via relatively short and lower-voltage connections to nearby grid sources.

3.2.7.1 Design

Electric power will be required for intakes, pumping plants, operable barriers, boat locks, and gate control structures throughout the proposed conveyance alignment. Temporary power will also be required during construction of water conveyance facilities.

New temporary electrical transmission lines to power construction activities will be built prior to construction of permanent transmission lines to power conveyance facilities. These lines will extend existing power infrastructure (lines and substations) to construction areas, generally providing electrical capacity of 12 kV at work sites. Main shafts for the construction of deep tunnel segments will require the construction of 69 kV temporary electrical transmission lines. Both temporary and permanent electrical transmission lines serving the PA are shown in Appendix 3.C *Conceptual Engineering Report, Volume 2*, Sheet 94. Temporary and permanent transmission lines are also shown in the map book, Appendix 3.A *Map Book for the Proposed Action*, Sheets 1 to 15.

Transmission lines to construct and operate the water conveyance facilities will connect to the existing grid in two different locations. The northern point of interconnection will be located north of Lambert Road and west of Highway 99 (Appendix 3.A *Map Book for the Proposed Action*, Sheet 4). From here, a new 230 kV transmission line will run west, along Lambert Road, where one segment will run south to the IF on Glannvale Tract, and one segment will run north to connect to a substation where 69 kV lines will connect to the intakes. At the southern end of the conveyance alignment, the point of interconnection will be in one of two possible locations: southeast of Brentwood near Brentwood Boulevard (Appendix 3.A, sheet 15) or adjacent to the Jones Pumping Plant (Appendix 3.A, sheet 13). While only one of these points of interconnection will be used, both are depicted in figures, and the effects of constructing transmission lines leading from both sites are combined and accounted for in the effects analysis. A 230 kV line will extend from one of these locations to a tunnel shaft northwest of CCF, and will then continue north, following tunnel shaft locations, to Bouldin Island. Lower voltage lines (Appendix 3.C *Conceptual Engineering Report, Volume 2,* Sheet 94) will be used to power intermediate and reception shaft sites between the main drive shafts. Because the power required during operation of the water conveyance facilities will be much less than that required during construction, and because it will largely be limited to the pumping plants, all of the new electrical transmission lines between the IF and the CCF will be temporary.

An existing 500kV line, which crosses the area proposed for expansion of the CCF, will be relocated to the southern end of the expanded forebay in order to avoid disruption of existing power facilities. No interconnection to this existing line is proposed.

Temporary substations will be constructed at each intake, at the IF, and at each of the launch shaft locations. To serve permanent pumping loads, a permanent substation will be constructed adjacent to the pumping plants at CCF, where electrical power will be transformed from 230 kV to appropriate voltages for the pumps and other facilities at the pumping plant site. For operation of the three intake facilities and IF, existing distribution lines will be used to power gate operations, lighting, and auxiliary equipment at these facilities.

Utility interconnections are planned for completion in time to support most construction activities, but for some activities that need to occur early in the construction sequence (e.g., constructing raised pads at shaft locations and excavating the shafts), onsite generation may be required on an interim basis. As soon as the connection to associated utility grid power is completed, electricity from the interim onsite generators will no longer be used.

3.2.7.2 Construction

Selection of transmission line alignments is subject to Appendix 3.F *General Avoidance and Minimization Measures*, *AMM12 Transmission Line Design and Alignment*, which identifies mandatory habitat avoidance measures and defines other aspects of transmission line design and routing. Temporary lines will be constructed from existing facilities to each worksite where power will be necessary for construction, following the alignments shown in Appendix 3.A *Map Book for the Proposed Action*. Construction of new transmission lines will require three phases: site preparation, tower or pole construction, and line stringing. For 12 kV and 69 kV lines, cranes will be used during the line stringing phase. For stringing transmission lines between 230 kV towers, cranes and helicopters will be used. Helicopters may fly as low as the top of the transmission towers, which may be as low as 60 feet. They will take-off and land in the right of ways obtained for transmission line construction, within the corridor identified on the construction footprint, or on other property obtained for the project, and identified on the project construction footprint, or designated existing helicopter pads (airstrips). They will not be allowed to land in sensitive habitat.

Construction of 230 kV and 69 kV transmission lines will require a corridor width of 100 feet and, at each tower or pole, a 100- by 50-foot area will be required for construction laydown, trailers, and trucks. Towers or poles will be located at intervals of 450 feet for 69kV lines, and 750 feet for 230kV lines. Construction will also require about 350 feet along the corridor (measured from the base of the tower or pole) at conductor pulling locations, which includes any turns greater than 15 degrees and/or every 2 miles of line. Construction will also require vehicular access to each tower or pole location. Vehicular access routes have not yet been determined, but will use existing routes to the greatest extent practicable, and are likewise subject to the siting constraints of AMM12.

For construction of 12 kV lines (when not sharing a 69 kV line), a corridor width of 25–40 feet will be necessary, with 25 feet in each direction along the corridor at each pole. Construction will also require 200 feet along the corridor (measured from the base of the pole) and a 50-foot-wide area at conductor pulling locations, which will include any turns greater than 15° and/or every 2 miles of line. For a pole-mounted 12 kV/480 volt transformer, the work area will only be that normally used by a utility to service the pole (typically about 20 by 30 feet adjacent to pole). For pad-mounted transformers, the work area will be approximately 20 by 30 feet adjacent to the pad (for construction vehicle access). Construction of 12kV lines will also require vehicular access to each tower or pole location. Vehicular access routes have not yet been determined, but will use existing routes to the greatest extent practicable, and are likewise subject to the siting constraints of AMM12.

3.2.8 Head of Old River Gate

3.2.8.1 Design

An operable gate will be constructed at the head of Old River, replacing the current practice of seasonally installing and removing a rock barrier at this location. The practice of seasonal installation and removal of a rock barrier at this location is planned to continue until the new operable gate begins operations. One purpose of the HOR gate is to keep outmigrating salmonids in the mainstem of the San Joaquin River and to prevent them from moving into the south Delta via Old River; another purpose is to improve water quality in the San Joaquin River (particularly the Stockton Deep Water Ship Channel) in the fall by keeping more water in the mainstem San Joaquin River. The barrier will be located at the divergence of the head of Old River and the San Joaquin River, as shown in Appendix 3.A. *Map Book for the Proposed Action*, Sheet 16; this location is approximately 300 feet west of the temporary rock barrier that is annually installed and removed under current conditions. Preliminary design of the HOR gate specifies that it will be 210 feet long and 30 feet wide overall, with top elevation of +15 feet (Appendix 3.C[5] *Conceptual Engineering Report, Volume 2*, Sheets 95 and 96). Design and construction of the structure are further detailed in Appendix 3.B[5] *Conceptual Engineering Report, Volume 1*, Section 17 *Operable Barrier*[17].

This structure will include seven bottom-hinged gates, totaling approximately 125 feet in length. Other components associated with this barrier are a fish passage structure[18], a boat lock, a control building, a boat lock operator's building, and a communications antenna. Appurtenant components include floating and pile-supported warning signs, water level recorders, and navigation lights. The barrier will also have a permanent storage area (180 by 60 feet) for equipment and operator parking. Fencing and gates will control access to the structure. A propane tank will supply emergency power backup.

The boat lock will be 20 feet wide and 70 feet long. The associated fish passage structure will be designed according to guidelines established by NMFS and USFWS, and will be 40 feet long and 10 feet wide, constructed with reinforced concrete. Stop logs will be used to close the fish passage structure when not in use to protect it from damage. When the gate is partially closed, flow will pass through the fish passage structure traversing a series of baffles. The fish passage structure is

[17] Design calls for an Obermeyer weir.

[18] The fish passage structure is designed for salmonids; it is assumed that the HOR Gate would not be able to pass sturgeon, either via the fish passage structure or the boat lock.

designed to maintain a 1-foot-maximum head differential across each set of baffles. The historical maximum head differential across the gate is 4 feet; therefore, four sets of baffles will be required. The vertical slot fish passage structure will be entirely self-regulating and will operate without mechanical adjustments to maintain an equal head drop through each set of baffles regardless of varying upstream and downstream water surface elevations.

3.2.8.1.1 HOR Gate Technical Team

Recognizing that design of these HOR gate is still in an early stage, DWR, Reclamation, NMFS, CDFW, and USFWS have determined that ongoing collaborative efforts will be needed to ensure that the final design and construction procedures for the HOR gate minimize effects on listed species. Accordingly, representatives from each of these agencies will participate in an HOR Gate Technical Team (HGTT). The HGTT will convene upon initiation of formal consultation for the PA and will meet periodically until DWR completes final design for the HOR gate (a time period expected to be at least two years). The HGTT will be charged with the following duties:

Based on construction information presented by DWR, review and make recommendations regarding provisions for fish passage at the HOR gate. In considering such provisions, the HGTT will consider preliminary costs and constructability.

Based on construction information presented by DWR, review and make recommendations regarding appropriate techniques for dewatering, fish rescue, and fish exclusion during in-water work. These measures will likely be needed for all cofferdam work at the HOR gate. In considering these techniques, the HGTT will consider preliminary costs and constructability.

Identify and describe near-term research/monitoring needs, if any, to reduce key uncertainties prior to construction.

Prepare draft and final reports summarizing HGTT recommendations. The final report must be provided no less than 8 months prior to DWR's completion of final design, so that recommendations can be incorporated into construction contract documents.

HGTT recommendations will be reviewed by the five agencies for consideration. Adopted recommendations will be incorporated to HOR gate final design specifications prior to construction contract issuance. DWR will abide by monitoring provisions and other measures sufficient to demonstrate implementation of these recommendations.

3.2.8.2 Construction

Appendix 3.D *Construction Schedule for the Proposed Action* presents the schedule for HOR gate construction. The operable barrier will be sited within the confines of the existing channel, with no levee relocation. To ensure the stability of the levee, a sheet pile retaining wall will be installed in the levee where the operable barrier connects to it. Construction will comply with relevant avoidance and minimization measures detailed in Appendix 3.F *General Avoidance and Minimization Measures*, including the following.

AMM2 Construction Best Management Practices and Monitoring

AMM3 Stormwater Pollution Prevention Plan

AMM4 Erosion and Sediment Control Plan

AMM5 Spill Prevention, Containment, and Countermeasure Plan

AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material

AMM7 Barge Operations Plan

AMM8 Fish Rescue and Salvage Plan

AMM9 Underwater Sound Control and Abatement Plan

AMM11 Design Standards and Building Codes

AMM14 Hazardous Materials Management

AMM15 Construction Site Security

AMM16 Fugitive Dust Control

AMM17 Notification of Activities in Waterways

3.2.8.2.1 Dredging

Dredging to prepare the channel for gate construction will occur along 500 feet of channel, from 150 feet upstream to 350 feet downstream from the proposed barrier. A total of up to 1,500 cubic yards of material will be dredged. Dredging will last approximately 15 days, will be performed during the in-water work window[6], and will otherwise occur as described in Section 3.2.10.8 *Dredging and Riprap Placement*, and subject to the constraints described in Appendix 3.F *General Avoidance and Minimization Measures, AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material*. Dredging may use either a hydraulic or a sealed clamshell dredge, in either case operated from a barge in the channel.

Dredging is proposed to deviate from the procedure described in AMM6 in one respect. Assuming that on-land disposal of dredged material is determined by the appropriate review authorities to be suitable, the material will be spread on adjacent agricultural fields in a layer approximately 1-foot thick, subject to landowner approval. If required to use an existing dredged material disposal site, the site currently used for dredged material disposal in association with temporary rock barrier placement and removal will be used. This site, at the junction of Old and Middle rivers, is shown in Appendix 3.A *Map Book for the Proposed Action*, Sheet 16.

3.2.8.2.2 Gate Construction

The HOR gate will be constructed using cofferdam construction, which will create a dewatered construction area for ease of access and egress. Construction will occur in two phases. The first phase will include construction of half of the operable barrier, masonry control building, operator's building, and boat lock. The second phase will include construction of the second half of the operable barrier, the equipment storage area, and the remaining fixtures, including the communications antenna and fish passage structure. The construction period is estimated to be up to 32 months, with a maximum construction crew of 80 people. A temporary work area of up to 15 acres will be sited in the vicinity of the barrier for such uses as storage of materials, fabrication of concrete forms or gate panels, placing of stockpiles, office trailers, shops, and construction equipment maintenance. The operable barrier construction site, including the temporary work area, has for many years been used for seasonal construction and removal of a temporary rock barrier, and all proposed work will occur within the area that is currently seasonally disturbed for temporary rock barrier construction. Site access roads and staging areas used in the past for rock barrier installation and removal will be used for construction, staging, and other construction support facilities for the proposed barrier.

All in-water work, including the construction of cofferdams, sheetpile walls and pile foundations, and placing rock bedding and stone slope protection, will occur during the proposed in-water work windows[6] to minimize effects on fish. All other construction will take place from a barge or from the levee crown and will occur throughout the year.

The construction of the cofferdam and the foundation for the HOR gate will require in-water pile driving, performed as described in Section 3.2.10.11 *Pile Driving*. The installation of the cofferdams will require approximately 550 sheet piles (275 per season). Approximately 15 piles, a maximum of 50 feet long and to a depth of 13.5 to 15 feet, will be set per day with an estimated 210 strikes per pile over a period of approximately 18 days per season. Sheet piles will be installed starting with a vibratory hammer, then switching to impact hammer if refusal is encountered before target depths. The installment of the foundation for the operable barrier will require 100 14-inch steel pipe or H-piles (50 per season) to be set with 1 pile driver on site. Approximately 15 piles, a maximum of 50 feet long and to a depth of 13.5 to 15 feet, will be set per day with an estimated 1,050 strikes per pile over a period of approximately 3 days per season. Foundation pile driving may be done in the dry or in the wet. It is possible that cast-in-drilled-hole concrete foundation piles will be used, in which case pile driving of foundation piles will not be required, but that determination awaits results of geotechnical analysis and further design work; the effects analysis assumes that impact driving will occur.

The first construction phase involves installing a cofferdam in half of the channel and then dewatering the area (see Section 3.2.10.7 *Dewatering*). The cofferdam will remain in the water until the completion of half of the gate. The cofferdam will then be flooded, and removed or cut off at the required invert depth, and another cofferdam installed in the other half of the channel. In the second phase, the gate will be constructed using the same methods, with the cofferdam either removed or cut off. Cofferdam construction will in both phases begin in August and last approximately 18 days. Construction has been designed so that the south Delta temporary barriers at this site can continue to be installed and removed as they are currently until the permanent gates are fully operable, however, the installation and removal of the temporary barriers is not part of the PA.

3.2.9 Temporary Access and Work Areas

Construction work areas for the conveyance facilities will include areas for construction equipment and worker parking, field offices, a warehouse, maintenance shops, equipment and materials laydown and storage, and stockpiled topsoil strippings saved for reuse in landscaping, as discussed in Section 3.2.10.10 *Landscaping and Associated Activities*.

Surface vehicular access will be needed for construction of all water conveyance facilities. Geotechnical exploration sites on water or on agricultural lands can be accessed by suitable vehicles, but all other construction sites will require road access. All-weather roads (asphalt paved) will be needed for year-round construction at all facilities, while dry-weather roads (minimum 12 inch thick gravel or asphalt paved) can be used for construction activities restricted to the dry season (May 1 to October 31). Dust abatement will be addressed in all construction areas as provided by Appendix 3.F *General Avoidance and Minimization Measures, AMM16 Fugitive Dust Control*. Heavy construction equipment, such as diesel-powered dozers, excavators, rollers, dump trucks, fuel trucks, and water trucks will be used during excavation, grading, and construction of access/haul roads. Detour roads will be needed for all intakes and for traffic circulation around the work areas.

Temporary barge unloading facilities will be constructed, used, and decommissioned as detailed in Section 3.2.10.9 *Barge Landing Construction and Operations*.

As described in Appendix 3.B *Conceptual Engineering Report, Volume 1*, Section 24.3.4 *Concrete Batch Plants, Pug Mills, and Cement Storage*, temporary concrete batch plants will be needed due to the large amount of concrete required for construction and the schedule demands of the PA. A batch plant is proposed for siting at each TBM launch shaft or TBM retrieval shaft location (listed in Table 3.2-8). Since there is no TBM launch shaft or TBM retrieval shaft at the site of the HOR Gate, no concrete batch plant will be sited at the HOR Gate. The area required for these plants will be within the construction footprint for these facilities as shown in Appendix 3.A *Map Book for the Proposed Action*, but precise facility siting within the construction site has not yet been determined. Other facilities to be co-located with concrete batch plants within the construction site footprint will include fuel stations, pug mills, soil mixing facilities, cement storage, and fine and coarse aggregate storage. Fuel stations will be needed for construction equipment fueling. Pug mills will be needed for generating processed soil materials used at the various sites. Soil mixing facilities will be needed for some of the muck disposal and for ground improvement activities. Cement and required admixtures will be stored at each site to support concrete, slurry walls, ground improvement, soil mixing, and other similar needs. TBM launch sites may also contain facilities for production of precast tunnel segments. If constructed, these will be located adjacent to concrete plants, and will also be within the construction site footprint as shown in Appendix 3.A. It is likely that each precast segment plant would require approximately 10 acres for offices, concrete plant, materials storage, and casting facilities.

All storage and processing areas will be properly contained as required for environmental and regulatory compliance. In addition, work at all sites will be required to comply with terms of all applicable avoidance and minimization measures listed in Appendix 3.F, *General Avoidance and Minimization Measures*.

3.2.10 Common Construction-Related Activities

3.2.10.1 Clearing

Essentially all lands within the temporary and permanent impact footprint are assumed to be cleared; the only exceptions are lands that are underlain by a structure (TBM-excavated tunnels), or that are beneath a structure (electrical transmission line wires, between the towers), or that are underwater (in association with the Delta intakes, the CCF, the Banks and Jones connections, and the HOR gate). Grading will be performed where required by the project design. Clearing and grading will be performed using standard equipment such as bulldozers. Topsoil from cleared areas will be stockpiled and reused at the close of construction (see Section 3.2.10.10 *Landscaping and Associated Activities*).

Clearing will be the principal conveyance construction impact on listed species of wildlife, resulting in habitat removal as well as potential effects on animals. Impacts due to clearing and grading will be treated as permanent when they persist for more than one year, which will be the case for all conveyance construction components except geotechnical exploration (see Section 3.2.1 *Geotechnical Exploration*, for explanation). Clearing work will be subject to relevant avoidance and minimization measures including *AMM2 Construction Best Management Practices and Monitoring, AMM3 Stormwater Pollution Prevention plan, AMM4 Erosion and Sediment Control Plan, AMM5 Spill Prevention, Containment, and Countermeasure Plan, AMM14 Hazardous Material Management, AMM16 Fugitive Dust Control*, and the appropriate species-specific measures applicable to modeled habitat at the construction site (see Appendix 3.F *General Avoidance and Minimization Measures* for full detail on these measures).

3.2.10.2 Site Work

Site work will occur within previously cleared areas. It will include construction of site access, establishment of stockpiles and staging and storage areas, site fencing, onsite electric (such as a substation), and erection of temporary construction buildings (primarily offices and storage). Equipment used during site work mainly will include large vehicles and vehicle-mounted equipment such as cranes, which have the potential to create noise and light comparable to other construction equipment. Performance of site work will entail the risk of spills associated with vehicles and with materials transport, and the potential for erosion or stormwater effects associated with cleared areas. These risks will be minimized by implementing all of the same avoidance and minimization measures named above for clearing and grading work.

3.2.10.3 Ground Improvement

Ground improvement will occur within previously cleared areas. Ground improvement serves to improve existing substrates at a site so that they can bear heavy loads and otherwise support the design of the proposed construction. Activities performed in ground improvement will include drilling, and injection of materials. Ground improvement commonly will occur in association with grading (Section 3.2.10.1 *Clearing*) and dewatering (Section 3.2.10.7 *Dewatering*). Ground improvement constitutes a permanent impact; improved ground will remain in place for the duration of the PA and thereafter. Equipment used in ground improvement will include large vehicle-mounted drilling and injection equipment with potential to create noise and light comparable to other construction equipment. Performance of ground improvement will entail the risk of spills associated with vehicles and with materials transport. These risks will be minimized by implementing avoidance and minimization measures *AMM2 Construction Best Management Practices and Monitoring, AMM5 Spill Prevention, Containment, and Countermeasure Plan*, and *AMM14 Hazardous Material Management*.

3.2.10.4 Borrow Fill

The total amount of borrow material for engineered fill used in all aspects of the PA will be approximately 21 million cy (as bank cubic yards). This total amount will include approximately 3 million cy for tunnel shaft pads, 6.5 million cy for the CCF embankments, 2 million cy for the IF embankments, 6.7 million cy at the three intake sites (approximately 2 million cy each), and 2.6 million cy at the CCPP site. Source locations for this borrow material will be within the work area footprint shown in Appendix 3.A *Map Book for the Proposed Action*. Appendix 3.B *Conceptual Engineering Report, Volume 1*, Section 21 *Borrow Sites,* describes the criteria for selection of borrow sites and identifies suitable geological materials that could be used as sources of borrow material. Apart from engineering specifications, the criteria for selection of borrow sites will include the following:

Borrow material should not require post-excavation processing (other than moisture conditioning).

Borrow material should be exposed at surface and require no, or very limited, overburden removal.

Borrow areas should be selected to minimize the impact or encroachment on existing surface and subsurface development and environmentally sensitive areas as much as possible.

3.2.10.5 Fill to Flood Height

Permanent levees, embankments, and fills on which structures are sited at the intakes, the IF, the CCPP, and the Banks and Jones connections, will be filled to the design flood height, which is the level of the 0.5% annual exceedance flood (i.e., the 200-year flood), plus an 18-inch allowance for sea level rise. Since current ground elevations at most of the construction sites are at or slightly below sea level, substantial volumes of material will be needed to construct these fills, and the weight of this material will cause substantial compaction and settling in the underlying ground. Compaction and settling issues will be addressed by ground improvement (Section 3.2.10.3 *Ground Improvement*) and dewatering wells (Section 3.2.10.7 *Dewatering*), which are used to reduce hydraulic pressure within the sediments and accelerate the rate of compaction.

Fills to flood height will occur at sites that have previously been cleared. The fill material will be sourced from borrow sites (Section 3.2.10.4 *Borrow Fill*) and transported using conventional earthmoving equipment, or possibly conveyors if the distances involved are short and are entirely within the area cleared for facility construction. Performance of this work will entail the risk of spills associated with vehicles and with materials transport, and the potential for erosion or stormwater effects associated with cleared areas. These risks will be minimized by implementing all of the same avoidance and minimization measures named above for clearing and grading work (Section 3.2.10.1 *Clearing*).

3.2.10.6 Dispose Spoils

Spoils will include materials removed from the construction area and placed for nonstructural purposes. The principal sources of spoils will be materials removed during excavation of tunnels (RTM) and dredging of the CCF. Secondary sources will include structural excavations during facilities construction.

Dredged material composition is not currently determined. Composition, potential contamination, and resulting considerations in disposition of this material are described in Appendix 3.F *General Avoidance and Minimization Measures, AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material*. Properties and disposition of RTM are detailed below.

RTM is the by-product of tunnel excavation using a TBM. The RTM will be a plasticized mix consisting of soil cuttings, air, water, and may also include soil conditioning agents. Soil conditioning agents such as foams, polymers, and bentonite may be used to make soils more suitable for excavation by a TBM. Soil conditioners are non-toxic and biodegradable. During tunnel construction the daily volume of RTM withdrawn at any one shaft location will vary, with an average volume of approximately 6,000 cubic yards per day. It is expected that the transport of the RTM out of the tunnels and to the RTM storage areas will be nearly continuous during mining or advancement of the TBM. The RTM will be carried on a conveyor belt from the TBM to the base of the launch shaft. The RTM will be withdrawn from the tunnel shaft with a vertical conveyor and placed directly into the RTM work area using another conveyor belt system. From the RTM work area, the RTM will be roughly segregated for transport to RTM storage and water treatment (if required) areas as appropriate. Appendix 3.A *Map Book for the Proposed Action*, Sheets 1–5 and 7–15 show conveyor belt and RTM storage area locations.

RTM must be dewatered in order to stabilize it for long-term placement in a storage area. Atmospheric drying by tilling and rotating the material, combined with subsurface collection of excess liquids will typically be sufficient to render the material dry and suitable for long-term storage or reuse. Leachate will drain from ponds to a leachate collection system, then be pumped to leachate ponds for possible additional treatment. Disposal of the RTM decant liquids will require permitting in accordance with NPDES and Regional Water Quality Control Board regulations. A retaining dike and underdrain liquid collection system (composed of a berm of compacted soil, gravel and collection piping, as described below), will be built at each RTM storage area. The purpose of this berm and collection system will be to contain any liquid runoff from the drying material. The dewatering process will consist of surface evaporation and draining through a drainage blanket consisting of rock, gravel, or other porous drain material. The drainage system will be designed per applicable permit requirements. Treatment of liquids (primarily water) extracted from the material could be done in several ways, including conditioning, flocculation, settlement/sedimentation, and/or processing at a package treatment plant to ensure compliance with discharge requirements.

Disposition and reuse of all spoils will be subject to Appendix 3.F *General Avoidance and Minimization Measures, AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material*. That AMM prescribes criteria for the selection of spoils storage areas; preparation of storage areas; and the procedures for draining, chemical characterization, and treatment of spoils, including how any existing contamination of the spoils will be addressed.

Table 3.2-11 provides a summary of how spoils would be stored, and Table 3.2-12 summarizes the disposition of spoils material. Designated spoils storage areas are shown in the map book, Appendix 3.A *Map Book for the Proposed Action*. RTM will be the largest source of this material, and disposition of that material will be, on an acreage basis, one of the largest impacts of the PA. Dredged material from the CCF will be the second largest source of spoils.

Table 3.2-11. Spoils and Reusable Tunnel Material Storage: Key Construction Information

Final locations for storage of spoils, RTM, and dredged material will be selected based on the guidelines presented in *AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F, *General Avoidance and Minimization Measures*).
Conventional earthmoving equipment, such as bulldozers and graders, would be used to place the spoil. Some spoil, with the exception of RTM, may be placed on the landside toes of canal embankments and/or setback levees.
Spoils may temporarily be placed in borrow pits or temporary spoil laydown areas pending completion of embankment or levee construction. Borrow pits created for this project will be the preferred spoil location.
RTM that may be have potential for re-use in the PA (such as levee reinforcement, embankment or fill construction) will be stockpiled. The process for testing and reuse of this material is described further in *AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material* (Appendix 3.F, *General Avoidance and Minimization Measures*).
A berm of compacted imported soil will be built around the perimeter of the RTM storage area to ensure containment. The berm will conform to USACE guidelines for levee design and construction.
RTM will be stacked to an average depth of 10 ft; precise stacking depth will vary across disposal sites.
Maximum capacity of RTM storage ponds will be less than 50 af.
RTM areas may be subdivided by a grid of interior earthen berms in RTM ponds for dewatering.
Dewatering will involve evaporation and a drainage blanket of 2 ft-thick pea gravel or similar material placed over an impervious liner.
Leachate will drain from ponds to a leachate collection system, then be pumped to leachate ponds for possible additional treatment.
Transfer of RTM solids to disposal areas may be handled by conveyor, wheeled haul equipment, or barges, at the contractor's discretion.
Where feasible, the invert of RTM ponds will be a minimum of 5 ft above seasonal high groundwater table.
An impervious liner will be placed on the invert and along interior slopes of berms, to prevent groundwater contamination.
RTM will not be compacted.
Spoil placed in disposal areas will be placed in 12-inch lifts, with nominal compaction.
The maximum height for placement of spoil is expected to be 6 ft above preconstruction grade (10 ft above preconstruction grade for sites adjacent to CCF), and have side slopes of 5H:1V or flatter.
After final grading of spoil is complete, the area will be restored based on site-specific conditions following project restoration guidelines.

Table 3.2-12. Spoils Disposition, Volumes and Acreages

Disposal Site	Volume (cy)	Disposal Area (acres)
RTM and dredged material disposal site near Intake 2	1,020,000	45.6
RTM disposal sites near IF	9,060,000	404.7
RTM disposal site on Bouldin Island	8,340,000	1,208.8
RTM and dredged material disposal sites near CCF	5,370,000 (RTM) 7,000,000 (dredged)	899.6
TOTAL	**30,790,000**	**2,558.7**

RTM is expected to be reusable, suitable as engineered fill for varied applications, and also suitable for restoration work such as tidal habitat restoration. However, end uses for that material have not yet been identified. It is likely that the material will remain in designated storage areas for a period of years before a suitable end use is identified, and any such use will be subject to environmental evaluation and permitting independent of the PA. Therefore disposition of RTM is assumed to be permanent, and future reuse of this material is not part of the PA.

Materials removed during surface excavation and dredging, or from clearing of the sedimentation basins, may also be reusable. Much of this material is expected to have a high content of fines and/or organic matter and thus may not be suitable for use as engineered fill, but may be suitable for use in habitat restoration projects. As with RTM, no end uses for this material have yet been identified, such use is not part of the PA, and the material will be permanently disposed in the designated RTM and dredged material storage areas. The exception to this statement is topsoil removed during clearing for construction. Topsoil is not classified as spoils; it will be stockpiled and reused for landscaping and restoration, as described in Section 3.2.10.10 *Landscaping and Associated Activities*.

Sacramento River sediment removed from the water column at the intake sedimentation basins will be reused as described above. However, to the maximum extent practicable, the first and preferred disposition of this material will be to reintroduce it to the water column in order to maintain Delta water quality (specifically, turbidity, as a component of Delta Smelt critical habitat; as described in Section 6.1.3.5.3 *Sediment Removal (Water Clarity)*). DWR will collaborate with USFWS and CDFW to develop and implement a sediment reintroduction plan that provides the desired beneficial habitat effects of maintained turbidity while addressing related permitting concerns (the proposed sediment reintroduction is expected to require permits from the Central Valley Regional Water Quality Control Board and USACE). USFWS and NMFS will have approval authority for this plan and for monitoring measures, to be specified in the plan, to assess its effectiveness. Current conceptual design for the plan suggests that it will incorporate placement of sediment during low flow periods at a seasonally inundated location along the mainstem river, such as a bench constructed for the purpose. The sediment would then be remobilized and carried downstream following inundation during seasonal high flows (generally, the winter and spring months). The sediment reintroduction would be designed for consistency with Basin Plan objectives for turbidity, viz., “"For Delta waters, the general objectives for turbidity apply subject to the following: except for periods of storm runoff, the turbidity of Delta waters shall not exceed 50 NTUs in the waters of the Central Delta and 150 NTUs in other Delta waters. Exceptions to the Delta specific objectives will be considered when a dredging operation can cause an increase in turbidity. In this case, an allowable zone of dilution within which turbidity in excess of limits can be tolerated will be defined for the operation and prescribed in a discharge permit" (Central Valley Water Board 1998, p. III-9.00).

3.2.10.7 Dewatering

Due to the generally high groundwater table in the Delta, the location of much of the construction alignment at below-sea-level elevations, and the extensive construction of below-grade structures, dewatering will be needed for nearly all components of conveyance construction. “Dewatering” as used in this document refers to the removal of water from a work area or from excavated materials, and discharge of the removed water to surface waters in accordance with the terms and conditions of a valid NPDES permit and any other applicable Central Valley Regional Water Quality Control Board requirements.

Dewatering will generally be accomplished by electrically powered pumps, which will either dewater via groundwater wells (thereby drawing down the water table to minimize the amount of water entering a work area) or by direct removal of water from an excavation or other work area (such as a cofferdam or the bottom of a completed tunnel access shaft). Dewatering of excavated materials would be accomplished in a similar manner, by stockpiling the material and allowing the water to infiltrate to an impervious layer such as a liner or the bottom of a storage tank, and then pumping or draining it prior to treatment or discharge. At most conveyance facilities, dewatering will be an ongoing activity throughout most of the period of construction activity.

Dewatering water is subject to contamination. Groundwater at a site may be contaminated due to a preexisting condition, such as elevated salinity; or contaminants may be introduced by construction activity. The most frequent contaminants are expected to be alkalinity caused by water contact with curing concrete or ground improvement materials, or viscous binders used in drilling mud or to treat sediments being excavated by a TBM. There is also the potential for accidental contamination due to spillage of construction materials such as diesel fuel. Dewatering waters will be stored in sedimentation tanks; tested for contaminants and treated in accordance with permit requirements; and discharged to surface waters. Treatment of the removed groundwater has not yet been determined and could include conditioning, flocculation, settlement/sedimentation, and/or processing at a package treatment plant. Velocity dissipation structures, such as rock or grouted riprap, will be used to prevent scour where dewatering discharges enter the river. Location of dewatering discharge points will be determined at time of filing for coverage under the NPDES general permit or before start-up of discharge as appropriate. Additional information will be developed during design and the contractor will be required to comply with permit requirements.

3.2.10.8 Dredging and Riprap Placement

For the purposes of this analysis, dredging and riprap placement are defined to be activities that occur in fish-bearing waters. This definition thus excludes, for instance, dredging that occurs in the sedimentation basins at the intakes, or riprap placement that occurs in a dewatered area.

Dredging is subject to constraints imposed by the Federal permit for the activity, and further would be conducted as specified in Appendix 3.F *General Avoidance and Minimization Measures, AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.* AMM6 requires preparation of a sampling and analysis plan; compliance with relevant NPDES and SWRCB requirements; compliance with the proposed in-water work windows[19]; and other measures intended to minimize risk to listed species.

Riprap placement would also comply with relevant NPDES and SWRCB requirements; and with the proposed in-water work windows[6].

3.2.10.9 Barge Landing Construction and Operations[20]

Contractors will use barges to deliver TBM components to TBM launch sites, and may also use barges to deliver other heavy or bulky equipment or materials to those sites, or to haul such materials from those sites.

[19] Dredging operations at south CCF and the barge landings will be limited to the impact pile driving work windows specified for these facilities. Dredging of the North CCF will take place after fish recovery.

[20] For more information on barge landings, barge operations, and barge traffic, see Permit Resolution Log items #13, #14, #37, #40, #41 and #161.

This activity will include barge landing construction, barge operations in the river, tug operations, and barge landing removal.

Barge landings[21] will be constructed at seven locations: Snodgrass Slough north of Twin Cities Road (adjacent to proposed intermediate forebay), Little Potato Slough (Bouldin Island south), San Joaquin River (Venice Island south), San Joaquin River (Mandeville Island east at junction with Middle River), Connection Sl. (Bacon Island north), Old River (Victoria Island northwest), and Old River (junction with West Canal at Clifton Court Forebay). No other barge landings are proposed. Appendix 3.D *Construction Schedule for the Proposed Action* presents the schedule for barge landing construction. Locations of the barge landings are shown in Appendix 3.A *Map Book for the Proposed Action*. Locations are approximate; precise siting and dimensions of these docks are to be determined by DWR's construction contractors; but each barge landing will be sited within the confines of the sites shown in Appendix 3.A. Further points characterizing the barge landings will include the following items.

Barges could be used for pile-driving rigs and barge-mounted cranes; suction dredging equipment; transporting RTM; crushed rock and aggregate; precast tunnel segment liner sections, etc.; post-construction underwater debris removal; and other activities.

Barges will be required to use existing barge landings where possible and maintain a minimum waterway width greater than 100 ft (assuming maximum barge width of 50 ft).

The cumulative physical extent of all barge landing sites will be approximately 33 acres.

Each barge landing site will have an approximately 300 ft by 50 ft, pile-supported dock to provide construction access and construction equipment to portal sites.

Barge landings are assumed not to require dredging for construction or maintenance. No such dredging is proposed and take authorization for it is not requested.

Each dock will be supported by 24-inch steel piles placed approximately every 20 ft under the dock, for a total of up to 51 piles[22]. An additional 56 piles will be required to construct the connecting bridge. See Section 3.2.10.11 *Pile Driving* and Appendix 3.E *Pile Driving Assumptions for the Proposed Action* for details on piling and pile driving associated with barge landing construction.

Each dock will be in use during the entire construction period at each location, five to six years. All docks will be removed at the end of construction. All piling will either be removed, or cut at the mudline.

Approximately 5,900 barge trips[23] are projected to carry tunnel segment liners from ports (locations not yet determined, but likely in the Sacramento area) to barge landings via the Sacramento River,.

[21] Note that two corrections were made to the names of the waterways at two barge landing locations, Bacon and Victoria Islands. The correct barge landing locations have been analyzed in the BA and therefore no further revisions are necessary in Chapter 3 or the effects analysis chapters.
[22] Note that this description is inconsistent with that presented in Appendix 3.B. The engineering staff have stated that the approach presented in Appendix 3.B has been superseded by this approach.
[23] See BO #13 Barge Unloading Facility Pile Quantities and Barge Trip Estimates

Because barges may also be used for other purposes, such as transportation of bulk materials, a total of 9,400 barge trips are projected as a conservative assumption (i.e., a greater number of trips is not expected to occur). This is a small increase relative to existing marine traffic in the area. Barges used will be commercial vessels propelled by tugboats. Barge sizes have not been determined. Commercial barge operators on the Sacramento River are required to operate in compliance with navigational guidelines.

From June 1 through October 31, barge traffic may travel from all three locations (Stockton, San Francisco and Antioch). From November 1 through February 28, barge traffic is limited to travel from Port of Stockton to Bouldin Island. From March 1 through May 31, barge traffic should be restricted to move critical heavy construction equipment in the San Joaquin River due to emigrating listed steelhead and spring-run CS from the San Joaquin River basin. To further minimize potential effects to fish species, plans will be developed for materials that can be transported by truck or rail to launch and retrieval points along the proposed tunnel alignment. This includes investigating the potential of using rail to deliver materials and components to Stockton and the CCF location.

See Appendix 3.B *Conceptual Engineering Report*, *Volume 1*, Section 23.3 *Barge Traffic and Landing Facilities*, for further discussion of barge traffic and barge docks.

All barge operations will be required to comply with the provisions of a barge operations plan, as specified in Appendix 3.F *General Avoidance and Minimization Measures, AMM7 Barge Operations Plan*. As there stated, the barge operations plan will be subject to review and approval by DWR and the other resource agencies (CDFW, NMFS, and USFWS included), and will address the following.

Bottom scour from propeller wash.

Bank erosion or loss of submerged or emergent vegetation from propeller wash and/or excessive wake.

Sediment and benthic community disturbance from accidental or intentional barge grounding or deployment of barge spuds (extendable shafts for temporarily maintaining barge position) or anchors.

Accidental material spillage.

Hazardous materials spills (e.g., fuel, oil, hydraulic fluids).

Potential for suspension of contaminated sediments.

3.2.10.10 Landscaping and Associated Activities

The construction phase at most conveyance facilities will conclude with landscaping. Revegetation of disturbed areas will be determined in accordance with guidance given by DWR's WREM No. 30a, Architectural Motif, State Water Project and through coordination with local agencies through an architectural review process. This guidance from DWR WREM No 30a is set forth as follows.

> If possible, the natural environment will be preserved. If not possible, a re-vegetation plan will be developed. Landscaping plans may be required if deemed appropriate to

> enhance facility attractiveness, for the control of dust/mud/wind/unauthorized access, for reducing equipment noise/glare, for screening of unsightly areas from visually sensitive areas. Planting will use low water-use plants native to the Delta or the local environment, with an organic/natural landscape theme without formal arrangements. For longevity and minimal visual impact, low maintenance plants and irrigation designs will be chosen. Planting plans will use native trees, shrubs or grasses and steps will be taken to avoid inducing growth of non-native invasive plant species/CA Plant Society weedy species[24]. Planting of vegetation will be compatible with density and patterns of existing natural vegetation areas and will be placed in a manner that does not compromise facility safety and access. Planting will be done within the first year following the completion of the project and a plant establishment plan will be implemented.

Landscaping in cleared areas will reuse topsoil stockpiled at the time of site clearing. Site revegetation plans will be developed for restoration of areas disturbed by PA activities.

Other activities occurring at the conclusion of construction will include site cleanup, installation of operational lighting, and installation of security fencing.

Site cleanup will consist of removal of all construction equipment, materials, and debris from the site. Construction debris will be disposed at a regional facility authorized to receive such materials.

Operational lighting will be needed at the intakes, the IF, the consolidated pumping plant at CFF, at the HOR gate, and at the control structures associated with the Banks and Jones connections; operational lighting will also continue to be provided at the existing CVP/SWP facilities. Lighting for the proposed facilities will be designed in accordance with guidance given by DWR's WREM No. 30a, Architectural Motif, State Water Project and through coordination with local agencies through an architectural review process. This guidance is set forth as follows.

> All artificial outdoor lighting is to be limited to safety and security requirements. All lighting is to provide minimum impact on the surrounding environment and is to be shielded to direct the light only towards objects requiring illumination. Lights shall be downcast, cut-off type fixtures with non-glare finishes set at a height that casts low-angle illumination to minimize incidental spillover of light onto adjacent properties, open spaces or backscatter into the nighttime sky. Lights shall provide good color rendering with natural light qualities with the minimum intensity feasible for security, safety and personnel access. All outdoor lighting will be high pressure sodium vapor with individual photocells. Lighting will be designed per the guidelines of the Illuminating Engineering Society (IES). Additionally, all lights shall be consistent with energy conservation and are to be aesthetically pleasing. Lights will have a timed on/off program or will have daylight sensors. Lights will be programmed to be on whether personnel is present or not.

The intakes, the IF, the consolidated pumping plant at CFF, and the HOR gate will be provided with security fencing to prevent unauthorized public access. Security camera systems and intrusion alarm

[24] This text refers to plant species identified as invasive by the California Invasive Plant Council. For further information see http://www.cal-ipc.org/.

systems will be located at these sites. Admission to the sites and buildings will require credentialed entry through access control gates and secure doors, respectively. At each site, the fence line will be coincident with or within the area of permanent impact shown in Appendix 3.A, *Mapbook for the Proposed Action*.

3.2.10.11 Pile Driving

Sheet pile and tubular steel pile driving will be required for intake construction, barge dock construction, embankment work at CCF, the Banks and Jones connections, and construction of the HOR gate. Multiple pile driving rigs may be operated simultaneously; the minimum spacing between rigs will be 200 feet. In practice, the spacing is expected to depend on contractor means and methods. Both vibratory and impact pile driving are expected to occur at each of these locations, as structural requirements call for impact pile driving to refusal.

In-water pile driving will be subject to abatement, hydroacoustic monitoring, and compliance with timing limitations as described in Appendix 3.F, *General Avoidance and Minimization Measures, AMM9 Underwater Sound Control and Abatement Plan*. Pile driving will be limited to the in-water work windows, specific to each construction area, detailed in the introductory paragraphs of Section 3.2 *Conveyance Facility Construction*. For all sheetpile cofferdams proposed at the Delta intakes, CCF, and HOR gate, it is assumed that approximately 70% of the length of each pile can be placed using vibratory pile driving, with impact driving used to finalize pile placement. Piles will be installed using vibratory methods or other non-impact driving methods for the intakes, wherever feasible, to minimize adverse effects on fish and other aquatic organisms. However, the degree to which vibratory driving can be performed effectively is unknown at this time due to as yet undetermined geologic conditions at the construction sites. The remaining pile driving would be conducted using an impact pile driver. Once constructed, if the foundation design for either the Delta intakes or HOR gate requires pile driving, such work would be conducted from within the cofferdam; it is still undetermined if the foundation would use piles or concrete-in-drilled-hole methods, which does not require pile driving. If driven foundation piles are included in the design, DWR will require contractors to isolate pile driving activities within dewatered cofferdams as a means of minimizing noise levels and potential adverse effects on fish.

The barge docks would require pile driving of 24-inch tubular steel piles in the water. DWR will work with contractors to minimize pile driving, particularly impact pile driving. If dock piles for barge landings cannot be installed using vibratory methods, the construction contractor will use a bubble curtain or other attenuation device to minimize underwater noise.

Table 3.2-13 shows the approximate channel widths, timing, and duration of pile driving for each facility or structure where pile driving is proposed to occur in open water or on land within 200 feet of open water.

Table 3.2-13. Pile Driving Sites and Durations

Facility or Structure	Average Width of Water Body (feet)	Construction Year(s)	Number of Pile Drivers	Duration of Pile Driving (days)[1]
Intake 2 Cofferdam	700	Year 8	4	42
Intake 2 Foundation	700	Year 9	4	19
Intake 3 Cofferdam	500	Year 7	4	42
Intake 3 Foundation	500	Year 8	4	14
Intake 5 Cofferdam	600	Year 5	4	42
Intake 5 Foundation	600	Year 6	4	19
Barge Landings	265–1,030	Years 1-3[2]	4	2
CCF Cofferdams	10,500	Years 9-10	4	85
NCCF Siphon	10,500	Years 6-7	2	36
HOR gate Cofferdams	150	Years 3-4	1	19
HOR gate Foundation	150	Years 3-4	1	4

Notes: [1] Indicates number of days per site per year based on concurrent operation of total number of pile drivers.
[2] Two years of pile driving per site; three years to complete pile driving at all facilities.

3.3 Operations and Maintenance of New and Existing Facilities

This section of Chapter 3 discusses proposed operations and maintenance of the PA, which includes new and existing CVP/SWP facilities in the Delta. It includes the following subsections.

Section 3.3.1, *Implementation*

Section 3.3.2, *Operational Criteria,* describes the approach to flow management and identify specific operational criteria applying to both existing and proposed CVP/SWP facilities in the Delta.

Section 3.3.3, *Real-Time Operational (RTO) Decision-Making Process,* describes how those criteria will be implemented in real time using available system status information.

Section 3.3.4, *Operation of South Delta Facilities,* describes how the south Delta facilities are operated to minimize harm to listed species of fish, and to control invasive aquatic vegetation.

Section 3.3.5, *Water Transfers,* describes what water transfers are and defines the extent to which they are covered activities under the PA.

Section 3.3.6, *Maintenance of the Facilities,* describes how the new and existing facilities will be maintained under the PA.

The operational criteria in this section that are in addition to the criteria prescribed by existing biological opinions were developed, based on the best scientific and commercial data available, as part of a proposed habitat conservation plan for the purpose of contributing to the recovery of listed and nonlisted covered species. In addition, those criteria will only take effect once the north Delta export facilities become operational and Reclamation determines, after conferring with FWS and

NMFS, that those criteria are required to ensure the coordinated operations of the CVP and SWP are not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of designated critical habitat for those species. Further, those criteria were developed based on the best available scientific information at the time this document was prepared. This determination will be based on the best scientific and commercial data available at the time the north Delta export facilities become operational, including data collected and analysis conducted through the collaborative science and adaptive management program described in Section 3.4.8.3, *Monitoring Prior to Operations*. If those data and analyses indicate that one or more of the water operations flow criteria in Table 3.3-1 should be eliminated or modified, Reclamation will, if required, reinitiate consultation pursuant to Section 7 of the ESA and/or DWR will, if required, commence a permit amendment process under California law to modify the operating criteria, as appropriate.

As previously stated, DWR has entered into a settlement agreement with CCWD, the effects of which are not evaluated in this BA. When operational and maintenance actions associated with implementation of the agreement are sufficiently defined to provide for analysis of potential adverse effects to listed species and critical habitat, a supplement to this BA will be provided to the Services.

3.3.1 Implementation

Implementation of the PA will include operations of both new and existing water conveyance facilities once the new north Delta diversion facilities are completed and become operational, Most existing facilities will continue to be operated consistent with existing regulatory authorizations, including the USFWS (2008) and NMFS (2009)[26] BiOps. However, operational limits included in this PA for south Delta export facilities will replace the south Delta operational limits currently implemented in compliance with the USFWS (2008) and NMFS (2009) BiOps when the proposed north Delta diversion becomes operational. See Table 3.1-1 for a complete summary of facilities and actions included in the proposed action. The PA also includes criteria for spring outflow and new minimum flow criteria at Rio Vista during the months of January through August that will apply when the proposed north Delta diversion becomes operational. The north Delta diversions and the head of Old River gate are 'new' facilities for the SWP and will be operated consistent with the PA criteria presented in this BA for these facilities.

The USFWS (2008) and NMFS (2009) BiOps for CVP/SWP operations will continue to apply for CVP/SWP activities not covered in this BA. For Shasta operations, the NMFS (2009) RPA adjustment (Action Suite 1.2) for seasonal temperature management that will likely be completed in late 2016 will apply. The proposed CWF operating criteria are not intended to change Shasta operations; thus, the NMFS (2009) RPA adjustment (Action suite 1.2) for seasonal temperature management will control if there are any unforeseen conflicts in Shasta operations between the proposed CWF operating criteria and the adjusted RPA. To summarize the proposed action includes modified or new operational criteria for the following facilities:

north Delta Intakes

[26] Note: Any reference to the NMFS (2009) BO in this Chapter is to include the amendments to that BO, as issued by NMFS on April 7, 2011.

south Delta export facilities

Head of Old River (HOR) gate operations

Additionally, the operation of the following facilities is included in the PA once the north Delta diversions are operational, but no changes to their operations are proposed.

Delta Cross Channel (DCC) gate operations

Suisun Marsh facilities

North Bay Aqueduct (NBA) Intake

The proposed operational criteria are described in the following sections and in Table 3.3-1. The longfin smelt is a species listed under the California Endangered Species Act (CESA). Therefore, it will be necessary for DWR to meet CESA permit issuance criteria for this species. To avoid a reduction in overall abundance for longfin smelt, the PA includes spring outflow criteria, which are intended to be provided by appropriate beneficiaries through the acquisition of water from willing sellers. If sufficient water cannot be acquired for this purpose, the spring outflow criteria will be accomplished through operations of the CVP/SWP to the extent an obligation is imposed on either the SWP or CVP under federal or applicable state law. Best available science, including that developed through a collaborative science program, will be used to analyze and make recommendations on the role of such flow in supporting longfin smelt abundance to CDFW, who will determine whether it is necessary to meet CESA permitting criteria.

Operations under the PA may result in substantial change in Delta flows compared to the expected flows under the existing Delta configuration, and in some instances real-time operations will be applied for water supply, water quality, flood control, and/or fish protection purposes. Two key drivers of CVP/SWP operations, Fall X2 and spring outflow, as well as many of the individual operational components described below, are designed to adapt to developing scientific information as a consequence of the level of uncertainty associated with those criteria. A Collaborative Science and Adaptive Management Program will be used to evaluate and consider changes in the operational criteria based on information gained before and after the new facilities become operational. Described in more detail in Section 3.4.6 *Collaborative Science and Adaptive Management Program* this program will be used to consider and address scientific uncertainty regarding the Delta ecosystem and to inform implementation of the operational criteria in the near term for existing BiOps for the coordinated operations of the CVP/SWP (U.S. Fish and Wildlife Service 2008, National Marine Fisheries Service 2009) and the 2081b permit for the SWP facilities and operations (California Department of Fish and Game 2009), as well as in the future for the new BiOp and 2081(b) for this PA.

3.3.2 Operational Criteria

Table 3.3-1 provides an overview of the proposed new criteria and other key criteria assumed for Delta operations when the proposed north Delta diversion intakes are operational. The proposed operational criteria were developed in coordination with NMFS, USFWS, and DFW to minimize project effects on listed species. Further descriptions, including the intent of the specific criteria for each facility are described below, except the spring outflow criterion which is not associated with any facility.

The purpose of the spring outflow criteria is to maintain spring outflows consistent with the current Biological Opinions (FWS 2008; NMFS 2009), as described above.

A brief description of the modeling assumptions for each criterion is included. Additional detail regarding modeling assumptions is included in Table 3.3-2. Actual operations will also rely on real-time operations as described in Section 3.3.3, *Real-Time Operational Decision-Making Process*. Criteria presented in Table 3.3-1, as annotated, for south Delta operations represent the maximum restrictions on exports. Even though this BA attempts to describe the temporal scale at which some of the operational criteria will be implemented (e.g. north Delta bypass flow requirements and OMR requirements), a detailed operations plan will be developed by Reclamation and DWR in coordination with DFW, NMFS and USFWS prior to the new facilities becoming operational.

Table 3.3-1. New and Existing Water Operations Flow Criteria and Relationship to Assumptions in CALSIM II Modeling[27]

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]
New Criteria Included in the Proposed Action		
North Delta bypass flows[28]	• Bypass Flow Criteria (specifies bypass flow required to remain downstream of the North Delta intakes): ○ October, November: Minimum flow of 7,000 cfs required in river after diverting at the North Delta intakes. ○ December through June: see below ○ July, August, September: Minimum flow of 5,000 cfs required in river after diverting at the North Delta intakes. • Pulse Protection: ○ Low-level pumping of up to 6% of total Sacramento River flow at Freeport such that bypass flow never falls below 5,000 cfs. No more than 300 cfs can be diverted at any one intake. ○ Low level pumping maintained during the pulse protection period. ○ Pulse is determined based on the real- time monitoring of juvenile fish movement as described in Section 3.3.3.1 *North Delta Diversion* ○ If the initial pulse begins and ends before Dec 1, the bypass flow criteria for	• Initial Pulse Protection: ○ Low-level pumping of up to 6% of total Sacramento River flow such that bypass flow never falls below 5,000 cfs. No more than 300 cfs can be diverted at any one intake. ○ If the initial pulse begins and ends before Dec 1, criteria for the appropriate month (Oct–Nov) go into effect after the pulse until Dec 1. On Dec 1, the Level 1 rules defined in Table 3.3-2 apply until a second pulse, as defined in Table 3.3-3 occurs. The second pulse will have the same protective operation as the first pulse.

[27] In coordination with NMFS, USFWS, and CDFW, several updates to CWF operational criteria were made during the ESA and CESA consultation processes. An analysis was performed (model results submitted to USFWS on 5/5/17) to determine if the updated operational criteria would result in additional effects outside of those analyzed in this BA. The modeling results confirmed the effects of the operational updates are within the range analyzed in the BA. As a result, the PA effects analysis in Chapters 5 and 6 are representative of potential project effects and no additional analysis is necessary.
[28] Sacramento River flow upstream of the intakes to be measured flow at Freeport. Bypass flow is the Sacramento River flow quantified downstream of the Intake # 5. Sub-daily north Delta intakes' diversion operations will maintain fish screen approach and sweeping velocity criteria

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]
	the month (Oct-Nov) when the pulse occurred would take effect. On Dec 1, the Level 1 rules defined below apply unless a second pulse occurs. • Post-pulse Criteria (specifies bypass flow required to remain downstream of the North Delta intakes): ○ December through June: once the pulse protection ends, post-pulse bypass flow operations will not exceed Level 1 pumping unless specific criteria have been met to increase to Level 2 or Level 3. If those criteria are met, operations can proceed as defined in Table 3.3-2. Allowable diversion will be greater of the low-level pumping or the diversion allowed by the post-pulse bypass flow rules in Table 3.3-2.The specific criteria for transitioning between and among pulse protection, Level 1, Level 2, and/or Level 3 operations, will be developed and based on real-time fish monitoring and hydrologic/behavioral cues upstream of and in the Delta as discussed in Section 3.3.3.1, *North Delta Diversion*. During operations, adjustments to the default allowable diversion level specified in Table 3.3-2 are expected to be made to improve water supply and/or migratory conditions for fish by making real-time adjustments to the diversion levels at the north Delta intakes. These adjustments are expected to fall within the operational bounds analyzed for the BA and will be managed	

South Delta operations[29][30]	• October, November: To be determined based on real time operations and protection of the D-1641 San Joaquin River 2-week pulse. December: OMR flows will not be more negative than an average of -5,000 cfs when the Sacramento River at Wilkins Slough pulse (same as north Delta diversion bypass flow pulse defined in Table 3.3-2) triggers[31], and no more negative than an average of -2,000 cfs when the delta smelt USFWS (2008) BiOp action 1 triggers. No OMR flow restriction prior to the Sacramento River pulse or delta smelt action 1 triggers.	• October, November[32]: Assumed no south Delta exports during the D- 1641 San Joaquin River 2-week pulse, no OMR restriction during 2 weeks prior to pulse, and −5,000 cfs in November after pulse. • December: −5,000 cfs only when the Sacramento River pulse based on the Wilkins Slough flow (same as the pulse for the north Delta diversion) occurs. If the USFWS (2008) BiOp Action 1 is triggered,−2,000 cfs

[29] The criteria do not fully reflect the complexities of CVP/SWP operations, dynamic hydrology, or spatial and temporal variation in the distribution of aquatic species. As a result, the criteria will be achieved by operating within an initial range of real time operational criteria from January through March and in June. This initial range, including operational triggers, will be determined through future discussion, including a starting point of -1250 to -5000 cfs based on a 14-day running average, and will be informed by the Adaptive Management Program, including real time monitoring. Further, the 3-day averaging period may be modified through future discussion. Modifications to the 3-day average period and the range of operating criteria may be needed, in part, because: 1) the water year type is forecasted in February but not finalized until May and 2) 0 cfs, or positive, OMR in wet and above normal years may be attained coincident with unimpaired flows.

[30] OMR measured through the currently proposed index-method (Hutton 2008) with a 14-day averaging period consistent with the current operations (USBR 2014).

[31] December Sacramento River pulse determined by flow increases at Wilkins Slough of greater than 45% within 5- day period and exceeding 12,000 cfs at the end of 5-day period, and real-time monitoring of juvenile fish movement. Preliminary discussions with engineers indicates ramping down can begin within an hour of the trigger and full ramp down could be complete within approximately 12 hours. The Wilkins Slough trigger will be reviewed through future discussion, which will be informed by the Adaptive Management Program, including real time monitoring.

[32] As a result of formal consultation with USFWS and NMFS, and as a result of DFW's issuance of the Draft 2081(b) ITP, DWR and Reclamation have included clarifications to the CWF operations flow criteria contained in Table 3.3-1 table. Although the October/November south Delta operational criteria were updated for the PA (see criteria described in the left column), for CALSIM modeling purposes in the effects analysis for the BA, the operational criteria listed here were used in the PA scenario to compare against the NAA, which has no OMR flow restrictions in October or November. As described in footnote 27, an analysis (model results submitted to USFWS on 5/5/17) was performed which indicated that the effects of the updated operational criteria are consistent with the effects analyzed in this BA; therefore, it was determined no changes to the CALSIM II modeling assumptions or performance of additional analysis was necessary.

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]
	• January, February[33]: OMR flows will not be more negative than a 3-day average of 0 cfs during wet years, −3,500 cfs during above-normal years, or −4,000 cfs during below-normal to critical years, except −5,000 in January of dry and critical years. • March[34]: OMR flows will not be more negative than a 3-day average of 0 cfs during wet or above- normal years or −3,500 cfs during below-normal and dry year and -3,000 cfs during critical years. • April, May[35]: Allowable OMR flows depend on gaged flow measured at Vernalis, and will be determined by a linear relationship. If Vernalis flow is below 5,000 cfs, OMR flows will not be more negative than -2000 cfs. If Vernalis is 6,000 cfs, OMR flows will not be less than +1000 cfs. If Vernalis is 10,000 cfs, OMR flows will not be less than +2,000 cfs. If Vernalis is 15,000 cfs, OMR flows will not be less than +3,000 cfs. If Vernalis is at or exceeds 30,000 cfs, OMR flows will not be less than 6,000 cfs. • June: Similar to April and May, allowable flows depend on gaged flow measured at Vernalis (except without interpolation). If Vernalis is less than 3,500 cfs, OMR flows will not be more negative than −3,500 cfs. If Vernalis exceeds 3,500 cfs up to 10,000 cfs, OMR flows will not be less than 0 cfs. If Vernalis exceeds 10,000 cfs up to 15,000 cfs, OMR flows will not be less than +1,000 cfs. If Vernalis exceeds 15,000 cfs, OMR flows will not be less than +2,000 cfs. • July, August, September: No OMR flow constraints[36]. • OMR criteria under 2008 USFWS and 2009 NMFS BiOps or the above, whichever results in	requirement for 14 days is assumed. Remaining Dec days were assumed to have an allowable OMR of -8000 cfs to compute a composite monthly allowable OMR level. • April, May: OMR requirement for the Vernalis flows between 5000 cfs and 30000 cfs were determined by linear interpolation. For example, when Vernalis flow is between 5,000 cfs and 6,000 cfs, OMR requirement is determined by linearly interpolating between −2,000 cfs and +1,000 cfs. • January–March and June–September: Same as the criteria • New OMR criteria modeled as monthly average values.

33 Water year type based on the Sacramento 40-30-30 index to be based on 50% forecast per current approaches; the first update of the water year type to occur in February. CALSIM II modeling uses previous water year type for October through January, and the current water year type from February onwards

34 Water year type as described in the above footnote.

35 When OMR target is based on Vernalis flow, will be a function of 5-day average measured flow.

36 The PA operations include a preference for south Delta pumping in July through September months to provide limited flushing flows to manage water quality in the south Delta.

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]
	more positive, or less negative OMR flows, will be applicable[37].	
HOR gate operations	• October 1–November 30: RTO management – with the current expectation being that the HOR gate will be operated to protect the D- 1641 pulse flow. • January-March 31, and June 1-15: RTO will determine exact operations to protect salmon fry when migrating, During this migration, operation will be to close the gate subject to RTO for purposes of water quality, stage, and flood control considerations. • April-May: Initial operating criterion will be to close the gate 100% of time subject to RTO for purposes of water quality, stage, and flood control considerations (Section 3.3.3, *Real-Time Operational Decision-Making Process).* Reclamation, DWR, NMFS, USFWS, and DFW will actively explore the implementation of reliable juvenile salmonid tracking technology that may enable shifting to a more flexible real time operating criterion based on the presence/absence of listed fishes. • June 16 to September 30, December: Operable gates will be open.	• Assumed 50% open from January 1 to June 15, and during days in October prior to the D-1641 San Joaquin River pulse. Closed during the pulse. 100% open in the remaining months.

[37] Change in CVP/SWP pumping from the south Delta will occur to comply with OMR targets and will be achieved to the extent exports can control the flow. The OMR targets would not be achieved through releases from CVP/SWP reservoirs. The combined CVP/SWP export rates from the proposed north Delta intakes and the existing south Delta intakes will not be required to drop below 1,500 cfs to provide water supply for health and safety needs, critical refuge supplies, and obligation to senior water rights holders.

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]
Delta Cross Channel Gates	• Operating criteria as required by NMFS (2009) BiOp Action IV.1 and D-1641, and DCC closure for downstream flood control will be based on Sacramento River flow at Freeport, upstream of the NDD facilities.	• Delta Cross Channel gates are closed for a certain number of days during October 1 through December 14 based on the Wilkins Slough flow, and the gates may be opened if the D-1641 Rock Slough salinity standard is violated because of the gate closure. Delta Cross Channel gates are assumed to be closed during December 15 through January 31. February 1 through June 15, Delta Cross Channel gates are operated based on D-1641 requirements.
Spring Outflow[38]	March, April, May: Initial operations will maintain the March–May average delta outflow that would occur with existing facilities under the operational criteria described in the 2008 USFWS BiOp and 2009 NMFS BiOp (U.S. Fish and Wildlife Service 2008; National Marine Fisheries Service 2009).[39]	• 2011 NMFS RPA for San Joaquin River i-e ratio constraint is the primary driver for the Apr-May Delta outflow under the No Action Alternative, this criterion was used to constrain Apr-May total Delta exports under the PA to meet Mar- May Delta outflow targets.
Key Existing Delta Criteria Included in Modeling[40]		
Fall Outflow	• No change. September, October, November: implement the USFWS 2008 BO Fall X2 requirements in wet (W) and above normal (AN) year types.	• September, October, November: implement the 2008 USFWS BiOp "Action 4: Estuarine Habitat During Fall" (Fall X2) requirements (U.S. Fish and Wildlife Service 2008).
Winter and summer outflow	• No change. Flow constraints established under D-1641 will be followed if not superseded by criteria listed above.	• SWRCB D-1641 Delta outflow and February – June X2 criteria.

Parameter	Criteria	Summary of CALSIM II Modeling Assumptions[a]

[38] For modeling purposes, the criteria described in the CALSIM modeling assumptions column were used for the PA scenario. However, the 2081(b) ITP is expected to include final operations related to spring outflow. Although the expected spring outflow requirements from DFW are not components for the proposed action, DFW's expected operational criteria related to spring outflow was modeled and included in the draft 2081(b) ITP and presented in the table below: ***Spring Outflow Criteria*** *Upon initiation of the Test Period and throughout the CDFW permit term, average Delta outflow for LFS based on the 50% exceedance forecast for the current month's ELT 8 River Index (8RI).)* (From DFW ITP)

[39] If best available science resulting from collaborative scientific research program shows that Longfin Smelt abundance can be maintained in the absence of spring outflow, and DFW concurs, an alternative operation for spring outflow could be developed to follow flow constraints established under D-1641. Any changes in the PA will be implemented consistent with the CWF AMP, including coordination with USFWS and NMFS

[40] All the CALSIM II modeling assumptions are described in Appendix 5.A, *CALSIM Methods and Results*.

Rio Vista minimum flow standard[41]	• September through December: flows per D-1641	• Same as PA criteria
Suisun Marsh Salinity Control Gates	• No change. Gates will continue to be closed up to 20 days per year from October through May.	For the DSM2 modeling, used generalized seasonal and tidal operations for the gates. • Seasonal operation: The radial gates are operational from Oct to Feb if Martinez EC is higher than 20000, and for remaining months they remain open. • Tidal operations when gates are operational: Gates close when: downstream channel flow is < 0.1 (onset of flood tide); Gates open when: upstream to downstream stage difference is greater than 0.3 ft (onset of ebb tide)
Export to inflow ratio	• Operational criteria are the same as defined under D-1641, and applied as a maximum 3-day running average. • The D-1641 export/inflow (E/I) ratio calculation was largely designed to protect fish from south Delta entrainment. For the PA, Reclamation and DWR propose that the NDD be excluded from the E/I ratio calculation. In other words, Sacramento River inflow is defined as flows downstream of the NDD and only south Delta exports are included for the export component of the criteria.	• Combined export rate is defined as the diversion rate of the Banks Pumping Plant and Jones Pumping Plant from the south Delta channels. • Delta inflow is defined as the sum of the Sacramento River flow downstream of the proposed north Delta diversion intakes, Yolo Bypass flow, Mokelumne River flow, Cosumnes River flow, Calaveras River flow, San Joaquin River flow at Vernalis, and other miscellaneous in-Delta flows.
[a] See Table 3.3-2 for Proposed Action CALSIM II Modeling Assumptions		

[41] Rio Vista minimum monthly average flow in cfs (7-day average flow not be less than 1,000 below monthly minimum), consistent with the SWRCB D-1641

Table 3.3-1. Proposed Action CALSIM II Criteria and Modeling Assumptions

Dual Conveyance Scenario with 9,000 cfs North Delta Diversion (includes Intakes 2, 3 and 5 with a maximum diversion capacity of 3,000 cfs at each intake)
1. North Delta Diversion Bypass Flows These parameters define the criteria for modeling purposes and provide the real-time operational criteria levels as operations move between and among the levels. Actual operations will be based on real-time monitoring of hydrologic conditions and fish presence/movement as described in Section 3.3.3.1, *North Delta Diversions*.
Low-Level Pumping (Dec-Jun) Diversions of up to 6% of total Sacramento River flow such that bypass flow never falls below 5,000 cfs. No more than 300 cfs can be diverted at any one intake.
Initial Pulse Protection Low level pumping as described in Table 3.3-1 will be maintained through the initial pulse period. For modeling, the initiation of the pulse is defined by the following criteria: (1) Sacramento River flow at Wilkins Slough increasing by more than 45% within a five-day period and (2) flow on the fifth day greater than 12,000 cfs. The pulse (and low-level pumping) continues until either (1) Sacramento River flow at Wilkins Slough returns to pre-pulse flow level (flow on first day of pulse period), or (2) Sacramento River flow at Wilkins Slough decreases for 5 consecutive days, or (3) Sacramento River flow at Wilkins Slough is greater than 20,000 cfs for 10 consecutive days. After pulse period has ended, operations will return to the bypass flow table (Sub-Table A). If the initial pulse period begins and ends before Dec 1st in the modeling, then any second pulse that may occur before the end of June will receive the same protection, i.e., low level pumping as described in Table 3.3-1.
Post-Pulse Operations After initial pulse(s), allowable diversion will go to Level I Post-Pulse Operations (see Sub-Table A) until 15 total days of bypass flows above 20,000 cfs occur. Then allowable diversion will go to the Level II Post-Pulse Operations until 30 total days of bypass flows above 20,000 cfs occur. Then allowable diversion will go to the Level III Post-Pulse Operations.
Sub-Table A. Post-Pulse Operations for North Delta Diversion Bypass Flows Implement following bypass flow requirements sufficient to minimize any increase in the upstream tidal transport at two points of control: (1) Sacramento River upstream of Sutter Slough and (2) Sacramento River downstream of Georgiana Slough. These points are used to minimize any increase in upstream transport toward the proposed intakes or into Georgiana Slough. Allowable diversion will be greater of the low-level pumping or the diversion allowed by the following bypass flow rules.

Level I Post-Pulse Operations			Level II Post-Pulse Operations			Level III Post Pulse Operations		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**
Dec–Apr								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000 cfs	no limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,000 cfs plus 0% of the amount over 20,000 cfs
May								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 40% of the amount over 9,000 cfs

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post Pulse Operations**		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**
17,000 cfs	20,000 cfs	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	12,400 cfs plus 0% of the amount over 20,000 cfs
Jun								
0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs	0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	15,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	11,000 cfs	Flows remaining after constant low level pumping	5,000 cfs	9,000 cfs	Flows remaining after constant low level pumping
15,000 cfs	17,000 cfs	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000 cfs	15,000 cfs	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000 cfs	15,000 cfs	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000 cfs	20,000 cfs	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000 cfs	20,000 cfs	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000 cfs	20,000 cfs	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000 cfs	no limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000 cfs	no limit	11,800 cfs plus 0% of the amount over 20,000 cfs

Level I Post-Pulse Operations			**Level II Post-Pulse Operations**			**Level III Post Pulse Operations**		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**	**If Sacramento River flow is over...**	**But not over...**	**The bypass is...**

Bypass flow requirements in other months:		
If Sacramento River flow is over...	**But not over...**	**The bypass is...**
Jul–Sep		
0 cfs	5,000 cfs	100% of the amount over 0 cfs
5,000 cfs	No limit	A minimum of 5,000 cfs
Oct–Nov		
0 cfs	7,000 cfs	100% of the amount over 0 cfs
7,000 cfs	No limit	A minimum of 7,000 cfs

2. South Delta Channel Flows

OMR Flows

All of the baseline model logic and input used in the No Action Alternative as a surrogate for the OMR criteria required by the various fish protection triggers (density, calendar, turbidity and flow based triggers) described in the 2008 USFWS and the 2009 NMFS CVP/SWP BiOps were incorporated into the modeling of the PA except for NMFS BO Action IV.2.1 – San Joaquin River i/e ratio. The PA includes the proposed operational criteria, as well[42]. Whenever the BiOps' triggers require OMR be less negative or more positive than those shown below, those OMR requirements will be met. These newly proposed OMR criteria (and associated HOR gate operations) are in response to expected changes under the PA, and only applicable after the proposed north Delta diversion becomes operational. Until the north Delta diversion becomes operational, only the OMR criteria under the current BiOps apply to CVP/SWP operations.

Combined Old and Middle River flows must be no less than values below[a] (cfs)

(Water year type classification based Sacramento River 40-30-30 index)

Month	W	AN	BN	D	C
Jan	0	-3,500	-4,000	-5,000	-5,000
Feb	0	-3,500	-4,000	-4,000	-4,000
Mar	0	0	-3,500	-3,500	-3,000
Apr	varies[b]	varies[b]	varies[b]	varies[b]	varies[b]

[42] As previously mentioned, as a result of formal consultation with USFWS and NMFS, and as a result of DFW's issuance of the Draft 2081(b) ITP, DWR and Reclamation have included clarifications to the CWF operations flow criteria contained in Table 3.3-1 table. Although the October/November south Delta operational criteria were updated for the PA, for CALSIM modeling purposes in the effects analysis for the BA, the specific operational criteria was not revised based on a sensitivity analysis (model results submitted to USFWS on 5/5/17) that indicated that the effects of the updated operational criteria are consistent with the effects analyzed in this BA; therefore, it was determined no changes to the CALSIM II modeling assumptions or performance of additional analysis was necessary.

May	varies[b]	varies[b]	varies[b]	varies[b]	varies[b]
Jun	varies[b]	varies[b]	varies[b]	varies[b]	varies[b]
Jul	N/A	N/A	N/A	N/A	N/A
Aug	N/A	N/A	N/A	N/A	N/A
Sep	N/A	N/A	N/A	N/A	N/A
Oct	varies[c]	varies[c]	varies[c]	varies[c]	varies[c]
Nov	varies[c]	varies[c]	varies[c]	varies[c]	varies[c]
Dec	-5,000[d]	-5,000[d]	-5,000[d]	-5,000[d]	-5,000[d]

[a] Values are monthly averages for use in modeling. The model compares these minimum allowable OMR values to 2008 USFWS BiOp RPA OMR requirements and uses the less negative flow requirement.

[b] Based on San Joaquin inflow relationship to OMR provided below in Sub-Table B.

[c] Two weeks before the D-1641 pulse (assumed to occur October 16-31 in the modeling), No OMR restrictions (for modeling purposes an OMR requirement of -5,000 cfs was assumed during this 2 week period)
Two weeks during the D-1641 pulse, no south Delta exports
Two weeks after the D-1641 pulse, -5,000 cfs OMR requirement (through November)

[d] OMR restriction of -5,000 cfs for Sacramento River winter-run Chinook salmon when North Delta initial pulse flows are triggered or OMR restriction of -2,000 cfs for delta smelt when triggered. For modeling purposes (to compute a composite Dec allowable OMR), remaining days were assumed to have an allowable OMR of -8000 cfs.

Head of Old River Operable (HOR) Gate Operations/Modeling assumptions (% OPEN)[43]			
MONTH	HOR Gate[a]	MONTH	HOR Gate[a]
Oct	50% (except during the pulse)[b]	May	50%
Nov	100% (except during the post-pulse period)[b]	Jun 1–15	50%
Dec	100%	Jun 16–30	100%
Jan	50%[c]	Jul	100%
Feb	50%	Aug	100%
Mar	50%	Sep	100%
April	50%		

[a] Percent of time the HOR gate is open. Agricultural barriers are in and operated consistent with current practices. HOR gate will be open 100% whenever flows are greater than 10,000 cfs at Vernalis.

HOR gate operation is triggered based upon State Water Board D-1641 pulse trigger. For modeling assumptions only, two weeks before the D-1641 pulse, it is assumed that the HOR gate will be open 50%.

[b] During the D-1641 pulse (assumed to occur October 16-31 in the modeling), it is assumed the HOR gate will be closed.
For two weeks following the D-1641 pulse, it was assumed that the HOR gate will be open 50%.
Exact timing of the action will be based on hydrologic conditions.

[c] The HOR gate becomes operational at 50% when salmon fry are migrating (based on real time monitoring). This generally occurs when flood flow releases are being made. For the purposes of modeling, it was assumed that salmon fry are migrating starting on January 1.

In the CALSIM II modeling, the "HOR gate open percentage" specified above is modeled as the percent of time within a month that HOR gate is open. In the DSM2 modeling, HOR gate is assumed to operate such that the above-specified percent of "the flow that would have entered the Old River if the HOR gate were fully open", would enter the Old River.

Sub-Table B. San Joaquin Inflow Relationship to OMR

April and May		June	
If San Joaquin flow at Vernalis is the following	Average OMR flows would be at least the following (interpolated linearly between values)	If San Joaquin flow at Vernalis is the following	Average OMR flows would be at least the following (no interpolation)
≤ 5,000 cfs	-2,000 cfs	≤ 3,500 cfs	-3,500 cfs
6,000 cfs	+1,000 cfs	3,501 to 10,000 cfs	0 cfs
10,000 cfs	+2,000 cfs		
15,000 cfs	+3,000 cfs	10,001 to 15,000 cfs	+1,000 cfs
≥30,000 cfs	+6,000 cfs	>15,000 cfs	+2,000 cfs

43 The following HOR gate operating criteria represent assumptions used in the CALSIM modeling for the PA scenario. Refer to Table 3.3-1 and Section 3.3.4 for a description of HOR gate operations under the PA.

3. Delta Cross Channel Gate Operations
Assumptions Per SRWCB D-1641 with additional days closed from Oct 1 – Jan 31 based on NMFS BiOp (Jun 2009) Action IV.1.2 (closed during flushing flows from Oct 1 – Dec 14 unless adverse water quality conditions). This criterion is consistent with the No Action Alternative.
4. Rio Vista Minimum Instream Flows
Assumptions Sep–Dec: Per D-1641; Jan-Aug: Minimum of 3,000 cfs
5. Delta Outflow
Delta Outflow SWRCB D-1641 requirements, or outflow per requirements noted below, whichever is greater

Months	Delta Outflow Requirement
Spring (Mar–May):	Additional spring outflow requirement[a]
Fall (Sep–Nov):	Implement USFWS 2008 BO Fall X2 requirement

Notes: [a] For modeling purposes, the spring outflow criteria described in Table 3-3.1 (see footnote 38) were used to model the PA scenario. However, the 2081 ITP will include final operations related to spring outflow. These operations include the following: Protective outflows from March through May every year shall be determined by the use of a lookup table derived from a linear relationship between the 50% exceedance forecast for the current month's 8RI and recent historic Delta outflow (1980 – 2016). Operators shall utilize Net Delta Outflow Index (NDOI) data to confirm that the average Delta outflow target was met during each 30 day period from March – May. Operators shall provide daily NDOI data quantifying daily Delta outflow in each 30 day period to CDFW on or before April 20, May 21, and June 20 every year. Reduction in exports down to minimum health and safety requirements established in D-1641 (currently 1500 cfs) may be necessary. These targets are intended to be provided through the acquisition of water from willing sellers and through operations of the CVP/SWP. Operators shall achieve Delta outflow targets through shared export allocations between the NDD and South Delta, consistent with required Operating Criteria described in the CDFW ITP. If the target average Delta outflow is greater than 44,500 cfs operators shall consult with CDFW to determine how to allocate exports between the NDD and the South Delta.
[a]

Spring Outflow Criteria (presents the operational requirements expected to be included in the 2081(b) ITP, as represented in DFW's draft 2081(b)ITP. Upon initiation of the Test Period and throughout the CDFW permit term, average Delta outflow for LFS based on the 50% exceedance forecast for the current month's ELT 8 River Index (8RI).).

March ELT 8RI (TAF)	March Average Delta Outflow Target (cfs)	April ELT 8RI (TAF)	April Average Delta Outflow Target (cfs)	May ELT 8RI (TAF)	May Average Delta Outflow Target (cfs)
0	0	0	0	0	0
450	7100	425	7100	250	4000
1000	7100	1000	7100	1000	4000
1650	7100	1750	7100	1600	4000
1700	8100	1930	7500	1700	4900
1800	10300	2000	8700	1800	6200

1900	12500
2000	14700
2100	16800
2200	19000
2300	21200
2400	23400
2500	25500
2600	27700
2700	29900
2800	32100
2900	34300
3000	36400
3100	38600
3200	40800
3300	43000
3370	44500
≥ 3370	44500

2100	10900
2200	13100
2300	15300
2400	17600
2500	19800
2600	22000
2700	24300
2800	26500
2900	28700
3000	31000
3100	33200
3200	35400
3300	37600
3400	39900
3500	42100
3600	44300
≥ 3600	44500

1900	7500
2000	8700
2100	10000
2200	11300
2300	12500
2400	13800
2500	15000
2600	16300
2700	17600
2800	18800
2900	20100
3000	21400
3100	22600
3200	23900
3300	25200
3400	26400
3500	27700
3600	29000
3700	30200
3800	31500
3900	32800
4000	34000
4100	35300
4200	36500
4300	37800
4400	39100
4500	40300
4600	41600
4700	42900
4830	44500

	≥ 4830	44500

6. Operations for Delta Water Quality and Residence Time
<u>Assumptions</u> Jul–Sep: Prefer south delta intake up to total pumping of 3,000 cfs; No specific intake preference beyond 3,000 cfs. Oct–Jun: Prefer north delta intake; (real-time operational flexibility)
7. In-Delta Agricultural and Municipal & Industrial Water Quality Requirements
<u>Assumptions</u> Existing D-1641 AG and MI standards
8. D-1641 E-I Ratio Computation
<u>Assumptions</u> In computing the E-I Ratio in the CALSIM II model, the North Delta Diversion is not included in the export term, and the Sacramento River inflow is as modeled downstream of the North Delta Intakes.

Flow criteria are applied seasonally (month by month) and according to the following five water-year types. Under the observed hydrologic conditions over the 82-year period (1922–2003), the number of years of each water-year type is listed below. The water-year type classification, unless otherwise noted, is based on the Sacramento Valley 40-30-30 Water Year Index defined under Revised D-1641.

Wet (W) water-year: the wettest 26 years of the 82-year hydrologic data record, or 32% of years.

Above-normal (AN) water-year: 12 years of 82, or 15%.

Below-normal (BN) water-year: 14 years of 82, or 17%.

Dry (D) water-year: 18 years of 82, or 22%.

Critical (C) water-year: 12 years of 82, or 15%.

The above noted frequencies are expected to change slightly under projected climate conditions at year 2030. The number of years of each water-year type per D-1641 Sacramento Valley 40-30-30 Water Year Index under the projected climate condition assumed for this BA, over the 82-year period (1922–2003) is provided below. Appendix 5A, Section 5.A.3, *Climate Change and Sea Level Rise* provides more information on the assumed climate change projection at year 2030 for this BA.

Wet water-year: the wettest 26 years of the 82-year hydrologic data record, or 32% of years.

Above-normal water-year: 13 years of 82, or 16%.

Below-normal water-year: 11 years of 82, or 13%.

Dry water-year: 20 years of 82, or 24%.

Critical water-year: 12 years of 82, or 15%.

3.3.2.1 Operational Criteria for North Delta CVP/SWP Export Facilities

The proposed operational criteria were developed based on the scientific information available at the time of document preparation and are intended to minimize project effects on listed species while providing water supply reliability. The proposed north Delta diversions will allow the PA to export water, consistent with applicable criteria, during periods of high flow. Thus, north Delta diversions will be greatest in wetter years and lowest in drier years, when south Delta diversions will provide the majority of the CVP/SWP exports. North Delta bypass flow criteria were developed primarily to avoid impacts on listed species, with the considerations enumerated below. Real time operations will also be used to adjust operations to further limit effects on listed species and maximize water supply benefits (Section 3.3.3, *Real-Time Operational Decision-Making Process)*. Additionally, the PA operations include a preference for south Delta facility pumping in July through September to limit any potential water quality degradation in the south Delta. Delta channel flows and diversions may be modified in response to real-time operational needs such as those related to Old and Middle Rivers (OMR), Delta Cross Channel operations (DCC), or North Delta bypass flows.

In addition to the bypass flow criteria described below and in Table 3.3-1 and Table 3.3-2, constraints incorporated in the design and operation of the north Delta intakes include the following.

The new north Delta diversion intakes will consist of three separate intake units with a total, combined intake capacity not exceeding 9,000 cfs (maximum of 3,000 cfs per unit); details in Section 3.2.2, *North Delta Diversions*.

Project conveyance will be provided by a tunnel capacity sized to provide for gravity-assisted flow from an IF to the south Delta pumping facilities when supported by sufficient flow conditions.

The facility will, during operational testing and as needed thereafter, demonstrate compliance with the then-current NOAA, USFWS, and CDFW fish screening design and operating criteria, which govern such things as approach and sweeping velocities and rates of impingement. In addition, the screens will be operated to achieve the following performance standard: Maintain listed juvenile salmonid survival rates through the reach containing new north Delta diversion intakes (0.25 mile upstream of the upstream-most intake to 0.25 mile downstream of the downstream-most intake) of 95% or more of the existing survival rate in this reach. The reduction in survival of up to 5% below the existing survival rate will be cumulative across all screens and will be measured on an average monthly basis.

The facility will precede full operations with a phased test period during which DWR, as project applicant, in close collaboration with NMFS and CDFW, will develop detailed plans for appropriate tests and use those tests to evaluate facility performance across a range of pumping rates and flow conditions. This phased testing period will include biological studies and monitoring efforts to enable the measurement of survival rates (both within the screening reach and downstream to Chipps Island), and other relevant biological parameters which may be affected by the operation of the new intakes.

Operations will be managed at all times to avoid increasing the magnitude, frequency, or duration of flow reversals in the Sacramento River at the Georgiana Slough junction above pre-north Delta diversion intakes operations levels.

The fish and wildlife agencies (i.e., USFWS, NMFS, and CDFW) retain responsibility for determination of the operational criteria and constraints (i.e., which pumping stations are operated and at what pumping rate) during testing. The fish and wildlife agencies are also responsible for evaluating and determining whether the diversion structures are achieving performance standards for listed species of fish over the course of operations. Consistent with the experimental design, the fish and wildlife agencies will also determine when the testing period should end and full operations consistent with developed operating criteria can commence. In making this determination, fish and wildlife agencies expect and will consider that, depending on hydrology, it may be difficult to test for a full range of conditions prior to commencing full operations. Therefore, tests of the facility to ensure biological performance standards are met are expected to continue intermittently after full operations begin, to enable testing to be completed for different pumping levels during infrequently occurring hydrologic conditions.

The Collaborative Science and Adaptive Management Program will, among other things, develop and use information focused on minimizing uncertainties related to the design and operation of the fish screens (Section 3.4.6 *Collaborative Science and Adaptive Management Program*).

Once full operation begins, the real-time operations program (Section 3.3.3, *Real-Time Operational Decision Making Process*) will be used to ensure that adjustments in pumping are made when needed for fish protection or as appropriate for water supply, water quality, flood control, and/or fish protection purposes as described in Section 3.3.3 for each real-time operational component.

The Collaborative Science and Adaptive Management Program will review the efficacy of the North Delta bypass criteria, to determine what adjustments, if any, are needed to further minimize adverse effects on listed species of fish.

The objectives of the north Delta diversion bypass flow criteria include regulation of flows to (1) maintain fish screen sweeping velocities, (2) minimize potential increase in upstream transport of productivity in the channels downstream of the intakes, (3) support salmonid and pelagic fish movements to regions of suitable habitat, (4) reduce losses to predation downstream of the diversions, and (5) maintain or improve rearing habitat conditions in the north Delta.

To ensure that these objectives are met, diversions must be restricted at certain times of the year that bracket the main juvenile salmon migration period (mostly from December through June). This is achieved by restricting the north Delta diversion to low level pumping (maximum diversion of 6% of Sacramento River flow measured upstream of the intakes up to 900 cfs [300 cfs per intake]) when the juvenile fish begin their outmigration, which generally coincides with seasonal high flows triggered by fall/winter rains followed by a ramping up of allowable diversion rates, while ensuring flows are adequate to be protective of aquatic species during the remainder of the outmigration. Additional but less restrictive requirements apply for the late spring to late fall period. See Table 3.3-1 and Section 3.3.3 for a description of NDD operational criteria and RTO under the PA.

In addition, north Delta diversion at the three intakes are subjected to approach velocity and sweeping velocity restrictions at the proposed fish screens. Appendices 5A and 5B describes the assumptions used in modeling the sweeping velocity restrictions on the north Delta diversion.

3.3.2.2 Operational Criteria for South Delta CVP/SWP Export Facilities

The objective of the new south Delta flow criteria is to further minimize take at south Delta pumps by reducing the hydrodynamic effects of south Delta operations that may affect fish movement and migration routing during critical periods for listed fish species. The south Delta channel flow criteria are based on the parameters for Old and Middle River (OMR) flows and the San Joaquin River inflow, as summarized below and in Table 3.3-1 and Table 3.3-2, and HOR gate operations (summarized in Section 3.3.2.3, *Operational Criteria for the Head of Old River Gate*).

Additionally, the PA operations include a preference for south Delta pumping in July through September to provide limited flushing flows to manage water quality in the south Delta.

The OMR flow criteria chiefly serve to constrain the magnitude of reverse flows in the Old and Middle Rivers to limit fish entrainment into the south Delta and increase the likelihood that Delta smelt can successfully reproduce in the San Joaquin River. The rational for using OMR flow criteria is based on the USFWS (2008) and NMFS (2009) BiOp RPA Actions, and are described in Table 3.3-1 and Table 3.3-2. The proposed OMR criteria (and associated HOR gate operations), described in Table 3.3-1, are designed primarily to provide additional protections related to fish habitat under the PA, (i.e., they would lessen reverse flows in Old and Middle Rivers); and they are only applicable only after the proposed north Delta diversion becomes operational.

In April, May, and June, minimum allowable OMR flow values would be based upon the San Joaquin River inflow (Table 3.3-1 and Table 3.3-2). October and November operations will be determined on real time operations and protection of the D-1641 San Joaquin River 2-week pulse.

Additionally, criteria based on the water year type in December through June will be implemented as described in detail in Table 3.3-1. The criteria generally constrain the south Delta exports more under the wetter years compared to the requirements under the USFWS (2008) and NMFS (2009) BiOps. The OMR criteria (and associated HOR gate operations) are proposed to reduce reverse flow conditions under the PA, and are only applicable after the proposed north Delta diversion becomes operational. Until the north Delta diversion becomes operational only the OMR criteria under the current BiOps apply to CVP/SWP operations.

3.3.2.3 Operational Criteria for the Head of Old River Gate

As described in Section 3.2, *Conveyance Facility Construction*, a new permanent, operable gate at the head of Old River (at the divergence from the San Joaquin River) will be constructed and operated to protect outmigrating San Joaquin River salmonids in the spring and to provide water quality improvements in the San Joaquin River in the fall. The new HOR gate will replace the temporary rock barrier that is typically installed at the same location. (Temporary agricultural barriers on Middle River and Old River near Tracy and Grant Line Canal will continue to be installed consistent with current operations). Operation of the HOR gate could vary from completely open (lying flat on the channel bed) to completely closed (erect in the channel, prohibiting any flow of San Joaquin River water into Old River), with the potential for operations in between that will allow partial flow. The operational criteria are described in Table 3.3-1. The actual operation of the gate will be determined by real-time operations (Section 3.3.3, *Real-Time Operational Decision-Making Process*) based on actual flows and/or fish presence.

3.3.2.4 Operational Criteria for the Delta Cross Channel Gates

The Delta Cross Channel (DCC) is a gated diversion channel in the Sacramento River near Walnut Grove and Snodgrass Slough (Appendix 3.A *Map Book for the Proposed Action*, Sheet 5) that is owned and operated by Reclamation. No changes to DCC operational criteria from the operations described in D-1641 and the USFWS (2008) and NMFS (2009) BiOps are proposed. Flows into the DCC from the Sacramento River are controlled by two 60-foot by 30-foot radial gates. When the gates are open, water flows from the Sacramento River through the cross channel to channels of the lower Mokelumne and San Joaquin Rivers toward the interior Delta. The DCC operation improves water quality in the interior Delta by improving circulation patterns of higher-quality water from the Sacramento River towards Delta diversion facilities.

Reclamation operates the DCC in the open position to (1) improve water quality in the interior Delta, and (2) reduce saltwater intrusion rates in the western Delta. During the late fall, winter, and spring, the gates are often periodically closed to protect out-migrating salmonids from entering the interior Delta. In addition, whenever flows in the Sacramento River at Sacramento reach 20,000 to 25,000 cfs (on a sustained basis), the gates are closed to reduce potential scouring and flooding that might occur in the channels on the downstream side of the gates.

Flow rates through the gates are determined by Sacramento River stage and are not affected by export rates in the south Delta. The DCC also serves as a link between the Mokelumne River and the Sacramento River for small craft. It is used extensively by recreational boaters and anglers whenever it is open. Because alternative routes around the DCC are quite long, Reclamation tries to provide adequate notice of DCC closures so boaters may plan for the longer excursion.

Under the PA, the DCC will continue to be operated as it is now operated under the terms of the NMFS (2009) BiOp IV.1 and D-1641. The gates will be closed if fish are present in October and November, with closure decisions at that time reached through the existing real-time operations process described in Section 3.3.3, *Real-Time Operational Decision Making Process*. The CALSIM II modeling assumed DCC operations as required by NMFS (2009) BiOp RPA Action IV.1.2 by using a regression of Sacramento River monthly flow at Wilkins Slough and the number of days in the month when the daily flow would be greater than 7500 cfs. The latter was assumed to be an indicator that salmonids would be migrating to the delta. In the modeling, DCC gates are closed for the same number of days as Wilkins Slough is estimated to exceed 7500 cfs during October 1 through December 14, and the gates may be opened if the D-1641 Rock Slough salinity standard is violated because of the gate closure. DCC gates are assumed to be closed during December 15 through January 31. February 1 through June 15, DCC gates are operated based on D-1641 requirements. DCC closure for downstream flood control will be based on Sacramento River flow at Freeport upstream of the NDD facilities.

3.3.2.5 Operational Criteria for the Suisun Marsh Facilities

The Suisun Marsh facilities are jointly operated by CVP/SWP and include the Suisun Marsh Salinity Control Gates (SMSCG), Roaring River Distribution System (RRDS), Morrow Island Distribution System (MIDS), and Goodyear Slough Outfall. No changes to the operations of the Suisun Marsh facilities from those described in the USFWS (2008) and NMFS (2009) BiOps are proposed.

3.3.2.5.1 Suisun Marsh Salinity Control Gates

The SMSCG are located on Montezuma Slough about two miles downstream from the confluence of the Sacramento and San Joaquin Rivers, near Collinsville (Appendix 3.A *Map Book for the Proposed Action*, Sheet 17). Operation of the SMSCG began in October 1988 as Phase II of the Plan of Protection for the Suisun Marsh. The objective of SMSCG operation is to decrease the salinity of the water in Montezuma Slough. The facility, spanning the 465-foot width of Montezuma Slough, consists of a boat lock, a series of three radial gates, and removable flashboards. The gates control salinity by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide. Operation of the gates in this fashion lowers salinity in Suisun Marsh channels and results in a net movement of water from east to west.

When Delta outflow is low to moderate and the gates are not operating, tidal flow past the gate is approximately 5,000 to 6,000 cfs while the net flow is near zero. When operated, flood tide flows are arrested while ebb tide flows remain in the range of 5,000 to 6,000 cfs. The net flow in Montezuma Slough becomes approximately 2,500 to 2,800 cfs. The Corps of Engineers permit for operating the SMSCG requires that it be operated between October and May only when needed to meet Suisun Marsh salinity standards. Historically, the gate has been operated as early as October 1, while in some years (e.g., 1996) the gate was not operated at all. When the channel water salinity decreases sufficiently below the salinity standards or at the end of the control season, the flashboards are removed and the gates raised to allow unrestricted movement through Montezuma Slough. Details of annual gate operations can be found in "Summary of Salinity Conditions in Suisun Marsh During WYs 1984–1992", or the "Suisun Marsh Monitoring Program Data Summary" produced annually by DWR, Division of Environmental Services.

The approximately 2,800 cfs net flow induced by SMSCG operation is effective at moving the salinity downstream in Montezuma Slough. Salinity is reduced by roughly one-hundred percent at Beldons Landing, and lesser amounts further west along Montezuma Slough. At the same time, the salinity field in Suisun Bay moves upstream as net Delta outflow (measured nominally at Chipps Island) is reduced by gate operation. Net outflow through Carquinez Strait is not affected.

The boat lock portion of the gate is held open at all times during SMSCG operation to allow for continuous salmon passage opportunity. With increased understanding of the effectiveness of the gates in lowering salinity in Montezuma Slough, salinity standards have been met with less frequent gate operation, compared to the early years of operations (prior to 2006). For example, despite very low outflow in fall 2007 and fall 2008, gate operation was not required at all in 2007, and was limited to 17 days during winter 2008. Assuming no significant, long-term changes in the drivers mentioned above, this level of operational frequency (10 to 20 days per year) can generally be expected to continue to meet standards in the future except perhaps during the most critical hydrologic conditions and/or other conditions that affect Delta outflow.

3.3.2.5.2 Roaring River Distribution System

The RRDS (Appendix 3.A *Map Book for the Proposed Action*, Sheet 17) was constructed during 1979 and 1980 as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The system was constructed to provide lower salinity water to 5,000 acres of private and 3,000 acres of DFG-managed wetlands on Simmons, Hammond, Van Sickle, Wheeler, and Grizzly islands.

The RRDS includes a 40-acre intake pond that supplies water to Roaring River Slough. Motorized slide gates in Montezuma Slough and flap gates in the pond control flows through the culverts into the pond. A manually operated flap gate and flashboard riser are located at the confluence of Roaring River and Montezuma Slough to allow drainage back into Montezuma Slough for controlling water levels in the distribution system and for flood protection. DWR owns and operates this drain gate to ensure the Roaring River levees are not compromised during extremely high tides.

Water is diverted through a bank of eight 60-inch-diameter culverts equipped with fish screens into the Roaring River intake pond on high tides to raise the water surface elevation in RRDS above the adjacent managed wetlands. Managed wetlands north and south of the RRDS receive water, as needed, through publicly and privately owned turnouts on the system.

The intake to the RRDS is screened to prevent entrainment of fish larger than approximately 25 mm. DWR designed and installed the screens based on CDFW criteria. The screen is a stationary vertical screen constructed of continuous-slot stainless steel wedge wire. All screens have 3/32-inch slot openings. To minimize the risk of delta smelt entrainment, RRDS diversion rates are controlled to maintain an average approach velocity below 0.2 ft/s at the intake fish screen. Initially, the intake culverts were held at about 20% capacity to meet the velocity criterion at high tide. Since 1996, the motorized slide gates have been operated remotely to allow hourly adjustment of gate openings to maximize diversion throughout the tide.

3.3.2.5.3 Morrow Island Distribution System

The MIDS (Appendix 3.A *Map Book for the Proposed Action*, Sheet 17) was constructed in 1979 and 1980 in the south-western Suisun Marsh as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. The contractual requirement for Reclamation and DWR is to provide water to the ownerships so that lands may be managed according to approved local management plans. The system was constructed primarily to channel drainage water from the adjacent managed wetlands for discharge into Suisun Slough and Grizzly Bay. This approach increases circulation and reduces salinity in Goodyear Slough.

The MIDS is used year-round, but most intensively from September through June. When managed wetlands are filling and circulating, water is tidally diverted from Goodyear Slough just south of Pierce Harbor through three 48-inch culverts. Drainage water from Morrow Island is discharged into Grizzly Bay by way of the C-Line Outfall (two 36-inch culverts) and into the mouth of Suisun Slough by way of the M-Line Outfall (three 48- inch culverts), rather than back into Goodyear Slough. This helps prevent increases in salinity due to drainage water discharges into Goodyear Slough. The M-Line ditch is approximately 1.6 miles in length and the C-Line ditch is approximately 0.8 miles in length.

3.3.2.5.4 Goodyear Slough Outfall

The Goodyear Slough Outfall (Appendix 3.A *Map Book for the Proposed Action*, Sheet 17) was constructed in 1979 and 1980 as part of the Initial Facilities in the Plan of Protection for the Suisun Marsh. A channel approximately 69 feet wide was dredged from the south end of Goodyear Slough to Suisun Bay (about 2,800 feet). The excavated material was used for levee construction. The control structure consists of four 48-inch culverts with flap gates on the bay side. On ebb tides, Goodyear Slough receives watershed runoff from Green Valley Creek and, to a lesser extent, Suisun Creek. The system was designed to draw creek flow south into Goodyear Slough, and thereby reduce salinity, by draining water one-way from the lower end of Goodyear Slough into Suisun Bay on the ebb tide. The one-way flap gates at the Outfall close on flood tide keeping saltier bay water from mixing into the slough. The system creates a small net flow in the southerly direction overlaid on a larger, bidirectional tidal flow. The system provides lower salinity water to the wetland managers who flood their ponds with Goodyear Slough water. Another initial facility, the MIDS, diverts from Goodyear Slough and receives lower salinity water. Since the gates are passively operated (in response to water surface elevation differentials) there are no operations schedules or records. The system is open for free fish movement except very near the Outfall when flap gates are closed during flood tides.

3.3.2.6 Operational Criteria for the North Bay Aqueduct Intake

The Barker Slough Pumping Plant diverts water from Barker Slough into the North Bay Aqueduct (NBA) for delivery in Napa and Solano Counties. Maximum pumping capacity is 175 cubic feet per second (cfs) (pipeline capacity). During the past few years, daily pumping rates have ranged between 0 and 140 cfs. The current maximum pumping rate is 140 cfs due to the physical limitations of the existing pumps. Growth of biofilm in a portion of the pipeline also limits the NBA ability to reach its full pumping capacity.

The NBA intake is located approximately 10 miles from the mainstem Sacramento River at the end of Barker Slough (Appendix 3.A *Map Book for the Proposed Action*, Sheet 17). Per salmon screening criteria, each of the ten NBA pump bays is individually screened with a positive barrier fish screen consisting of a series of flat, stainless steel, wedge-wire panels with a slot width of 3/32 inch. This configuration is designed to exclude fish approximately one inch or larger from being entrained. The bays tied to the two smaller units have an approach velocity of about 0.2 feet per second (ft/s). The larger units were designed for a 0.5 ft/s approach velocity, but actual approach velocity is about 0.44 ft/s. The screens are routinely cleaned to prevent excessive head loss, thereby minimizing increased localized approach velocities.

The NBA fish screens are also designed to comply with USFWS criteria for delta smelt protection (Reclamation 2008), which are likewise protective of longfin smelt. A larval delta smelt monitoring program occurs each spring in the sloughs near NBA. This monitoring program is used to trigger NBA export reductions when delta smelt larvae are nearby.

Delta smelt monitoring was required at Barker Slough under the March 6, 1995 OCAP BiOp. Starting in 1995, monitoring was required every other day at three sites from mid- February through mid-July, when delta smelt may be present. As part of the Interagency Ecological Program, DWR has contracted with DFW to conduct the required monitoring each year since the BO was issued. Details about the survey and data are available on DFG’s website (http://www.delta.dfg.ca.gov/data/NBA). Beginning in 2008, the NBA larval sampling was replaced by an expanded 20-mm survey (described at http://www.delta.dfg.ca.gov/data/20mm) that has proven to be fairly effective at tracking delta smelt distribution and reducing entrainment. The expanded survey covers all existing 20-mm stations, in addition to a new suite of stations near the NBA. The expanded survey also has an earlier seasonal start and stop date to focus on the presence of larvae in the Delta. These surveys also collect information on longfin smelt.

3.3.3 Real-Time Operational Decision-Making Process

The real-time operational decision-making process (real-time operations (RTO) allows short-term (*i.e*., daily and weekly) adjustments to be made to water operations, within the range of criteria described in Section 3.3.1, *Implementation*, and Section 3.3.2, *Operational Criteria*. RTO will be implemented to maximize water supply for CVP/SWP, subject to providing the necessary protections for listed species, through the existing decision-making process and related technical work teams identified in Section 3.1.5.2 *Groups Involved in Real-Time Decision Making and Information Sharing*[46].

To complement the RTO process, a separate Operational Opportunities subcommittee, as part of the Interagency Implementation Coordination Group (IICG) described in the *Agreement For Implementation Of An Adaptive Management Program For Project Operations*, will be convened on a case-by-case basis to consider and make recommendations regarding specific short term (within one year) ecological or water supply opportunities that may be available without reducing the ability of the SWP or CVP to deliver water, imposing additional funding obligations on the SWP/CVP Contractors, or adversely impacting Protected Species. Decision-making will still happen as it currently does under the USFWS (2008) and NMFS (2009) BiOps, as outlined in Appendix 1: Project Description to the NMFS 2009 BiOp where it states (p.28):

“The process to identify actions for protection of listed species varies to some degree among species but follows this general outline: A Fisheries or Operations Technical Team compiles and assesses current information regarding species, such as stages of reproductive development, geographic distribution, relative abundance, physical habitat conditions, then provides a recommendation to the agency with statutory obligation to enforce protection of the species in question. The agency’s staff and management will review the recommendation and use it as a basis for developing, in cooperation with Reclamation and DWR, a modification of water operations that will minimize adverse effects to listed species by the Projects. If the Project Agencies do not agree with the action, then the fishery agency with the statutory authority will make a final decision on an action that they deem necessary to protect the species. In the event it is not possible to refine the proposed action in order that it does not violate section 7(a)(2) of the ESA, the Project and fisheries agencies will reinitiate consultation.

The outcomes of protective actions that are implemented will be monitored and documented, and this information will inform future recommended actions.”

The operational adjustments made through the RTO processes apply only to the facilities and activities identified in the PA. RTOs are expected to be needed during at least some part of the year at the north and south Delta diversions and the HOR gate. The extent to which real time adjustments that may be made to each parameter related to these facilities shall be limited by the criteria and/or ranges set out in Section 3.3.2, *Operational Criteria*. That is, operational adjustments shall be consistent with the criteria, and within any ranges, established in the PA. Subsections 3.3.3.1, *North Delta Diversion*; 3.3.3.2, *South Delta Diversion*; and 3.3.3.3, *Head of Old River Gate*, provide considerations for the real-time operations. Any modifications to- the

[46] The decision-making process and technical work teams identified here are provisional and may be subject to further revision, either through future coordination or as developed through the Collaborative Science and Adaptive Management Program described in Section 3.4.6.

criteria and/or ranges set out in the operating criteria shall occur through the adaptive management Program, and the effects of any such modifications shall be analyzed by Reclamation and DWR, in consultation with NMFS and USFWS, to determine if Reclamation and DWR should reinitiate consultation prior to implementation. Nothing in this section shall limit the Services ability to make adjustments pursuant to existing BiOps or limit their existing authorities to exercise discretion pursuant to existing regulations and procedures.

The CVP-SWP operators conduct seasonal planning of the CVP-SWP operations, taking into account many factors such as the existing regulatory requirements, forecasted hydrology, contractual demands, *etc*. The operators also consider any recommendations resulting from the RTO decision making to minimize adverse effects for listed species while meeting permit requirements and contractual obligations for water deliveries.

3.3.3.1 North Delta Diversion

Operations for North Delta bypass flows will be managed according to the following criteria:

- **October, November:** Minimum bypass flows of 7,000 cfs required after diverting at the North Delta intakes.
- **December through June:** As described below, post-pulse bypass flow operations will be operated within the range of pulse protection, and Levels 1, 2, and 3, depending on risk to fish and with consideration for other factors such as water supply and other Delta conditions, and by implementing pulse protection periods when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations may remain at Level 1 pumping depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping. During operations, adjustments are expected to be made to improve water supply and/or migratory conditions for fish by making real-time adjustments to the pumping levels at the north Delta diversions. These adjustments will be managed under RTOs as described below.
- **July, August, September:** Minimum bypass flows of 5,000 cfs required after diverting at the north Delta diversion intakes.

Real-time operations of the north Delta intakes are intended to allow for the project objective of water diversion while also providing for the protection of migrating and rearing salmonids. RTOs will be a key component of NDD operations, and will likely govern operations for the majority of the December through June salmonid migration period. Under RTOs, the NDD would be operated within the range of pulse protection, and Levels 1, 2, and 3, depending on risk to fish and with consideration for other factors such as water supply and other Delta conditions, and by implementing pulse protection periods when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations may remain at Level 1 pumping depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping. The specific criteria for transitioning between and among pulse protection and post-pulse bypass flow operations will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the PA's Collaborative Science and Adaptive Management Plan (Section 3.4.6). Based on the outcome of the studies listed in Section 3.4.6, information about appropriate triggers, off-ramps, and other RTO management of NDD operations will be integrated into the operations of the PA. The RTOs will be used to support the successful migration of salmonids past the NDD and through the Delta, in combination with other operational components of the PA[47].

The following operational framework serves as an example that is based on the recommended NDD RTO process (Marcinkevage and Kundargi 2016). A 5-agency technical team co-chaired by NMFS and CDFW will incorporate results from ongoing monitoring and studies to revise specific fish triggers and may further refine the RTO process based on the amount of time it takes to make the RTO change in pumping rates and a science plan developed through the collaborative science process and finalized through the adaptive management process prior to commencement of actual operations of the north Delta facilities.

3.3.3.1.1 Pulse-Protection

- A fish pulse is defined as combined catch of X_p[48] winter-run and spring-run sized Chinook salmon in a single day at specified locations[46].
- Upon initiation of fish pulse, operations must reduce to low-level pumping.
- Pumping may not exceed low-level pumping for the duration of fish pulse. However, additional pumping above low-level may be allowed as long as a minimum of 35,000 cfs[49] bypass flow is maintained during the period of pulse protection. A fish pulse is considered over after X[50] consecutive days with daily combined catch of winter- and spring run-sized Chinook salmon less than X_p[46] at or just downstream of the new intakes.
- Post-pulse bypass flow operations will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping.

[47] Operations necessary to support Delta rearing of juvenile salmonids will be addressed through the adaptive management program, due to limited information on rearing flow needs at this time.

[48] Preliminary evaluation of the effects of the proposed operations will use triggers developed from data provided by existing monitoring stations. The values and monitoring location would depend upon operation of a new/additional station, the method used to identify winter- and spring-run Chinook salmon, collection of sufficient data, and the time of year. DFW's draft 2081(b) ITP includes a condition related to pulse protection which triggers a pulse based on a Knights Landing catch index (X_p) greater than or equal to 5 winter-run-sized and spring-run-sized fish.

[49] Preliminary evaluation of the effects of the proposed operations will use a minimum off-ramp bypass flow developed from existing data. The off-ramp bypass flow required will be determined based on pre-construction studies identified in Section 3.4.7.3

[50] Preliminary evaluation of the effects of the proposed operations will use triggers developed from data provided by existing monitoring stations. The values and monitoring location would depend upon operation of a new/additional station, the method used to identify winter- and spring-run Chinook salmon, collection of sufficient data, and the time of year. DFW's draft 2081 permit includes a condition related to pulse protection which considers a pulse to be over when Knights Landing catch index (X_p) is less than 5 for a duration (X) of 5 days.

- All subsequent pulses of winter- and spring-run Chinook salmon will be afforded the same level of protection as the first pulse[46, 48]
- Unlimited fish pulses are protected in any given year.

The south Delta diversions will be managed under RTO throughout the year based on fish protection triggers (e.g., salvage density, calendar, species distribution, entrainment risk, turbidity, and flow based triggers [Table 3.3-3]). Increased restrictions as well as relaxations of the OMR criteria outside of the range defined in Table 3.3-3 may occur through adaptive management as a result of observed physical and biological information. Additionally, RTO will also be managed to distribute pumping activities among the three north Delta and two south Delta intake facilities to maximize both survival of listed fish species in the Delta and water supply.

Table 3.3-3. Salvage Density Triggers for Old and Middle River Real-Time Flow Adjustments January 1 to June 15[a] (source: National Marine Fisheries Service 2011).

First Stage Trigger
(1) Daily CVP/SWP older juvenile Chinook salmon[b] loss density (fish per TAF) is greater than incidental take limit divided by 2,000 (2% WRJPE ÷ 2,000), with a minimum value of 2.5 fish per taf, or (2) Daily CVP/SWP older juvenile Chinook salmon loss is greater than 8 fish per TAF multiplied by volume exported (in TAF), or (3) Coleman National Fish Hatchery coded wire tagged late fall-run Chinook salmon or Livingston Stone National Fish Hatchery coded wire tagged winter-run Chinook salmon cumulative loss is greater than 0.5% for each surrogate release group, or (4) Daily loss of wild steelhead (intact adipose fin) is greater than 8 fish per TAF multiplied by volume exported (in TAF).[c] Response: Reduce exports to achieve an average net OMR flow of -3,500 cfs for a minimum of 5 consecutive days. The 5-day running average OMR flows will be no more than 25% more negative than the targeted flow level at any time during the 5-day running average period (e.g., -4,375 cfs average over 5 days). Resumption of -5,000 cfs flows is allowed when average daily fish density is less than trigger density for the last 3 days of export reduction.[c] Reductions are required when any one criterion is met.
Second Stage Trigger
(1) Daily CVP/SWP older juvenile Chinook salmon loss density (fish per TAF) is greater than incidental take limit divided by 1,000 (2% of WRJPE ÷ 1,000), with a minimum value of 5 fish per TAF, or (2) Daily CVP/SWP older juvenile Chinook salmon loss is greater than 12 fish per TAF multiplied by volume exported (in TAF), or (3) Daily loss of wild steelhead (intact adipose fin) is greater than 12 fish per TAF multiplied by volume exported (in TAF). Response: Reduce exports to achieve an average net OMR flow of -2,500 cfs for a minimum 5 consecutive days. Resumption of -5,000 cfs flows is allowed when average daily fish density is less than trigger density for the last 3 days of export reduction. Reductions are required when any one criterion is met.

End of Triggers
Continue action until June 15 or until average daily water temperature at Mossdale is greater than 72°F (22°C) for 7 consecutive days (1 week), whichever is earlier.
Response:
If trigger for end of OMR regulation is met, then the restrictions on OMR are lifted for the remainder of the water year.
[a] Salvage density triggers modify PA operations only within the ranges proposed in Table 3.3-1. Triggers will not be implemented in a manner that reduces water supplies in amounts greater than modeled outcomes. [b] *Older juvenile Chinook salmon* is defined as any Chinook salmon that is above the minimum length for winter-run Chinook salmon, according to the Delta Model length-at-date table used to assign individuals to race. [c] Three consecutive days in which the combined loss numbers are below the action triggers are required before the OMR flow reductions can be relaxed to no more negative than -5,000 cfs. A minimum of 5 consecutive days of export reduction are required for the protection of listed salmonids under the action. Starting on day 3 of the export curtailment, the level of fish loss must be below the action triggers for the remainder of the 5-day export reduction to relax the OMR requirements on day 6. Any exceedance of a more conservative trigger restarts the 5-day OMR action response with the 3 consecutive days of loss monitoring criteria. TAF = thousand acre-feet. WRJPE = the current year's winter-run Chinook salmon juvenile production estimate.

3.3.4.1 Head of Old River Gate

Operations for the HOR gate will be managed under RTOs as follows.

October 1–November 30th: RTO management – with the current expectation being that the HOR gate will be operated to protect the D-1641 pulse flow.

January-March 31st , and June 1-15: RTO will determine exact operations to protect salmonid juveniles when migrating, During this migration, operation will be to close the gate subject to RTO for purposes of water quality, stage, and flood control considerations.

April-May: Initial operating criterion will be to close the gate 100% of time subject to RTO for purposes of water quality, stage, and flood control considerations. Reclamation, DWR, NMFS, USFWS, and DFW will actively explore the implementation of reliable juvenile salmonid tracking technology that may enable shifting to a more flexible real time operating criterion based on the presence/absence of listed fishes.

June 16 to September 30, December: Operable gates will be open.

To reduce downstream flood risks based on current conditions, HOR gate will remain open if San Joaquin River flow at Vernalis is greater than 10,000 cfs (threshold may be revised to align with any future flood protection actions).

3.3.5 Operation of South Delta Facilities

This section describes how the existing South Delta facilities, including the CVP's C.W. "Bill" Jones Pumping Plant and Tracy Fish Collection Facility and the SWP's Harvey O. Banks Pumping Plant and Skinner Delta Fish Protective Facility, are operated to minimize the risks of predation and entrainment of listed species of fish[56], and how the Clifton Court Forebay is managed for control of invasive aquatic vegetation. These operations are unchanged from those described in and regulated by the USFWS (2008) and NMFS (2009) BiOps.

3.3.5.1 C.W. "Bill" Jones Pumping Plant and Tracy Fish Collection Facility

The CVP and SWP use the Sacramento River, San Joaquin River, and Delta channels to transport water to export pumping plants located in the south Delta. The CVP's Jones PP, about five miles north of Tracy, consists of six available pumps. The Jones PP is located at the end of an earth-lined intake channel about 2.5 miles in length. At the entrance to the intake channel, louver screens (that are part of the Tracy Fish Collection Facility) intercept fish, which are then collected, held, and transported by tanker truck to release sites more than 20 km away from the pumping plants, in the west Delta near the Sacramento/San Joaquin confluence. Currently those sites include the Emmaton and Delta Base release sites for the CVP, and the Curtis Landing and Horseshoe Bend release sites for the SWP.

Jones Pumping Plant has a permitted diversion capacity of 4,600 cfs with maximum pumping rates capable of achieving that capacity.

The Tracy Fish Collection Facility (TFCF) is located in the south-west portion of the Sacramento-San Joaquin Delta and uses behavioral barriers consisting of primary louvers and secondary screens to guide entrained fish into holding tanks before transport by truck to release sites within the Delta. The primary louvers are located in the primary channel just downstream of a trashrack structure. The secondary screens consist of a travelling positive barrier fish screen. The louvers and screens allow water to pass through into the pumping plant but the openings between the slats prevent fish with a body width greater than 2 inches from passing between them and redirect them toward one of four bypass entrances along the louver arrays. Smaller fish, that can pass through the louvers, may be behaviorally redirected by the louver structure. The louvers perform best at flows low enough to allow fish to behaviorally redirect before they contact the structure.

There are approximately 52 different species of fish entrained into the TFCF per year; however, the total numbers are significantly different for the various species salvaged. Also, it is difficult if not impossible to determine exactly how many safely make it all the way to the collection tanks awaiting transport back to the Delta. Hauling trucks used to transport salvaged fish to release sites inject oxygen and contain an eight parts per thousand salt solution to reduce stress. The CVP uses two release sites, one on the Sacramento River near Horseshoe Bend and the other on the San Joaquin River immediately upstream of the Antioch Bridge. The transition boxes and

[56] Note that there would be no salvage operations performed when diversion flows originated solely from NCCF, and Skinner louver flows would be stopped at those times. Otherwise, salvage operations would be the same as current practice. Future south Delta operations will be managed to maintain, or reduce, the loss of covered fish by a variety of mechanisms including preservation of existing louver salvage efficiencies when possible. Dual operations, which are intended to reduce dependence on south Delta facilities that present fish hazards, may affect the frequency that the south Delta louvers are able to operate at ideal salvage efficiencies, but would neither preclude such efficiencies from being attained nor would be expected to result in greater overall loss of covered species at the south Delta facilities.

conduits between the louvers and fish screens were rehabilitated during the San Joaquin pulse period of 2004.

When south Delta hydraulic conditions allow, and within the original design criteria for the TFCF, the louvers are operated with the D-1485 and NMFS (2009) BiOp objectives of achieving water approach velocities: for striped bass of approximately 1 foot per second (ft/s) from May 15 through October 31, and for salmon of approximately 3 ft/s from November 1 through May 14. Channel velocity criteria are a function of bypass ratios through the facility. Due to changes in south Delta hydrology and seasonal fish protection regulations over the past twenty years, the present-day TFCF is able to meet these conditions approximately 55% of the time.

Fish passing through the facility are sampled at intervals of no less than 30 minutes every 2 hours when listed fish are present, generally December through June. When listed fish are not present, sampling intervals are 10 minutes every 2 hours. Fish observed during sampling intervals are identified by species, measured to fork length, examined for marks or tags, and placed in the collection facilities for transport by tanker truck to the release sites in the North Delta away from the pumps. In addition, TFCF personnel are currently required, per the court order, to monitor for the presence of spent female delta smelt in anticipation of expanding the salvage operations to include sub-20 mm larval delta smelt detection.

CDFW is leading studies of fish survival during the collection, handling, transportation, and release process, examining delta smelt injury, stress, survival, and predation. Thus far it has presented initial findings at various interagency meetings (Interagency Ecological Program, Central Valley Fish Facilities Review Team, and American Fisheries Society) showing relatively high survival and low injury. DWR has concurrently been conducting focused studies examining the release phase of the salvage process including a study examining predation at the point of release and a study examining injury and survival of delta smelt and Chinook salmon through the release pipe. Based on these studies, improvements to release operations and/or facilities, including improving fishing opportunities in Clifton Court Forebay (CCF) to reduce populations of predator fish, are being implemented.

CDFW and USFWS evaluated pre-screen loss and facility/louver efficiency for juvenile and adult delta smelt at the Skinner Delta Fish Protective Facility. DWR has also conducted pre-screen loss and facility efficiency studies for steelhead.

3.3.5.2 Harvey O. Banks Pumping Plant and Skinner Delta Fish Protective Facility

SWP facilities in the southern Delta include Clifton Court Forebay, John E. Skinner Delta Fish Protective Facility (Skinner), and the Banks Pumping Plant (Banks PP).

Clifton Court Forebay will be extensively modified and repurposed under the PA, as described in Section 3.2.5, *Clifton Court Forebay*, however, the modifications will not impact or change operations of the existing Banks and Skinner facilities.

Skinner is located west of the CCF, two miles upstream of the Banks PP. Skinner screens fish away from the pumps that lift water into the California Aqueduct. Large fish and debris are directed away from the facility by a 388-foot long trash boom. Smaller fish are diverted from the intake channel into bypasses by a series of metal louvers, while the main flow of water continues through the louvers and towards the pumps. The diverted fish pass through a secondary system of screens and pipes into seven holding tanks, where a sub-sample is counted and recorded. The salvaged fish are then returned to the Delta in oxygenated tank trucks.

The Banks PP is in the South Delta, about eight miles northwest of Tracy, and marks the beginning of the California Aqueduct. By means of 11 pumps, including two rated at 375 cfs capacity, five at 1,130 cfs capacity, and four at 1,067 cfs capacity, the plant provides the initial lift of water 244 feet into the California Aqueduct. The nominal capacity of the Banks Pumping Plant is 10,300 cfs, although Corps permits restrict 3- and 7-day averages to 6,680 cfs.

3.3.5.3 Clifton Court Forebay Aquatic Weed Control Program

DWR will apply herbicides or will use mechanical harvesters on an as-needed basis to control aquatic weeds and algal blooms in CCF. Herbicides may include Komeen®, a chelated copper herbicide (copper-ethylenediamine complex and copper sulfate pentahydrate) and Nautique®, a copper carbonate compound. These products are used to control algal blooms that can degrade drinking water quality through tastes and odors and production of algal toxins. Dense growth of submerged aquatic weeds, predominantly *Egeria densa*, can cause severe head loss and pump cavitation at Banks Pumping Plant when the stems of the rooted plant break free and drift into the trashracks. This mass of uprooted and broken vegetation essentially forms a watertight plug at the trashracks and vertical louver array. The resulting blockage necessitates a reduction in the pumping rate of water to prevent potential equipment damage through cavitation at the pumps. Cavitation creates excessive wear and deterioration of the pump impeller blades. Excessive floating weed mats also reduce the efficiency of fish salvage at the Skinner Fish Facility. Ultimately, this all results in a reduction in the volume of water diverted by the SWP. Herbicide treatments will occur only in July and August on an as needed basis in the CCF, dependent upon the level of vegetation biomass in the enclosure.

3.3.5.4 Contra Costa Canal Rock Slough Intake

The CCWD diverts water from the Delta for irrigation and M&I uses under its CVP contract and under its own water right permits and license, issued by SWRCB for users. CCWD's water system includes the Mallard Slough, Rock Slough, Old River, and Middle River (on Victoria Canal) intakes; the Contra Costa Canal and shortcut pipeline; and the Los Vaqueros Reservoir. The Rock Slough Intake facilities, the Contra Costa Canal, and the shortcut pipeline are owned by Reclamation, and operated and maintained by CCWD under contract with Reclamation. Reclamation completed construction of the fish screen at the Rock Slough intake in 2011, and testing and the transfer of operation and maintenance to CCWD is ongoing. Mallard Slough Intake, Old River Intake, Middle River Intake, and Los Vaqueros Reservoir are owned and operated by CCWD. The operation of the Rock Slough intake is included in the PA; the operation of the other intakes, and Los Vaqueros Reservoir, are not included in the PA.

The Rock Slough Intake is located about four miles southeast of Oakley, where water flows through a positive barrier fish screen into the earth-lined portion of the Contra Costa Canal. The fish screen at this intake was constructed by Reclamation in accordance with the CVPIA and the

1993 USFWS BiOp for the Los Vaqueros Project to reduce take of fish through entrainment at the Rock Slough Intake. The Canal connects the fish screen at Rock Slough to Pumping Plant 1, approximately four miles to the west. The Canal is earth-lined and open to tidal influence for approximately 3.7 miles from the Rock Slough fish screen. Approximately 0.3 miles of the Canal immediately east (upstream) of Pumping Plant 1 have been encased in concrete pipe, the first portion of the Contra Costa Canal Encasement Project to be completed. When fully completed, the Canal Encasement Project will eliminate tidal flows into the Canal because the encased pipeline will be located below the tidal range elevation. Pumping Plant 1 has capacity to pump up to 350 cfs into the concrete-lined portion of the Canal. Diversions at Rock Slough Intake are typically taken under CVP contract. With completion of the Rock Slough fish screen, CCWD can divert approximately 30% to 50% of its total annual supply (approximately 127 TAF) through the Rock Slough Intake depending upon water quality there.

The Rock Slough fish screen has experienced problems; the current rake cleaning system on the screens is unable to handle the large amounts of aquatic vegetation that end up on the fish screen (National Marine Fisheries Service 2015: 2). Reclamation is testing alternative technology to improve vegetation removal, an action that NMFS (2015: 4) has concluded will improve screen efficiency by minimizing the risk of fish entrainment or impingement at the fish screen. Reclamation's testing program is expected to continue at least until 2018. The PA presumes continued operation and maintenance of the fish screen design that is operational when north Delta diversion operations commence, subject to any constraints imposed pursuant to the ongoing ESA Section 7 consultation on Rock Slough fish screen operations.

3.3.6 Water Transfers (source: DWR 2009 and BDCP 2013)

California Water Law and the CVPIA promote water transfers as important water resource management measures to address water shortages provided certain protections to source areas and users are incorporated into the water transfer. Parties seeking water transfers generally acquire water from sellers who have available contract water and available stored water; sellers who can pump groundwater instead of using surface water; or sellers who will fallow crops or substitute a crop that uses less water in order to reduce normal consumptive use of surface diversions.

Water transfers occur when a water right holder within the Sacramento-San Joaquin River watershed undertakes actions to make water available for transfer. The PA does not address the upstream operations and authorizations (e.g., consultations under ESA Section 7) that may be necessary to make water available for transfer.

Transfers requiring export from the Delta are done at times when pumping and conveyance capacity at the CVP or SWP export facilities is available to move the water. Additionally, operations to accomplish these transfers must be carried out in coordination with CVP/SWP operations, such that the capabilities of the projects to exercise their own water rights or to meet their legal and regulatory requirements are not diminished or limited in any way. In particular, parties to the transfer are responsible for providing for any incremental changes in flows required to protect Delta water quality standards. All transfers will be in accordance with all existing regulations and requirements.

Purchasers of water for transfers may include Reclamation, CVP contractors, DWR, SWP entitlement holders, other State and Federal agencies, and other parties. DWR and Reclamation have operated water acquisition programs in the past to provide water for environmental programs and additional supplies to SWP entitlement holders, CVP contractors, and other parties. Past transfer programs include the following.

DWR administered the 1991, 1992, 1994, and 2009 Drought Water Banks and Dry Year Programs in 2001 and 2002.

Water transfers in the Delta watershed.

Reclamation operated a forbearance program in 2001 by purchasing CVP contractors' water in the Sacramento Valley to support CVPIA instream flows and to augment water supplies for CVP contractors south of the Delta and wildlife refuges. Reclamation administers the CVPIA Water Acquisition Program for Refuge Level 4 supplies and fishery instream flows.

DWR is a signatory to the Yuba River Accord Water Transfer Agreement through 2025 that provides fish flows on the Yuba River and water supply that is exported at DWR and Reclamation Delta Facilities. Reclamation may also become a signatory to that agreement in the future.

Reclamation and the San Luis Delta-Mendota Water Authority issued a ROD and NOD for the Long-term Transfers Program, which addressed water transfers from water agencies in northern California to water agencies south of the Sacramento-San Joaquin Delta (Delta) and in the San Francisco Bay Area. Water transfers will occur through various methods, including, but not limited to, groundwater substitution and cropland idling, and will include individual and multiyear transfers from 2015 through 2024.

In the past, CVP contractors and SWP entitlement holders have independently acquired water and arranged for pumping and conveyance through CVP/SWP facilities.

3.3.7 Maintenance of the Facilities

The PA includes the maintenance of the new north Delta facilities (intakes, conveyance facilities, and appurtenance structures), the HOR gate, and the south Delta facilities, as described below. This discussion is provided for informational purposes only; the PA does not seek incidental take authorization for facilities maintenance (see Section 3.1.6 *Take Authorization Requested*). Accordingly Reclamation will conduct a separate Section 7 consultation addressing facilities maintenance, if and when such a consultation is necessary. In-water facilities maintenance would comply with the in-water work windows[6] unless specified otherwise in subsequent Section 7 consultations. See Attachment BO#164 for further information on the frequency of maintenance activities.

3.3.7.1 North Delta Diversions

Appendix 3.B, *Conceptual Engineering Report, Volume 1*, Section 6.3, *Maintenance Considerations,* discusses maintenance needs at the intakes. These include intake dewatering, sediment removal, debris removal, biofouling, corrosion, and equipment needs.

3.3.7.1.1 Intake Dewatering

The intake structure on the land side of each screen bay group (i.e., a group of 6 fish screens) will be dewatered by closing the slide gates on the back wall of the intake structure, installing bulkheads in guides at the front of the structure, and pumping out the water with a submersible pump; see Appendix 3.C, *Conceptual Engineering Report, Volume 2*, drawings 15, 16, 17, 19, and 22, for illustrations of this structure. The intake collector box conduits can be dewatered by closing the gates on both sides of the flow control sluice gates and flowmeter and pumping out the water between the gates. Dewatering could be done to remove accumulated sediment (described below) or to repair the fish screens.

Intake dewater would likely be disposed by discharge to conveyance, an activity which would have to potential to affect listed species. Any discharge of dewatering waters to surface water (the Sacramento River) would occur only in accordance with the terms and conditions of a valid NPDES permit and any other applicable Central Valley Regional Water Quality Control Board requirements.

3.3.7.1.2 Sediment Removal

Sediment can bury intakes, reduce intake capability, and force shutdowns for restoration of the intake. Maintenance sediment removal activities include activities that will occur on the river side of the fish screens, as well as activities that will occur on the land side of the fish screens. The former have the potential to affect listed species. They include suction dredging around the intake structure, and mechanical excavation around intake structures using track-mounted equipment and a clamshell dragline. Mechanical excavation will occur behind a floating turbidity control curtain. These maintenance activities will occur on an approximately annual basis, depending upon the rates of sediment accumulation.

Sediment will also be annually dredged from within the sedimentation basins using a barge mounted suction dredge, will periodically be removed from other piping and conduits within the facility by dewatering, and will be annually removed from the sediment drying lagoons using equipment such as a front-end loader. Since these activities will occur entirely within the facility, they have no potential to affect listed species. The accumulated sediment will be tested and disposed in accordance with the materials reuse provisions of AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material*.

Maintenance dredging will occur only during NMFS- and USFWS-approved in-water work windows[6]. Potential effects to listed species from maintenance dredging will be further minimized by compliance with terms and conditions issued pursuant to regulatory authorizations for the dredging work. These authorizations typically include a permit for in-water work from the USACE and a water quality certification from the Central Valley Regional Water Quality Control Board. Such certifications include provisions minimizing the risk of turbidity, mobilization of contaminated sediment, or spill of hazardous material (such as diesel fuel).

3.3.7.1.3 Debris Removal

After heavy-to-extreme hydrologic events, the intake structures will be visually inspected for debris. If a large amount of debris has accumulated, the debris must be removed. Intake screens, which remove debris from the surface of the water, are maintained by continuous traveling cleaning mechanisms, or other screen cleaning technology. Cleaning frequency depends on the debris load.

A log boom system will be aligned within the river alongside the intake structure to protect the fish screens and fish screen cleaning systems from being damaged by large floating debris. Spare parts for vulnerable portions of the intake structure will be kept available to minimize downtime, should repairs be needed.

3.3.7.1.4 Biofouling

Biofouling, the accumulation of algae and other biological organisms, could occlude the fish screens and impair function. A key design provision for intake facilities is that all mechanical elements can be moved to the top surface for inspection, cleaning, and repairs. The intake facilities will have top-side gantry crane systems for removal and insertion of screen panels, tuning baffle assemblies, and bulkheads. All panels will require periodic removal for pressure washing. Additionally, screen bay groups will require periodic dewatering (as described above) for inspection and assessment of biofouling rates. With the prospective invasion of quagga and zebra mussels into inland waters, screen and bay washing will become more frequent. Coatings and other deterrents to reduce the need for such maintenance will be investigated during further facility design. In-water work is not expected to be necessary to address biofouling, as the potentially affected equipment is designed for ready removal. However, if needed, in-water work would be performed consistent with NMFS- and USFWS-approved in-water work windows[6].

3.3.7.1.5 Corrosion

Materials for the intake screens and baffles will consist of plastics and austenitic stainless steels. Other systems will be constructed of mild steel, provided with protective coatings to preserve the condition of those buried and submerged metals and thereby extend their service lives. Passive (galvanic) anode systems can also be used for submerged steel elements. Maintenance consists of repainting coated surfaces and replacing sacrificial (zinc) anodes at multi-year intervals.

3.3.7.1.6 Equipment Needs

Operation and maintenance equipment for the intake facilities include the following.

A self-contained portable high-pressure washer unit to clean fish screen and solid panels, concrete surfaces, and other surfaces.

Submersible pumps for dewatering.

A floating work platform for accessing, inspecting, and maintaining the river side of the facility.

A hydraulic suction dredge.

A man basket or bridge inspection rig to safely access the front of the intake structure from the upper deck.

3.3.7.1.7 Sedimentation Basins and Drying Lagoons

The sedimentation system at each intake will consist of a jetting system in the intake structure that will resuspend accumulated river sediment through the box conduits to two unlined earthen sedimentation basins where it will settle out, and then on to four drying lagoons (Appendix 3.C, *Conceptual Engineering Report, Volume 2,* Sheets 10-13, 18-21, and 28-30; see also Appendix 3.B, *Conceptual Engineering Report, Volume 1,* Section 6.1.2, *Sedimentation System General Arrangement*, for detailed description of the sedimentation system). Sediment particles larger than 0.002 mm are expected to be retained (settle out) in the sedimentation basins, while particles smaller than 0.002 mm (i.e., colloidal particles) will flow through to the tunnel system to the IF.

At each intake, a barge-mounted suction dredge will hydraulically dredge the sedimentation basins through a dedicated dredge discharge pipeline to 4 drying lagoons. Dredging will occur annually. Dredged material will be disposed at an approved upland site.

3.3.7.2 Tunnels

Maintenance requirements for the tunnels have not yet been finalized. Some of the critical considerations include evaluating whether the tunnels need to be taken out of service for inspection and, if so, how frequently. Typically, new water conveyance tunnels are inspected at least every 10 years for the first 50 years and more frequently thereafter. In addition, the equipment that the facility owner must put into the tunnel for maintenance needs to be assessed so that the size of the tunnel access structures can be finalized. Equipment such as trolleys, boats, harnesses, camera equipment, and communication equipment will need to be described prior to finalizing shaft design, as will ventilation requirements. As described above, it is anticipated that, following construction, large-diameter construction shafts will be modified to approximately 20-foot diameter access shafts.

3.3.8 Intermediate Forebay

The IF embankments will be maintained to control vegetation and rodents (large rodents, such as muskrat and beaver, have been known to undermine similarly constructed embankments, causing embankment failure.) Embankments will be repaired in the event of island flooding and wind/wave action. Maintenance of control structures could include roller gates, radial gates, and stop logs. Maintenance requirements for the spillway will include the removal and disposal of any debris blocking the outlet culverts.

The majority of easily settled sediments are removed at the sedimentation basins at each intake facility (see Section 3.3.6.1.2 *Sediment Removal*). The IF provides additional opportunity to settle sediment. It is anticipated that over a 50-year period, sediments will accumulate to a depth of approximately 4.1 feet, which is less than one-half the height of the overflow weir at the outlet of the IF. Thus maintenance dredging of the IF is not expected to be necessary during the term of the proposed action.

3.3.8.1 Clifton Court Forebay and Pumping Plant

The CCF embankments and grounds, including the vicinity of the consolidated pumping plant as well as the NCCF and SCCF, will all be maintained to control of vegetation and rodents (large rodents, such as muskrat and beaver, have been known to undermine similarly constructed embankments, causing embankment failure). They will also be subject to embankment repairs in the event of island flooding and wind/wave action. Maintenance of forebay control structures could include roller gates, radial gates, and stop logs. Maintenance requirements for the spillway will include the removal and disposal of any debris blocking the structure. Riprap slope protection on the water-side of the embankments will require periodic maintenance to monitor and repair any sloughing. In-water work, if needed (e.g. to maintain riprap below the ordinary high-water mark), would be performed during NMFS- and USFWS-approved in-water work windows[6].

The small fraction of sediment passing through the IF is transported through the tunnels to NCCF. Given the upstream sediment removal and the large storage available at the forebay, sediment accumulation at NCCF is expected to be minimal over a even 50-year period, and no maintenance dredging is expected to be needed during the life of the facility.

3.3.8.2 Connections to Banks and Jones Pumping Plants

Maintenance requirements for the canal will include erosion control, control of vegetation and rodents, embankment repairs in the event of island flooding and wind wave action, and monitoring of seepage flows. Sediment traps may be constructed by over-excavating portions of the channel upstream of the structures where the flow rate will be reduced to allow suspended sediment to settle at a controlled location. The sediment traps will be periodically dredged to remove the trapped sediment.

3.3.8.3 Power Supply and Grid Connections

Three utility grids could supply power to the PA conveyance facilities: Pacific Gas and Electric Company (PG&E) (under the control of the California Independent System Operator), the Western Area Power Administration (Western), and/or the Sacramento Municipal Utility District (SMUD). The electrical power needed for the conveyance facilities will be procured in time to support construction and operation of the facilities. Purchased energy may be supplied by existing generation, or by new generation constructed to support the overall energy portfolio requirements of the western electric grid. It is unlikely that any new generation will be constructed solely to provide power to the PA conveyance facilities. It is anticipated the providers of the three utility grids that supply power to the PA will continue to maintain their facilities.

3.3.8.4 Head of Old River Gate

For the operable barrier proposed under the PA, maintenance of the gates will occur every 5 to 10 years. Maintenance of the motors, compressors, and control systems will occur annually and require a service truck.

Each miter or radial gate bay will include stop log guides and pockets for stop log posts to facilitate the dewatering of individual bays for inspection and maintenance. Each gate bay will be inspected annually at the end of the wet season (April) for sediment accumulation. Maintenance dredging around the gate will be necessary to clear out sediment deposits. Dredging around the gates will be conducted using a sealed clamshell dredge. Depending on the rate of sedimentation, maintenance dredging is likely to occur at intervals of 3 to 5 years, removing no more than 25% of the original dredged amount. The timing and duration of maintenance dredging will comply with the proposed in-water work windows[6]. Spoils will be dried in the areas adjacent to the gate site. A formal dredging plan with further details on specific maintenance dredging activities will be developed prior to dredging. Guidelines related to dredging are given in Appendix 3.F, *General Avoidance and Minimization Measures,* AMM6 *Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material.* AMM6 requires preparation of a sampling and analysis plan; compliance with relevant NPDES and SWRCB requirements; compliance with proposed in-water work windows; and other measures intended to minimize risk to listed species.

3.3.8.5 Existing South Delta Export Facilities

The PA will include maintenance of CVP/SWP facilities in the south Delta after the proposed intakes become operational.

Maintenance means those activities that maintain the capacity and operational features of the CVP/SWP water diversion and conveyance facilities described above. Maintenance activities include maintenance of electrical power supply facilities; maintenance as needed to ensure continued operations; replacement of facility or system components when necessary to maintain system capacity and operational capabilities; and upgrades and technological improvements of facilities to maintain system capacity and operational capabilities, improve system efficiencies, and reduce operations and maintenance costs.

3.4 Conservation Measures

Conservation measures are actions intended to avoid, minimize, and offset effects of the PA on listed species, and to provide for their conservation and management. This section describes the types of effects that require avoidance or minimization, and conservation measures to offset effects by providing compensatory habitat. This section also summarizes the protection and restoration required to meet the species-specific compensation commitments. The compensation commitments provided in this section are based on discussions with CDFW, NMFS, and USFWS[57] and on typical species compensation provided through past Section 7 consultations, including programmatic BiOps, and taking into account the quality of habitat to be impacted relative to quality of the proposed compensation areas.

The PA includes a number of activities that are expected to cause few to no effects on listed species and therefore will not require compensation. These activities include acquisition and protection of mitigation lands for listed species of wildlife, the enhancement and management of protected and restored lands, and monitoring for listed species of fish and wildlife.

The protection of land requires no on-the-ground action or disturbance and thus has no potential to adversely affect species. Properly sited land protection will benefit listed species of wildlife by expanding and connecting existing protected lands. Grassland and vernal pool habitats will be

[57] USACE is also engaged in coordination regarding mitigation needs vis-à-vis compliance with provisions of USACE permits sought under the Proposed Action. Attachment BO#153 for letters documenting USACE participation in the consultation process.

protected to benefit San Joaquin kit fox, California tiger salamander, California red-legged frog, vernal pool fairy shrimp, and vernal pool tadpole shrimp. For details regarding the siting of lands that will be protected to benefit these species, see Section 3.4.5, *Terrestrial Species Conservation*.

Enhancement and management, and monitoring on protected and restored lands have potential to have some minor effects. For example, individuals could be harmed or harassed by management vehicles or personnel. These effects will be minimized through education and training, as described in Appendix 3.F, *General Avoidance and Minimization Measures*. Monitoring will be performed by qualified biologists. If handling of the species is necessary, this work will be done by qualified personnel with appropriate scientific collection permits.

Construction associated with the PA (Section 3.2, *Conveyance Facility Construction*) will result in the permanent and temporary removal of suitable habitat for listed species. Construction-related effects will be minimized through design, and through avoidance and minimization measures (Appendix 3.F, *General Avoidance and Minimization Measures*). The water conveyance facility design has considered and incorporated elements intended to minimize the total extent of the built facilities footprint, minimize loss of sensitive wildlife habitat, protect water quality, reduce noise and lighting effects, and reduce the total amount of transmission lines. In addition, there are commitments to entirely avoid the loss of habitat from certain activity types. Similarly, a number of operational and design features associated with the new intake facilities, and operational features of the PA, have been designed to minimize effects on fish and their critical habitat. These avoidance and minimization measures, as well as the proposed compensation for the loss of suitable habitat, are described for each species in Section 3.4.3 *Summary of Restoration for Fish Species,* and Section 3.4.5, *Terrestrial Species Conservation*.

The conservation measures include compensation for the loss of habitat for listed species that occurs as a result of restoration actions to be implemented for the mitigation of effects of construction and/or operation of the proposed facilities on listed species and wetlands. These restoration actions are components of the PA and are intended to meet requirements pursuant to various laws and regulations including the California Endangered Species Act, the California Environmental Quality Act, the National Environmental Policy Act, and the Clean Water Act. Habitat compensation will occur prior to the impacts being compensated. All lands protected as compensation for effects on habitat will be owned in fee title or through conservation easements, or will be included in approved conservation banks. All such lands will be protected and maintained, in the manner described in this section, in perpetuity[58]. The methods for quantifying loss of listed species habitat from restoration activities are described in Appendix 6.B, *Terrestrial Effects Analysis Methods*. The compensatory mitigation strategy is further detailed in Attachment BO#89 *Compensatory Mitigation Strategy*.

This biological assessment does not request take authorization for construction and maintenance of habitat restoration sites; such authorization will be sought, as needed, during the siting, design, and permitting work for each restoration site (see Section 3.1.6 *Take Authorization Requested*).

[58] For information on how the conservation measures will be funded, see Chapter 7 of the 2081(b) permit application, available at http://cms.capitoltechsolutions.com/ClientData/CaliforniaWaterFix/uploads/Ch_7_Funding.pdf.

The approximate location of the restoration sites is described for each species below. For each species, a technical team consisting of representatives from Reclamation, NMFS, USFWS, DWR and CDFW will be established to develop siting, design, and performance criteria for the needed habitat restoration. This group will work collaboratively to select the most biologically appropriate and cost-effective restoration site(s), design the restoration plan, set performance criteria, and develop the restoration unit management plan for the site(s).

3.4.1 Restoration and Protection Site Management Plans

DWR, as project applicant, will prepare and implement a management plan for each listed species habitat restoration and protection site. Management plans may be for an individual parcel or for multiple parcels that share common management needs. Reclamation and DWR will conduct surveys to collect the information necessary to assess the ecological condition and function of conserved species habitats and supporting ecosystem processes, and based on the results, will identify actions necessary to achieve the desired habitat condition at each site.

Management plans will be prepared in collaboration with CDFW, NMFS, and USFWS, consistent with their authority, and submitted to those agencies for approval within 2 years of the acquisition of each site. This schedule is designed to allow time for site inventories and identification of appropriate management techniques. During the interim period, management of the site will occur using best practices and based on successful management at the same site prior to acquisition or based on management at other similar sites. The plans will be working documents that are updated and revised as needed to incorporate new acquisitions suitable for coverage under the same management plan and to document changes in management approach that have been agreed to by Reclamation, DWR, and the appropriate wildlife agency or agencies (CDFW, NMFS, and USFWS), consistent with their authority.

Each management plan will include, but not be limited to, descriptions of the following elements.

- The species-specific objectives to be achieved with management of each site covered by the plan.

- Baseline ecological conditions (e.g., habitat maps, assessment of listed species habitat functions, occurrence of listed species and other native wildlife species, vegetation structure and composition, assessment of nonnative species abundance and effect on habitat functions, occurrence and extent of nonnative species).

- Vegetation management actions that benefit natural communities and listed species and reduce fuel loads, as appropriate, and that are necessary to achieve the management plan objectives.

- If applicable, a fire management plan developed in coordination with the appropriate agencies and, to the extent practicable, consistent with achieving the management plan objectives.

- Infrastructure, hazards, and easements.

- Existing and adjacent land uses and management practices and their relationship to listed species habitat functions.
- Applicable permit terms and conditions.
- Terms and conditions of conservation easements when applicable.
- Management actions and schedules.
- Monitoring requirements and schedules.
- Established data acquisition and analysis protocols.
- Established data and report preservation, indexing, and repository protocols.
- Adaptive management approach.
- Any other information relevant to management of the preserved parcels.

Management plans will be periodically updated to incorporate changes in maintenance, management, and monitoring requirements as they may occur.

Based on the assessment of existing site conditions (e.g., soils, hydrology, vegetation, occurrence of listed species) and site constraints (e.g., location and size), and depending on biological objectives of the restoration sites, management plans will specify measures for enhancing and maintaining habitat as appropriate.

3.4.2 Conservation Banking

To provide protection and restoration in a timely manner without incurring temporal loss of listed species habitat, DWR may use existing conservation banks, establish its own conservation banks, or provide habitat protection/restoration in advance of anticipated impacts.

DWR may opt to use existing conservation banks to meet its mitigation needs for listed species. An example is the Mountain House Conservation Bank in eastern Alameda County. This bank has available conservation credits for San Joaquin kit fox, California tiger salamander, California red-legged frog, and vernal pool fairy shrimp; and the PA is in the service area for this bank for all four species. However, no approved conservation banks in the action area could address the needs of listed species of fish.

DWR may also opt to create its own conservation banks, subject to conclusion of appropriate agreements with USFWS (noting that no such banks are included in the PA and no such agreements have yet been concluded). If such banks are operational at the time impacts accrue under the PA, DWR may then use bank credits to mitigate for impacts incurred under the PA. Protection and restoration of grasslands, riparian woodlands, and nontidal wetlands may be suitable subjects for this approach.

3.4.3 Summary of Restoration for Fish Species

Similar to the listed species of wildlife, the precise siting of parcels used to achieve habitat restoration for listed species of fish has yet to be determined. In consequence, this biological assessment does not seek take coverage for the performance of habitat restoration; rather, restoration sites will be subject to site-specific ESA Section 7 consultation prior to performance of restoration. The following descriptions of restoration actions offsetting effects to listed fish species, however, describes in general terms how and where restoration will be sited and constructed.

Given species occurrence locations and habitat requirements, the regions where restoration is likely to occur can be generally defined. Impact maximums have been determined for each species and summarized in Table 3.4-1. The conservation measures provide for the restoration of suitable habitat for Delta Smelt, Chinook salmon, steelhead, and green sturgeon.

The PA will occur, and its effects will be expressed, within designated critical habitat for each of the fish species, which encompasses waters throughout the entire legal Delta. The primary loss of habitat will occur in and around the proposed NDD. DWR and/or Reclamation will develop the siting and design of each individual tidal and channel margin restoration site consistent with the performance standards set by FWS and/or NMFS; final selection of restoration sites will be subject to NMFS and FWS concurrence as applicable. Each restoration site will be managed in accordance with a site-specific management plan, as described in Section 3.4.1, *Restoration and Protection Site Management Plans*.

Table 3.4-1 relies on the analyses presented in Chapters 5 and 6 pertaining to the permanent and temporary construction and operation effects on fish habitat. A GIS analysis was used to determine the acreage of effect for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures, and the temporary areas of effect (i.e., areas that will only be affected during construction activities; although all Delta Smelt habitat impacts are considered permanent because they are typically an annual fish.) Although there will be dredging and other construction-related disturbances in the Clifton Court Forebay, it is not considered critical habitat for any of the species, and the AMMs associated with construction will minimize effects.

Table 3.4-1. Summary of Maximum Direct Impact, Proposed Compensation, and Potential Location of Restoration for Federally Listed Fish Species

Resource	Location of Impact	Maximum Direct Impacts — Total Impacts: Permanent	Maximum Direct Impacts — Total Impacts: Temporary	Mitigation Ratio	Total Compensation, Restoration by Impact Area	Total Compensation, Restoration	Potential Location of Proposed Restoration
Chinook salmon and CCV steelhead							
Channel margin habitat (linear miles)	North Delta Diversions	Construction: 1.02; operations: 0.42	0 (occur within same footprint as permanent impacts)	3:1	4.3	4.3 miles	Sacramento River, Steamboat and Sutter Sloughs, or other areas agreed to by NMFS and CDFW[1]
Tidal perennial habitat (acres)	North Delta Diversions	6.6	20.1	3:1	80.1	154.8 acres	Sherman Island, North Delta, South Delta, or other areas agreed to by NMFS and CDFW, commensurate with area of specific effect
	Head of Old River[2]	2.9	0	3:1	7.5		
	Barge Landings	22.4	0	3:1	67.2		
Green sturgeon							
Tidal perennial habitat (acres)	North Delta Diversions	6.6	20.1	3:1	80.1	154.8 acres	Sherman Island, North Delta, or other areas agreed to by NMFS and CDFW
	Head of Old River[2]	2.9	0	3:1	7.5		
	Barge Landings	22.4	0	3:1	67.2		
Delta smelt							
Shallow water habitat (acres)	Shallow water critical habitat near North Delta Diversions and shallow water (non-critical) habitat from I Street Bridge to Knights Landing[3]	500.6[4]	All impacts are considered permanent to Delta smelt because of the species' predominately one-year life cycle		1,753	1827.7	Sherman Island, Cache Slough, North Delta or other areas agreed to by USFWS and CDFW
Tidal perennial habitat (acres)	Head of Old River[2]	2.9			7.5		
	Barge Landings	22.4			67.2		

[1] For purposes of estimating impacts of proposed restoration, it was assumed restoration will occur on the Sacramento River or Sutter or Steamboat Sloughs.
[2] The impacts of the temporary rock barrier have been mitigated, and therefore approximately 0.5 acres of impact is not assigned to the PA.
[3] The mitigation is for potential reduced access to shallow water critical and non-critical habitat because of the higher shoreline velocities expected from the NDD. [4] The 500.6 acres estimate is based on the total shallow water acres from downstream end of intake 5 to Knights Landing, including the footprint of the three intakes + wing wall transitions and associated in-water work during construction.

3.4.3.1 Chinook Salmon and CCV Steelhead

3.4.3.1.1 Avoidance and Minimization Measures

AMMs that will be implemented to avoid or minimize effects on Chinook salmon and steelhead are detailed in Appendix 3.F, *General Avoidance and Minimization Measures*, and are summarized in Table 3.2-2. General AMMs specifically applicable to Chinook salmon and CCV steelhead include AMMs 1 to 10, AMM14, AMM15, and AMM17. Furthermore, in-water activities associated with the proposed action will, as described in Section 3.2 *Conveyance Facility Construction*, comply with the proposed in-water work windows.[6] In addition, the following species-specific avoidance and minimization measure will be implemented to minimize the potential for adverse effects on Chinook salmon and CCV steelhead.

3.4.3.1.1.1 Nonphysical Fish Barrier at Georgiana Slough

Installation and seasonal operation of nonphysical barriers are hypothesized to improve survival of juvenile salmonids migrating downstream by guiding fish into channels in which they experience lower mortality rates (Welton et al. 2002; Bowen et al. 2012; Bowen and Bark 2012; Perry et al. 2014; California Department of Water Resources 2012b). The need to reduce juvenile salmonid entry into the interior Delta was recognized in the NMFS BiOp (2009a, 2011), which requires that engineering solutions be investigated to achieve a reduction in entrainment and that an approach be implemented if a NMFS-approved solution is identified by the process outlined in NMFS (2009a). Like other CVP/SWP operations, operation of any implemented engineering solution will be governed by the 2009 NMFS and 2008 USFWS biological opinions until this proposed action is operational; at that time, the operations of any barrier will be governed by the biological opinion(s) issued for this biological assessment. This AMM does not directly offset the effect of the operation of the NDD (that is, it does not reduce the extent of harm to fish that pass the NDD). However, it is expected to provide a higher probability of survival for fish that pass the NDD and encounter the Sacramento River-Georgiana Slough junction since the reduced Sacramento River flows that result from the operation of the NDD could increase the potential for entrainment into Georgiana Slough.

Since 2011, DWR has been testing various engineering solutions in the Sacramento River at Georgiana Slough. Two types of structures have been tested at this location and are considered options for this AMM. The first is a true nonphysical barrier that functions by inducing behavioral aversion to a noxious stimulus, e.g., visual or auditory deterrents (Noatch and Suski 2012). In 2011 and 2012 DWR tested a BioAcoustic Fish Fence (BAFF), which employs a three-component system comprising an acoustic deterrent within a bubble curtain that is illuminated by flashing strobe lights. The second type of structure, a floating fish guidance structure (FFGS), was tested in 2014. Though not a true nonphysical barrier because the structure contains physical screens, the structure induces behavioral aversion while essentially all the flow maintains its direction.

Because the design of the barrier associated with the PA has not yet been determined, construction of the barrier is not included in the PA and will instead be a separate Section 7 consultation, as required by NMFS (2009a) RPA IV.1.3, completed prior to the initiation of NDD operations (e.g., a Corps permit for installation and removal of the barrier will provide a future Federal nexus requiring consultation). At that time, the results of the investigations of various engineering solutions as required by the NMFS BiOp (2009a, 2011) are expected to be adequate to develop a proposal for barrier design, seasonal installation and removal, and detailed, design-specific protocols for operation. These design and operation specifics will be detailed in a biological assessment supporting what is expected to be a formal consultation.

In 2011 and 2012, DWR began to study the effectiveness of a BAFF at the Georgiana Slough–Sacramento River junction in preventing outmigrating juvenile Chinook salmon from entering Georgiana Slough (California Department of Water Resources 2012b; Perry et al. 2014). This type of nonphysical barrier has shown promising results in field studies at other locations such as a field experiment on Atlantic salmon (*Salmo salar*) smolts in the River Frome, UK (Welton et al. 2002). For the studies at the Georgiana Slough junction, approximately 1,500 acoustically tagged juvenile late fall–run Chinook salmon produced at the Coleman National Fish Hatchery (and, in 2012, approximately 300 steelhead) were released into the Sacramento River upstream of Georgiana Slough and their downstream migrations past the BAFF and divergence with Georgiana Slough were monitored (California Department of Water Resources 2012b; Perry et al. 2014). During the 2011 study period, the percentage of salmon smolts passing the junction that were entrained into Georgiana Slough was reduced from 22.1% (barrier off) to 7.4% (barrier on) due to implementation of the barrier (California Department of Water Resources 2012b; Perry et al. 2014). This improvement produced an overall efficiency rate of 90.8%; that is, 90.8% of fish that entered the area when the barrier was on exited by continuing down the Sacramento River. There was some indication that the behavior and movement patterns of juvenile salmon were influenced by the high river flows that occurred in spring 2011. However, at high (> 0.25 meter per second) and low (< 0.25 meter per second) across-barrier velocities, BAFF operations resulted in statistically significant increases in overall efficiency for juvenile salmon.

A second evaluation of the BAFF system at this location in 2012, a much drier year than 2011, showed somewhat lower fish exclusion rates into Georgiana Slough. During the 2012 study period, the percentage of salmon smolts passing the junction that were entrained into Georgiana Slough was reduced from 24.2% (barrier off) to 11.8% (barrier on) due to implementation of the barrier, with a similar reduction for steelhead (26.4% to 11.6%) (California Department of Water Resources 2015). This lower rate may be because of the notably lower river flow conditions in 2012 compared to 2011 (California Department of Water Resources 2015).

Perry et al. (2014) observed that fish more distant (i.e., across the channel) from the BAFF were less likely to be entrained into Georgiana Slough than those closer to the BAFF as they passed the slough, suggesting that guiding fish further away from the Georgiana Slough entrance would reduce entrainment into the slough. In essence, fish on the Georgiana Slough side of the critical streakline (the streamwise division of flow vectors entering each channel, or the location in the channel cross section where the parcels of water entering Georgiana Slough or remaining in the Sacramento River separate) have a higher probability of entering Georgiana Slough; by inducing a behavioral aversion to barrier stimuli, the BAFF increases the likelihood that fish remain on the Sacramento River side of the critical streakline. With this understanding, in 2014 DWR began a study of the effectiveness of a floating fish guidance structure at Georgiana Slough (California Department of Water Resources 2013). This structure uses steel panels suspended from floats to change water currents so that fish are guided towards the center of the river (away from the entrance to Georgiana Slough), but it does not substantially change the amount of water entering the slough. Studies of this technology in other locations have found it to be successful for guiding fish toward more desirable routes, e.g., at the Lower Granite Dam on the Snake River, Washington (Adams et al. 2001, as cited by Schilt 2007). This technology is considered as a potential design for this AMM because the large majority of flow does not change its destination; as with the BAFF, the structure's purpose is to keep fish on the Sacramento River side of the critical streakline. The results from the study of the FFGS are not yet available.

The uncertainties regarding the effectiveness of nonphysical barriers on all listed species, and at different flow rates, are continuing to be evaluated. While the response by juvenile hatchery-origin late fall–run Chinook salmon to the nonphysical barrier at Georgiana Slough appears positive, it does not necessarily reflect the response of other salmonids, particularly the smaller wild-origin winter-run (California Department of Water Resources 2012b) and spring-run Chinook salmon and young-of-the-year fall-run Chinook salmon.

Given the uncertainty of the structure design, the nascent science behind the effectiveness of any design at this location, and the lack of availability of FFGS results, the PA assumes that the operation of this AMM will provide a similar reduction in entrainment as was observed during the low flow conditions of 2012.

3.4.3.1.2 Restoration Actions[59]

Existing Commitments. DWR, Reclamation and the State and Federal Water Contractors commit to non-operational habitat and related actions that are part of the NMFS 2009 RPA, including:

NMFS 2009 RPA Action I.7: Improve Yolo Bypass Adult Fish Passage

Pursuant to the RPA in the 2009 NMFS biological opinion for the long-term operations of the Central Valley Project and State Water Project, DWR, Reclamation and the State and Federal Water Contractors shall improve adult salmonid and sturgeon passage through the Yolo Bypass – including the Fremont Weir – by modifying or removing barriers. This action will include preventing straying at Wallace Weir; improving several agricultural road crossings; improving Lisbon Weir; and improving the existing Fremont Weir fish ladder. This is expected to reduce migratory delays and straying of adult salmonids and sturgeon because insufficient adult fish passage at flood bypass weirs combined with attraction flows leads to stranding risk and reduced fish survival, timing, and condition. Additional updated information related to implementation is available in the Salmon Resiliency Strategy.

NMFS 2009 RPA Action I.6.1: Increase Juvenile Salmonid Access to Yolo Bypass, and Increase Duration and Frequency of Yolo Bypass Floodplain Inundation

Pursuant to the RPA in the 2009 NMFS biological opinion for the long-term operations of the Central Valley Project and State Water Project, DWR, Reclamation and the State and Federal Water Contractors shall increase juvenile salmonid access to the Yolo Bypass and improve adult fish passage by constructing an operable gated structure in the Fremont Weir. The facility shall be operated to increase the duration and frequency of Yolo bypass inundation between November 1 and mid-March, providing 17,000+ acres of enhanced floodplain habitat. This is

[59] See Permit Resolution Log, Item # 24. Proposed additional text in underline; insert directly after subsection title.

expected to benefit salmonids because lack of floodplain connectivity limits food availability and production and leads to reduced fish growth and subsequent survival. Additional updated information related to implementation is available in the Salmon Resiliency Strategy.

NMFS 2009 RPA Action NF 4: Implementation of Pilot Reintroduction Program above Shasta Dam

Pursuant to the RPA in the 2009 NMFS biological opinion for the long-term operations of the Central Valley Project and State Water Project, DWR, Reclamation and the State and Federal Water Contractors shall complete all required actions, monitoring, and reporting to guide establishment of an additional population of winter-run Chinook salmon and identify the benefits and risks of reintroduction for spring-run Chinook salmon and steelhead in the McCloud River and/or upper Sacramento River. This action is a Priority 1 NMFS recovery action and is required by Action Suite 5 Near-Term Fish Passage Actions of the NMFS 2009 biological opinion. Additional updated information related to implementation is available in the Salmon Resiliency Strategy.

NMFS 2009 RPA Action IV.1.3: Engineering Solutions to reduce Diversion into Interior Delta (Including Georgiana Slough Non-Physical Barrier)

Pursuant to the RPA in the 2009 NMFS biological opinion for the long-term operations of the Central Valley Project and State Water Project, DWR, Reclamation and the State and Federal Water Contractors shall increase the overall through-Delta survival of salmonids by reducing juvenile salmon entry into the interior Delta. This action is expected to benefit salmonids because it affects multiple habitat attributes that are hypothesized to affect juvenile survival, including predation and competition, outmigration cues, and entrainment risk. This action is consistent with a priority 1 NMFS recovery action for winter run Chinook salmon. Additional updated information related to implementation is available in the Salmon Resiliency Strategy.

NMFS 2009 RPA Action I.2.6: Complete Battle Creek Salmon and Steelhead Restoration Project

Pursuant to the RPA in the 2009 NMFS biological opinion for the long-term operations of the Central Valley Project and State Water Project, DWR, Reclamation and the State and Federal Water Contractors shall provide improved instream flow releases and safe fish passage to prime salmon and steelhead habitat on Battle Creek for winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley steelhead. This is a Priority 1 NMFS recovery action and required Action I.2.6, pursuant to the NMFS 2009 biological opinion. The project has been supported with federal, state and private funding. Additional updated information related to implementation is available in the Salmon Resiliency Strategy.

EcoRestore

California EcoRestore is an initiative to help coordinate and advance critical habitat restoration in the Delta by 2020. EcoRestore targets a broad range of habitat restoration projects, including aquatic, sub-tidal, tidal, riparian, flood plain, and upland ecosystem over 30,000 acres. A portion of the target restoration is associated with existing mandates for habitat restoration described above and is funded by the state and federal water contractors. Five thousand acres of habitat enhancements associated with EcoRestore are supported by Proposition 1 grants to local governments, non-profit organizations, and other entities. Funding will come primarily from the Delta Conservancy, the California Department of Fish and Wildlife, and the California Department of Water Resources. These efforts are neither proposed as nor considered mitigation for the PA.

Commitments Included for CWF Mitigation

The PA includes conservation measures to provide restoration of 154.8 acres of tidal perennial habitat suitable for Chinook salmon and steelhead and 4.3 miles of channel margin habitat to offset permanent and temporary losses of migration and rearing habitat due to construction-related effects. Implementation of these measures will be determined through the CWF Adaptive Management Program (AMP) IICG and funded out of the project budget related to construction costs and not through the additional funds as described below.

As a condition of approval of the incidental take permit under Section 2081(b) of the CA Fish & Game Code (2081(b) ITP)[60], DFW is requiring that, upon issuance of a final water right order by the State Water Resources Control Board that approves the changes in point of diversion for the Project, DWR will provide funds to implement multiple restoration actions necessary and sufficient to offset effects of the project on listed salmonids. DWR will provide $4,000,000 annually to benefit spring run chinook salmon (CHNSR) and winter run chinook salmon (CHNWR) and Steelhead in the Sacramento River watershed, with primary focus on projects upstream of the Delta (over and above those implemented as part of the existing commitments described above), consistent with the CWF AMP IICG process.

Upstream Habitat Restoration Actions. As a condition of the 2081(b) ITP, DFW is requiring DWR to improve spawning and rearing habitat for spring run chinook salmon (CHNSR), winter run chinook salmon (CHNWR) and steelhead, and contribute to establishment of additional populations of winter run, support adult spawning, egg incubation and juvenile production. The funding described above will be initially used specifically to establish a new population of CHNWR through introduction and reintroduction of fish into Sacramento River tributaries (which may include Battle Creek and/or upstream of Shasta Reservoir) and to support that population with associated habitat restoration and other measures prior to operation of the NDD or within 12 years of order issuance[61]. Consistent with the 2081(b) ITP, the goal of this action is to establish a new CHNWR population in the Sacramento River watershed within the term of this permit that meets the low extinction risk criteria identified by the Central Valley Technical Recovery Team (CVTRT) (Lindley et al.2007). As a condition of the 2081(b) ITP, DWR will fully fund and implement reintroduction and restoration action effectiveness monitoring and extinction risk monitoring to ensure that the goal is met. Additionally, the 2081(b) ITP requires that funding commitments will be sufficient to support creation and enhancement of Sacramento River spawning and instream and/or off-channel rearing habitat and measurable expansion of salmonid habitat capacity. Consistent with the 2081(b) ITP, the goal of this effort is to contribute to the quantity, quality, and diversity of important rearing habitat along the Sacramento River corridor for CHNWR, CHNSR, and steelhead, and may include use of mitigation bank(s) as appropriate. Initially efforts will be focused on restoring 80 acres of spawning and rearing habitat in the upper Sacramento River above the Red Bluff Diversion Dam

[60] According to draft permit conditions transmitted to DWR on May 5, 2017. A final permit decision by DFW has not been made and therefore the condition and decision to issue a permit may be subject to change consistent with DFW's requirements under CESA and according to compliance with the California Environmental Quality Act.
[61] As stated previously, according to the draft DFW's 2081(b) ITP, permit terms become operative at issuance of the SWRCB order approving the change of point of diversion for DWR and Reclamation, consistent with the requirements of the Delta Reform Act of 2009.

(RBDD). Restoration of rearing habitat in particular above RBDD is targeted at reducing density dependent reductions in CHNWR survival above RBDD. The committed annual funds may also be used to restore habitat in the middle Sacramento River (e.g., in Sutter Bypass). DWR will coordinate with CDFW, NMFS, FWS, Reclamation and other entities undertaking restoration and enhancement actions to identify the highest priority projects for funding annually. Restoration opportunities will align with species recovery needs and be guided by information in the Salmon Resiliency Strategy. This measure may be terminated with written approval from CDFW and NMFS upon demonstration that the measure has offset the population level effects of the CWF operations.

Delta Habitat Restoration. DWR and Reclamation commit to improve and expand the diversity, quantity, and quality of rearing and refuge habitat in the tidal portions of the Delta and Suisun Marsh, including conservation measures discussed below in 3.4.3.1.2.1 *Tidal Perennial Habitat Restoration*. As described in this section, the PA includes conservation measures to provide restoration of at least 1,800 acres of tidal habitat prior to operation of the NDD, consistent with the multi-species benefits that exist with restoration associated with the delta smelt conservation measures described below and other restoration efforts, that will contribute to improved growth, survival, and migratory success of juvenile CHNWR, CHNSR, and steelhead, including potential use of mitigation banks as deemed appropriate. Implementation of these measures will be funded out of the project budget related to construction costs and not through the additional funds as described above, and is in addition to the 9,000 acres of restoration currently being implemented through the previously described Existing Commitments.

It is expected that through the measures described above, additional tidal restoration will be provided to sufficiently address potential undesirable hydrodynamic effects of NDD operations (e.g. reverse flows). DWR and Reclamation commit to ongoing analytical efforts as part of the CWF AMP to accurately characterize the conditions in the near future when benefits of in-progress restoration projects (e.g., Cache Slough and Suisun Marsh) have begun to be realized. DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations. Restoration opportunities will align with species recovery needs and be guided by information in the Salmon Resiliency Strategy. Furthermore, DWR and Reclamation commit as part of the AMP to a monitoring program to assess the performance of these actions and modify the mitigation approach as necessary to offset the effects of the project as they are better understood.

Survival Rates

As a condition of the 2081(b) ITP, DFW is requiring DWR to operate the SWP, including CWF, to achieve pre-project juvenile CHNWR and CHNSR survival rates[62] at Chipps Island. The

[62] Based on the draft NMFS CWF BiOp's effects analysis, through-Delta (defined from Freeport to Chipps Island) survival rates of juvenile Chinook salmon vary based on Sacramento River flow. Specifically, the analysis conducted by Perry et al. (2017) demonstrates that acoustically tagged, hatchery-origin juvenile late fall-run Chinook salmon migration through the Delta is positively correlated with Sacramento River flow at Freeport. Flow-

2081(b) ITP provides that, if alternative migratory routes and/or other CWF mitigation efforts are able to increase the number of juvenile CHNSR and CHNWR successfully passing Chipps Island or improve downstream survival rates offsetting through-Delta loss associated with NDD operations, DFW will consider it as a potential mechanism to meet this criterion. As a condition of the 2081(b) ITP, DFW is requiring that the Test Period and Full Project Operations survival rates shall be determined by Post-Construction Study 12 (see Condition of Approval 9.6.11). DFW is requiring that survival estimates be provided to CDFW, the TOT and the NDDTT on an annual basis and used in the AMP to determine if criterion is being achieved.

Tidal Perennial Habitat Restoration

The PA includes 154.8 acres of tidal perennial habitat restoration to offset effects on salmonid rearing and migration habitat, as shown in Table 3.4-1.

Tidal perennial habitat restoration site selection and design will occur in coordination with CDFW, USFWS and NMFS. Restoration will primarily occur through breaching or setback of levees, thereby restoring tidal fluctuation to land parcels currently isolated behind those levees. Factors to be considered when evaluating sites for potential location and design of tidal perennial habitat restoration include the potential to create small (1^{st} and 2^{nd} order) dendritic tidal channels (channels that end in the upper marsh) for rearing (Fresh 2006); tidal freshwater sloughs with rich production of such insects as chironomid (midge) larvae; brackish marshes with emergent vegetation providing insect larvae, mysids, and epibenthic amphipods; and open-water habitats with drifting insects, zooplankton such as crab larvae, pelagic copepods, and larval fish (Quinn 2005).

Shallow subtidal areas in large portions of the Delta support extensive beds of nonnative submerged aquatic vegetation (SAV) that adversely affect listed species of fish (Nobriga et al. 2005; Brown and Michniuk 2007; Grimaldo et al. 2012). In other portions of the Delta, shallow subtidal areas provide suitable habitat for native species, such as Delta Smelt in the Liberty Island/Cache Slough area, and do not promote the growth of nonnative SAV (Nobriga et al. 2005; McLain and Castillo 2009). Tidal perennial habitat restoration is not intended to restore large areas of shallow subtidal aquatic habitat, which would collaterally create habitat for nonnative predators; rather, shallow subtidal aquatic habitat restoration is proposed in association with tidal habitat, which will provide more heterogeneity and support pelagic habitat adjacent to emergent wetland. Additionally, bench habitats will be incorporated into site selection and design to provide added specific benefits to salmonids, such as shallow-water foraging and refuge habitat. Tidal perennial habitat restoration will be sited in consultation with NMFS, USFWS, and CDFW, within areas of the Delta appropriate for offsetting effects of the PA.

specific survival rates of juvenile CHNWR and CHNSR are currently not available. As such, current flow-specific survival rates for acoustically tagged, hatchery-origin late fall-run Chinook salmon are used as preliminary estimates, and vary between ~35% and ~65% depending on flow with DCC closed and between <20% and ~45% with DCC open. The final flow-specific survival rates for the SWP, including CWF, for CHNWR and CHNSR will be determined by the results of Pre-construction Study 12 in Condition of Approval 9.6.10 through the AMP and final approval by CDFW and NMFS. The initial target survival rate is 40 %, but will be revised based on the pre-construction study. Upstream survival rates (e.g. RBDD to KNLRST) will also be assessed and improvements there will be considered in contributing to this target. Consideration of full system effects (e.g. restoration actions contributing to better growth and survival at ocean entry) may be included in the future based on monitoring and through the AMP.

Where practicable and appropriate, portions of restoration sites will be raised to elevations that will support tidal marsh vegetation following levee breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation (Ingebritsen et al. 2000). Surface grading will create a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored tidal perennial habitat is presented in Figure 3.4-1.

A technical team consisting of representatives from Reclamation, NMFS, USFWS, DWR and CDFW will be established to develop siting, design, and performance criteria for tidal perennial habitat restoration. This group will work collaboratively to select the most biologically appropriate and cost-effective restoration site(s), design the restoration plan, set performance criteria, and develop the restoration unit management plan for the site(s).

Completion of construction at each site will precede the corresponding impacts associated with conveyance facility construction. Full compliance with the conservation measures in this biological assessment will be based on performance of the completed site consistent with the success criteria stated in the site-specific design documents, as demonstrated in reports to be provided to CDFW, USFWS and NMFS by Reclamation.

General AMMs described in Appendix 3.F *General Avoidance and Minimization Measures* will be implemented during tidal restoration construction. General AMMs applicable to tidal restoration work include AMMs 1 to 10, AMM14, AMM15, and AMM17.

Construction of tidal perennial habitat restoration could affect salmonids by potential spills of construction equipment fluids; increased turbidity; increased exposure to methylmercury, pesticides and other contaminants when upland soils are inundated; and increased exposure to contaminants from disturbed aquatic sediments. However, these effects will be temporary and will be offset by the long-term benefits of the restored habitat (any sites so contaminated as to produce contrary results will be deemed unsuitable for restoration).

Actions to be taken during restoration are expected to include pre-breach management of the restoration site to promote desirable vegetation and elevations within the restoration area and levee maintenance, improvement, or redesign. This may require substantial earthwork outside but adjacent to tidal and other aquatic environments. Levee breaching will require removing levee materials from within and adjacent to tidal and other aquatic habitats. Levee breaching will entail in-water work using construction equipment such as bulldozers and backhoes; any in-water work will be performed during an in-water work window to be approved by CDFW, NMFS and USFWS. Removed levee materials will be placed on the remaining levee sections, placed within the restoration area, or hauled to a disposal area previously approved by CDFW, NMFS and USFWS. Construction at tidal habitat restoration sites is expected to involve the following activities.

Excavating channels to encourage the development of sinuous, high-density dendritic channel networks within restored marsh plain.

Modifying ditches, cuts, and levees to encourage more natural tidal circulation and better flood conveyance based on local hydrology.

Removal or breaching of existing levees or embankments or creation of new structures to allow restoration to take place while protecting adjacent land.

Prior to breaching, recontouring the surface to maximize the extent of surface elevation suitable for establishment of tidal marsh vegetation by scalping higher elevation land to provide fill for placement on subsided lands to raise surface elevations.

Prior to breaching, importing dredge or fill material and placing it in shallowly subsided areas to raise ground surface elevations to a level suitable for establishment of tidal marsh vegetation.

Tidal habitat restored adjacent to farmed lands may require construction of dikes to maintain those land uses.

Channel Margin Habitat Restoration

The PA includes 4.3 linear miles of channel margin restoration to offset effects on salmonid rearing and migration habitat caused by the reduction in frequency of inundation of existing restored benches and habitat loss due to the NDD. The proposed compensation is based on GIS analysis of the permanent and temporary footprint for the NDD, and a review of the magnitude of change for the select benches in the analysis. GIS was used to determine the acreage of effect for each structure, including areas located in designated critical habitat that could be affected by placement of permanent in-water structures as well as the temporary areas of effect. The construction-related portion reflects the footprint of the combined three NDD (5,367 linear feet, or 1.02 miles), including their association wing wall transitions. The operations-related portion reflects potentially less frequent inundation of riparian benches because of NDD water diversions. The total linear extent of riparian bench effects (2,212 feet, or 0.42 miles) was derived as follows, based on the greatest differences between NAA and PA from the analysis presented in Section 5.4.1.3.1.2.2.1.1, *Operational Effects*, in Chapter 5, *Effects Analysis for Chinook Salmon, Central Valley Steelhead, Green Sturgeon, and Killer Whale*:

- 29% lower riparian bench inundation index under PA in the Sacramento River from Sutter Steamboat sloughs to Rio Vista (1,685 feet of bench): 0.29 × 1,685 = 489 feet;
- 24% lower riparian bench inundation index under PA in the Sacramento River below the NDD to Sutter/Steamboat sloughs (3,037 feet of bench): 0.24 × 3,037 = 729 feet;

- 19% lower riparian bench inundation index under PA in Sutter/Steamboat Sloughs (5,235 feet of bench): 0.19 × 5,235 = 995 feet.

Channel margin restoration will be accomplished by improving channel geometry and restoring riparian, marsh, and mudflat habitats on the water side of levees along channels that provide rearing and outmigration habitat for juvenile salmonids, similar to what is currently done by the USACE and others when implementing levee improvements. Channel margin enhancements associated with federal project levees will not be implemented on the levee, but rather on benches to the waterward side of such levees, and flood conveyance will be maintained as designed. Channel margin enhancements associated with federal project levees may require permission from USACE in accordance with USACE's authority under the Rivers and Harbors Act (33 USC Section 408) and USACE levee vegetation policy. Accordingly, sites for the channel margin enhancements have not yet been determined, but they will be sited within the action area at locations along the Sacramento River, Steamboat and Sutter Sloughs, or in other areas subject to approval by NMFS and CDFW. On behalf of the State of California, DWR and the Central Valley Flood Protection Board are in coordination with USACE to minimize issues and identify a pathway for compliance. Any such enhancements will be designed, constructed, and maintained to ensure no reduction in performance of the federal flood project. Linear miles of enhancement will be measured along one side of a given channel segment (e.g., if both sides of a channel were enhanced for a length of 1 mile, this would account for a total of 2 miles of channel margin enhancement).

Chinook salmon and steelhead use channel margin habitat for rearing and protection from predators, and the primary purpose of channel margin habitat restoration is to offset shoreline effects caused by permanent habitat removal. Vegetation along channel margins contributes woody material, both instream and on channel banks, which increases instream cover for fish and enhances habitat for western pond turtle. Channel margin habitat is expected to provide rearing habitat and improve conditions along important migration corridors by providing increased habitat complexity, overhead and in-water cover, and prey resources for listed species of fish. This conservation measure is intended to increase habitat diversity and complexity, provide long-term nutrient storage and substrate for aquatic macroinvertebrates, moderate flow disturbances, increase retention of leaf litter, and provide refuge for fish during high flows. Channel margin habitat is expected to increase rearing habitat for Chinook salmon fry in particular, through enhancement and creation of additional shallow-water habitat that will provide foraging opportunities and refuge from unfavorable hydraulic conditions and predation.

Channel margin enhancement will be achieved by implementing site-specific projects. The following habitat suitability factors will be considered when evaluating sites for potential location and design of enhanced channel margins.

Existing poor habitat quality and biological performance for listed species of fish combined with extensive occurrence of listed species of fish.

Locations where migrating salmon and steelhead are likely to require rest during high flows.

The length of channel margin that can be practicably enhanced and the distance between enhanced areas (there may be a tradeoff between enhancing multiple shorter reaches that have less distance between them and enhancing relatively few longer reaches with greater distances between them).

The potential for native riparian plantings to augment breeding and foraging habitat for listed species using riparian habitat, such as Swainson’s hawk, western yellow-billed cuckoo, tricolored blackbird, or riparian brush rabbit, in proximity to known occurrences.

The potential cross-sectional profile of enhanced channels (elevation of habitat, topographic diversity, width, variability in edge and bench surfaces, depth, and slope).

The potential amount and distribution of installed woody debris along enhanced channel margins.

The extent of shaded riverine aquatic overstory and understory vegetative cover needed to provide future input of large woody debris.

A technical team consisting of representatives from Reclamation, NMFS, USFWS, DWR and CDFW will be established to develop siting, design, and performance criteria for channel margin restoration. This group will work collaboratively to select the most biologically appropriate and cost-effective restoration site(s), design the restoration plan, set performance criteria, and develop the restoration unit management plan for the site(s).

Prior to channel margin enhancement construction (the on-the-ground activities that will put the channel margin enhancements in place) for each project, preparatory actions will include interagency coordination, feasibility evaluations, site acquisition, development of site-specific plans, and environmental compliance. Completion of construction at each site will precede the corresponding impacts associated with conveyance facility construction, but full compliance with the conservation measures in this biological assessment will be based on performance of the completed site consistent with the success criteria stated in the site-specific design documents, as demonstrated in reports to be provided to CDFW, USFWS and NMFS by Reclamation.

General AMMs described in Appendix 3.F, *General Avoidance and Minimization Measures* will be implemented, and an in-water work windows subject to approval by CDFW, USFWS and NMFS will be observed, during implementation of channel margin enhancement. General AMMs applicable to channel margin enhancement work include AMMs 1 to 10, AMM14, AMM15, and AMM17. After construction, each project will be monitored and adaptively managed to ensure that the success criteria outlined in the site-specific restoration plan are met.

Channel margin enhancement actions are expected to be performed in the following manner.

Use large mechanized equipment (typically, a trackhoe) to remove riprap from channel margins.

Use grading equipment such as trackhoes and bulldozers to modify the channel margin side of levees or setback levees to create low floodplain benches with variable surface elevations that create hydrodynamic complexity and support emergent vegetation.

Use construction equipment such as trackhoes, bulldozers and cranes to install large woody material (e.g., tree trunks and stumps) into constructed low benches or into existing riprapped levees to provide physical complexity.

Use personnel and small powered equipment such as off-road vehicles (ORV) to plant riparian and emergent wetland vegetation on created benches.

3.4.3.1.2 South Delta Habitat Restoration

The PA includes construction in the central and south Delta of the HOR gate and several barge landings. This construction will convert areas that are considered aquatic habitat for salmon into physical structures that commonly attract predatory fish and may reduce habitat complexity for native fishes. The affected habitat largely consists of rip-rap, and effects on this habitat will be offset by the restoration shown, for each listed species, in Table 3.4-1. Mitigation proposed as part of the PA includes restoration actions that will offset ,at a 3:1 ratio, any habitat impacts that may occur due to HOR gate and barge landing construction. The PA restoration actions will adhere to the following principles, which assure that the proposed habitat restoration benefits salmonids.

Habitat restoration and mitigation efforts will target migration routes commonly used by San Joaquin River basin salmonids to the extent possible. Highest priority for restoration site selection will apply to sites near the south Delta construction sites. Sites upstream of the head of Old River will also be considered if those locations provide greater benefit.

The restoration will focus on creating benefits for salmonids through improved habitat function. Some combination of channel margin and tidal perennial habitat, cited and designed in coordination with NMFS and CDFW, will be targeted to achieve these benefits, consistent with restoring south Delta historical habitat function and processes (see Whipple et al. 2012). Habitat functions most beneficial to salmonids and native species will therefore be the focus on the restoration mitigation efforts. Examples include restoration of floodplain habitat, riparian habitat with appropriate vegetation to deliver organic inputs and terrestrial invertebrates to the adjacent riverine system, refugia from predators or elevated velocities resulting from high flows, and seasonal flooding during winter and spring even in drier water year types.

As part of the restoration of tidal perennial and/or channel margin habitat restoration, features may include small-scale levee setbacks or benches that provide seasonally inundated terraces during high runoff events. Restoration plans will consider areas where this functionality can be restored or created. An Engineer Technical Letter variance will need to be obtained from the Corps of Engineers, and may limit the areas that can be restored.

Restoration areas will promote benefits for native species and deterrents to non-native species. For instance, seasonal flooding and draining with varying inundation periods are a natural deterrent to colonization of invasive plants and species. Vegetation on the created terraces or floodplains will be monitored for invasive plant species. Control of invasive plants will be performed in a manner to be determined in consultation with the resource agencies to avoid infestations.

3.4.3.2 Green Sturgeon

3.4.3.2.1 Avoidance and Minimization Measures

The AMMs shown in Table 3.2-2 also apply to green sturgeon. Details of each of these measures are provided in Appendix 3.F, *General Avoidance and Minimization Measures*.

Tidal Perennial Habitat Restoration Actions

Based on the current estimate of effects, the PA includes restoration of 154.8 acres of tidal perennial habitat suitable for green sturgeon, with a focus on intertidal and subtidal areas for foraging (Israel and Klimley 2008). The general approach to tidal perennial habitat restoration will parallel that described in Section 3.4.3.1.2.1 *Tidal Perennial Habitat Restoration*. As with tidal habitat restoration benefitting Chinook salmon and steelhead, a technical team consisting of representatives from Reclamation, NMFS, USFWS, DWR and CDFW will be established to develop siting, design, and performance criteria for tidal perennial habitat restoration. This group will work collaboratively to select the most biologically appropriate and cost-effective restoration site(s), design the restoration plan, set performance criteria, and develop the restoration unit management plan for the site(s). To the extent practicable, tidal perennial habitat restoration benefitting green sturgeon will be colocated with tidal perennial habitat restoration benefitting Chinook salmon and steelhead.

Tidal perennial habitat will be sited in areas suitable for creation of intertidal and subtidal habitat, which will provide important foraging habitat for green sturgeon (Israel and Klimley 2008). On the basis of the observed areas occupied by acoustically tagged juvenile green sturgeon (Klimley et al. 2015), it is expected that areas prioritized for salmonid restoration will also provide suitable function for green sturgeon if including elevations to yield intertidal and subtidal habitat.

3.4.3.3 Southern Resident Killer Whale

3.4.3.3.1 Avoidance and Minimization Measures

Since the proposed action is not identified as having adverse effects on Southern Resident killer whale, and the species is not known to occur in the action area, no avoidance and minimization measures are proposed for this species.

3.4.3.3.2 Restoration Actions

Since the proposed action is not identified as having adverse effects on Southern Resident killer whale, and the species is not known to occur in the action area, no compensation measures are proposed for this species.

3.4.3.4 Delta Smelt

3.4.3.4.1 Avoidance and Minimization Measures

AMMs that will be implemented to avoid or minimize effects on Delta Smelt are detailed in Appendix 3.F, *General Avoidance and Minimization Measures*, and are summarized in Table 3.2-2. General AMMs specifically applicable to Delta Smelt include AMMs 1 to 7, AMM8, AMM9, AMM14, AMM15, and AMM17. Furthermore, in-water activities associated with the proposed action will, as described in Section 3.2 *Conveyance Facility Construction*, comply with the proposed in-water work windows[6].

3.4.3.4.2 Conservation Measures

The following conservation measure is proposed for Delta Smelt: Restoration of nearly 1830 acres of habitat suitable for Delta Smelt, of which nearly 102.7 acres is intended to offset construction impacts on Delta Smelt and their habitat, and approximately 1750[63] acres are intended to offset potential impaired Delta Smelt access to shallow water habitat in the vicinity and upstream of the NDDs (Table 3.4-1). In consultation with CDFW and USFWS staff, this acreage was developed to provide flexibility in meeting the current and future habitat needs of Delta Smelt, rather than a more rigid interpretation of mitigation ratios based on existing habitat features. Restoration will be performed at a site(s) in the vicinity of Sherman Island, Cache Slough, or the north Delta to be approved by USFWS. The proposed habitat restoration, shown in Table 3.4-1, will offset effects on Delta Smelt spawning, rearing, and migration habitat. Of this total, the PA proposes to mitigate approximately 1750 acres of shallow water habitat for impacts related to the potential changes in access to shallow water habitat adjacent to and upstream of the proposed NDD. In addition to potential use of this habitat during the early part of the life cycle, Delta Smelt may also use this habitat during spawning, which is believed to occur in sandy beach areas. In addition to the acreage commitment to offset effects to this habitat, a program to study spawning habitat requirements as well as augment the quantity and quality of spawning habitat Delta Smelt can access will be implemented. See Attachment BO#163 for additional details. The effects analysis hypothesizes that this potential spawning area may become inaccessible to Delta Smelt because of the presence of the NDD (see Chapter 6). Monitoring of Delta Smelt use of this area will occur to evaluate whether this effect is occurring, and the consultation will be reinitiated if it is found that Delta Smelt use this area in the future.

Habitat restoration site selection and design will occur in coordination with USFWS and NMFS. Restoration will primarily occur through breaching or setback of levees, thereby restoring tidal fluctuation to land parcels currently isolated behind those levees. Factors to be considered when evaluating sites for potential location and design of habitat restoration include the potential to create desirable habitat features, as summarized by Sommer and Mejia (2013) in their suggestions for pilot Delta Smelt restoration projects: low salinity (< 6 ppt); moderate temperature (7–25°C); high turbidity (>12 NTU); sand-dominated substrate; at least moderately tidal; high copepod density; low SAV; low *Microcystis*; and open water habitat adjacent to long residence time habitat. These factors are similar to those considered in terms of crediting restoration sites in the Delta:

Improved rearing habitat: High order, marsh-adjacent channels; energetic; turbid, cool, low salinity water over a diverse landscape for capturing prey and decreased predation; accessible to Delta Smelt for direct use.

[63] Note this mitigation acreage accounts for the NDD footprint/construction effects, which is also included in the preceding mitigation acreage for overall construction-related effects. In total, 1,827.7 acres of shallow water habitat restoration is proposed to offset effects to Delta smelt due to PA construction and operations. See Table 3.4-1 for more information on restoration acreages under the PA.

Improved spawning habitat: Sandy beaches with appropriate water velocities and depths to maintain the habitat and is accessible to Delta Smelt for direct use. Must have appropriate water quality conditions for Delta Smelt.

Geographic priority will be given to sites in the vicinity of Sherman Island, Cache Slough, and the North Delta. Tidal perennial habitat restoration will replace loss of such habitat at barge landings and the HOR gate, whereas shallow water habitat restoration will replace loss of such habitat in the north Delta as a result of NDD construction and operations.

Shallow subtidal areas in large portions of the Delta support extensive beds of nonnative SAV that adversely affect listed species of fish (Nobriga et al. 2005; Brown and Michniuk 2007; Grimaldo et al. 2012). In other portions of the Delta, shallow subtidal areas provide suitable habitat for native species, such as Delta Smelt in the Liberty Island/Cache Slough area, and do not promote the growth of nonnative SAV (Nobriga et al. 2005; McLain and Castillo 2009). Shallow water and tidal perennial habitat restoration is not intended to restore large areas of shallow subtidal aquatic habitat, which would collaterally create habitat for nonnative predators; rather, shallow subtidal aquatic habitat restoration is proposed in association with tidal habitat, which will provide more heterogeneity and support pelagic habitat adjacent to emergent wetland. Tidal perennial habitat restoration will be sited in the vicinity of Sherman Island, Cache Slough, or at other sites in the north Delta.

Where practicable and appropriate, portions of restoration sites will be raised to elevations that will support tidal marsh vegetation following levee breaching. Depending on the degree of subsidence and location, lands may be elevated by grading higher elevations to fill subsided areas, importing clean dredged or fill material from other locations, or planting tules or other appropriate vegetation to raise elevations in shallowly subsided areas over time through organic material accumulation (Ingebritsen et al. 2000). Surface grading will create a shallow elevation gradient from the marsh plain to the upland transition habitat. Based on assessments of local hydrodynamic conditions, sediment transport, and topography, restoration activities may be designed and implemented in a manner that accelerates the development of tidal channels within restored marsh plains. Following reintroduction of tidal exchange, tidal marsh vegetation is expected to establish and maintain itself naturally at suitable elevations relative to the tidal range. Depending on site-specific conditions and monitoring results, patches of native emergent vegetation may be planted to accelerate the establishment of native marsh vegetation on restored marsh plain surfaces. A conceptual illustration of restored tidal perennial habitat is presented in Figure 3.4-1.

A technical team consisting of representatives from Reclamation, NMFS, USFWS, DWR and CDFW will be established to develop siting, design, and performance criteria for tidal perennial habitat restoration. This group will work collaboratively to select the most biologically appropriate and cost-effective restoration site(s), design the restoration plan, set performance criteria, and develop the restoration unit management plan for the site(s).

Completion of construction at each site will precede the corresponding impacts associated with conveyance facility construction. Full compliance with the conservation measures in this biological assessment will be based on performance of the completed site consistent with the success criteria stated in the site-specific design documents, as demonstrated in reports to be provided to CDFW, USFWS and NMFS by Reclamation.

General AMMs described in Appendix 3.F *General Avoidance and Minimization Measures* will be implemented during tidal restoration construction. General AMMs applicable to tidal restoration work include AMMs 1 to 10, AMM14, AMM15, and AMM17.

Construction of shallow water and tidal perennial habitat restoration could affect Delta Smelt by potential spills of construction equipment fluids; increased turbidity; increased exposure to methylmercury, pesticides and other contaminants when upland soils are inundated; and increased exposure to contaminants from disturbed aquatic sediments. However, these effects will be temporary and will be offset by the long-term benefits of the restored habitat (any sites so contaminated as to produce contrary results will be deemed unsuitable for restoration).

Actions to be taken during restoration are expected to include pre-breach management of the restoration site to promote desirable vegetation and elevations within the restoration area and levee maintenance, improvement, or redesign. This may require substantial earthwork outside but adjacent to tidal and other aquatic environments. Levee breaching will require removing levee materials from within and adjacent to tidal and other aquatic habitats. Levee breaching will entail in-water work using construction equipment such as bulldozers and backhoes; any in-water work will be performed during an in-water work window to be approved by CDFW, NMFS and USFWS. Removed levee materials will be placed on the remaining levee sections, placed within the restoration area, or hauled to a disposal area previously approved by CDFW, NMFS and USFWS. Construction at tidal habitat restoration sites is expected to involve the following activities.

Excavating channels to encourage the development of sinuous, high-density dendritic channel networks within restored marsh plain.

Modifying ditches, cuts, and levees to encourage more natural tidal circulation and better flood conveyance based on local hydrology.

Removal or breaching of existing levees or embankments or creation of new structures to allow restoration to take place while protecting adjacent land.

Prior to breaching, recontouring the surface to maximize the extent of surface elevation suitable for establishment of tidal marsh vegetation by scalping higher elevation land to provide fill for placement on subsided lands to raise surface elevations.

Prior to breaching, importing dredge or fill material and placing it in shallowly subsided areas to raise ground surface elevations to a level suitable for establishment of tidal marsh vegetation.

Tidal habitat restored adjacent to farmed lands may require construction of dikes to maintain those land uses.

3.4.4 Spatial Extent, Location, and Design of Restoration for Listed Species of Wildlife

The spatial extent of restoration and protection activities will be determined by the spatial extent of impacts and the applied mitigation ratios. While actual impacts and compensation will be determined on an annual basis during construction of the PA, as detailed in Section 3.4.1, *Restoration and Protection*, maximum impact limits will be set to define the upper bounds of effects on suitable habitat for listed species of wildlife. Table 3.4-2 summarizes the maximum impact limit, mitigation ratios, and total proposed compensation. This includes compensation for species protected under CESA because this compensation is a component of the PA. The maximum impact on habitat for listed species is estimated using the methods described in Appendix 6.B, *Terrestrial Effects Analysis Methods*. The total compensation proposed to offset effects if all impacts occur is described in Section 3.4.5 *Terrestrial Species Conservation*. The results of the impact analysis are summarized in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*.

The precise siting of parcels used to achieve habitat restoration and protection has yet to be determined. Compensation will be sited near the location of impacts if and when practicable and feasible. Given species occurrence locations and habitat requirements, the regions where restoration and protection are likely to occur can be generally defined. The regions are summarized in Table 3.4-2 and further described below. Impacts on habitat for listed species of wildlife as a result of conservation measures are described and quantified in Chapter 6, *Effects Analysis for Delta Smelt and Terrestrial Species*. If, during construction, impacts exceed the limits set forth here, the Section 7 consultation will need to be reinitiated. The conservation measures provide for the restoration of suitable habitat for giant garter snake, valley elderberry longhorn beetle, vernal pool fairy shrimp, and vernal pool tadpole shrimp.

Restoration of nontidal wetlands for the giant garter snake is likely to occur in the central or east central portion of the legal Delta, or to the east of the legal Delta. Recent sightings of giant garter snake on Webb Island, Empire Tract, Bacon Island, and Decker Island suggest the species could benefit from nontidal wetland restoration in the central or east central Delta. Other potential locations for restoration include the Stone Lakes Wildlife Refuge, the Cosumnes-Mokelumne area, and the Caldoni Marsh/White Slough region.

Restoration of valley elderberry longhorn beetle suitable habitat will likely occur in the north Delta. This region includes several known occurrences (just southwest of West Sacramento) and will allow riparian restoration to be part of a larger tidal or riparian restoration effort as part of the California WaterFix. Valley elderberry longhorn beetle restoration could also be achieved as part of channel margin enhancement efforts as part of the California WaterFix (Section 3.4.3 *Summary of Restoration for Fish Species*).

Vernal pool restoration to compensate for effects on vernal pool fairy shrimp and vernal pool tadpole shrimp will be prioritized in the Altamont Hills recovery area, just northwest of the Clifton Court Forebay, which also coincides with the vernal pool fairy shrimp critical habitat unit that will be affected by the PA. Other restoration opportunities might exist in this region, but outside the recovery area. This region is nearest the impact location, includes occurrences of these two species, and is located at the urban edge of a larger complex of protected, intact vernal pools where restoration opportunities likely exist. There is also potential to mitigate effects on these species through use of a conservation bank. The restoration locations for all listed species will be determined in coordination with USFWS staff. Siting criteria for restoration activities is detailed in Section 3.4.5, *Terrestrial Species Conservation*.

Table 3.4-2. Summary of Maximum Direct Impact, Proposed Compensation, and Potential Location of Restoration and Protection for Federally Listed Species of Wildlife[64]

Resource	Total Modeled Habitat in the Action Area (Acres)	Maximum Direct Impacts		Mitigation Ratios		Total Proposed Compensation if All Impacts Occur		Potential Location of Proposed Restoration and Protection
		Total Impacts						
		Permanent (Acres)	Temporary Disturbance[1] (Acres)	Protection	Restoration	Total Compensation, Protection	Total Compensation, Restoration	
San Joaquin kit fox	2,956	47	11	3:1	-	141	0	Byron Hills Region, East Contra Costa County, or FWS-approved conservation bank
Western yellow-billed cuckoo	11,224	32	0	0	2:1	0	64	USFWS approved location
Giant garter snake								
Aquatic habitat	26,328	205	0	2:1 to 3:1		410 to 615		Northeast and Central Delta
Upland habitat	62,619	570	7	2:1 to 3:1		1,140 to 1,710		
California red-legged frog								
Aquatic habitat	118	1[i]	1	3:1		3		Byron Hills Region, East Contra Costa County or FWS approved conservation bank
Upland cover and dispersal habitat	3,498	51[e]	17	3:1	-	153	0	
California tiger salamander	12,724	50[e]	8	3:1	-	150	0	Byron Hills Region, East Contra Costa County or FWS approved conservation bank
Valley elderberry longhorn beetle								
Riparian vegetation	16,300	49	19	-	-[c]	0	70[c]	North, east, and south Delta
Nonriparian channels and grasslands	15,195	227	87	-	-[c]	0	-[c]	
Vernal pool fairy shrimp								
Vernal pool complex - Direct	89	6	0	-	2:1/3:1[d]	0	12/18[d]	Byron Hills Region, west of Clifton Court Forebay, prioritizing Altamont Hills Recovery Area, or conservation bank.
Vernal pool tadpole shrimp								
Vernal pool complex – Direct	89	6	0	-	2:1/3:1[d]	0	12/18[d]	Byron Hills Region, west of Clifton Court Forebay,

[64] Maximum direct impacts presented here do not include effects from restoration/mitigation because take associated with restoration/mitigation will not be authorized under the biological opinion.

Resource	Total Modeled Habitat in the Action Area (Acres)	Maximum Direct Impacts — Total Impacts: Permanent (Acres)	Maximum Direct Impacts — Total Impacts: Temporary Disturbance[1] (Acres)	Mitigation Ratios: Protection	Mitigation Ratios: Restoration	Total Proposed Compensation if All Impacts Occur: Total Compensation, Protection	Total Proposed Compensation if All Impacts Occur: Total Compensation, Restoration	Potential Location of Proposed Restoration and Protection
								prioritizing Altamont Hills Recovery Area, or conservation bank
Least Bell's vireo	11,224	32	0	0	2:1	0	64	USFWS approved location

[1] Temporary disturbance will be mitigated by returning disturbed areas to pre-project conditions. This disturbance mostly includes overland travel and temporary work areas in grasslands and agricultural lands.

[a] Giant garter snake upland habitat will be created or protected in association with the protected and restored aquatic habitat.

[b] Aquatic and upland compensation is primarily based on the loss of aquatic habitat, however, the loss of upland habitat patches that are not adjacent to effected aquatic habitat will be mitigated 3:1. There is 52 acres of upland habitat loss that is not adjacent to effected aquatic habitat therefore 156 acres of protection and restoration is required for compensation. 1/3 (52 acres) of the 156 acres of compensation will be achieved through aquatic protection and restoration and 2/3 (104 acres) will be achieved by upland protection and restoration.

[c] The impact assessment is based on the loss of elderberry bush stems and the compensation is based on the required number of transplants, elderberry seedlings, and native plant plantings.

[d] Compensation varies for vernal pool crustaceans, depending on whether the compensation is achieved with by conservation bank/or non-bank means.

[e] Includes 47 acres within the construction footprint and 4 acres of upland habitat potentially subject to vibrations adjacent to construction.

3.4.5 Terrestrial Species Conservation

The following sections detail aspects of the PA intended to avoid and minimize adverse effects on listed species of wildlife and describe offsetting measures intended to compensate for adverse effects on listed species of wildlife. In addition to species-specific avoidance and minimization measures (AMMs) discussed below, general avoidance and minimization measures that would be implemented uniformly during construction and maintenance/management of proposed water facilities and performance of conservation measures are fully detailed in Appendix 3.F, *General Avoidance and Minimization Measures*.

3.4.5.1 Riparian Brush Rabbit

3.4.5.1.1 Habitat Description

Riparian brush rabbit suitable habitat is defined in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, Section 4.A.5.6, *Suitable Habitat Definition*. Within the action area, based on the known distribution of the species, suitable habitat is defined to include the area south of SR 4 and Old River Pipeline. Within this area, suitable riparian habitat includes the vegetation types that comprise a dense, brushy understory shrub layer with a minimum patch size of 0.05 acres. Riparian brush rabbit grassland habitat includes grasslands with a minimum patch size of 0.05 acres that are adjacent to riparian brush rabbit riparian habitat. As described in Section 4.A.6.7, *Head of Old River Gate Habitat Assessment*, there is no suitable habitat within the project footprint.

3.4.5.1.2 Avoidance and Minimization Measures

3.4.5.1.2.1 Head of Old River Gate

Construction of the HOR gate will fully avoid loss of riparian brush rabbit habitat. As described in Section 4.A.5.7, *Head of Old River Gate Habitat Assessment*, there is no potentially suitable habitat for riparian brush rabbit within the construction footprint. As stated in Section 3.2.8.2.2, *Gate Construction*, the gate construction site, including the temporary work area, has for many years been used for seasonal construction and removal of a temporary rock barrier, and all proposed work will occur within the area that is currently seasonally disturbed for temporary rock barrier construction. Site access roads and staging areas used in the past for rock barrier installation and removal will be used for construction, staging, and other construction support facilities for the proposed barrier.

DWR will implement the following measures to avoid and minimize noise and lighting related effects on riparian brush rabbit:

Establish a 1,200-foot nondisturbance buffer between any project activities and suitable habitat.

Establish a 1,400-foot buffer between any lighting and pile driving and suitable habitat.

Screen all lights and direct them down toward work activities away from potential occupied habitat. A biological construction monitor will ensure that lights are properly directed at all times.

Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work*.

Limit construction during nighttime hours (10:00 p.m. to 7:00 a.m.) such that construction noise levels do not exceed 50 dBA L_{max} at the nearest residential land uses.

Limit pile driving to daytime hours (7:00 a.m. to 6:00 p.m.).

3.4.5.1.2.2 Geotechnical Exploration
Geotechnical exploration for the PA will not occur in or near riparian brush rabbit suitable riparian habitat.

3.4.5.1.2.3 Power Supply and Grid Connections
Power supply and gird connections for the PA will not occur within or near riparian brush rabbit suitable riparian habitat.

3.4.5.1.2.4 Restoration Activities
Restoration activities for the PA will not occur within riparian brush rabbit suitable riparian habitat, or within 100 feet of such habitat.

3.4.5.2 San Joaquin Kit Fox

3.4.5.2.1 Habitat Definition
San Joaquin kit fox suitable habitat is defined in Section 4.A.6.6, *Suitable Habitat Definition*. Within the action area, based on the known distribution of the species, suitable habitat as grasslands in the area depicted in Figure 6.3-1 and 6.3-2. San Joaquin kit fox preconstruction surveys will be required for activities occurring on, or within 200 feet[65] of, suitable habitat. A USFWS-approved biologist will conduct these pre-construction surveys.

3.4.5.2.2 Avoidance and Minimization Measures
AMMs are described below first for activities with fixed locations including the Clifton Court Forebay canal. Additional AMMs are then described for activities with flexible locations: habitat restoration, transmission lines, and geotechnical investigations. General AMMs are discussed in Appendix 3.F, *General Avoidance and Minimization Measures*.

3.4.5.2.2.1 Activities with Fixed Locations
Construction of the Clifton Court Forebay canal and any operations and maintenance activities involving use of heavy equipment associated with these facilities in the vicinity of San Joaquin kit fox habitat, will follow the avoidance and minimization measures described below. Additionally, once the transmission lines have been sited, construction associated with these activities will follow the avoidance and minimization measures described below.

[65] This is the distance from the activity within which a natal/pupping den survey is required as stated in the *Standardized Recommendations for Protection of the Endangered San Joaquin Kit Fox prior to or during Ground Disturbance* (U.S. Fish and Wildlife Service 2011).

Workers will confine ground disturbance and habitat removal to the minimal area necessary to facilitate construction activities. Additionally, to avoid direct effects of the PA on San Joaquin kit fox, the following measures will be implemented. These measures are based on USFWS's *Standardized Recommendations for Protection of the Endangered San Joaquin Kit Fox prior to or during Ground Disturbance* (U.S. Fish and Wildlife Service 2011).

3.4.5.2.2.1.1 San Joaquin Kit Fox Surveys

Within 14 to 30 days prior to ground disturbance related to PA activities, a USFWS-approved biologist with experience surveying for and observing the species will conduct preconstruction surveys in those areas identified as having suitable habitat per the habitat model described in Section 4.A.6.6, *Suitable Habitat Definition*, or per the recommendation of the USFWS approved biologist. The USFWS-approved biologist will survey the worksite footprint and the area within 200 feet beyond the footprint to identify known or potential San Joaquin kit fox dens. Adjacent parcels under different land ownership will not be surveyed unless access is granted within the 200-foot radius of the construction activity. The USFWS-approved biologists will conduct these searches by systematically walking 30- to 100-foot-wide transects throughout the survey area; transect width will be adjusted based on vegetation height and topography (California Department of Fish and Game 1990). The USFWS-approved biologist will conduct walking transects such that 100% visual coverage of the worksite footprint is achieved. Dens will be classified in one of the following four den status categories outlined in the *Standardized Recommendations for Protection of the Endangered San Joaquin Kit Fox Prior to or During Ground Disturbance* (U.S. Fish and Wildlife Service 2011).

Potential den. Any subterranean hole within the species' range that has entrances of appropriate dimensions for which available evidence is sufficient to conclude that it is being used or has been used by a kit fox. Potential dens comprise any suitable subterranean hole or any den or burrow of another species (e.g., coyote, badger, red fox, or ground squirrel) that otherwise has appropriate characteristics for kit fox use. If a potential den is found, the biologist will establish a 50-foot buffer using flagging.

Known den. Any existing natural den or artificial structure that is used or has been used at any time in the past by a San Joaquin kit fox. Evidence of use may include historical records; past or current radiotelemetry or spotlighting data; kit fox sign such as tracks, scat, and/or prey remains; or other reasonable proof that a given den is being or has been used by a kit fox.

Natal or pupping den. Any den used by kit foxes to whelp and/or rear their pups. Natal/ pupping dens may be larger with more numerous entrances than dens occupied exclusively by adults. These dens typically have more kit fox tracks, scat, and prey remains near the den and may have a broader apron of matted dirt and/or vegetation at one or more entrances. A natal den, defined as a den in which kit fox pups are actually whelped but not necessarily reared, is a more restrictive version of the pupping den. In practice, however, it is difficult to distinguish between the two; therefore, for purposes of this definition, either term applies. If a natal den is discovered, a buffer of at least 200 feet will be established using fencing.

Atypical den. Any artificial structure that has been or is being occupied by a San Joaquin kit fox. Atypical dens may include pipes, culverts, and diggings beneath concrete slabs and buildings. If an atypical den is discovered, the biologist will establish a 50-foot buffer using flagging.

The USFWS-approved biologist will flag all potential small mammal burrows within 50 feet of the worksite to alert biological and work crews of their presence.

3.4.5.2.2.1.2 Avoidance of San Joaquin Kit Fox Dens

Disturbance to all San Joaquin kit fox dens will be avoided, to the extent possible. Limited den destruction may be allowed, if avoidance is not a reasonable alternative, provided the following procedures are observed.

If an atypical, natal, known or potential San Joaquin kit fox den is discovered at the worksite, the den will be monitored for three days by a USFWS-approved biologist using a tracking medium or an infrared beam camera to determine if the den is currently being used.

Unoccupied potential, known, or atypical dens will be destroyed immediately to prevent subsequent use. The den will be fully excavated by hand, filled with dirt, and compacted to ensure that San Joaquin kit foxes cannot reenter or use the den during the construction period.

If an active natal or pupping den is found, USFWS will be notified immediately. The den will not be destroyed until the pups and adults have vacated and then only after further coordination with USFWS. All known dens will have at least a 100-foot buffer established using fencing.

If kit fox activity is observed at the potential, known, or atypical den during the pre-construction surveys, den use will be actively discouraged, as described below, and monitoring will continue for an additional five consecutive days from the time of the first observation to allow any resident animals to move to another den. For dens other than natal or pupping dens, use of the den can be discouraged by partially plugging the entrance with soil such that any resident animal can easily escape. Once the den is determined to be unoccupied, it may be excavated under the direction of the Service-approved biologist. Alternatively, if the animal is still present after five or more consecutive days of plugging and monitoring, the den may have to be excavated by hand when, in the judgment of a Service-approved biologist, it is temporarily vacant (i.e., during the animal’s normal foraging activities). If at any point during excavation a kit fox is discovered inside the den, the excavation activity will cease immediately and monitoring of the den, as described above, will be resumed. Destruction of the den may be completed when, in the judgment of the biologist, the animal has escaped from the partially destroyed den.

Construction and operational requirements from *Standardized Recommendations for Protection of the San Joaquin Kit Fox prior to or during Ground Disturbance* (U.S. Fish and Wildlife Service 2011) or the latest guidelines will be implemented.

If potential, known, atypical, or natal or pupping dens are identified at the worksite or within a 200-foot buffer, exclusion zones around each den entrance or cluster of entrances will be demarcated. The configuration of exclusion zones will be circular, with a radius measured outward from the den entrance(s). No activities will occur within the exclusion zones. Exclusion zone radii for atypical dens and suitable dens will be at least 50 feet and will be demarcated with four to five flagged stakes. Exclusion zone radii for known dens will be at least 100 feet and will be demarcated with staking and flagging that encircle each den or cluster of dens but do not prevent access to the den by the foxes.

Written results of the surveys will be submitted to USFWS within five calendar days of the completion of surveys and prior to the beginning of ground disturbance and/or construction activities in San Joaquin kit fox modeled habitat.

3.4.5.2.2.1.3 Construction Related Avoidance and Minimization Measures

During construction, the following measures will be implemented for all activities in suitable San Joaquin kit fox habitat (as determined by a USFWS-approved biologist):

Vehicles will observe a daytime speed limit of 20-mph throughout the worksite, where it is practical and safe to do so, except on county roads and state and Federal highways; vehicles will observe a nighttime speed limit of 10-mph throughout the worksite; this is particularly important at night when kit foxes are most active. Nighttime construction in or adjacent to San Joaquin kit fox habitat will be minimized to the greatest extent practicable.

To prevent inadvertent entrapment of kit foxes or other animals during construction, all excavated, steep-walled holes or trenches more than 2 feet deep will be covered at the close of each working day by plywood or similar materials. If the trenches cannot be closed, one or more escape ramps constructed of earthen-fill or wooden planks will be installed. Before such holes or trenches are filled, they will be thoroughly inspected for trapped animals. If at any time a trapped or injured kit fox is discovered, USFWS will be contacted.

Kit foxes are attracted to den-like structures such as pipes and may enter stored pipes and become trapped or injured. All construction pipes, culverts, or similar structures with a diameter of 4 inches or greater that are stored at a construction site within suitable kit fox habitat for one or more overnight periods will be thoroughly inspected for kit foxes before the pipe is subsequently buried, capped, or otherwise used or moved in any way. If a kit fox is discovered inside a pipe, that section of pipe will not be moved until USFWS has been consulted. If necessary, and under the direct supervision of the USFWS-approved biologist, the pipe may be moved only once to remove it from the path of construction activity until the fox has escaped.

All food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in securely closed containers and removed at least once a week from a construction site in suitable kit fox habitat.

No firearms will be allowed at worksites.

No pets, such as dogs or cats, will be permitted at worksites to prevent harassment, mortality of kit foxes, or destruction of dens.

Use of rodenticides and herbicides in areas that are in modeled kit fox habitat will be prohibited.

The USFWS-approved biologist for San Joaquin kit fox will be the contact source for any employee or contractor who might incidentally kill or injure a kit fox or who finds a dead, injured, or entrapped kit fox.

An employee education program (AMM1 *Worker Awareness Training*) will be conducted for any activities that will be conducted in San Joaquin kit fox habitat. The program will consist of a brief presentation by the USFWS-approved biologist for San Joaquin kit fox to explain endangered species concerns to all personnel who will be working in the construction area. The program will include the following: A description of the San Joaquin kit fox and its habitat needs; a report of the occurrence of kit fox at the worksite; an explanation of the status of the species and its protection under the Endangered Species Act; and a list of measures being taken to reduce impacts on the species during construction and operations. A fact sheet conveying this information will be prepared for distribution to all worksite personnel.

Upon completion of construction at a worksite, all areas subject to temporary ground disturbances will be re-contoured if necessary, and revegetated to promote restoration of the area to pre-construction conditions. An area subject to “temporary” disturbance means any area that is disturbed during construction, but after construction will be revegetated. Appropriate methods and plant species used to revegetate such areas will be determined on a site-specific basis in consultation with USFWS.

Any personnel who are responsible for incidentally killing or injuring a San Joaquin kit fox will immediately report the incident to the USFWS-approved biologist. The USFWS-approved biologist will contact USFWS immediately in the case of a dead, injured, or entrapped kit fox. USFWS will be contacted at the numbers below.

The San Francisco-Bay-Delta Fish and Wildlife Office will be notified immediately of the accidental death or injury to a San Joaquin kit fox. Notification must include the date, time, and location of the incident or of the finding of a dead or injured animal and any other pertinent information. The USFWS contact is the Assistant Field Supervisor of Endangered Species, at the addresses and telephone numbers below.

New sightings of kit fox will be reported to the California Natural Diversity Database (CNDDB). A copy of the reporting form and a topographic map clearly marked with the location of where the kit fox was observed will also be provided to USFWS at the address below.

Any information required by USFWS or questions concerning the above conditions or their implementation may be directed in writing to USFWS at: Bay-Delta Fish & Wildlife Office, 650 Capitol Mall, Suite 8-300, Sacramento, CA 95814, (916) 930-5604 office).

Clifton Court Forebay Operations and Maintenance

Following completion of Clifton Court Forebay modifications, the area to be operated and maintained within suitable kit fox habitat will be fenced with chain link fencing that prevents entry of San Joaquin kit fox. The fencing will be inspected annually to ensure there are no holes or gaps in the fencing that would allow kit foxes to enter.

3.4.5.2.2.2 Activities with Flexible Locations

3.4.5.2.2.2.1 Geotechnical Exploration

Geotechnical work in and within 200 feet of San Joaquin kit fox habitat will be limited to daytime hours.

Vehicles will access the work site following the shortest possible route from the levee road. All site access and staging shall limit disturbance to the riverbank, or levee as much as possible and avoid sensitive habitats. When possible, existing ingress and egress points shall be used. The USFWS-approved biologist for San Joaquin kit fox will survey the sites for kit fox no less than 14 days and no more than 30 days prior to beginning of Geotechnical exploration activities.

Project activities will not take place at night when kit foxes are most active.

Off-road traffic outside of designated project areas will be prohibited.

A USFWS-approved biological monitor will be stationed near the work areas to assist the construction crew with environmental issues as necessary. If kit foxes are encountered by a USFWS-approved biological monitor during construction, activities shall cease until appropriate corrective measures have been completed or it has been determined that the species will not be harmed.

To prevent inadvertent entrapment of kit foxes or other animals during the construction phase of a project, all excavated, steep-walled holes or trenches more than 2 feet (0.6 m) deep will be covered at the close of each working day by plywood or similar materials, or provided with one or more escape ramps constructed of earth fill or wooden planks. Before such holes or trenches are filled, they will be thoroughly inspected for trapped animals.

All construction pipes, culverts, or similar structures with a diameter of 4 inches (10 cm) or greater that are stored at a construction site for one or more overnight periods should be thoroughly inspected for kit foxes before the pipe is used or moved in any way. If a kit fox is discovered inside a pipe, construction activities will be halted and that section of pipe will not be moved until the USFWS-approved biologist monitoring the project construction site has contacted the USFWS. Once the Service has given the construction monitor instructions on how to proceed or the kit fox has escaped on its own volition, the pipe may be moved.

No firearms shall be allowed on the project site.

Noise will be minimized to the extent possible at the work site to avoid disturbing kit foxes.

To prevent harassment, mortality of kit foxes or destruction of dens by dogs or cats, no pets are permitted on project sites.

Rodenticides and herbicides will not be used during geotechnical exploration.

If a San Joaquin kit fox is incidentally injured or killed or entrapped, the USFWS-approved biological monitor shall immediately report the incident to the USWFS. Notification must include the date, time, and location of the incident or of the finding of a dead or injured animal and any other pertinent information.

3.4.5.2.2.2.2 Power Supply and Grid Connections

Prior to final design for the transmission line alignments, a USFWS-approved biologist will survey potential transmission line locations where suitable San Joaquin kit fox habitat is present. These surveys will be conducted as described in Section 3.4.5.2.2.1.1, *San Joaquin Kit Fox Surveys,* except that the surveys will be conducted early enough to inform the final transmission line design but no less than 14 days and no more than 30 days prior to beginning of PA activities. Therefore, multiple surveys may be required.

If any occupied dens are found, USFWS will be immediately contacted and the project will be designed to avoid the occupied dens by 200 feet. After the final transmission line alignment has been determined, the avoidance and minimization measures described in Section 3.4.5.2.1.1, *Activities with Fixed Locations,* will be followed. These measures will be applied to both transmission line construction and long-term maintenance.

3.4.5.2.2.2.3 Restoration

Prior to final design for vernal pool restoration, a USFWS-approved biologist will survey potential restoration locations where suitable San Joaquin kit fox habitat is present. These surveys will be conducted as described in Section 3.4.5.2.2.1.1, *San Joaquin Kit Fox Surveys,* except that the surveys will be conducted early enough to inform the restoration design but no less than 14 days and no more than 30 days prior to beginning of PA activities. Therefore, multiple surveys may be required. If any occupied dens are found, USFWS will be immediately contacted and the project will be designed to avoid the occupied dens by 200 feet. After the final restoration design is completed, the avoidance and minimization measures described in Section 3.4.5.2.1.1, *Activities with Fixed Locations,* will be followed during construction and management of the vernal pool habitat.

3.4.5.2.3 Compensation for Effects

DWR will protect San Joaquin kit fox habitat at a ratio of 3:1 (protected: lost) at a location subject to USFWS approval, adjacent to other modeled San Joaquin kit fox habitat to provide a large, contiguous habitat block. 47 acres of suitable San Joaquin kit fox habitat will be affected and therefore 141 acres of habitat will be protected (Table 3.4-3). San Joaquin kit fox protection will be accomplished either through the purchase of mitigation credits through an existing, USFWS-approved conservation bank or will be purchased in fee-title by DWR or a DWR partner organization with approval from the USFWS. If purchased in fee-title, a permanent, USFWS-approved conservation easement will be placed on the property.

Table 3.4-3. Compensation for Effects on San Joaquin Kit Fox Habitat.

San Joaquin Kit Fox Modeled Habitat	Maximum Total Impact (Acres)	Habitat Protection Compensation Ratio	Total Habitat Protection (Acres)
Breeding, Foraging, and Dispersal Habitat	47	3:1	141

3.4.5.2.4 Siting Criteria for Compensation of Effects

Suitable San Joaquin kit fox habitat will be acquired for protection in the Byron Hills area, subject to USFWS approval, where there is connectivity to existing protected habitat and to other adjoining kit fox habitat. Grassland protection will focus in particular on acquiring the largest remaining contiguous patches of unprotected grassland habitat, which are located south of SR 4. This area connects to over 620 acres of existing habitat that was protected under the East Contra Costa County HCP/NCCP. Grasslands will also be managed and enhanced to increase prey availability and to increase mammal burrows, which could benefit the San Joaquin kit fox by increasing potential den sites, which are a limiting factor for the kit fox in the northern portion of its range. These management and enhancement actions are expected to benefit the San Joaquin kit fox by increasing the habitat value of the protected grasslands. Alternatively, credits may be purchased at a FWS-approved conservation bank.

3.4.5.2.5 Management and Enhancement

Management and enhancement activities on protected San Joaquin kit fox habitat will be designed and conducted in coordination with (or by) the East Contra Costa County Habitat Conservancy or East Bay Regional Park District. Both of these entities have extensive experience conducting successful grassland management and to benefit San Joaquin kit fox in the area where this habitat will be protected to mitigate the effects of the PA. Management plans on San Joaquin kit fox conservation land will be subject to Service approval.

Vegetation management. Vegetation will be managed to reduce fuel loads for wildfires, reduce thatch, minimize nonnative competition with native plant species, increase biodiversity, and provide suitable habitat conditions for San Joaquin kit fox. Grazing will be the primary mechanism for vegetation management on protected San Joaquin kit fox habitat.

Burrow availability. Grasslands (including the grassland natural community and grasslands within vernal pool complex and alkali seasonal wetland complex natural communities) will be enhanced and managed to increase the availability of burrows and to increase prey availability for San Joaquin kit fox). Ground-dwelling mammals are important prey for San Joaquin kit fox, and kit foxes in the northern extent of their range often modify ground squirrel burrows for their own use. Some rodent control measures will likely remain necessary in certain areas where dense rodent populations may compromise important infrastructure (e.g., pond berms, road embankments, railroad beds, levees, dam faces). The land manager will introduce livestock grazing (where it is not currently used) to reduce vegetative cover and thus encourage ground squirrel expansion and colonization. Burrow availability may also be increased on protected grasslands by encouraging ground squirrel occupancy through the creation of berms, mounds, edges, and other features designed to attract and encourage burrowing activity. The use of any rodenticides on San Joaquin kit fox conservation lands is prohibited as its use does not meet the general standards for San Joaquin kit fox conservation areas and does not align with San Joaquin kit fox management.

3.4.5.3 California Least Tern

3.1.1.1.1 Habitat Definition

California least tern suitable habitat is defined in Appendix 4.A, *Status of the Species and Critical Habitat Accounts,* Section 4.A.7.6, *Suitable Habitat Definition*. The implementation of general construction avoidance and minimization measures including best management practices and worker awareness training (Appendix 3.F, *General Avoidance and Minimization Measures*) will minimize the effects of construction on California least tern foraging habitat.

3.1.1.1.2 Avoidance and Minimization Measures

If suitable nesting habitat for California least tern (flat, unvegetated areas near aquatic foraging habitat) is identified during planning-level surveys, at least three preconstruction surveys for this species will be conducted during the nesting season by a qualified biologist with experience observing the species and its nests. Projects will be designed to avoid loss of California least tern nesting colonies. No construction will take place within 200 feet of a California least tern nest during the nesting season (April 15 to August 15, or as determined through surveys).

Only inspection, maintenance, research, or monitoring activities may be performed during the least tern breeding season in occupied least tern nesting habitat with USFWS and CDFW approval under the supervision of a qualified biologist. General AMMs are discussed in Appendix 3.F, *General Avoidance and Minimization Measures*.

Safe havens, RTM, and transmission lines will fully avoid California least tern foraging habitat. Transmission lines may cross waterways, but must avoid disturbance of open water habitat.

3.4.5.4 Western Yellow-Billed Cuckoo

3.4.5.4.1 Habitat Definition

AMMs for western yellow-billed cuckoo will be required for activities occurring within suitable habitat, or in the vicinity of suitable habitat, as defined in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, Section 4.A.8.6, *Suitable Habitat Definition*. To conservatively estimate effects of the PA on western yellow-billed cuckoo, a model for western yellow-billed cuckoo migratory habitat was created (Appendix 4.A, Section 4.A.8.7, *Species Habitat Suitability Model*). Prior to disturbing an area potentially supporting habitat for the species, a USFWS approved biologist will evaluate the area to identify suitable habitat as described in Section 3.4.8.2, *Required Compliance Monitoring.* The following avoidance and minimization measures will be applied within suitable habitat for western yellow-billed cuckoo.

3.4.5.4.2 Avoidance and Minimization Measures

3.4.5.4.2.1 Activities with Fixed Locations

Activities with fixed locations include all construction activities described in Section 3.2, *Conveyance Facility Construction* except geotechnical exploration, safe haven intervention sites, and transmission lines. The following measures will be required for construction, operation, and maintenance related to fixed location activities in suitable migratory habitat. The following measures will also be required for activities with flexible locations once their locations have been fixed, if they occur in suitable habitat. Permanent or temporary loss of all suitable migratory habitat will be minimized by all activities associated with the PA through project design and no more than 33 acres of migratory habitat will be removed by activities associated with the PA.

Prior to construction, all suitable western yellow-billed cuckoo habitat in the construction area will be surveyed, with surveys performed in accordance with any required USFWS survey protocols and permits applicable at the time of construction.

If surveys find cuckoos in the area where vegetation will be removed, vegetation removal will be done when cuckoos are not present.

If an activity is to occur within 1,200 feet of western yellow-billed cuckoo habitat (or within 2,000 feet if pile driving will occur) during the period of from June 15 through September 1[66], the following measures will be implemented to avoid noise effects on migrating western yellow-billed cuckoos.

Prior to the construction, a noise expert will create a noise contour map showing the 60 dBA noise contour specific to the type and location of construction to occur in the area.

During the period between June 15 and September 1, a USFWS-approved biologist will survey any suitable migratory habitat for yellow-billed cuckoos within the 60 dBA noise contour on a daily basis during a two-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour). If a yellow-billed cuckoo is found, sound will be limited to 60dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.

Limit pile driving to daytime hours (7:00 a.m. to 7:00 p.m.).

Locate, store, and maintain portable and stationary equipment as far as possible from suitable western yellow-billed cuckoo habitat.

Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.

Route truck traffic in order to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable western yellow-billed cuckoo migratory habitat during migration periods.

Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.

[66] Based on occurrence data, this is the period within which yellow-billed cuckoos have been observed in the legal Delta.

Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.

Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work.*

3.4.5.4.2.2 Activities with Flexible Locations

3.4.5.4.2.2.1 Geotechnical Exploration

During geotechnical activities, a USFWS approved biologist will be onsite to avoid the loss or degradation of suitable western yellow-billed cuckoo habitat by exploration activities.

3.4.5.4.2.2.2 Safe Haven Work Areas

During the siting phase of safe haven construction, a USFWS approved biologist will work with the engineers to avoid loss or degradation of suitable western yellow-billed cuckoo migratory habitat. This includes ensuring that safe haven work areas are not sited in western yellow-billed cuckoo habitat. This also includes ensuring noise from safe haven work areas do not exceed 60 dBA at nearby western yellow-billed cuckoo migratory habitat.

3.4.5.4.2.2.3 Power Supply and Grid Connections

The final transmission line alignment will be designed to minimize removal of western yellow-billed cuckoo migratory habitat by removing no more than four acres of this habitat. To minimize the chance of western yellow-billed cuckoo bird strikes at transmission lines, bird strike diverters will be installed on project and existing transmission lines in a configuration that research indicates will reduce bird strike risk by at least 60% or more. Bird strike diverters placed on new and existing lines will be periodically inspected and replaced as needed until or unless the project or existing line is removed. The most effective and appropriate diverter for minimizing strikes on the market according to best available science will be selected.

Safe Havens

Safe haven sites will avoid western yellow-billed cuckoo migratory habitat. All work associated with safe haven sites will be conducted during daylight hours, and will not require any lighting.

3.4.5.4.2.2.4 Restoration/Mitigation Activities

A USFWS biologist will work with the restoration siting and design team to avoid the permanent loss of suitable western yellow-billed cuckoo migratory habitat. (Furthermore, the biological opinion for the PA will not authorize take resulting from restoration/mitigation actions.

3.4.5.4.3 Compensation to Offset Impacts

DWR will offset the loss of 32 acres of western yellow-billed cuckoo migratory habitat through the creation or restoration at a 2:1 ratio, for a total of 64 acres of migratory riparian habitat creation or restoration in the action area. DWR will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

3.4.5.5 Giant Garter Snake

3.4.5.5.1 Habitat Definition[67]

Giant garter snake suitable habitat is defined in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, Section 4.A.9.6, *Suitable Habitat Definition*. The giant garter snake habitat model, described in Appendix 4.A, Section 4.A.9.2, *Life History and Habitat Requirements*, was created to conservatively estimate effects to habitat, because access to activity areas is not possible at this time.

During project implementation and prior to project construction, DWR, in agreement with CDFW and USFWS, will:

When each site is available for surveys, a giant garter snake expert, approved by USFWS and CDFW, will then delineate giant garter snake habitat at each project site, based on the definition of suitable habitat, including both aquatic and upland habitat.

Once habitat has been delineated, the giant garter snake expert may use giant garter snake surveys performed using a method approved by the USFWS to determine presence/absence of the species on the project site to enable further determination of mitigation requirements as described below in Section 3.4.5.5.3, *Compensation for Effects*.

For sites where such surveys are performed, the surveys will conform to protocol and reporting need per a plan to be jointly developed by DWR and USFWS to provide population and occurrence data for the species in the Delta.

To the greatest extent possible, identified and delineated habitat will be completely avoided.

When avoidance is not possible, the measures discussed below in Section 3.4.5.5.2, *Avoidance and Minimization Measures*, are required.

3.4.5.5.2 Avoidance and Minimization Measures

AMMs for giant garter snakes will be required for activities occurring within suitable aquatic and upland habitat. For general AMMs see Appendix 3F, *General Avoidance and Minimization Measures*).

3.4.5.5.2.1 Activities with Fixed Locations

Activities with fixed locations include all construction activities described in Section 3.2, *Conveyance Facility Construction*, except geotechnical exploration, safe haven intervention sites, and transmission lines. DWR will implement the following AMMs for construction, operation, and maintenance related to fixed location activities in delineated habitat. DWR will also implement the following measures for activities with flexible locations once their locations have been fixed, if they occur in delineated habitat.

Initiate construction and clear suitable habitat in the summer months, between May 1 and October 1, and avoid giant garter snake habitat during periods of brumation (between

[67] For more on Giant Garter Snake habitat, see Permit Resolution Log, items # 49-60

October 1 and May 1). Suitability of aquatic and upland habitat characteristics will be determined by the USFWS-approved biologist consistent with the USFWS habitat description outlined in Section 4.A.9.6, *Suitable Habitat Definition.* Once a construction site has been cleared and exclusionary fencing is in place, work within the cleared area can occur between October 1 and May 1.

To the extent practicable, conduct all activities within paved roads, farm roads, road shoulders, and similarly disturbed and compacted areas; confine ground disturbance and habitat removal to the minimal area necessary to facilitate construction activities.

For construction activities, dredging, and any conveyance facility maintenance involving heavy equipment, giant garter snake aquatic and upland habitat that can be avoided will be clearly delineated on the work site, with exclusionary fencing and signage identifying these areas as sensitive. The exclusionary fencing will be installed during the active period for giant garter snake (May 1–October 1) and will consist of 3-foot-tall non-monofilament silt fencing extending to 6 inches below ground level.

For activities requiring exclusionary fencing, the biological monitor and construction supervisor will be responsible for checking the exclusionary fences around the work areas daily to ensure that they are intact and upright. Any necessary repairs will be immediately addressed. The exclusionary fencing will remain in place for the duration of construction. For additional detail on exclusionary fencing type, size, and height, see Appendix 3.F, *General Avoidance and Minimization Measures,* Section 3.F.2.2, *AMM2 Construction Best Management Practices and Monitoring*.

The USFWS-approved biologist will also survey suitable aquatic and upland habitat in the entire work site for the presence of giant garter snakes, as well at 50 feet outside the work site exclusion fencing in suitable habitat.

If exclusionary fencing is found to be compromised, a survey of the exclusion fencing and the area inside the fencing will be conducted immediately preceding construction activity that occurs in delineated giant garter snake habitat or in advance of any activity that may result in take of the species. The biologist will search along exclusionary fences, in pipes, and beneath vehicles before they are moved. Any giant garter snake found will be captured and relocated to suitable habitat a minimum of 200 feet outside of the work area in a location that is approved by USFWS and CDFW prior to resumption of construction activity.

All construction personnel, and personnel involved in operations and maintenance in or near giant garter snake habitat, will attend worker environmental awareness training as described in Appendix 3.F, *General Avoidance and Minimization Measures*, *AMM1 Worker Awareness Training*. This training will include instructions to workers on how to recognize giant garter snakes, their habitat(s), and the nature and purpose of protection measures.

Within 24 hours prior to construction activities, dredging, or maintenance activities requiring heavy equipment, a USFWS-approved biologist will survey all of the activity area not protected by exclusionary fencing where giant garter snake could be present. This survey of the work area will be repeated if a lapse in construction or dredging activity of two weeks or greater occurs during the aestivation period (October 1 through May 1) or if the lapse in construction activity is more than 12 hours during active season (May 1–October 1). If a giant garter snake is encountered during surveys or construction, cease activities until appropriate corrective measures have been completed, it has been determined that the giant garter snake will not be harmed, or the giant garter snake has left the work area.

The USFWS-approved biological monitor will help guide access and construction work around wetlands, active rice fields, and other sensitive habitats capable of supporting giant garter snake, to minimize habitat disturbance and risk of injuring or killing giant garter snakes.

Report all observations of giant garter snakes to the USFWS-approved biological monitor.

Maintain all construction and operations and maintenance equipment to prevent leaks of fuel, lubricants, and other fluids and use extreme caution when handling and or storing chemicals (such as fuel and hydraulic fluid) near waterways, and abide by all applicable laws and regulations. Follow all applicable hazardous waste best management practices (BMPs) and keep appropriate materials on site to contain, manage, and clean up any spills as described in Appendix 3.F, *General Avoidance and Minimization Measures, AMM5 Spill Prevention, Containment, and Countermeasure Plan.*

Conduct service and refueling procedures in uplands in staging areas and at least 200 feet away from giant garter snake upland habitat and waterways when practicable. See also Appendix 3.F, *General Avoidance and Minimization Measures*, *AMM5, Spill Prevention, Containment, and Countermeasure Plan*.

During construction and operation and maintenance activities in and near giant garter snake habitat, employ erosion (non-monofilament silt fence), sediment, material stockpile, and dust control (BMPs on site). Avoid fill or runoff into wetland areas or waterways to the extent practicable.

Return temporary work areas to pre-existing contours and conditions upon completion of work. Where re-vegetation and soil stabilization are necessary in non-agricultural habitats, revegetate with appropriate non-invasive native plants at a density and structure similar to that of pre-construction conditions.

Properly contain and remove from the worksite all trash and waste items generated by construction and crew activities to prevent the encouragement of predators such as raccoons and coyotes from occupying the site.

Permit no pets, campfires, or firearms at the worksite.

Store equipment in designated staging area areas at least 200 feet away from giant garter snake aquatic habitat to the extent practicable.

Confine any vegetation clearing to the minimum area necessary to facilitate construction activities.

Limit vehicle speed to 10 miles per hour (mph) on access routes (except for public roads and highways) and within work areas that are within 200 feet of giant garter snake aquatic habitat but not protected by exclusion fencing to avoid running over giant garter snakes.

Visually check for giant garter snake under vehicles and equipment prior to moving them. Cap all materials onsite (conduits, pipe, etc.), precluding wildlife from becoming entrapped. Check any crevices or cavities in the work area where individuals may be present including stockpiles that have been left for more than 24 hours where cracks/crevices may have formed.

For activities that will occur within the giant garter snake inactive season (October 2 through April 30), and will last more than two weeks, DWR will implement the following additional avoidance and minimization measures.

For proposed activities that will occur within suitable aquatic giant garter snake habitat, during the active giant garter snake season (May 1 through October 1) prior to proposed construction activities that will commence during the inactive period, and when unavoidable, all aquatic giant garter snake habitat will be dewatered for at least 14 days prior to excavating or filling the dewatered habitat. De-watering is necessary because aquatic habitat provides prey and cover for giant garter snake; de-watering serves to remove the attractant, and increase the likelihood that giant garter snake will move to other available habitat. Any deviation from this measure will be done in coordination with, and with approval of, the U.S. Fish and Wildlife Service.

Following de-watering of aquatic habitat, all potential impact areas that provide suitable aquatic or upland giant garter snake habitat will be surveyed for giant garter snake by the USFWS-approved biologist. If giant garter snakes are observed, they will be passively allowed to leave the potential impact area, or the USFWS will be consulted to determine the appropriate course of action for removing giant garter snake from the potential impact area.

Once habitat is deemed giant garter snake-free, exclusion fencing will be constructed around the construction site so not snakes may re-enter prior to or during construction.

Maintenance activities such as vegetation and rodent control, embankment repair, and channel maintenance will occur at conveyance facilities with permanent structures (e.g., NDD, pumping plant, etc.). The following avoidance and minimization measures will be applied to maintenance activities in suitable aquatic habitat and uplands within 200 feet of suitable aquatic habitat, to minimize effects on the giant garter snake.

Vegetation control will take place during the active period (May 1 through October 1) when snakes are able to move out of areas of activity.

Trapping or hunting methods will be used for rodent control, rather than poison bait. All rodent control methods will be approved by USFWS. If trapping or other non-poison methods are ineffective, the USFWS will be consulted to determine the best course of action.

Movement of heavy equipment will be confined to outside 200 feet of the banks of giant garter snake aquatic habitat to minimize habitat disturbance.

All construction personnel, and personnel involved in operations and maintenance in or near giant garter snake habitat, will attend worker environmental awareness training as described in Appendix 3.F *General Avoidance and Minimization Measures, AMM1 Worker Awareness Training*. This training will include instructions to workers on how to recognize giant garter snakes, their habitat(s), and the nature and purpose of protection measures.

3.4.5.5.2.2 Activities with Flexible Locations

Activities with flexible locations are activities that cannot yet be precisely sited because they require design or site-specific information that will not be available until the PA is already in progress. These include geotechnical exploration, safe haven intervention sites, transmission lines, and habitat restoration.

Geotechnical Activities

Geotechnical activities will avoid giant garter snake aquatic habitat. To the extent practicable, all activities within giant garter snake upland habitat, as delineated by a USFWS approved biologist and based on the suitable habitat definition in Section 4.A.9.6, will be avoided. The following avoidance and minimization measures will be used to minimize unavoidable effects on the giant garter snake upland habitat.

- Geotechnical activity in giant garter snake upland habitat will be confined to the giant garter snake's active period (May 1 through October 1).
- Movement of heavy equipment will be confined to existing roads as much as possible, and will avoid suitable upland giant garter snake habitat .
- Construction personnel will receive USFWS-approved worker environmental awareness training instructing workers to recognize giant garter snakes and their habitat.

Safe Haven Work Areas

Safe haven work areas will avoid giant garter snake aquatic and upland habitat.

Power Lines and Grid Connections

Giant garter snake avoidance and minimization measures for transmission lines will be the same as described in Section 3.4.5.5.2.1, *Activities with Fixed Locations.* These power lines and grid connections will be designed to avoid giant garter snake aquatic habitat.

Maintenance

Maintenance activities such as vegetation and rodent control, embankment repair, and channel maintenance will occur at conveyance facility and restoration sites with flexible locations (e.g., transmission line right of ways, restoration locations, etc.). The following avoidance and minimization measures will be applied to maintenance activities in suitable aquatic habitat, as delineated by an USFWS approved biologist, and uplands within 200 feet of suitable aquatic habitat, to minimize effects on the giant garter snake.

Vegetation control will take place during the active period (May 1 through October 1) when snakes are able to move out of areas of activity.

Trapping or hunting methods will be used for rodent control, rather than poison bait. All rodent control methods will be approved by USFWS. If trapping or other non-poison methods are ineffective, the USFWS will be consulted to determine the best course of action.

Movement of heavy equipment will be confined to outside 200 feet of the banks of potential giant garter snake habitat to minimize habitat disturbance.

Construction personnel will receive USFWS-approved worker environmental awareness training instructing workers to recognize giant garter snakes and their habitat.

Maintenance activities that cannot avoid giant garter snake habitat will implement the avoidance and minimization measures described in Section 3.4.5.5.2.1, *Activities with Fixed Locations*.

3.4.5.5.3 Compensation for Effects

Where identified and delineated giant garter snake habitat cannot be avoided, compensation for the loss of the habitat will occur at a rate of 3:1 for each, aquatic and upland habitat, with in-kind habitat type compensation (Table 3.4-4). An estimated 775 acres of giant garter snake habitat will be affected, therefore 2,325 acres of giant garter snake habitat will be protected or restored. Insofar as mitigation is created/protected in a USFWS agreed-to high-priority conservation area, such as the eastern protection area between Caldoni Marsh and Stone Lakes, a mitigation rate of 2:1 for each, aquatic and upland habitat type, will apply which may lower the above example to 1,550 acres of mitigation. A combination of in-kind and high-priority mitigation may be used.

Giant garter snake upland mitigation will be placed and protected adjacent to aquatic habitat protected for giant garter snake. The upland habitat will not exceed 200 feet from protected aquatic habitat (unless research shows a larger distance is appropriate and USFWS agrees).

Incidental injury and/or mortality of giant garter snakes within protected and restored habitat will be avoided and minimized by establishing 200-foot buffers between protected giant garter snake habitat and roads (other than those roads primarily used to support adjacent cultivated lands and levees).

Protected and restored giant garter snake habitat will be at least 2,500 feet from urban areas or areas zoned for urban development.

Characteristics of restored and protected habitat may change from the above descriptors if new information and best available science indicate greater benefits as agreed upon by USFWS.

Table 3.4-4. Compensation for Direct Effects on Giant Garter Snake Habitat

	Permanent Habitat Loss	Compensation Ratios		Total Compensation	
	Total Maximum Habitat Loss (Acres)	Protection	Restoration	Protection[2]	Restoration[2]
Aquatic Total	205	3:1 or 2:1[1]		615 or 410	
Upland Total	570			1,710 or 1,140	
TOTAL	775			2,325 or 1,550	

[1] The 3:1 mitigation ratio will be applied when "in-kind" mitigation is used. In-kind mitigation is that mitigation that replaces a habitat of similar quality, character, and location as that which was lost within the known range of the giant garter snake as described in Section 4.A.9.6, *Suitable Habitat Definition*. DWR will mitigate at a rate of 2:1 for each acre of lost aquatic and upland habitat if the mitigation is created/protected in a USFWS agreed-to high-priority conservation location for GGS, such as the eastern protection area between Caldoni Marsh and Stone Lakes

[2] Compensation can be achieved through restoration or protection. The protection component of habitat compensation will be limited to up to 1/3 of the total compensation.

3.4.5.5.4 Siting Criteria for Compensation for Effects

Siting and design requirements for the restoration and protection of giant garter snake nontidal wetland habitat are listed below.

For in-kind mitigation sites, those site mitigated at a ratio of 3:1, the aquatic and upland habitat quality, character, and location must be of equal or greater value than the habitat quality which was lost.

For conservation mitigation sites, those sites mitigated at a 2:1 ratio, restored or protected giant garter snake habitat will either be adjacent to, or connected to, Caldoni Marsh or the White Slough Wildlife Area, or will create connections from the White Slough population to other areas in the giant garter snake's historical range in the Stone Lakes vicinity or at another location, or corridors between these areas, to be selected by DWR, subject to USFWS approval.

Conservation mitigation sites, those mitigated at a 2:1 ratio, will be characterized as nontidal marsh and will meet the following design criteria.

Restored nontidal marsh will be characterized by sufficient water during the giant garter snake's active summer season (May 1 –October 1) to supply constant, reliable cover and sources of food such as small fish and amphibians.

Restored nontidal marsh will consist of still or slow-flowing water over a substrate composed of soil, silt, or mud characteristic of those observed in marshes, sloughs, or irrigation canals.

Restoration designs will not create large areas of deep, perennial open water that will support nonnative predatory fish. The restored marsh will be characterized by a heterogeneous topography providing a range of depths and vegetation profiles consisting of emergent, herbaceous aquatic vegetation that will provide suitable foraging habitat and refuge from predators.

Aquatic margins or shorelines will transition to uplands consisting of grassy banks, with the dense grassy understory required for sheltering. These margins will consist of approximately 200 feet of high ground or upland habitat above the annual high water mark to provide cover and refugia from floodwaters during the dormant winter season.

The upland habitat will have ample exposure to sunlight to facilitate giant garter snake thermoregulation and will be characterized by low vegetation, bankside burrows, holes, and crevices providing critical shelter for snakes throughout the day. All giant garter snake upland and aquatic habitat will be established at least 2,500 feet from urban areas or areas zoned for urban development.

The loss of tidal aquatic habitat for giant garter snake may be mitigated through restoration of tidal habitat with a design that provides equal or greater habitat value for the species as agreed upon by USFWS.

Topography of the restored wetlands will be designed to provide adjacent terrestrial refuge persisting above the high water mark. Terrestrial features will be sited in close proximity to aquatic foraging areas at all tide levels, with slopes and grading designed to avoid exposing largely denuded intertidal mud flats during low tide. Management and Enhancement

The following management actions will be implemented for giant garter snake habitat to be restored at high-priority mitigation sites. In-kind mitigation sites will be managed in a manner that maintains or exceeds the quality of habitat impacted by project activities. If a USFWS approved mitigation bank is used to fulfill the restoration requirement, then the management and enhancement that is in place for that mitigation bank will suffice.

Manage vegetation density (particularly nonnatives such as water primrose) and composition, water depth, and other habitat elements to enhance habitat values for giant garter snakes.

Maintain upland refugia (islands or berms) within the restored marsh.

Maintain permanent upland habitat at least 200 feet wide around all restored nontidal freshwater emergent wetland habitats to provide undisturbed (uncultivated) upland cover, basking and overwintering habitat immediately adjacent to aquatic habitat.

Manage bank slopes and upland habitats to enhance giant garter snake use, provide cover, and encourage burrowing mammals for purposes of creating overwintering sites for giant garter snake.

3.4.5.6 California Red-Legged Frog

3.4.5.6.1 Habitat Definition

AMMs for California red-legged frogs will be required for activities occurring within suitable aquatic and upland habitat, and also, whenever the species is incidentally encountered. Within the action area, based on the known distribution of the species, suitable habitat is defined to include the area south and west of SR 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard) to Byron Highway; then south and west along the county line to Byron Highway; then west of Byron Highway to I-205, north of I-205 to I-580, and west of I-580. Within this area, suitable aquatic habitat is defined to include perennial and intermittent streams, managed wetland, freshwater emergent wetland, and perennial aquatic natural communities.

Suitable upland habitat is defined as upland areas within 300 feet of the top of bank of a creek, stream, waterbody, or wetlands that provide aquatic habitat for the species (U.S. Fish and Wildlife Service 2014). A USFWS-approved biologist will conduct a field evaluation of the California red-legged frog modeled habitat to ascertain the distribution of suitable upland and aquatic habitat in the worksite vicinity. Surveys within suitable upland habitat will identify suitable aquatic features that may not have been identified during the habitat modeling.

Modeled upland dispersal habitat includes agricultural lands within the area described above and within 1 mile of aquatic habitat, except for agricultural lands where dispersal is bounded on the west by Byron Highway. There is no known, high-value breeding habitat east of that significant boundary.

3.4.5.6.2 Avoidance and Minimization Measures

AMMs are described below first for activities with fixed locations including the Clifton Court Forebay canal and the Clifton Court Embankment. Additional AMMs are then described for activities with uncertain locations: habitat restoration, transmission lines, and geotechnical investigations.

3.4.5.6.2.1 Activities with Fixed Locations

If aquatic habitat cannot be avoided, aquatic habitats in potential work areas, will be surveyed for tadpoles and egg masses. If California red-legged frog tadpoles or egg masses are found, and the aquatic habitat cannot be avoided, USFWS will be contacted, and if determined to be appropriate, measures will be developed to relocate tadpoles and eggs to the nearest suitable aquatic habitat, as determined by the USFWS-approved biologist.

If the PA does not fully avoid effects on suitable habitat, the following measures will be required.

The USFWS-approved biologist will conduct employee education training for employees working on earthmoving and/or construction activities. Personnel will be required to attend the presentation that will describe the California red-legged-frog avoidance, minimization, and conservation measures, legal protection of the animal, and other related issues. All attendees will sign an attendance sheet along with their printed name, company or agency, email address, and telephone number. The original sign-in sheet will be sent to the USFWS within seven (7) calendar days of the completion of the training.

Preconstruction surveys will be implemented after the planning phase and prior to any ground-disturbing activity.

The biological monitor and construction supervisor will be responsible for checking the exclusion fences around the work areas daily to ensure that they are intact and upright. This will be especially critical during rain events, when flowing water can easily dislodge the fencing. Any necessary repairs will be immediately addressed. The amphibian exclusion fencing will remain in place for the duration of construction.

If the exclusion fence is found to be compromised at any time, a survey will be conducted immediately preceding construction activity that occurs in designated California red-legged frog habitat or in advance of any activity that may result in take of the species.

The USFWS-approved biologist will search along exclusion fences, in pipes, and beneath vehicles before they are moved. The survey will include a careful inspection of all potential hiding spots, such as along exclusion fencing, large downed woody debris, and the perimeter of ponds, wetlands, and riparian areas. Any California red-legged frogs found will be captured and relocated to suitable habitat, a minimum of 300 feet outside of the work area that has been identified in the relocation plan (described below) and approved by a USFWS-approved biologist prior to commencement of construction.

Initial ground-disturbing activities will not be conducted between November 1 and March 31 in areas identified during the planning stages as providing suitable California red-legged frog habitat, to avoid the period when they are most likely to be moving through upland areas. Once the initial ground disturbance has occurred, the area has been cleared, and exclusionary fencing is in place, work within the disturbed area can occur outside the construction window.

Surface-disturbing activities will be designed to minimize or eliminate effects on rodent burrows that may provide suitable cover habitat for California red-legged frog. Surface-disturbing activities will avoid areas with a high concentration of burrows to the greatest extent practicable. In addition, when a concentration of burrows is present in a worksite, the area will be staked or flagged to ensure that work crews are aware of their location and to facilitate avoidance of the area.

No initial clearing activities will occur during rain events or within 24-hours following a rain event, prior to clearing a site and installing exclusionary fencing. An approved biologist will check the exclusion fencing daily to ensure it is intact, and if there are any breaches in the fencing, the approved biologist will survey the work area of California red-legged frogs. If the species is found, the approved biologist will relocate the frog consistent with an approved relocation plan.

To the maximum extent practicable, nighttime construction will be minimized or avoided by DWR, as project applicant, when working in suitable California red-legged frog habitat. Because dusk and dawn are often the times when the California red-legged frog is most actively moving and foraging, to the greatest extent practicable, earthmoving and construction activities will cease no less than 30 minutes before sunset and will not begin again prior to no less than 30 minutes after sunrise. Except when necessary for driver or pedestrian safety artificial lighting at a worksite will be prohibited during the hours of darkness when working in suitable where California red-legged frog habitat. No more than 24 hours prior to any ground disturbance that could affect potential California red-legged frog habitat, preconstruction surveys for California red-legged frog will be conducted by a USFWS-approved biologist. These surveys will consist of walking the worksite limits. The USFWS-approved biologists will investigate all potential areas that could be used by the California red-legged frog for feeding, breeding, sheltering, movement or other essential behaviors. This includes an adequate examination of mammal burrows, such as California ground squirrels or gophers. If any adults, subadults, juveniles, tadpoles, or eggs are found, the USFWS-approved biologist will contact the USFWS to determine if moving any of the individuals to pre-approved location within the relocation plan is appropriate. If the USFWS approves moving animals, the USFWS-approved biologist will be given sufficient time to move the animals from the work site before ground disturbance is initiated. Only USFWS-approved biologists will capture, handle, and monitor the California red-legged frog.

If work must be conducted at night, all lighting will be directed away and shielded from California red-legged frog habitat outside the construction area to minimize light spillover to the greatest extent possible. If light spillover into adjacent California red-legged frog habitat occurs, a USFWS-approved biologist will be present during night work to survey for burrows and emerging California red-legged frogs in areas illuminated by construction lighting. If California red-legged frog is found above-ground the USFWS-approved biologist has the authority to terminate the project activities until the light is directed away from the burrows, the California red-legged frog moves out of the illuminated area, or the California red-legged frog is relocated out of the illuminated area by the USFWS-approved biologist.

At least 15 days prior to any ground disturbance activities, DWR, as project applicant, will prepare and submit a relocation plan for USFWS's written approval. The relocation plan will contain the name(s) of the USFWS-approved biologist(s) to relocate California red-legged frogs, the method of relocation (if different than described), a map, and a description of the proposed release site(s) within 300 feet of the work area or at a distance otherwise agreed to by USFWS, and written permission from the landowner to use their land as a relocation site.

Aquatic habitats within the areas that will be permanently affected by the proposed action will be surveyed for California red-legged frog adults and metamorphs. Any California red-legged frog adults or metamorphs found will be captured and held for a minimum amount of time necessary to relocate the animal to suitable habitat a minimum of 300 feet outside of the work area. Prior to and after handling frogs, the biologist will observe the appropriate decontamination procedures to ensure against spread of chytrid fungus or other pathogens.

If construction activities will occur in streams, temporary aquatic barriers such as hardware cloth will be installed both up and downstream of the stream crossing, and animals will be relocated and excluded from the work area. The USFWS-approved biologists will establish an adequate buffer on both sides of creeks and around potential aquatic habitat and will restrict entry during the construction period.

The USFWS-approved biologist(s) will kill any aquatic exotic wildlife species, such as bullfrogs and crayfish from the worksite, to the greatest extent practicable.

Each encounter with the California red-legged frog will be treated on a case-by-case basis in coordination with the USFWS, but the procedure will follow the pre-approved Relocation Plan and will be conducted is as follows: (1) the animal will not be disturbed if it is not in danger; or (2) the animal will be moved to a secure location if it is in any danger. These procedures are further described below:

When a California red-legged frog is encountered, all activities that have the potential to result in the harassment, injury, or death of an individual will cease immediately and the Onsite Project Manager and USFWS-approved biologist will be notified. The USFWS-approved biologist will then assess the situation and select a course of action to avoid or minimize adverse effects to the animal. To the maximum extent possible, contact with the frog will be avoided and the applicant will allow it to move out of the potentially hazardous situation to a secure location on its own volition. This measure does not apply to animals that are uncovered or otherwise exposed or in areas where there is not sufficient adjacent habitat to support the species should the individual move away from the hazardous location.

California red-legged frogs that are at risk of being injured or killed will be relocated and released by the USFWS-approved biologist outside the construction area within the same riparian area or watershed. If such relocation is not feasible (e.g., there are too many individuals observed per day), the USFWS-approved biologist will relocate the animals to a location previously approved by USFWS. Prior to the initial ground disturbance, DWR, as project applicant, will obtain approval of the relocation plan from the USFWS in the event that a California red-legged frog is encountered and needs to be moved away from the worksite. Under no circumstances will a California red-legged frog be released on a site unless the written permission of the landowner has been obtained.

The USFWS-approved biologist will limit the duration of the handling and captivity of the California red-legged frog to the minimum amount of time necessary to complete the task. If the animal must be held in captivity, it will be kept in a cool, dark, moist, aerated environment, such as a clean and disinfected bucket or plastic container with a damp sponge. The container used for holding or transporting the individual will not contain any standing water.

The USFWS will be immediately notified once the California red-legged frog and the site is secure.

For onsite storage of pipes, conduits and other materials that could provide shelter for California red-legged frogs, an open-top trailer will be used to elevate the materials above ground. This is intended to reduce the potential for animals to climb into the conduits and other materials.

Plastic monofilament netting (erosion control matting), loosely woven netting, or similar material in any form will not be used at the worksite because California red-legged frogs can become entangled and trapped in such materials. Any such material found on site will be immediately removed by the USFWS-approved biologist or construction personnel. Materials utilizing fixed weaves (strands cannot move), polypropylene, polymer or other synthetic materials will not be used.

Dust control measures will be implemented during construction, or when necessary in the opinion of the USFWS-approved biologist, USFWS, or their authorized agent. These measures will consist of regular truck watering of construction access areas and disturbed soil areas with water or organic soil stabilizers to minimize airborne dust and soil particles generated from graded areas. Regular truck watering will be a requirement of the construction contract. Guidelines for truck watering will be established to avoid any excessive runoff that may flow into contiguous or adjacent areas containing potential habitat for the California red-legged frog.

Trenches or pits one (1) foot or deeper that are going to be left unfilled for more than forty eight (48) hours will be securely covered with boards or other material to prevent the California red-legged frog from falling into them. If this is not possible, DWR, as project applicant, will ensure wooden ramps or other structures of suitable surface that provide adequate footing for the California red-legged frog are placed in the trench or pit to allow for their unaided escape. Auger holes or fence post holes that are greater than 0.10 inch in diameter will be immediately filled or securely covered so they do not become pitfall traps for the California red-legged frog. The USFWS-approved biologist will inspect the trenches, pits, or holes prior to their being filled to ensure there are no California red-legged frogs in them. The trench, pit, or hole also will be examined by the USFWS- and CDFW-approved biologist each workday morning at least one hour prior to initiation of work and in the late afternoon no more than one hour after work has ceased to ascertain whether any individuals have become trapped. If the escape ramps fail to allow the animal to escape, the biologist will remove and transport it to a safe location, or contact the USFWS for guidance.

To minimize harassment, injury death, and harm in the form of temporary habitat disturbances, all vehicle traffic related to the PA will be restricted to established roads, construction areas, equipment staging, and storage, parking, and stockpile areas. These areas will be included in pre-construction surveys and, to the maximum extent possible, established in locations disturbed by previous activities to prevent further adverse effects.

All vehicles will observe a 20-mile per hour speed limit within construction areas where it is safe and feasible to do so, except on County roads, and state and Federal highways. Off-road traffic outside of designated and fenced work areas will be prohibited.

If a work site is to be temporarily dewatered by pumping, intakes shall be completely screened with wire mesh not larger than five millimeters to prevent California red-legged frogs from entering the pump system. Water shall be released or pumped downstream at an appropriate rate to maintain downstream flows during construction. Upon completion of construction activities, any barriers to flow shall be removed in a manner that would allow flow to resume with the least disturbance to the substrate.

Uneaten human food and trash attracts crows, ravens, coyotes, and other predators of the California red-legged frog. A litter control program will be instituted at each worksite. All workers will ensure their food scraps, paper wrappers, food containers, cans, bottles, and other trash are deposited in covered or closed trash containers. The trash containers will be removed from the worksite at the end of each working day.

All grindings and asphaltic-concrete waste may be temporally stored within previously disturbed areas absent of habitat and at a minimum of 150 feet from any culvert, pond, creek, stream crossing, or other waterbody. On or before the completion of work at the site, the waste will be transported to an approved disposal site.

Loss of soil from runoff or erosion will be prevented with straw bales, straw wattles, or similar means provided they do not entangle, block escape or dispersal routes of the California red-legged frog.

Insecticides or herbicides will not be applied at the worksite during construction or long-term operational maintenance where there is the potential for these chemical agents to enter creeks, streams, waterbodies, or uplands that contain potential habitat for the California red-legged frog.

No pets will be permitted at the worksite, to avoid and minimize the potential for harassment, injury, and death of the California red-legged frog.

No firearms will be allowed at the worksite except for those carried by authorized security personnel, or local, state, or Federal law enforcement officials to avoid and minimize the potential for harassment, injury, and death of the California red-legged frog.

3.4.5.6.2.2 Activities with Flexible Locations

3.4.5.6.2.2.1 Geotechnical Exploration

Geotechnical exploration will be sited outside of California red-legged aquatic habitat. Geotechnical exploration within suitable upland habitat will include the following measures, adopted from the September 3, 2010 BiOp on *Engineering Geotechnical Studies for the Bay Delta Conservation Plan (BDCP) and/or the Preliminary Engineering Studies for the Delta Habitat Conservation and Conveyance Program (DHCCP)* (81410-2010-F-0022).

To the extent practicable, all activities will avoid impacts to California red-legged frog suitable habitat that possesses cracks or burrows that could be occupied by California red-legged frogs.

Pre-construction surveys will be conducted by a qualified biologist. A biological monitor will be present during all drilling activities in California red-legged frog upland habitat to ensure there are no significant impacts to California red-legged frog.

Work will be done during the dry season (May 1 to October 31) and measures, such as having vehicles follow shortest possible routes from levee road to the drill or CPT sites, will be taken to minimize the overall project footprint.

3.4.5.6.2.2.2 Power Lines and Grid Connections

The final transmission line alignments will be designed to avoid California red-legged frog aquatic habitat, and to minimize effects on upland habitat. The transmission lines will be sited at least 300 feet from occupied California red-legged frog aquatic habitat as determined through protocol-level surveys of any suitable aquatic habitat in the potential transmission line alignment. Occupancy may be assumed, in order to forego the need for protocol-level surveys. After the final transmission line alignment has been determined, the avoidance and minimization measures described in Section 3.4.5.6.2.1, *Activities with Fixed Locations,* will be followed.

3.4.5.6.2.2.3 Restoration

Restoration activities will avoid effects on California red-legged frog and its habitat with the exception of vernal pool complex restoration that may occur in California red-legged frog upland habitat. Any vernal pool creation or restoration will be sited at least 300 feet from occupied California red-legged frog aquatic habitat as determined through protocol-level surveys of any suitable aquatic habitat in the potential restoration area. Occupancy may be assumed to forego the need for protocol-level surveys.

3.4.5.6.3 Compensation to Offset Impacts

California red-legged frog upland habitat will be protected at a ratio of 3:1 within the East San Francisco Bay core recovery area, at locations subject to USFWS approval. This compensation ratio is typically applied to upland habitat within 300 feet of aquatic habitat, based on the Programmatic Biological Opinion for Issuance of Permits under Section 404 for the species (U.S. Fish and Wildlife Service 2014). For the purposes of the PA, this compensation ratio is applied to all modeled upland cover and dispersal habitat, regardless of its distance to aquatic habitat. Therefore, 51 acres of upland habitat will be affected (including 47 acres within the construction footprint and four acres adjacent to the construction footprint, potentially subject to vibrations) and 153acres of upland cover and dispersal habitat will be protected.

California red-legged frog aquatic breeding habitat will be protected at a ratio of 3:1 within the East San Francisco Bay core recovery area as described in the Recovery Plan for the California Red-Legged Frog (U.S. Fish and Wildlife Service 2002), at a location subject to USFWS approval. The increased habitat extent and connectivity will increase opportunities for genetic exchange and allow for colonization of extirpated populations and restored habitats. Therefore, 1 acres of aquatic habitat will be affected and 3 acres of aquatic habitat will be protected (Table 3.4-5).

The above compensation ratios apply only if protection occurs prior to or concurrent with the impact. If protection occurs after an impact, the ratio will increase as shown in Table 3.4-5.

All lands protected and restored for compensation of effects on California red-legged frog habitat will be protected and managed in perpetuity. Adequate funds will be provided by DWR to ensure that the Conservation Area is managed in perpetuity. DWR, as project applicant, will dedicate an endowment fund or similar perpetual funding mechanism for this purpose, and designate the party or entity that will be responsible for long-term management of the Conservation Area. USFWS will be provided with written documentation that funding and management of the Conservation Area will be provided in perpetuity.

Improve habitat linkages by controlling the height and density of grassland and improving culverts to facilitate California red-legged frog movement across the landscape and thus enhance habitat linkages. Increasing opportunities for California red-legged frog to move through grassland habitats will enhance genetic exchange and the ability to recolonize any areas where the species may have been locally extirpated.

Table 3.4-5. Compensation for Direct Effects on California Red-Legged Frog Habitat.

California Red-Legged Frog Modeled Habitat	Maximum Total Impact (Acres)	Habitat Protection Compensation Ratio	Total Habitat Protection if all Direct Impacts Occur (Acres)
Upland and dispersal	51	3:1	153
Aquatic	1	3:1	3
Total	**52**	**–**	**156**

3.4.5.6.4 Siting Criteria for Compensation for Effects

Grassland (and associated vernal pools and alkali seasonal wetlands) protection to benefit California red-legged frog will be prioritized based on the following characteristics.

Grasslands containing stock ponds and other aquatic features that provide aquatic breeding habitat for California tiger salamander.

Lands that connect with existing protected grassland, vernal pool complex, and alkali seasonal wetland complex landscapes, including those in the East San Francisco Bay core recovery area for California red-legged frog.

3.4.5.6.5 Management and Enhancement

The following management and enhancement measures will be implemented on protected California red-legged frog habitat. These management and enhancement activities will be designed and conducted in coordination with (or by) the East Contra Costa County Habitat Conservancy or East Bay Regional Park District. Both of these entities have extensive experience conducting successful grassland and aquatic habitat management and restoration to benefit California red-legged frog in the area where this habitat will be protected to mitigate the effects of the PA.

Aquatic features in protected grasslands will be maintained and enhanced for California red-legged frog to provide suitable inundation depth and duration and suitable composition of vegetative cover to support breeding for California red-legged frog. Stock ponds, intermittent drainages, and other aquatic features are common in grasslands throughout the Byron Hills area. Grasslands that support suitable aquatic features for California red-legged frog will be prioritized for acquisition.

California red-legged frogs require vegetation, usually emergent vegetation, on which to deposit egg masses and cattle using a pond can trample the necessary vegetation. Stock ponds within grasslands protected for California red-legged frog will be managed for livestock exclusion to promote growth of aquatic emergent vegetation with appropriate characteristics favorable to breeding California red-legged frogs and other native amphibians and aquatic reptiles. The surrounding grassland will provide dispersal and aestivation habitat.

The appropriate depth and duration of aquatic features will be maintained for California red-legged frog to ensure that conditions are favorable for supporting the entire aquatic life cycle from breeding through metamorphosis from larval to adult stages. If appropriate, aquatic features may be managed such that they are dry in late summer, to reduce habitat suitability for bullfrogs and nonnative fish that prey on California red-legged frog.

3.4.5.7 California Tiger Salamander

3.4.5.7.1 Habitat Definition

AMMs for California tiger salamander will be required for activities occurring within suitable aquatic or upland habitat, or wherever the species is encountered. Within the action area, based on the known distribution of the species, suitable habitat is defined to occur within the area west of the Yolo Basin but including the Tule Ranch Unit of the California Department of Fish and Wildlife (CDFW) Yolo Basin Wildlife Area; east of the Sacramento River between Freeport and Hood-Franklin Road; east of I-5 between Twin Cities Road and the Mokelumne River; and in the area south and west of SR 4 from Antioch (Bypass Road to Balfour Road to Brentwood Boulevard) to Byron Highway; then south and west along the county line to Byron Highway; then west of Byron Highway to Interstate 205 (I 205), north of I-205 to Interstate 580 (I 580), and west of I-580. Within this area, suitable terrestrial cover and aestivation habitat is defined as grassland with a minimum patch size of 100 acres (40.5 hectares), and suitable aquatic habitat is defined to consist of vernal pools and stock ponds. Once a construction area has been cleared, it will no longer be considered suitable habitat.

A USFWS-approved biologist familiar with the species and its habitat will conduct a field evaluation of suitable upland or aquatic habitat for California tiger salamander for all activities in the PA that occur within modeled habitat (as described in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, Section 4.A.11, *California Tiger Salamander*), or within areas of suitable habitat located by a USFWS-approved biologist during the field evaluation.

3.4.5.7.2 Avoidance and Minimization Measures

3.4.5.7.2.1 Activities with Fixed Locations

AMMs are described below first for activities with known locations including the Clifton Court Forebay canal. Additional AMMs are then described for activities with uncertain locations: habitat restoration, transmission lines, and geotechnical exploration.

3.4.5.7.2.2 Activities with Fixed Locations

The following measures will be implemented for activities with known locations. No aquatic habitat for California tiger salamander will be affected.

Site Preparation-

The perimeter of construction sites will be fenced with amphibian exclusion fencing by no more than 14 days prior to the start of construction. The Onsite Project Manager and the USFWS-approved biologist (in cooperation with USFWS) will determine where exclusion fencing will be installed to protect California tiger salamander habitat adjacent to the defined site footprint and to minimize the potential for California tiger salamanders to enter the construction work area. The locations of exclusion fencing will be determined, in part, by the locations of suitable habitat for the species (defined above). A conceptual fencing plan will be submitted to USFWS prior to the start of construction and the California tiger salamander exclusion fencing will be shown on the final construction plans. DWR, as project applicant, will include the amphibian exclusion fence specifications including installation and maintenance criteria in the bid solicitation package special provisions. The amphibian exclusion fencing will remain in place for the duration of construction and will be regularly inspected and fully maintained. The biological monitor and construction supervisor will be responsible for checking the exclusion fencing around the work areas daily to ensure that they are intact and upright. This will be especially critical during rain events, when flowing water can easily dislodge the fencing. Repairs to the amphibian exclusion fence will be made within 24 hours of discovery. Where construction access is necessary, gates will be installed with the exclusion fence.

At least 15 days prior to any ground disturbance activities, DWR, as project applicant, will prepare and submit a Relocation Plan for USFWS's written approval. The Relocation Plan will contain the name(s) of the USFWS-approved biologist(s) to relocate California tiger salamanders, the method of relocation (if different than described), a map, and a description of the proposed release site(s) within 300 feet of the work area or at a distance otherwise agreed to by USFWS, and written permission from the landowner to use their land as a relocation site.

Preconstruction surveys will be conducted by a USFWS-approved biologist immediately prior to the initiation of any ground disturbing activities or vegetation clearing in areas identified as having suitable California tiger salamander habitat. Prior to initiating surveys, water trucks will spray the work area to influence emergence. Watering will occur at dusk, trucks will make a single pass, and the USFWS-approved biologist(s) will survey the watered area for one hour following the spraying. If California tiger salamander are found, they will be relocated consistent with the Relocation Plan described above. Also see *Species Observation and Handling Protocol*, below.

Initial Clearance/Ground Disturbance

Except for limited vegetation clearing necessary to minimize effects to nesting birds, initial suitable habitat clearance and disturbance will be confined to the dry season (July 15 to October 15). All initial clearing will be limited to periods of no or low rainfall (less than 0.08 inches per 24-hour period and less than 40% chance of rain). Clearing activities within California tiger salamander habitat will cease 24 hours prior to a 40% or greater forecast of rain from the closest National Weather Service (NWS) weather station. Clearing may continue 24 hours after the rain ceases, if no precipitation is in the 24-hour forecast. If clearing must continue when rain is forecast (greater than 40% chance of rain), a USFWS-approved biologist will survey the worksite before clearing begins each day rain is forecast. If rain exceeds 0.5 inches during a 24-hour period, clearing will cease until the NWS forecasts no further rain. Modifications to this timing may be approved by USFWS based on site conditions and expected risks to California tiger salamanders. Once the ground has been cleared and perimeter fencing is in place, these restrictions do not apply.

During Construction

The USFWS-approved biologist shall conduct clearance surveys at the beginning of each day and regularly throughout the workday when construction activities are occurring that may result in take of California tiger salamander. These surveys will consist of walking surveys within the worksites and investigating suitable aquatic and upland habitat including refugia habitat such as small woody debris, refuse, burrow entries, etc. All mammal burrows within the worksite limits that cannot be avoided will be hand-excavated and collapsed so that they do not attract California tiger salamanders during construction.

If the exclusion fence is compromised during the rainy season, when California tiger salamanders are likely to be active, a survey will be conducted immediately preceding construction activity that occurs in modeled or suitable California tiger salamander habitat, as determined by a USFWS-approved biologist, or in advance of any activity that may result in take of the species. The biologist will search along exclusion fences, in pipes, and beneath vehicles each morning before they are moved. The survey will include a careful inspection of all potential hiding spots, such as along exclusion fencing, large downed woody debris, and the perimeter of ponds, wetlands, and riparian areas. Any tiger salamanders found will be captured and relocated to suitable habitat with an active rodent burrow system at a location predetermined prior to commencement of construction in the Relocation Plan (as described below).

To avoid entrapment of animals during construction, pipes or similar structures will be capped if stored overnight. Excavated holes and trenches will have escape ramps, and any open holes and trenches more than 6 inches deep will be closed with plywood at the end of each workday. The USFWS-approved biologist will inspect all holes and trenches at the beginning of each workday and before the holes and trenches are filled. All pipes, culverts, or similar structures sored in the work area overnight will be inspected before they are subsequently moved, capped, and/or buried. If a California tiger salamander is discovered, the Onsite Project Manager and USFWS-approved biologist will be notified immediately, and the USFWS-approved biologist will move the animal to a safe nearby location (as described by the species observation and handling protocol below) and monitor it until it is determined that it is not imperiled by predators, or other dangers.

If verbally requested before, during, or upon completion of ground disturbance and construction activities where suitable California tiger salamander habitat is present, DWR, as project applicant, will ensure that USFWS can immediately access and inspect the worksite for compliance with the description of the PA, and avoidance and minimization measures, and to evaluate effects on the California tiger salamander and its habitat. A USFWS-approved biologist will be onsite during all activities that may result in take of California tiger salamander. This biologist will carry a working mobile phone whose number will be provided to USFWS prior to the start of construction and ground disturbance. USFWS will consider the implementation of specific activities without the oversight of an onsite USFWS-approved biologist on a case-by-case basis.

The USFWS-approved biologist will have the authority to stop activities at the worksite if they determine that any of avoidance and minimization measures are not being fulfilled.

The USFWS-approved biologist will maintain monitoring records that include (1) the beginning and ending time of each day’s monitoring effort; (2) a statement identifying the covered species encountered, including the time and location of the observation; (3)

the time the specimen was identified and by whom and its condition;(4) the capture and release locations of each individual; (5) photographs and measurements (snout to vent and total length) of each individual; and (6) a description of any actions taken. The USFWS-approved biologist will maintain complete records in their possession while conducting monitoring activities and will immediately provide records to USFWS upon request. If requested, all monitoring records will be provided to USFWS within 30 days of the completion of monitoring work.

To the extent possible, earthmoving and construction activities will cease no less than 30 minutes before sunset and will not begin again until no less than 30 minutes after sunrise within 300 feet of California tiger salamander habitat. Except when necessary for driver or pedestrian safety, to the greatest extent practicable, artificial lighting at a worksite will be prohibited during the hours of darkness.

If work must be conducted at night within 300 feet of California tiger salamander habitat, all lighting will be directed away and shielded from California tiger salamander habitat outside the construction area to minimize light spillover to the greatest extent possible. If light spillover into adjacent California tiger salamander habitat occurs, a USFWS-approved biologist will be present during night work to survey for burrows and emerging California tiger salamanders in areas illuminated by construction lighting. If California tiger salamander is found above-ground the USFWS-approved biologist has the authority to terminate the project activities until the light is directed away from the burrows, the California tiger salamander moves out of the illuminated area, or the California tiger salamander is relocated out of the illuminated area by the USFWS-approved biologist.

No rodenticides will be used during construction or long-term operational maintenance in areas that support suitable upland habitat for California tiger salamander.

To prevent California tiger salamander from becoming entangled, trapped, or injured by erosion control structures, erosion control measures that use plastic or synthetic monofilament netting will not be used within areas designated to have suitable California tiger salamander habitat. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine, or other similar fibers. Following site restoration, erosion control materials, such as straw wattles, will be placed so as not to block movement of the California tiger salamander.

Species Observation and Handling Protocol If a California tiger salamander is observed, the USFWS-approved biologist will implement the following species observation and handling protocol. Only USFWS-approved biologists will participate in activities associated with the capture, handling, and monitoring of California tiger salamanders. If a California tiger salamander is encountered in a construction area, activities within 50 feet of the individual will cease immediately and the Onsite Project Manager and USFWS-approved biologist will be notified. Based on the professional judgment of the USFWS-approved biologist, if activities at the worksite can be conducted without harming or injuring the California tiger salamander, it may be left at the location of discovery and monitored by the USFWS-approved biologist. All personnel on site will be notified of the finding and at no time will work occur within 50 feet of the California tiger salamander without a USFWS-approved biologist present. If it is determined by the USFWS-approved biologist that relocating the California tiger salamander is necessary, the following steps will be followed:

Prior to handling and relocation, the USFWS-approved biologist will take precautions to prevent introduction of amphibian diseases in accordance with the *Interim Guidance on Site Assessment and Field Surveys for Determining Presence or a Negative Finding of the California Tiger Salamander* (U.S. Fish and Wildlife Service 2003). Disinfecting equipment and clothing is especially important when biologists are coming to the action area to handle amphibians after working in other aquatic habitats. California tiger salamanders will also be handled and assessed according to the *Restraint and Handling of Live Amphibians* (U.S. Geological Survey National Wildlife Health Center 2001).

California tiger salamanders will be captured by hand, dipnet, or other USFWS-approved methodology, transported, and relocated to nearby suitable habitat outside of the work area and released as soon as practicable the same day of capture. Individuals will be relocated no greater than 300 feet outside of the work area to areas with an active rodent burrow or burrow system (unless otherwise approved by USFWS). Holding/transporting containers and dipnets will be thoroughly cleaned, disinfected, and rinsed with freshwater prior to use within the action area. USFWS will be notified within 24 hours of all capture, handling, and relocation efforts. USFWS- and CDFW-approved biologists will not use soaps, oils, creams, lotions, repellents, or solvents of any sort on their hands within two hours before and during periods when they are capturing and relocating individuals. To avoid transferring disease or pathogens of handling of the amphibians, USFWS-approved biologists will follow the Declining Amphibian Populations Task Force’s “Code of Practice.”

If an injured Central California tiger salamander is encountered and the USFWS--approved biologist determines the injury is minor or healing and the salamander is likely to survive, the salamander will be released immediately, consistent with the pre-approved Relocation Plan as described above. The California tiger salamander will be monitored until it is determined that it is not imperiled by predators or other dangers.

If the USFWS-approved biologist determines that the California tiger salamander has major or serious injuries because of activities at the worksite, the USFWS-approved biologist, or designee, will immediately take it to a USFWS-approved facility. If taken into captivity, the individual will not be released into the wild unless it has been kept in quarantine and the release is authorized by USFWS. DWR, as project applicant, will bear any costs associated with the care or treatment of such injured California tiger salamanders. The circumstances of the injury, the procedure followed and the final disposition of the injured animal will be documented in a written incident report. Notification to USFWS of an injured or dead California tiger salamander in the action area will be made as described under the Reporting Requirements measure (described above), and reported whether or not its condition resulted from activities related to the PA. In addition, the USFWS-approved biologist will follow up with USFWS in writing within two calendar days of the finding. Written notification to USFWS will include the following information: the species, number of animals taken or injured, sex (if known), date, time, location of the incident or of the finding of a dead or injured animal, how the individual was taken, photographs of the specific animal, the names of the persons who observe the take and/or found the animal, and any other pertinent information. Dead specimens will be preserved, as appropriate, and held in a secure location until instructions are received from the USFWS regarding the disposition of the specimen.

3.4.5.7.2.3 Activities with Flexible Locations

3.4.5.7.2.3.1 Geotechnical Exploration

Geotechnical exploration will be sited outside of California tiger salamander aquatic habitat. Geotechnical exploration within suitable upland habitat will include the following measures, adopted from the September 3, 2010 BiOp on *Engineering Geotechnical Studies for the Bay Delta Conservation Plan (BDCP) and/or the Preliminary Engineering Studies for the Delta Habitat Conservation and Conveyance Program (DHCCP)* (81410-2010-F-0022).

To the extent practicable, all project activities within California tiger salamander suitable habitat will avoid impacts to areas that possesses cracks or burrows that could be occupied by California tiger salamanders.

Pre-construction surveys will be conducted by a qualified biologist. A biological monitor will be present during all drilling activities to ensure there are no significant impacts to California tiger salamander.

Work will be done during the dry season (July 15 to October 15) and measures, such as having vehicles follow shortest possible routes from levee road to the drill or CPT sites, will be taken to minimize the overall project footprint.

Geotechnical exploration activities will cease no less than 30 minutes before sunset and will not begin again until no less than 30 minutes after sunrise within 300 feet of California tiger salamander habitat.

3.4.5.7.2.3.2 Safe Havens

Safe havens will avoid suitable California tiger salamander habitat.

3.4.5.7.2.3.3 Power Supply and Grid Connections

The final transmission line alignments will be sited to avoid California tiger salamander aquatic habitat, and to minimize effects on upland habitat. The transmission lines will be sited at least 300 feet from occupied California tiger salamander aquatic habitat as determined through protocol-level surveys of any suitable aquatic habitat within the potential transmission line alignment. Occupancy may be assumed, in order to forego the need for protocol-level surveys. After the final transmission line alignment has been determined, the avoidance and minimization measures described in Section 3.4.5.7.2.1, *Activities with Fixed Locations*, will be followed, with the following exception.

Transmission line construction activities will cease no less than 30 minutes before sunset and will not begin again until no less than 30 minutes after sunrise within 300 feet of California tiger salamander habitat.

3.4.5.7.2.3.4 Restoration

3.4.5.7.2.3.4.1 Vernal Pool Restoration

Vernal pool complex restoration may result in temporary effects on California tiger salamander upland habitat. These effects will be minimized to the greatest extent practicable. Vernal pool restoration is expected to provide long-term benefit to California tiger salamander.

During the restoration planning phase, suitable habitat in potential work areas will be surveyed for California tiger salamander larvae, eggs, and adults. If California tiger salamander larvae or eggs are found, the restoration will be designed to avoid impacts on the aquatic habitat and these life stages.

Vernal pool restoration activities in upland habitat will be minimized during the wet season (October 16 to July 14). Surface-disturbing activities will be designed to minimize or eliminate effects on rodent burrows that may provide suitable aestivation habitat. Areas with a high concentration of burrows will be avoided by surface-disturbing activities to the greatest extent practicable. In addition, when a concentration of burrows is present at a worksite, the area will be staked or flagged to ensure that work crews are aware of their location and to facilitate avoidance of the area.

After the restoration design is completed, the avoidance and minimization measures described in Section 3.4.5.7.2.1, *Activities with Fixed Locations,* will be followed.

3.4.5.7.2.3.4.2 Tidal Restoration

Tidal restoration activities have potential to affect California tiger salamander habitat in the Jepson Prairie area. This includes portions of critical habitat that overlap with the western terminus of Lindsey Slough, west of Rio Dixon Road. Tidal restoration projects will be designed to avoid areas within 250 feet of any of the physical or biological features (PBFs)[69] of California tiger salamander habitat within the designated critical habitat unit, or some lesser distance if it is determined through project review and concurrence by USFWS that tidal restoration actions will not result in changes in hydrology or soil salinity that could adversely modify these PBFs. With the application of the AMM, adverse modification to PBFs of California tiger salamander critical habitat will be avoided.

3.4.5.7.3 Compensation for Effects

DWR will protect California tiger salamander habitat at a ratio of 3:1 (protected to lost) at locations subject to USFWS approval, adjacent to or near occupied upland habitat that is on a conservation easement, has a management plan, and endowment, or similar funding mechanism, to fund management in perpetuity. The 3:1 ratio applies if protection occurs prior to or

[69] The designations of critical habitat for listed species have generally used the term primary constituent elements (PCEs). NMFS and USFWS have amended the regulations for designating critical habitat (81 FR 7414; February 11, 2016), replacing the term PCEs with physical or biological features (PBFs). At the same time, NMFS and USFWS issued a final rule revising the regulatory definition of "destruction or adverse modification" of critical habitat (81 FR 7214; February 11, 2016), which refers to PBFs, not PCEs. The shift in terminology does not change the approach used in conducting an analysis of the effects of the proposed action on critical habitat, which is the same regardless of whether the original designation identified PCEs or PBFs. In this biological assessment, we use the term PBFs to include PCEs.

concurrent with the impacts. If protection occurs after the impacts, the ratio will increase as shown in Table 3.4-6. California tiger salamander habitat protection will be located in the Byron Hills area, west of the worksite. While there is no recovery plan available for California tiger salamander to inform the location of conservation lands, conservation in this area will benefit the California tiger salamander by providing habitat in a region where high-quality habitat and extant occurrences are known to exist. Grasslands targeted for protection will be located near important areas for conservation that were identified in the *East Contra Costa County HCP/NCCP* (East Contra Costa County Habitat Conservancy 2006) (not all of which will be acquired by that plan) and will include appropriate upland and aquatic features, e.g., rodent burrows, stock ponds, intermittent drainages, and other aquatic features, etc. An estimated 50 acres of habitat will be affected (47 acres within the construction footprint and 3 acres adjacent to construction, potentially subject to vibrations); therefore, 150 acres of habitat will be protected.

Table 3.4-6. Compensation for Direct Effects on California Tiger Salamander Habitat.

	Maximum Total Impact (Acres)	Habitat Protection Compensation Ratio	Total Habitat Protection if all Direct Impacts Occur (Acres)
Terrestrial cover and aestivation	50	3:1	150
Total	**50**	**-**	**150**

3.4.5.7.4 Siting Criteria for Compensation for Effects

Grasslands, associated vernal pools, and alkali seasonal wetlands will be protected in perpetuity as compensation for effects on California tiger salamander. Land acquisition for California tiger salamander grassland habitat management lands will be prioritized based on the following characteristics:

Large contiguous landscapes that consist of grasslands, vernal pool complex, and alkali seasonal wetland complex and encompass the range of vegetation, hydrologic, and soil conditions that characterize these communities.

Lands that maintain connectivity with protected grassland, vernal pool complex, and alkali seasonal wetland complex landscapes near proposed construction sites, including connectivity with lands that have been protected or may be protected in the future under the East Contra Costa County HCP/NCCP.

Grasslands containing stock ponds and other aquatic features that provide aquatic breeding habitat for California tiger salamander.

3.4.5.7.5 Management and Enhancement

The following management and enhancement activities will be implemented on grasslands protected to benefit California tiger salamander. These management and enhancement activities will be designed and conducted in coordination with (or by) the East Contra Costa County Habitat Conservancy or East Bay Regional Park District. Both of these entities have extensive experience conducting successful grassland and aquatic habitat management and restoration to benefit California tiger salamander in the area where this habitat will be protected to mitigate the effects of the PA.

Maintain hydrology and water quality. Hydrologic functions to be maintained within vernal pool and alkali seasonal wetland complexes include surface water storage in the pool, subsurface water exchange, and surface water conveyance (Butterwick 1998:52). Aspects of surface water storage such as timing, frequency, and duration of inundation will be monitored, enhanced, and managed to benefit California tiger salamander. Techniques used to enhance and manage hydrology may include invasive plant control, removal of adverse supplemental water sources into reserves (e.g., agricultural or urban runoff), and topographic modifications. Any pesticides used for invasive plant control will be applied during the dry season (July 15 to October 15) when ponds and other aquatic features are not inundated. Disking or mowing will not be used to control vegetation in California tiger salamander habitat.

Repairs may be made to improve water retention in stock ponds that are not retaining water due to leaks and, as a result, not functioning properly as habitat for California tiger salamander. Additionally, pond capacity and water duration may be increased (e.g., by raising spillway elevations) to support California tiger salamander populations. To the greatest extent practicable, repairs will be implemented outside the California tiger salamander breeding season to minimize effects on the species[70].

To retain the habitat quality of stock ponds over time, occasional sediment removal may be needed to address the buildup of sediment that results from adjacent land use or upstream factors. To the greatest extent practicable, dredging will be conducted during the nonbreeding periods for California tiger salamander to minimize impacts on the species.

Control nonnative predators. Habitat management and enhancement will include trapping and other techniques to control the establishment and abundance of bullfrogs, barred tiger salamander, and other nonnative predators that threaten wildlife species in vernal pools, seasonal wetlands, and stock ponds. DWR, as project applicant, or the land manager will work to reduce and, where possible, eradicate invasive species that adversely affect native species. These efforts will include prescribed methods for removal of bullfrogs, mosquitofish, and nonnative predatory fish from stock ponds and wetlands in the habitat management lands, including limiting the hydroperiod of stock ponds.

DWR, as project applicant, will work to reduce, and if possible eradicate, nonnative predators (e.g., bullfrogs, barred tiger salamander, nonnative predatory fish) from aquatic habitat for covered amphibian species through habitat manipulation (e.g., periodic draining of ponds), trapping, hand-capturing, electroshocking, or other control methods. These activities will be carried out by qualified biologists familiar with California tiger salamander, and will be conducted in a manner that avoids take of California tiger salamanders. Draining ponds annually, sterilizing or removing subsoil, and removing bullfrogs can be effective at reducing predation by bullfrogs and other invasive species

[70] Maintaining California tiger salamander use of stock ponds on livestock ranches for breeding appears to be a critical link in the conservation and recovery of this species. In 2004, because of the conservation benefit to the species, USFWS under Section 4(d) of the ESA (69 FR 47212) determined that routine management and maintenance activities of stock ponds on private lands are exempt from the take prohibitions under section 9 of the ESA.

on covered amphibians and reptiles (Doubledee et al. 2003). Some ponds in the habitat management lands might be retrofitted with drains if the nonnative species populations cannot be controlled by other means. Ponds without drains and that do not drain naturally may need to be drained annually using pumps. Drainage of stock ponds and other wetlands will be carried out during the summer or fall dry season (July 15 to October 15). Models predict that draining ponds every 2 years will decrease the likelihood that bullfrogs will persist in ponds (Doubledee et al. 2003). Limiting the hydroperiod of stock ponds also shifts the competitive balance from nonnative barred tiger salamander and hybrid salamanders in favor of native California tiger salamanders (Johnson et al. 2010).

<u>Maintain or enhance burrow availability</u>. Ground-dwelling mammals such as California ground squirrel provide burrows for California tiger salamander. Historically, ground squirrel populations were controlled by ranchers and public agencies. Eliminating ground squirrel control measures on habitat management lands may enable increased squirrel populations in some areas. However, some rodent control measures will likely remain necessary in certain areas where dense rodent populations may compromise important infrastructure (e.g., pond berms, road embankments, railroad beds, levees, dam faces). The use of rodenticides or other rodent control measures will be prohibited in habitat management lands except as necessary to address adverse impacts on essential structures in or immediately adjacent to these lands, including recreational facilities incorporated into the reserve system. DWR or the land manager will introduce livestock grazing (where it is not currently used, and where conflicts with worksite activities will be minimized) to reduce vegetative cover and thus encourage ground squirrel expansion and colonization.

<u>Manage livestock grazing</u>. Grazing by livestock and native herbivores is proposed to manage grassland vegetation and thatch to facilitate dispersal of California tiger salamander, for which dense vegetation may hinder movement. Appropriate grazing programs will be developed for enhancing and maintaining habitat for California tiger salamanders based on site-specific characteristics of the community, the spatial location of important ecological features in each pasture, the history of grazing on the site, species composition of the site, grazer vegetation preference, and other relevant information. Grazing exclusion will be used as a management alternative where appropriate.

3.4.5.8 Valley Elderberry Longhorn Beetle

3.4.5.8.1 Habitat Definition

Valley elderberry longhorn beetle suitable habitat is defined in Section 4.A.12.6, *Suitable Habitat Definition*, of Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, AMMs for valley elderberry longhorn beetle will only be required for activities occurring within suitable habitat. Suitable habitat is defined as elderberry shrubs within the action area. Elderberry shrubs in the action area could be found in riparian areas, along levee banks, grasslands, and in agricultural settings where vegetation is not being maintained (e.g., fence rows, fallow fields) (Appendix 4.A, Section 4.A.12.6, *Suitable Habitat Definition*).

3.4.5.8.2 Avoidance and Minimization Measures

AMMs are described below first for activities with fixed locations including the intake facilities, reusable tunnel material placement areas, intermediate forebay, Clifton Court Forebay expansion area, vent shafts, and retrieval shafts. Additional AMMs are then described for activities with flexible locations: habitat restoration, safe haven intervention sites, transmission lines, and geotechnical investigations.

3.4.5.8.2.1 Activities with Fixed Locations

The following measures will be required for construction, operation, and maintenance related to fixed location activities. The following measures will also be required for activities with flexible locations once their locations have been determined.

Preconstruction surveys for elderberry shrubs will be conducted within all facility footprints and areas within 100 feet by a USFWS-approved biologist familiar with the appearance of valley elderberry longhorn beetle exit holes in elderberry shrubs. Preconstruction surveys will be conducted in the calendar year prior to construction and will follow the guidance of USFWS's *Conservation Guidelines for the Valley Elderberry Longhorn Beetle* (U.S. Fish and Wildlife Service 1999), herein referred to as the 1999 VELB Conservation Guidelines. The results of preconstruction surveys will be reported to USFWS. Elderberry shrubs will be avoided to the greatest extent practicable. Complete avoidance (i.e., no adverse effects) may be assumed when a buffer of at least a 100 feet is established and maintained around elderberry plants containing stems measuring 1 inch or greater in diameter at ground level. Firebreaks may not be included in the buffer zone. USFWS will be consulted before any disturbances, including construction, within the 100-foot buffer area are considered. Any damaged area within the buffer zones will be restored following the conclusion of construction in the work area.

Elderberry shrubs that must be removed will be transplanted to USFWS-approved Conservation Areas (the areas where plantings will occur to offset impacts). Transplanting, avoidance measures, and associated compensation will follow the 1999 VELB Conservation Guidelines except where modified with site specificity as stated herein. Avoidance measures for shrubs not directly affected by construction but within 100-feet of ground disturbing activities will follow the guidance outline in the 1999 VELB Conservation Guidelines as well.

For shrubs not directly affected by construction but that occur between 20 feet and 100 feet from ground-disturbing activities, the following measures will be implemented.

Fence and flag areas to be avoided during construction activities. In areas where encroachment on the 100-foot buffer has been approved by USFWS, provide a minimum setback of at least 20 feet from the dripline of each elderberry plant.

To the greatest extent practicable, construction will be limited during the valley elderberry longhorn beetle active season, March 15th through June 15th.

Brief contractors on the need to avoid damaging the elderberry plants and the possible penalties for not complying with these requirements (see AMM1 in Appendix 3.F, *General Avoidance and Minimization Measures,* for more detail).

Erect signs every 50 feet along the edge of the avoidance area with the following information: “This area is habitat of the valley elderberry longhorn beetle, a threatened species, and must not be disturbed. This species is protected by the Endangered Species Act of 1973, as amended. Violators are subject to prosecution, fines, and imprisonment.” The signs will be clearly readable from a distance of 20 feet, and must be maintained for the duration of construction.

Instruct work crews about the status of the beetle and the need to protect its elderberry host plant.

During construction activities, no insecticides, herbicides, fertilizers, or other chemicals that might harm the beetle or its host plant will be used in the 100-foot buffer area.

To the greatest extent practicable, nighttime construction will be minimized or avoided by DWR, as project applicant, between March 15th and June 15th where valley elderberry longhorn beetle is likely to be present. Because there is potential for valley elderberry valley longhorn beetles to be attracted to nighttime light and thus increase the potential for predation, activities will cease no less than 30 minutes before sunset and will not begin again prior to no less than 30 minutes after sunrise. Except when necessary for driver or pedestrian safety, to the greatest extent practicable, artificial lighting at a construction site will be prohibited during the hours of darkness where valley elderberry longhorn beetle is likely to be present.

Night lighting of valley elderberry beetle habitat will be minimized to the extent practicable. If night lighting is to be used, to the greatest extent possible it will be pointed toward work areas and way from riparian, other sensitive habitats, and other areas that contain elderberry shrubs.

Restore any damage done to the buffer area (area within 100 feet of elderberry plants) during construction. Provide erosion control and re-vegetate with appropriate native plants.

For those parts of the water conveyance facility that will require ongoing maintenance (e.g., intake facilities, pump facilities at Clifton Court Forebay, in right of ways around permanent transmission lines, around vent shafts, etc.), buffer areas must continue to be maintained for the protection of the species after construction with measures such as fencing, signs, weeding, and trash removal as appropriate.

A written description of how the buffer areas are to be restored and maintained for the protection of the species will be provided to USFWS.

To prevent fugitive dust from drifting into adjacent habitat, all clearing, grubbing, scraping, excavation, land leveling, grading, cut and fill, demolition activities, or other dust generating activities will be effectively controlled for fugitive dust emissions utilizing application of water or by presoaking work areas.

For shrubs directly affected by construction, and within 20 feet of disturbance activities if this area is also disturbed, the following measures will be followed for transplantation.

A USFWS-approved biologist (monitor) must be onsite for the duration of the transplanting of the elderberry plants to ensure that no unauthorized take of the valley elderberry longhorn beetle occurs. If unauthorized take occurs, the monitor must have the authority to stop work until corrective measures have been completed. The monitor must immediately report any unauthorized take of the beetle or its habitat to the USFWS and to the CDFW.

Elderberry shrubs will be transplanted during their dormant season, which occurs from November, after they have lost their leaves, through the first two weeks in February. If transplantation occurs during the growing season, increased compensation ratios will apply. Compensation ratios could be up to three times the standard compensation ratios as determined in consultation with USFWS staff.

Transplantation procedure will be as specified in the 1999 VELB Conservation Guidelines.

Elderberry shrubs will be transplanted into the area where plantings will occur to offset impacts (Section 3.4.4, *Spatial Extent, Location, and Design of Restoration for Terrestrial Species*), referred to in the 1999 VELB Conservation Guidelines as the *Conservation Area*.

If a plant appears to be unlikely to survive transplantation, then transplantation is not required, but a higher compensation ratio may be applied. In this instance, the USFWS will be contacted to determine the appropriate action.

3.4.5.8.2.2 Activities with Flexible Locations

Activities with flexible locations are activities that cannot yet be precisely sited because they require design or site-specific information that will not be available until the PA is already in progress. These include geotechnical exploration, safe haven intervention sites, transmission lines, and habitat restoration.

During the planning phase, for these not fully sited activities, preconstruction surveys for elderberry shrubs will be conducted in potential work areas by a USFWS-approved biologist familiar with the appearance of valley elderberry longhorn beetle exit holes in elderberry shrubs. Preconstruction surveys will be conducted in accordance with the protocol provided in the 1999 VELB Conservation Guidelines, and survey results will be reported to USFWS. Elderberry shrubs will be avoided to the greatest extent practicable. Complete avoidance (i.e., no adverse effects) may be assumed when a buffer of at least a 100 feet is established and maintained around elderberry plants containing stems measuring 1 inch or greater in diameter at ground level. Firebreaks may not be included in the buffer zone. USFWS will be consulted before any disturbances, including construction, within the 100-foot buffer area are considered. Any damaged area within the buffer zones will be restored following the conclusion of construction in work areas.

3.4.5.8.2.2.1 Geotechnical Activities

Based on the planning level surveys, geotechnical exploration activities for the PA will fully avoid effects on valley elderberry longhorn beetle and its habitat. Valley elderberry longhorn beetle avoidance and minimization measures for geotechnical activities will be the same as described in Section 3.4.5.8.2.1, *Activities with Fixed Locations.*

3.4.5.8.2.2.2 Safe Haven Work Areas

Workers will confine ground disturbance and habitat removal to the minimal area necessary to facilitate construction activities. In addition, avoidance and minimization measures for safe haven interventions will be the same as described in Section 3.4.5.8.2.1, *Activities with Fixed Locations.*

3.4.5.8.2.2.3 Power Lines and Grid Connections

Based on the planning level surveys, the siting of transmission towers and poles will avoid elderberry shrubs to the extent practicable. Valley elderberry longhorn beetle avoidance and minimization measures for transmission lines will be the same as described in Section 3.4.5.8.2.1, *Activities with Fixed Locations.*

3.4.5.8.2.2.4 Restoration

Selection of restoration sites will be by DWR, subject to approval by the jurisdictional fish and wildlife agencies (CDFW, NMFS, and USFWS). Based on planning level surveys, restoration activities will be designed to fully avoid valley elderberry longhorn beetle habitat, with the exception of tidal restoration and channel margin enhancement, which may affect elderberry shrubs. These types of restoration will be designed to minimize effects in valley elderberry longhorn beetle habitat. Restoration activities that cannot avoid habitat will implement the avoidance and minimization measures described in Section 3.4.5.8.2.1, *Activities with Fixed Locations*.

3.4.5.8.3 Compensation to Offset Impacts

DWR will offset impacts on elderberry shrubs by either creating valley elderberry longhorn beetle habitat or by purchasing the equivalent credits at a USFWS approved conservation bank with a service area that overlaps with the action area consistent with the 1999 VELB Conservation Guidelines. These guidelines require replacement of each impacted elderberry stem measuring one inch or greater in diameter at ground level, in the Conservation Area, with elderberry seedlings or cuttings at a ratio ranging from 1:1 to 8:1 (new plantings to affected stems), and planting of associated native riparian plants. These ratios will apply if compensation occurs prior to or concurrent with the impacts. If compensation occurs after the impacts, a higher ratio may be required by USFWS. Table 3.4-7 provides these ratios and the number of elderberry shrubs and associated native riparian plants that will be required to mitigate for the estimated 107 elderberry shrubs that will be affected by fully sited construction activities if all impacts occur. Table 3.4-8 through Table 3.4-14 provide the estimated number of shrubs that will be affected by each covered activity. The planting area will provide at a minimum 1,800 square feet for each transplanted shrub. As many as five additional elderberry plantings (cuttings or seedlings) and up to five associated native species plantings may also be planted within the 1,800 square foot area with the transplant. An additional 1,800 square feet will be provided for every additional 10 conservation plants. Additional detail regarding the Conservation Area within which these plantings will take place is provided in the 1999 VELB Conservation Guidelines and below under Section 3.4.5.8.4, *Siting Criteria for Compensation for Effects*.

Table 3.4-7. Compensation for Direct Effects from All Activities

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (25 shrubs, 500 stems)	Greater than or equal to 1 inch, less than 3 inches	280	No	151	1:1	1:1	151	151	
			Yes	129	2:1	2:1	258	516	
	Greater than or equal to 3 inches, less than 5 inches	115	No	62	2:1	1:1	124	124	
			Yes	53	4:1	2:1	212	424	
	Greater than or equal to 5 inches	105	No	57	3:1	1:1	170	170	
			Yes	48	6:1	2:1	291	582	
Riparian (58 shrubs, 1,058 stems)	Greater than or equal to 3 inches, less than 5 inches	709	No	348	2:1	1:1	696	348	
			Yes	361	4:1	2:1	1,444	722	
	From 3 to 5 inches	179	No	86	3:1	1:1	258	86	
			Yes	93	6:1	2:1	558	186	
	Greater than or equal to 5 inches	170	No	84	4:1	1:1	336	84	
			Yes	86	8:1	2:1	688	172	
						Total	**5,186**	**3,565**	**8,751**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 107 shrubs occur. Total seedlings/cuttings and associated natives = 15,002

83 transplants plus 830 seedlings/cuttings and natives x 1,800 sq ft = 149,400 sq ft = 3.43 acres

7,921 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 1,425,780 sq ft = 32.7 acres

Total area = 36.1 acres

Table 3.4-8. Compensation for Direct Effects from North Delta Intakes

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (3 shrubs, 60 stems)	Greater than or equal to 1 inch, less than 3 inches	34	No	18	1:1	1:1	18	18	
			Yes	16	2:1	2:1	31	62	
	Greater than or equal to 3 inches, less than 5 inches	14	No	7	2:1	1:1	15	15	
			Yes	6	4:1	2:1	25	51	
	Greater than or equal to 5 inches	13	No	7	3:1	1:1	20	20	
			Yes	6	6:1	2:1	35	70	
Riparian (12 shrubs, 240 stems)	Greater than or equal to 3 inches, less than 5 inches	161	No	79	2:1	1:1	157	157	
			Yes	82	4:1	2:1	329	658	
	From 3 to 5 inches	41	No	20	3:1	1:1	60	60	
			Yes	21	6:1	2:1	125	250	
	Greater than or equal to 5 inches	38	No	19	4:1	1:1	75	75	
			Yes	20	8:1	2:1	157	314	
						Total	**1,048**	**1,751**	**2,799**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 15 shrubs occur. Total seedlings/cuttings and associated natives = 2,799.

15 transplants plus 150 seedlings/cuttings and natives X 1,800 sq ft = 27,000 sq ft = 0.6198 acres.

2,649 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 476,814 sq ft = 10.946 acres.

Total area = 11.566 acres.

Table 3.4-9. Compensation for Direct Effects from RTM Storage Areas

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (6 shrubs, 120 stems)	Greater than or equal to 1 inch, less than 3 inches	67	No	36	1:1	1:1	36	36	
			Yes	31	2:1	2:1	62	124	
	Greater than or equal to 3 inches, less than 5 inches	28	No	15	2:1	1:1	30	30	
			Yes	13	4:1	2:1	51	102	
	Greater than or equal to 5 inches	25	No	14	3:1	1:1	41	41	
			Yes	12	6:1	2:1	70	140	
Riparian (13 shrubs, 260 stems)	Greater than or equal to 3 inches, less than 5 inches	174	No	85	2:1	1:1	170	170	
			Yes	89	4:1	2:1	357	713	
	From 3 to 5 inches	44	No	22	3:1	1:1	65	65	
			Yes	23	6:1	2:1	136	271	
	Greater than or equal to 5 inches	42	No	20	4:1	1:1	81	81	
			Yes	21	8:1	2:1	170	341	
						Total	**1,268**	**2,113**	**3,381**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 19 shrubs occur. Total seedlings/cuttings and associated natives = 3,381.

19 transplants plus 190 seedlings/cuttings and natives = 34200 sq. feet = 0.785123967 acres.

3,191 remaining seedlings/cuttings and native and 10 per 1,800 square foot = 574,425 sq ft =13.187 acres.

Total area = 13.972 acres.

Table 3.4-10. Compensation for Direct Effects from HOR Gate

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (1shrub, 20 stems)	Greater than or equal to 1 inch, less than 3 inches	11	No	6	1:1	1:1	6	6	
			Yes	5	2:1	2:1	10	21	
	Greater than or equal to 3 inches, less than 5 inches	5	No	2	2:1	1:1	5	5	
			Yes	2	4:1	2:1	8	17	
	Greater than or equal to 5 inches	4	No	2	3:1	1:1	7	7	
			Yes	2	6:1	2:1	12	23	
Riparian (no shrubs)	Greater than or equal to 3 inches, less than 5 inches	0	No	0	2:1	1:1	0	0	
			Yes	0	4:1	2:1	0	0	
	From 3 to 5 inches	0	No	0	3:1	1:1	0	0	
			Yes	0	6:1	2:1	0	0	
	Greater than or equal to 5 inches	0	No	0	4:1	1:1	0	0	
			Yes	0	8:1	2:1	0	0	
						Total	**48**	**79**	**127**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on 1 shrub occurs. Total seedlings/cuttings and associated natives = 127.

1 transplants plus 10 seedlings/cuttings and natives = 1,800 sq ft = 0.041 acres.

117 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 21,046 sq ft = 0.483 acres.

Total area = 0.524 acres.

Table 3.4-11. Compensation for Direct Effects from Water Conveyance Facilities

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (5 shrubs, 100 stems)	Greater than or equal to 1 inch, less than 3 inches	56	No	30	1:1	1:1	30	30	
			Yes	26	2:1	2:1	52	103	
	Greater than or equal to 3 inches, less than 5 inches	23	No	12	2:1	1:1	25	25	
			Yes	11	4:1	2:1	42	85	
	Greater than or equal to 5 inches	21	No	11	3:1	1:1	34	34	
			Yes	10	6:1	2:1	58	116	
Riparian (18 shrubs, 360 stems)	Greater than or equal to 3 inches, less than 5 inches	241	No	118	2:1	1:1	236	236	
			Yes	123	4:1	2:1	494	987	
	From 3 to 5 inches	61	No	30	3:1	1:1	90	90	
			Yes	31	6:1	2:1	188	376	
	Greater than or equal to 5 inches	58	No	28	4:1	1:1	113	113	
			Yes	29	8:1	2:1	236	472	
						Total	**1,596**	**2,666**	**4,262**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 23 shrubs occur. Total seedlings/cuttings and associated natives = 4,262.

23 transplants plus 230 seedlings/cuttings and natives x 1,800 sq ft = 41,400 sq ft = 0.950 acres.

4,032 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 725,744 sq ft = 16.661 acres.

Total area = 17.611 acres.

Table 3.4-12. Compensation for Direct Effects from Clifton Court Forebay Modifications

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (6 shrubs, 120 stems)	Greater than or equal to 1 inch, less than 3 inches	67	No	36	1:1	1:1	36	36	
			Yes	31	2:1	2:1	62	124	
	Greater than or equal to 3 inches, less than 5 inches	28	No	15	2:1	1:1	30	30	
			Yes	13	4:1	2:1	51	102	
	Greater than or equal to 5 inches	25	No	14	3:1	1:1	41	41	
			Yes	12	6:1	2:1	70	140	
Riparian (1 shrub, 20 stems)	Greater than or equal to 3 inches, less than 5 inches	13	No	7	2:1	1:1	13	13	
			Yes	7	4:1	2:1	27	55	
	From 3 to 5 inches	3	No	2	3:1	1:1	5	5	
			Yes	2	6:1	2:1	10	21	
	Greater than or equal to 5 inches	3	No	2	4:1	1:1	6	6	
			Yes	2	8:1	2:1	13	26	
						Total	**365**	**598**	**963**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 7 shrubs occur. Total seedlings/cuttings and associated natives = 963.

7 transplants plus 70 seedlings/cuttings and natives x 1,800 sq ft = 12,600 sq ft = 0.289 acres.

893 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 160,750 sq ft = 3.690 acres.

Total area = 3.980 acres.

Table 3.4-13. Compensation for Direct Effects from Transmission Lines

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (3 shrubs, 60 stems)	Greater than or equal to 1 inch, less than 3 inches	34	No	18	1:1	1:1	18	18	
			Yes	16	2:1	2:1	31	62	
	Greater than or equal to 3 inches, less than 5 inches	14	No	7	2:1	1:1	15	15	
			Yes	6	4:1	2:1	25	51	
	Greater than or equal to 5 inches	13	No	7	3:1	1:1	20	20	
			Yes	6	6:1	2:1	35	70	
Riparian (8 shrubs, 160 stems)	Greater than or equal to 3 inches, less than 5 inches	107	No	52	2:1	1:1	105	105	
			Yes	55	4:1	2:1	219	439	
	From 3 to 5 inches	27	No	13	3:1	1:1	40	40	
			Yes	14	6:1	2:1	83	167	
	Greater than or equal to 5 inches	26	No	13	4:1	1:1	50	50	
			Yes	13	8:1	2:1	105	210	
						Total	**747**	**1,246**	**1,993**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 11 shrubs occur. Total seedlings/cuttings and associated natives = 1,993.

11 transplants plus 110 seedlings/cuttings and natives = 19,800 sq ft = 0.455 acres.

1,883 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 338,922 sq ft = 7.781 acres.

Total area = 8.235 acres.

Table 3.4-14. Compensation for Direct Effects from Safe Haven Work Areas

Location of Affected Plants	Stems (maximum diameter at ground level) of Affected Plants		Exit Holes on Affected Shrub (Yes/No)[1]		Elderberry Seedling Ratio[2]	Associated Native Plant Ratio[3]	Elderberry Seedling Requirement[4]	Associated Native Plant Requirement[4]	
Non-riparian (1 shrub, 20 stems)	Greater than or equal to 1 inch, less than 3 inches	11	No	6	1:1	1:1	6	6	
			Yes	5	2:1	2:1	10	21	
	Greater than or equal to 3 inches, less than 5 inches	5	No	2	2:1	1:1	5	5	
			Yes	2	4:1	2:1	8	17	
	Greater than or equal to 5 inches	4	No	2	3:1	1:1	7	7	
			Yes	2	6:1	2:1	12	23	
Riparian (6 shrubs, 120 stems)	Greater than or equal to 3 inches, less than 5 inches	13	No	7	2:1	1:1	13	13	
			Yes	7	4:1	2:1	27	55	
	From 3 to 5 inches	3	No	2	3:1	1:1	5	5	
			Yes	2	6:1	2:1	10	21	
	Greater than or equal to 5 inches	3	No	2	4:1	1:1	6	6	
			Yes	2	8:1	2:1	13	26	
						Total	**124**	**205**	**328**

[1] Presence or absence of exit holes indicating presence of valley elderberry longhorn beetle. All stems measuring one inch or greater in diameter at ground level on a single shrub are considered occupied when exit holes are present anywhere on the shrub.

[2] Ratios in this column correspond to the number of cuttings or seedlings to be planted per elderberry stem (one inch or greater in diameter at ground level) affected by a covered activity.

[3] Ratios in this column correspond to the number of associated native species to be planted per elderberry seedling or cutting planted.

[4] Numbers of elderberry seedlings and associated native plants are the required numbers of plantings for compensation if impacts on all 7 shrubs occur. Total seedlings/cuttings and associated natives = 1,336.

2 transplants plus 20 seedlings/cuttings and natives = 1,800 sq ft = 3,600sq ft = 0.0826acres.

308 remaining seedlings/cuttings and natives and 10 per 1,800 sq ft = 55,519 sq ft = 1.274acres.

Total area = 1.357 acres.

3.4.5.8.4 Siting Criteria for Compensation for Effects

Each Conservation Area will provide at least 1,800 square feet for each transplanted elderberry plant. As many as 10 conservation plantings (i.e., elderberry cuttings or seedlings and/or associated native plants) may be planted within the 1,800 square foot area with each transplanted elderberry. An additional 1,800 square feet will be provided for every additional 10 conservation plants. Each planting will have its own watering basin measuring approximately three feet in diameter. Watering basins will be constructed with a continuous berm measuring approximately eight inches wide at the base and six inches high.

Depending on adjacent land use, a buffer area may also be needed between the Conservation Area and the adjacent lands. For example, herbicides and pesticides are often used on orchards or vineyards. These chemicals may drift or run off onto the Conservation Area if an adequate buffer area is not provided.

3.4.5.8.4.1 Long-Term Protection

Each Conservation Area will be protected in perpetuity as habitat for the valley elderberry longhorn beetle. A conservation easement or deed restrictions to protect the Conservation Area must be arranged. Conservation Areas may be transferred to a resource agency or appropriate private organization for long-term management. USFWS must be provided with a map and written details identifying the Conservation Area; and DWR, as project applicant, must receive approval from USFWS that the Conservation Area is acceptable prior to initiating the conservation program. A true, recorded copy of the deed transfer, conservation easement, or deed restrictions protecting the Conservation Area in perpetuity must be provided to USFWS before construction activities begin.

Adequate funds must be provided to ensure that the Conservation Area is managed in perpetuity. DWR, as project applicant, must dedicate an endowment fund, or similar perpetual funding mechanism, for this purpose, and designate the party or entity that will be responsible for long-term management of the Conservation Area. USFWS will be provided with written documentation that funding and management of the Conservation Area will be provided in perpetuity.

3.4.5.8.5 Management and Enhancement

The following management and enhancement activities will be implemented to benefit valley elderberry longhorn beetle. If a mitigation bank is used to offset effects, it will be USFWS-approved and will meet the requirements set forth above.

3.4.5.8.5.1 Levee Maintenance

All levee maintenance that involves ground-disturbing activities will implement relevant measures described above under Section 3.4.5.8.2, *Avoidance and Minimization Measures*. Vegetation burning or nonselective herbicide use kills elderberry shrubs required by the valley elderberry longhorn beetle. Other methods such as managed goat grazing may be an effective and biologically preferred vegetation management method along levees (with goatherds used to limit grazing on desirable species).

3.4.5.8.5.2 Weed Control

Weeds and other plants that are not native to the Conservation Area will be removed at least once a year, or at the discretion of the USFWS. Mechanical means will be used; herbicides are prohibited unless approved by the USFWS.

3.4.5.8.5.3 Pesticide and Toxicant Control

Measures will be taken to insure that no pesticides, herbicides, fertilizers, or other chemical agents enter the Conservation Area. No spraying of these agents will be done within 100 feet of the Conservation Area, or if they have the potential to drift, flow, or be washed into the area in the opinion of biologists or law enforcement personnel from the USFWS.

3.4.5.8.5.4 Litter Control

No dumping of trash or other material may occur within a Conservation Area. Any trash or other foreign material found deposited within a Conservation Area will be removed within 10 working days of discovery.

3.4.5.8.5.5 Fencing

Permanent fencing will be placed completely around each Conservation Area to prevent unauthorized entry by off-road vehicles, equestrians, and other parties that might damage or destroy the habitat of the beetle, unless approved by the USFWS. DWR will obtain written approval from the USFWS that the fencing is acceptable prior to initiation of the conservation program. The fence will be maintained in perpetuity, and will be repaired or replaced within 10 working days if it is found to be damaged. Some Conservation Areas may be made available to the public for appropriate recreational and educational opportunities, subject to written approval from the USFWS. In these cases appropriate fencing and signs informing the public of the beetle's threatened status and its natural history and ecology will be used and maintained in perpetuity.

3.4.5.8.5.6 Signs

A minimum of two prominent signs will be placed and maintained in perpetuity at each Conservation Area, unless otherwise approved by the USFWS. The signs will note that the site is habitat of the federally threatened valley elderberry longhorn beetle and, if appropriate, include information on the beetle's natural history and ecology. The signs will be subject to USFWS approval. The signs will be repaired or replaced within 10 working days if they are found to be damaged or destroyed.

3.4.5.9 Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp

3.4.5.9.1 Habitat Definitions

Vernal pool fairy shrimp and vernal pool tadpole shrimp suitable habitat is defined in Section 4.A.13.6, *Suitable Habitat Definition*, and Section 4.A.14.6, *Suitable Habitat Definition*, of Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, respectively. AMMs are described below first for activities with known locations including the CCF canal, Clifton Court expansion area, and RTM placement areas. Additional AMMs are then described for activities with uncertain locations: habitat restoration, transmission lines, and geotechnical investigations. The AMMs listed in Appendix 3.F, *General Avoidance and Minimization Measures,* will also be applicable to all construction activities.

The AMMs below and those listed in Appendix 3.F, *General Avoidance and Minimization Measures,* will also be applicable to all operations and maintenance activities. AMMs that require exclusion fencing or monitoring will not be required for routine operations and maintenance activities but will be implemented for maintenance activities that involve ground disturbance and/or vegetation removal in suitable habitat for the species.

3.4.5.9.2 Avoidance and Minimization Measures

3.4.5.9.2.1 Activities with Known Locations

Habitat for vernal pool fairy shrimp and vernal pool tadpole shrimp in the action area is defined as vernal pools, seasonal wetlands, and alkali seasonal wetlands. Vernal pool fairy shrimp can also be found in artificial features such as seasonal ditches and un-vegetated low spots that pool during the winter, though these areas may not be suitable for vernal pool tadpole shrimp if they are not inundated for a sufficient period of time.

Staging areas will be designed so that they are more than 250 feet from vernal pool fairy shrimp or vernal pool tadpole shrimp habitat. All vehicles will access the work site following the shortest possible route from the levee road. All site access and staging shall limit disturbance to the riverbank, or levee as much as possible and avoid sensitive habitats. When possible, existing ingress and egress points shall be used.

A vehicle inspection and fueling area will be established at least 250 ft away from any vernal pools or seasonal wetlands to reduce the potential for chemical pollution such as oil, diesel, or hydraulic fluid. An inspection and fueling plan will be developed and construction workers trained so that any contamination is minimized. An emergency spill response plan will be completed and all workers will be trained on how to respond to emergency spills of chemicals.

If habitat is avoided (preserved) at the site, a USFWS-approved biologist (monitor) will inspect any construction-related activities at the activity site to ensure that no unnecessary take of listed species or destruction of their habitat occurs. The USFWS-approved biologist will have the authority to stop all activities that may result in take or destruction until appropriate corrective measures have been completed. The USFWS-approved biologist also will be required to immediately report any unauthorized impacts to USFWS.

Topographic depressions that are likely to serve as seasonal vernal pools will be flagged and avoided where possible.

Silt fencing will be installed wherever activities occur within 250 ft of vernal pool type seasonal wetlands. To avoid additional soil disturbances caused by silt fence installation, the bottom portion of the fence will be secured by waddles instead of buried.

All onsite construction personnel will receive instruction regarding the presence of listed species and the importance of avoiding impacts on the species and their habitat (AMM1 in Appendix 3.F, *General Avoidance and Minimization Measures*).

DWR, as project applicant, will ensure that activities that are inconsistent with the maintenance of the suitability of remaining habitat and associated onsite watershed that supports vernal pool fairy shrimp or vernal pool tadpole shrimp habitat are prohibited. This includes, but is not limited to (1) alteration of existing topography or any other alteration or uses for any purposes; (2) placement of any new structures on these parcels; (3) dumping, burning, and/or burying of rubbish, garbage, or any other wastes or fill materials; (4) building of any new roads or trails; (5) killing, removal, alteration, or replacement of any existing native vegetation; (6) placement of storm water drains; (7) fire protection activities not required to protect existing structures at the site; and (8) use of pesticides or other toxic chemicals.

3.4.5.9.2.2 Activities with Uncertain Locations

Geotechnical exploration activities, the construction and operation and maintenance of transmission lines, and restoration activities for the PA will fully avoid effects on vernal pool fairy shrimp and vernal pool tadpole shrimp and their habitat. Full avoidance requires a minimum 250-foot no-disturbance buffer around all vernal pools and other aquatic features potentially supporting vernal pool fairy shrimp or vernal pool tadpole shrimp.

3.4.5.9.3 Compensation for Effects

Conservation measures for vernal pool fairy shrimp and vernal pool tadpole shrimp are listed below.

For every acre of habitat directly or indirectly affected, at least two vernal pool credits will be purchased within a USFWS-approved ecosystem preservation bank. Alternatively, based on USFWS evaluation of site-specific conservation values, three acres of vernal pool habitat may be preserved at the affected site or on another non-bank site as approved by the USFWS (Table 3.4-15).

For every acre of habitat directly affected, at least one vernal pool creation credit will be dedicated within a USFWS-approved habitat mitigation bank, or, based on USFWS evaluation of site-specific conservation values, two acres of vernal pool habitat will be created and monitored at the affected site or on another non-bank site as approved by the USFWS (Table 3.4-15).

Compensation ratios for non-bank compensation may be adjusted to approach those for banks if the USFWS considers the conservation value of the non-bank compensation area to approach that of USFWS-approved conservation banks.

Table 3.4-15. Compensation for Effects on Vernal Pool Fairy Shrimp and Vernal Pool Tadpole Shrimp Habitat

Covered Activity/Proposed Compensation	Direct Effect (Acres)	Indirect Effect (Acres)	Habitat Compensation Ratio		Total Habitat Compensation if all Impacts Occur (Acres)	
			Conservation Bank[1]	Non-bank Site[2, 3]	Conservation Bank[1]	Non-bank Site[2, 3]
RTM Storage Areas	0	0.2	NA	NA	NA	NA
Clifton Court Forebay Modifications	6	0	NA	NA	NA	NA
Protection (direct and indirect effects)	6	0.2	2:1	3:1	12	18
Restoration/Creation (direct effects only)	6	NA	1:1	2:1	6	12

1 Compensation ratios for credits dedicated in Service-approved mitigation banks
2 Compensation ratios for acres of habitat outside of mitigation banks
3 Compensation ratios for non-bank compensation may be adjusted to approach those for banks if the Service considers the conservation value of the non-bank compensation area to approach that of Service-approved mitigation banks.

3.4.5.9.4 Siting Criteria for Compensation for Effects

3.4.5.9.4.1 Protection

If protection occurs outside a USFWS-approved conservation bank, protection will be prioritized in the Livermore recovery unit, which is one of the core recovery areas identified in the *Vernal Pool Recovery Plan* (U.S. Fish and Wildlife Service 2005) and is adjacent to existing protected vernal pool complex. Protected sites will be prioritized within the affected critical habitat unit for vernal pool fairy shrimp, unless rationale is provided to USFWS for lands to be protected outside of the critical habitat unit. Protected sites will include the surrounding upland watershed necessary to sustain the vernal pool functions (e.g., hydrology, uplands to provide for pollinators, etc.)

3.4.5.9.4.2 Restoration

If vernal pool restoration is conducted outside of a USFWS-approved conservation bank, the restoration sites will meet the following site selection criteria.

The site has evidence of historical vernal pools based on soils, remnant topography, remnant vegetation, historical aerial photos, or other historical or site-specific data.

The site supports suitable soils and landforms for vernal pool restoration.

The adjacent land use is compatible with restoration and long-term management to maintain natural community functions (e.g., not adjacent to urban or rural residential areas).

Sufficient land is available for protection to provide the necessary vernal pool complex restoration and surrounding grasslands to provide the local watershed for sustaining vernal pool hydrology, with a vernal pool density representative of intact vernal pool complex in the vicinity of the restoration site.

Acquisition of vernal pool restoration sites will be prioritized based on the following criteria.

- The site will contribute to establishment of a large, interconnected vernal pool and alkali seasonal wetland complex reserve system (e.g., adjacent to existing protected vernal pool complex or alkali seasonal wetland complex).
- The site is close to known populations of vernal pool fairy shrimp or vernal pool tadpole shrimp.

3.4.5.9.4.3 Site-Specific Restoration Plans

A site-specific restoration plan will be developed for the vernal pool restoration site. The restoration plan will include the following elements.

- A description of the aquatic functions, hydrology/topography, soils/substrate, and vegetation, for the design reference site, the existing condition of the restoration site, and the anticipated condition of the restored site.
- Success criteria for determining whether vernal pool or alkali seasonal wetland functions have been successfully restored.
- A description of the restoration monitoring, including methods and schedule consistent with relevant monitoring actions, metrics, and timing and duration, for determining whether success criteria have been met.
- An implementation and management plan and schedule that includes a description of site preparation, seeding, and irrigation.
- A management plan which includes a description of maintenance activities and a maintenance schedule to be implemented until success criteria are met.

Contingency measures will be implemented if success criteria are not met within the established monitoring timeframe.

3.4.5.9.5 Management and Enhancement

The following management and enhancement activities will be provided to USFWS for review in a management plan and implemented to benefit vernal pool fairy shrimp and vernal pool tadpole shrimp, subject to USFWS approval. These management and enhancement activities will be designed and conducted in coordination with (or by) the East Contra Costa County Habitat Conservancy or East Bay Regional Park District. Both of these entities have extensive experience conducting successful habitat management to benefit vernal pool fairy shrimp in the area where this habitat will be protected to mitigate the effects of the PA. If a USFWS-approved mitigation bank is used to fulfill the restoration requirement, then the management and enhancement that is in place for that mitigation bank will suffice.

3.4.5.9.5.1 Vegetation Management

On sites where vernal pools are protected or restored, vegetation will be managed to control invasive species and minimize thatch build-up. Grazing will be the preferred approach for vegetation management. Mechanical control may be employed as needed for highly invasive species: this method involves the use of machinery such as bulldozers, backhoes, cable yarders, and loaders, and may be used where invasive plant density is high and it would not result in adverse effects on sensitive resources such as rare plant populations or critical habitat for vernal pool species.

3.4.5.9.5.2 Hydrologic Function of Vernal Pools

Hydrologic functions to be maintained within vernal pool wetland complexes include surface water storage in the pool, subsurface water exchange, and surface water conveyance (Butterwick 1998:52). Aspects of surface water storage such as timing, frequency, and duration of inundation will be monitored, enhanced, and managed to benefit the vernal pool crustaceans. Techniques used to enhance and manage hydrology may include invasive plant control, removal of adverse supplemental water sources into restored or protected vernal pool complexes (e.g., agricultural or urban runoff), and topographic modifications.

3.4.6 Least Bell's Vireo

3.4.6.1.1 Habitat Definition

AMMs for least Bell's vireo will be required for activities occurring within suitable habitat, or in the vicinity of suitable habitat, as defined in Appendix 4.A, *Status of the Species and Critical Habitat Accounts*, Section 4.A.15.6, *Suitable Habitat Definition*. The model for least habitat is described in Appendix 4.A, Section 4.A.15.7, *Species Habitat Suitability Model*). Prior to disturbing an area potentially supporting habitat for the species, a USFWS approved biologist will evaluate the area to identify suitable habitat as described in Section 3.4.8.2, *Required Compliance Monitoring.* The following avoidance and minimization measures will be applied within suitable habitat for least Bell's vireo.

3.4.6.1.2 Avoidance and Minimization Measures

3.4.6.1.2.1 Activities with Fixed Locations

Activities with fixed locations include all construction activities described in Section 3.2, *Conveyance Facility Construction* except geotechnical exploration, safe haven intervention sites, and transmission lines. The following measures will be required for construction, operation, and maintenance related to fixed location activities in suitable habitat. The following measures will also be required for activities with flexible locations once their locations have been fixed, if they occur in suitable habitat.

Prior to construction, all suitable least Bell's vireo habitat in the construction area will be surveyed, with surveys performed in accordance with any required USFWS survey protocols and permits applicable at the time of construction.

If surveys find least Bell's vireos in the area where vegetation will be removed, vegetation removal will be done when the birds are not present.

If an activity is to occur within 1,200 feet of least Bell's vireo habitat (or within 2,000 feet if pile driving will occur) during the breeding period for least Bell's vireos, the following measures will be implemented to avoid noise effects on least Bell's vireo.

Prior to the construction, a noise expert will create a noise contour map showing the 60 dBA noise contour specific to the type and location of construction to occur in the area.

During the breeding period for least Bell's vireo, a USFWS-approved biologist will survey any suitable habitat for least Bell's vireo within the 60 dBA noise contour on a daily basis during a two-week period prior to construction. While construction is occurring within this work window, the USFWS-approved biologist will conduct daily surveys in any suitable habitat where construction related noise levels could exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour). If a least Bell's vireo is found, sound will be limited to 60dBA in the habitat being used until the USFWS-approved biologist has confirmed that the bird has left the area.

Limit pile driving to daytime hours (7:00 a.m. to 7:00 p.m.).

Locate, store, and maintain portable and stationary equipment as far as possible from suitable least Bell's vireo habitat.

Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.

Route truck traffic in order to reduce construction noise impacts and traffic noise levels within 1,200 feet of suitable least Bell's vireo habitat during migration periods.

Limit trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m.

Screen all lights and direct them down toward work activities away from migratory habitat. A biological construction monitor will ensure that lights are properly directed at all times.

Operate portable lights at the lowest allowable wattage and height, while in accordance with the National Cooperative Highway Research Program's *Report 498: Illumination Guidelines for Nighttime Highway Work*.

3.4.6.1.2.2 Activities with Flexible Locations

3.4.6.1.2.2.1 Geotechnical Exploration

During geotechnical activities, a USFWS approved biologist will be onsite to avoid the loss or degradation of suitable least Bell's vireo habitat by exploration activities.

3.4.6.1.2.2.2 Safe Haven Work Areas

During the siting phase of safe haven construction, a USFWS approved biologist will work with the engineers to avoid loss or degradation of suitable least Bell's vireo habitat. This includes ensuring that safe haven work areas are not sited in least Bell's vireo habitat. This also includes ensuring noise from safe haven work areas do not exceed 60 dBA at nearby least Bell's vireo habitat.

3.4.6.1.2.2.3 Power Supply and Grid Connections

The final transmission line alignment will be designed to minimize removal of least Bell's vireo habitat by removing no more than three acres of this habitat. To minimize the chance of least Bell's vireo bird strikes at transmission lines, bird strike diverters will be installed on project and existing transmission lines in a configuration that research indicates will reduce bird strike risk by at least 60% or more. Bird strike diverters placed on new and existing lines will be periodically inspected and replaced as needed until or unless the project or existing line is removed. The most effective and appropriate diverter for minimizing strikes on the market according to best available science will be selected.

3.4.6.1.2.2.4 Safe Havens

Safe haven sites will avoid least Bell's vireo habitat. All work associated with safe haven sites will be conducted during daylight hours, and will not require any lighting.

3.4.6.1.2.2.5 Restoration/Mitigation Activities

A USFWS biologist will work with the restoration siting and design team to avoid the permanent loss of suitable least Bell's vireo habitat. (Furthermore, the biological opinion for the PA will not authorize take resulting from restoration/mitigation actions.

3.4.6.1.3 Compensation to Offset Impacts

DWR will offset the loss of 32 acres of least Bell's vireo habitat through the creation or restoration at a 2:1 ratio, for a total of 64 acres of riparian habitat creation or restoration in the action area. DWR will develop a riparian restoration plan that will identify the location and methods for riparian creation or restoration, and this plan will be subject to USFWS approval.

3.4.7 Collaborative Science and Adaptive Management Program

Considerable scientific uncertainty exists regarding the Delta ecosystem, including the needs of the species, the effects of CVP/SWP operations and the related operational criteria for the PA. To address this uncertainty, Reclamation, DWR, USFWS, NMFS, CDFW, and the public water agencies will establish a robust program of collaborative science, monitoring, and adaptive management. It is expected that this program will be based on the draft framework described in Appendix 3.H *Adaptive Management Framework for the California Water Fix (CWF) and 2008/2009 Biological Opinions on the combined operations of the Central Valley Project (CVP) and State Water Project (SWP)*. The draft adaptive management framework describes concepts to develop an adaptive management program for the CWF joint ESA Biological Opinion and 2081(b) Incidental Take Permit, and the CVP/SWP 2008/2009 BiOps and CESA authorizations.

DWR and Reclamation commit to implementing the Adaptive Management Program, consistent with the *Agreement For Implementation Of An Adaptive Management ProgramFor Project Operations*. The CWF AMP includes a cost estimate and DWR and Reclamation commit to implementing the categories of actions described in the cost estimate. Final determination of the specific actions, implementation plans, and costs associated with implementation of those actions will be determined through the IICG.

3.4.8 Monitoring and Research Program

Monitoring will be performed to measure a population's state and structure, to characterize the condition of a species' habitat and to detect and track presence or occupancy by listed species. Four general types of monitoring will occur:

Continuation of existing monitoring required by the current BiOps (U.S. Fish and Wildlife Service 2008; National Marine Fisheries Service 2009) related to continuing operations of existing facilities and their effects on listed species.

Monitoring required by permits and authorizations for construction of the proposed new facilities (i.e., NDD, HOR gate, CCF), including the MMRP that will be required under CEQA approvals and any additional monitoring required to assess effectiveness of AMMs and inform any necessary revision.

Monitoring and studies related to operation of the proposed new facilities that must occur prior to operation of the new facilities, including those necessary to inform design and assess effects of the proposed NDD, HOR gate and modified CCF.

Monitoring and studies related to operation of the proposed new facilities that must occur after operation of the new facilities has commenced (e.g., to support real-time operation of HOR gate), including those necessary to monitor the condition of both the species and the habitat conditions that may be influenced by the new facilities (e.g., upstream temperatures, potential for redd dewatering, Delta rearing conditions, water quality, etc.).

Monitoring and studies related to evaluation of the effectiveness of proposed facilities (e.g., non-physical barrier at Georgiana Slough), habitat restoration and other mitigation measures after operation of the new facilities has commenced.

In addition to the monitoring commitments specified in the remainder of this section, monitoring under the PA is expected to also be initiated through the adaptive management framework described in Appendix 3.H *Adaptive Management Framework for the California Water Fix (CWF) and 2008/2009 Biological Opinions on the combined operations of the Central Valley Project (CVP) and State Water Project (SWP)*. Implementation of such monitoring actions would only occur if take authorization for the action were approved by the jurisdictional fish and wildlife agencies.

3.4.8.1 Impacts of Continued Monitoring and Operations on Listed Species

Existing monitoring, which has been mandated under existing BiOps and authorizations (U.S. Fish and Wildlife Service 2008; California Department of Fish and Game 2009; National Marine Fisheries Service 2009), includes monitoring to track the status of each listed species of fish, and also monitoring to ascertain performance of minimization measures associated with operations of the south Delta export facilities and their fish salvage programs. Monitoring programs required under the existing NMFS (2009) BiOp includes the following items, called for under RPA Action 11.2.1.3 *Monitoring and Reporting Requirements*.

1. Reclamation and DWR shall participate in the design, implementation, and funding of the comprehensive CV steelhead monitoring program on CVP- and SWP-controlled streams.

Reclamation and DWR shall ensure that all monitoring programs regarding the effects of CVP and SWP operations and which result in the direct take of winter-run, spring-run, CV steelhead, or Southern DPS of green sturgeon, are conducted by a person or entity that has been authorized by NMFS.

Reclamation and DWR shall submit weekly reports to the interagency Data Assessment Team (DAT) regarding the results of monitoring and incidental take of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon associated with operations of project facilities.

Reclamation and DWR shall provide an annual written report to NMFS describing the results of real-time monitoring of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon associated with operations of the DCC/CVP/SWP Delta pumping facilities, and other Division level operations authorized through this RPA.

Reclamation and DWR shall continue the real-time monitoring between October 1 and June 30 each year of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon in the lower Sacramento River, the lower San Joaquin River, and the Delta to establish presence and timing to serve as a basis for the management of Delta pumping operations consistent with actions in this RPA.

Reclamation and DWR shall submit weekly DAT reports and an annual written report to NMFS describing the results of real-time monitoring of winter-run, spring-run, CV steelhead, and Southern DPS of green sturgeon associated with operations of Delta pumping facilities and other Division level operations authorized through this RPA.

Reclamation shall coordinate with NMFS, FWS, and DFW to continue implementing and funding fisheries monitoring of spring-run and CV steelhead in Clear Creek to aide in determining the benefits and effects of flow and temperature management.

Reclamation and DWR shall jointly fund these monitoring locations for the duration of the Opinion (through 2030) to ensure compliance with the RPA and assess the performance of the RPA actions.

a. Upstream: Adult escapement and juvenile monitoring for spring-run, winter-run, and steelhead on the Sacramento River, American River, Feather River, Clear Creek, Mill Creek, Deer Creek and Battle Creek.

b. Red Bluff Diversion Dam – completed.

c. Installed and operating at Tisdale Bypass.

d. Delta: Continuation of the following monitoring stations that are part of the IEP: Chipps Island Trawl, Sacramento Trawl, Knights Landings RST, and beach seining program. Additionally, assist in funding new studies to determine green sturgeon relative abundance and habitat use in the Delta.

e. San Joaquin River monitoring shall include: Adult escapement and juvenile monitoring for steelhead on the Stanislaus River; Mossdale Kodiak Trawling to determine steelhead smolt passage; steelhead survival studies associated with VAMP; monitoring at HORB to determine steelhead movement in and around the barrier; predation studies in front of HORB and at the three agricultural barriers in the South Delta; and new studies to include the use of non-lethal fish guidance devices (e.g., sound, light, or air bubbles) instead of rock barriers to keep juveniles out of the area influenced by export pumping.

Existing monitoring programs will continue, and information from these programs will facilitate tracking status of listed species of fish and evaluating effectiveness of minimization measures. This existing monitoring to track the status of listed species of fish is performed by the Interagency Ecological Program[71], and incidental take associated with this monitoring is authorized via ESA Section 10(a)(1)(A) Research and Enhancement Permits and state Scientific Collection Permits. Monitoring to track performance of the south Delta export facilities and their fish salvage programs is authorized through the existing BiOps (National Marine Fisheries Service 2009, Section 13.4; U.S. Fish and Wildlife Service 2008, *Monitoring Requirements*). Use of scientific collection permits constitutes a conservative approach to take authorization associated with monitoring activities because such permits need periodic renewal, at which time methodology can be updated to ensure that incidental take is minimized consistent with available knowledge and techniques. Thus it is expected that continuation of existing monitoring would receive take authorization either through issuance of scientific collection permits, or through an alternative consultation pathway.

3.4.8.2 Required Compliance Monitoring

Monitoring required by permits and authorizations for construction of proposed new facilities consists of compliance monitoring. Fulfillment of compliance monitoring and reporting requirements is solely the responsibility of Reclamation, DWR, and their contractors. Reclamation and DWR will track and ensure compliance monitoring is conducted in accordance with provisions of all permits and authorizations provided to the PA, and will provide results to CDFW, NMFS and the USFWS at their request.

The principal permits and authorizations requiring monitoring are those related to ESA, CESA, NEPA and CEQA authorizations. Authorizations related to ESA include the terms and conditions of the BiOp for the PA, as well as the take limits identified in the incidental take statement within the BiOp. Authorizations related to CESA include the terms of the incidental take permit issued for the PA by the CDFW. That permit will be issued subsequent to the record of decision and its terms are additional to those of the other authorizations issued to the PA. Authorizations related to NEPA and CEQA include, respectively, a Record of Decision and a Notice of Determination. Most notably, the CEQA authorization includes a requirement to implement all provisions of the Mitigation Monitoring and Reporting Program (MMRP), as required by CCC §18.04. At this time an MMRP has not been prepared for the PA, but it is a required component prior to issuance of a Notice of Determination; a draft MMRP will be provided to USFWS and NMFS prior to issuance of the BiOp for the PA.

Although the terms and conditions of the BiOp are not known at this time, DWR, as the project applicant, will commit to track impacts of the PA on suitable habitat and the type and extent of habitat protection and restoration completed, and report the results to the jurisdictional fish and wildlife agencies (NMFS, USFWS) on an annual basis. Additionally, DWR will assess impacts anticipated for the following year and determine the type, extent, and timing of future habitat protection and restoration needs. DWR will also perform monitoring to ascertain performance relative to the limits identified in the BiOp incidental take statement. This monitoring will be achieved by performance, on an ongoing basis during the operational life of the facility, as

[71] This program is described and data are archived at http://www.water.ca.gov/iep/activities/monitoring.cfm

specified in items 4, 5 and 10 in Table 3.4-17. Those items deal with monitoring of incidental take in the vicinity of the NDDs through the mechanisms of entrainment, impingement, and predation.

Furthermore, DWR commits to track impacts of the PA on habitat related issues associated with the modifications to Clifton Court Forebay and the HOR gate, and report the results to the jurisdictional fish and wildlife agencies (CDFW, NMFS, USFWS) on an annual basis. DWR will work closely with CDFW, USFWS and NMFS to ensure that these monitoring efforts support RTOs for the HOR gate; study drivers/predictors of loss, predation rates and survival; fish presence and movement around these structures and elsewhere in the south Delta; and water quality and circulation patterns in and around CCF.

The effects of the proposed action in this biological assessment have been estimated conservatively to provide an analysis of the maximum potential adverse effects to the listed species. DWR, as the project applicant, has incorporated measures into the description of the proposed action to adequately offset the potential maximum adverse effects to the listed species. DWR will implement the required mitigation commensurate to the level of the actual effect to the listed species, provided that effects remain below the allowable take limits (otherwise reinitiation of consultation would be required, per 50 CFR 402.16).

DWR will ground-truth impact areas prior to initiating proposed actions to determine the extent of suitable habitat present. Suitable habitat is defined for each species in Appendix 4.A, *Status of the Species and Critical Habitat Accounts.* After work is complete, DWR will field-verify the amount of impacts that have actually occurred with implementation of avoidance and minimization measures. DWR will track predicted and actual impacts at each project site and provide that information in annual compliance reporting.

3.4.8.3 Monitoring Prior to Operations

Monitoring and studies related to operation of the proposed new facilities, that must occur prior to operation of the new facilities, is focused on the conveyance facilities and their potential effects on listed fish species. This monitoring begins with gathering baseline data to compare with post-construction monitoring and studies. While a more detailed effort has already been made regarding monitoring for the NDD, monitoring prior to operations will be required throughout the action area, including CCF, the HOR gate, and key habitat areas downstream and upstream of the new facilities. DWR will commit to working with the fish agencies to develop the specifics of that monitoring, which will be a key charge of both the Clifton Court Forebay Technical Team (Section 3.2.5.1.3 *Clifton Court Forebay Technical Team*) and HOR gate (Section 3.2.8.1.1 *HOR Gate Technical Team*).

For the NDD, specific monitoring studies will be also developed in collaboration with USFWS, CDFW, and NMFS that are focused on preconstruction conditions and on design of the diversions. These monitoring efforts prior to operations will build off the work done by the Fish Facilities Technical Team (2011), which identified monitoring associated with the north Delta intakes and their effects. The pre-construction studies identified by this group were focused on specific key questions rather than general monitoring needs and are listed in Table 3.4-16. Monitoring studies focused on the NDDs were developed during the BDCP process and include items 7 and 8 as listed in Table 3.4-17. These studies and their projected timeframes will be revisited as the final monitoring plan is developed.

Table 3.4-16. Preconstruction Studies at the North Delta Diversions

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
1. This action includes preconstruction study 1, *Site Locations Lab Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to develop physical hydraulic models to optimize hydraulics and sediment transport at the selected diversion sites.	What is the relationship between proposed north Delta intake design features and expected intake performance relative to minimization of entrainment and impingement risks?	Ten months to perform study; must be complete prior to final intake design.
2. This action includes preconstruction study 2, *Site Locations Numerical Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to develop site-specific numerical studies (mathematical models) to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions.	How do tides and diversion rates affect flow conditions at the north Delta intake screens and at the Georgiana Slough junction?	Eight months to perform study; must be complete prior to final intake design.
3. This action includes preconstruction study 3, *Refugia Lab Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to test and optimize the final recommendations for fish refugia that will be incorporated in the design of the north Delta intakes.	How should north Delta intake refugia be designed in principle to achieve desired biological function?	Nine months to perform study; must be complete prior to final intake design.
4. This action includes preconstruction study 4, *Refugia Field Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to evaluate the effectiveness of using refugia as part of north Delta intake design for the purpose of providing areas for juvenile fish passing the screen to hold and recover from swimming fatigue and to avoid exposure to predatory fish.	How do alternative north Delta intake refugia designs perform with regard to desired biological function?	Two years to perform study; must be complete prior to final intake design.
5. This action includes preconstruction study 5, *Predator Habitat Locations* as described by the Fish Facilities Working Team (2013). The purpose of this study is to perform field evaluation of similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities.	Where is predation likely to occur near the new North Delta intakes?	One to two years to perform study; must be complete prior to final intake design.
6. This action includes preconstruction study 6, *Baseline Fish Surveys* as described by the Fish Facilities Working Team (2013), somewhat modified based on discussions with NMFS during 2014. The purpose of this study is to perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District), to determine if these techniques also take	What are the best predator reduction techniques, i.e., which techniques are feasible, most effective, and best minimize potential impacts on listed species?	Two years to perform study; must be complete prior to final intake design.

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
listed species of fish, and to assess ways to reduce such by-catch, if necessary.		
7. This action includes preconstruction study 7, *Flow Profiling Field Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to characterize the water velocity distribution at river transects within the proposed diversion reaches for differing flow conditions. Water velocity distributions in intake reaches will identify how hydraulics change with flow rate and tidal cycle, and this information will be used in fish screen final design and in model-based testing of fish screen performance (preconstruction study 8, below).	What is the water velocity distribution at river transects within the proposed intake reaches, for differing river flow conditions?	One year to perform study; must be complete prior to final intake design.
8. This action includes preconstruction study 8, *Deep Water Screens Study* as described by the Fish Facilities Working Team (2013). The purpose of this study is to use a computational fluid dynamics model to identify the hydraulic characteristics of deep fish screen panels.	What are the effects of fish screens on hydraulic performance?	Nine months to perform study; must be complete prior to final intake design.
9. This action includes preconstruction study 9, *Predator Density and Distribution* as described by the Fish Facilities Working Team (2013); and includes post-construction study 9, *Predator Density and Distribution*, as described by the Fish Facilities Technical Team (2011). The purpose of this study is to use an appropriate technology (to be identified in the detailed study plan) at two to three proposed screen locations; the study will also perform velocity evaluation of eddy zones, if needed. The study will also collect baseline predator density and location data prior to facility operations, compare that to density and location of predators near the operational facility; and identify ways to reduce predation at the facilities.	What are predator density and distribution in the north Delta intake reaches of the Sacramento river?	Start in 2016 to collect multiple annual datasets before construction begins. The post-construction study will cover at least 3 years, sampling during varied river flows and diversion rates.
10. This action includes preconstruction study 10, *Reach-Specific Baseline Juvenile Salmonid Survival Rates* as described by the Fish Facilities Working Team (2013); and includes post-construction study 10, *Post-Construction Juvenile Salmon Survival Rates* as described by the Fish Facilities Technical Team (2011). The purpose of this study is to determine baseline rates of survival for juvenile Chinook salmon and steelhead within the Sacramento River near proposed north Delta diversion sites for comparison to post-project survival in the same area, with sufficient statistical power to detect a 5% difference in survival. Following initiation of project operations, the study will continue, using the same methodology and same locations. The study will identify the change in survival rates due to construction/operation of the intakes.	How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	The pre-construction study will cover at least 3 years and must be completed before construction begins. The post-construction study will cover at least 3 years, sampling during varied river flows and diversion rates.
11. This action includes preconstruction study 11, *Baseline Fish Surveys* as described by the Fish	How will the new north Delta intakes affect delta	Pre-construction study will cover at least 3 years. Post-

Potential Research Action[1]	Key Uncertainty Addressed	Timeframe
Facilities Working Team (2013) and includes post-construction study 11, *Post-Construction Fish Surveys* as described by the Fish Facilities Technical Team (2011). The purpose of this study is to determine baseline densities and seasonal and geographic distribution of all life stages of delta and longfin smelt inhabiting reaches of the lower Sacramento River where the north Delta intakes will be sited. Following initiation of diversion operations, the study will continue sampling using the same methods and at the same locations. The results will be compared to baseline catch data to identify potential changes due to intake operations.	and longfin smelt density and distribution in the affected reach of the Sacramento River?	construction study will be performed for duration of project operations (or delisting of species), with timing and frequency to be determined.

Notes
[1] All research actions listed in this table are part of the PA. For all proposed research actions, a detailed study design must be developed prior to implementation. The study design must be reviewed and approved by CDFW, NMFS, and USFWS prior to implementation.

Table 3.4-17. Monitoring Actions for Listed Species of Fish for the North Delta Intakes

Monitoring Action(s)	Action Description[1]	Timing and Duration
1. Fish screen hydraulic effectiveness	This action includes post-construction study 2, *Long-term Hydraulic Screen Evaluations*, combined with post-construction study 4, *Velocity Measurement Evaluations*, as described by the Fish Facilities Technical Team (2011). The purpose of this monitoring is to confirm screen operation produces approach and sweeping velocities consistent with design criteria, and to measure flow velocities within constructed refugia. Results of this monitoring will be used to "tune" baffles and other components of the screen system to consistently achieve compliance with design criteria.	Approximately 6 months beginning with initial facility operations.
2. Fish screen cleaning	This action includes post-construction study 3, *Periodic Visual Inspections* as described by the Fish Facilities Technical Team (2011). The purpose of this monitoring is to perform visual inspections to evaluate screen integrity and the effectiveness of the cleaning mechanism, and to determine whether cleaning mechanism is effective at protecting the structural integrity of the screen and maintaining uniform flow distribution through the screen. Results of this monitoring will be used to adjust cleaning intervals as needed to meet requirements.	Initial study to occur during first year of facility operation with periodic re-evaluation over life of project.
3. Refugia effectiveness	This action includes post-construction study 5, *Refugia Effectiveness* as described by the Fish Facilities Technical Team (2011). The purpose is to monitor refugia to evaluate their effectiveness relative to design expectations. This includes evaluating refugia operation at a range of river stages and with regard to effects on target species or agreed proxies. Results of this monitoring will be used to "tune" the screen system to consistently achieve compliance with design criteria.	Approximately 6 months beginning with initial facility operations.

Monitoring Action(s)	Action Description[1]	Timing and Duration
4. Fish screen biological effectiveness	This action includes post-construction study 7, *Evaluation of Screen Impingement* as described by the Fish Facilities Technical Team (2011). The purpose of this monitoring is to observe fish activity at the screen face (using technology to be identified in the detailed study plan) and use an appropriate methodology (to be identified in the detailed study plan) to evaluate impingement injury rate. Results of this monitoring are to be used to assess facility performance relative to take allowances, and otherwise as deemed useful via the collaborative adaptive management process.	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.
5. Fish screen entrainment	This action includes post-construction study 8, *Screen Entrainment* as described by the Fish Facilities Technical Team (2011). The purpose of this monitoring is to measure entrainment rates at screens using fyke nets located behind screens, and to identify the species and size of entrained organisms. Results of this monitoring are to be used to assess facility performance relative to take allowances, and otherwise as deemed useful via the collaborative adaptive management process.	Study to be performed at varied river stages and diversion rates, during first 2 years of facility operation.
6. Fish screen calibration	Perform hydraulic field evaluations to measure velocities over a designated grid in front of each screen panel. This monitoring will be conducted at diversion rates close to maximum diversion rate. Results of this monitoring will be used to set initial baffle positions and confirm compliance with design criteria.	Initial studies require approximately 3 months beginning with initial facility operations.
7. Fish screen construction	Document north Delta intake design and construction compliance with fish screen design criteria (note, this is simple compliance monitoring).	Prior to construction and as-built.
8. Operations independent measurement	Document north Delta intake compliance with operational criteria, with reference to existing environmental monitoring programs including (1) Interagency Ecological Program Environmental Monitoring Program: Continuous Multi-parameter Monitoring, Discrete Physical/ Chemical Water Quality Sampling; (2) DWR and Reclamation: Continuous Recorder Sites; (3) Central Valley RWQCB: NPDES Self- Monitoring Program; and (4) USGS Delta Flows Network and National Water Quality Assessment Program. The purpose of this monitoring is to ensure compliance and consistency with other relevant monitoring programs, and to ensure that this information is provided to CDFW, NMFS, and USFWS in association with other monitoring reporting.	Start prior to construction of water diversion facilities and continue for the duration of the PA.
9. Operations measurement and modeling	Document north Delta intake compliance with the operational criteria using flow monitoring and models implemented by DWR. The purpose of this monitoring is to ensure and demonstrate that the intakes are operated consistent with authorized flow criteria.	Start prior to completion of water diversion facilities and continue for the duration of the permit term.

Monitoring Action(s)	Action Description[1]	Timing and Duration
10. North Delta intake reach salmonid survivorship	Determine the overall impact on survival of juvenile salmonids through the diversion reach, related to the operation of the new north Delta intakes. Use mark/recapture and acoustic telemetry studies (or other technology to be identified in the detailed study plan) to evaluate effects of facility operations on juvenile salmonids, under various pumping rates and flow conditions. Results of this monitoring are to be used to assess whether survival objectives for juvenile salmonids traversing the diversion reach are being met, to determine whether take allowances are exceeded, and otherwise as deemed useful via the collaborative adaptive management process	Study to be performed at varied river flows and diversion rates, during first 2 to 5 years of facility operation.

Notes
[1] All monitoring actions are part of the PA. For all proposed monitoring actions, a detailed study design must be developed prior to implementation. The study design must be reviewed and approved by CDFW, NMFS, and USFWS prior to implementation.

3.4.8.4 Monitoring after Operations Commence

Monitoring and studies related to CVP and SWP Delta operations, that must occur after operation of the new facilities has commenced, broadly consists of four types of monitoring, performed to assess system state and effects on listed species: monitoring addressing the operation of the proposed new facilities, monitoring related to species condition and habitat that may be influenced by operations of the new facilities, monitoring to evaluate the effectiveness of the proposed facilities, and monitoring addressing the habitat protection and restoration sites.

3.4.8.4.1 Monitoring Addressing Conveyance Facilities Operations

Monitoring and studies related to operation of the proposed new facilities, that must occur after operation of the new facilities has commenced, is focused on potential effects on listed fish species.

Specific monitoring studies focused on the effects of operating the north Delta diversions will be developed in collaboration with USFWS, CDFW, and NMFS. The Fish Facilities Technical Team (2011) also identified monitoring associated with the north Delta intakes and their post-construction effects. Some of this work was focused on specific key questions rather than general monitoring and is described in Section 3.4.11, *Research Program*, while the monitoring studies include items 1-6 and 8-10 as listed in Table 3.4-17. Items 6-10 in Table 3.4-17 are studies focused on NDD performance, which were developed after the Fish Facilities Technical Team work during the BDCP process. For Delta Smelt, no specific monitoring plan is proposed, however, a future FWS-approved monitoring plan may be developed once operations commence.

Monitoring and studies will also be developed for the new South Delta facilities, including specifically the modified CCF and HOR gate, as part of the respective tech teams for these components of the PA. These will focus on entrainment and salvage; drivers/predictors of fish loss, predation rates and survival; fish presence and movement around these structures; and water quality and circulation patterns.

3.4.8.4.2 Monitoring Addressing Habitat Affected by Operations of the New Facilities

Overall operational monitoring will also be needed in areas upstream and downstream of the new facilities. The specific monitoring studies will be developed in collaboration with USFWS, CDFW, and NMFS and focus on entrainment into the interior delta, outflow, temperature, redd dewatering, fish presence and movement, and through-delta survival

3.4.8.4.3 Monitoring Addressing Habitat Protection and Restoration Sites

Metrics and protocols for wildlife species effectiveness monitoring will be developed after land acquisition but before restoration actions or enhancement and management activities are begun. Table 3.4-18 details the proposed effectiveness monitoring actions and success criteria relevant to listed species of wildlife. Effectiveness monitoring actions listed in Table 3.4-18 would be implemented for the duration of the incidental take authorizations provided in the BiOps for the PA.

Research under the PA could also by initiated through the adaptive management framework . Implementation of such research actions would only occur if take authorization for the action were approved by the jurisdictional fish and wildlife agencies.

Table 3.4-18. Proposed Effectiveness Monitoring Actions and Success Criteria

Monitoring Type	Action Description	Metric	Success Criteria	Protected Lands Timing and Duration	Restoration Site Timing and Duration
Valley Elderberry Longhorn Beetle – Valley Foothill Riparian	Representative/rotating sampling to assess health of shrubs; survey for signs of valley elderberry longhorn beetle. Survey for stem counts and increased density of shrubs on restoration site.	Health assessment of shrub(s); Dispersal and expansion of valley elderberry longhorn beetle where there are known source populations. Overall shrub health and number of stems and shrubs at restoration locations.	Growth and range expansion of populations above baseline.	All shrubs during the first year; 50% of the shrubs for each of the next two years; every five years thereafter, randomly sampled subset.	All shrubs during each of the first three years; 50% of the shrubs for each of the next six years; every five years thereafter, randomly sampled subset.
San Joaquin Kit Fox – Grasslands	Camera trap for San Joaquin kit fox, depending on site topography and access. Spotlighting will not be used (Fiehler pers. comm.). Protocol will consist of camera stations baited with a cat food can staked to the ground, on which San Joaquin kit fox will readily deposit scat. Camera station details will be consistent with the methods used by Constable et al. (2009), including tracking of competitors and prey.	Number of individuals; Growth and range expansion of populations.	Growth and range expansion of populations above baseline.	Annual surveys for at least 5 years to establish a baseline of whether or not the action area supports persistent populations (Fiehler pers. comm.). At least 5 years of baseline surveys will be repeated after habitat has been restored or conserved. Additionally, whenever a sighting is reported, baited cameras will be placed in the area to confirm the detection. Surveys must be conducted between May 1 and November 1 (U.S. Fish and Wildlife Service 1999).	Annual surveys for at least 5 years to establish a baseline of whether or not the action area supports persistent populations (Fiehler pers. comm.). At least 5 years of baseline surveys will be repeated after habitat has been restored or conserved. Additionally, whenever a sighting is reported, baited cameras will be placed in the area to confirm the detection. Surveys must be conducted between May 1 and November 1 (U.S. Fish and Wildlife Service 1999).
California Tiger Salamander – Grasslands	Dip netting and visual surveys.	Number of individuals per site.	Growth and range expansion of populations above baseline.	One year of surveys at each site; 50% in the second year, and 50% in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.	One year of surveys at each site; 50% in the second year, and 50% in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.

Monitoring Type	Action Description	Metric	Success Criteria	Protected Lands Timing and Duration	Restoration Site Timing and Duration
California Red-Legged Frog – Grasslands	Eye shine and call surveys for California red-legged frog.	Number of individuals per site.	Growth and range expansion of populations above baseline.	One year of surveys at each site; 50% in the second year, and 50% in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.	One year of surveys at each site; 50% in the second year, and 50% in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.
Branchiopods – Vernal Pools/Alkali Seasonal Wetlands	Sample for individuals.	Number of individuals per site.	Growth and range expansion of populations above baseline; self-sustaining populations.	Two branchiopod surveys per site; all pools/wetlands sampled the first year; 50% second year; 50% third year; then 50% sampled every five years thereafter.	Two branchiopod surveys per site; all pools/wetlands sampled the first year; 50% second year; 50% third year; then 50% sampled every five years thereafter.
Giant Garter Snakes – Nontidal Freshwater Perennial Emergent Wetland	Trapping surveys to detect presence of individuals; measure giant garter snake habitat connectivity.	Number of individuals at each restored site; acreage of connected habitat	Growth and range expansion of populations above baseline; increase in connectivity from baseline.	One year of trapping at each site; 50% of sites sampled in the second year, and 50% of sites sampled in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.	One year of trapping at each site; 50% of sites sampled in the second year, and 50% of sites sampled in the third year; two of the four sites randomly sampled for presence every three years for 10 years and then every five years thereafter.

3.5 Reinitiation of Consultation

As provided in 50 CFR 402.16:

> *Reinitiation of formal consultation is required and shall be requested by the Federal agency or by the Service where discretionary Federal involvement or control over the action has been retained or is authorized by law and:*
>
> *(a) If the amount or extent of taking specified in the incidental take statement is exceeded;*
>
> *(b) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;*
>
> *(c) If the identified action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in the biological opinion; or*
>
> *(d) If a new species is listed or critical habitat designated that may be affected by the identified action.*

Reclamation or USACE as the federal action agencies, with DWR as the project applicant, will re-initiate consultation with USFWS and/or NMFS if any of these circumstances occur. Reinitiation of formal consultation may also be appropriate if there are indications that water operations flow criteria may be eliminated or otherwise modified while maintaining the requirements of Section 7 of the ESA and Section 2081 of the Fish and Game Code.

3.6 Interrelated or Interdependent Actions

Interrelated actions are defined under ESA as actions that are part of a larger action and depend on the larger action for their justification. Interdependent actions are defined as actions that have no independent utility apart from the action under consideration (50 CFR 402.02). To determine if an action is interrelated to or interdependent with a proposed action, the agency "should ask whether another activity in question would occur 'but for' the proposed action under consultation" (FWS Consultation Handbook at 4-26). In doing so, the agency must be "careful not to reverse the analysis by analyzing the relationship of the proposed action against the other activity." *Id*. For instance, "if the proposed action is the addition of a second turbine to an existing dam, the question is whether the dam (the other activity) is interrelated to or interdependent with the proposed action (the addition of the turbine), not the reverse." *Id*. In this case, the PA is the proposed action under consultation, so the agency should determine whether any other action in question would occur "but for" the PA.

Before determining whether an action was considered interrelated or interdependent, actions that are considered ongoing or reasonably foreseeable and occur wholly or in part within the action area, and that may be functionally related to the PA, were evaluated and screened. Functional relationship was defined as applying to projects dealing with surface water resource management and/or habitat protection or restoration actions affecting listed species. Examples of functionally related projects include management of upstream reservoirs, of levees and other flood control works in the Delta, of other surface water intakes located in the action area; and planned habitat protection restoration connected, for instance, with existing and proposed habitat conservation plans in the action area. With one exception, described below, none of these actions are part of the PA, and their utility does not depend upon the PA, in whole or in part, and are therefore not considered interdependent and interrelated.

Given the close coordination of reservoir operations and Delta operations for the CVP and SWP, the upstream operations have received particular attention in the BA. However, upstream operations of the CVP and SWP (the other activity) will continue—consistent with existing biological opinions--whether or not the PA (the action under consultation) is authorized, constructed, and operated. Thus, upstream actions are not interrelated to or interdependent with the PA.

Additionally, as to why upstream operations are no considered interrelated and interdependent with the PA:

the PA does not include any changes in the applicable operating criteria of upstream reservoirs;

the effects of these operations are evaluated and authorized in the existing Biological Opinion (National Marine Fisheries Service 2009) and would continue unless and until Reclamation proposes changes to the criteria and/or re-initiation is triggered; and

none of the Delta operational changes included in this PA necessitate changes in upstream criteria or operations.

Therefore, continued operations of upstream reservoirs is not considered, for purposes of ESA, interdependent or interrelated to the PA.

The management of levees and other flood works in the action area is also not interdependent or interrelated to the PA. Water diversions and flow changes that would occur under the PA have no potential to alter flood frequency or severity. Although the PA would replace some existing flood control facilities with new engineered structures, the structures would be functionally equivalent in terms of their utility for flood control, and thus would not alter the distribution or utility of flood control infrastructure, or of any planned flood control facilities.

One interrelated or interdependent action has been identified in connection with the PA and is therefore described and analyzed in this BA. As described in Section 3.3.4.4, *Contra Costa Canal Rock Slough Intake,* and in Section 4.3.2.2.3, *Water Supply Facilities and Facility Operations*, CCWD's water system includes the Mallard Slough, Rock Slough, Old River, and Middle River (on Victoria Canal) intakes. The PA includes Reclamation's operation of the Rock Slough intake to the Contra Costa Canal, but CCWD operates the Mallard Slough, Old River, and Middle River intakes. CCWD can divert approximately 30% to 50% of its total annual supply (approximately 127 TAF) through the Rock Slough Intake, depending upon water quality there; the remainder of their total annual withdrawal (i.e., 50% to 70% of the total) would thus use the CCWD-owned intakes. Most of this diversion would occur at the Old River intake (250 cfs capacity), which is used year-round, and the Middle River intake (250 cfs capacity), used primarily in late summer and fall to provide better water quality than is obtainable from the other three intakes. Note that these capacities and seasonal variations in diversion use have been incorporated in the hydrodynamic modeling used to develop the effects analysis for listed fish species.

The Mallard Slough intake (39 cfs capacity) is used primarily in winter and spring during wet periods when water quality is sufficiently high. Thus diversions at the three CCWD-owned intakes are primarily determined by seasonal fluctuations in water quality, rather than by the availability of the Rock Slough diversion. Nonetheless, increased withdrawals at the other intakes, insofar as they provide acceptable water quality, would result if withdrawals at Rock Slough were curtailed for any reason; similarly, increased withdrawals at Rock Slough could result in reduced withdrawals at the other intakes.

3.7 **Drought Procedures**

Drought is a gradual phenomenon and can best be thought of as a condition of water shortage for a particular user in a particular location. Although persistent drought may be characterized as an emergency, it differs from typical emergency events. Most natural disasters, such as floods or forest fires, occur relatively rapidly and afford little time for preparing for disaster response. Droughts occur slowly, over a period of time. There is no universal definition of when a drought begins or ends. Impacts of drought are typically felt first by those most reliant on annual rainfall -- ranchers engaged in dryland grazing, rural residents relying on wells in low-yield rock formations, or small water systems lacking a reliable water source. Drought impacts increase with the length of a drought, as carry-over supplies in reservoirs are depleted and water levels in groundwater basins decline.

Measurements of California water conditions cover only a small slice of the past. Widespread collection of rainfall and streamflow information began around the turn of the 20th century. During our period of recorded hydrology, the most significant statewide droughts occurred during 1928-34, 1976-77, 1987-92, 2007-10, and 2013-2016. Historical data combined with estimates created from indirect indicators such as tree rings suggest that the 1928-34 event may have been the driest period in the Sacramento River watershed since about the mid-1550s.

3.7.1 Water Management in Drought Conditions

3.7.1.1 Historic Drought Management Actions

Previous droughts that have occurred throughout California's history continue to shape and spur innovation in the ways in which DWR and Reclamation meet the needs of both public health standards and urban and agricultural water demand, as well as protecting the ecosystem and its inhabitants. The most notable droughts in recent history are the droughts that occurred in 1976-77, 1987-92, and 2013-2016. These periods of drought have helped shape legislation and stressed the importance of maintaining water supplies for all water users.

The impacts of a dry hydrology in 1976 were mitigated by reservoir storage and groundwater availability. The immediate succession of an even drier 1977, however, set the stage for widespread impacts. In 1977 CVP agricultural water contractors received 25 percent of their allocations, municipal contractors received 25 to 50 percent, and the water rights or exchange contractors received 75 percent. SWP agricultural contractors received 40 percent of their allocations and urban contractors received 90 percent.

Managing Delta salinity was a major challenge, given the competing needs to preserve critical carry-over storage and to release water from storage to meet Bay-Delta water quality standards. In 1977, the present-day Coordinated Operation Agreement between DWR and USBR was not in effect. In February 1977, the SWRCB adopted an interim water quality control plan to modify Delta standards to allow the SWP to conserve storage in Lake Oroville. As extremely dry conditions continued that spring, the SWRCB subsequently adopted an emergency regulation superseding its interim water quality control plan, temporarily eliminating most water quality standards and forbidding the SWP to export stored water. As a further measure to conserve reservoir storage, DWR constructed temporary facilities (i.e., rock barriers, new diversions for Sherman Island agricultural water users, and facilities to provide better water quality for duck clubs in Suisun Marsh) in the Delta to help manage salinity with physical, rather than hydraulic, approaches.

In 1977, SWP and CVP contractors used water exchanges to respond to drought; one of the largest exchanges involved 435 TAF of SWP entitlement made available by MWD and three other SWP Southern California water contractors for use by San Joaquin Valley irrigators and urban agencies in the San Francisco Bay area. The MWD entitlement supplied water to Marin Municipal Water District via an emergency pipeline laid across the San Rafael Bridge and a complicated series of exchanges under which DWR delivered the water to the Bay Area via the South Bay Aqueduct. Public Law 95-18, the Emergency Drought Act of 1977, authorized Reclamation to purchase water from willing sellers on behalf of its contractors; Reclamation purchased about 46 TAF of water from sources including groundwater substitution and the SWP. Reclamation’s ability to operate the program was facilitated by CVP water rights that broadly identified the project’s service area as the place of use, allowing transfers within the place of use. Institutional constraints and water rights laws limited the transfer/exchange market at this time, and transfer activity outside of those exchanges arranged by DWR and Reclamation’s drought water bank was relatively small-scale.

The Western Governors’ Conference named a western regional drought action task force in 1977 and used that forum to coordinate state requests for federal assistance. Multi-state drought impacts led to increased appropriations for traditional federal financial assistance programs (e.g., USDA assistance programs for agricultural producers), and two drought-specific pieces of federal legislation. The Emergency Drought Act of 1977 authorized the Department of the Interior to take temporary emergency drought mitigation actions and appropriated $100 million for activities to assist irrigated agriculture, including Reclamation’s water transfers programs. The Community Emergency Drought Relief Act of 1977 authorized $225 million for the Economic Development Agency’s drought program, of which $175 million was appropriated ($109 million for loans and $66 million for grants) to assist communities with populations of 10,000 or more, tribes, and special districts with urban water supply actions. Projects in California received 41 percent of the funding appropriated pursuant to this act.

Within California, the Governor signed an executive order naming a drought emergency task force in 1977. Numerous legislative proposals regarding drought were introduced, about one-third of which became law. These measures included: authorization of a loan program for emergency water supply facilities; authorization of funds for temporary emergency barriers in the Delta (the barriers were ultimately funded by the federal Emergency Drought Act instead); prohibition of public agencies’ use of potable water to irrigate greenbelt areas if the SWRCB found that recycled water was available; authorization for water retailers to adopt conservation plans; addition of drought to the definition of emergency in the California Emergency Services Act.

During the 1987-92 drought, the state's 1990 population was close to 80 percent of present amounts and irrigated acreage was roughly the same as that of the present, but the institutional setting for water management differed significantly. Delta regulatory constraints affecting CVP and SWP operations were based on SWRCB water right decision D-1485, which had taken effect in 1978 immediately following the 1976-77 drought. In addition to D-1485 requirements on SWP and CVP operations in the Delta, other operational constraints included temperature standards imposed by the SWRCB through Orders WR 90-5 and 91-01 for portions of the Sacramento and Trinity Rivers. On the Sacramento River below Keswick Dam, these orders included a daily average water temperature objective of 56°F during periods of salmon egg and pre-emergent fry incubation. As part of managing salinity during the drought, DWR installed temporary barriers at two South Delta locations – Middle River and Old River near the Delta-Mendota Canal intake — to improve water levels and water quality/water circulation for agricultural diverters.

In response to Executive Order W-3-91 in 1991, DWR developed a drought water bank that operated in 1991 and 1992. The bank bought water from willing sellers and made it available for purchase to agencies with critical water needs. Critical water needs were understood to be basic domestic use, health and safety, fire protection, and irrigation of permanent plantings.

In 1992, NMFS issued its first biological opinion for the Sacramento River winter-run Chinook salmon, which had been listed as threatened pursuant to the ESA in 1989. The Central Valley Project Improvement Act of 1992 (CVPIA) was enacted just at the end of the drought, so provisions reallocating project yield for environmental purposes were not in effect for 1992 water operations. The CVPIA dedicated 800,000 acre-feet of project yield for environmental purposes. The regulatory framework for the SWP and CVP has changed significantly in terms of new ESA requirements to protect certain fish species, and SWRCB water rights decisions governing the water projects' operations in the Delta.

When executed in 1994 the Monterey amendments provided that an equal annual allocation would be made to urban and agricultural contractors. The prior provisions in effect during the 1987-92 drought called for agricultural contractors to take a greater reduction in their allocations during shortages than urban contractors, which had resulted in the zero allocation to the agricultural contractors in 1991.

The institutional setting for water management has changed greatly since the 1987-92 drought. Some of the most obvious changes have affected management of the state's largest water projects, such as the CVP, SWP, Los Angeles Aqueduct, or Colorado River system. New listings and management of fish populations pursuant to the ESA have impacted operations of many of the state's water projects, including the large projects affected by listing of Central Valley fish species as well as smaller projects on coastal rivers where coho salmon populations have been listed.

The current regulatory framework for CVP and SWP operations is distinctly different from that of 1987-92. The first biological opinion for the then-threatened winter-run Chinook salmon was issued in 1992, just at the end of the drought; in 1994 winter-run were reclassified as endangered. A significant provision of the initial 1992 biological opinion for winter-run salmon, and also of subsequent opinions, was a requirement to provide additional cold water in Sacramento River spawning areas downstream of Keswick Dam, resulting in increased late-season reservoir storage. Delta smelt were listed as threatened in 1993. Subsequently, other fish species listed pursuant to the federal ESA or the California ESA included the longfin smelt, Central Valley spring-run Chinook salmon, California Central Valley steelhead, and Southern distinct population segment of North American green sturgeon.

The biological opinions for operation of the CVP and SWP, together with changes in SWRCB Bay-Delta requirements, represent a major difference between 1987-92, when SWRCB's Water Rights Decision D-1485 governed the projects' Delta operations, and the present. SWRCB's Water Rights Decision D-1641 reduced water project exports in order to provide more water for Delta outflow. Requirements of the most recent biological opinions for operation of the CVP and SWP afforded additional protections to listed fish species than D-1641 requirements, further reducing the water projects' delivery capabilities by imposing greater pumping curtailments and Delta outflow requirements. Additionally, the CVPIA mandate to reallocate 800 TAF of CVP yield for environmental purposes and to provide a base water supply for wildlife refuges was not in effect for 1987-92 water operations.

3.7.1.2 Recent Drought Management Processes and Tools

On January 17, 2014, Governor Brown proclaimed a State of Emergency due to severe drought conditions and directed the State Water Board, among other things, to consider modifying requirements for reservoir releases or diversion limitations that were established to implement a water quality control plan. The Proclamation stated that such modifications may be necessary to conserve cold water stored in upstream reservoirs that may be needed later in the year to protect salmon and steelhead, to maintain water supply, and to improve water quality. The Proclamation was followed by several executive orders continuing the State of Emergency and identifying and expediting actions necessary for state and local agencies and Californians to take to reduce the harmful effects of the drought, including streamlined processing of permits and increased enforcement, conservation, and coordination.

Reclamation and DWR reviewed the ability of the CVP and SWP to meet existing regulatory standards and objectives contained in their water rights permits and licenses, as well as environmental laws and regulations, based on the current and projected hydrology, exceedance forecasts, reservoir levels, etc. This included consideration of the requirements of D-1641, and the 2008 USFWS and 2009 NMFS Biological Opinions on the Coordinated Long-term Operation of the CVP and SWP (BiOps). Reclamation and DWR then jointly developed proposed modifications to D-1641 and operations consistent with the BiOps and prepared appropriate documentation to support the permitting and consultation processes. This included preparation of a Temporary Urgency Change Petition (TUCP) for submittal to the SWRCB, and Endangered Species Act (ESA) and California Endangered Species Act (CESA) consultation letters/memorandums for exchange with USFWS, NMFS, and CDFW. These documents typically included the following elements: 1) proposed action description, 2) hydrologic forecasts, 3) modeling output, and 4) biological review. The process relied heavily on on-going communication and coordination among six agencies (Reclamation, DWR, USFWS, NMFS, CDFW, and SWRCB) through the Real Time Drought Operations Management Team (RTDOMT) and frequent meetings of the executive leadership of these agencies. State agencies also provided enhanced monitoring in the Delta. The effectiveness of the actions under the TUCP and BiOps and results of the monitoring activities were reviewed and utilized, in light of the species responses, to inform the continued response to drought.

A variety of tools were used to plan, implement, and monitor WY 2014 and 2015 drought response actions. These included participation by technical staff, managers, and directors in various ongoing and new multi-agency teams, hydrologic and biological modeling efforts, and monitoring activities including:

a. Multi-agency communication and coordination teams, including but not limited to RTDOMT, Delta Operations for Salmon and Sturgeon (DOSS), Smelt Working Group (SWG), and the Water Operations Management Team (WOMT)
b. Modeling
    i. Hydrologic forecasts and exceedances (50%, 90%, 99%)
    ii. Operations plans
        1. Reservoir releases
        2. Salinity levels
        3. Storage levels
        4. Projected inflows and depletions
    iii. Fish survival models
c. Monitoring, including but not limited to:
    i. Fish
        1. Aerial redd and carcass surveys
        2. Redd dewatering surveys
        3. Fall mid water trawl
        4. Spring Kodiak trawl
        5. Rotary screw trap
        6. Delta smelt early warning survey
    ii. Water quality
        1. Sediment
        2. Turbidity plume
        3. Algae
        4. Temperature
    iii. First flush events and runoff associated with precipitation events

3.7.2 Proposed Future Drought Procedures

In order to evaluate the challenges related to the 2013-2016 drought, federal and state agencies (Reclamation, DWR, USFWS, NMFS, CDFW, and SWRCB) relied heavily on on-going communication and coordination through the RTDOMT and frequent meetings of the executive leadership of these agencies. In order to better prepare for future droughts, this type of coordination and communication will need to begin as early as possible.

Therefore, on October 1st, if the prior water year was dry or critical[72], Reclamation and DWR will convene a multi-agency drought management team to include representatives from Reclamation, DWR, USFWS, NMFS, SWRCB, and CDFW and be charged with evaluating current hydrologic conditions and the potential for continued dry conditions that may necessitate the need for development of a drought contingency plan for the water year.

The drought management team will commit to convening at least every month to assess hydrologic conditions and forecast predictions and identify the potential need for development of a drought contingency plan until it is clear that drought conditions for that year will not persist. Information and recommendations from the drought management team will be reported back to the executive leadership of the agencies. These assessments would also inform what actions should be included in a drought contingency plan, depending on the updated hydrology assessment and the magnitude and duration of the preceding dry conditions. While a drought contingency plan may recommend adhering to the operations as identified in existing regulatory authorizations, in longer periods of dry conditions, the plan could also propose other drought response actions. Such a contingency plan should, at a minimum, include information pertaining to: an evaluation of current and forecasted hydrologic conditions and water supplies; recommended actions or changes needed to respond to drought (including changes to project operations, contract deliveries, and regulatory requirements) and any associated water supply or fish and wildlife impacts; identified timeframes; potential benefits; monitoring needs and measures to avoid and minimize fish and wildlife impacts; and proposed mitigation (if necessary).

[72] For either Sacramento Valley or San Joaquin Water Year classifications

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Appendix 3.F, General Avoidance and Minimization Measures

3.F General Avoidance and Minimization Measures

3.F.1 Introduction

The general avoidance and minimization measures (AMMs) described here have been developed to avoid and minimize effects that could result from the proposed action (PA) on listed species, defined to include the species listed in Table 1-3 of the biological assessment. These AMMs will be implemented as specified in the PA[1] (Chapter 3). General AMMs are implemented at all phases of a project, from siting through design and construction, and on to operations and maintenance. Table 3.F-1 briefly summarizes the general AMMs.

Table 3.F-1. Summary of the General Avoidance and Minimization Measures

Number	Title	Summary
AMM1	Worker Awareness Training	Includes procedures and training requirements to educate construction personnel on the applicable environmental rules and regulations, the types of sensitive resources in the project area, and the measures required to avoid and minimize effects on these resources.
AMM2	Construction Best Management Practices and Monitoring	Standard practices and measures that will be implemented prior to, during, and after construction to avoid or minimize effects of construction activities on sensitive resources (e.g., species, habitat), and monitoring protocols for verifying the protection provided by the implemented measures.
AMM3	Stormwater Pollution Prevention Plan	Includes measures that will be implemented to minimize pollutants in stormwater discharges during and after construction, and that will be incorporated into a stormwater pollution prevention plan to prevent water quality degradation related to project area runoff to receiving waters.
AMM4	Erosion and Sediment Control Plan	Includes measures that will be implemented for ground-disturbing activities to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities, and that will be incorporated into plans developed and implemented as part of the National Pollutant Discharge Elimination System permitting process for covered activities.
AMM5	Spill Prevention, Containment, and Countermeasure Plan	Includes measures to prevent and respond to spills of hazardous material that could affect navigable waters, as well as emergency notification procedures.
AMM6	Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material	Includes measures for handling, storage, and disposal of excavation or dredge spoils and reusable tunnel material, including procedures for the chemical characterization of this material or the decant water to comply with permit requirements, and reducing potential effects on aquatic habitat, as well as specific measures to avoid and minimize effects on species in the areas where reusable tunnel material would be used or disposed.
AMM7	Barge Operations Plan	Includes measures to avoid or minimize effects on aquatic species and habitat related to barge operations by establishing specific protocols for the operation of all project-related vessels at the construction and/or barge landing sites. Also includes monitoring protocols to verify compliance with the plan and procedures for contingency plans.

[1] Note that the PA, including the AMMs presented in this appendix, has not yet received approval. Consistent with the environmental review process under various regulatory requirements, the PA including these AMMs might require revision.

Number	Title	Summary
AMM8	Fish Rescue and Salvage Plan	Includes measures that detail procedures for fish rescue and salvage to avoid and minimize the number of Chinook salmon, steelhead, green sturgeon, and other listed species of fish stranded during construction activities, especially during the placement and removal of cofferdams at the intake construction sites.
AMM9	Underwater Sound Control and Abatement Plan	Includes measures to minimize the effects of underwater construction noise on fish, particularly from impact pile driving activities. Potential effects of pile driving will be minimized by restricting work to the least sensitive period of the year and by controlling or abating underwater noise generated during pile driving.
AMM10	Methylmercury Management	Design and construct wetland mitigation sites to minimize ecological risks of methylmercury production.
AMM11	Design Standards and Building Codes	Ensure that the standards, guidelines, and codes, which establish minimum design criteria and construction requirements for project facilities, will be followed. Follow any other standards, guidelines, and code requirements that are promulgated during the detailed design and construction phases and during operation of the conveyance facilities.
AMM12	Transmission Line Design and Alignment Guidelines	Design the alignment of proposed transmission lines to minimize impacts on sensitive terrestrial and aquatic habitats when siting poles and towers. Restore disturbed areas to preconstruction conditions. In agricultural areas, implement additional best management practices (BMPs). Site transmission lines to avoid greater sandhill crane roost sites or, for temporary roost sites, relocate roost sites prior to construction if needed. Site transmission lines to minimize bird strike risk.
AMM13	Noise Abatement	Develop and implement a plan to avoid or reduce the potential in-air noise impacts related to construction, maintenance, and operations.
AMM14	Hazardous Material Management	Develop and implement site-specific plans that will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities and required emergency-response procedures in case of a spill. Before construction activities begin, establish a specific protocol for the proper handling and disposal of hazardous materials.
AMM15	Construction Site Security	Provide all security personnel with environmental training similar to that of onsite construction workers, so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.
AMM16	Fugitive Dust Control	Implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust and ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedures are followed.
AMM17	Notification of Activities in Waterways	Before in-water construction or maintenance activities begin, notify appropriate agency representatives when these activities could affect water quality or aquatic species.

The PA has been designed to avoid and minimize effects on listed species. DWR will ensure that activities under the PA are sited and designed to minimize take of listed species, by means of the applicable AMMs. During the project design phase, measures set forth in AMMs to avoid and minimize effects on listed species will be included in the following plans developed as needed to comply with state and federal regulations.

- Stormwater pollution prevention plan (SWPPP) as required by the Central Valley Regional Water Quality Control Board (AMM3).

- Erosion and sediment control plan (AMM4).

- Spill prevention, containment, and countermeasure (SPCC) plan (AMM5).
- Disposal and reuse of spoils, reusable tunnel material (RTM), and dredged material (AMM6).
- Barge operations plan (AMM7).
- Fish rescue and salvage plan (AMM8).
- Underwater sound control and abatement plan (AMM9).

3.F.2 Avoidance and Minimization Measures

3.F.2.1 AMM1 Worker Awareness Training

DWR or its designees will provide training to field management and construction personnel on the importance of protecting sensitive natural resources (i.e., listed species and designated critical and/or suitable habitat for listed species). Training will be conducted during preconstruction meetings so that construction personnel are aware of their responsibilities and the importance of compliance. All trainees will be required to sign a sheet indicating their attendance and completion of environmental training. The training sheets will be provided to the fish and wildlife agencies if requested. These requirements also pertain to operations and maintenance personnel working in and adjacent to suitable habitat for listed species.

Construction personnel will be educated on the types of sensitive resources located in the project area and the measures required to avoid and minimize effects on these resources. Materials covered in the training program will include environmental rules and regulations for the specific project, requirements for limiting activities to approved work areas, timing restrictions, and avoidance of sensitive resource areas. In general, trainings will include the following components.

- Important timing windows for listed species (i.e., timing of fish migration, spawning, and rearing; and wildlife mating, nesting, and fledging).
- Specific training related to the relevant AMMs that will be implemented during construction for the protection of listed species and their habitat.
- The legal requirements for resource avoidance and protection.
- Identification of listed species potentially affected at the worksite, which will depend upon the work to be performed and the location of the work.
- Protocol for identifying the proper AMMs to implement for the protection of listed species based upon the nature, timing, and location of construction activities to be performed.
- Brief discussions of listed species of concern.

- Boundaries of the work area.
- Avoidance and minimization commitments.
- Exclusion and construction fencing methods.
- Roles and responsibilities.
- What to do when listed species are encountered (dead, injured, stressed, or entrapped) in work areas.
- Penalties for noncompliance.

A fact sheet or other supporting materials containing this information will be prepared and will be distributed along with a list of contacts (names, numbers, and affiliations) prior to initiating construction activities. A representative will be appointed by the project proponent to be the primary point of contact for any employee or contractor who might inadvertently take a listed species, or a representative will be identified during the employee education program and the representative's name and telephone number provided to the fish and wildlife agencies.

If new construction personnel are added to the project, the contractor will ensure that the personnel receive the mandatory training and sign a sheet indicating their attendance and completion of the environmental training before starting work. The training sheets for new construction personnel will be provided to the fish and wildlife agencies, if requested.

3.F.2.2 AMM2 Construction Best Management Practices and Monitoring

All construction and operation and maintenance activities in and adjacent to suitable habitat for listed species will implement BMPs and have construction monitored by a qualified technical specialist(s). Depending on the resource of concern and construction timing, construction activities and areas will be monitored for compliance with water quality regulations (SWPPP monitoring) and with AMMs developed for sensitive biological resources (biological monitoring).

Before initiating construction, DWR or its designee will prepare a construction monitoring plan for the protection of listed species. The plan will include, but not be limited to, the following elements.

- Reference to or inclusion of the SWPPP prepared under the Construction General Permit (CGP), where one is needed (AMM3).
- Summaries or copies of planning and preconstruction surveys (if applicable) for listed species.
- Description of AMMs to be implemented.
- Descriptions of monitoring parameters (e.g., turbidity), including the specific activities to be monitored (e.g., dredging, grading activities) and monitoring frequency and duration

(e.g., once per hour during all in-water construction activities), as well as parameters and reporting criteria.

- Description of the onsite authority of the monitors to modify construction activity and protocols for notifying CDFW, NMFS, and USFWS, if needed.

- A daily monitoring log prepared by the construction monitor, which documents the day's construction activities, notes any problems identified and solutions implemented to rectify those problems, and notifies the construction superintendent and/or the fish and wildlife agencies of any exceedances of specific parameters (e.g., turbidity) or observations of listed species. The monitoring log will also document construction start/end times, weather and general site conditions, and any other relevant information.

The following measures will be implemented prior to and during performance of the proposed action, for the protection of listed species and their habitat.

- All in-water construction activities within jurisdictional waters will be conducted during the ~~allowable~~ following in-water work windows ~~established by authorities having jurisdiction (USFWS, NMFS, and CDFW) for the protection of listed species~~:
  Geotechnical exploration: August 1 to October 31;
  Barge landings: July 1 to August 31;
  NDDs: June 1 to October 31, except that in-water impact pile driving is limited to June 15 to September 15;
  CCF and Banks/Jones Connections: July 1 to to October 31; and
  HOR gate: August 1 to October 31.
  Note: With regard to impact pile driving, work windows for the NDD may be lengthened subject to NMFS and USFWS approval based on success of bubble curtain and real-time monitoring for fish presence. In-water activities associated with mobilization and demobilization are not subject to the work windows. In-water impact pile installation may occur outside of the work windows if performed within a dewatered cofferdam and with in-channel acoustic monitoring to verify that generated sound thresholds do not exceed the 150 dB behavioral criterion. Apart from impact pile driving, any other work may occur within a dewatered cofferdam regardless of the timing of in-water work windows. Any extension/reduction of work windows would focus on half-month increments.

- Qualified biologists will monitor construction activities in areas identified as having listed species or their designated critical habitat. The intent of the biological monitoring is to ensure that specific AMMs that have been integrated into the project design and permit requirements are being implemented correctly during construction and are working appropriately and as intended for the protection of listed species.

- Biological monitors will be professional biologists selected for their knowledge of the listed species that may be affected by construction activities. The qualifications of the biologist(s) will be presented to the fish and wildlife agencies for review and written approval prior to initiating construction. The biological monitors will have the authority to temporarily stop work in any area where a listed species has been observed until that individual has passively or physically been moved outside of the work area, or when any AMMs or BMPs are not functioning appropriately for the protection of listed species.

- Exclusionary fencing may be placed at the edge of active construction activities and staging areas (after having been cleared by biological surveys) to restrict wildlife access from the adjacent habitats. The need for exclusionary fencing will be determined during the preconstruction surveys and the construction planning phase and may vary depending on the species and habitats present. Exclusionary fencing will consist of taut silt fabric (non-monofilament), 24 inches high (36 inches high for California red-legged frog and giant garter snake), staked at 10-foot intervals, with the bottom buried 6 inches below grade. Fence stakes will face toward the work area (on the opposite side of adjacent habitat) to prevent wildlife from using stakes to climb over the exclusionary fencing. Exclusionary fencing will be maintained such that it is intact during rain events. Fencing will be checked by the biological monitor or construction foreman periodically throughout each work day. If fencing becomes damaged, it will be immediately repaired upon detection and the monitoring biologist will stop work in the vicinity of the fencing as needed to ensure that no sensitive wildlife species have entered. Active construction and staging areas will be delineated with high-visibility temporary fencing at least 4 feet in height, flagging, or other barrier to prevent encroachment of construction personnel and equipment outside the defined project footprint. Such fencing will be inspected and maintained daily by the construction foreman until completion of the project. Fencing will be removed from work areas only after all construction activities are completed and equipment is removed. No project-related construction activities will occur outside the delineated project construction areas.

- Project-related vehicles will observe a speed limit of 20 miles per hour in construction areas where it is safe and feasible to do so, except on county roads and state and federal highways. A vehicle speed limit of 20 miles per hour will be posted and enforced on all nonpublic access roads, particularly on rainy nights when California tiger salamanders and California red-legged frogs are most likely to be moving between breeding and upland habitats. Extra caution will be used on cool days when giant garter snakes may be basking on roads.

- All ingress/egress at the project site will be restricted to those routes identified in the project plans and description.

- All vehicle parking will be restricted to established areas, existing roads, or other suitable areas.

- To avoid attracting predators, all food-related trash items such as wrappers, cans, bottles, and food scraps will be disposed of in enclosed containers and trash will be removed and disposed of at an appropriate facility at least once a week from the construction or project site.

- To avoid injury or death to wildlife, no firearms will be allowed on the project site except for those carried by authorized security personnel or local, state, or federal law enforcement officials.

- To prevent harassment, injury, or mortality of sensitive wildlife by dogs or cats, no canine or feline pets will be permitted in the construction area.

- To prevent inadvertent entrapment of wildlife during construction, all excavated, steep-walled holes or trenches more than 1 foot deep will be covered at the close of each working day with plywood or similar material, and/or provided with one or more escape ramps constructed of earth fill or wooden planks. Before such holes or trenches are filled, they will be thoroughly inspected for trapped animals. If a listed species is encountered during construction work, to the extent feasible, construction activities should be diverted away from the animal until it can be moved by a USFWS- or CDFW-approved biologist.

- Capture and relocation of trapped or injured wildlife will only be performed by personnel with appropriate USFWS and CDFW handling permits. Any sightings and any incidental take will be reported to CDFW and USFWS via email within 1 working day of the discovery. A follow-up report will be sent to these agencies, including dates, locations, habitat description, and any corrective measures taken to protect listed species encountered. For each listed species encountered, the biologist will submit a completed CNDDB field survey form (or equivalent) to CDFW no more than 90 days after completing the last field visit to the project site.

- Plastic monofilament netting or similar material will not be used for erosion control, because smaller wildlife may become entangled or trapped in it. This includes products that use photodegradable or biodegradable synthetic netting, which can take several months to decompose. Acceptable materials include natural fibers such as jute, coconut, twine, or other similar fibers or tackified hydroseeding compounds. This limitation will be communicated to the contractor through specifications or special provisions included in the construction bid solicitation package.

- Listed species of wildlife can be attracted to den-like structures such as pipes and may enter stored pipes and become trapped or injured. All construction pipes, culverts, or similar structures, construction equipment, or construction debris left overnight in areas that may be occupied by wildlife will be inspected by the biological monitor or the contractor prior to being used for construction. Such inspections will occur at the beginning of each day’s activities, for those materials to be used or moved that day. If necessary, and under the direct supervision of the biologist, the structure may be moved up to one time to isolate it from construction activities, until the listed species has moved from the structure of their own volition, been captured and relocated, or otherwise been removed from the structure.

- Rodenticides and herbicides will be used in accordance with the manufacturer recommended uses and applications and in such a manner as to prevent primary or secondary poisoning of listed species and depletion of prey populations upon which they depend. All uses of such compounds will observe label and other restrictions mandated by the U.S. Environmental Protection Agency (EPA), the California Department of Pesticide Regulation, and other appropriate state and federal regulations, as well as additional project-related restrictions imposed by USFWS, NMFS and/or CDFW. If rodent control must be conducted in San Joaquin kit fox habitat, zinc phosphide should be used because of its proven lower risk to kit fox. In addition, the method of rodent control will comply with provisions of the 4(d) rule published in the final listing rule for California tiger salamander (69 *Federal Register* [FR] 47211–47248).

- Nets or bare hands may be used to capture and handle individuals of listed species. A professional biologist will be responsible for and direct any efforts to capture and handle listed species. Any person who captures and handles listed species will not use soaps, oils, creams, lotions, insect repellents, solvents, or other potentially harmful chemicals of any sort on their hands within 2 hours before handling listed species. Latex gloves will not be used either. To avoid transferring diseases or pathogens between aquatic habitats during the course of surveys or the capture and handling of listed species, all species captured and handled will be released in a safe, aquatic environment as close to the point of capture as possible, and not transported and released to a different water body. When capturing and handling listed species of amphibians, the biologists will follow the Declining Amphibian Task Force's *Code of Practice* (U.S. Fish and Wildlife Service no date). While in captivity, individual amphibians will be kept in a cool, moist, aerated environment such as a dark (i.e., green or brown) bucket containing a damp sponge. Containers used for holding or transporting these species will be sanitized and will not contain any standing water.

- CDFW, NMFS and/or USFWS will be notified within 1 working day of the discovery of, injury to, or mortality of a listed species that results from project-related construction activities or is observed at the project site. Notification will include the date, time, and location of the incident or of the discovery of an individual listed species that is dead or injured. For a listed species that is injured, general information on the type or extent of injury will be included. The location of the incident will be clearly indicated on a U.S. Geological Survey 7.5-minute quadrangle and/or similar map at a scale that will allow others to find the location in the field, or as requested by CDFW, NMFS and/or USFWS. The biologist is encouraged to include any other pertinent information in the notification.

- Permanent and temporary construction disturbances and other types of ongoing project-related disturbance activities in suitable habitat for listed species will be minimized by adhering to the following activities. Project designs will limit or cluster permanent project features to the smallest area possible while still permitting achievement of project goals. To minimize temporary disturbances, all project-related vehicle traffic and material storage will be restricted to established and/or designated ingress/egress points, construction areas, and other designated staging/storage areas. These areas will be included in preconstruction surveys and, to the extent possible, will be established in locations disturbed by previous activities to prevent further effects.

- Upon completion of the project, all areas subject to temporary ground disturbance will be recontoured to preproject elevations, as appropriate and necessary, and revegetated with native vegetation to promote restoration of the area to preproject conditions. An area subject to "temporary" disturbance is any area that is disturbed to allow for construction of the project, but is not required for operation or maintenance of any project-related infrastructure, will not be subject to further disturbance after project completion, and has the potential to be revegetated. Appropriate methods and native plant species used to revegetate such areas will be determined on a site-specific basis in consultation with USFWS, NMFS, and/or CDFW, and biologists.

3.F.2.3 AMM3 Stormwater Pollution Prevention Plan

DWR commits to implementing measures, as described below, as part of the construction activities and in advance of any necessary permit(s). In accordance with these environmental commitments, DWR will ensure the preparation and implementation of SWPPPs to control short-term and long-term effects associated with construction-generated stormwater runoff. It is anticipated that multiple SWPPPs may be prepared for different aspects of the PA, each taking into account site-specific conditions (e.g., proximity to surface water, drainage). The SWPPPs will include all the necessary state requirements regarding construction-generated stormwater collection, detention, treatment, and discharge that will be in place throughout the construction period.

DWR is required to obtain coverage under the General Permit for Construction and Land Disturbance Activities (CGP) (currently, Order No. 2010-0014-DWQ) issued from the State Water Resources Control Board (SWRCB), for projects that will disturb 1 or more acres of land. The intent of the CGP is to protect receiving waters from pollutants potentially occurring in construction stormwater discharges. The CGP requires the development and implementation of a SWPPP for National Pollutant Discharge Elimination System (NPDES) permit coverage for stormwater discharges. Projects that disturb 1 or more acres of land have the potential to alter stormwater runoff. This includes projects that require excavation, grading, or stockpiling material at project sites, which could result in temporary and/or permanent changes to drainage patterns, paths, and facilities that would, in turn, cause changes in drainage flow rates, directions, and velocities of runoff, or constituents of runoff. For the PA, a series of separate but related SWPPPs will be prepared by a Qualified SWPPP Developer (QSD) and will be implemented under the supervision of a Qualified SWPPP Practitioner (QSP).

As part of the procedure to gain coverage under the CGP, the risk level of the site will be determined. This determination will be based on the probability of a significant risk of causing or contributing to an exceedance of a water quality standard, based on the construction activities to be performed, the existing water quality, soil and sediment conditions, without the implementation of additional requirements (per Order No. 2009-0009-DWQ as amended by Order Nos. 2010-0014-DWQ and 2012-2006-DWQ). The risk is calculated separately for sediment and receiving water, with two risk categories for receiving water (low and high) and three risk categories for sediment risk (low, medium, and high). The overall project risk levels (1, 2, or 3) are then determined through a matrix, where Risk Level 1 applies to projects with low receiving water and sediment risks, Risk Level 3 applies to projects with high receiving water and sediment risks, and Risk Level 2 applies to all other combinations of sediment and receiving water risks. These project risk levels determine the level of protection (i.e., BMPs) and monitoring that is required for the project. If the site is Risk Level 2 or 3, water sampling for pH and turbidity will be required and the SWPPP will specify sampling locations and schedule, sample collection and analysis procedures, and recordkeeping and reporting protocols. Other typical requirements for such situations are provided below under Risk Levels 2 and 3.

Changes in runoff characteristics associated with construction activities have the potential to be detrimental to listed species, as well as aquatic habitat associated with receiving waters, through changes in ambient water temperature, sediment, and pollutants resulting from stormwater runoff. The objectives of the SWPPP are to identify pollutant sources associated with construction activities and operations that may affect the quality of stormwater and to identify, construct, and implement stormwater pollution prevention measures to reduce pollutants in stormwater discharges during and after construction. The SWPPP will be kept onsite during construction activity and operations and will be made available upon request to representatives of the San Francisco Bay and Central Valley Regional Water Quality Control Boards.

In accordance with the CGP, the SWPPP will describe site topographic, soil, and hydrologic characteristics; construction activities and schedule; construction materials, including sources of imported fill material to be used and other potential sources of pollutants at the construction site; potential nonstormwater discharges (e.g., trench dewatering); erosion and sediment control measures; “housekeeping” BMPs to be implemented; a BMP implementation schedule; a site and BMP inspection schedule; and ongoing personnel training requirements. The SWPPP will also include a hazardous materials management plan, described in AMM14.

These SWPPP provisions are intended to prevent water quality degradation related to pollutant discharge to receiving waters, and to prevent or constrain changes to the pH of receiving waters. Performance standards will be met by implementing standard stormwater pollution prevention BMPs, as well as those tailored to site-specific conditions, including determining the risk level of individual construction sites. These environmental commitments mirror the requirements to gain and maintain coverage under the CGP. DWR will coordinate with the appropriate regional water quality control board to determine the appropriate aggregation of specific construction activities, or groups of activities, to be authorized under the CGP.

It is anticipated that multiple SWPPPs will be prepared for different construction sites, with a given SWPPP prepared to cover a specific project component (e.g., intermediate forebay or tidal habitat restoration site) or groups of components (e.g., intakes). The risk level will be identified for each action covered by a specific SWPPP. These SWPPPs will generally follow the EPA (2007) guidelines for such plans and will typically identify the following list of BMPs, which are requirements common to all risk-level sites; however, some detail is provided under the “Inspection and monitoring” bullet, below, on various risk-level requirements.

- Erosion control measures
    - Implement effective wind erosion BMPs, such as watering, application of soil binders/tackifiers, and covering inactive stockpiles.
    - Provide effective soil cover for inactive areas and all finished slopes and utility backfill areas, such as seeding with a native seed mix, application of hydraulic mulch and bonded fiber matrices, and installation of erosion control blankets and rock slope protection.
- Sediment control measures

  - Prevent transport of sediment at the construction site perimeter, toe of erodible slopes, soil stockpiles, and into storm drains.
  - Capture sediment via sedimentation and stormwater detention facilities.
  - Reduce runoff velocity on exposed slopes.
  - Reduce offsite sediment tracking.
- Management measures for construction materials
  - Cover and berm loose inactive stockpiled construction materials.
  - Store chemicals in watertight containers.
  - Minimize exposure of construction materials to stormwater.
  - Designate refueling and equipment inspection/maintenance locations.
  - Control drift and runoff from areas treated with herbicides, pesticides, and other chemicals that may be harmful to aquatic habitats.
- Waste management measures
  - Prevent offsite disposal or runoff of any rinse or wash waters.
  - Implement concrete and truck washout facilities and appropriately sized storage, treatment, and disposal practices.
  - Ensure the containment of sanitation facilities (e.g., portable toilets).
  - Clean or replace sanitation facilities (as necessary) and inspect regularly for leaks/spills.
  - Cover waste disposal containers during rain events and at end of any day when rain is forecast.
  - Protect stockpiled waste material from wind and rain.
- Construction site dewatering and pipeline testing measures
  - Reclaim site dewatering discharges to the extent practicable, or use for other construction purposes (e.g., dust control).
  - Implement appropriate treatment and disposal of construction site dewatering from excavations to prevent discharges to surface waters, unless discharge is permitted by authorities having jurisdiction.
  - Dechlorinate pipeline testing discharges to surface waters.

- Accidental spill prevention and response measures
  - Maintain equipment and materials necessary for cleanup of accidental spills onsite.
  - Clean up accidental spills and leaks immediately and dispose of properly.
  - Ensure that trained spill response personnel are available.
- Nonstormwater management measures
  - Control all nonstormwater discharges during construction.
  - Wash vehicles in such a manner as to prevent nonstormwater discharges to surface waters.
  - Clean streets in such a manner as to prevent nonstormwater discharges from reaching surface water.
  - Discontinue the application of any erodible landscape material during rain, or within 2 days before a forecasted rain event.
- Inspection and monitoring common to all risk-level sites
  - Ensure that all inspection, maintenance repair, and sampling activities at the construction site are performed or supervised by a QSP representing the discharger.
  - Develop and implement a written site-specific construction site monitoring program.
- Inspection, monitoring, and maintenance activities based on the risk level of the construction site (as defined in the SWRCB General Permit)
  - Risk Level 1 sites
    - Perform weekly inspections of BMPs, and at least once each 24-hour period during extended storm events.
    - At least 2 business days (48 hours) prior to each qualifying rain event (a rain event producing 0.5 inch or more of precipitation), visually inspect: stormwater drainage areas to identify any spills, leaks, or uncontrolled pollutant sources; all BMPs to identify whether they have been properly implemented in accordance with the SWPPP; and stormwater storage and containment areas to detect leaks and ensure maintenance of adequate freeboard.
    - Visually observe stormwater discharges at all discharge locations within 2 business days (48 hours) after each qualifying rain event, identify additional BMPs as necessary, and revise the SWPPP accordingly.

    - Conduct minimum quarterly visual inspections of each drainage area for the presence of (or indications of prior) unauthorized and authorized nonstormwater discharges and their sources.

    - Collect one or more samples of construction site effluent during any breach, malfunction, leakage, or spill observed within the construction site during a visual inspection that could result in the discharge of pollutants to surface waters whether visually detectable or not.

- Risk Level 2 sites

    - Perform all of the same visual inspection, monitoring, and maintenance measures specified for Risk Level 1 sites.

    - Perform sampling and analysis of stormwater discharges to characterize discharges associated with construction activity from the entire disturbed area at all points where stormwater is discharged offsite.

    - At a minimum, collect three samples per day of a qualifying rain event and analyze for pH and turbidity. The CGP also requires the discharger to revise the SWPPP and immediately modify existing BMPs and/or implement new BMPs such that subsequent discharges are below the relevant numeric action levels (NALs). It may be a violation of the CGP if the discharger fails to take corrective action to reduce the discharge below the NALs specified by the CGP.

    - When an active treatment system is deployed on the site or a portion of the site, collect active treatment system effluent samples and measurements from the discharge pipe or another location representative of the nature of the discharge.

- Risk Level 3 sites

    - Perform all of the same visual inspection, monitoring, and maintenance measures specified for Risk Level 1 and 2 sites.

    - In the event that a numerical effluent limit (NEL) of the CGP (i.e., pH and turbidity) is violated and has a direct discharge into receiving waters, the discharger will subsequently sample receiving waters for all parameter(s) monitored in the discharge. An exceedance of the NEL is considered a violation of the CGP, and the discharger must electronically submit all storm-event sampling results to the state and regional water boards via Stormwater Multiple Application and Report Tracking System (SMARTS) no later than 5 days after the conclusion of the storm event.

    - If disturbing 30 acres or more of the landscape and discharging directly into receiving waters, conduct a benthic macroinvertebrate bioassessment of receiving waters prior to and after commencement of construction activities to determine if significant degradation to the receiving water's biota has occurred. However, if commencement of construction is outside of an index period (i.e., the period of time during which bioassessment samples must be collected to produce results suitable for assessing the biological integrity of streams and rivers) for the site location, the discharger will participate in the State of California's Surface Water Ambient Monitoring Program (SWAMP).

The SWPPP will also specify the forms and records that must be uploaded to SWRCB online SMARTS, such as quarterly nonstormwater inspection and annual compliance reports.

If the QSP determines the site is Risk Level 2 or 3, water sampling for pH and turbidity will be required, and the SWPPP will specify sampling locations and schedule, sample collection and analysis procedures, and recordkeeping and reporting protocols. In accordance with the CGP NAL requirements, DWR's contractor's QSD will revise the SWPPP and modify existing BMPs or implement new BMPs when effluent monitoring indicates that daily average runoff pH is outside the range of 6.5 to 8.5 and that the daily average turbidity is greater than 250 nephelometric turbidity units (NTUs). Such BMPs may include those that are more costly to construct and maintain, such as construction of sediment traps and sediment basins, use of Baker tanks, installation of rock slope protection, covering of stockpiles with water-repellant geotextiles, dewatering basins, and use of Active Treatment Systems. The ability of other areas to withstand excessive erosion and sedimentation may be increased by applying additional mulching, bonded fiber matrices, and erosion control blankets; reseeding with a native seed mix; and installing additional fiber rolls, silt fences, and gravel bag berms. The QSD may also specify changes in the manner and frequency of BMP inspection and maintenance activities. The determination of which BMP should be applied in a given situation is very site-specific. QSDs typically refer to the California Stormwater Quality Association's *Stormwater Best Management Practice Handbook Portal: Construction* or the similar Caltrans manual for selecting BMPs for particular site conditions.

Additionally, if a given construction component is Risk Level 3, DWR will report to the SWRCB when effluent monitoring for that component indicates that daily average runoff pH is outside the range of 6.0 to 9.0 or the daily average turbidity is greater than 500 NTUs. In the event that the turbidity NEL is exceeded, DWR may also be required to sample and report pH, turbidity, and suspended sediment concentration of receiving waters to the SWRCB for the duration of construction.

The contractor will also conduct sampling of runoff effluent when a leak, spill, or other discharge of pollutants is detected.

The CGP has specific monitoring and action level requirements for the risk levels, which are summarized in Table 3.F-2.

Table 3.F-2. Stormwater Pollution Prevention Plan Monitoring and Action Requirements

Stormwater Pollution Prevention Plan Requirements	Risk Level/Type		
	1	2	3
Minimum stormwater and nonstormwater BMPs	✓	✓	✓
Numeric action levels (NAL) NAL for pH: 6.5–8.5 pH units NAL for turbidity: 250 NTU		✓	✓
Numeric effluent limitations (NEL) NEL for pH: 6–9 pH units NEL for turbidity: 500 NTU			✓
Visual monitoring (weekly; before, during, after rain events; non-stormwater)	✓	✓	✓
Runoff monitoring		✓	✓
Receiving water monitoring			✓

Note: The SWRCB has suspended the applicability of NELs for pH and turbidity at Risk Level 3/LUP Type 3 construction sites. In addition, because receiving-water monitoring is required only if the NELs are triggered, all receiving-water monitoring requirements are also suspended. The Level 3/Type 3 NEL are presented here assuming that such NELs will be reinstated when project construction commences.
BMP = best management practice; pH = potential hydrogen; NTU = nephelometric turbidity unit.

The QSD preparing a SWPPP may include in the SWPPP BMPs such as preservation of existing vegetation, perimeter control, seeding, mulching, fiber roll and silt fence barriers, erosion control blankets, protection of stockpiles, watering to control dust entrainment, rock slope protection, tracking control, equipment refueling and maintenance, concrete and solid waste management, and other measures to ensure compliance with the pH and turbidity level requirements defined by the CGP. Partly because the potential adverse effect on receiving waters depends on location of a work area relative to a waterway, the BMPs will be site-specific. For example, BMPs applied to level island-interior sites will be different than BMPs applied to water-side levee conditions. The QSP will be responsible for day-to-day implementation of the SWPPP, including BMP inspections, maintenance, water quality sampling, and reporting to SWRCB. If the water quality sampling results indicate an exceedance of NALs and NELs for pH and turbidity, as described above, the QSD will modify the type and/or location of the BMPs by amending the SWPPP to reduce pH, turbidity, and other contaminants to acceptable levels, consistent with NALs and NELs and with the water quality objectives and beneficial uses set forth in the Water Quality Control Plan (Basin Plan) for the California Regional Water Quality Control Board, Central Valley Region (Central Valley Regional Water Quality Control Board 2011).

3.F.2.4 AMM4 Erosion and Sediment Control Plan

An erosion and sediment control plan is typically required for ground-disturbing projects as part of the NPDES permitting process (U.S. Environmental Protection Agency 2007), depending on the size of the disturbed area. The proposed Phase II EPA rules would cover projects with greater than 1 acre of ground disturbance. DWR commits to implementing measures as described below as part of the construction activities and in advance of any necessary permit. In accordance with these environmental commitments, DWR will ensure the preparation and implementation of erosion and sediment control plans to control short-term and long-term erosion and sedimentation effects and to restore soils and vegetation in areas affected by construction activities. It is anticipated that multiple erosion and sediment control plans will be prepared for the construction activities included in the PA, each taking into account site-specific conditions such as proximity to surface water, erosion potential, drainage, etc. The plans will include all the necessary state requirements regarding erosion control and will implement BMPs for erosion and sediment control that will be in place for the duration of construction activities. These BMPs will be incorporated into the SWPPP (Section 3.F.1.1.1, *Conduct Planning-Level Surveys*).

The following erosion control measures will be included in the SWPPP.

- Install physical erosion control stabilization BMPs (hydroseeding with native seed mix, mulch, silt fencing, fiber rolls, sand bags, and erosion control blankets) to capture sediment and control both wind and water erosion. Erosion control may not utilize plastic monofilament netting or similar materials.
- Maintain emergency erosion control supplies onsite at all times during construction and direct contractor(s) to use these emergency stockpiles as needed. Ensure that supplies used from the emergency stockpiles are replaced within 48 hours. Remove materials used in construction of erosion control measures from the work site when no longer needed (property of the contractor).
- Design grading to be compatible with adjacent areas and result in minimal disturbance of the terrain and natural land features and minimize erosion in disturbed areas to the extent practicable.
- Divert runoff away from steep, denuded slopes, or other critical areas with barriers, berms, ditches, or other facilities.
- Retain native trees and vegetation to the extent feasible to stabilize hillsides, retain moisture, and reduce erosion.
- Limit construction, clearing of native vegetation, and disturbance of soils to areas of proven stability.
- Implement construction management and scheduling measures to avoid exposure to rainfall events, runoff, or flooding at construction sites to the extent feasible.
- Conduct frequent site inspections (before and after significant storm events) to ensure that control measures are intact and working properly and to correct problems as needed.
- Install drainage control features (e.g., berms and swales, slope drains) as necessary to avoid and minimize erosion.
- Install wind erosion control features (e.g., application of hydraulic mulch or bonded fiber matrix).

The following sediment control measures will be included in the SWPPP.

- Use sediment ponds, silt traps, wattles, straw bale barriers, or similar measures to retain sediment transported by onsite runoff.

- Collect and direct surface runoff at non-erosive velocities to the common drainage courses.

- When ground-disturbing activities are required adjacent to surface water, wetlands, or aquatic habitat, use of sediment and turbidity barriers, and implement measures for soil stabilization and revegetation of disturbed surfaces.

- Prevent mud from being tracked onto public roadways by installing gravel on primary construction ingress/egress points, and/or truck tire washing.

- Deposit or store excavated materials away from drainage courses and cover if left in place for more than 5 days or if storm events are forecast within 48 hours.

After construction is complete, site-specific restoration efforts will include grading, erosion control, and revegetation. Self-sustaining, local native plants that require little or no maintenance and do not create an extreme fire hazard will be used. All disturbed areas will be recontoured to preproject contours as feasible, and seeded with a native seed mix. Consideration will also be given to additional replacement of or upgrades to drainage facilities to avoid and minimize erosion. Paved areas damaged from use over and above ordinary wear-and-tear from lawful use by construction activities will be repaved to avoid erosion due to pavement damage.

3.F.2.5 AMM5 Spill Prevention, Containment, and Countermeasure Plan

As required by local, state, or federal regulations, DWR will require that construction contractors develop an SPCC plan for implementation at each site where ground-disturbing activities occur. Each SPCC plan will comply with the regulatory requirements of the Spill Prevention, Control, and Countermeasure Rule (40 Code of Federal Regulations [CFR] 112) under the Oil Pollution Act of 1990. This rule regulates non-transportation-related onshore and offshore facilities that could reasonably be expected to discharge oil into navigable waters of the United States or adjoining shorelines. The rule requires the preparation and implementation of site-specific SPCC plans to prevent and respond to oil discharges that could affect navigable waters. Each SPCC plan will address actions used to prevent spills in addition to specifying actions that will be taken should any spills occur, including emergency notification procedures. The SPCC plans will include the following measures and practices.

- Discharge prevention measures will include procedures for routine handling of products (e.g., loading, unloading, and facility transfers) (*40 CFR 112.7(a)(3)(i)*).

- Discharge or drainage controls will be implemented such as secondary containment around containers and other structures and equipment, and procedures for the control of a discharge (*40 CFR 112.7(a)(3)(ii)*).

- Countermeasures will be implemented for discharge discovery, response, and cleanup (both the facility's capability and those that might be required of a contractor) (*40 CFR 112.7(a)(3)(iii)*).

- Methods of disposal of recovered materials will comply with applicable legal requirements (*40 CFR 112.7(a)(3)(iv)*).

- Personnel will be trained in emergency response and spill containment techniques, and will also be made aware of the pollution control laws, rules, and regulations applicable to their work.

- Petroleum products will be stored in nonleaking containers at impervious storage sites from which an accidental spill cannot escape.

- Absorbent pads, pillows, socks, booms, and other spill containment materials will be stored and maintained at the hazardous materials storage sites for use in the event of an accidental spill.

- Watertight forms and other containment structures will be used to prevent spills or discharge of raw concrete, wash water, and other contaminants from entering surface waters and other sensitive habitats during overwater activities (e.g., casting of barge decks).

- Contaminated absorbent pads, pillows, socks, booms, and other spill containment materials will be placed in nonleaking sealed containers until transported to an appropriate disposal facility.

- When transferring oil or other hazardous materials from trucks to storage containers, absorbent pads, pillows, socks, booms, or other spill containment material will be placed under the transfer area.

- Refueling of construction equipment will occur only in designated areas that will be a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.

- Equipment used in direct contact with water will be inspected daily for oil, grease, and other petroleum products. All equipment will be cleaned of external petroleum products prior to beginning work where contact with water may occur in order to prevent the release of such products to surface waters.

- Oil-absorbent booms will be used when equipment is used in or immediately adjacent to waters.

- All reserve fuel supplies will be stored only within the confines of a designated staging area, to be located a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands.

- Fuel transfers will take place a minimum of 150 feet from surface waters and other sensitive habitats, such as wetlands, and absorbent pads will be placed under the fuel transfer operation.

- Staging areas will be designed to contain contaminants such as oil, grease, fuel, and other petroleum products so that should an accidental spill occur they do not drain toward receiving waters or storm drain inlets.

- All stationary equipment will be staged in appropriate staging areas and positioned over drip pans.

- In the event of an accidental spill, personnel will identify and secure the source of the discharge and contain the discharge with sorbents, sandbags, or other material from spill kits and will contact appropriate regulatory authorities (e.g., National Response Center will be contacted if the spill threatens navigable waters of the United States or adjoining shorelines, as well as other appropriate response personnel).

Methods of cleanup may include the following.

- Physical methods for the cleanup of dry chemicals include the use of brooms, shovels, sweepers, or plows.

- Mechanical methods could include the use of vacuum cleaning systems and pumps.

- Chemical methods include the use of appropriate chemical agents such as sorbents, gels, and foams.

3.F.2.6 AMM6 Disposal of Spoils, Reusable Tunnel Material, and Dredged Material

In the course of constructing or operating project facilities, substantial quantities of material are likely to be removed from their existing locations based upon their properties or the need for excavation of particular features. Spoils refer to excavated native soils and are associated with construction of proposed new facilities. RTM refers to the mixture of saturated soils and biodegradable soil conditioners or additives that will be generated by tunneling operations and are appropriate for reuse based upon chemical characterization and physical properties. Dredged material refers to sediment removed from the bottom of a body of water for the purposes of in-water construction or water conveyance operations (e.g., sediment collected at intake sites). The quantities of these materials generated by construction or operation of proposed facilities will vary based on various factors, such as location, topography, and structure being constructed. These materials will require handling, storage, and disposal, as well as chemical characterization. Storage areas are designated for these materials. Many of these materials will be suitable for reuse (e.g., as engineered fill or for purposes of habitat restoration), but such use is not part of the PA and projects using this material have not been identified.

3.F.2.6.1 Storage Area Determination

Spoils, RTM, and dredged material will be stored in designated storage areas, shown in Appendix 3.A *Mapbook.*

The designated storage areas are sized to accommodate all material expected to be generated by the PA, i.e., it is assumed that none of that material will be reused, sold, or otherwise relocated under the PA. In practice, the area that will be needed for material storage will depend on several factors.

- The speed with which material is brought to the surface, stored, dried, tested, and moved to storage locations will be important in determining the final size of storage areas. If alternative end uses for the material can be identified and if those uses can be permitted within the timeframe of the PA (such permitting is not included in the PA, so separate authorizations would have to be obtained), then a smaller area may be needed for material storage.

- The depth to which the material is stacked. Material that is stored in deeper piles will require less area but may dry more slowly. Calculation of needed materials storage areas has assumed that materials would be placed in piles with a depth of six feet.

3.F.2.6.2 Storage Site Preparation

A portion of the storage sites selected for storage of spoils, RTM, and dredged material will be set aside for topsoil storage. The topsoil will be saved for reapplication to disturbed areas postconstruction. Vegetative material from work site clearing will be chipped, stockpiled, and spread over the topsoil after earthwork is completed, when practicable and appropriate to do so and where such material does not contain seeds of undesirable nonnative species (i.e., nonnative species that are highly invasive and threaten the ecological function of the vegetation community to be restored in that location). Cleared areas will be grubbed as necessary to prepare them for grading or other construction activities. Rocks and other inorganic grubbed materials will be used to backfill borrow areas. The contractor will remove from the work site all debris, rubbish, and other materials not directed to be salvaged, and will dispose of them in an approved disposal site after obtaining all permits required.

3.F.2.6.3 Draining, Chemical Characterization, and Treatment

RTM and associated decant liquid will undergo chemical characterization by the contractor(s) prior to reuse or discharge, respectively, to determine whether it will meet NPDES and the Central Valley Regional Water Quality Control Board requirements. Should RTM decant liquid constituents exceed discharge limits, these tunneling byproducts will be treated to comply with NPDES permit requirements. Discharges from RTM draining operations will be conducted in such a way as to not cause erosion at the discharge point. If RTM liquid requires chemical treatment, chemical treatment will ensure that RTM liquid will be nontoxic to aquatic organisms.

While additives used to facilitate tunneling will be nontoxic and biodegradable, it is possible that some quantity of RTM will be deemed unsuitable for reuse. In such instances, which are anticipated to occur in less than 1% each of excavated spoils, RTM, and dredged material, the material will be disposed of at a site for which disposal of such material is approved.

Hazardous materials excavated during construction will be segregated from other construction spoils and properly handled in accordance with applicable federal, state, and local regulations. Riverine or in-Delta sediment dredging and dredged material disposal activities may involve potential contaminant discharges not addressed through typical NPDES or SWRCB CGP processes. Construction of dredge material disposal sites will likely be subject to the SWRCB General Permit (Order No. 2009-0009-DWQ).

As described in Appendix 3.F, *General Avoidance and Minimization Measures, AMM6 Disposal and Reuse of Spoils, Reusable Tunnel Material, and Dredged Material,* to better define potential effects to listed species or aquatic habitat, and to streamline the collection and incorporation of newer information (i.e., monitoring data or site-specific baseline information), the following protocol will be followed. The action agency will work with State and Federal resource agencies with authorization and jurisdiction to identify the timeline for information gathering in relation to initiation of the specific action, but it is anticipated to be at least several months prior to the initiation of the action. At that time, DWR and Reclamation will follow the protocol below.

- DWR will ensure the preparation and implementation of a pre-dredge sampling and analysis plan (SAP). The SAP will be developed and submitted by the contractor(s) as part of the water plan required per standard DWR contract specifications (Section 01570). Prior to initiating any dredging activity, the SAP will evaluate the presence of contaminants that may affect water quality from the following discharge routes.
    - Instream discharges during dredging.
    - Direct exposure to contaminants in the material through ingestion, inhalation, or dermal exposure.
    - Effluent (return flow) discharge from an upland disposal site.
    - Leachate from upland dredge material disposal that may affect groundwater or surface water.
- Concentrations of the identified chemical constituents in the core samples will be screened through appropriate contaminant screening tables to ensure compliance with applicable agency guidelines.
- Results of the sediment analyses and the quality guidelines screening will determine the risk associated with the disturbance of the sediment horizons by identifying specific pathways of exposure to adverse effects.
- Results of the testing will be provided to all relevant State and Federal agencies for their use in monitoring or regulating the activities under consideration.
- If the results of the chemical analyses of the sediment samples indicate that one or more chemical constituents are present at concentrations exceeding screening criteria, then additional alternative protocols to further minimize or eliminate the release of sediments into the surrounding water column must be implemented.
- The applicant must provide to CDFW, NMFS and USFWS a plan to reduce or eliminate the release of contaminated sediment prior to the start of any actions that will disturb the sediments in the proposed construction area. Plans using a shrouded hydraulic cutterhead, or an environmentally sealed clamshell bucket may be acceptable provided

that adequate supporting information is provided with the proposed plan. Plans should also include descriptions of the methods employed to treat, transport, and dispose of the contaminated sediment, as well as any resulting decant waters.

The following list of BMPs will be implemented during handling and disposal of any potentially hazardous dredged material.

- Conduct dredging within the allowable in-water work specified in AMM2 *Construction Best Management Practices*~~windows established by USFWS, NMFS, and CDFW~~.
- Conduct dredging activities in a manner that will not cause turbidity in the receiving water, as measured in surface waters 300 feet down-current from the construction site, to exceed the Basin Plan objectives beyond an approved averaging period by the Central Valley Regional Water Quality Control Board and CDFW. Existing threshold limits in the Basin Plan for turbidity generation are as follows.
    - Where natural turbidity is between 0 and 5 NTUs, increases will not exceed 1 NTU.
    - Where natural turbidity is between 5 and 50 NTUs, increases will not exceed 20%.
    - Where natural turbidity is between 50 and 100 NTUs, increases will not exceed 10 NTUs.
    - Where natural turbidity is greater than 100 NTUs, increases will not exceed 10%.
- If turbidity generated during dredging exceeds implementation requirements for compliance with the Basin Plan objectives, silt curtains will be used to control turbidity. Exceptions to turbidity limits set forth in the Basin Plan may be allowed for dredging operations; in this case, an allowable zone of dilution within which turbidity exceeds the limits will be defined and prescribed in a discharge permit.
- The dredged material disposal sites will be designed to contain all of the dredged material. All systems and equipment associated with necessary return flows from the dredged material disposal site to the receiving water will be operated to maximize treatment of return water and optimize the quality of the discharge.
- The dredged material disposal sites will be designed by a registered professional engineer.
- The dredged material disposal sites will be designed, constructed, operated, and maintained to prevent inundation or washout due to floods with a 100-year return frequency.
- Two feet of freeboard above the 100-year flood event elevation will be maintained in all dredged material disposal site settling ponds at all times when they may be subject to washout from a 100-year flood event.

- Dredging equipment will be kept out of riparian areas and dredged material will be disposed of outside of riparian corridors.

Temporary storage sites will be constructed using appropriate BMPs such as erosion and sediment control measures (*AMM4 Erosion and Sediment Control Plan* and *AMM3 Stormwater Pollution Prevention Plan*) to prevent discharges of contaminated stormwater to surface waters or groundwater.

Once the excavated spoils, RTM, or dredged material have been suitably dewatered, and as the constituents of the material will allow, it will be placed in either a lined or unlined storage area suitable for long-term storage. These long-term storage areas may be the same areas in which the material was previously dewatered or it may be a new area adjacent to the dewatering site. The storage areas will be created by excavating and stockpiling the native topsoil for future reuse. Once the area has been suitably excavated, and if a lined storage area is required, an impervious liner will be placed on the invert of the material storage area and along the interior slopes of the berms surrounding the pond. Due to the expected high groundwater tables, it is anticipated that there will be minimal excavation for construction of the long-term material storage areas. Additional features of the long-term material storage areas will include berms and erosion protection measures to contain storm runoff as necessary and provisions to allow for truck traffic during construction.

3.F.2.7 AMM7 Barge Operations Plan

DWR will require that any construction contractor proposing to use barges (to perform construction or to transport materials or equipment) develop a barge operations plan as required by local, state, or federal regulation. Each plan will be developed and submitted by the construction contractors per standard DWR contract specifications as part of the traffic plans required by those specifications (Section 01570 of standard DWR construction contracts). Each barge operations plan will be part of a comprehensive traffic control plan coordinated with the U.S. Coast Guard for large channels. The comprehensive traffic control plan will address traffic routes and machines used to deliver materials to and from the barges. The barge operations plan will address the following.

- Bottom scour from propeller wash.

- Bank erosion or loss of submerged or emergent vegetation from propeller wash and/or excessive wake.

- Accidental material spillage.

- Sediment and benthic community disturbance from accidental or intentional barge grounding or deployment of barge spuds (extendable shafts for temporarily maintaining barge position) or anchors.

- Hazardous materials spills (e.g., fuel, oil, hydraulic fluids).

The barge operations plan will serve as a guide to barge operations and to a biological monitor who will evaluate barge operations on a daily basis during construction with respect to stated performance measures. This plan, when approved by the DWR and other resource agencies, will be read by barge operators and kept aboard all vessels operating at the construction sites and barge landings.

3.F.2.7.1 Sensitive Resources

The barge operations plan is intended to protect listed species of fish in the vicinity of barge operations. The plan will be developed to avoid barge-related effects on listed species of fish; if and when avoidance is not possible, the plan will include provisions to minimize effects on listed species of fish as described in Section 3.F.2.7.3, *Avoidance Measures*, Section 3.F.2.7.4, *Environmental Training*, and Section 3.F.2.7.5, *Dock Approach and Departure Protocol*. The sensitive resources potentially affected by barge maneuvering and anchoring in affected areas are listed below.

- Sediments that could cause turbidity or changes in bathymetry if disturbed.
- Bottom-dwelling (benthic) invertebrates that provide a prey base for listed species of fish.
- Riparian vegetation that provides shade, cover, habitat structure, and organic nutrients to the aquatic environment.
- Submerged aquatic vegetation that provides habitat structure and primary (plant) production.

3.F.2.7.2 Responsibilities

Construction contractors operating barges in the process of constructing the water conveyance facilities will be responsible for the following.

- Operate vessels safely and following the barge operations plan and other reasonable measures to prevent adverse effects on aquatic resources of the Delta.
- Read, understand, and follow the barge operations plan.
- Report to the project biological monitor any vessel grounding or other deviations from the barge operations plan that could have resulted in the disturbance of bottom sediments, damage to river banks, or loss of submerged, emergent, or riparian vegetation.
- Immediately report material fuel or oil spills to the CDFW Office of Spill Prevention and Response, the project biological monitor, and DWR.
- Follow all other relevant plans, including the hazardous materials management plan, SWPPP, and SPCC plan.

The biological monitor will be responsible for the following.

- Observe a sample of barge operation activities including loading and unloading at least one barge at each of the barge loading and unloading facilities.
- Provide same-day reports to DWR on any observed problems with barge operations.
- Provide annual reports to DWR, summarizing monitoring observations over the course of each construction year, including an evaluation of the plan performance measures. The annual report will also include a description of and representative photographs and/or videos of conditions of river banks and vegetation.
- Visit each intake and barge landing site to determine the extent of emergent and riparian vegetation, bank conditions, and general site conditions during the growing season prior to initiation of construction and then annually during and after construction. Monitor construction including observation of barge landing, loading, or unloading; departure of one or more barges at each active barge landing site and the condition of both river banks at each landing site; pile-driving; and other in-water construction activity as directed by DWR. The condition of river banks and vegetation will be photographed and verbally described in an annual monitoring report.

3.F.2.7.3 Avoidance Measures

The following avoidance measures will be implemented to ensure that the goal of avoiding impacts on aquatic resources from tugboat and barge operations will be achieved: training of tug boat operators; limiting vessel speed to minimize the effects of wake impinging on unarmored or vegetated banks and the potential for vessel wake to strand small fish; limiting the direction and/or velocity of propeller wash to prevent bottom scour and loss of aquatic vegetation; and prevention of spillage of materials and fluids from vessels.

If deviations from these procedures are required to maintain the safety of vessels and crew, the biological monitor will be informed of the circumstances and any apparent impacts on water quality, habitats, fish, or wildlife. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.

3.F.2.7.4 Environmental Training

All pilots operating at the barge landings and intake construction sites will be required to read and follow the barge operations plan and to keep a copy aboard and accessible. All pilots responsible for operating a vessel at either the intake or barge landing sites will read the barge operations plan and sign an affidavit as provided in the plan.

3.F.2.7.5 Dock Approach and Departure Protocol

DWR will require that construction contractors develop and implement a protocol for dock approach and departure to ensure the following.

- Vessel operators will obey all federal and state navigation regulations that apply to the Delta.

- All vessels will approach and depart from the intake and barge landing sites at dead slow in order to reduce vessel wake and propeller wash at the sites frequented by tug and barge traffic.

- To minimize bottom disturbance, anchors and barge spuds will be used to secure vessels only when it is not possible to tie up.

- Barge anchoring will be preplanned. Anchors will be lowered into place and not be allowed to drag across the channel bed.

- Vessel operators will limit vessel speed as necessary to maintain wake heights of less than 2 feet at shore.

- Vessel operators will avoid pushing stationary vessels up against the cofferdam, dock, or other structures for extended periods, because this could result in excessive directed propeller wash impinging on a single location. Barges will be tied up whenever possible to avoid the necessity of maintaining stationary position by tugboat or by the use of barge spuds.

- Barges will not be anchored where they will ground during low tides.

- All vessels will obey U.S. Coast Guard regulations related to the prevention, notification, and cleanup of hazardous materials spills.

- All vessels will keep an oil spill containment kit and spill prevention and response plan onboard.

- In the event of a fuel spill, CDFW Office of Spills Prevention and Response will be contacted immediately at 800-852-7550 or 800-OILS-911 (800-645-7911) to report the spill.

- When transporting loose materials (e.g., sand, aggregate), barges will use deck walls or other features to prevent loose materials from blowing or washing off of the deck.

3.F.2.7.6 Performance Measures

Performance will be assessed based on the results of the biological monitoring reports. The assessment will evaluate observations for the following indicators of impacts.

- **Emergent vegetation loss.** The extent and dominant species of emergent vegetation will be determined and mapped by a global positioning system (GPS) unit at and cross-channel from each of the intake and barge landing sites during the growing seasons prior to, during, and after construction. Extent will be mapped as linear coverage along the landing and opposite banks. In the event that the linear extent of emergent vegetation is found to have decreased by 20% or more following construction (or as otherwise conditioned by applicable CDFW streambed alteration agreements), the position and nature of the change will be evaluated for the probability that the loss was due to barge grounding, propeller wash, or other effects related to barge operations. Adequate performance will be achieved if the linear extent of riparian and emergent vegetation following construction is at least 80% of the preconstruction extent (or as otherwise conditioned by applicable CDFW streambed alteration agreements).

- **Bank erosion and riparian vegetation loss.** The linear extent of bank erosion will be mapped by GPS at each of the intake and barge landing sites prior to, during, and after construction. Photos and written descriptions will be recorded for each area of eroded bank to describe the extent of the erosion. In the event that the linear extent of eroded bank is found to have increased by 20% or more following construction, the position and nature of the change will be evaluated for the probability (low, moderate, or high) that the erosion was due to barge grounding, propeller wash, or other effects related to barge operations, and preconstruction and postconstruction photographs will be compared to determine if riparian vegetation was also lost as a result of the erosion.

- **Cargo containment.** The biological monitor will note the use of deck walls or other appropriate containment during loading and unloading of sand, aggregate, or other materials from a barge at each landing site. Adequate performance will be achieved if appropriate measures are in use during each observed loading and unloading. In the unlikely event that an accidental spill occurs in spite of appropriate containment, the barge crew will describe the type, amount, and location of the spill to the biological monitor. The biological monitor will make observations at the site of the material spill and evaluate the potential impacts of the spill on biological resources. This will help the biological monitor evaluate whether mitigation is required and will be included in the annual monitoring report. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.

- **Fuels spill prevention.** Vessels operating in accordance with the SPCC plan and all applicable federal, state, and local safety and environmental laws and policies governing commercial vessel and barge operations will be considered to be performing adequately with regard to fuel spill prevention.

- **Barge grounding.** Barges are not to be grounded or anchored where falling tides are reasonably expected to cause grounding during a low tide. Barge grounding has the potential to disturb bottom sediments and benthic organisms, as well as creating a temporary obstacle to fish passage. Performance will be considered adequate if no cases of vessel grounding occur.

3.F.2.7.7 Contingency Measures

In the event that the performance measures are not met, DWR will coordinate with NMFS, USFWS, CDFW, and Central Valley Regional Water Quality Control Board to determine appropriate rectification or compensation for impacts on aquatic resources.

3.F.2.8 AMM8 Fish Rescue and Salvage Plan

Fish rescue operations will occur at any in-water construction site where dewatering and resulting isolation of fish may occur. Fish rescue and salvage plans will be developed by DWR or its contractors and will include detailed procedures for fish rescue and salvage to minimize the number of individuals of listed fish species subject to stranding during placement and removal of cofferdams. The plans will identify the appropriate procedures for removing fish from construction zones and preventing fish from reentering construction zones prior to dewatering and other construction activities. A draft plan will be submitted to the fish and wildlife agencies for review and approval. An authorization letter from NMFS, USFWS, and CDFW will be required before in-water construction activities with the potential for stranding fish can proceed.

Construction activities at the north Delta intakes, Clifton Court Forebay, and HOR gate include placement of cofferdams to isolate construction areas and minimize adverse effects to aquatic species and habitat during construction activities. However, these species can become trapped within the cofferdam and will need to be rescued or salvaged prior to dewatering. Although the following discussion focuses primarily on the application of this plan to cofferdam construction, the plan will also need to describe potential fish protection methods that may be implemented during other in-water activities with the potential to trap fish. For example, potential measures to exclude fish from active dredging areas in CCF include deployment of silt curtains in a manner that directs fish away from the silt curtains and prevents fish from re-entering these areas during dredging operations. Fish rescue operations at NCCF prior to dewatering will require special considerations given its large surface area, depth, and large numbers of fish that may be present.

All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist and in accordance with required permits. Each fish rescue plan will identify the appropriate procedures for excluding fish from the construction zones, and procedures for removing fish, should they become trapped. The primary procedure will be to block off the construction area and use seines (nets) and/or dip nets to collect and remove fish, although electrofishing techniques may also be authorized under certain conditions. It is critical that fish rescue and salvage operations begin as soon as possible and be completed within 48 hours after isolation of a construction area to minimize potential predation and adverse water quality impacts (high water temperature, low dissolved oxygen) associated with confinement. In the case of cofferdam construction, the cofferdam will be installed to block off the construction area before fish removal activities occur. For other in-water construction activities, block nets or other temporary exclusion methods (e.g., silt curtains) could be used to exclude fish or isolate the construction area prior to the fish removal process. The appropriate fish exclusion or collection method will be determined by a qualified fish biologist, in consultation with a designated fish and wildlife agency biologist, based on site-specific conditions and construction methods. Capture, release, and relocation measures will be consistent with the general guidelines and procedures set forth in Part IX of the most recent edition of the *California Salmonid Stream Habitat Restoration Manual* (currently, California Department of Fish and Game 2010) to minimize impacts on listed species of fish and their habitat.

All fish rescue and salvage operations will be conducted under the guidance of a fish biologist meeting the qualification requirements of Section 3.F.2.8.1 *Qualifications of Fish Rescue Personnel*. The following description includes detailed fish collection, holding, handling, and release procedures of the plan. Unless otherwise required by project permits, the construction contractor will provide the following:

- A minimum 7-day notice to the appropriate fish and wildlife agencies, prior to an anticipated activity that could result in isolating fish, such as installation of a cofferdam.
- A minimum 48-hour notice to the appropriate fish and wildlife agencies of dewatering activities that are expected to require fish rescue.
- Unrestricted access for the appropriate fish and wildlife agency personnel to the construction site for the duration of implementation of the fish rescue plan.
- Temporary cessation of dewatering if fish rescue workers determine that water levels may drop too quickly to allow successful rescue of fish.
- A work site that is accessible and safe for fish rescue workers.

3.F.2.8.1 Qualifications of Fish Rescue Personnel

Personnel active in fish rescue efforts will include at least one person with a 4-year college degree in fisheries or biology, or a related degree. This person also must have at least 2 years of professional experience in fisheries field surveys and fish capture and handling procedures. The person will have completed an electrofishing training course such as Principles and Techniques of Electrofishing (USFWS, National Conservation Training Center), or similar course, if electrofishing is used. In order to avoid and minimize the risk of injury to fish, attempts to seine and/or net fish will always precede the use of electrofishing equipment.

3.F.2.8.2 Seining and Dipnetting

Fish rescue and salvage operations will begin prior to or immediately after completing the cofferdam. For example, it may be necessary to herd fish from the construction area before installing the last sections of the cofferdam. For example, in CCF, where embankment cofferdams may extend for thousands of feet, fish exclusion and/or rescue activities may need to be conducted incrementally in coordination with cofferdam placement to minimize the number of fish subjected to prolonged confinement and stressful conditions associated with crowding, capture, and handling. If the enclosed area is wadable (less than 3 feet deep), fish can be herded out of the cofferdam enclosure by dragging a seine (net) through the enclosure, starting from the enclosed end and continuing to the cofferdam opening. Depending on conditions, this process may need to be conducted several times. After completing this fish herding process, the net or an exclusion screen will be positioned at the cofferdam opening to prevent fish from reentering the enclosure while the final section of the cofferdam is installed. The net or screen mesh will be no greater than 0.125 inch, with the bottom edge of the net (lead line) securely weighted down to prevent fish from entering the area by moving under the net. Screens will be checked periodically and cleaned of debris to permit free flow of water.

After installing the last sections of the cofferdam, remaining fish in the enclosed area will be removed using seines, dip nets, electrofishing techniques, or a combination of these depending on site conditions. If the water depth within the cofferdam is too deep to effectively remove fish using these methods, dewatering activities may be used to reduce the water level to an appropriate and safe depth (Section 3.F.2.8.5, *Contingency Plans*). Dewatering activities will also conform to the guidelines specified below (Section 3.F.2.8.4, *Dewatering*).

Following each sweep of a seine through the enclosure, the fish rescue team will do the following.

- Carefully bring the ends of the net together and pull in the wings, ensuring the lead line is kept as close to the substrate as possible.

- Slowly turn the seine bag inside out to reveal captured fish, ensuring fish remain in the water as long as possible before transfer to an aerated container.

- Follow the procedures outlined in Section 3.F.2.8.3, *Electrofishing*, and relocate fish to a predetermined release site.

Dipnetting is best suited for very small, shallow pools in which fish are concentrated and easily collected. Dip nets will be made of soft (nonabrasive) nylon material and small mesh size (0.125 inch) to collect small fish.

3.F.2.8.3 Electrofishing

After conducting the herding and netting operations described above, electrofishing may be necessary to remove as many fish as possible from the enclosure. Electrofishing will be conducted in accordance with NMFS electrofishing guidelines (National Marine Fisheries Service 2000) and other appropriate fish and wildlife agency guidelines. Electrofishing will be conducted by one or two 3- to 4-person teams, with each team having an electrofishing unit operator and two or three netters. At least three passes will be made through the enclosed cofferdam areas to remove as many fish as possible. Fish initially will be placed in 5-gallon buckets filled with river water. Following completion of each pass, the electrofishing team will do the following.

- Transfer fish into 5-gallon buckets filled with clean river water at ambient temperature.

- Hold fish in 5-gallon buckets equipped with a lid and an aerator, and add fresh river water or small amounts of ice to the fish buckets if the water temperature in the buckets becomes more than 2°F warmer than ambient river waters.

- Maintain a healthy environment for captured fish, including low densities in holding containers to avoid effects of overcrowding.

- Use water-to-water transfers whenever possible.

- Release fish at predetermined locations.

- Segregate larger fish from smaller fish to minimize the risk of predation and physical damage to smaller fish from larger fish.

- Limit holding time to about 10 minutes, if possible.
- Avoid handling fish during processing unless absolutely necessary. Use wet hands or dip nets if handling is needed.
- Handle fish with hands that are free of potentially harmful products, including but not limited to sunscreen, lotion, and insect repellent.
- Avoid anesthetizing or measuring fish.
- Note the date, time, and location of collection; species; number of fish; approximate age (e.g., young-of-the-year, yearling, adult); fish condition (dead, visibly injured, healthy); and water temperature.
- If positive identification of fish cannot be made without handling the fish, note this and release fish without handling.
- In notes, indicate the level of accuracy of visual estimates to allow appropriate reporting to the appropriate fish and wildlife agencies (e.g., “Approx. 10–20 young-of-the-year steelhead”).
- Release fish in appropriate habitat either upstream or downstream of the enclosure, noting release date, time, and location.
- Stop efforts and immediately contact the appropriate fish and wildlife agencies if mortality during relocation or the limits on take (harm or harassment) of federally listed species exceeds 5%.
- Place dead fish of listed species in sealed plastic bags with labels indicating species, location, date, and time of collection, and store them on ice.
- Freeze collected dead fish of listed species as soon as possible and provide the frozen specimens to the appropriate fish and wildlife agencies, as specified in the permits.
- Sites selected for release of rescued fish either upstream or downstream of the construction area will be similar in temperature to the area from which fish were rescued, contain ample habitat, and have a low likelihood of fish reentering the construction area or being impinged on exclusion nets/screens.

3.F.2.8.4 Dewatering

Dewatering will be performed in coordination with fish rescue operations as described above. A dewatering plan will be submitted as part of the SWPPP/Water Pollution Control Program detailing the location of dewatering activities, equipment, and discharge point. Dewatering pump intakes will be screened to prevent entrainment of fish in accordance with NMFS screening criteria for salmonid fry (National Marine Fisheries Service 1997), including the following.

- Perforated plate: screen openings shall not exceed 3/32 inch (2.38 mm), measured in diameter.
- Profile bar: screen openings shall not exceed 0.0689 inch (1.75 mm) in width.
- Woven wire: screen openings shall not exceed 3/32 inch (2.38 mm), measured diagonally (e.g., 6–14 mesh).
- Screen material shall provide a minimum of 27% open area.

During the dewatering process, a qualified biologist or fish rescue team will remain onsite to observe the process and remove additional fish using the rescue procedures described above.

3.F.2.8.5 Contingency Plans

Where fish rescue and salvage operations cannot be conducted effectively or safely by fish rescue workers, it may be necessary to begin the dewatering process prior to fish rescue. During the dewatering process, a qualified biologist or fish rescue team will be onsite with the aim of minimizing the number of fish that become trapped in isolated areas or impinged on pump screen(s) or isolation nets, based on the professional judgment of the onsite fish biologist and the terms and conditions of the incidental take permit. In the event that the proposed methods are found to be insufficient to avoid undue losses of fish, the qualified biologist will modify these methods or implement alternative methods to minimize subsequent losses.

3.F.2.8.6 Final Inspections and Reporting

Upon dewatering to water depths at which neither electrofishing nor seining can effectively occur (e.g., less than 3 inches [0.1 meter]), the fish rescue team will inspect the dewatered areas to locate any remaining fish. Collection by dip net, data recording, and relocation will be performed as necessary according to the procedures outlined in Section 3.F.2.8.3, *Electrofishing*. The fish rescue team will notify the contractor when the fish rescue has been completed and construction can recommence. The results of the fish rescue and salvage operations (including date, time, location, comments, method of capture, fish species, number of fish, approximate age, condition, release location, and release time) will be reported to the appropriate fish and wildlife agencies, as specified in the pertinent permits.

3.F.2.9 AMM9 Underwater Sound Control and Abatement Plan

DWR will develop and implement an underwater sound control and abatement plan outlining specific measures that will be implemented to avoid and minimize the effects of underwater construction noise on listed species of fish, particularly the underwater noise effects associated with impact pile driving activities. Potential underwater noise effects on listed species from impact pile driving will be avoided and minimized by regulating the period during which impact pile driving is permitted and by controlling and/or abating underwater noise generated during impact pile driving.

The underwater sound control and abatement plan will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on listed species of fish in the context of applicable and interim underwater noise thresholds established for disturbance and injury of fish (California Department of Transportation 2009). The thresholds include the following.

- Injury threshold for fish of all sizes includes a peak sound pressure level of 206 decibels (dB) relative to 1 micropascal.
- Injury threshold for fish less than 2 grams is 183 dB relative to 1 micropascal cumulative sound exposure level, and 187 dB relative to 1 micropascal cumulative sound exposure level for fish greater than or equal to 2 grams.
- Disturbance threshold for fish of all sizes is 150 dB root mean square relative to 1 micropascal.

The specific number of pilings that will be driven per day with an impact pile driver, and thus the number of pile strikes per day, will be defined as part of the design of project elements that require pilings. See Appendix 3.E *Pile Driving Assumptions for the Proposed Action* for pile driving needs associated with each phase of the proposed action.

Most of the impact pile driving activities will occur at the north Delta intake sites, for either the installation of cofferdams to isolate subsequent intake construction activities from the water, or inside the work area isolated by the cofferdams. Additional impact pile driving may also occur at the barge landing sites, at construction sites at and near Clifton Court Forebay, and at the HOR gate construction site. The sound control and abatement plan will restrict in-water work to the in-water work windows specified in ~~permits issued by the fish and wildlife agencies~~AMM2 *Construction Best Management Practices*.

The underwater noise generated by impact pile driving will be abated using the best available and practicable technologies. Examples of such technologies include, but are not limited to, the use of cast-in-drilled-hole rather than driven piles; use of vibratory rather than impact pile driving equipment; using an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation using of pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions

In addition to primarily using vibratory pile driving methods and establishing protocols for attenuating underwater noise levels produced during in-water construction activities, DWR will develop and implement operational protocols for when impact pile driving is necessary. These operational protocols will be used to minimize the effects of impact pile driving on listed species of fish. These protocols may include, but not be limited to, the following: monitoring the in-water work area for fish that may be showing signs of distress or injury as a result of pile driving activities and stopping work when distressed or injured fish are observed; initiating impact pile driving with a “soft-start,” such that pile strikes are initiated at reduced impact and increase to full impact over several strikes to provide fish an opportunity to move out of the area; restricting impact pile driving activities to specific times of the day and for a specific duration to be determined through coordination with the fish and wildlife agencies; and, when more than one pile driving rig is employed, ensure pile driving activities are initiated in a way that provides an escape route and avoids "trapping" fish between pile drivers in waters exposed to underwater noise levels that could potentially cause injury. These protocols are expected to avoid and minimize the overall extent, intensity, and duration of potential underwater noise effects associated with impact pile driving activities.

3.F.2.10 AMM10 Methylmercury Management

Tidal restoration under the PA has the potential to result in increased availability of mercury, and specifically the bioavailable form methylmercury, to the foodweb in the Delta system. Due to the complex and very site-specific factors that will determine if mercury becomes mobilized into the foodweb, AMM10 Methylmercury Management is included to provide for site-specific evaluation for each restoration project. AMM10 will be implemented in coordination with other similar efforts to address mercury in the Delta, and specifically with the DWR Mercury Monitoring and Analysis Section, as further described below.

This AMM will promote the following actions.

- Assessment of pre-restoration conditions to determine the risk that the project could result in increased mercury methylation and bioavailability
- Definition of design elements that minimize conditions conducive to generation of methylmercury in restored areas
- Definition of strategies that can be implemented to monitor and minimize actual postrestoration creation and mobilization of methylmercury into environmental media and biota

The restoration design will always focus on the ecosystem restoration objectives and design elements to mitigate mercury methylation that will not interfere with restoration objectives. Design elements that help to mitigate mercury methylation will be integrated into site-specific restoration designs based on site conditions, community type (tidal marsh, nontidal marsh, floodplain), and potential concentrations of mercury in pre-restoration sediments. Strategies to minimize postrestoration creation and mobilization of methylmercury can be applied where site conditions indicate a high probability of methylmercury generation and effects on listed species.

3.F.2.10.1 Implementation

AMM10 will be developed and implemented in coordination with the Sacramento-San Joaquin Delta Methylmercury Total Maximum Daily Load (Methylmercury TMDL) (Central Valley Regional Water Quality Control Board 2011a) and Amendments to the Water Quality Control Plan for the Sacramento River and San Joaquin River Basins for the Control of Methylmercury and Total Mercury in the Sacramento-San Joaquin Delta Estuary (Mercury Basin Plan Amendments)(Central Valley Regional Water Quality Control Board 2010 and 2011). AMM10 will also be implemented to meet requirements of the U.S. Environmental Protection Agency (EPA) or the California Department of Toxic Substances Control actions.

The DWR Mercury Monitoring and Evaluation Section is currently working on DWR's compliance with the Methylmercury TMDL and Mercury Basin Plan Amendments. The Methylmercury TMDL programs are responsible for developing measures to control methylmercury generation and loading into the Delta in accordance with Methylmercury TMDL goals. Phase I emphasizes studies and pilot projects to develop and evaluate management practices to control methylmercury. Phase I (effective October 2011) will be underway for the next 7 years, with an additional 2 years to evaluate Phase I results and plan for Phase II. Phase II involves implementation of mercury control measures.

The DWR Mercury Monitoring and Evaluation Section is required as part of Phase I to submit final reports that present the results and descriptions of methylmercury control options, their preferred methylmercury controls, and proposed methylmercury management plan(s) (including implementation schedules) for achieving methylmercury allocations. Results will be integrated into Project-Specific Mercury Management Plans, which will be developed for each tidal wetland restoration project. The Plans will include the components listed below.

- A brief review of available information on levels of mercury expected in site sediments/soils based on proximity to sources and existing analytical data.
- A determination if sampling for characterization of mercury concentrations
- A plan for conducting the sampling, if characterization sampling is recommended.
- A determination of the potential for the restoration action to result in increased mercury methylation
- If a potential for increased mercury methylation under the restoration action is identified, the following will also be included:
    - Identification of any restoration design elements, mitigation measures, adaptive management measures that could be used to mitigate mercury methylation, and the probability of success of those measures, including uncertainties
    - Conclusion on the resultant risk of increased mercury methylation, and if appropriate, consideration of alternative restoration areas

Because methylmercury is an area of active research in the Delta, each new project-specific methylmercury management plan will be updated based on the latest information about the role of mercury in Delta ecosystems or methods for its characterization or management. Results from monitoring of methylmercury in previous restoration projects will also be incorporated into subsequent project-specific methylmercury management plans.

In each of the project-specific methylmercury management plans developed under AMM10, relevant findings and mercury control measures identified as part of TMDL Phase I control studies will be considered and integrated into restoration design and management plans.

3.F.2.11 AMM11 Design Standards and Building Codes

DWR will ensure that the standards, guidelines, and codes listed below (or the most current applicable version at the time of implementation), which establish minimum design criteria and construction requirements for project facilities, will be followed by the design engineers. The design engineers will also follow any other standards, guidelines, and code requirements not listed below that are promulgated during the detailed design and construction and can feasibly be incorporated into the work. DWR will also ensure that the design specifications are properly executed during construction. The minimum design and construction requirements act as performance standards for engineers and construction contractors. Because the design and construction parameters of these codes and standards are intended to reduce the potential for structural damage or risks to human health due to the geologic and seismic conditions that exist at construction sites, project area and in the surrounding region, as well as climate change, an uncontrolled release of water, a flood event, and accidents during construction, their use is considered an environmental commitment of DWR. These standards, guidelines, and codes include the following.

- California Code of Regulations, Title 8.
- DWR Division of Flood Management FloodSAFE Urban Levee Design Criteria, May 2012.
- State of California Sea-Level Rise Task Force of the Coastal and Ocean Working Group of the California Climate Action Team, Sea-Level Rise Interim Guidance Document, 2010.
- U.S. Army Corps of Engineers (Corps, CESPK-ED-G), Geotechnical Levee Practice, SOP EDG-03, 2004.
- USACE Design and Construction of Levees, EM 1110-2-1913, 2000.
- USACE Engineering and Design—Structural Design and Evaluation of Outlet Works, EM 1110-2-2400, 2003.
- USACE Slope Stability, EM 1110-2-1902, 2003.
- USACE Engineering and Design—Settlement Analysis, EM 1110-1-1904, 1990.
- USACE Engineering and Design—Design of Pile Foundations, EM 1110-2-2906, 1991.
- U.S. Department of the Interior and U.S. Geological Survey Climate Change and Water Resources Management: A Federal Perspective, Circular 1331.

3.F.2.12 AMM12 Transmission Line Design and Alignment

The location and design of the proposed new transmission lines will be in accordance with electric and magnetic field guidance adopted by the California Public Utility Commission (2006) *EMF Design Guidelines for Electrical Facilities*. The guidelines describe the routine magnetic field reduction measures that all regulated California electric utilities will consider for new and upgraded transmission line and transmission substation construction.

The alignment of proposed transmission lines will be designed to avoid sensitive terrestrial and aquatic habitats when siting poles and towers, to the maximum extent feasible. Lines will be co-located where feasible, when such co-location would minimize effects on greater sandhill cranes and other sensitive resources. In cases where this is not feasible, DWR will ensure that impacts are minimized to the greatest degree feasible, and disturbed areas will be returned as near as reasonably and practically feasible to preconstruction conditions by reestablishing surface conditions through careful grading, reconstructing features such as irrigation and drainage facilities, and replanting vegetation and crops and/or compensating farmers for crops losses. Temporary transmission lines will be designed to avoid removal of wetted acres of vernal pools and alkali seasonal wetlands.

Further, tower and pole placement will avoid existing structures to the extent feasible. Where poles or towers are to be constructed in agricultural areas, the following BMPs will be implemented as applicable and feasible.

- Use single-pole structures instead of H-frame or other multiple-pole structures to reduce the potential for land impacts and minimize weed-encroachment issues.
- Locate new transmission lines along existing transmission line corridors to the extent feasible.
- Use special transmission designs to span existing irrigation systems or, if necessary, reconfigure the irrigation system at the utilities' expense, if feasible.

For stringing transmission lines between 230 kV towers, cranes and helicopters will be used. Helicopters may fly as low as the top of the transmission towers, which may be as low as 60 feet. They will take-off and land in the right of ways obtained for transmission line construction, within the corridor identified on the construction footprint, or on other property obtained for the project, and identified on the project construction footprint, or designated existing helicopter pads (airstrips). They will not be allowed to land in sensitive habitat.

3.F.2.13 AMM13 Noise Abatement

In addition to the underwater sound control and abatement plan (AMM9), DWR and contractors hired to construct any components of the water conveyance facilities will implement a noise abatement plan to avoid or reduce potential in-air noise impacts related to construction, maintenance, and operations. As applicable, the following components will be included in the plan.

3.F.2.13.1 Construction and Maintenance Noise

- To the extent feasible, the contractor will employ best practices to reduce construction noise during daytime and evening hours (7:00 a.m. to 10:00 p.m.) such that construction noise levels do not exceed 60 dBA (A-weighted decibel) L_{eq} (1 hour) at the nearest residential land uses.

- Limit construction during nighttime hours (10:00 p.m. to 7:00 a.m.) such that construction noise levels do not exceed 50 dBA L_{max}[2] at the nearest residential land uses. Limit pile driving to daytime hours (7 a.m. to 7 p.m.).

- In the event of complaints by nearby residents due to construction noise generated during nighttime hours, the contractor will monitor noise levels intermittently between 10:00 p.m. to 7:00 a.m. at the property line of the nearest residential use. In the event that construction noise during nighttime hours exceeds 50 dBA L_{max}, the construction contractor will cease nighttime construction activity in the area until sound-attenuating mitigation measures, such as temporary sound walls, are implemented, and nighttime construction noise at the nearest residential use is reduced to a level of 50 dBA L_{max}or lower.

- Locate, store, and maintain portable and stationary equipment as far as possible from nearby residents.

- Employ preventive maintenance including practicable methods and devices to control, prevent, and minimize noise.

- Route truck traffic in order to reduce construction noise impacts and traffic noise levels at noise-sensitive land uses (i.e., places where people reside, schools, libraries, and places of worship).

- To the extent feasible, schedule construction activities so that the loudest noise events, such as blasting, occur during peak traffic commute hours.

- Limit offsite trucking activities (e.g., deliveries, export of materials) to the hours of 7:00 a.m. to 10:00 p.m. to minimize impacts on nearby residences.

3.F.2.13.2 Operation Noise

Pump station facilities will be designed and constructed such that facility operation noise levels at nearby residential land uses do not exceed 50 dBA L_{eq} during daytime hours (7:00 a.m. to 10:00 p.m.) and 45 dBA L_{eq} during nighttime hours (10 p.m. to 7 a.m.). Acoustical measures such as terrain shielding, pump enclosures, and acoustical building treatments will be incorporated into the facility design to meet this performance standard.

3.F.2.14 AMM14 Hazardous Materials Management

DWR will ensure that each contractor responsible for site work under the PA will develop and implement a hazardous materials management plan (HMMP) before beginning construction. It is anticipated that multiple HMMPs will be prepared for the various construction sites, each taking into account site-specific conditions such as hazardous materials present onsite and known

[2] L_{max} is the maximum sound level measured for a given interval of time.

historical site contamination. A database on historical instances of contamination and results of any field inspections regarding the presence of hazardous chemicals will be maintained. The HMMPs will provide detailed information on the types of hazardous materials used or stored at all sites associated with the water conveyance facilities (e.g., intake pumping plants, maintenance facilities); phone numbers of applicable city, county, state, and federal emergency response agencies; primary, secondary, and final cleanup procedures; emergency-response procedures in case of a spill; and other applicable information. The HMMPs will include appropriate practices to reduce the likelihood of a spill of toxic chemicals and other hazardous materials during construction and facilities operation and maintenance. A specific protocol for the proper handling and disposal of hazardous materials will be established before construction activities begin and will be enforced by DWR.

The HMMPs will include, but not be limited to, the following measures or practices.

- Fuel, oil, and other petroleum products will be stored only at designated sites.
- Hazardous materials containment containers will be clearly labeled with the identity of the hazardous materials contained therein, handling and safety instructions, and emergency contact.
- Storage, use, or transfer of hazardous materials in or near wet or dry streams will be consistent with California Fish and Game Code (Section 5650) and/or with the permission of CDFW.
- Material Safety Data Sheets will be made readily available to the contractor’s employees and other personnel at the work site.
- The accumulation and temporary storage of hazardous wastes will not exceed 90 days.
- Soils contaminated by spills or cleaning wastes will be contained and removed to an approved disposal site.
- Hazardous waste generated at work sites, such as contaminated soil, will be segregated from other construction spoils and properly handled, hauled, and disposed of at an approved disposal facility by a licensed hazardous waste hauler in accordance with state and local regulations. The contractor will obtain permits required for such disposal.
- Emergency spill containment and cleanup kits will be located at the facility site. The contents of the kits will be appropriate to the type and quantities of chemical or goods stored at the facility.

3.F.2.15 AMM15 Construction Site Security

To ensure adequate construction site security, the DWR or their contractors will arrange to provide for 24-hour onsite security personnel. Security personnel will monitor and patrol construction sites, including staging and equipment storage areas. Security personnel will serve as the first line of defense against criminal activities and nuisances at construction sites. Private patrol security operators hired to provide site security will have the appropriate licenses from the California Bureau of Security and Investigative Services. Individual security personnel will have a minimum security guard registration license that meets the California Bureau of Security and Investigative Services requirements for training and continuation training as required for that license. All security personnel will also receive environmental training similar to that of onsite construction workers so that they understand the environmental conditions and issues associated with the various areas for which they are responsible at a given time.

Security operations and field personnel will be given the emergency contact phone numbers of environmental response personnel for rapid response to environmental issues resulting from vandalism or incidents that occur when construction personnel are not onsite. Security operations will also maintain a contact list of backup support from city police, county sheriffs, California Highway Patrol, water patrols (such as the Contra Costa County Marine Patrol), helicopter response, and emergency response (including fire departments, ambulances/emergency medical technicians). The appropriate local and regional contact list will be made available to security personnel by DWR or their contractors, as will the means to make that contact via landline phones, mobile phones, or radios. When on patrol, security personnel will always have the ability to contact backup using mobile phones or two way radios. Security personnel who are on patrol will have the appropriate geographic contact list for their location and the ability to summon appropriate backup or response via the security patrol local dispatch site or outside authorities.

3.F.2.16 AMM16 Fugitive Dust Control

DWR or their contractors will implement basic and enhanced control measures at all construction and staging areas to reduce construction-related fugitive dust. Although the following measures are outlined in the Sacramento Metropolitan Air Quality Management District's (SMAQMD) CEQA guidelines, they are required for the entirety of the construction area, including areas within the Bay Area Air Quality Management District (BAAQMD), San Joaquin Valley Air Pollution Control District (SJVAPCD), and Yolo-Solano Air Quality Management District (YSAQMD), and are sufficient to address BAAQMD, SJVAPCD, and YSAQMD fugitive dust control requirements. DWR or their contractors will ensure the project commitments are appropriately implemented before and during construction, and that proper documentation procedure is followed.

3.F.2.16.1 Basic Fugitive Dust Control Measures

DWR or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during general construction activities.

- Water will be applied to all exposed surfaces as reasonably necessary to prevent visible dust from leaving work areas. Frequency will be increased during especially dry or windy periods or in areas with a lot of construction activity. Exposed surfaces include (but are not limited to) soil piles, graded areas, unpaved parking areas, staging areas, and access roads.

- Cover or maintain at least 2 feet of freeboard space on haul trucks transporting soil, sand, or other loose material on the site. Any haul trucks that will be traveling along freeways or major roadways should be covered.

- Use wet power vacuum street sweepers to remove any visible trackout mud or dirt onto adjacent public roads at least once a day. Use of dry power sweeping is prohibited.

- Limit vehicle speeds on unpaved roads to 15 miles per hour.

- All roadway, driveway, sidewalk, and parking lot paving should be completed as soon as possible. In addition, building pads should be laid as soon as possible after grading unless seeding or soil binders, or other reasonable mitigation measures are used.

3.F.2.16.2 Enhanced Fugitive Dust Control Measures for Land Disturbance

DWR or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during soil disturbance activities.

- Water exposed soil with adequate frequency for continued moist soil. However, do not overwater to the extent that sediment flows off the site.

- Suspend excavation, grading, and/or demolition activity when wind speeds exceed 20 miles per hour.

- Install wind breaks (e.g., plant trees, solid fencing) on windward side(s) of construction areas.

- Plant vegetative ground cover (fast-germinating native grass seed) in disturbed areas as soon as possible after construction is completed. Water appropriately until vegetation is established.

3.F.2.16.3 Measures for Entrained Road Dust

DWR or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control entrained road dust from unpaved roads.

- Install wheel washers for all exiting trucks, or wash off all trucks and equipment leaving the site.

- Treat site accesses to a distance of 100 feet from the paved road with a 6- to 12-inch layer of wood chips, mulch, or gravel to reduce generation of road dust and road dust carryout onto public roads.

- Post a publicly visible sign with the telephone number and person to contact at the lead agency regarding dust complaints. This person will respond and take corrective action within 48 hours. The phone number of the air quality management district will also be visible to ensure compliance.

3.F.2.16.4 Measures for Concrete Batching

DWR or their contractors will take steps to ensure that the following measures will be implemented to the extent feasible to control dust during concrete batching activities.

- Implementation of fugitive dust control measures to achieve a 70% reduction in dust from concrete batching.
- Implementation of fugitive dust control measures to achieve an 80% reduction in dust from aggregate and sand pile erosion at the concrete batch plants.
- Use of a hood system vented to a fabric filter/baghouse during cement delivery and hopper and central mix loading.

3.F.2.17 AMM17 Notification of Activities in Waterways

Similar to the requirements specified in the barge operations plan (AMM7), fish rescue and salvage plan (AMM8), and underwater sound control and abatement plan (AMM9), before in-water construction or maintenance activities begin, DWR will ensure notification of appropriate fish and wildlife agency representatives when these activities could affect water quality or aquatic species. The notification procedures will follow stipulations included in applicable permit documents for the construction operations. However, in general, the notification information will include site location(s), schedules, and work activities. Information on detours will include site-specific details regarding any temporary partial channel closures, including contacting the U.S. Coast Guard, boating organizations, marina operators, city or county parks departments, and the California Department of Pesticide Regulation, where applicable.

3.F.3 References Cited

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Adaptive Management Program for the California Water Fix and Current Biological Opinions on the Coordinated Operations of the Central Valley and State Water Projects

Contents

1 Executive Summary

Adaptive management is a science-based, flexible approach to resource management decision-making. When correctly designed and executed, adaptive management programs provide the ability to make and implement decisions while simultaneously conducting research to reduce the ecological uncertainty of a decision's outcome. These characteristics facilitate a management regime that is transparent, collaborative, and responsive to changes in scientific understanding.

The Delta Reform Act of 2009 identified adaptive management as the desired approach to reduce the ecological uncertainty associated with the management of the Sacramento-San Joaquin Delta system. The Federal and State water operations agencies (Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR)) and the State and Federal fisheries agencies (U.S. Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (CDFW)) (collectively the 'Five Agencies') agree that adaptive management is the approach best suited to improve the management of the Delta and its resources.

Together, the Five Agencies commit to ongoing adaptive management under the current Biological Opinions of the combined operations of the Central Valley Project (CVP) and State Water Project (SWP), as well as the effects of future operations under California WaterFix (CWF). This document sets forth the Adaptive Management Program (AMP) to reduce uncertainty and improve the performance of Central Valley Project and State Water Project water operations under the current Biological Opinions and CWF. This document also seeks to further highlight significant new investments in related research, monitoring and modeling needed to support this management effort, while explaining how each (existing efforts and new) will build on each other. This document will be used by the new Interagency Implementation Coordination Group (IICG) for their coordination and recommendation functions and by the five agencies for the purposes of making decisions on those recommendations.

Together, the IICG and Five Agencies are referred to throughout as the Implementing Entities for the AMP. For all adaptive management changes affecting Delta operations and other adaptive management changes outside the Delta otherwise agreed by the IICG, the IICG shall make its recommendations to the Five Agencies for a decision by the agency or agencies with final decision-making authority. Except those addressed by the IICG, adaptive management changes that do not affect operations in the Delta will generally be implemented by the Five Agencies.

This Adaptive Management Program includes a framework for a structured decision-making process with four overarching phases: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt.

- During **Phase 1: Plan**, initial operation and research priorities are set through the respective Operational criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans. The operations criteria set water supply expectations while the science plans address how uncertainties associated with the operational and stressors affecting covered species will be addressed. The Science Plan will be developed collaboratively using the CSAMP/CAMT process. The Science to be conducted to address uncertainties will undergo independent review coordinated by the Delta Science Program.

- Through **Phase 2: Assess**, the products developed through the Science plan and the subsequent synthesis will undergo independent review, and the outcomes of this research will provide the basis for future proposals for management adjustments developed during Phase 3.

- In **Phase 3: Integrate**, interagency and agency-stakeholder discussions (based on the results of Phase 2's scientific assessments) will inform development of management adjustment proposals and additional research alternatives through a structured decision-making process. This 'scoping' process will also lead to the development of additional adaptive management questions to continue to address covered species and operational needs, assess benefits and identify uncertainty.

- During **Phase 4: Adapt**, the agency or agencies with final decision-making authority decide whether to adopt or reject a management adjustment proposal. Decisions will be evaluated to determine whether reinitiation of consultation and/or permit amendment is required.

The IICG will be co-led by Reclamation and DWR. Members of the IICG will include a representative of Reclamation, USFWS, and NMFS and one designated representative[1] each from DWR, CDFW, a participating SWP contractor, and a participating CVP contractor. The IICG's role in implementing this AMP is described in Section 4.1.1.

Success of the adaptive management process outlined within this AMP hinges upon significant new investments in related research, monitoring and modeling that build on existing efforts. These investments will address key uncertainties related to water operations and threatened and endangered species that have been raised in a number of different venues (e.g., the IEP Management, Analysis, and Synthesis Team and Salmon and Sturgeon Assessment of Indicators by Lifestage and the Collaborative Science and Adaptive Management Program (CSAMP) Salmon Scoping Team) as well as during the development of a Biological Assessment for CWF. The Implementing Entities are committed to leveraging the expertise found in these different venues; filling critical data and information gaps in the areas of integrated monitoring and research, mechanistic studies and models, information synthesis, and data access.

Working through the collaborative process outlined herein, the Five Agencies commit to reach consensus within the IICG on operational decisions to the maximum extent possible, while still retaining individual agency discretion to make decisions (as appropriate). To that end, the Implementing Entities seek to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with taking actions in the face of uncertainty and achieving the best near-term outcomes possible.

[1] "Designated Representative" means in the case of DWR and CDFW the official representative designated by the Governor to act on his behalf, and in the case of the SWP/CVP contractors the official representative designated by an elected board of directors to act on their behalf.

2 Introduction

"Adaptive Management" is defined in California Water Code, section 85052, as "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives." At its most basic level, adaptive management is a learning cycle and feedback loop whereby resource managers may simultaneously make management decisions while gathering further knowledge and information about a single resource or set of natural resources. Adaptive management is inherently collaborative, requiring "communication and transparency among all interest groups as well as a willingness to overcome the institutional barriers to collaborative decision-making," (Luoma *et al.* 2015). Starting with Holling (1978) and Walters and Hilborn (1978), a general framework for adaptive management has emerged as a structured decision-making process that incorporates uncertainty by recognizing there are different possible outcomes to management actions. Adaptive management then relies on flexible decision-making that is adjusted as outcomes from management actions and other events become better understood.

Defined objectives and clearly identified expectations of management outcomes are critical to the adaptive management process (Williams, 2011). Based on objectives (and allowing for uncertainty), resource managers can then develop hypotheses about potential resource responses to various management actions and implement the selected action(s), while collecting information to compare the outcomes expected to those observed (Williams *et al.* 2009). The goal of any adaptive management program is to incrementally reduce uncertainty and management risks by learning more about how the target resource responds to the management regime being evaluated. The challenge becomes how to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with achieving the best near-term outcome possible (Allan and Stankey, 2009). In practice, the bigger challenge has been reaching general agreement among parties about management tactics and their efficacy.

3 Intent and Objectives

Through the Adaptive Management Program described in this document, the Implementing Entities are committing to the ongoing adaptive management of operation of the CVP and SWP. The CWF would modify the existing SWP, which is operated in coordination with the CVP, to construct and operate three new screened diversions in the north Delta. These new facilities would be operated in conjunction with the existing south Delta diversion facilities to reduce reliance on south Delta exports, improve operational flexibility, and increase water supply reliability. A robust application of ecological, social, and economic science to support decisions that affect the operations of the CVP and SWP, and to support achievement of the co-equal goals[2] described in the Delta Reform Act of 2009 is critical to achieving success under this AMP. More specifically, the intent of this AMP is to guide the Implementing Entities as they:

1. Create an adaptive management plan for long-term operations of the CVP and SWP that is consistent with state and federal endangered species laws and the co-equal goals of the Delta Reform Act.

2. Develop and implement a robust science program needed to implement the adaptive management plan.

3. Identify the key uncertainties about how Central Valley water operations and other management actions to benefit the species can be implemented to avoid jeopardy and meet other regulatory standards applicable to state and federally-listed fishes, including future effects associated with the CWF.

4. Describe the basic processes and governance principles that will be needed to ensure the application of best available scientific information to all aspects of decision-making on multiple time scales (*i.e.*, multi-year, annual planning/forecasting, and even real-time operations considered within the bounds of annual planning[3]).

5. Communicate and provide transparency to the broader community of state, federal and local agencies; universities; scientific investigators; public water agencies and nongovernment stakeholders on how existing operations and other management actions will be assessed, how new scientific investigations will be prioritized (and funded) and how the results of those investigations will be integrated into adaptive management decisions.

6. Describe how the proposed adaptive management program can build on and support existing efforts of the Interagency Ecological Program (IEP), Collaborative Science and Adaptive Management Program (CSAMP), Delta Stewardship Council/Delta Science Program (DSP), and individual agency science initiatives.

7. Describe how management relevant science in the areas of a) integrated monitoring and research, b) studies and models, c) information synthesis, and d) data access will be augmented.

A preliminary set of objectives associated with the application of this Adaptive Management Program are included in *Appendix 1—Initial Objectives Derived From Current Biops/CESA* and CWF. Final objectives for this adaptive management program will be developed using collaborative processes and

[2] The co-equal goals are to provide a more reliable water supply for California and to protect, restore and enhance the Delta ecosystem.
[3] As described in Section 5.2, below, the adaptive management and decision making processes described in this Program are not applicable to real-time operations. However real-time operations are mentioned in this Program to provide context.

limited to those actions necessary to achieve applicable regulatory standards. The IICG will consider those final objectives when implementing this AMP.

Key Uncertainties

With regard to CVP and SWP water operations under the 2008 USFWS Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the CVP and SWP, the 2009 NMFS Biological Opinion and Conference Opinion on the Long-term Operations of the CVP and SWP (current BiOps), and related authorizations under the California Endangered Species Act (CESA) for the SWP, there remain a number of key uncertainties associated with identifying biological response to management actions. These uncertainties have been raised in a number of different venues (e.g. by the Long-term operations biological opinions independent review panel (LOBO IRP), Interagency Ecological Program (IEP) Management, Analysis, and Synthesis Team (MAST) & Salmon and Sturgeon Assessment of Indicators by Lifestage (SAIL), and CSAMP Salmon Scoping Team (SST)) as well as during the development of a Biological Assessment and application for incidental take under Section 2081(b) of CESA for CWF.

Through IEP, the MAST and SAIL reports provide recommendations to fill critical data and information gaps, enhance the existing monitoring network and improve quantitative modeling capability to support transparent decision-making. Key recommendations from the MAST report to address critical data and information gaps include:

- Study the toxicity of delta contaminants on the health and viability of Delta Smelt,
- Refine entrainment and transport estimates of all life stages of Delta Smelt to quantify their effect on overall population viability,
- Develop estimates of predation loss to quantify its effect on Delta Smelt viability,
- Develop tools to better evaluate and monitor Delta Smelt food availability and composition, and
- Research the control and suppression of harmful algal blooms.

The SAIL report reviews multiple qualitative, statistical, and numerical approaches and summarizes how they may be applied to improve the scientific understanding of how water operations decisions affect salmonids and sturgeon (IEP SAIL 2016). The SAIL report further illustrates how the existing Delta monitoring network can be leveraged with the inclusion of updated technologies to improve data collection and analysis. The following list from the SAIL report identifies five system-wide recommendations to enhance the existing monitoring network and enable information to be incorporated into salmonid and/or sturgeon lifestage models:

- Incorporate genetic information to identify individual runs of Chinook Salmon,
- Develop juvenile abundance estimates for salmonids and sturgeon,
- Collect data associated with different life history metrics at multiple life stages for salmonids and sturgeon,
- Expand, enhance, and integrate fish survival and water quality monitoring, and
- Collect fish condition data on salmonids and sturgeon.

The CSAMP SST also prepared a report on the key findings of historical research and monitoring efforts and provided a gap analysis of existing and missing data that are critical to our understanding of salmon and steelhead survival in the Delta in the context of hydrodynamic conditions and water exports. Like the SAIL report, the SST report, *Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta* (CSAMP SST 2016), recommends building on the current and substantial body of scientific understanding. This CSAMP SST report also highlights key information gaps, which, if filled would likely improve our ability to more effectively manage operations and hydrodynamics to increase survival of salmonids emigrating through the Delta. These information gaps include our understanding of the role of factors influencing salmonid survival through the Delta, the role of Delta conditions in salmonid fitness at the individual and population level, and opportunities to improve salmonid population abundance and viability through changes to Delta conditions and water project operations. The SST's report recommendations are broken into four categories of action:

- Continue existing survival studies, monitoring, and analysis of data
- Implement short-term actions to improve salvage facility operations
- Develop a long-term monitoring, research and adaptive management plan
- Implement the long-term monitoring, research and adaptive management plan

Collectively, these efforts and others have sought to assess the current state of Delta science and highlight opportunities to assess the value of taking or modifying certain actions, reduce environmental uncertainty, and inform future management actions and decisions. Key uncertainties exist in five focus areas (described further in appendices 2-6).

- Listed Fish Performance (*Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species*): This focus area includes monitoring and research to reduce uncertainties related to the movement, behavior and survival of fish listed as threatened or endangered under the Federal ESA or the CESA. This focus area also examines a suite of hydrodynamic effects in the North and South Delta; as well as the effects of fish screens, nonphysical barriers, and predator removals on listed species.

- Yolo Bypass (*Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass*): This focus area includes monitoring and research to reduce uncertainties related to the effects of fish passage barriers and managed inundation of the Yolo Bypass.

- Tidal Wetland Restoration (*Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration*): This focus area includes effectiveness monitoring and research to examine the ecological function of planned tidal wetland restoration. Many of these monitoring actions and research studies while performed at the scale of an individual restoration site will be conducted using consistent sampling techniques developed by the Tidal Wetland Monitoring Project Work Team of IEP and will have a regional focus.

- Riparian, Channel Margin & Floodplain Restoration (*Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration*): This focus area includes effectiveness monitoring and research studies examining floodplain, channel margin, and riparian restoration projects intended to benefit listed terrestrial and fish species.

- Delta outflow (*Appendix 6—Delta Outflow*): This focus area will continue and expand existing research into the ecological mechanisms that are supported by Delta outflow in order to robustly support any future modifications to Delta outflow requirements.

4 Conceptual Framework: Decision Making, Process, Governance

Given the uncertainties involved in assessing the effects of water operations and restoration activities on listed species, it is the decision of the Five Agencies that the only practicable way forward is with a firm commitment and explicit plans to meet the co-equal Delta goals and to take management actions that comply with applicable federal and state legal requirements intended to protect species listed as threatened or endangered while giving due consideration to new scientific and operational information. The proposed approach outlined in this Adaptive Management Program incorporates aspects of adaptive management that are both "active" (where managers and operations are pushed in a process of experimentation to explore the benefits, limits and response to management actions) and "passive" (which lacks explicit experimentation and is instead more an assessment of existing and future conditions and circumstances). Ultimately the approach used in this Adaptive Management Program will proceed with an iterative development of management alternatives whereby managers will use a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a management decision.

4.1 Decision-Making

This Adaptive Management Program outlines a collaborative process that will be essential to the success of the overall adaptive management program for the ongoing operation of the CVP and SWP, including future implementation and operation of the CWF. Under the adaptive management program, new information gained during implementation will inform operational decisions within the ranges of criteria and effects analyzed in applicable BiOps and CESA authorizations. The Five Agencies commit to working through the collaborative process outlined in the Agreement for Implementation of an Adaptive Management Program for Project Operations (MOA) to reach consensus on operational decisions and other management actions to the extent possible and to elevate any disputes over decisions to appropriate levels of officials for each agency. Each agency retains discretion to make decisions as appropriate within its authority after considering the available information and taking into account the input of relevant groups described in this document and the MOA. If any operational decisions are not within the ranges of criteria and effects analyzed in applicable BiOps or CESA authorizations, Reclamation will reinitiate formal consultation under ESA section 7 and implementing regulations (50 CFR 402.16), if necessary, and/or DWR will commence a permit amendment process under California law, if necessary.

Additional efforts or groups will be needed to fulfill all aspects of this Adaptive Management Program and support the decision-making process by the IICG, especially those resulting from implementation of CWF. Descriptions of certain groups and how they will be involved in the various phases of this Program may be found in *Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*.

4.1.1 Interagency Implementation and Coordination Group (IICG)

The IICG, co-led by Reclamation and DWR, will include a representative of Reclamation, USFWS, and NMFS, as well as one designated representative[4] each from DWR, CDFW, a participating SWP contractor, and a participating CVP contractor. These representatives on the IICG will likely be senior managers/biologists. Additional staff from any of the IICG members and/or consultants may also participate to provide technical assistance or other support.

The IICG shall have primary responsibility for support, coordination and implementation of the AMP and shall:

[4] "Designated Representative," as described in the MOA, means in the case of DWR and CDFW the official representative designated by the Governor to act on his behalf, and in the case of the SWP/CVP contractors the official representative designated by an elected board of directors to act on their behalf.

1. Be responsible for supporting those priority science needs identified by Collaborative Science Workgroups that the IICG determines are necessary to carry out the Adaptive Management Program.

2. Identify priority science needs not addressed by Collaborative Science Workgroups, and route requests for those science needs with, if necessary, appropriate funding to the appropriate entity with the capacity to complete them, or at its discretion, the IICG may initiate work to address priority science needs using its own staff, staff from its members, or any appropriate entity.

3. Establish mechanisms for developing and agreeing to Adaptive Management Changes, such as through preparation of an annual adaptive management work plan or development of specific proposals that identify the compliance implications of the proposed change.

4. Promote and fund scientific activities/monitoring that the IICG determines are necessary to carry out the Adaptive Management Program.

5. Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency.

6. Refer management related actions or proposals, as appropriate, to the Delta Science Program for review by an independent science panel for example, the Long-term operations biological opinions independent review panel (LOBO IRP).

7. Assure transparency consistent with the requirements of the Delta Plan.

8. Review funding commitments and any implementation issues relative to priorities and recommendations from the Delta Science Program, CAMT, or related adaptive management fora.

9. Identify and secure needed infrastructure and resources to support scientific activities/monitoring.

10. Review and approve the Annual Monitoring and Research Plan and progress reports.

11. Maintain an Operational Opportunities subcommittee made up of one technical representative from each of its members. The subcommittee shall consider all Operational Opportunities requests within 24 hours and simultaneously issue a recommendation to the IICG and the agency with authority to implement the Operational Opportunities.

In implementing this AMP, the Five Agencies will also bring forward adaptive management proposals outside the Delta, that may impact Delta operations, to the IICG for its recommendation and input.

4.2 Relationship of Adaptive Management to Real-Time Operations

Under the current BiOps, a “real-time operations” mechanism allows for adjustment of water operations, within established parameters, to respond in real time to changing conditions for the dual purposes of increasing fish protection when it is warranted and for increasing water exports within established bounds for fish protection (Figure 5-1). The adaptive management and decision-making processes described here do not apply to these real-time operations; where individual real-time operations decisions must be made on a daily, weekly or monthly time scale; because new research efforts cannot be developed and deployed in that same window of time. However, changes to operational criteria in the current BiOps and associated CESA and CWF authorizations may be changed over time through the adaptive management process based on new information as part of the annual review.

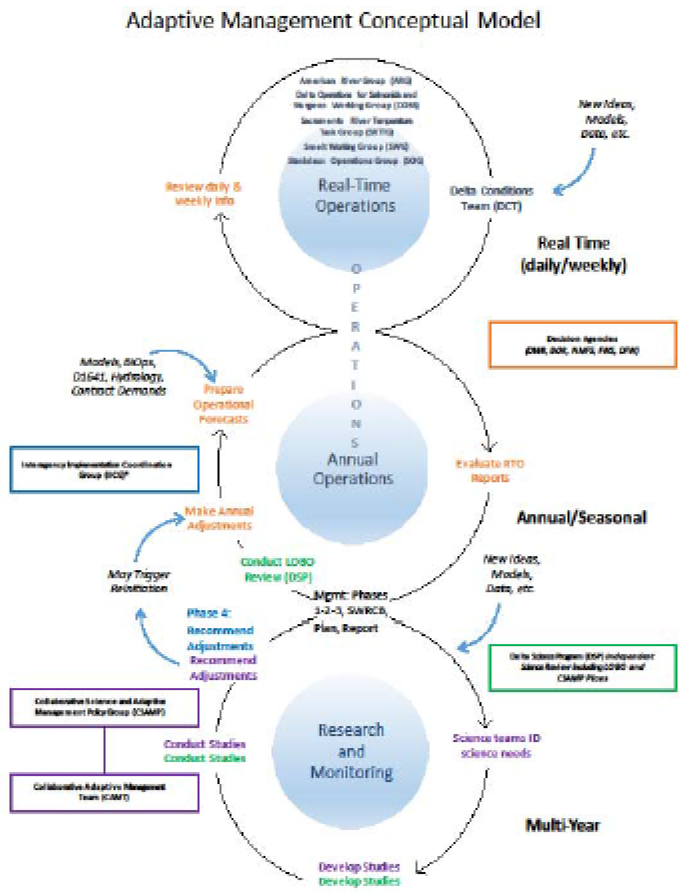

Figure 5-1. Describing the multiple time-scales of adaptive management for the California Water Fix and current USFWS and NMFS Biological Opinions on the coordinated operations of the Central Valley and State Water Projects

4.3 Adaptive Management Response to Climate Change

Gradual long-term changes in sea level, watershed hydrology, precipitation, wind patterns, and air and water temperature are projected to occur due to climate change. These changes contribute to uncertainty related to the factors affecting native species, water project operations and ecological responses. Because of this, climate change projections will be incorporated into management and science plans. Implementation of this Program requires monitoring of climate change effects and projections, taking management actions, and adjusting water operations, research and monitoring in response as needed. Such adaptive management responses may include, for instance, identifying alternative locations for implementing restoration or habitat protection actions to increase habitat availability and suitability, increase productivity of the food web, better manage predators and invasive species, or to allow species movement across environmental gradients. Adjustments to water operations associated with inflow, outflow and exports is another example of potential adaptive responses.

Incorporating projected climate trends and year to year variability into the operational decision making process will initially be based on downscaled results of near-term (5 years) and long-term (25 years) Coupled Model Intercomparison Project, Phase 3 (CMIP3) and Phase 5 (CMIP5) climate and hydrology projections.[5] The Implementing Entities will evaluate the effects of climate change on both species and the operational environment, as well as the ability to achieve the co-equal goals, and consider whether there is a need to identify and implement adaptive management changes in light of both the laws and regulations in effect at the time and those effects of climate change. The effectiveness of any remedial measures to reduce and/or control adverse effects of climate change will be monitored over time and, based on their efficacy, such measures may be adjusted through this Program.

4.4 Adaptive Management Program

This Adaptive Management Program is modeled after the adaptive management approach used in the Comprehensive Everglades Restoration Plan (CERP 2006) which describes the interrelationship between the identification of uncertainties, development of management questions, objectives, management alternatives, monitoring and research design, synthesis and decision making. Again, under this Program, adaptive management changes to operations and other implementation actions would occur on an annual or longer (multi-year) basis, and are not intended to apply to real-time operations. This conceptual framework also includes specific elements described in the Delta Science Plan (DSP 2013) and recommendations from the Delta Independent Science Board (2016).

Four process diagrams, referred to here as “phases,” illustrate the major components of the proposed adaptive management process: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt. The four diagrams (Figures 5-2 – 5-5) describe each phase of the process as well as how each phase relates to one another.

Certain analytical tools are useful during implementation of the phases of adaptive management, and are described below. Section 5.4.5 describes structured decision making and its utility in formulating research, monitoring and adaptive management actions at multiple scales, from the individual study up to overall program management. Section 5.4.6 describes the use of conceptual models in adaptive management and provides examples of how such models are already in use to address ecological questions in the Delta. Further evolution of these models will be an integral part of the adaptive management process.

[5] http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/

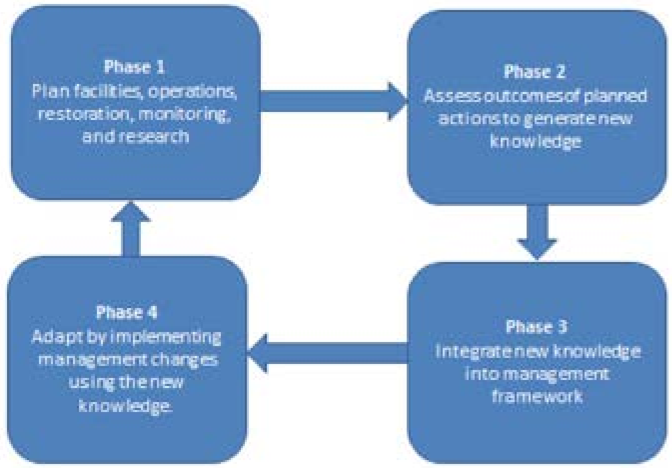

Figure 5-X. The four phases of the adaptive management process.

Phase 1: Plan

During **Phase 1**, initial operation and research priorities are set through the respective Operational criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans. The operations criteria set water supply expectations while the science plans address how uncertainties associated with the operational and stressors affecting covered species will be addressed. The Science Plan will be developed by the IICG. Changes to the Operations and Science Plans beyond year-1 could incorporate any management adjustments made in **Phase 4: Adapt**, that are based on the written proposals for management adjustment or the results of scientific study developed by the interagency and agency-stakeholder scoping process in **Phase 3: Integrate**. A diagram of the decision-making process for effecting an adaptive management change under the Program is described in Appendix 7.

One such adaptive management question in need of assessment is how effective are predator refugia areas around the NDD facilities? In this example, initial designs will be based on results and final recommendations from Preconstruction Study 3: Refugia Lab Study (Fish Facility Working Team, 2013). Change may be made based on modeling and assessment of original design prior to construction. Performance post-construction will require monitoring, and further assessment and will likely be an element of the CWF BiOp.

4.4.1 Phase 1: Plan

Define the bounds of the management problem and set management and research objectives.

As recommended in the 2016 Independent Science Board (ISB) report, an iterative learning cycle will be applied throughout the implementation of CVP and SWP water operations, associated habitat restoration actions, and other management actions. This includes activities related to design and management of new water diversion facilities as part of CWF, CVP and SWP operating criteria, any associated mitigation, and the design and implementation of monitoring and research programs to address efficacy of other major management strategies and topics of scientific disagreement. Successfully bounding ecological uncertainty with regard to management outcomes is critical and must include clearly defined problem statements or questions (and the objectives that will be used to inform decision points) and the means to address those questions (i.e., a sufficiently funded and staffed science and research program).

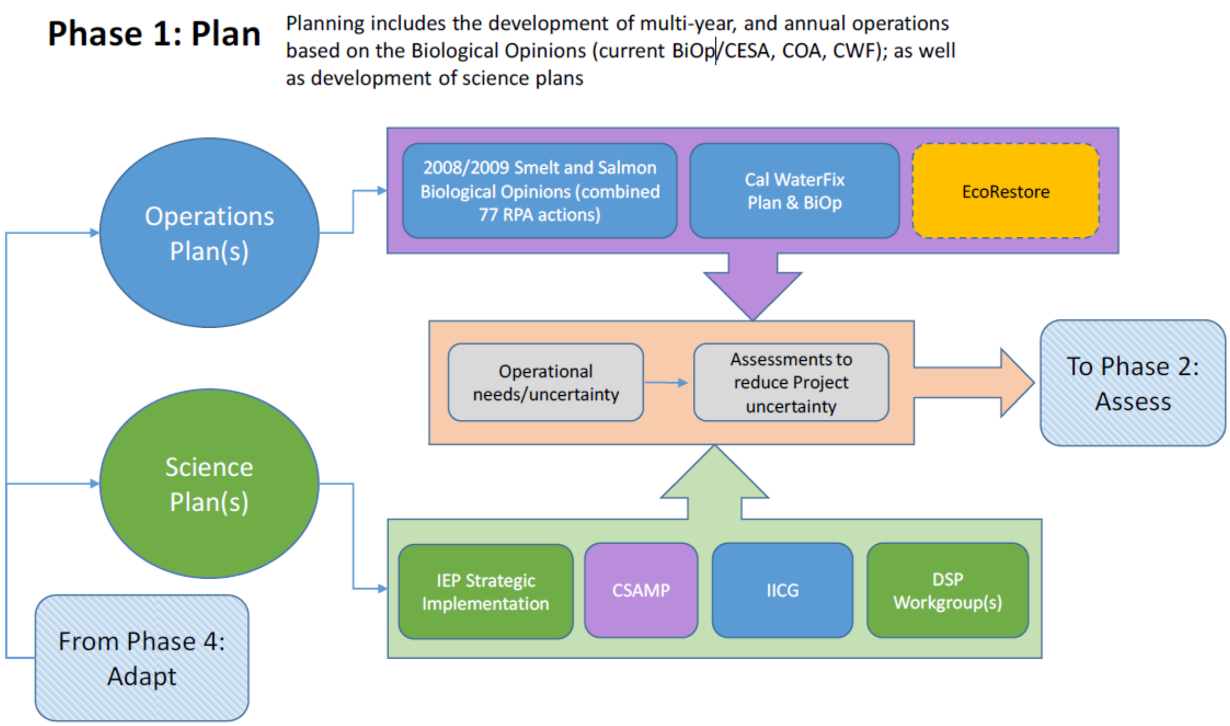

Figure 5-2 Phase 1, Plan: Facilities and operations, restoration/ecosystem management, and monitoring and research.

4.4.1.1 Design and Operations Planning in the Context of Endangered Species Act and CESA

4.4.1.1.1 Multi-year Planning:

The basic flow of the planning phase is shown in Figure 5-2. The CVP and SWP operate under the U.S. Army Corps of Engineers (USACE) flood control rules, State of California water quality standards, current BiOps and CESA authorizations, Memorandums of Understanding between Reclamation, DWR, and DFW, as well as other statutory and regulatory requirements. The current BiOps include some Reasonable and Prudent Alternative (RPA) elements intended to be implemented in an adaptive management framework. In addition, the operations planning completed to date for CWF involves substantial reliance on adaptive management.

The IICG anticipate continuing to explore many of the questions and uncertainties related to the effects for the current Projects' operations on listed species and the efficacy of actions such as Old and Middle Rivers (OMR) flow restrictions, fall outflow and San Joaquin Inflow to Export requirements. Additionally, there will be new questions about the effects of the north Delta diversions (NDD) and their operation on out-migrating Sacramento River salmonids and green sturgeon, and possibly on Delta Smelt. Appendices 2 through 6 list key uncertainties identified in 2012 and 2013 within the development of materials for the Bay Delta Conservation Plan (BDCP), components of which are now part of the CWF. This AMP is also intended to address future research needs and is designed to answer these and other ecological and engineering questions through the process envisioned in Phase 2 (as shown in Figure 5-3).

4.4.1.1.2 Setting Objectives and Triggers:

While the current BiOps generally contain rationales and a sound conceptual foundation for individual actions, many actions do not explicitly contain measureable objectives needed for the design and planning of an adaptive management program. Species specific objectives included in *Appendix 1—Initial Objectives Derived From Current BiOps/CESA and CWF* are adopted into the framework document as an initial set of objectives, against which performance of operations and other management actions can be assessed. These initial objectives are subject to further refinement as the process continues.

Given that adaptive management is intended to accommodate change both in the management of a resource and the corresponding response, objective triggers are an essential component of this Adaptive Management Program to signal when an alternative management action may be warranted. Triggers are defined, pre-set and measurable conditions that prompt evaluation of information collected to that point in the context of current conditions and considering whether potential alternative approaches are warranted. For the purposes of this Adaptive Management Program, triggers will be focused on longer term outcomes. Current BiOps specify (and the CWF biological opinion is expected to) specify, the amount or extent of incidental take that will trigger reinitiation of consultation as described within their respective incidental take statements. Reinitiation of ESA consultation is also required under 50 CFR 402.16 if the action (Central Valley water operation under the current BiOps and as stated in the CWF biological opinion) is subsequently modified in a manner that causes an effect to the listed species or critical habitat that had not been considered; if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; or if a new species is listed or critical habitat designated that may be affected by the identified action. CESA's regulations include amendment conditions and it is anticipated that the CWF CESA permit will include additional criteria that may trigger permit amendment.

Phase 2: Assess

Through **Phase 2: Assess**, identified operational needs and uncertainties are translated in a collaborative setting into research studies designed to reduce these uncertainties. Agency and stakeholder groups conducting research and modeling to answer adaptive management questions will vary depending on the logistics involved (e.g., major field studies will probably require the IEP). Annual operational decisions will be made using a few alternative scenarios to explore potential benefits and consequences and their relative uncertainty. Annual operating plans should identify potential opportunities to vary operations within the year in order to better meet the co-equal goals in the Delta while meeting regulatory requirements. Products pertinent to annual operations and assessments to reduce operational uncertainty will be peer-reviewed by independent review panels convened by the DSP. The review of these products will provide the basis for future management proposals developed during the scoping process of **Phase 3: Integrate**.

Continuing with the example of the NDD predator refugia; as part of the CWF RPM, the ability of the refugia to help salmon and other fishes successfully pass fish screens will be monitored and assessed. If the assessment includes a major field study component, the IEP will have a role in designing and implementing said study to assess

4.4.2 Phase 2: Assess

Represent existing scientific understanding through current operational decisions while continuing to identify uncertainty and alternate hypotheses as a result of ongoing monitoring and research.

The 2015 ISB report, *Fishes and Flows in the Sacramento-San Joaquin Delta* (ISB 2015) recommended implementation of integrative scientific approaches grounded on management questions and focused on processes, drivers and predictions. The approach outlined in Figure 53 reflects the complexities of the ecological responses being examined by individual research projects and tracked by system-wide monitoring.

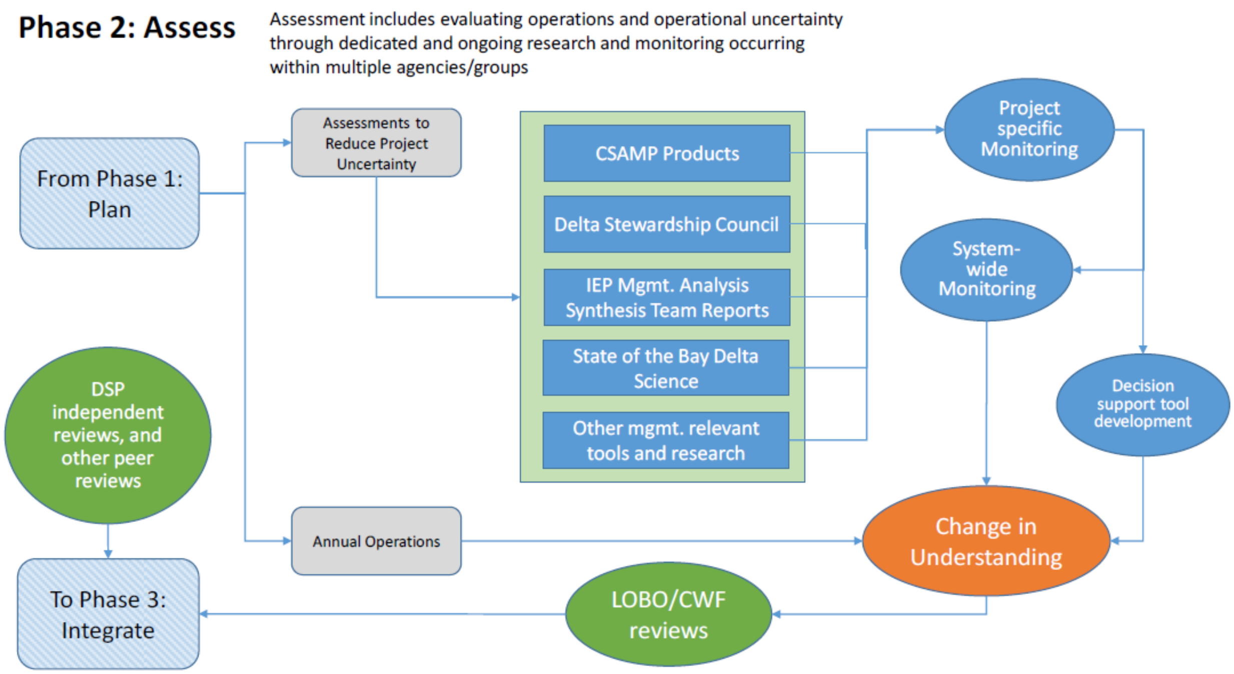

Figure 5-3. Phase 2, Assess: Collaborative Science, synthesis and performance assessment to inform management direction and change as uncertainty is addressed

An essential element of this Adaptive Management Program, or any adaptive management process, is the development and execution of a scientifically rigorous research, monitoring and assessment program to provide a robust information base, as well as the synthesis of the resulting information to analyze and understand responses of the ecosystem to a particular management regime. This requires the implementation of an integrated core monitoring network for water operations that also incorporates many project specific monitoring actions (See Section 6: *Tools and Scientific Support*). The scientific and technical information generated from this comprehensive program will be organized to provide a process to assess progress against the triggers and objectives.

4.4.2.1 Annual Review

In order to ensure the realization of objectives of the current BiOps and CESA authorizations and those for the CWF and to support water supply reliability, periodic reviews of annual operations will be conducted as agreed on by the IICG. These reviews will be scheduled to occur in conjunction with the bi-annual Long-term Operations Biological Opinions Science Review (LOBO) review and will include an evaluation of operations using new and/or updated modeling, integrating the latest scientific, technical, and planning information (*i.e.*, Phase 3: Integration). This integrative adaptive management approach supports iterative improvement of system performance as learning and knowledge about the Delta and its tributaries improves. The Salmon Gap Analysis, Salmon Science Plan, Delta Smelt entrainment studies, Fall X2 studies, and Longfin Smelt flow abundance relationship studies, are all examples of studies from which new information regarding facility design, ecosystem restoration, other management actions, and annual operations may be evaluated. Based on the performance of models incorporating new information from those studies, it will be determined whether annual operations are meeting the requirements of the ESA and CESA. When appropriate, results of these evaluations will be used to inform proposed management alternatives within Phase 3 (Integrate) and the consideration of those alternatives in Phase 4 (Adapt).

Additionally, the DSP will at times be asked to provide technical review and assessments regarding ongoing and future research priorities, science plans, study designs, water operations, other management actions, or habitat restoration actions. Together these independent reviews, along with the research products from the many Delta science-related groups, will provide greater understanding to inform new management and research options as detailed in Phase 3 (Integrate).

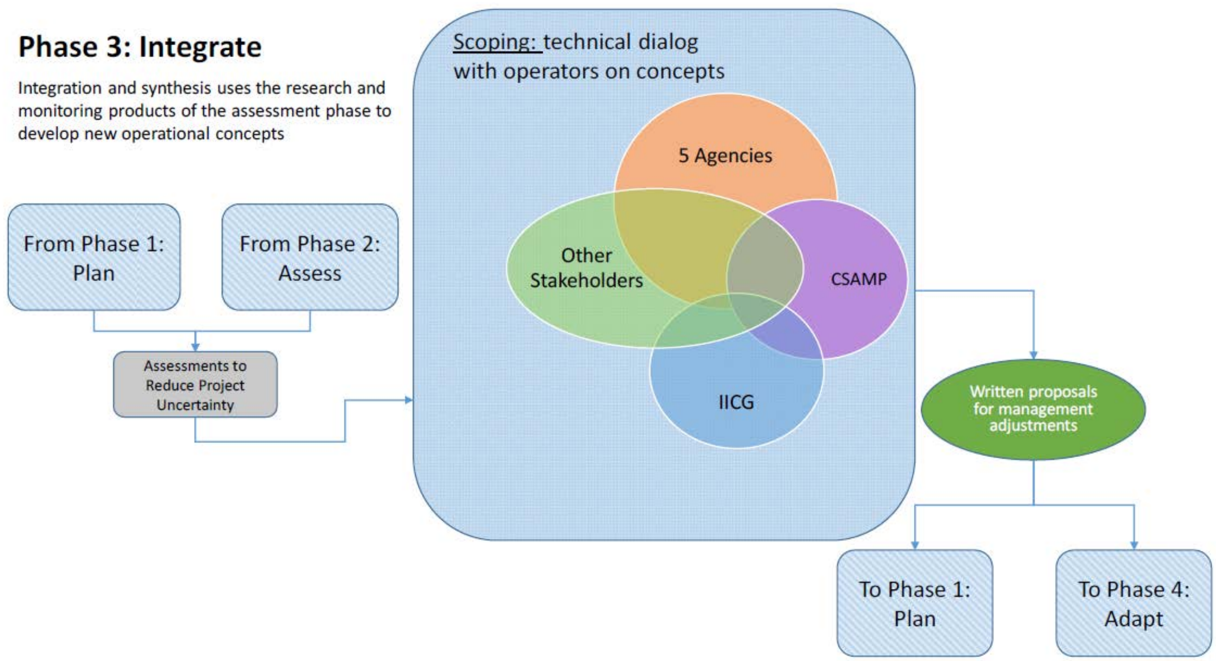

Figure 5-4. Phase 3, Integrate: Management and Science Integration

Phase 3: Integrate

The development of new executive level adaptive management questions to address operational needs and uncertainty occurs via several pathways and at multiple levels; these are generally described as scoping in **Phase 3: Integrate**. Through the structured decision making process, designed to test management strategies and data collection, interagency and agency-stakeholder discussions inform management and research alternatives based on the results of scientific assessments from **Phase 2: Assess**.

The results of both science products and their independent reviews are considered at multiple levels and at multiple venues including: between the Five Agencies, within CSAMP, and with the IICG. Determinations regarding whether the results of studies (e.g. monitoring post-construction performance of refugia areas) constitute a significant enough change in understanding to trigger changes to the management of the refugia or their monitoring and research will be made as part of a formal response to independent review and through the structured dialog of the scoping process. In this example, if the monitoring and research indicate that a management adjustment could improve the performance of the predator refugia, proposals to make said adjustment will be developed through the same scoping process.

4.4.3 Phase 3: Integrate

Reflect on outcomes and consider new approaches to management and research based on new understanding.

During the integration phase, which occurs on a continuing basis, the Implementing Entities will develop recommendations for adaptive changes to management actions and, in some cases, may also recommend changes to monitoring and research approaches (Figure 5-4). In the development of these recommendations, the Implementing Entities will engage stakeholders, academic scientists and other relevant groups through a scoping process to collaborate on the development of management actions and research projects stemming from Phase 2. The scoping process will use a structured decision making approach to address key uncertainties and otherwise maximize the transparency of decisions. Key structured decision making concepts include making decisions based on clearly articulated objectives, addressing uncertainties, and responding transparently to legal mandates and the public in decision making. Under this Program, the CSAMP, in coordination with the IICG, is the venue in which to collaboratively define management relevant problems, establish objectives, define potential available alternatives, and clearly define the remaining uncertainty and research needs. The resulting proposals developed by these groups must be feasible, science-based and address identified problems and uncertainties. New knowledge revealing a potential opportunity to improve conditions or operations in the Delta and/or its tributaries could then lead to a change to CVP/SWP operations, other management actions, or another such adaptive management change in Phase 4 (Adapt).

Within Phase 3, the objective of scoping is to first determine whether information developed in Phase 2's assessment is significant enough to trigger consideration of changes to a management action or a monitoring and/or research program, and, if so, to determine the resources needed to implement the change. Scoping via structured decision-making will involve operators and scientists from the Implementing Entities with input from participating science and stakeholder groups. Through scoping dialogue, experts, stakeholders and agency managers seek to develop a common interpretation and understanding of the monitoring and research products. If, through structured decision-making, it is determined that a change in a management action is appropriate, the group will then develop options or approaches to modify the management action to more effectively achieve its desired objectives.

The primary products envisioned for Phase 3 are written proposals for adjustment of management actions that will describe the anticipated effects of the recommended management change on listed species and water supply reliability and describe the actions necessary to implement said change. Following this Program, these proposals will include input from stakeholders gained during the scoping process. Further, because the issues that trigger written proposals for management adjustments may have far-reaching effects, participation by Agency managers is a necessity during Phase 3, Peer review of proposed management actions and their scientific basis will be essential prior to making any decisions related to recommendations for a major management adjustment.

A critical element of Phase 3 will be to communicate the results of implemented actions, research, and monitoring to policy makers, managers, stakeholders, the scientific community, and the public, so that they can understand and evaluate progress toward addressing uncertainties and respond as necessary. With input from CSAMP and the IEP, the IICG will prepare communications from time to time, as needed, and develop materials regarding adaptive management and monitoring matters for communication with a broader range of interests as part of the scoping process. The IICG will ensure that study products are unbiased and explicitly and evenhandedly deal with uncertainty and disagreement in the analysis and interpretation, and that opposing points of view are clearly and evenhandedly presented in materials presented to stakeholders, external review bodies, and the public. To facilitate this understanding, the IICG, with the assistance of the CSAMP process, and IEP will develop reports that serve the following purposes.

- Provide the necessary data and information to demonstrate that the current BiOps and CESA authorizations and those for the CWF being properly implemented.
- Identify the effect of current operations and those with CWF on covered species and the effectiveness of the conservation measures and mitigation.
- Disclose planned annual and long-term science priorities and programs and the synthesis of the information developed through the science program and their relevance to project operations and the requirements of the BiOps and CESA authorizations.
- Document actions taken under the adaptive management program (e.g., process, decisions, changes, results, or corrective actions).
- Disclose issues and challenges concerning implementation under current BiOps and CESA authorizations and those for the CWF and identify potential modifications or amendments that would increase the likelihood of success.

To demonstrate compliance with the co-equal goals in the Delta and the current BiOps, CESA authorizations and those for the CWF, an Annual Progress Report will be prepared by the IICG Manager and approved by the IICG. The highlights of the Annual Progress Report will be presented at a public workshop, presentations to the SWRCB, the DSC, DISB and DPIIC and the report will be made available to the public.

Phase 4: Adapt

The decision and final authority regarding whether to adopt or reject a management adjustment lies with the agency or agencies with decision-making authority (most often, the Bureau of Reclamation or Department of Water Resources in their respective capacities as operators of the CVP and SWP), and occurs during **Phase 4: Adapt**. Management decisions consider the proposals developed during **Phase 3: Integrate** and are based on the assessment and review of **Phase 2: Assess**. Depending on whether or not the proposed modification is considered within the adaptive limits of operations, changes to the operations criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans may require reinitiation of consultation or permit amendment.

Using our refugia example, the IICG will collectively consider proposals regarding any adjustment to management or monitoring and research related to predator refugia, to determine if the adjustment is within the flexibility of the existing RPA or new Reasonable and Prudent Measure (RPM). If a decision is made by the IICG that changes the management or monitoring and research related to predator refugia that meets the criteria for reinitiation of consultation under 50 CFR 402.16, the Action Agency would request reinitiation of consultation with USFWS and/or NMFS and seek a permit amendment.

4.4.4 Phase 4: Adapt

Revise models and/or management actions based on information gained.

The fourth phase of this Adaptive Management Program encompasses the decision to implement a management change through adjustments in water operations, restoration tactics, or monitoring and research support (Figure 5-5). The Implementing Entities will use the written proposals and recommendations from Phase 3 to make recommendations and management decisions based on their authorities. At the conclusion of this process, the Directors of the Five Agencies will decide whether or not to take the action proposed. The final decision will be consistent with the requirements of al relelvant laws and regulations, including ESA, CESA, NEPA, the California Environmental Quality Act, Clean Water Act, Delta Plan, and the Bay Delta Water Quality Control Plan.

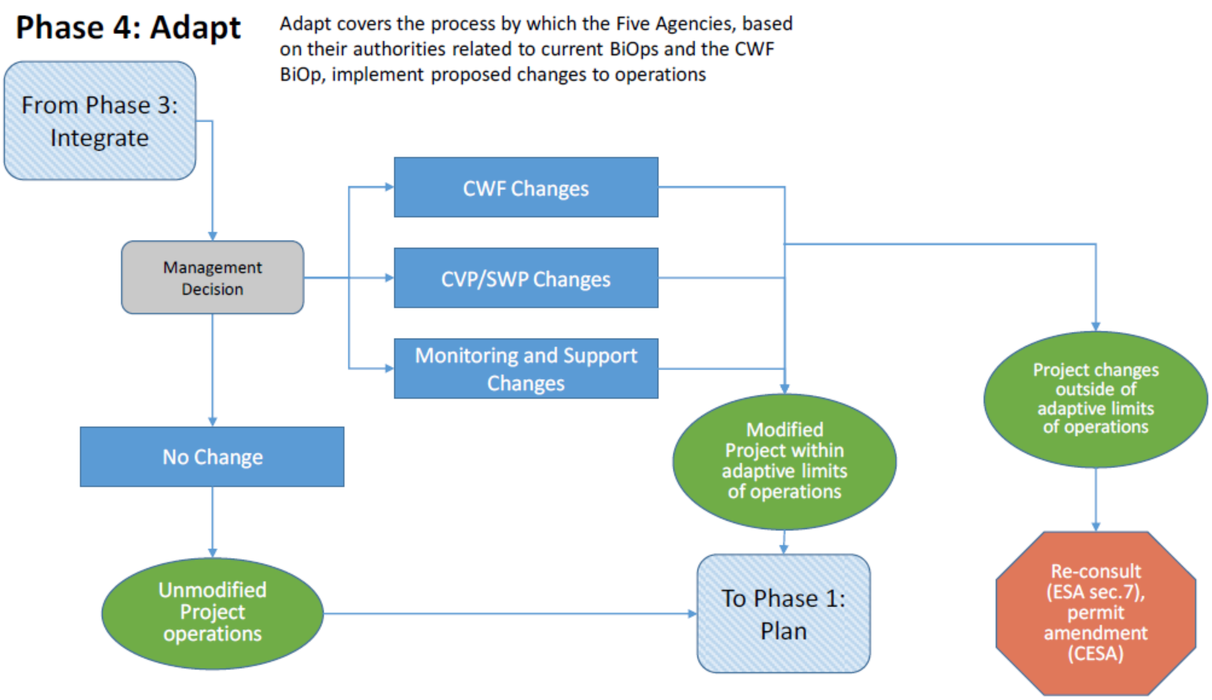

Figure 5-5. Phase 4, Adapt, Process for making an adaptive management change

4.4.5 Structured Decision Making

Structured decision making (SDM) is a general term used for a suite of analysis tools that can help achieve useful, robust decisions. The ESA Section 7 process itself is an example of an SDM process, with specified steps to assess the risk to species associated with a proposed adaptive management change. Every decision consists of several primary elements: management objectives, decision options, and predictions of decision outcomes. By analyzing each component separately and thoughtfully within a comprehensive decision framework, it is possible to improve the quality of decision making. Existing Section 7 SDM processes and the table below are tools that may be used to implement all Phases of adaptive management. Ultimately, the uncertainties identified above and other questions that arise during the implementation of CVP and SWP operations, will be addressed in this Adaptive Management Program through the steps outlined in Table 1 below.

Table 1. Structured Decision Making

Step	**Information to be Developed**	**Responsible Party(ies)**
1. Define the problem	What specific decision has to be made? What is the spatial and temporal scope of the decision?	Implementing Entities , other stakeholders
2. Define issues and objectives	What are the management objectives? Ideally, these are stated in quantitative terms that relate to metrics that can be measured. Setting objectives falls in the realm of policy, and should be informed by legal and regulatory mandates, as well as stakeholder viewpoints.	IICG
3. Develop alternatives	What are the different management actions from which we can choose? This element requires explicit articulation of the alternatives available to the decision makers. The range of permissible options is often constrained by legal or political considerations, but structured assessment may lead to creative new alternatives.	Implementing Entities , other stakeholders
a. Understand the uncertainty associated with each alternative	Because we rarely know precisely how management actions will affect natural systems, decisions are frequently made in the face of uncertainty. Uncertainty makes choosing among alternatives far more difficult. A good decision-making process will confront uncertainty explicitly, and evaluate the likelihood of different outcomes and their possible consequences.	Implementing Entities

	b. Identify risk tolerance	Identifying the uncertainty that impedes decision-making, then analyzing the risk that uncertainty presents to management is an important step in making a sound decision. Understanding the level of risk a decision-maker is willing to accept, or the risk response determined by law or policy, will make the decision-making process more objectives-driven, transparent, and defensible.	Implementing Entities
	c. Identify linked decisions	Many important decisions are linked over time. The key to effectively addressing issues associated with linked decisions is to isolate and resolve the near-term issues while sequencing the collection of information needed for future decisions.	Implementing Entities
4.	Quantify the consequences of alternative management actions	What are the consequences of different management actions? To what degree would each alternative lead to successfully reaching a given objective? Depending on the information available or the quantification desired for a structured decision process, consequences may be modeled with highly scientific computer applications, or with personal judgment elicited carefully and transparently. Ideally, models are quantitative, but they need not be; what is most important is that they link actions to consequences.	Implementing Entities
5.	Understand the tradeoffs	If there are multiple objectives, how do they trade off with each other? Numerous tools are available to help determine the relative importance or weights among conflicting objectives; this information is used to compare alternatives across multiple attributes to find the 'best' solutions.	Implementing Entities, other stakeholders
6.	Decide, take action, and monitor	For those decisions that are iterated over time, actions taken early on may provide a learning opportunity that improves management later. Decisions should be well-documented outcomes of steps 1-5	Agency or agencies with final decision-making authority

	above.	

4.4.6 Conceptual Models

In the history of Delta ecosystem research, the term "conceptual model" has generally been used to refer to a process-based diagrammatic conceptual model that identifies sensitive resources and physical or biological processes that determine their state. An early example was the suite of models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), ca. 2008. An example dealing with factors affecting fish habitat is shown in Figure 56.

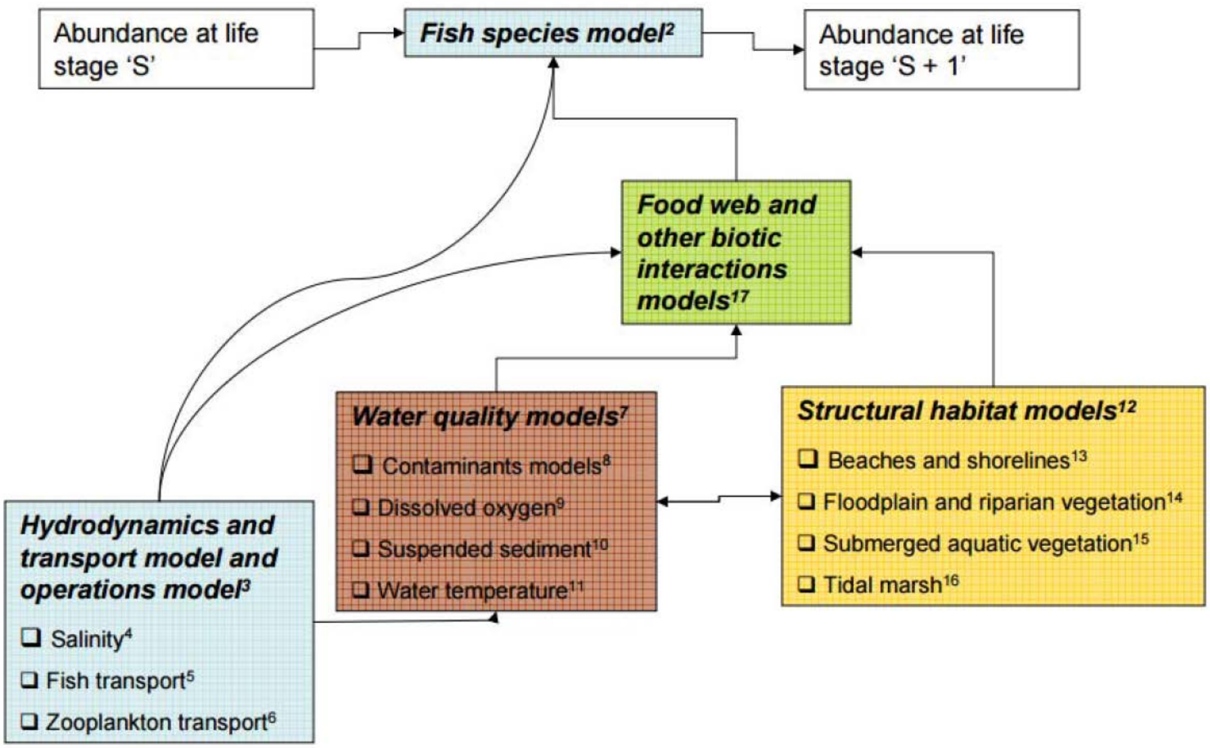

Figure 5-6. The Delta Aquatic Habitat Linkage Model of Nobriga (2008), an example DRERIP model.

Since this early example, there has been considerable development in the number and complexity of conceptual models being used to study Delta ecosystems. The 2015 annual report of the Collaborative Adaptive Management Team (CAMT 2015), for instance, refers to the use of conceptual models for the following:

- A life cycle model for winter-run salmonids in the south Delta
- A process model for Delta Smelt entrainment risk with reference to Old and Middle River flows
- An approach to aggregating study a suite of hydrodynamic, water quality, and particle tracking models, referred to collectively as an individual-based model (IBM), to identify adult Delta Smelt behaviors that best explain movement towards SWP and CVP, and entrainment.
- A re-evaluation of the re-examine life cycle model results of Maunder and Deriso (2011) using updated data sets and revised assumptions.

- Critically review the conceptual models that underlie adult Delta Smelt salvage and determine through multi-regression models the best suite of variables that explain historical salvage patterns.

- Use an existing life cycle model to understand the effects of entrainment on the Delta Smelt population.

- Perform a gap analysis evaluating the analytical tools currently in place to evaluate water project effects on salmonid survival.

These and similar efforts illustrate the utility of conceptual modeling tools to formalize understanding of how water operations affect fish, to assess the accuracy of these concepts in the context of information acquired through monitoring, research, and numerical modeling tools, and to formulate proposals to further test and improve the conceptual models. Foreseeable uses of conceptual models to assess California WaterFix include hypothesis development and testing regarding many aspects of the proposed action. Examples include the following.

- Fish movement into and through the redesigned Clifton Court Forebay, and means of minimizing incidental take associated with this.

- Entrainment, impingement, and predation in the intakes reach of the Sacramento River.

- Entrainment at the south Delta diversions and how it changes under dual operations.

- Effects of channel margin habitat restoration on salmonid predation, rearing, and passage through the affected channels.

- The effectiveness of real-time operations as a take minimization measure.

- Overall role of water operations with respect to fish population viability.

5 Research and Scientific Support

The current understanding of research needs that support adaptive management, has been developed based on a variety of sources. In assembling information regarding future research needs, the Implementing Entities will rely as much as possible on peer-reviewed published literature. When such literature is not available, the Implementing Entities will utilize agency reports that are available to the public (e.g., the MAST and SAIL reports). In some cases, the Implementing Entities will also rely on information from reports or articles that have been submitted to scientific journals but that have not yet been accepted for publication. The below sections outline a commitment from the Implementing Entities to invest in more robust tools, monitoring and research efforts to support this Adaptive Management Program.

5.1 Delta Smelt Research and Understanding

Much of our current understanding of Delta Smelt is summarized in a synthesis report developed by the IEP MAST (IEP 2015). The MAST summary is structured around a conceptual model that includes a suite of hypotheses that outline the majority of the knowledge base for current Delta Smelt management efforts. The overall conceptual model is organized in a tiered structure and describes how Landscape, Drivers, and Habitat Attributes successively affect Delta Smelt survival, growth, health and reproduction. Moreover, more detailed models nested within the conceptual model describe how these factors are thought to affect individual Delta Smelt lifestages.

While the Delta Smelt MAST report reflects the significant progress of scientific understanding that has occurred over the past 20 years, the report also emphasized the need for additional monitoring, focused studies, and/or additional analysis and synthesis of existing data to better address a few unquantified, but often cited, sources of mortality. The biggest information gap may be the paucity of tools that attempt to quantitatively evaluate the impact of water operations on the Delta Smelt population in the context of other important ecosystem changes (e.g., habitat, prey and predators, contaminant loading, etc.). As noted in the Delta Smelt MAST report, filling these information gaps is critically important for improving management strategies for Delta Smelt and increasing their resiliency to foreseeable and unforeseeable future changes. Major areas where additional work is still needed include: 1) filling a few remaining critical data and information gaps; 2) improving modeling capability; and 3) applying numerical models in the adaptive management cycle. With respect to #1, the following list of remaining critical data and information gaps is organized around environmental drivers and habitat attributes identified in the MAST conceptual models.

Contaminants and Toxicity: There is a general awareness that exposure to contaminants can impair the health of Delta Smelt. A few studies have documented these adverse effects, but whether contaminants meaningfully impair the production and health of Delta Smelt (or their prey), or substantially limit their ability to compete with other fishes or avoid predators, is uncertain. Recommended studies include focused laboratory studies on metals, pesticides, pharmaceutical products, or mixtures of contaminants, as well as effects of nutrient loading on the food web, including phytoplankton and copepod growth.

Entrainment and Transport: Improved entrainment estimates will more accurately depict how entrainment affect key population attributes (e.g., population dynamics and viability). In order to avoid under- or over-estimating these effects, more precise estimates of entrainment losses of all life stages are needed.

Predation Risk: Predation is thought to be the largest source of mortality to Delta Smelt both historically and in the present. Important questions are how/if the rate at which predators remove Delta Smelt has changed, and how variations in various abiotic factors affect predator distribution and success. Key gaps include: 1) the distribution and diet of major predators – particularly Mississippi silversides (for larvae) and juvenile striped bass (for juveniles and adults) and 2) quantitative effects of environmental factors (turbidity, salinity, temperature, and hydrology) on the resulting distribution of predators and their predation rate on Delta Smelt.

Food: Poor feeding conditions can affect Delta smelt health and even increase the rate of predation on fishes; as such, food availability must be a critical aspect of Delta Smelt habitat that could be affected by several management actions. Critical data needs include:

1. tools that can be used to evaluate the impact of different invertebrate restoration strategies (e.g., tidal marsh, wastewater treatment, overbite clam control, suppressing competition from other fishes, etc.). The development of such tools would benefit from improved sampling of prey in under sampled regions (e.g., Cache Slough complex);

2. expansion of the four major surveys monitoring Delta Smelt (Spring Kodiak Trawl, 20 mm, Tow Net Survey, Fall Mid-Water Trawl) to more consistently sample prey;

3. studies of Delta Smelt growth (using otoliths) and feeding habits (using stomach contents) concurrent with zooplankton sampling; and

4. evaluation of the role of alternative prey, such as amphipods, in Delta Smelt diets.

Harmful Algal Blooms: High concentrations of harmful algal blooms (HABs) in the Delta may be having both direct (e.g. direct toxicity) and indirect effects (e.g. impacts to the Delta food web) to the Delta smelt population. Quantitative monitoring programs that collect data on HAB distribution and research on how to minimize adverse effects of these blooms, including through control and suppression, is needed.

5.2 Longfin Smelt Research and Understanding

Our current understanding of Longfin Smelt is summarized in the status review which supported the listing of the species as threatened under the California Endangered Species Act in 2009 (CDFW 2009). The survival of young Longfin Smelt may be influenced by mechanisms that stem from variation in Delta outflow, with peak survival for larvae that reared in the low-salinity zone (~2–4 psu; Hobbs et al. 2010). As a result, Longfin Smelt abundance is strongly affected by outflow; the effect of outflow on recruitment is believed to take place during the egg and larval stages, which occur during winter and spring (*Appendix 6—Delta Outflow*). However, the exact mechanisms driving the relationship between Longfin Smelt abundance and winter-spring outflow are unclear and is an active area of research.

Adult Longfin Smelt use a variety of Bay-Delta tributaries for spawning, including the Sacramento River, San Joaquin River, upper Suisun Marsh, the Napa River, and possibly a number of other smaller tributaries to San Pablo, Central and South Bays. The early juvenile life stages rear over a wide geographic area from the west Delta to San Pablo Bay and even into South Bay during wet years. There is uncertainty about the distribution of larval Longfin Smelt, because traditional surveys cover only a portion of the potential range. The only Bay Area tributary that is sampled is the Napa River. The fraction of the subadult Longfin Smelt population leaving and returning to the estuary is another key aspect of their biology that could use better quantification.

Longfin Smelt distribution in the north, east, and south Delta is influenced by water year type, with higher distributions occurring in these areas during dryer hydrologies. The life stages of Longfin Smelt affected by project operations are spawning adults, eggs, and larvae/small juveniles. Between June and October, the typical distribution of juvenile and adult Longfin Smelt is primarily in brackish water and coastal marine waters of San Pablo and San Francisco Bays downstream of the Delta and Suisun Bay. Longfin Smelt abundance within the Bay-Delta estuary has been highly variable, but generally declining since regular DFW surveys began. Recent Fall Mid-Water Trawl (FMWT) indices are very low compared to prior years.

Individual stressors affect Longfin Smelt at different times based on environmental conditions. Important threats and stressors to Longfin Smelt include reduced quality of rearing habitat; particularly, decreases in the availability of food, competition with and predation by nonnative species (e.g., competition with nonnative clams for food and predation on larvae), entrainment at water diversion facilities, and degrading water quality conditions (e.g., increasing temperatures and decreasing turbidity). Key scientific questions relative to Longfin Smelt are:

- the population effects of entrainment of adults and larvae in the south Delta,
- the mechanisms that support the well-documented January-June outflow abundance relationship, and
- the quantitative impact to food availability that can be made through restoration; for example, can it affect the abundance of Longfin Smelt?

Many of the research topics identified for Delta Smelt above apply to Longfin Smelt and should be developed to address both species.

Restoration of tidal wetlands and seasonally inundated floodplain under the current BiOps, Longfin 2081(b) and CESA consistency determinations, and EcoRestore are anticipated to increase primary and secondary productivity that may benefit Longfin Smelt in two major ways: an anticipated increase in copepod abundance and an indirect benefit to the extent that suitable food is exported downstream to rearing areas in the low-salinity zone. Restored intertidal wetlands also appear to provide spawning and rearing habitat.

During the past several decades, substantial changes in the species' composition and reductions in the abundance of the preferred food resources for larval, juvenile, and adult Longfin Smelt have been observed. The FMWT index for Longfin Smelt is positively correlated (in a multiple linear regression) with the previous spring's *Eurytemora affinis* (an important zooplankton prey organism for larval Longfin Smelt) abundance. The spring population abundance of *Eurytemora* has itself been positively correlated with outflow between March and May since the introduction of *Potamocorbula* (a small marine bivalve) as well as inversely correlated with mean ammonium concentrations and other variables affecting nutrient pollution in the low-salinity zone (Gilbert et al. 2011).

The role of total ammonia concentrations may be another factor affecting listed fish species by inhibiting primary productivity or altering the role of invasive species. The frequency, severity, and distribution of effects from total ammonia concentrations are the subject of ongoing research, but current science indicates a high likelihood that decreasing loading of total ammonia would have beneficial consequences for phytoplankton productivity and thus the productivity of the pelagic foodweb in and downstream of the Sacramento River.

A proposal focused on developing a conceptual model of Longfin Smelt life history based on current knowledge to support development or hypotheses regarding environmental drivers and life-stage specific vital rates (growth, survival etc.) that can be tested is currently being prepared for the IEP Scientific Management Team. Such an investigation should result in a synthesis useful for interpreting management relevant outcomes. The proposal will identify timelines and milestones, subject to change based on the actual magnitude of work and availability of resources to complete the work.

Current Longfin Smelt investigations resulting from settlement of litigation over the California Fish and Game Code Section 2081(b) permit for the SWP include:

1. Extension of the DFW Smelt Larva Survey (SLS) into Napa River. DFW is developing a means to generate an absolute abundance measures based on SLS sampling. This methodology can be used to generate estimates of regional contributions to Longfin Smelt hatch and rearing.

2. UC Davis is completing a second winter of sampling in lower estuary tributaries for Longfin Smelt larvae and adults (plankton and otter trawls) and has documented adult and larval use of Napa River, Napa Marsh (larvae only), Sonoma Creek, Petaluma River, Coyote Creek (large juveniles and adults only). UC Davis researchers also collected water from each of the tributaries and recently conducted otolith chemistry scans of otoliths from 2015 sampling conducted by both UC Davis and the DFW San Francisco Bay study. This information, combined with the otoliths, seeks to confirm that chemistry of rearing tributaries is “recorded.” Otoliths from Bay Study LFS samples will be used to determine whether tributary contributions can be detected in older age groups (i.e., inferring successful reproduction).

3. Investigation into potential bias of the Fall Midwater Trawl. Investigations are also planned or underway to evaluate vertical and lateral distributions of Longfin Smelt and use of tidal marsh.

5.3 Salmonid and Sturgeon Research and Understanding

Water project facilities and their operations, coupled with other management actions (e.g., habitat restoration, fish passage, and harvest/hatchery management) have profound and complex effects on migratory fish and their habitats. There is high uncertainty in how native and migratory fishes will respond to these large changes in physical and biological conditions. Water exported from the north Delta with CWF infrastructure rather than south Delta will change the hydrology and hydrodynamics of the Delta. Operational flexibilities created by the new water project facilities may lead to system-wide shifts in water release strategies. Changes in both riverine hydrographs and Delta hydrodynamics will likely have a large influence on juvenile life stages of salmon, steelhead and sturgeon. Because few linkages between flows for these life stages have been studied, and future flow regimes may be novel, the expected response of anadromous fish populations to these changes is highly uncertain (Delta Independent Science Board, 2015).

What is certain is the needs for considerable attention placed on evaluating the direct and localized effects of building and operating a new water diversion facility in the north Delta on native and migratory fish. To that end, a robust monitoring plan is also needed to better understand how salmon, steelhead and sturgeon respond to changes in the physical and biological conditions at this particular location. Further, new water project facilities and changes to water operations in general and beyond CWF may have widespread effects that reverberate throughout the Delta and its tributaries.

Using the recommendations of the SAIL report and the CAMT SST report, we focus here on identifying long-term integrated core monitoring, research efforts, and synthesis tools that will be necessary to reduce uncertainties about how current and future water project operations impact migratory fish populations. The prioritized items below are not a comprehensive list of the science necessary for successful adaptive management. Rather, they are intended to highlight strategic system-wide science efforts that would benefit from integration into a broader management and regulatory context to facilitate funding security and consistency in implementation at the appropriate scales. Much of our most valuable monitoring and analytical tool development suffers from a lack of long-term funding security and fragmented implementation, which together lead to inefficiencies in applied science to better inform management decisions.

5.3.1 Integrated Scientific and Management Information System

Enhanced integrated core water quality and biological monitoring designed with adequate precision to support information needs on salmon, steelhead, and sturgeon abundance, movement, and/or survival at critical life stages linked to factors that have immediate effects on fishes' behavior and vital rates. Information needs more specifically include:

Quantify stock-specific juvenile salmon abundances

The current salmon monitoring network provides information on the presence and timing of salmon at various monitoring locations. However, more informative monitoring metrics, such as the abundance of individual salmon runs or populations, are required. Non-lethal genetic sampling coupled with new approaches to estimating trawl and seine efficiencies (e.g., paired coded wire tag and acoustic releases, multi-pass beach seining) can provide accurate information on stock-specific abundances of salmon at strategic locations of scientific and management value (e.g., Sacramento Trawl, Chipps Island, salvage, others). Specific guidance on how to implement this recommendation for juvenile salmonids is provided in the SAIL (IEP 2016).

Expand and integrate electronic tagging with water quality monitoring

A collaboratively designed and implemented expanded tagging program in the Sacramento River system would provide a better understanding of how water project operations influence Chinook salmon survival. This expanded tagging will require increased capacity for data management and capture-recapture modeling. The data generated from this program will build our understanding of how hydrologic variation, water project operations, habitat restoration and other management actions influence salmon survival. Real time monitoring of acoustic tags (in concert with representative tagging) will improve our understanding of where fish are in the system, potentially increasing operational flexibility and an increased ability to meet the Delta's co-equal goals.

Monitor and manage for life history diversity at multiple life stages

Maintenance and regeneration of life history diversity is central to salmon recovery plans and restoration actions, yet it is one of the most challenging metrics to monitor. Genetic, otolith, and passive integrated transponder (PIT) tagging tools will assist in the development of diversity indicators and insights into how to manage water project operations and restoration efforts to support life history diversity and long-term resilience. In order to inform management decisions for the protection of life history diversity, it would be valuable to enhance the current monitoring network with both parentage-based tagging (PBT) and otolith collection from adult spawners with funding and protocols for long-term archiving (i.e., the DFW Tissue Archive). Though relatively new, both of these technologies are well-tested, and would provide substantial management-relevant information. A complementary approach to assess the lifetime survival of the diversity of salmon outmigrants, many too small to acoustically tag, is to tag representative sizes of juveniles with PIT tags throughout the monitoring program to be sampled in downstream monitoring surveys or upon return in adult carcass surveys.

Develop Green Sturgeon dynamic rate functions and abundance

A number of key parameters regarding green sturgeon spawning distribution and indices of juvenile abundance are in need of further development. With significant improvement, these parameters could be compared to environmental conditions to identify those conditions associated with green sturgeon production. Further developing an index of age-0 juvenile green sturgeon abundance; juvenile green sturgeon telemetry studies; run size and spawning distribution estimates; and quantitative modeling methods to generate estimates of life stage abundance and survival; will greatly improve our understanding of biology, habitat preference, and potential effects of large-scale projects and restoration actions on life stage. Specific guidance on how to implement this recommendation has been investigated and can be led by IEP affiliated scientists investigating sturgeon, and as identified in the SAIL (IEP 2016).

Develop marking/tagging program to identify all hatchery salmonids

To ensure our ability to estimate the proportion of natural origin fall-run and the impacts of hatchery practices on the viability of Central Valley fall-run Chinook salmon and ESA-listed stocks, we will need a long-term marking/tagging program of all hatchery salmonids and tag recoveries in the ocean and escapement surveys, as was recommended by the California Hatchery Scientific Review Group (2012). The ability to identify a hatchery fish allows greater flexibility to take actions similar to what is implemented through hatchery reform in the Pacific Northwest to minimize domestication or fitness reduction in salmonid populations (e.g., segregation weirs). A universal hatchery marking/tagging program would allow for focused research on understanding impacts of hatcheries on naturally-reproducing salmonid populations.

Implement steelhead monitoring plan to assess factors influencing anadromy

The status of the anadromous life history in natural *O. mykiss* remains largely unmonitored with current, extremely limited population trend data. This limitation can begin to be addressed by PIT tagging juvenile *O.mykiss* and quantifying river residency, response to temperature management, and the proportion that outmigrate and survive to adulthood as a means to determine whether management actions aimed at supporting the contribution of anadromy to the population are effective. DFW has developed a steelhead monitoring plan which is being implemented and will provide valuable data to initiate a systematic and deeper understanding of steelhead in the Central Valley. NMFS SWFSC has also been conducting genetic analyses of above-barrier hatchery broodstock and Central Valley floor populations of *O.mykiss* to better understand genetic structure and genes relevant to the expression of anadromy. These actions, combined with genetic analyses and acoustic tagging studies could provide valuable insights into the genetic and environmental factors favoring the different life history forms.

Update and centralize a seamless bathymetry and topography of the Central Valley watershed

Restoration in the Delta will likely have substantial effects on Delta hydrodynamics, perhaps even above water project operations. Thus, accurate bathymetry information as it relates to current conditions and future restoration planning will be increasingly necessary. Further, accurate biological modeling must be predicated on the accuracy of the physical channel morphology and bathymetry which drives hydrodynamics and floodplain inundation. Given that current measurements are outdated and datasets from different areas do not always align, it would be valuable to develop system-wide bathymetry and elevation data that is centrally available and covering the headwaters to the Bay, including the South Delta in particular.

5.3.2 Mechanistic Studies

Field, laboratory and modeling research that focuses on understanding mechanisms (e.g., habitat carrying capacities, disease, predation, food availability, contaminants) linking flow and temperature to different life stages of salmon is required. Specific studies include those that:

5.3.2.1 Assess impacts of predation

Salmon mortality varies across locations in a way that strongly suggests that predation by other fish is the proximate cause. Salmon survival also appears to have declined over time, concurrent with an increase in predatory fish such as large-mouth bass. Recent CAMT and SAIL technical teams working on south Delta salmonid survival and life cycle mechanisms, respectively, highlight that little is known about what ecological mechanisms are directly impacting salmon and sturgeon migration behavior and survival. These analyses and early modeling results indicate predation is non-random in the environment, happening mostly in a small percentage of a river system at “hotspots”. From these data, predictive models can be developed to determine hotspot locations. These models require regional calibration, so surveys throughout the Delta as well as the Sacramento River basin will be needed.

5.3.2.2 Investigate salmon route selection and fish guidance technology

Landscape-scale survival studies suggest that the route a fish uses during outmigration strongly influences their survival to the ocean. Factors including distance to ocean, habitat quality, and predatory density, differ among routes and these differences affect overall salmon survival. Two-dimensional fish tracking suggests that routing of fish at channel junctions is determined by their position relative to a demarcation of flow divergence (i.e., the critical streak line). It is important to continue these studies of fish behavior at junctions and the extent to which engineering solutions can enhance fish survival/growth benefits. Current efforts evaluating the use of guidance structures to influence the proportion of fish diverted towards a higher survival route are underway. The CSAMP SST report suggested a broad suite of studies that may be needed to assess fish behavioral responses to various drivers (e.g., velocity, salinity gradients, tidal fluctuations, etc.) which will be important to adapt key operational parameters such as Old and Middle River flow (OMR) and the Inflow to Export ratio (I:E). Engineering solutions may also prove valuable depending on the extent to which the reach containing the NDD of CWF becomes a lower survival reach than alternative routes.

5.3.2.3 Implement restoration science and effectiveness monitoring

Focused research on how freshwater habitats influence salmonid size and timing of ocean entry and how this freshwater experience influences their overall ocean performance is needed. Floodplain and shallow water habitats, such as tidal marshes, and bays are not well-sampled by existing monitoring programs. Targeted studies are needed to examine the predicted benefits and risks of these habitats and the influence of associated restoration actions on Chinook salmon and sturgeon populations. Additionally, the benefits of restoration will likely be in fish quality (e.g., condition and growth), diversity in outmigration timing, and delayed survival benefits (e.g., ocean survival) rather than a potential direct increase in juvenile abundance in the freshwater.

5.3.3 Modeling and Synthesis

This category includes life-cycle models that integrate core monitoring and mechanistic study data to evaluate the influence of management actions (e.g., water operation, restoration, reintroductions, harvest, hatcheries, invasive species, climate change) into changes in the future viability of fish populations. Specific studies needed include those that:

5.3.3.1 Support system-wide physical models

Water project facilities and operations, by design, alter the timing and amounts of water flows, and thus water depth and velocities. The development and refinement of process-based model frameworks that track the movement of water and relevant constituents (e.g., heat, particles, contaminants, dissolved oxygen, etc.) throughout the entire Central Valley system would be very useful. The CSAMP SST report highlighted the need to update the Delta Simulation Model II (DSM2) as a critical step to better assessing the effect of Delta water operations.

5.3.3.2 Support system-wide ecosystem models

Biological models, coupled to physical models, are the basis for making the quantitative predictions required for effective adaptive management of anadromous fish and water resources. The development of process-based model frameworks to capture the fundamental biological processes (e.g., growth, survival, reproduction, evolution, movement, interactions with predators, competitors, prey, parasites, and pathogens, etc.) at each domain, and how the biotic components (e.g., prey, predators) move between domains. A variety of modeling frameworks should be developed and tailored to accommodate different management questions and biological endpoints.

5.3.3.3 Support salmon and sturgeon life cycle models

Develop a salmonid life cycle model tailored expressly to assist with evaluating salmonid responses to the long-term operations of the state and federal water projects as mandated by the courts and echoed by the Delta Science Program's panel review (NMFS 2009; Rose et al, 2011). While significant progress has been made in the development, refinement, documentation, and implementation of the life cycle model (LCM) for winter-run Chinook salmon, the modification to water project infrastructure and operational decisions as part of CWF will continue to generate new information that can be used to further refine our understanding and the models.

5.3.3.4 Develop winter-run Chinook salmon ocean forecast model

Salmon populations are also highly responsive to changes in ocean conditions, which may obscure population responses to management if not accounted for. The development of an ocean forecast model will determine if ocean ecosystem metrics (coupled with stock-specific abundance estimates at ocean entry) can be used to forecast abundance of age 2 and 3 Sacramento River winter-run Chinook salmon in the mixed-stock fishery. Directly quantifying juvenile Chinook salmon in the coastal ocean is virtually impossible due to low population size, and yet understanding early ocean mortality may be the missing gap necessary to better evaluate how different sources of mortality impact the larger population of winter run.

5.3.3.5 Develop real-time salmon movement and survival model

The Delta Operations of Salmon and Sturgeon (DOSS) team uses multiple sources of information to infer the likely proportion of a stock that remains in the river vs. in the Delta during that stock's outmigration. The DOSS team provides managers with a weekly outlook regarding the vulnerability of ESA-listed stocks to Delta water project operations, yet this outlook is based on the judgement of experts and does not have a quantitative tool to assist in this evaluation and integration of information. The development of a statistical GIS movement and survival framework to process real-time salmon acoustic detections to better quantify salmon distribution and movement would further validate DOSS advice.

5.3.4 Data Access

Improved data availability, consolidation, and statistical support for real-time water project operations is critical, and key to this effort is data access.

The majority of biological monitoring data (except salmon escapement in Grandtab) is not readily available to the public or agency scientists. Staff members have to be contacted individually to acquire basic monitoring information which makes synthesis efforts challenging and laborious. In addition, identifying the point of contact for data can also be challenging. The development of a centralized accessible network for relevant physical and biological data necessary for management decisions related to salmon and water resource management would provide for more effective access and enhanced transparency.

6 Funding

As part of the current BiOps and CESA authorizations and the Bay Delta Water Quality Control Plan, a number of monitoring and research actions in the Delta are currently being implemented through the IEP and south Delta fish facilities management and enhancement efforts, as well as through the Fish Restoration Program Tidal Restoration Monitoring Program. IEP continuously reassesses its monitoring and research efforts to address management specific actions. Most recently, the SAIL has identified actions to improve tracking and real time decision support monitoring. Upstream monitoring on the Sacramento, Feather, American and Stanislaus rivers related to upstream reservoir management actions to protect listed fish species is also conducted. CSAMP has developed study plans and budgets for specific research efforts to address south Delta operational effects on salmon, Delta Smelt entrainment, and the Fall X2 action in the FWS 2008 OCAP BiOp. CSAMP is also developing study plans to address additional areas of scientific uncertainty related to operation of the SWP/CVP in the Delta. DFW as part of a settlement agreement with water agencies has created a Longfin Smelt technical team to address uncertainties related to current sampling approaches and how Longfin Smelt abundance is characterized, as discussed above this effort is expected to expand in the future.

Additional CWF scientific research and monitoring (identified in sections above) will be required to address the effects of water operations with North Delta Diversions in place, as well as questions related to the design and operation of the facilities themselves to minimize effects on listed species. During implementation of the current BiOps and CESA authorizations it has become apparent that additional resources for monitoring and research are need to address uncertainties and to provide better information upon which to base management decisions. Further, the additional work identified through the SAIL effort and the CSAMP Salmon Gap Analysis will need additional funding.

Current and future funding requirements and schedules will be determined by the IICG.

7 Summary of Relationships to Other Programs

Important efforts are underway to implement science-based adaptive management to improve the scientific basis of operational decisions on annual or multi-year time scales. The Adaptive Management Program will build on and augment the existing and planned efforts summarized below that are developing and implementing science to apply adaptive management principles to the Delta ecosystem. As the Adaptive Management Program is developed, specific linkage to each of these efforts will be defined.

7.1 Current Efforts

The original IEP studies of the influence of Delta flows on the recruitment of striped bass and the function of their supporting food web were an ambitious interagency attempt at an "adaptive management" program that pre-date the current definition of the phrase adaptive management (used in this Program). In this context, the IEP program has expanded and morphed as agency priorities have evolved. As a result of this cooperative history, there are several very important efforts already underway to implement science-based decision support tools that seek to thereby improve the scientific basis of operational decisions at an annual or multi-year time scale (*Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*).

To be most successful, this Adaptive Management Program will build on and augment the existing efforts that have been developing and implementing science to apply adaptive management principles to the Delta ecosystem since the 1960s. In particular, this Program will incorporate many elements of the process and structure of the IEP and the Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team (CSAMP/CAMT), and the State and Federal Contractors Water Agency Science Program, and will continue to rely on the Delta Science Program for peer review and research support. Because these existing efforts will form core elements of this Program, each effort is described below.

7.1.1 CSAMP

The CSAMP was launched following decisions by the United States District Court for the Eastern District of California to remand the current BiOps to the USFWS and NMFS for further consideration in accordance with the decisions (*San Luis & Delta-Mendota Water Authority v. Salazar*, 760 F.Supp.2d 855 (E.D. Cal. 2010); *Consolidated Salmonid Cases*, 791 F.Supp.2d 802 (E.D. Cal. 2011)), and more specifically following a decision by that court on April 9, 2013 (*In re Consolidated Delta Smelt Cases*, 2013 WL 1455592 (E.D. Cal. 2013) (2013 Court Order)). The 2013 Court Order was issued in response to a motion to extend the court-ordered remand schedule for completing revisions to the current BiOps and completing review under the National Environmental Policy Act (NEPA).

The 2013 Court Order allowed the parties making the motion (i.e., Reclamation, USFWS, NMFS, and DWR) additional time for the development of a proposed robust science and adaptive management program, with collaboration of the scientists and experts from the Public Water Agencies ('PWAs') and the non-governmental organization (NGO) community with the intent to inform the management actions incorporated into the current BiOps (and Reasonable and Prudent Alternatives) and consideration of alternative management actions.

The 2013 Court Order granted a one-year extension of time to deadlines associated with the cases' remand. The parties filed an annual progress report in February 2014, and the court granted a second one-year extension in March 2014. The parties prepared a second annual progress report in February 2015, requesting a third one-year extension. However, the Ninth Circuit Court of Appeals reversed the court's decisions that remanded the current BiOps to USFWS and NMFS (*San Luis & Delta-Mendota Water Authority v. Jewell*, 747 F.3d 581 (9th Cir. 2014), *cert. denied* 135 S.Ct. 950 (2015); *San Luis & Delta-Mendota Water Authority v. Locke*, 776 F.3d 971 (9th Cir. 2014)).

After reversal of the court's decisions requiring remand of the current BiOps, in 2015, all parties agreed to continue the CSAMP to promote the collaborative development of scientific information to inform sound decision-making in the future.

7.1.1.1 Organization

The CSAMP is structured as a four-tiered organization comprised of:

1. Policy Group consisting of agency directors and top-level executives from the entities that created CSAMP;

2. CAMT made up of managers and staff scientists that serve at the direction of the Policy Group;

3. Scoping Teams created on an as-needed basis to scope specific science studies; and

4. Investigators contracted to conduct studies.

7.1.1.2 Mission Statement

The CAMT mutually agreed on the following mission statement at its July 23, 2013 meeting:

> *The Collaborative Adaptive Management Team (CAMT) will work, with a sense of urgency, to develop a robust science and adaptive management program that will inform both the implementation of the current Biological Opinions, including interim operations; and the development of revised Biological Opinions.*

CAMT expects to revisit its mission statement (by increasing its scope) as it develops its Five Year Plan for CAMT. In the meantime, CAMT intends to remain focused on completing the studies initiated in 2014 and identify new initiatives based on the results of these studies.

Current products that are being developed by the CAMT scoping teams and principle investigators include analysis and synthesis tools and reports concerning Delta Smelt Entrainment, Gear Efficiency, Fall Habitat, and Salmonid survival. These reports from the two scoping teams will identify key findings, issues and recommendations for next steps. The next steps recommended in the two scoping teams' reports will be evaluated and prioritized by CAMT members. The highest prioritized efforts will be presented to the CAMT Policy Group and will be incorporated into the CAMT five year plan that CAMT is currently developing.

Items in the CAMT Five Year Plan may also support and contribute to advancing the objectives of other efforts including CWF and IEP. The CWF Five Agencies will ensure that efforts being implemented via CAMT or IEP are integrated and continue to move forward in those forums.

7.1.2 Interagency Ecological Program

The IEP has brought state and federal natural resource and regulatory agencies together to monitor and study ecological changes and processes in the Delta since 1972. The IEP currently consists of nine member entities: three state agencies (DWR, DFW, and the State Water Resources Control Board), six federal agencies (USFWS, Reclamation, USGS, USACE, NMFS, and U.S. Environmental Protection Agency), and two (current) partners: the San Francisco Estuary Institute and the Delta Science Program. These agencies and partners work together to develop a better understanding of the estuary′s ecology and the effects of the SWP/CVP operations on the physical, chemical, and biological conditions of the estuary. The 2014 IEP Strategic Plan describes IEP's goals and strategies to achieve them (http://www.water.ca.gov/iep/docs/IEP_Strategic_Plan102214.pdf).

7.1.2.1 Organization

The IEP is structured as a four-tiered organization comprised of:

1. Member agency directors;
2. IEP Coordinators made up of senior level managers who oversee the program
3. Science Management Team made up of managers and staff scientists that serve at the direction of the Coordinators to scope specific science studies. The IEP Lead Scientist provides strategic direction for, and oversight of, IEP science efforts, acts as the chief science advisor to the IEP Coordinators and Directors, chairs the Science Management Team, and serves as the primary scientific voice to all the groups;
4. Ad hoc project work teams that also develop scientific study concepts that can be recommended to the Science Management Team. The project work teams have included not only agency staff but have had extensive participation from academics and stakeholders; and
5. Investigators who are either agency staff or are academics or consultants contracted to conduct studies.

The IEP has coordinated Bay-Delta monitoring and research activities conducted by state and federal agencies and other science partners for over 40 years (*Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program*). IEP monitoring activities are generally carried out to document CVP and SWP compliance with water rights decisions and California Endangered Species Act (CESA) authorizations and/or current BiOp conditions. Most of the monitoring under the IEP focuses on open-water areas and the major Delta waterways conveying water to the SWP/CVP facilities in the south Delta and downstream, including the entire Bay-Delta and portions of its watershed. The IEP produces publicly accessible data that include fish and invertebrate status and trends, water quality, estuarine hydrodynamics, and foodweb monitoring. Because of the history, size, and scope of this program's monitoring and research efforts in the Delta, it will continue to be a primary component in the implementation of CWF's adaptive management and monitoring program.

Although IEP member agencies have varying priorities, IEP provides a common ground for shared science priorities to come together and focus on supporting management needs for the Bay-Delta ecosystem and the water that flows through it. Some priorities are very explicit, such as monitoring specified in a permit or agreement. Others are focused on informing pending decisions or seeking new understandings that allow better decision making in water project operations or prevent new challenges such as invasive species.

Science Agenda

To meet anticipated science needs of the member agencies and provide the scientific tools and advice that resource managers can rely upon, the IEP has developed an IEP Science Agenda to focus on overarching management challenges anticipated in the next 3-5 years (http://www.water.ca.gov/iep/docs/2016_IEP_Science_Agenda_FINAL.pdf). The agenda serves as an outline for achieving important objectives by identifying and organizing science needs in the context of conceptual models, related information gaps and uncertainties, and strategies and priorities. The IEP Lead Scientist and IEP Coordinators have guided the development of the agenda, while drawing insights from the program scientists, project work teams, managers, and stakeholders particularly via the CSAMP.

7.1.3 Delta Stewardship Council, Delta Independent Science Board (DISB) and Delta Science Program (DSP)

Established by 2009 Delta Reform Act, the Delta Stewardship Council is charged with achieving the co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The DISB provides a standing board of nationally or internationally prominent scientists with appropriate expertise to evaluate the broad range of scientific programs that support adaptive management of the Delta. The DISB will provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs and reports to the Delta Stewardship Council. The Delta Science Program's mission is to provide the best possible unbiased scientific information to inform water and environmental decision making in the Bay-Delta region. The Delta Science Program's objectives are to:

- Initiate, evaluate and fund research that will fill critical gaps in the understanding of the current and changing Bay-Delta system.
- Facilitate analysis and synthesis of scientific information across disciplines.
- Promote and provide independent, scientific peer review of processes, plans, programs, and products.
- Coordinate with agencies to promote science-based adaptive management.
- Interpret and communicate scientific information to policy- and decision-makers, scientists, and the public.
- Foster activities that build the community of Delta science.

The Delta Science Program has particular expertise and experience organizing and facilitating independent scientific reviews. It also has primary responsibility for developing and implementing the Delta Science Plan. The Delta Science Program is expected to support CWF in the review of monitoring and research methods and results, and to provide technical support to the adaptive management process.

In its January 2016 review, *Improving Adaptive Management in the Sacramento-San Joaquin Delta*, the Delta Independent Science Board (ISB 2016) provided a number of insights regarding the way adaptive management has been applied to the Delta ecosystem as well as a number of recommendations for future implementation. Key findings and recommendations included:

- Agencies must become more actively engaged in collaborations;
- Adaptive Management must be identified as a high priority;

- Supporting Adaptive Management with dependable and flexible funding;
- Design and support monitoring to fit the magnitude of management actions and timing of ecosystem processes;
- Develop a framework for setting decision points or thresholds that would trigger a management response;
- Use restoration sites to test adaptive management and monitoring protocols.

The Delta Science Program has also identified a nine step adaptive management process. This Program proposes to use a four-phase approach to adaptive management which has been described in Section 5. Figure 8-1 describes how this Program's approach relates to the nine-step process.

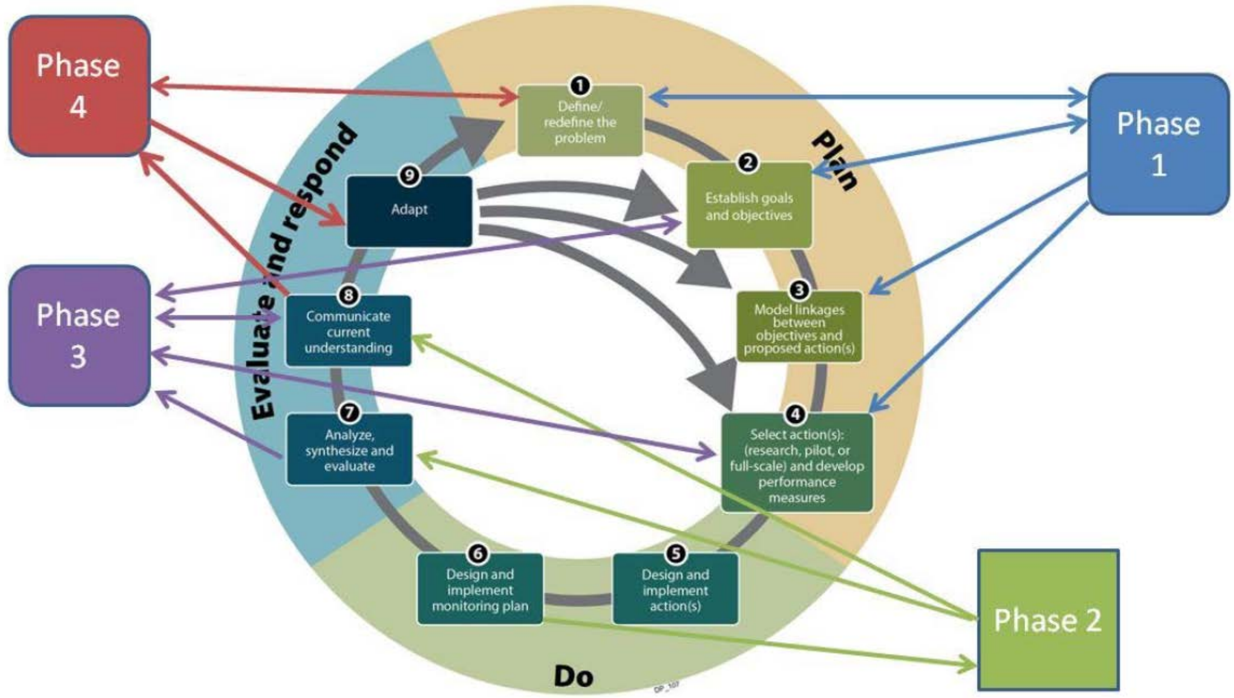

Figure 8-1. Describing the relationship between the DSP's nine step adaptive management process and the four phase process described in this Program

Arrows "from" a phase means that particular step is contained within the phase, where arrows "to" a phase mean that that step influences a phase. Double arrows are both within and influencing the phase.

The overarching objective of the BiOps and CESA authorizations is to avoid jeopardy or adverse modification of critical habitat for the covered species. During Phase 1 the development of management actions to be tested via the science plans/priorities is similar to Step 4 and based on the problems defined by Step 1. In the development of management actions and science plans objectives (*i.e.* Step 2) will be clearly defined and modeled linkages of Step 3 will be created between proposed actions/studies and the objectives. Phase 1 results in the Operations plan and Science plan, as well as their implementation (*i.e.* Steps 5 & 6).

During Phase 2 the results of management actions and science plans implemented in Phase 1 are analyzed, synthesized and evaluated (Step 7); the results of which are communicated (Step 8) across agencies and stakeholders. Phase 3 then, develops the new understanding from Phase 2 products to advance a common understanding of those results (Step 8). Based on that understanding managers (agency staff, IICG, CSAMP) could redefine problem statements or develop new problem statements (Step 1) and establish new research or management objectives (Step 2) and recommend actions for management and or research (STEP 4). Ultimately during Phase 4, recommendations communicated from Phase 3 (Step 8) are adopted based on those recommendations (Step 9). If the recommendations would fall outside the analysis of the current BiOps and or CESA authorizations or those for CWF then the Action Agency would request reinitiation of consultation or seek a CESA permit amendment.

8 Reporting

Reports and plans will constitute the most visible documentation of the adaptive management process. In general, each adaptive management action will be proposed in a plan and its outcomes described in a report. Reports will take into account other existing processes and augment those efforts.

8.1 Annual Work Plan and Budget

On an annual basis, the IICG will prepare an Annual Work Plan and Budget for the upcoming year. The Work Plan will describe the proposed activities of the adaptive management and monitoring program. The Budget will set out projected expenditures and identify the sources of funding for those expenditures.

The IICG will develop and approve the Annual Work Plan and Budget.. As part of this process, the Five Agencies will participate in developing the draft plan. As part of their participation on the IICG, the Five Agencies will ensure the draft plan accurately sets forth and makes adequate provision for the implementation of the applicable permit terms under which the CVP and SWP operate.

A draft of the Annual Work Plan and Budget will be developed by the IICG, working with the Collaborative Science Workgroups, and posted for review and comment. A final Annual Work Plan and Budget will be completed no later than 1 month prior to the beginning of the activities described therein.

At a minimum, the Annual Work Plan and Budget will contain the following information.

- A description of the planned actions under the adaptive management processes.
- A description of the planned monitoring actions and the entities that will implement those actions, based on the structured decision-making described below.
- A description of the anticipated research studies to be undertaken and the entities that will conduct the studies.
- A budget reflecting the costs of implementing the planned actions.
- A description of the sources of funds that will be used to support the budget.

8.2 Annual Progress Report

At the end of each implementation year, the IICG will begin preparation of an Annual Progress Report. The report will be based upon existing information, data, and analysis. The report will provide an overview of the IICG activities carried out during the previous implementation year and provide information sufficient to demonstrate that the proposed action is being implemented consistent with the provisions of the Work Plan, the MOA, and all applicable BiOps, Permits and the associated regulatory authorizations.

The IICG shall solicit input on the draft of the Annual Progress Report from its members prior to its review and approval. The IICG shall finalize and approve the Annual Progress Report within six months of the close of the reporting year.

The annual progress report will include, among other things, the following types of information.

- Documentation of the implementation of habitat restoration and protection measures specified in the Proposed Action in relation to their schedule (see Appendix 8 *Implementation Schedule for the Adaptive Management Program for the Existing Biological Opinions and CESA Authorizations for the Long-term Operation of the CVP and SWP and for CWF* for presentation of schedule of possible AMP components) and performance specifications, including the following components.
    - A summary of the habitat protection and restoration actions that have been initiated, are in progress, or have been completed, including information regarding the type, extent, and location of protected and restored habitat for listed species. The report will document these actions on an annual and cumulative basis.
    - The status of the protected and restored habitat and an assessment of the progress toward meeting all land acquisition goals for habitat protection and restoration. This will include details on compliance with restoration requirements.
    - A general summary of all land management activities undertaken on protected and restored habitat, including a description of the management issues associated with each habitat protection or restoration site.
    - Identification of actions that have not been implemented on schedule and an explanation for the deviation from schedule. For actions that are behind schedule, a suggested schedule or process for completing them will also be included.
- Descriptions of actions taken pursuant to the adaptive management programs.
    - Documentation of the results of monitoring and research actions prescribed in the PA or its authorizations as issued by the Five Agencies, or directed by the IICG. This is to include a summary of the actions that have been initiated, are in progress, or have been completed for each conservation measure, including information related to type, location, and method of implemented actions. The report will document this on an annual and cumulative basis.
    - Adaptive management decisions made during the reporting period, including the scientific rationale for the action.
    - Use of independent scientists or other experts in the adaptive management decision-making processes.
    - Changes in the manner in which conservation measures are the proposed action is implemented, based on interpretation of monitoring results and research findings, or other information.
- An accounting of the funding provided to support the monitoring, research, and adaptive management programs. The accounting will identify the source of the funds, the annual and cumulative expenditures to support the programs by cost category, and any deviations in expenditures from the associated ***Annual Workplan and Budget***.

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10 APPENDICES

Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF

Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species

Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass

Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration

Appendix 6—Delta Outflow

Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program

Appendix 8- Implementation Schedule for the Adaptive Management Program for the Existing Biological Opinions and CESA Authorizations for the Long-term Operation of the CVP and SWP and for CWF

Appendix 1—Initial Objectives Derived From BDCP, Current Biops/CESA and CWF

This appendix and the table below describe species-specific objectives that were originally identified during the BDCP planning process. The objectives are preliminary. They are not necessarily achievable by the Central Valley Project and State Water Project, given the extensive physical, chemical and biological changes that have occurred within the ecosystem, many of which are not due to the CVP or SWP. Further, the preliminary objectives were developed to achieve a conservation standard that is not required to meet the Section 7 standard of avoiding the CVP and SWP from jeopardizing or adversely modifying designated critical habitat. Final objectives for this adaptive management program will be developed using collaborative processes and limited to those actions necessary to achieve applicable regulatory standards. The IICG will consider those final objectives when implementing this AMP.

Objectives (Triggers for Adaptive Management action)	**BiOp and CWF Focus Area addressed**
Restore at least 8,000 acres of tidal brackish and freshwater emergent marsh and shallow sub-tidal habitat and transitional uplands in Suisun Marsh and Cache Slough to accommodate sea level rise and in the western Delta to improve aquatic primary productivity and habitat for listed and other native species.	Tidal Wetland Restoration
Restore 17,000 acres of floodplains (through Yolo Bypass Fishery Enhancement Plan Implementation) to improve adult and juvenile fish passage and to avoid and minimize effects on listed terrestrial species by providing a range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more) areas. This restoration action will provide species with a range of habitat conditions, upland habitat values, and refugia during most flood events.	Listed Fish Performance; Yolo Bypass; Riparian, Channel Margin & Floodplain Restoration
Enhance 4.5 miles of channel margin in the Sacramento River system to provide habitat along important migratory routes for anadromous fish and to improve wildlife movement.	Riparian, Channel Margin & Floodplain Restoration

Species-Specific Objectives	
Delta Smelt	
Limit entrainment mortality associated with operations of water facilities in the south Delta to ≤5% of the total Delta Smelt population, calculated as a 5-year running average of entrainment for subadults and adults in the fall and winter and for their progeny in the spring and summer. Assure that the proportional entrainment risk is evenly distributed over the adult migration and larval-juvenile rearing time-periods.	Listed Fish Performance
Longfin Smelt	
Limit entrainment mortality associated with operation of water facilities to ≤5% of the longfin smelt population, calculated as a 5-year running average of entrainment for subadults and adults in the fall and winter and for their progeny in the winter and spring. Assure that the proportional entrainment risk is evenly distributed over the adult migration and larval-juvenile rearing periods.	Listed Fish Performance
Chinook Salmon, Sacramento River Winter-Run Evolutionarily Significant Unit	
For winter-run Chinook salmon, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 52%. This survival metric is an interim value based on limited data from fall-run Chinook salmon in the Sacramento River. This survival metric will be revised to account for new monitoring data and improved modeling when available.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for outmigrating winter-run Chinook salmon juveniles.	Listed Fish Performance; Yolo Bypass
Limit adult winter-run Chinook salmon passage delays in the Yolo Bypass to fewer than 36 hours and avoid false attraction into the Colusa Basin.	Yolo Bypass
Operate water facilities to support a wide range of life-history strategies for winter-run Chinook salmon without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance
Chinook Salmon, Central Valley Spring-Run Evolutionarily Significant Unit	
For spring-run Chinook salmon originating in the Sacramento River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 50% (up from an estimated 40%) as measured between Knights Landing and Chipps Island. The Sacramento River survival metric is an interim value based on limited data from fall-run Chinook salmon in the Sacramento River. This survival metric will be revised to account for new monitoring data and improved modeling when available. For spring-run Chinook salmon originating in the San Joaquin River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 33% as measured between Mossdale and Chipps Island.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for out-migrating spring-run Chinook salmon juveniles.	Yolo Bypass
Operate water facilities to support a wide range of life-history strategies for spring-run Chinook salmon without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance
Steelhead, California Central Valley Distinct Population Segment	

For steelhead originating in the San Joaquin River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 44% (increased from an estimated 10%) as measured between Mossdale and Chipps Island. For steelhead originating in the Sacramento River and its tributaries, achieve through CWF and other actions a 5-year geometric mean interim through-Delta survival objective of 54% (increased from an estimated 45%) as measured between Knights Landing and Chipps Island. These survival metrics are interim values based on limited data from fall-run Chinook salmon in the San Joaquin and Sacramento Rivers. These survival metrics will be revised to account for new monitoring data and improved modeling when available.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for outmigrating steelhead juveniles.	Listed Fish Performance; Yolo Bypass
Limit adult steelhead passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Action Area (e.g., Stockton Deep Water Ship Channel) to fewer than 36 hours.	Listed Fish Performance; Yolo Bypass; Riparian, Channel Margin & Floodplain Restoration
Operate water facilities to support a wide range of life-history strategies for steelhead without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance
Green Sturgeon, Southern Distinct Population Segment	
Increase juvenile green sturgeon survival (as a proxy for juvenile abundance and population productivity) and increase adult green sturgeon survival (as a proxy for adult abundance and productivity) throughout the CWF project term.	Listed Fish Performance; Yolo Bypass; Tidal Wetland Restoration; Riparian, Channel Margin & Floodplain Restoration
Eliminate stranding of adult green sturgeon at Fremont Weir, the scour pools directly below Fremont Weir, and the Tule Pool.	Listed Fish Performance; Yolo Bypass
Improve water quality parameters and physical habitat characteristics in the Bay-Delta to increase the spatial distribution of green sturgeon in the Action Area.	Tidal Wetland Restoration

Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species

Key Uncertainty	Potential Research Actions
What is the relationship between proposed intake design features and expected intake performance relative to minimization of entrainment and impingement risks?	Develop physical hydraulic model(s) to optimize hydraulics and sediment transport at selected diversion sites (same as preconstruction study 1, Site Locations Lab Study [Fish Facilities Working Team 2013]). 10 months to perform study; needed prior to final design.
What tidal effects and withdrawals on flow conditions occur at screening locations?	Develop site-specific numerical studies (mathematical models) to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions (same as preconstruction study 2, Site Locations Numerical Study [Fish Facility Working Team 2013]). 8 months to perform study; needed prior to final design.
What is the optimal design of refugia areas (macro, micro, and base refugia)?	Test and optimize the final recommendations for refugia that will be required for installation at the north Delta diversion facilities (same as preconstruction study 3, Refugia Lab Study [Fish Facility Working Team 2013]). 9 months to perform study; needed prior to final design.
How does refugia function at future fish screens?	Evaluate the effectiveness of using refugia as part of diversion structure design for the purpose of providing areas for juvenile fish passing the screen to hold and recover from swimming fatigue and to avoid exposure to predatory fish. In addition, gain insights (through observation) into the biological benefits of incorporating refugia into diversion structures (same as preconstruction study 4, Refugia Field Study [Fish Facility Working Team 2013]). 2 years to perform study; needed prior to final design.
How does water velocity distribution at river transects within the proposed intake reaches vary under differing river flow conditions?	Characterize the water velocity distribution at river transects. Water velocity modeling in the Sacramento River will identify how NDDs affect hydraulics in conjunction with changes in flow rate and tidal cycle (same as preconstruction study 7, Flow Profiling Field Study [Fish Facility Working Team 2013]). 1 year to perform study; needed prior to final design.
What are the effects of deep-water screens on hydraulic performance?	Use a computational fluid dynamics model to identify the hydraulic characteristics of deep water fish screen panels (same as preconstruction study 8, Deep Water Screens Study [Fish Facility Working Team 2013]). 9 months to perform study; needed prior to final design.
How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	Determine baseline rates of survival for juvenile Chinook salmon and steelhead within the Sacramento River in the vicinity of proposed north Delta diversion sites for comparison to post-project survival in the same area, with sufficient statistical power to detect a 5 percent difference in survival. Following initiation of project operations, continue studies using same methodology and same locations. Identify changes in survival rates due to construction/operation of the intakes (same as preconstruction study 10, Reach-

Key Uncertainty	Potential Research Actions
	Specific Baseline Juvenile Salmonid Survival Rates, and post construction study 10, Post-Construction Juvenile Salmon Survival Rates [Fish Facilities Technical Team 2011; Fish Facility Working Team 2013]). The preconstruction study will require at least 3 years, and must be completed before construction begins. Post construction study to cover at least 3 years, with sampling during varied river flows and diversion rates.
Where is predation likely to occur in the vicinity of the new North Delta intakes?	Perform field evaluation of similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities (same as FFTT preconstruction study 5, Predator Habitat Locations). This 1 or 2 year study is needed prior to intake facility final design.
What is the density and distribution of predators in the intake reach of the Sacramento River?	Use a Didson camera or other technology and/or acoustic telemetry at two to three proposed screen locations; perform velocity evaluation of eddy zones if needed. Collect baseline predator density and location data prior to facility operations; compare to density and location of predators near operational facility. Identify ways to reduce predation at the facilities (same as FFTT study 9. Predator Density and Distribution, both pre- and post-construction). These studies should be started as soon as possible to collect multiple annual datasets before construction begins. The studies should continue 3 years post construction (provided varied river flows and sufficient predator populations).
What are the best predator reduction techniques? Which are feasible, most effective, and best minimize potential impacts on listed species?	Perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District). Test and evaluate various predator reduction techniques at operational south Delta facilities with regards to efficacy, logistics, feasibility, cost and benefits, and public acceptance. Determine if these techniques also take listed fishes and assess ways to reduce such by-catch, if necessary (extended version of FFTT Pre-construction study 6, Predator Reduction Methods). This 2 year study must be completed prior to final design of north Delta intakes.
How do reductions in south Delta exports and presence of the operable gate at the head of Old River, together with other conservation measures, influence through-Delta survival of San Joaquin River region juvenile salmonids?	Assess survival using acoustically tagged juvenile salmonids, employing methods similar to those of Buchanan et al. (2013). Overall through-Delta survival, together with reach-specific (e.g., head of Old River to Middle River) and pathway-specific (e.g., Chipps Island via Old River) survival, would be used to assess the importance of CWF operations as well as the effectiveness of other mitigation measures. Predation near the proposed head of Old River barrier (at and near the operable gate) would be studied with a multi-receiver hydroacoustic array. Conduct 3-5 years of study prior to CWF implementation in order to capture years

Key Uncertainty	Potential Research Actions
	with varying hydrology; another 3-5 years of study is needed after CWF implementation.
What are the effects of localized predator reduction measures on predator fish and listed fish species?	Use before and after studies to evaluate the distribution and abundance of predators and listed fish species at treatment location and nearby sites. Metrics include abundance, age classes, and distribution of predators such as striped bass, largemouth bass, and other smaller piscivorous fish. Measure rates of site recolonization by predators following reduction treatments. This 2- to 3-year study should be performed by year 5 of CWF implementation.
Under what circumstances and to what degree does predation limit the productivity of listed fish species?	Evaluate predation effect on productivity of listed fish species using life-cycle simulation models and site-specific bioenergetics modeling (Loboschefsky et al. 2012). This would be a 1-year study, best performed after other studies (listed above) investigating the overall incidence of predation.
How should hotspots for localized predator reduction and/or habitat treatment be prioritized?	Document the extent and locations of predator hotspots within the Delta, and evaluate relative intensity of predation and feasibility of treatment. Use a habitat suitability approach at known hotspots to identify specific physical features and hydrodynamic conditions that facilitate elevated predation loss. Perform tagging studies to identify areas that facilitate intense predation (e.g., Bowen et al. 2009; Vogel 2011). This 1-year study, should be performed by year 5 of CWF implementation.
Which predator species and life stages have the greatest potential impact on listed fish species?	Determine whether large predators that are comparatively easy to target for reduction are the key predators of some or many listed fishes. Conduct site-specific monitoring of predator abundance (by species and life stage) during periods when listed fish species (particularly juvenile salmonids) are present. Determine site-specific diet composition of predators (e.g., using DNA analysis of predator stomach contents). This 1- to 3-year study should be performed by year 5 of CWF implementation.
Is modification of sportfishing regulations a viable and effective means of achieving localized predator reduction?	Perform literature review and interviews with qualified agency and independent scientists to summarize potential benefits, hazards, costs, and implementation issues associated with using modification of sportfishing regulations to manage predatory fish in the Delta. This up-to-1-year study should be performed by year 5.
How have other actions implemented as part of the current BiOps, CWF mitigation, and EcoRestore affected the distribution and intensity of predation in the Action Area?	Restoration actions are expected to create additional habitat for some species of predators along with listed species (e.g. Yolo Bypass Fisheries Enhancement, Tidal habitat Restoration, Seasonally Inundated Floodplain Restoration, Channel Margin Enhancement, and Riparian Natural Community Restoration). Monitoring and potential active adaptive management studies will be developed, if increased predation is suspected or

Key Uncertainty	Potential Research Actions
	demonstrated in conjunction with habitat restoration or enhancement projects. Study timing and duration to be determined by CAMT; studies performed periodically during ongoing implementation the current BiOps, EcoRestore and CWF.
How effective are nonphysical barriers at keeping salmonid fishes in desired channels over the long term?	Multiple studies can inform this question, including (1) evaluate change in distribution, abundance and survivorship of listed species in barrier vicinity; (2) evaluate listed species behavioral response to barriers; (3) evaluate effectiveness of barriers in high-flow areas and reversing-flow areas; and (4) evaluate the barrier performance with studies using tagged juvenile salmonids.
How do nonphysical barriers affect predators?	Determine the abundance of predators, by species, within the area of the nonphysical barriers, both before and after installation, and evaluate the effect of the barriers on the survival of out-migrating juvenile salmonids. Determine whether predators are attracted to the nonphysical barriers, and if so, the locations relative to the barrier where they aggregate, and how they respond to changes in barrier operation.
Do nonphysical barriers delay upstream- migrating adult salmonids and sturgeons?	Evaluate the behavior of upstream-migrating adult salmonids and sturgeons at nonphysical barriers, for evidence of delay caused by the barriers. Viable methods may include conducting DIDSON monitoring, or by acoustic tagging.
Improve understanding of the relationship between flow regimes and year class recruitment for green sturgeon	Reanalysis of existing year-class strength data (e.g., from Fish [2010], with updates for additional years), with model selection of various potential explanatory flow variables (e.g., flows within the Action Area) in order to test clearly defined hypotheses (e.g., winter flows are important to migrating adults to stimulate upstream migration and gonadal maturation; Fish 2010). Possible field studies involving acoustically tagged sturgeon in the Action Area to assess the importance of Delta outflow on adult and juvenile migration success. Completion prior to initial operations of north Delta diversions, if possible, with additional study following implementation of CWF
To what extent does the CWF reduce straying of adult San Joaquin River region fall-run Chinook salmon?	Following the suggestions of Marston et al. (2012: 19), assess the influence on straying rate (as measured by coded wire tag returns) of 1) relative roles of south Delta exports and San Joaquin River flow, 2) the timing of pulse flows and export reductions, and 3) the role of pulse flows versus base flows. Changes in these factors and stray rate following implementation CWF would be examined, in addition to changes in total escapement. For field study, 3-5 years of study prior to CWF implementation in order to capture years with different varying hydrology; 3-5 years of study after CWF implementation.

Key Uncertainty	Potential Research Actions
Do lower attraction flows below the north Delta intakes result in greater straying of upstream migrating adult anadromous fishes from the Sacramento River region?	Capture and acoustically tag adult salmonids and sturgeons in San Francisco Bay or Suisun Bay, then track movement using existing hydroacoustic array. Assess proportion entering non-natal river region, then relate this to flow experienced during migration period. As an alternative or in addition, a study of existing coded-wire tag data from recovered carcasses could be done, in a similar manner to that of Marston et al. (2012), in order to assess the rate of straying in relation to flows during upstream migration. 3-5 years of study required prior to CWF implementation; another 3-5 years of study following CWF and EcoRestore tidal habitat restoration implementation; the actual number of years will be dependent on hydrology encountered and schedule of restoration.
How do north Delta intake bypass flows, Delta Cross Channel gate operations, and tidal habitat restoration in Cache Slough influence listed fish (primarily juvenile salmonid) movement into and survival in the interior Delta due to entry through Georgiana Slough and the Delta Cross Channel?	Conduct modeling including CWF operations and proposed tidal habitat restoration site designs to assess hydrodynamics in Action Area channels. Using acoustic tag studies, assess fish survival and movement in the Action Area, particularly at the Sacramento River-Georgiana Slough junction (would be studied as part of CWF6 assessment). Use flow data from existing gauges to derive Sacramento River inflow relationships with the flow split at the Sacramento River-Georgiana Slough divergence before and after implementation of CWF and tidal habitat restoration. 3-5 years of study prior to CWF implementation; 3-5 years of study following CWF and tidal habitat restoration implementation; number of years dependent on hydrology encountered and schedule of restoration.
To what extent does CWF change the abundance and distribution of Microcystis?	Assess abundance and distribution of Microcystis using field studies such as those of Lehman et al. (2005, 2010). Study to be performed during summer months following implementation of CWF (i.e., after north Delta intakes are completed and diversions at the south Delta export facilities decrease). Multiple year study to capture hydrological and operational variability.
How do CWF, BiOp and EcoRestore implementation alter suspended sediment concentrations and water clarity in the Delta?	Develop a suspended sediment model that includes representation of potential areas of tidal restoration and areas of flow alteration due to CWF water operations. Apply this model to develop and adapt sediment management actions, e.g., by modeling alternative locations for release of reusable tunnel material and sediment removed by the north Delta intakes, in order to maximize the potential for beneficial effects on suspended sediment in the Delta.

Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass

Key Uncertainty	Potential Research Actions
How effective are the fish passage modifications at Fremont Weir?	Evaluate the effectiveness of the fish passage gates at Fremont Weir and the effectiveness of the sturgeon ramps.
How effective are the fish passage modifications at Sacramento Weir?	Determine whether Sacramento Weir improvements have benefited fish passage and minimized stranding risk.
How effective are the fish passage modifications within the Yolo Bypass itself?	Determine whether stilling basin modification has reduced stranding risk for listed fishes. Determine effectiveness of Tule Canal/Toe Drain and Lisbon Weir improvements in reducing the delay, stranding, and loss of migrating salmon, steelhead, and sturgeon.
Have the Lower Putah Creek enhancements had the expected effects on fish passage?	Evaluate whether the Lower Putah Creek realignment has improved upstream and downstream passage of listed fish.
Is the modified inundation regime affecting predation on listed fishes in the Bypass?	Determine severity of predation effects on listed fish that use the Yolo Bypass.
Is the modified inundation regime improving production of forage for listed fishes?	Determine plankton and invertebrate production rates during periods of Fremont Weir operation.
Is the change in foraging resources producing improved growth rates among rearing salmonids?	Determine growth rates of juvenile salmonids that have entered the Yolo Bypass during Fremont Weir operation.
What proportion of upstream migrating adult salmonids and sturgeons enter the Yolo Bypass and may be subject to delay at passage barriers?	Capture and acoustically tag adult salmonids and sturgeons in San Francisco Bay or Suisun Bay, then track movement using existing hydroacoustic array, augmented as necessary with new hydrophones in the Yolo Bypass area. Assess use of different routes through the Yolo Bypass and Delta to upstream spawning areas. Study should include collection of 3-5 years of data prior to implementation of Yolo Bypass passage improvement projects in order to capture years with varying hydrology (including overtopping and no overtopping of Fremont Weir), and an additional 3-5 years of data collection after passage improvement projects have been implemented.

Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Key Uncertainty	Potential Research Actions
How does tidal marsh restoration affect production of food suitable for listed fish species both within and outside of the restored sites?	Quantify primary and secondary production, including food suitable for listed species, both within restored tidal marsh natural communities and transported from restored areas to adjacent open-water habitat and the fate of that production.
How have hydrodynamic changes associated with tidal restoration affected organic carbon transport and fate?	Quantify the flux of organic carbon produced in restored tidal marsh plain into existing channels in the Action Area.
How has tidal marsh restoration affected benthic invertebrate communities? In particular, how are invasive mollusks affecting zooplankton production in restored tidelands?	Document and evaluate water quality conditions in restored subtidal aquatic habitats. Assess density and foraging effectiveness of Asian clams or other invasive species that colonize restoration sites. Periodically repeat surveys to determine if delayed colonization occurs.
What is the relationship between life cycles of listed fish and those of invasive mollusks?	Identify constraints limiting larval transport, settlement and establishment of invasive mollusks; the role of nutrients in facilitating invasion; and potential control mechanisms for invasive mollusks.
To what extent does intertidal wetland restoration result in changes in contaminants that could affect listed fishes?	Compare contaminant concentrations at representative sites in/near restored areas before and after restoration has occurred. Must occur prior to restoration, and following restoration, with sufficient sampling intensity over a variety of hydrological conditions to allow inferences to be made about a range of water-year types.
How effectively do minimization measures limit production and mobilization of methylmercury from tidal restoration sites and the food web?	A connected group of studies will be needed, likely at a representative selection of restoration sites. Studies will evaluate wetland management strategies intended to minimize methylation, evaluate the ecological fate of wetland-generated methylmercury, evaluate the biological thresholds for mercury exposure for listed species to guide methylmercury objectives and Delta wetland management priorities, and evaluate the effectiveness of site screening.
What are the most effective designs of tidal restoration sites to achieve tidal flow velocities that preclude rooting by invasive aquatic vegetation (IAV)?	Resolution of this question requires conducting a linked series of studies: (1) empirical and lab studies to determine flow constraints on rooting of IAV species of concern, (2) model studies to assess velocity field for alternative restoration site design, and (3) field tests in restoration site projects.
How are restored natural communities being affected by IAV and have there been changes in existing areas of IAV presence?	Evaluate the effect of tidal restoration on the establishment of IAV in subtidal aquatic habitats. Evaluate whether or not there have been changes in the abundance and distribution of IAV that could be related to the Action (e.g., changes in Delta hydrodynamics).
Is it feasible to create conditions that favor the growth of native pondweeds (Stuckenia spp.) rather than IAV?	Various approaches exist to address this topic, potential ones include (1) evaluate environmental conditions that support native pondweed stands, focusing on abiotic factors (particularly salinity) that determine growth and distribution of native pondweeds, (2) evaluate how future salinity changes affect growth and distribution of pondweeds and Egeria; (3) determine environmental conditions and abiotic factors that favor Stuckenia over Egeria, (4) evaluate to what extent restoration sites can be designed to encourage colonization and growth of native pondweeds while discouraging Egeria, (5) determine the potential for native pondweed stands to contribute to

Key Uncertainty	Potential Research Actions
	restoration of native communities and ecosystem functions in the Delta, and (6) determine if the epifaunal invertebrate assemblages supported by native pondweed stands provide substantial foraging and cover benefits in comparison with Egeria.
Do juvenile sturgeon use restored tidal wetlands?	Capture and acoustically tag juvenile sturgeons in Action Area, then track movement using existing hydroacoustic array. Assess fraction of time in or adjacent to restored tidal wetlands. Begin the 3-5 year-long study when 20% of the tidal wetland restoration acreage is achieved.

Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration

Key Uncertainty	Potential Research Actions
How is predation affecting listed fishes in restored channel margin habitat?	Quantify abundance of nonnative fishes in restored channel margins. Assess effects of nonnative fish predation on listed species in restored sites. Identify ways to avoid and minimize those impacts.
Does channel margin enhancement contribute to an increase in survival of fry-sized Chinook salmon in restored river reaches?	At representative channel margin enhancement sites, mark and recapture fry-sized Chinook salmon. This work should include collection of 3-5 years of data before implementation at the site in order to establish a baseline condition capturing years with varying hydrology and an additional 3-5 years of data collection after the channel margin enhancement has been constructed.
How frequently are channel margins enhanced under the CWF inundated and how frequently are existing riparian and wetland benches inundated? How do these frequencies change as a result of the CWF?	Develop, in collaboration with USFWS, NMFS and DFW, a study to more precisely define this uncertainty and resolve it using a combination of modeling and field data collection.

Appendix 6—Delta Outflow

The Outflow Focus areas are a structured element that will assist in determining initial flow criteria for CWF. Any revisions to the operating criteria would be enacted according to the adaptive management process described in this Program. There are three outflow focus areas; two address summer and fall outflow and their importance to Delta Smelt and the other addresses spring outflow and its importance to longfin and Delta Smelt. (See the December 2013 public draft of BDCP Section 5.5.1.1.2, *Fall X2 Outflow Process*, for an explanation of the importance of the fall outflow to Delta Smelt, the potential outcomes associated with each branch of the fall outflow topic, and the prevailing sources of uncertainty in those outcomes. The December 2013 public draft of BDCP Section 5.5.2.1.1, *Spring Outflow Process*, provides the corresponding discussion for longfin smelt.)

Fall X2

Resolution of the fall X2 questions requires ascertaining Delta Smelt's fall outflow needs to determine what is needed to avoid jeopardy and adverse modification to Delta Smelt critical habitat. The fundamental premise is that Delta Smelt abundance can be improved by providing fall outflow consistent with the current RPA.

Resolution of the fall X2 questions requires the following process:

1. Convert existing conceptual models to a spatially explicit numeric model using studies that calibrate transitions between life stages within the conceptual model (Newman life-cycle model, USFWS in development).

2. Develop a numerical model based on Bever et al. (2016) to evaluate a range of scenarios that use various outflow values and various configurations of tidal restoration to describe flow-habitat equivalency.

The conceptual model for Delta Smelt performance is based upon the habitat metrics presented in the objective in Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF), which states:

Provide a monthly average of at least 37,000 acres of open-water habitat in hydrologically wet years, and at least 20,000 acres of connected open-water habitat in hydrologically above-normal years, of habitat surface area during July–November that is between 1-6 psu. This habitat will additionally meet all of the following criteria: extensive vertical circulation including gravitational circulation, contiguous with other open-water habitat, lateral mixing, and other hydrodynamic processes keeping Secchi disk depths less than 0.5 meters, high calanoid copepod densities (over 7,000 per cubic meter), hydrologically connected to substantial tidal marsh areas, and maximum water temperatures less than 25°C.

The habitat criteria dealing with hydrodynamics are intended to ensure sufficient turbulence to maintain water turbidity and thereby attain compliance with the Secchi disk criterion, so the criteria expressed in this objective become salinity, Secchi disk depth, calanoid copepod density, proximity to tidal marsh, and water temperature. These habitat suitability criteria can be measured in a spatially explicit manner to determine the acreage of qualifying habitat available under a given set of environmental conditions.

Table 1. Key Questions and Possible Investigative Approaches to Address Fall Outflow Management

Key Questions	Possible Investigative Approaches
Are there biases in the IEP survey data? How should the survey data be utilized if biases do exist?	Convene a workshop to discuss possible survey problems and identify opportunities to address with existing data.
Under what circumstances does survival in the fall affect subsequent winter abundance?	Quantitatively determine the contribution of Delta Smelt survivorship in the fall to inter-annual population variability. Review available lifecycle models for applicability.
Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of Delta Smelt?	Investigate the relationship between fall outflow and the relative change in Delta Smelt abundance using univariate and multivariate and available historic data.
How much variability in tidal, daily, weekly, and monthly fluctuations in fall X2 is attributable to water project operations?	Use hydrological modeling tools to determine the prospective locations of X2 in the fall under circumstances with and without project operations. An analysis of historical data will also be carried out to examine outflow during periods when the projects were required to meet specific outflow requirements, to evaluate the degree of control that has been possible at various time scales.
Under what circumstances is survival of Delta Smelt through the fall related to survival or growth rates in previous life stages?	Compare Delta Smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data are being collected as part of the Fall Outflow Adaptive Management Plan (FOAMP).
Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of Delta Smelt during the fall?	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Another option is to test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, as well as work by Kimmerer, Burnham & Manly.
Can an index based on multiple habitat attributes provide a better surrogate for Delta Smelt habitat than one based only on salinity and turbidity?	Review approaches in existing literature. There may be competing approaches that will be simultaneously pursued, depending on expert advice. One possible approach is to develop suitability index curves and combine geometrically to create a habitat quality index. Data from areas where Delta Smelt are frequently observed will be utilized to assess habitat quality.
Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on Delta Smelt survival?	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of Delta Smelt during the fall.
Source: Collaborative CAMT (2014)	

Spring Outflow

Based on the fall midwater trawl indices of longfin smelt abundance, there are significant correlations between Delta outflow during the winter-spring months and subsequent longfin smelt abundance in the fall (Rosenfield and Baxter 2007; Kimmerer et al. 2009; Baxter et al. 2010; Rosenfield 2010). Particular attention in CWF is focused on resolution of the spring outflow needs to avoid jeopardy and achieve the full mitigation standard for longfin smelt required under CESA. The fundamental premise for this is that longfin smelt performance can be improved, thereby improving Longfin Smelt abundance, by either increasing spring outflow, improving food availability by restoring tidal habitat or improving water quality (ammonium reduction), or by some combination of these changes. (See the December 2013 public draft of BDCP Section 5.5.2.1.1, *Spring Outflow Process*, for detailed explanation of the conceptual models underlying these options.) In the case of longfin smelt, it is not clear which particular months of increased outflow yield beneficial outcomes (e.g., winter vs. spring), whether increased outflow needs to be sustained or if they can be produced by pulse flows, or if increased outflow must occur in the context of other preconditioning circumstances such as availability of particular foraging resources. These uncertainties point to the need for substantial research to elucidate mechanisms whereby flow increases can benefit longfin smelt, prior to resolution of the spring outflow.

Resolution of the spring X2 questions requires research to answer the following:

- What are the mechanisms by which spring outflow is important for longfin smelt recruitment?
- What flow is required to make each mechanism work?
- What are the important sources of mortality for longfin smelt?
- Is there evidence that habitat restoration will increase longfin smelt recruitment per unit of spring outflow?
- How do different outflow operations (e.g., pulse flows vs. more continuous flow) in the spring affect longfin smelt recruitment?

Studies and Monitoring Supporting the Spring Outflow

Winter-spring outflow has remained positively correlated with the subsequent fall's abundance index of longfin smelt, despite fewer longfin smelt being produced per unit of outflow as a result of prey abundance after *Potamocorbula amurensis* invasion and even when corrected for estimated spawner abundance. A scientific understanding of what this flow correlation represents could be achieved with modeling studies. The modeling approach may facilitate the investigation of how different outflow operations (e.g., pulse vs. more continuous flow) might affect distribution and retention of young longfin smelt, should a retention mechanism be deemed of high importance.

Monitoring and research of food (i.e., zooplankton and other prey) produced within areas restored under the current BiOps and EcoRestore, and the extent to which this food is exported from these areas and consumed by longfin smelt, would be undertaken to inform the potential for habitat restoration to produce an increase in the number of longfin smelt per unit of spring outflow. Potential monitoring research actions supporting this work are described further in *Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species*, and ultimately would aim to quantify the fraction of longfin smelt production stemming from restored marsh areas (e.g., with studies of the isotopic signature of longfin smelt tissue in relation to the isotopic signature of marsh-derived phytoplankton and zooplankton). Resolution of the spring X2 questions then requires the following process:

1. Perform studies to better understand how longfin smelt use the Bay-Delta estuary.
2. Perform studies to better understand what habitat attributes are supporting longfin smelt performance and which ones are not.

3. Develop and calibrate a spatially explicit habitat suitability model to compare longfin smelt performance to a range of scenarios that use various outflow values and various configurations of tidal restoration to describe flow-habitat equivalency.

4. Refine quantitative life cycle models using the information from steps 1-3.

Longfin smelt distribution in the estuary could be better understood than it is presently. The current status of knowledge is summarized by Hobbs et al. (2014), who also identified a 5-year research plan incorporating a range of studies to resolve the principal remaining uncertainties (Table 1). These studies will also produce progress toward a better understanding what habitat attributes are supporting longfin smelt, but it is likely that a second round of studies, incorporating results from the work proposed by Hobbs et al. (2014), will be needed to improve that understanding to the point at which existing conceptual models are ready for transformation into revised numerical models. Further studies will likely be needed to achieve calibration and to compare flow scenarios in a manner similar to that described above for the fall X2.

Table 2. Research Questions Addressed in Longfin Smelt Study Plan of Hobbs et al. (2014)

Key Questions	Investigative Approaches
Longfin Smelt distribution and regional contribution to overall abundance	1. Do Longfin Smelt spawn in Bay tributaries? H_o : Longfin Smelt will not be found to spawn in Bay tributaries. H_a : Longfin Smelt will be found to spawn in Bay tributaries. 2. If spawning occurs in Bay tributaries, are there substantial differences in production during wet versus dry years? H_o : The magnitude of longfin smelt production in Bay tributaries does not vary by water year type. H_a : The magnitude of longfin smelt production in Bay tributaries is substantially higher in wet years. 3. Is longfin smelt larval production in Bay tributaries sufficient to influence the abundance indices of YOY and adult (age 1+) longfin smelt captured by DFW surveys in the estuary? How does the contribution of Bay tributary spawning to year class strength vary in response to variation in hydrologic conditions (e.g., wet vs. dry years, etc.)? H_o : Larval production in Bay tributaries does not influence the abundance index of YOY and/or adult longfin smelt. H_{a1} : Larval production in Bay tributaries does influence the abundance index of YOY and adult longfin smelt. H_{a2} : The magnitude of tributary spawning and the survival of longfin smelt spawned in Bay tributaries (i.e., contribution of tributary spawning to population abundance of juveniles and adults) varies among years in response to hydrologic conditions. 4. Will Bay tributaries have unique geochemical signatures that allow identification of regional geographic areas of production (e.g., differentiate production in Bay tributaries from Sacramento and San Joaquin river production) and, under the best case scenario, have geochemical signatures that would allow differentiation of production among individual tributaries? H_o : Geochemical signatures will not differ among the Sacramento and San Joaquin rivers and Bay tributaries. H_a : Geochemical signatures will be sufficiently different to discriminate between the Sacramento and San Joaquin rivers and Bay tributaries and possibly among individual Bay tributaries.

Key Questions	Investigative Approaches
	5. If geochemical signatures are discernible among geographical areas and salinity zones, what is the relative contribution of larvae rearing in different geographical areas and salinity zones to the YOY and adult (age 1+) population? H_o: Most longfin smelt production originates from upstream areas, specifically the low salinity zone of the Sacramento and San Joaquin rivers. H_a: Bay and Bay tributary production is a major contributor to the longfin smelt population. 6. Will geochemical signatures of the Bay differ from the nearshore marine coastal waters such that fish moving into or out of San Francisco Bay could be identified? H_o : Geochemical signatures of longfin smelt in San Francisco Bay will not differ from the nearshore coastal environment. H_a : Geochemical signatures of longfin smelt in San Francisco Bay will be significantly different from the nearshore coastal environment.
Longfin Smelt vertical	7. Do longfin smelt undergo a diel (daily) or tidal migration in the migration behavior water column? If present, does this behavior vary regionally (i.e., in central San Francisco Bay vs. Suisun Bay)? H_0: Longfin smelt do not exhibit any diel or tidal vertical migration behavior: catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) do not vary between night and day, or over tidal cycles. H_{a1}: Longfin smelt do exhibit diel or tidal vertical migration behavior: catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) varies between night and day, or over tidal cycles, or both. H_{a2}: Longfin smelt diel or tidal vertical migration behavior varies between regions of the estuary. 8. Is Longfin smelt catch affected by water transparency? H_0: Water transparency does not influence MWT or otter trawl catch of longfin smelt. H_a: Longfin smelt catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) varies with water transparency, with decreased catch in the upper water column at high levels of water clarity. This effect of water transparency would result in variation in the catch ratio of BWT:OT across water clarity levels.

Appendix 7—Groups Involved In Each Phase of the Adaptive Management Program

<u>Phase 1: Plan.</u> Facilities and Operations, Restoration/Ecosystem Management, and Monitoring and Research.

- Interagency Implementation Coordination Group (IICG convened by DWR and Reclamation) (NMFS, USFWS, DFW, DWR, BOR, SWC, SLDMWA).
  - Fish Facilities Design and Evaluation Teams (current BiOps/CESA, CWF)
  - NDD Facility design and associated engineering and evaluation (CWF)
  - Screen and Bypass criteria effectiveness evaluation Team (CWF)
  - Existing South Delta fish facilities Teams (current BiOps/CESA)
- Tidal Wetland Restoration Implementation (EcoRestore, current BiOps/CESA, CWF)
  - Fish Restoration Program (FRP) and State and Federal Contractors Water Agency (SFCWA) Tidal Wetland Restoration Project design and implementation Teams (current BiOps/CESA)
  - Fisheries Agencies Strategy Team (FAST)
  - FRP Monitoring (Tidal Restoration monitoring Project Work Team)
  - CWF tidal habitat mitigation
- Yolo Bypass Fishery Enhancement Plan Design and Implementation (current BiOps/CESA)
  - Yolo Bypass Cache Slough Partnership
- Interagency Ecological Program (current BiOps/CESA, CWF, Water Quality Control Plan)
  - Monitoring and research to support SWP/CVP operations, maintain permit compliance and address emerging science questions related to the health of the Delta and listed species affected by operations.
  - Organizational structure
- Current BiOps/CESA Implementation (USFWS, DFW, NMFS, Reclamation, DWR)
  - Biannual Review of operations and implementation of the current BiOps' RPA actions for purposes of change within Adaptive Management provisions (LOBO Independent Reviews conducted by DSP)
- Collaborative Science and Adaptive Management Process (current BiOps/CESA)
- Delta Science Program/Delta Science Plan
  - Interim Science Action Agenda – Priority Science for the Delta

  - Independent Review Panels (LOBO) regarding implementation of current BiOps and CWF
  - State of Bay-Delta Science
  - Host IEP Lead Scientist
- DFW Proposition 1 Delta Grants Program
- SFWCA Science Program
- Delta Regional Monitoring Program

Phase 2: Assess. Collaborative Science, Synthesis and Performance Assessment to Inform Management Direction and Change As Uncertainty Is Addressed.

- CSAMP
- Delta Stewardship Council
  - Delta Interagency Implementation Committee
- IEP Management Analysis Synthesis Team Reports (MAST, SAIL)
- LOBO reviews
- DSP Independent Reviews of CSAMP and other science products.
- Delta Independent Science Board review of Delta Science
- State of Bay Delta Science

Phase 3: Integrate. Management and Science Integration.

  - Five Agencies
  - CSAMP
  - IICG
  - DSP

Phase 4: Adapt. Process for Making Adaptive Management Changes.

- Five Agencies, based on their authorities related to SWP/CVP (current BiOps/CESA, CWF)
- SWRCB

**AGREEMENT FOR IMPLEMENTATION OF AN ADAPTIVE MANAGEMENT PROGRAM
FOR PROJECT OPERATIONS**

1.0 PURPOSES OF THIS AGREEMENT

Scientific uncertainty exists regarding the Delta ecosystem, including the effects of Central Valley Project/State Water Project (CVP/SWP) operations and the related operational criteria on the Protected Species and their habitats. To address this uncertainty, the Parties to this agreement will establish a robust program of collaborative science, monitoring, and adaptive management. The purposes of this Agreement are to set forth the Parties shared intentions to: 1) confirm the Parties' commitment to implementation of an Adaptive Management Program (Program) for the California Water Fix, including the Adaptive Management Framework (attached), and Current Biological Opinions on the combined operations of the Central Valley and State Water Projects consistent with the Biological Opinions and Permits, 2) clarify the provisions related to Adaptive Management expressed in related documents and the processes the Parties intend to follow to ensure successful implementation of the Adaptive Management Program, and 3) delineate responsibilities among the Parties in implementing the Adaptive Management Program.

2.0 PARTIES TO THIS AGREEMENT

This Agreement is made and entered into by and among the State of California, acting through the California Department of Water Resources (DWR) and the California Department of Fish and Wildlife (CDFW) of the State of California Natural Resources Agency, certain State Water Project and Central Valley Project contractor water agencies (SWP/CVP Contractors), and the United States Bureau of Reclamation (Reclamation) of the United States Department of the Interior, the United States Fish and Wildlife Service (USFWS) of the United States Department of the Interior, and the National Marine Fisheries Service (NMFS) of the United States Department of Commerce (collectively referred to as the Parties).

3.0 AUTHORITIES

3.1.1 CDFW

CDFW is a State Agency within the California Natural Resources Agency charged with responsibility for administering the California Endangered Species Act (CESA). CDFW enters into this Agreement pursuant to CESA and its implementing regulations.

3.1.2 DWR

DWR is a State Agency within the California Natural Resources Agency charged with responsibility for operating and maintaining the State Water Project's existing delta facilities, including the Clifton Court Forebay and the Banks Pumping Plant, and would be responsible for operating new State Water Project delta facilities contemplated under the proposed California WaterFix project. DWR enters this Agreement pursuant to the Burn-Porter Act and other applicable laws of the State of California.

3.1.3 NMFS

NMFS is the federal agency within the United States Department of Commerce charged with responsibility for administering the ESA and providing for the conservation of federally listed anadromous and marine species and their habitats. NMFS enters into this Agreement pursuant to the ESA and its implementing regulations and pursuant to the Fish and Wildlife Coordination Act.

3.1.4 Reclamation

Reclamation is a federal agency within the United States Department of the Interior charged with responsibility for operating and maintaining the Central Valley Project's (CVP) existing delta facilities, and would be responsible for coordinating operations with DWR on the new State Water Project delta facilities contemplated under the proposed California WaterFix project. Reclamation enters this Agreement pursuant to the Rivers and Harbors Act of August 30, 1935, 49 Stat. 1028, 1038 (1935), the Rivers and Harbors Act of August 26, 1937, 50 Stat 844, 850 (1937), as amended and supplemented by various laws, including the Central Valley Project Improvement Act (CVPIA), Public Law 102-575, 106 Stat. 476 (1992).

3.1.5 SWP/CVP Contractors

The SWP/CVP Contractors are public agencies that receive water under contract from the State Water Project and Central Valley Project. These public water agencies fund operation and maintenance of the existing State Water Project and Central Valley Project delta facilities, and will fund a portion of the costs to implement the proposed California WaterFix project, including a portion of the Adaptive Management Program. The SWP/CVP Contractors enter this Agreement pursuant to their individual authorizing legislation under the California Water Code.

3.1.6 USFWS

USFWS is a federal agency within the United States Department of the Interior charged with responsibility for administering the federal Endangered Species Act (ESA) and providing for the conservation of federally listed fresh water and semi-anadromous aquatic and terrestrial species and their habitats. USFWS enters into this Agreement pursuant to the ESA, the Fish and Wildlife Coordination Act, and the Fish and Wildlife Act of 1956.

4.0 DEFINITIONS

The following terms as used in this Agreement will have the meanings set forth below. Terms specifically defined in State or federal statutes, including the ESA or CESA, or the regulations adopted under those statutes, shall have the same meaning when used in this Agreement. Where such terms are defined in this Section 4.0, those definitions may elaborate on, but are not intended to conflict with, such statutory or regulatory definitions.

4.1 Action

"Action" means the following components that are subject to the Adaptive Management Program:

i. Operation of CVP/SWP facilities within the Delta under
   1. Biological Opinions and Permits existing prior to the Conveyance Facilities becoming operational
   2. new Biological Opinions and Permits for California WaterFix

ii. Design and operations of fish facilities (including existing fish facilities and intake screens)

iii. Habitat restoration and non-operational mitigation relative to in-Delta CVP/SWP operations under:
   1. Biological Opinions and Permits existing prior to the Conveyance Facilities becoming operational
   2. new Biological Opinions and Permit for California WaterFix

iv. Other CVP/SWP-related actions as agreed by the "Interagency Implementation Coordination Group"

v. Monitoring associated with all of the foregoing within the bounds of the Biological Opinions and Permits.

4.2 Adaptive Management

"Adaptive Management" is defined in California Water Code, section 85052, and means "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvements in management planning and implementation of a project to achieve specified objectives."

4.3 Adaptive Management Changes

"Adaptive Management Changes" means changes to monitoring schema and management actions that are encompassed in the Action and include changes intended to facilitate hypothesis-driven experiments and changes intended to be implemented on an ongoing basis subject to further adaptive management in the future.

4.4 Agreement

"Agreement" means this Agreement for Implementation of an Adaptive Management Program.

4.5 Annual Monitoring and Research Plan

"Annual Monitoring and Research Plan" means the annual plan prepared by the IICG Manager that identifies all of the monitoring and research actions to be carried out by IEP, CSAMP, or other Collaborative Science Workgroups related to the Biological Opinions and Permits during the implementation year in support of the Adaptive Management Program and includes, with respect to the subset of those monitoring and research actions initiated by the IICG, if any, budgets, funding sources, and timelines for those actions.

4.6 Application

"Application" means an application prepared by DWR in accordance with California Code of Regulations title 14, § 783.2 and § 783.3 to request the issuance of an incidental take permit by CDFW for authorization of take associated with the SWP operations in the Delta or the California WaterFix project under California Fish & Game Code § 2081(b) or a request for a consistency determination related to the 2008 Biological Opinion and 2009 Biological Opinion, submitted under California Fish & Game Code § 2080.1.

4.7 Biological Assessments

"Biological Assessments" means the information prepared by or under the direction of Reclamation or other federal action agency concerning federally listed and proposed species and designated and proposed critical habitat that may be present in the Action Area and the evaluation of potential effects of the action on such species and habitat, including the August 2008 Biological Assessment on the Continued Long-term Operations of the Central Valley Project and the State Water Project and the 2016 Biological Assessment for the California WaterFix.

4.8 Biological Opinions

"Biological Opinions" means the Biological Opinions that are issued by USFWS and NMFS to complete the Section 7 consultations associated with the Action, including the 2008 Biological Opinion on the Long-Term Operational Criteria and Plan (OCAP) for coordination of the Central Valley Project and State Water Project issued by USFWS ("2008 Biological Opinion"), the 2009 Biological Opinion on the Long-Term Operations of the Central Valley Project And State Water Project issued by NMFS ("2009 Biological Opinion"), the 2017 Biological Opinions for the California WaterFix issued by NMFS and USFWS, and any subsequent amendments, revisions or superseding Biological Opinions.

4.9 Central Valley Project or CVP

"Central Valley Project" or "CVP" means the Central Valley Project, as defined in 3404(d) of Title XXXIV of Public Law 102-575, and operated by Reclamation.

4.10 CESA

"CESA" means the California Endangered Species Act (Cal. Fish & Game Code §§ 2050–2116) and all rules, regulations and guidelines promulgated pursuant to that Act.

4.11 Collaborative Science Workgroups

"Collaborative Science Workgroups" means the Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team (CSAMP/CAMT), Interagency Ecological Program (IEP) and associated scoping and project work teams, Fish Facilities Design and Evaluation Team(s), and Fish Restoration Program/State Federal Water Contractors Association Tidal Wetland Restoration Project Design and Implementation Team(s). Additional workgroups or technical subgroups may be formed where appropriate and useful to carry out the collaborative science efforts.

4.12 Consensus

"Consensus" means that all members of the Interagency Implementation Coordination Group agree to the proposal at hand.

4.13 Conveyance Facilities

"Conveyance Facilities" means the proposed new delta conveyance facilities described as part of the Proposed Action in the 2016 Biological Assessment for the California WaterFix and as further described as Alternative 4A in the 2016 Final Environmental Impact Report/Environmental Impact Study for the Bay Delta Conservation Plan/California WaterFix.

4.14 Delta or Sacramento–San Joaquin Delta

"Delta" or "Sacramento–San Joaquin Delta" means the Sacramento–San Joaquin Delta as defined in California Water Code § 85058.

4.15 Designated Representative

"Designated Representative" means in the case of DWR and CDFW the official representative designated by the Governor to act on his behalf, and in the case of the SWP/CVP contractors the official representative designated by an elected board of directors to act on their behalf.

4.16 ESA

"ESA" means the federal Endangered Species Act of 1973, as amended (16 U.S.C §§ 1531–1544) and all rules, regulations and guidelines promulgated pursuant to that Act.

4.17 Fish and Wildlife Agencies

"Fish and Wildlife Agencies" means USFWS, NMFS, and CDFW.

4.18 Interagency Implementation Coordination Group

"Interagency Implementation Coordination Group" (IICG) primary responsibility will be for coordination and implementation of the Adaptive Management Program. The membership and functions of the Interagency Implementation Coordination Group are described in Section 5.3.2 of this Agreement.

4.19 IICG Manager

"IICG Manager" means the individual with responsibility for administration and management of the Adaptive Management Program. The IICG Manager's functions are described in Section 6.1.

4.20 NPPA

"NPPA" means the California Native Plant Protection Act (Cal. Fish & Game Code §§ 1900–1913) and all rules, regulations, and guidelines promulgated pursuant to that Act.

4.21 Party and Parties

"Party" and "Parties" mean the signatories to this Agreement, individually and collectively.

4.22 Permits

"Permits" means, collectively, the Consistency Determinations issued to DWR pursuant to 2080.1 of the California Fish & Game Code related to the 2008 and 2009 Biological Opinions, the 2009 Incidental Take Permit for take of Longfin Smelt issued to DWR pursuant to Section 2081(b) of the California Fish & Game Code and any successor to that permit, an Incidental Take Permit issued to DWR for the California WaterFix project, and the related NPPA permit issued to DWR pursuant to sections 1907 and 1908 of the California Fish & Game Code.

4.23 Protected Species

"Protected Species" means the federally listed species that are covered under a Biological Opinion and the State-listed or candidate species for which take is authorized under a Permit. Protected Species are listed in Exhibit A to this Agreement.

4.24 Operational Opportunities

Operational Opportunities means changes to the Action that may occur within one year, are considered on a case-by-case basis and are for the purpose of addressing a specific short-term ecological or water supply opportunity, without reducing the ability of the SWP or CVP to deliver water, imposing additional funding obligations on the SWP/CVP Contractors, or adversely impacting Protected Species.

4.25 State Water Project or SWP

"State Water Project" or "SWP" means the State Water Project as authorized by California Water Code sections 12930 *et seq*. and California Water Code sections 11100 *et seq*. and operated by DWR.

4.26 SWP/CVP Contractors

"SWP/CVP Contractors" means the individual water agencies that hold water delivery contracts with DWR for SWP water (SWP Contractors) or Reclamation for CVP water (CVP Contractors), or an entity comprising such agencies, and that have executed this Agreement. SWP/CVP Contractors may include the State and Federal Water Contractors Agency (SFWCA), a joint exercise of powers agency, and the San Luis & Delta Mendota Water Authority (SLDMWA), a joint exercise of powers agency. The SWP/CVP Contractors are listed on Exhibit B to this Agreement.

5.0 ADAPTIVE MANAGEMENT PROGRAM

5.1 Purpose

Scientific uncertainty exists regarding the Delta ecosystem, including the needs of the Protected Species, the effects of CVP/SWP operations on those species and their habitats, and the related operational criteria and other actions intended to minimize or mitigate those effects on the Protected Species. The Adaptive Management Program described here and in the Adaptive Management Framework (Exhibit C) is being implemented to enhance application of science to support decision making related to the operations of the CVP and SWP and to advance the co-equal goals of the Delta Reform Act of 2009, providing a more reliable water supply for California and protecting, restoring and enhancing the Delta ecosystem. Implementation of the Adaptive Management Program will support the SWP/CVP operations by helping to address scientific uncertainty where it exists, and as it relates to the benefits and impacts of the construction and operations of the Conveyance Facilities and existing CVP and SWP Delta facilities.

The broad purposes of the Adaptive Management Program are to: 1) promote collaborative science, 2) guide (by identifying, prioritizing, and funding) the development and implementation of scientific investigations and monitoring for both permit compliance and adaptive management, 3) apply new information and insights to management decisions and actions, and recommend changes in the Action to DWR and Reclamation, and 4) establish a long-term, funded science infrastructure,.. The Program relies upon existing and new Collaborative Science Workgroups, working in close coordination with each other, to identify and prioritize needed scientific investigations and monitoring.

5.2 Scope of Adaptive Management Program and Actions

5.2.1 Actions

The focus of the Adaptive Management Program is on the Action. Adaptive management changes would be implemented generally on an annual or longer-term basis. As of this time, the Adaptive Management Program is not intended to apply to real-time operations.

5.2.2 Other CVP and SWP-related Actions

Actions subject to Adaptive Management may also include other CVP and SWP-related actions as agreed by the Interagency Implementation Coordination Group.

5.2.3 Collaborative Science

The IICG, working in coordination with the Collaborative Science Workgroups, will identify and prioritize potential Adaptive Management Changes to be addressed by the collaborative science efforts. Collaborative science efforts will address uncertainties related to the effects of CVP/SWP operations, operational criteria and other actions intended to minimize or mitigate effects to Protected Species to inform implementation of such operations, measures, and actions to provide water supply reliability benefits and maintain compliance with CESA and the ESA. With respect to the Adaptive Management Program, collaborative science will have the following primary functions:

- lead active evaluation through studies, monitoring, and testing of reasonable current and new hypotheses associated with key water operating parameters, habitat restoration, and other minimization and mitigation measures;
- gather and synthesize relevant scientific information;
- develop new modeling or predictive tools to improve water management in the Delta; and
- inform the testing and evaluation of alternative operational strategies and other management actions to improve performance from both biological and water supply perspectives.

The IICG, through the IICG Manager, will report all internal decisions to DWR and Reclamation in the form of meeting notes.

5.2.4 Monitoring and Research

Monitoring and research associated with the Action will be used to facilitate evaluation of effects of components of the Action and guide determinations whether to make changes to improve them. Compliance and effectiveness monitoring program will include the elements as described in the Biological Opinions, Permits, and Applications.

5.2.5 Routine and Administrative Matters

Implementation of the Adaptive Management Program will include decisions on routine scientific matters and administration that do not result in substantive changes to the Action or to the Adaptive Management Program itself, or requirements of the Biological Opinions or Permits. Such routine and administrative matters include, for example, developing and distributing public communication products to assure transparency and determining meeting frequency and format(s). Decisions on these matters will be made by consensus.

5.3 Interagency Implementation Coordination Group

5.3.1 Purpose and Function

An Interagency Implementation Coordination Group shall be established as described in this Section 5.3. The Interagency Implementation Coordination Group shall have primary responsibility for support, coordination and implementation of the Adaptive Management Program and shall:

- Be responsible for supporting those priority science needs identified by Collaborative Science Workgroups that the IICG determines are necessary to carry out the Adaptive Management Program.
- Identify priority science needs not addressed by Collaborative Science Workgroups, and route requests for those science needs with, if necessary, appropriate funding to the appropriate entity with the capacity to complete them, or at its discretion, the IICG may initiate work to address priority science needs using its own staff, staff from its members, or any appropriate entity.
- Establish mechanisms for developing and agreeing to Adaptive Management Changes, such as through preparation of an annual adaptive management work plan or development of specific proposals that identify the compliance implications of the proposed change.
- Promote and fund scientific activities/monitoring that the IICG determines are necessary to carry out the Adaptive Management Program.
- Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency.
- Refer management related actions or proposals, as appropriate, to the Delta Science Program for review by an independent science panel for example, the Long-term operations biological opinions independent review panel (LOBO IRP)).
- Assure transparency consistent with the requirements of the Delta Plan.
- Review funding commitments and any implementation issues relative to priorities and recommendations from the Delta Science Program, CAMT, or related adaptive management fora.
- Identify and secure needed infrastructure and resources to support scientific activities/monitoring.
- Review and approve the Annual Monitoring and Research Plan and progress reports.
- Maintain an Operational Opportunities subcommittee made up of one technical representative from each of its IICG members. The subcommittee shall consider all Operational Opportunities requests by members within 24 hours and simultaneously issue a recommendation to the IICG and the agency with authority to implement the

Operational Opportunities.

5.3.2 Membership and Composition

The Interagency Implementation Coordination Group shall be convened by DWR and Reclamation and chaired by the IICG Manager and shall consist of one representative each of Reclamation, USFWS, and NMFS, and one Designated Representative each of DWR, CDFW, a participating SWP Contractor, and a participating federal CVP Contractor.

5.3.3 Decision-making and Review Process

Adaptive management recommendations by the IICG shall be by consensus of the representatives. In the event of a dispute within the IICG regarding different hypotheses, lines of evidence, or interpretations of science and/or data related to a proposed Adaptive Management Change, any member of the IICG may initiate a non-binding process for a review concerning the matter in dispute by providing IICG members with a written notice of dispute that describes the nature of the dispute and options that may be available to help resolve the matter. In such case, to facilitate dispute resolution the IICG will meet and confer to consider these options and to see if further collaborative work can be undertaken to determine whether agreement can be reached on the matter.

In the event that resolution of the dispute cannot be reached within the IICG, review of the issue in dispute may occur through the presentation of alternative viewpoints as part of the Long-term operations biological opinions annual review or a separate independent science review convened by the Delta Science Program. The members of the IICG, with the assistance of the IICG Manager, will describe the nature of the dispute to be considered by the panel in consultation with the Delta Science Program and the Delta Lead Scientist.

Within 30 days of the completion of panel selection, the parties to the dispute shall present their views in writing. A non-binding opinion shall be issued in writing by a majority of the panel.

Within 30 days of issuance of the panel’s non-binding opinion, the entity with final decision-making authority over the matter shall consider the panel opinions and provide a written response prior to final decision.

To the extent consistent with the purposes of this Agreement and allowed by law the entity with final decision making authority over the matter shall refrain from taking any action to implement its decision until the review process has been completed.

5.3.4 Meetings of the Interagency Implementation Coordination Group

The IICG shall determine its meeting schedule and administrative matters. The IICG Manager shall ensure that a record of IICG meetings and its actions are posted to a website or other appropriate electronic medium to ensure public access. The record should include a list of meeting attendees, meeting agenda, decisions and/or recommendations made, conflicting views, if any, of members, assignments to conduct additional work on a matter, audiovisual presentations or other materials distributed, and other documents relevant to the deliberations of the IICG.

5.3.4.1 Consideration of Adaptive Management Changes

Members of the IICG can propose Adaptive Management Changes to be considered by the IICG. After consideration of the proposal the IICG may propose Adaptive Management Changes to the Action to Reclamation and DWR. Proposed Adaptive Management Changes made by the IICG may or may not require reinitiation of consultation, subsequent consultation and/or amendment of the Permit prior to implementation. The process set out in the Adaptive Management Framework (Attachment X, Appendix 1) shall be used to effectuate any Adaptive Management change to a component of the Action.

5.4 Collaborative Science and Monitoring

Collaborative Science as described in 5.2.3 will be implemented through Annual Monitoring and Research Plans. The IICG Manager will prepare an Annual Monitoring and Research Plan, working in coordination with the Collaborative Science Workgroups. The Plan will be subject to approval by the IICG.

5.4.1.1 Staff Resources

Additional staff resources from DWR, Reclamation, the SWP/CVP Contractors, and the Fish and Wildlife Agencies may be utilized in the discretion of each party to support collaborative science and monitoring, provided such staff have the expertise or technical skills that would enable them to meaningfully contribute to the collaborative science and monitoring tasks.

5.5 Reinitiation of Consultation or Permit Amendment

The Parties recognize and agree that a change to a component of the Action subject to adaptive management as described in this Agreement may require reinitiation of consultation under the ESA or an amendment to the Permit issued for the Action.

The Parties agree that any decision on the operational criteria will be based on the best scientific and commercial data available at that time, including data collected and analysis conducted through the Adaptive Management Program pursuant to this Agreement. If those data and analyses indicate that one or more of the water operations flow criteria in the Biological Opinions or Permits should be changed, Reclamation will, if required, reinitiate consultation pursuant to Section 7 of the ESA and/or DWR will, if required, commence a permit amendment process under California law to modify the operating criteria, as appropriate.

6.0 IMPLEMENTATION STRUCTURE

6.1 IICG Manager

DWR or Reclamation will retain the IICG Manager to assist with implementation of the Adaptive Management Program. The IICG Manager will be selected based on the unanimous recommendation of the Interagency Implementation Coordination Group. The Interagency Implementation Coordination Group will manage the selection process, determine required qualifications, and evaluate the candidates. The IICG Manager may be removed upon the recommendation of a majority of the Interagency Implementation Coordination Group.

The IICG Manager will serve as chair of the Interagency Implementation Coordination Group; organize and support meetings of the Interagency Implementation Coordination Group; engage in regular communication and coordination with Collaborative Science Workgroups, and participate in their regularly scheduled meetings as appropriate, and other external science efforts such as the Delta Science Program; develop budgets and manage efforts funded by the Interagency Implementation Coordination Group. Support DWR and Reclamation in implementing adaptive management changes; and oversee the Adaptive Management Program. The IICG Manager shall also manage preparation of the Annual Monitoring and Research Plan.

6.2 DWR, Reclamation, and the SWP/CVP Contractors

DWR and Reclamation are ultimately responsible for implementation of the Action, including adaptive management changes. DWR, Reclamation, and the SWP/CVP Contractors will be responsible for ensuring that the management and implementation of the Action are carried out consistent with this Agreement, and the Biological Opinions and Permits. DWR, Reclamation, and the SWP/CVP Contractors may assign one or more individuals or entities with day-to-day responsibility for management of the Action.

7.0 MISCELLANEOUS PROVISIONS

7.1 Nature of Agreement

Nothing in this Agreement shall cause, or shall be deemed to cause, any delegation of authority from any Party to this Agreement to any other Party. This Agreement is legally nonbinding and in no way: (i) impairs any Party from continuing its own planning or project implementation; (ii) limits a Party from exercising its regulatory authority in any matter; (iii) infers that a Party's governing body or management will act in a particular manner; or (iv) gives any of the Parties any authority over matters within the jurisdiction of any other Party. Nothing in this Agreement creates any legal rights, obligations, benefits, or trust responsibilities, substantive or procedural, enforceable at law or in equity, by a Party against any other Party, a Party's officers, or any person.

7.2 Relationship to Other Regulatory Requirements

The terms of this Agreement are consistent with and will be governed by and construed in accordance with the ESA, CESA and other applicable State and federal laws. In particular, nothing in this Agreement is intended to limit the authority of USFWS, NMFS and CDFW to seek penalties for violations of, or otherwise fulfill its responsibilities under, the ESA or CESA. Moreover, nothing in this Agreement is intended to limit or diminish the legal obligations and responsibilities of USFWS or NMFS as agencies of the federal government or CDFW as an agency of the State of California.

7.3 References to Regulations

Any reference in this Agreement, the Biological Opinions, or the Permits to any regulation or rule of the Fish and Wildlife Agencies will be deemed to be a reference to such regulation or rule in existence at the time an action is taken.

7.4 Applicable Laws

All activities undertaken pursuant to this Agreement, the Biological Opinions, or the Permits must be in compliance with all applicable local, State and federal laws and regulations.

7.5 Entire Agreement

This Agreement constitutes the entire agreement among the Parties, supersedes any and all other agreements, either oral or in writing, among the Parties with respect to the subject matter hereof, and contains all of the covenants and agreements among them with respect to said matters. Each Party acknowledges that no representation, inducement, promise of agreement, oral or otherwise, has been made by any other Party or anyone acting on behalf of any other Party that is not embodied in this Agreement.

7.6 Severability

In the event one or more of the provisions contained in this Agreement is held to be invalid or illegal by any court of competent jurisdiction, the Parties will meet and confer to determine whether such portion will be deemed severed from this Agreement and the remaining parts of this Agreement will remain in full force and effect as though such invalid or illegal portion had never been a part of this Agreement.

7.7 Amendments

This Agreement may be amended only by the written agreement of all of the Parties.

7.8 No Third Party Beneficiaries

Without limiting the applicability of rights granted to the public pursuant to the ESA, CESA, or other applicable law, this Agreement will not create any right or interest in the public, or any member thereof, as a third party beneficiary thereof, nor will it authorize anyone not a Party to this Agreement to maintain an action at law or equity under the provisions of this Agreement. The duties, obligations, and responsibilities of the Parties to this Agreement with respect to third party beneficiaries will remain as imposed under existing State and federal law.

7.9 Availability of Funds

All Actions required of the United States or its agencies in implementing this Agreement are subject to appropriations by Congress. Nothing in this Agreement shall be interpreted as or constitute a commitment or requirement that the United States or its agencies obligate or pay funds in violation of the Anti-Deficiency Act, 31 U.S.C. § 1341, or other applicable law. Nothing in this Agreement is intended or shall be construed to commit a Federal official to expend Federal funds not appropriated for that purpose by Congress. To the extent that the expenditure or advance of any money or the performance of any obligation of the United States or its agencies, or any Secretary under this Agreement is to be funded by appropriation of funds by Congress, the expenditure, advance, or performance shall be contingent upon the appropriation of funds by Congress that are available for this purpose and the apportionment of such funds by the Office of Management and Budget. No breach of this Agreement shall result and no liability shall accrue to the United States or its agencies or any Secretary in the event such funds are not appropriated or apportioned. Nothing in this Agreement is intended or shall be construed to require the obligation, appropriation, reprogramming, or expenditure of any funds by the United States or its agencies, except as otherwise permitted by applicable law.

Implementation of this Agreement by DWR and CDFW is subject to the availability of appropriated funds. Consistent with applicable law, nothing in this Agreement will be construed by the Parties to require the obligation, appropriation, or expenditure of any money from the Treasury of the State of California. The Parties acknowledge and agree that DWR and CDFW will not be required under this Agreement to expend any State-appropriated funds unless and until an authorized official of that agency affirmatively acts to commit such expenditure as evidenced in writing.

7.10 Duplicate Originals

This Agreement may be executed in any number of duplicate originals. A complete original of this Agreement will be maintained in the official records of each of the Parties hereto.

7.11 Governing Law

This Agreement will be governed by and construed in accordance with the laws of the United States and the State of California, as applicable.

7.12 Due Authorization

Each Party represents and warrants that (1) the execution and delivery of this Agreement has been duly authorized and approved by all requisite action, (2) no other authorization or approval, whether of governmental bodies or otherwise, will be necessary in order to enable it to enter into and comply with the terms of this Agreement, and (3) the person executing this Agreement on behalf of each Party has the authority to execute this Agreement on behalf of that Party.

Executed this day of , 2017 in Sacramento, California.

California Department of Fish and Wildlife	Metropolitan Water District of Southern California
California Department of Water Resources	San Luis Delta Mendota Water Authority
National Marine Fisheries Service	Santa Clara Valley Water District
United States Bureau of Reclamation	State Water Contractors
United States Fish and Wildlife Service	Westlands Water District
Kern County Water Agency	Zone 7 Water Agency

Implementation Schedule for the Adaptive Management Program for the Existing Biological Opinions and CESA Authorizations for the Long-term Operation of the CVP and SWP and for CWF

Background

The California Department of Water Resources (DWR), U.S. Department of the Interior Bureau of Reclamation (Reclamation), California Department of Fish and Wildlife (DFW), U.S. Fish and Wildlife Service (Service), and National Marine Fisheries Service (NMFS) developed several documents to identify potential future costs associated with the implementation of the Adaptive Management Program (AMP) intended to support the existing 2008 Service Biological Opinion and the 2009 NMFS Biological Opinion and the California Endangered Species Act (CESA) authorizations for the Long-term Operation of the Central Valley Project (CVP) and the State Water Project (SWP), as well as in support of the implementation of the California WaterFix (CWF). These costs are conservative estimates intended to provide support for future planning, resource commitments, and decision-making for studies, projects, and monitoring requirements anticipated as a result of ongoing project operations and the operations of components included in the CWF.

Implementation Schedule Description

The cost breakdown documents in support of the AMP do not differentiate costs based on timing of implementation, nor does it take into consideration that some projects may have fixed durations and be completed within a specific timeframe. Therefore, the implementation schedule spreadsheet (attached), while not comprehensive and subject to revision based on science, resources, and information available during any given year of implementation, is intended to provide a depiction of AMP project implementation in 5-year increments beginning at the time of approval by the State Water Resources Control Board and lasting until after CWF facilities are operational. Not all projects listed within a five year increment will last the entire five years; instead, those projects would both begin and end within that 5-year implementation window.

The implementation schedule starts in late 2018/early 2019 based on the schedule tentatively anticipated in association with the State Water Resources Control Board’s hearing and approval process for DWR and Reclamation’s request for the change in the point of diversion in the Delta for CWF. Considering that the Board issues approval or findings in late 2018, the start date would be near the end of Federal fiscal year 2018 (ends September 30) or after the State’s fiscal year 2019 budget is approved in June 2018. Therefore, it is reasonable that 2019 would be the start of any new programs or activities requiring additional funding sources.

Finally, much of what is presented in the schedule presumes that projects that are currently funded and with an anticipated agreement or contract end date would be completed within the first 5-year window between 2019 and 2024. With a few exceptions, such as SAIL or life cycle model development, programs or projects that are not currently funded but are identified in other framework or planning documents typically fall into the 2024-2029 or 2029+ level of implementation. SAIL and life cycle models for Delta Smelt, salmon, and sturgeon are considered a higher priority and are included as earlier implementation actions despite current lack of identified funding sources.

Sources of Funding

DWR and Reclamation commit to securing all required funding from a variety of sources for implementing the Adaptive Management Program, consistent with the Agreement For Implementation Of An Adaptive Management Program For Project Operations. Neither the implementation schedule nor the AMP identify specific funding sources for project implementation, and current funding is not a representation of future out-year funding for these efforts. While DWR and Reclamation fund the majority of current programs for science and monitoring in the Central Valley, this does not preclude the participation of other State or Federal agencies from seeking further funding for program implementation.

Appendix B

Rangewide Status of the Species

and Critical Habitat

Table of Contents

List of Acronyms

Placeholder

1 APPENDIX B—RANGE-WIDE STATUS OF THE SPECIES AND CRITICAL HABITAT

This opinion examines the status of each species that would be adversely affected by the Proposed Action (PA). The status is determined by the level of extinction risk that the listed species face, based on parameters considered in documents such as recovery plans (the Central Valley Recovery Plan (NMFS 2014a)), status reviews (NMFS 2011a,b,c, 2015, 2016a,b,c), and listing decisions. This informs the description of the species' likelihood of both survival and recovery. This section also helps to inform the description of the species' current "reproduction, numbers, or distribution" as described in 50 CFR 402.02. The opinion also examines the condition of critical habitat throughout the designated area, including the various watersheds and coastal and marine environments that make up the designated area, and discusses the current function of the essential physical and biological features.

The designation(s) of critical habitat for most of the species covered in this opinion use(s) the term primary constituent element or essential features. The new critical habitat regulations (81 FR 7414; February 11, 2016) replace this term with physical or biological features (PBFs). The shift in terminology does not change the approach used in conducting a "destruction or adverse modification" analysis, which is the same regardless of whether the original designation identified primary constituent elements, physical or biological features, or essential features. In this opinion, we use the term PBF to mean PCE or essential feature, as appropriate for the specific critical habitat.

1.1 Sacramento River Winter-run Chinook Salmon Evolutionarily Significant Unit

- First listed as threatened (54 FR 32085; August 4, 1989), reclassified as endangered (59 FR 440; January 4, 1994)
- Reaffirmed as endangered (70 FR 37160; June 28, 2005)
- Designated critical habitat (58 FR 33212; June 16, 1993)

The Federally listed evolutionarily significant unit (ESU) of Sacramento River winter-run Chinook salmon (*Oncorhynchus tshawytscha*) and designated critical habitat occurs in the action area and may be affected by the PA.

1.1.1 Species Listing and Critical Habitat Designation History

The Sacramento River winter-run Chinook salmon ESU, currently listed as endangered, was listed as a threatened species under emergency provisions of the Endangered Species Act (ESA) on August 4, 1989 (54 FR 32085), and was listed as a threatened species in a final rule on November 5, 1990 (55 FR 46515). On January 4, 1994, NMFS re-classified winter-run Chinook salmon as an endangered species (59 FR 440). NMFS concluded that winter-run Chinook salmon in the Sacramento River warranted listing as an endangered species due to several factors, including the following:

1. The continued decline and increased variability of run sizes since its first listing as a threatened species in 1989

2. The expectation of weak returns in future years as the result of two small year classes (1991 and 1993)
3. Continued threats to winter-run Chinook salmon (59 FR 440; January 4, 1994)

On June 28, 2005, NMFS concluded that the winter-run Chinook salmon ESU was “in danger of extinction” due to risks to the ESU’s diversity and spatial structure and, therefore, continues to w; arrant listing as an endangered species under the ESA (70 FR 37160). In August 2011, NMFS completed a 5-year status review of five Pacific salmon ESUs, including the winter-run Chinook salmon ESU, and determined that the species’ status should again remain endangered (76 FR 50447; August 15, 2011). The 2011 review concluded that although the listing remained unchanged since the 2005 review, the status of the population had declined over the past 5 years (2005 to 2010) (NMFS 2011c). NMFS completed another status review in May 2016 of 28 listed species of Pacific salmon, steelhead (*O. mykiss*), and eulachon (*Thaleichthys pacificus*), which included the winter-run Chinook salmon ESU (81 FR 33468; May 26, 2016). The 2016 review concluded that the winter-run Chinook salmon ESU status should remain as endangered due to drought and poor ocean conditions since 2011 that have increased the extinction risk of the winter-run Chinook salmon ESU (NMFS 2016a).

The winter-run Chinook salmon ESU currently consists of only one population, which is confined to the upper Sacramento River (spawning below Shasta and Keswick dams) in California’s Central Valley. In addition, an artificial propagation program at the Livingston Stone National Fish Hatchery (LSNFH) produces winter-run Chinook salmon that are considered to be part of this ESU (70 FR 37160; June 28, 2005). Most components of the winter-run Chinook salmon life history (e.g., spawning, incubation, freshwater rearing) have been compromised by the habitat blockage in the upper Sacramento River. All historical spawning and rearing habitats have been blocked since the construction of Shasta Dam in 1943. Remaining spawning and rearing areas are completely dependent on cold water releases from Shasta Dam in order to sustain the remnant population (54 FR 32085; August 4, 1989).

NMFS designated critical habitat for winter-run Chinook salmon on June 16, 1993 (58 FR 33212).

1.1.2 Critical Habitat for Sacramento River Winter-run Chinook Salmon

Critical habitat for winter-run Chinook salmon was designated as the following waterways, bottom and water of the waterways, and adjacent riparian zones: the Sacramento River from Keswick Dam (river mile (RM) 302) to Chipps Island (RM 0) at the westward margin of the Sacramento-San Joaquin Delta (Delta); all waters from Chipps Island westward to the Carquinez Bridge, including Honker Bay, Grizzly Bay, Suisun Bay, and the Carquinez Strait; all waters of San Pablo Bay westward of the Carquinez Bridge; and all waters of San Francisco Bay north of the San Francisco-Oakland Bay Bridge from San Pablo Bay to the Golden Gate Bridge (58 FR 33212; June 16, 1993) (see Figure B-1). NMFS clarified that “adjacent riparian zones” are limited to only those areas above a stream bank that provide cover and shade to the nearshore aquatic areas (58 FR 33212, 33214; June 16, 1993). Although the bypasses (e.g., Yolo, Sutter, and Colusa) are not currently designated critical habitat for winter-run Chinook salmon, NMFS recognizes that they may be utilized when inundated with Sacramento River flood flows and are important rearing habitats for juvenile winter-run Chinook salmon. Also, juvenile winter-run

Chinook salmon may use tributaries of the Sacramento River for non-natal rearing (Maslin *et al.* 1997, Pacific States Marine Fisheries Commission 2014).

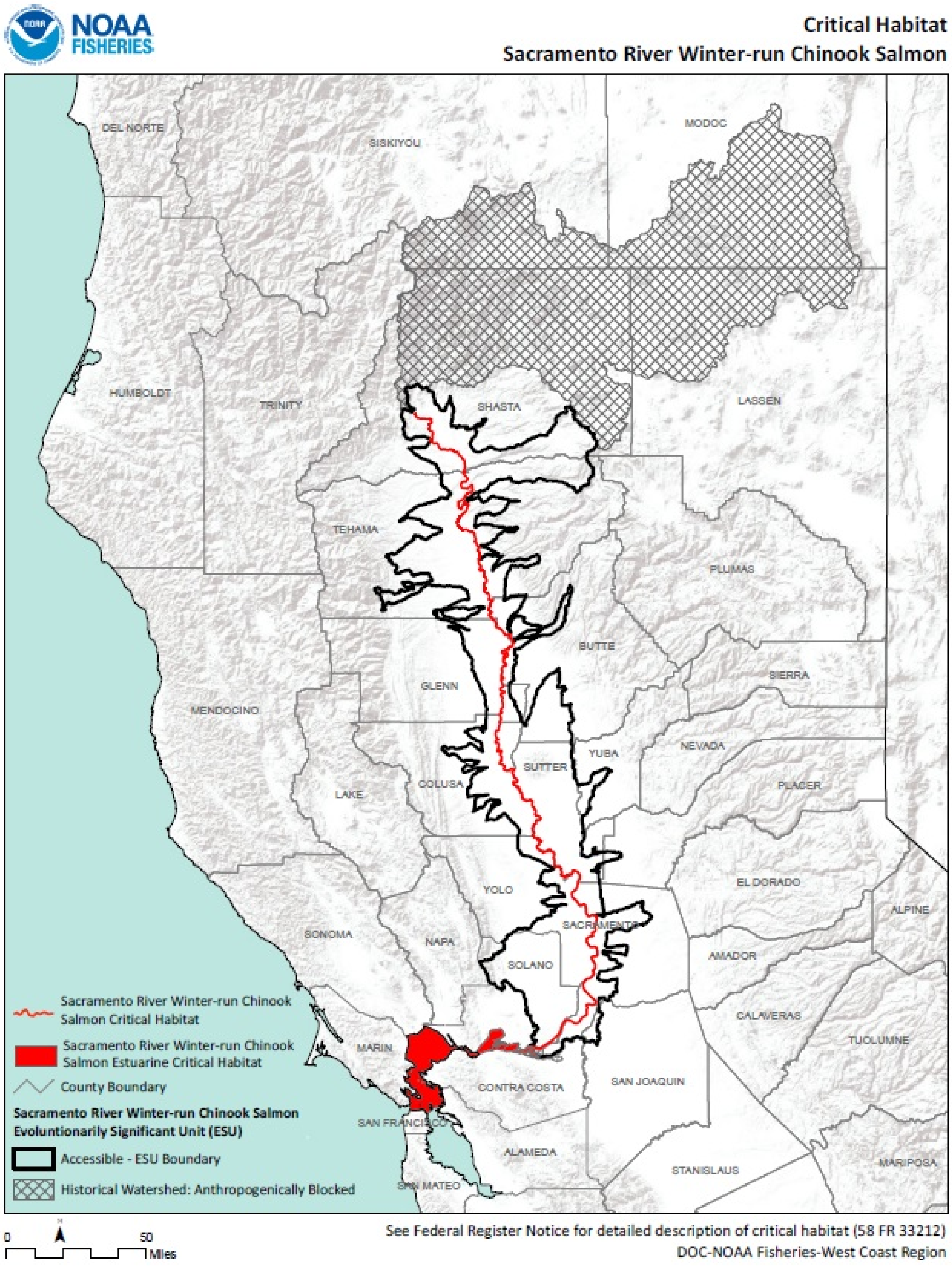

Figure B-1. Winter-run Chinook Salmon Critical Habitat in the Central Valley.

The following subsections describe the status of the PBFs of winter-run Chinook salmon critical habitat, which are listed in the critical habitat designation (58 FR 33212, 33216-33217; June 16, 1993).

1.1.2.1 Adult Migration Corridors

Winter-run Chinook salmon critical habitat PBFs include "access from the Pacific Ocean to appropriate spawning areas in the upper Sacramento River." Adult winter-run Chinook salmon generally migrate to spawning areas during the winter and spring. At that time of year, the migration route is accessible to the appropriate spawning grounds on the upper 60 miles of the Sacramento River. Much of this migratory habitat is degraded, however, and they must pass through a fish ladder at the Anderson-Cottonwood Irrigation Dam (ACID). In addition, the many flood bypasses are known to strand adults in agricultural drains due to inadequate screening (Vincik and Johnson 2013). Since the primary migration corridors are essential for connecting early rearing habitat with the ocean, even the degraded reaches are considered to have a high intrinsic value for the conservation of the species.

1.1.2.2 Spawning Habitat

Winter-run Chinook salmon critical habitat PBFs include "the availability of clean gravel for spawning substrate." Suitable spawning habitat for winter-run Chinook salmon exists in the upper 60 miles of the Sacramento River between Keswick Dam and Red Bluff Diversion Dam (RBDD) and is completely outside the historical range utilized by winter-run Chinook salmon upstream of Keswick Dam (NMFS 2014a). However, the majority of spawning habitat currently being used occurs in the first 10 miles below Keswick Dam (Stompe et al. 2016). Because Shasta and Keswick dams block gravel recruitment, the U.S. Bureau of Reclamation (Reclamation) annually injects spawning gravel into various areas of the upper Sacramento River which increases the availability of spawning substrate for a small naturally-spawning winter-run Chinook salmon population (NMFS 2016a). Even in degraded reaches, spawning habitat has a high value for the conservation of the species as its function directly affects the spawning success and reproductive potential of listed salmonids.

1.1.2.3 Adequate River Flows

Winter-run Chinook salmon critical habitat PBFs include "adequate river flows for successful spawning, incubation of eggs, fry development and emergence, and downstream transport of juveniles." An April 5, 1960, Memorandum of Agreement between Reclamation and the California Department of Fish and Wildlife (CDFW) (formerly California Department of Fish and Game (CDFG)) originally established flow objectives in the Sacramento River for the protection and preservation of fish and wildlife resources. In addition, Reclamation complies with the 1990 flow releases required in State Water Resource Control Board (SWRCB) Water Rights Order (WRO) 90-05 for the protection of Chinook salmon. This order includes a minimum flow release of 3,250 cubic feet per second (cfs) from Keswick Dam downstream to RBDD from September through February during all water year types, except critically dry (SWRCB 1990).

1.1.2.4 Water Temperatures

Winter-run Chinook salmon critical habitat PBFs include “water temperatures between 42.5 and 57.5 degrees F (5.8 and 14.1 degrees C) for successful spawning, egg incubation, and fry development.” Summer flow releases from Shasta Reservoir for agriculture and other consumptive uses drive operations of Shasta and Keswick dam water releases during the period of winter-run Chinook salmon migration, spawning, egg incubation, fry development, and emergence. This flow pattern, the opposite of the pre-dam hydrograph, can provide water temperatures suitable for winter-run Chinook salmon spawning and egg incubation for miles downstream during the hottest part of the year (Reclamation 2016). The extent to which winter-run Chinook salmon habitat needs are met depends on Reclamation’s other operational commitments, including those to water contractors, Delta requirements pursuant to State Water Rights Decision 1641 (D-1641), and Shasta Reservoir end of September storage levels required in the NMFS 2009 biological opinion on the long-term operations (LTOs) of the Central Valley Project (CVP) and State Water Project (SWP) (NMFS 2009a). WRO 90-05 and 91-01 require Reclamation to operate Shasta, Keswick, and Spring Creek Powerhouse to meet a daily average water temperature of 56°F (13.3°C) at RBDD. They also provide the exception that the water temperature compliance point (TCP) may be modified when the objective cannot be met at RBDD (SWRCB 1990, 1991). Based on these requirements, Reclamation models monthly forecasts and determines how far downstream 56°F (13.3°C) can be maintained throughout the winter-run Chinook salmon spawning, egg incubation, and fry development stages.

In every year since WRO 90-05 and 91-1 were issued, operation plans have included modifying the TCP to make the best use of the cold water available based on water temperature modeling and current spawning distribution. Once a TCP has been identified and established in May, it generally does not change, and, therefore, water temperatures are typically adequate through the summer for successful winter-run Chinook salmon egg incubation and fry development for those redds constructed upstream of the TCP (except for in some critically dry and drought years) (Reclamation 2016). By continually moving the TCP upstream, however, the spawning habitat PBF is degraded by reducing the spawning area in size and imprinting upon the next generation to return further upstream.

1.1.2.5 Habitat and Adequate Prey Free of Contaminants

Winter-run Chinook salmon critical habitat PBFs include “habitat areas and adequate prey that are not contaminated.” Overall, water quality conditions in the upper Sacramento River have improved since the 1980s due to stricter standards and Environmental Protection Agency (EPA) Superfund site cleanups such as the Iron Mountain Mine. No longer are there fish kills in the Sacramento River caused by the heavy metals (e.g., lead, zinc, and copper) found in the Spring Creek runoff. Legacy contaminants, such as mercury (and methyl mercury), polychlorinated biphenyls, heavy metals, and persistent organochlorine pesticides, however, continue to be found in watersheds throughout the Central Valley (EPA 2013). In 2010, the EPA listed the Sacramento River as impaired under Clean Water Act section 303(d), due to high levels of pesticides, herbicides, and heavy metals (http://www.waterboards.ca.gov/water_issues/programs/tmdl/2010state_ir_reports/category5_report.shtml).

Although most of these contaminants are at low concentrations in the food chain, they continue to work their way into the base of the food web, particularly when sediments are disturbed and previously entombed compounds are released into the water column (Cain et al. 2000).

Adequate prey for juvenile salmon to survive and grow consists of abundant aquatic and terrestrial invertebrates that make up the majority of their diet before entering the ocean. Exposure to these contaminated food sources, such as invertebrates, may create delayed sublethal effects that reduce fitness and survival (Laetz et al. 2009). Contaminants are typically associated with areas of urban development, agriculture, or other anthropogenic activities (e.g., mercury contamination as a result of gold mining or processing). Freshwater rearing habitat has a high intrinsic value for the conservation of the species even if the current conditions are significantly degraded from their natural state.

1.1.2.6 Riparian and Floodplain Habitat

Winter-run Chinook salmon critical habitat PBFs include “riparian habitat that provides for successful juvenile development and survival.” The channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento River system typically have low habitat complexity, low abundance of food organisms, and offer little protection from predators. Juvenile life stages of salmonids are dependent on the natural functioning of this habitat for successful survival and recruitment. Ideal habitat contains natural cover, such as riparian canopy structure, submerged and overhanging large woody material (LWM), aquatic vegetation, large rocks and boulders, side channels, and undercut banks, which augment juvenile and adult mobility, survival, and food supply. Riparian recruitment is prevented from becoming established due to the reversed hydrology (i.e., high summer time flows and low winter flows prevent tree seedlings from establishing). However, there are some complex, productive habitats within historical floodplains (e.g., Sacramento River reaches with setback levees - primarily located upstream of the City of Colusa) and flood bypasses (i.e., fish in Yolo and Sutter bypasses experience rapid growth and higher survival due to abundant food resources) seasonally available that remain in the system. Nevertheless, the current condition of degraded riparian habitat along the mainstem Sacramento River restricts juvenile growth and survival (Michel 2010, Michel et al. 2012).

1.1.2.7 Juvenile Emigration Corridors

Winter-run Chinook salmon critical habitat PBFs include “access downstream so that juveniles can migrate from the spawning grounds to San Francisco Bay and the Pacific Ocean” (58 FR 33212). Freshwater emigration corridors should be free of migratory obstructions, with water quantity and quality conditions that enhance migratory movements. Migratory corridors are downstream of the Keswick Dam spawning areas and include the mainstem of the Sacramento River to the Delta as well as non-natal rearing areas near the confluence of some tributary streams.

Migratory habitat condition is strongly affected by the presence of barriers, which can include dams (i.e., hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration. For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage (NMFS 2014a). Unscreened diversions that entrain juvenile salmonids are prevalent throughout the mainstem Sacramento River and in the Delta

(Herren and Kawasaki 2001). Predators, such as striped bass (*Morone saxatilis*) and Sacramento pikeminnow (*Ptychocheilus grandis*), tend to concentrate immediately downstream of diversions, resulting in increased mortality of juvenile Chinook salmon (Vogel 2011).

Water pumping at the CVP and SWP export facilities in the South Delta at times causes the flow in the river to move back upstream (reverse flow), further disrupting the emigration of juvenile winter-run Chinook salmon by attracting and diverting them to the interior Delta, where they are exposed to increased rates of predation, other stressors in the Delta, and entrainment at pumping stations. NMFS' biological opinion on the LTOs of the CVP and SWP (NMFS 2009a) sets limits to the strength of reverse flows in the Old and Middle rivers, thereby keeping salmon away from areas of highest mortality. Regardless of the condition, the remaining juvenile emigration corridors are of high value for the conservation of the species because they provide factors that function as rearing habitat and as an area of transition to the ocean environment.

1.1.2.8 Summary of the Physical or Biological Features of Winter-run Chinook Salmon Critical Habitat

Critical habitat for winter-run Chinook salmon is composed of physical or biological features that are essential for the conservation of winter-run Chinook salmon, including upstream and downstream access, and the availability of certain habitat conditions necessary to meet the biological requirements of the species. Currently, many of these physical or biological features are degraded and provide limited high quality habitat. Factors that lessen the quality of the migratory corridor for juveniles include unscreened diversions, altered flows in the Delta, and the lack of floodplain habitat.

In addition, water operations that limit the extent of cold water below Shasta Dam have reduced the available spawning habitat (based on water temperature). Although the critical habitat for winter-run Chinook salmon has been highly degraded, the importance of the reduced spawning habitat, migratory corridors, and rearing habitat that remains is of high value for the conservation of the species.

1.1.3 Life History

1.1.3.1 Adult Migration and Spawning

Winter-run Chinook salmon exhibit a unique life-history pattern (Healey 1994) compared to other salmon populations in the Central Valley (i.e., spring-run, fall-run, and late-fall-run Chinook salmon) because they spawn in the summer, and the juveniles are the first to enter the ocean the following winter and spring. Adults first enter San Francisco Bay from November through June (Hallock and Fisher 1985) and migrate up the Sacramento River, past the RBDD from mid-December through early August (NMFS 1997). The majority of the run passes RBDD from January through May, with the peak passage occurring in mid-March (Hallock and Fisher 1985). The timing of migration may vary somewhat due to changes in river flows, dam operations, and water year type (Table B-1) ((Yoshiyama et al. 1998, Moyle 2002).

Winter-run Chinook salmon tend to enter freshwater while still immature and travel far upriver and delay spawning for weeks or months upon arrival at their spawning grounds (Healey 1991). Spawning occurs primarily from mid-May to mid-August, with the peak activity occurring in June and July in the upper Sacramento River reach (50 miles) between Keswick Dam and RBDD (Vogel and Marine 1991). Winter-run Chinook salmon deposit and fertilize eggs in gravel beds known as redds, which are excavated by the female who then dies following spawning. Average fecundity was 5,192 eggs per female for the 2006 to 2013 returns to LSNFH, which is similar to other Chinook salmon runs (e.g., 5,401 average for Pacific Northwest (Quinn 2005). Chinook salmon spawning requirements for depth and velocities are broad, and the upper preferred water temperature is between 55 to 57 degrees Fahrenheit (°F) (13 to 14 degrees Celsius [°C]) (Snider et al. 2001). The majority of winter-run Chinook salmon adults return after 3 years.

Table B-1 shows the temporal occurrence of adult (a) and juvenile (b) winter-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

Table B-1. The Temporal Occurrence of Adult (a) and Juvenile (b) Winter-run in the Sacramento River.

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

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

1.1.3.2 Egg and Fry Emergence

Winter-run Chinook salmon incubating eggs are vulnerable to adverse effects from floods, flow fluctuations, siltation, desiccation, disease, predation during spawning, poor gravel percolation, and poor water quality. The optimal water temperature for egg incubation ranges from 46 to 56°F (7.8 to 13.3°C), and a significant reduction in egg viability occurs in mean daily water temperatures above 57.5°F (14.2°C) (Seymour 1956, Boles 1988, USFWS1999, U.S. Environmental Protection Agency 2003, Richter and Kolmes 2005, Geist et al. 2006).

Total embryo mortality can occur at temperatures above 62°F (16.7°C) (NMFS 1997). Depending on ambient water temperature, embryos hatch within 40 to 60 days, and alevin (yolk-sac fry) remain in the gravel beds for an additional 4 to 6 weeks. As their yolk-sacs become depleted, fry begin to emerge from the gravel and start exogenous feeding in their natal stream, typically in late July to early August and continuing through October (Fisher 1994).

1.1.3.3 Juvenile Rearing and Outmigration

Juvenile winter-run Chinook salmon have been found to exhibit variability in their life history dependent on emergence timing and growth rates (Beckman et al. 2007). Following spawning, egg incubation, and fry emergence from the gravel, juveniles begin to emigrate in the fall. Some juvenile winter-run Chinook salmon migrate to sea after only 4 to 7 months of river life, while others hold and rear upstream and spend 9 to 10 months in freshwater. Emigration of juvenile winter-run Chinook salmon fry and pre-smolts past RBDD (RM 242) may begin as early as mid-July, but typically peaks at the end of September (Table B-1), and can continue through March in dry years (Vogel and Marine 1991, NMFS1997).

1.1.3.4 Estuarine/Delta Rearing

Juvenile winter-run Chinook salmon emigration into the Delta and estuary occurs primarily from November through early May based on data collected from trawls in the Sacramento River at Sherwood Harbor (West Sacramento), RM 57 (USFWS2001). The timing of emigration may vary somewhat due to changes in river flows, Shasta Dam operations, and water year type, but has been correlated with the first storm event when flows exceed 14,000 cfs at Knights Landing, RM 90, which triggers abrupt emigration towards the Delta (del Rosario et al. 2013). The average residence time in the Delta for juvenile winter-run Chinook salmon is approximately 3 months based on median seasonal catch between Knights Landing and Chipps Island. In general, the earlier juvenile winter-run Chinook salmon enter the Delta, the longer they stay and rear. Peak departure at Chipps Island regularly occurs in March (del Rosario et al. 2013). The Delta serves as an important rearing and transition zone for juvenile winter-run Chinook salmon as they feed and physiologically adapt to marine waters during the smoltification process (change from freshwater to saltwater). The majority of juvenile winter-run Chinook salmon in the Delta are 104 to 128 millimeters (mm) long based on U.S. Fish and Wildlife (USFWS) Delta Juvenile Fish Monitoring Program trawl data (1995 to 2012) and are from 5 to 10 months old by the time they depart the Delta (Fisher 1994, Myers et al. 1998).

1.1.3.5 Ocean Rearing

Winter-run Chinook salmon smolts enter the Pacific Ocean mainly in spring (March to April) and grow rapidly on a diet of small fishes, crustaceans, and squid. Salmon runs that migrate to sea at a larger size tend to have higher marine survival rates (Quinn 2005). The diet composition of Chinook salmon from California consists of anchovy, rockfish, herring, and other invertebrates, in order of preference (Healey 1991). Most Chinook from the Central Valley move northward into Oregon and Washington, where herring make up the majority of their diet. However, upon entering the ocean, winter-run Chinook salmon tend to stay near the California coast and distribute from Point Arena southward to Monterey Bay. Winter-run Chinook salmon have high metabolic rates, feed heavily, and grow fast compared to other fishes in their range. They can double their length and increase their weight more than 10-fold in the first summer at sea (Quinn 2005). Mortality is typically highest in the first summer at sea, but can depend on ocean conditions. Winter-run Chinook salmon abundance has been correlated with ocean conditions such as periods of strong up-welling, cooler temperatures, and El Nino events (Lindley et al. 2009). Winter-run Chinook salmon spend approximately 1 to 2 years rearing in the ocean before returning to the Sacramento River as 2- to 3-year-old adults. Very few winter-run Chinook salmon reach age 4. Once they reach age 3, they are large enough to become vulnerable to commercial and sport fisheries.

1.1.4 Description of Viable Salmonid Population Parameters

As an approach to evaluate the likelihood of viability of the Sacramento River winter-run Chinook salmon ESU and determine the extinction risk of the ESU, NMFS uses the viable salmonid population (VSP) concept. In this section, NMFS evaluates the VSP parameters of abundance, productivity, spatial structure, and diversity. These specific parameters are important to consider because they are predictors of extinction risk, and the parameters reflect general biological and ecological processes that are critical to the growth and survival of salmon (McElhany et al. 2000).

1.1.4.1 Abundance

Historically, winter-run Chinook salmon population estimates were as high as 120,000 fish in the 1960s, but declined to less than 200 fish by the 1990s (NMFS 2011c). In recent years, since carcass surveys began in 2001 (Figure B-2), the highest adult escapement occurred in 2005 and 2006 with 15,839 and 17,296, respectively. However, from 2007 to 2013, the population has shown a precipitous decline, averaging 2,486 during this period, with a low of 827 adults in 2011 (Figure B-2). This recent declining trend is likely due to a combination of factors such as poor ocean productivity (Lindley et al. 2009); drought conditions from 2007 to 2009; low in-river survival (NMFS 2011c); and extreme drought conditions in 2012 to 2016 (NMFS 2016a). In 2015, the population was 3,015 adults, slightly above the 2007 to 2012 average, but below the high (17,296) for the last 10 years (CDFW 2016).

Although impacts from hatchery fish (i.e., reduced fitness, weaker genetics, smaller size, less ability to avoid predators) are often cited as having deleterious impacts on natural in-river populations (Matala et al. 2012), the winter-run Chinook salmon conservation program at LSNFH is strictly controlled by the USFWS to reduce such impacts. The average annual hatchery production at LSNFH is approximately 176,348 per year (2001 to 2010 average) compared to the estimated natural production that passes RBDD, which is 4.7 million per year based on the 2002 to 2010 average (Poytress and Carrillo 2011). Therefore, hatchery production typically represents approximately 3 to 4 percent of the total in-river juvenile production in any given year.

2014 was the third year of a drought that increased water temperatures in the upper Sacramento River, and egg-to-fry survival to the RBDD was approximately 5 percent (NMFS 2016a). Due to the anticipated lower than average survival in 2014, hatchery production from LSNFH was tripled (i.e., 612,056 released) to offset the impact of the drought (CVP and SWP Drought Contingency Plan 2014). In 2014, hatchery production represented 83 percent of the total in-river juvenile production. In 2015, egg-to-fry survival was the lowest on record (approximately 4 percent) due to the inability to release cold water from Shasta Dam in the fourth year of a drought. Winter-run Chinook salmon returns in 2016 are expected to be low as they show the impact of drought on juveniles from brood year 2013 (NMFS 2016a).

Figure B-2 shows winter-run Chinook salmon escapement numbers 1967 to 2015, based on ladder counts and carcass surveys. After 2001, hatchery broodstock and tributaries are included, but sport catch is excluded (CDFW 2016).

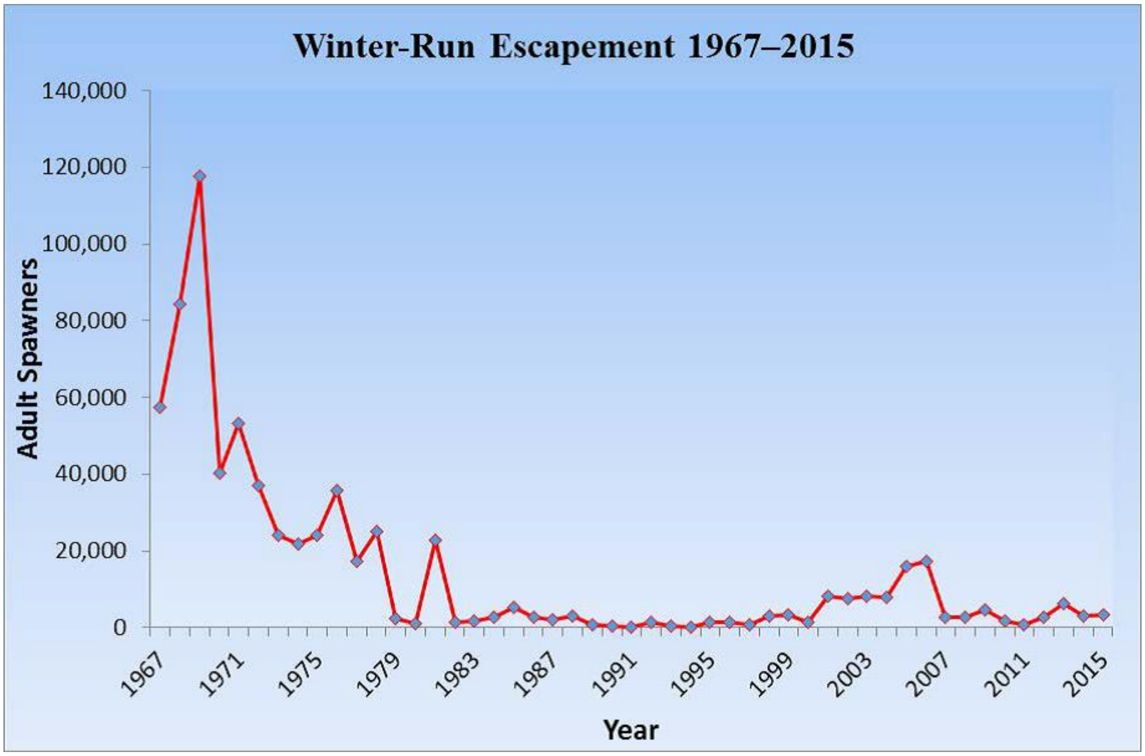

Figure B-2. Winter-run Chinook Salmon Escapement Numbers 1967 to 2015.

1.1.4.2 Productivity

ESU productivity was positive over 1989 to 2006, and adult escapement and juvenile production had been increasing annually until 2007 when productivity became negative (Figure B-3) with declining escapement estimates. The long-term trend for the ESU, therefore, remains negative because productivity is subject to impacts from environmental and artificial conditions. The population growth rate based on cohort replacement rate (CRR) for the period 2007 to 2012 suggested a reduction in productivity (Figure B-3) and indicated that the winter-run Chinook salmon population was not replacing itself. From 2013 and 2015, winter-run Chinook salmon experienced a positive CRR, possibly due to favorable in-river conditions in 2011 and 2012 (wet and below normal, respectively), which increased juvenile survival to the ocean.

Figure B-3 shows winter-run population trend using CRR derived from adult escapement, including hatchery fish from 1989 to 2015.

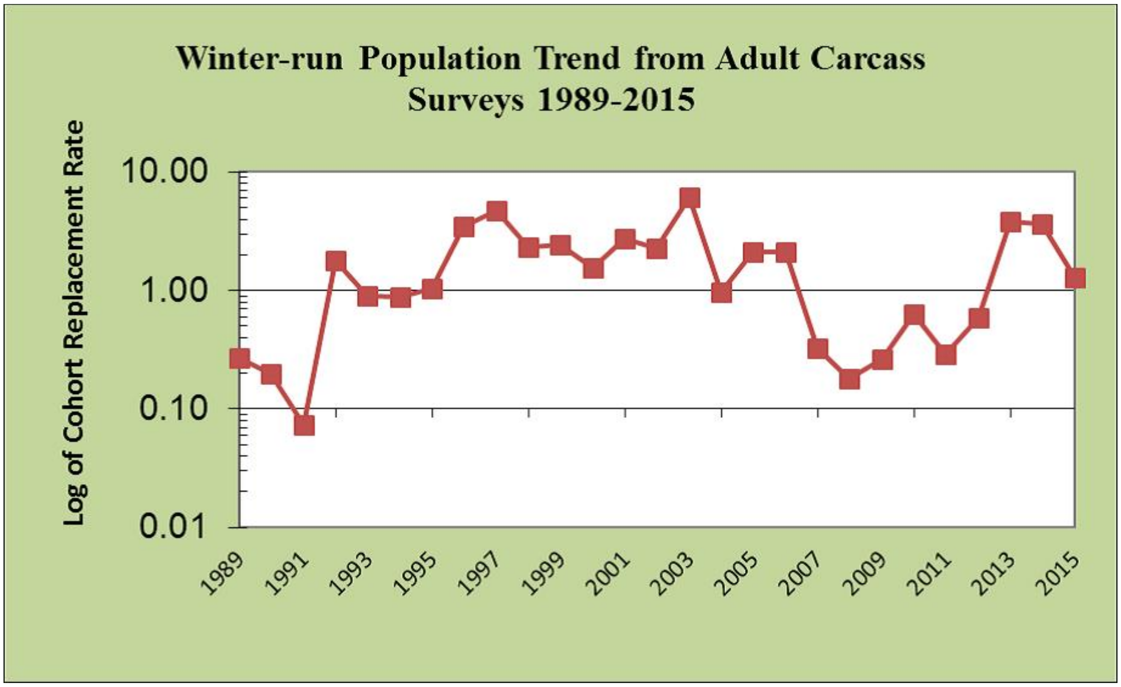

Figure B-3. Winter-run Chinook Salmon Population Trend Using Cohort Replacement Rate Derived from Adult Escapement, Including Hatchery Fish, 1989 to 2015.

An age-structured density-independent model of spawning escapement by Botsford and Brittnacher (1998) assessing the viability of winter-run Chinook salmon found the species was certain to fall below the quasi-extinction threshold of three consecutive spawning runs with fewer than 50 females (Good et al. 2005). Lindley and Mohr (2003) assessed the viability of the population using a Bayesian model based on spawning escapement that allowed for density dependence and a change in population growth rate in response to conservation measures. They found a biologically significant expected quasi-extinction probability of 28 percent. Although the growth rate for the winter-run Chinook salmon population improved up until 2006, it exhibits the typical variability found in most endangered species populations. The fact that there is only one population, dependent upon cold water releases from Shasta Dam, makes it vulnerable to periods of prolonged drought (NMFS 2011c). Productivity, as measured by the number of juveniles entering the Delta, or juvenile production estimate (JPE), has declined in recent years from a high of 3.8 million in 2007 to 124,521 in 2015 (Figure B-4). Due to uncertainties in the various JPE factors, it was updated in 2010 with the addition of confidence intervals (Cramer Fish Sciences model), and again in 2013 and 2014 with a change in survival based on acoustic tag data (NMFS 2014b). However, juvenile winter-run Chinook salmon productivity is still much lower than other Chinook salmon runs in the Central Valley and in the Pacific Northwest (Michel 2010).

Figure B-4 shows winter-run Chinook salmon adult and juvenile population estimates based on RBDD counts (1992 to 2001) and carcass counts (2001 to 2015). Estimates include survival to the Delta, but not through the Delta.

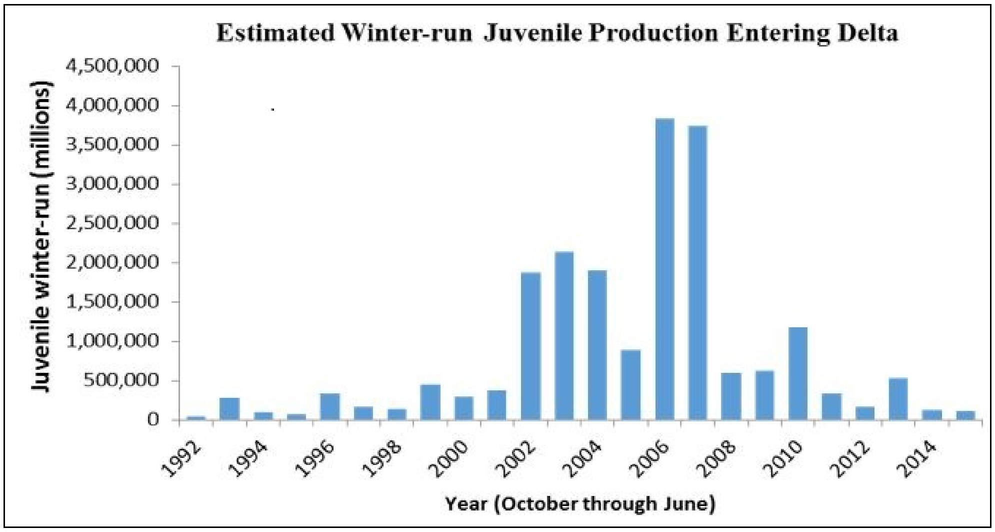

Figure B-4. Winter-run Chinook Salmon Adult and Juvenile Population Estimates Based on RBDD Counts (1992 to 2001) and Carcass Counts (2001 to 2015).

1.1.4.3 Spatial Structure

The distribution of winter-run Chinook salmon spawning and initial rearing historically was limited to the upper Sacramento River (upstream of Shasta Dam), McCloud River, Pitt River, and Battle Creek, where springs provided cold water throughout the summer, allowing for spawning, egg incubation, and rearing during the mid-summer period (Yoshiyama et al. 1998). The construction of Shasta Dam in 1943 blocked access to all these waters except Battle Creek, which currently has its own impediments to upstream migration (i.e., a number of small hydroelectric dams situated upstream of the Coleman National Fish Hatchery [NFH] weir). The Battle Creek Salmon and Steelhead Restoration Project is currently removing these impediments, which should restore spawning and rearing habitat for winter-run Chinook salmon in the future. Approximately 299 miles of former tributary spawning habitat above Shasta Dam is inaccessible to winter-run Chinook salmon. Yoshiyama et al. (2001) estimated that in 1938, the upper Sacramento River had a “potential spawning capacity” of approximately 14,000 redds equal to 28,000 spawners. Since 2001, the majority of winter-run Chinook salmon redds has occurred in the first 10 miles downstream of Keswick Dam. Most components of the winter-run Chinook salmon life history (e.g., spawning, incubation, freshwater rearing) have been compromised by the construction of Shasta Dam (NMFS 2014a).

The greatest risk factor for winter-run Chinook salmon lies within its spatial structure (NMFS 2011c). The remnant and remaining population cannot access 95 percent of their historical spawning habitat and must therefore be artificially maintained in the Sacramento River by the following means:

1. Spawning gravel augmentation
2. Hatchery supplementation
3. Regulation of the finite cold water pool behind Shasta Dam to reduce water temperatures

Winter-run Chinook salmon require cold water temperatures in the summer that simulate their upper basin habitat, and they are more likely to be exposed to the impacts of drought in a lower basin environment. Battle Creek is currently the most feasible opportunity for the ESU to expand its spatial structure, but restoration is not scheduled to be completed until 2020. The Central Valley Salmon and Steelhead Recovery Plan includes criteria for recovering the winter-run Chinook salmon ESU, including re-establishing a population into historical habitats upstream of Shasta Dam (NMFS 2014a). Additionally, NMFS (2009a) included a requirement for a pilot fish passage program above Shasta Dam.

1.1.4.4 Diversity

The current winter-run Chinook salmon population is the result of the introgression of several stocks (e.g., spring-run and fall-run Chinook salmon) that occurred when Shasta Dam blocked access to the upper watershed. A second genetic bottleneck occurred with the construction of Keswick Dam, which blocked access and did not allow spatial separation of the different runs (Good et al. 2005). Lindley et al. (2007) recommended reclassifying the winter-run Chinook salmon population extinction risk from low to moderate if the proportion of hatchery-origin fish from the LSNFH exceeded 15 percent due to the impacts of hatchery fish over multiple generations of spawners. Since 2005, the percentage of hatchery winter-run Chinook salmon recovered in the Sacramento River has only been above 15 in 4 years: 2005, 2012, 2014, and 2015 (Figure B-5). The average over the last 12 years (about four generations) is 13%, with the most recent generation at 20% hatchery influence, putting the population at a moderate risk of extinction (NMFS 2016a).

Concern over genetic introgression within the winter-run Chinook salmon population led to a conservation program at LSNFH that encompasses best management practices, including:

1. Genetic confirmation of each adult prior to spawning
2. A limited number of spawners based on the effective population size
3. Use of only natural-origin spawners since 2009

These practices reduce the risk of hatchery impacts on the wild population. Hatchery-origin winter-run Chinook salmon have made up more than 5 percent of the natural spawning run in recent years, except in 2012 when it exceeded 30 percent of the natural run (Figure B-5). The average over the last 16 years (approximately 5 generations) has been 8 percent, which is still below the low-risk threshold (15 percent) used for hatchery influence (Lindley et al. (2007). Drought conditions persisted in 2015, and hatchery production was increased again to 420,000 juveniles released, which was three times greater than what was produced naturally in-river (101,716) (CVP and SWP Drought Contingency Plan 2015).

Figure B-5 shows percentage of hatchery-origin winter-run Chinook salmon naturally spawning in the Sacramento River from 1996 to 2015.

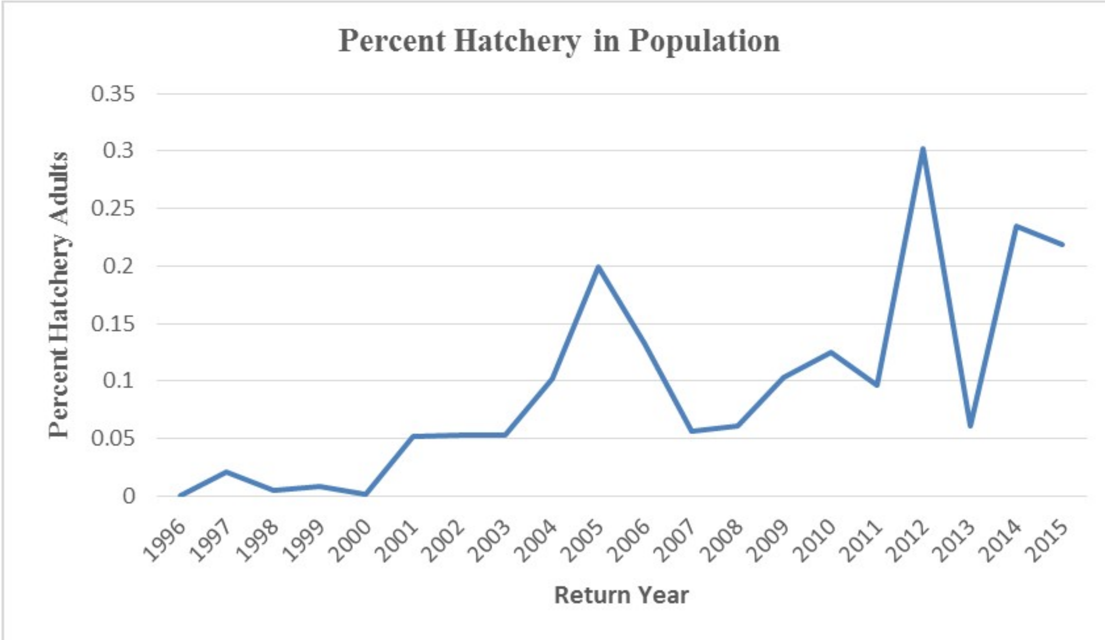

Figure B-5. Percentage of Hatchery-origin Winter-run Chinook Salmon Naturally Spawning in the Sacramento River (1996 to 2015). *(Source: unpublished data, (CDFW 2016).*

1.1.4.5 Summary of Evolutionarily Significant Unit Viability

There are several criteria (only one is required) that would qualify the winter-run Chinook salmon population at moderate risk of extinction, and because there is still only one population that spawns below Keswick Dam, the winter-run Chinook salmon ESU would be at high risk of extinction in the long term according to criteria in Lindley et al. (2007). Recent trends in those criteria are as follows:

1. Continued low abundance (Figure B-2)
2. A negative growth rate over 6 years (2006 to 2012), which is two complete generations (Figure B-3)
3. A significant rate of decline since 2006
4. Increased hatchery influence on the population (Figure B-5)
5. Increased risk of catastrophe from oil spills, wild fires, or extended drought (climate change)

The most recent 5-year status review (NMFS 2016a) on winter-run Chinook salmon concluded that the ESU has increased to a high risk of extinction.

In summary, the extinction risk for the winter-run Chinook salmon ESU has increased from moderate risk to high risk of extinction since 2005, and several listing factors have contributed to the recent decline, including drought and poor ocean conditions (NMFS 2016a). Large-scale fish passage and habitat restoration actions are necessary for improving the winter-run Chinook salmon ESU viability (NMFS 2016a).

The current condition of critical habitat for the winter-run Chinook salmon ESU is degraded over its historical conditions, particularly in the upstream riverine habitat of the Sacramento River. Within the Sacramento River, PBFs of critical habitat (i.e., migration corridor, adequate temperature, flows) have been impacted by human actions, substantially altering the historical river characteristics in which the winter-run Chinook salmon ESU evolved. In the Delta, the fabricated alterations may have a strong impact on the survival and recruitment of juvenile winter-run Chinook salmon due to changes in migration routes and their dependence on migration cues like high flows and increased turbidity.

While some conservation measures have been successful in improving habitat conditions for the winter-run Chinook salmon ESU since it was listed in 1989, fundamental problems with the quality of remaining habitat still remain (Cummins et al. 2008, Lindley et al. 2009, NMFS 2014a). As such, the habitat supporting this ESU remains in a highly degraded state, and it is unlikely that habitat quality has substantially changed since the last status of the species review in 2010 (NMFS 2016a).

1.2 Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit

- Listed as threatened (64 FR 50394; September 16, 1999); reaffirmed (70 FR 37160; June 28, 2005)
- Designated critical habitat (70 FR 52488; September 2, 2005)

The Federally listed ESU of Central Valley (CV) spring-run Chinook salmon and designated critical habitat occur in the action area and may be affected by the PA.

1.2.1 Species Listing and Critical Habitat Designation History

CV spring-run Chinook salmon were originally listed as threatened on September 16, 1999 (NMFS 1999) (64 FR 50394). This ESU consists of naturally spawned spring-run Chinook salmon originating from the Sacramento River basin. The Feather River Fish Hatchery (FRFH) spring-run Chinook salmon population has been included as part of the CV spring-run Chinook salmon ESU in the most recent CV spring-run Chinook salmon listing decision (NMFS 2005a) (70 FR 37160; June 28, 2005). Although the FRFH spring-run Chinook salmon program is included in the ESU, the take prohibitions in 50 CFR 223.203 do not apply to these fish because they do not have an intact adipose-fin. Critical habitat was designated for CV spring-run Chinook salmon on September 2, 2005 (NMFS 2005b) (70 FR 52488).

In the latest 5-year review, NMFS concluded that the species’ status should remain as previously listed (NMFS 2016b).

1.2.2 Critical Habitat for Central Valley Spring-run Chinook Salmon

Critical habitat for the CV spring-run Chinook salmon includes stream reaches of the Feather, Yuba, and American rivers; Big Chico, Butte, Deer, Mill, Battle, Antelope, and Clear creeks; and the Sacramento River, as well as portions of the northern Delta. Critical habitat includes the stream channels in the designated stream reaches (70 FR 52488; September 2, 2005).

The following subsections describe the status of the PBFs of CV spring-run Chinook salmon critical habitat, which are listed in the critical habitat designation (NMFS 2005b)) (70 FR 52488).

1.2.2.1 Spawning Habitat

The PBFs for CV spring-run Chinook salmon critical habitat include freshwater spawning sites with sufficient water quantity and quality conditions and substrate supporting spawning, incubation, and larval development. Most spawning habitat in the Central Valley for Chinook salmon is located in areas directly downstream of dams containing suitable environmental conditions for spawning and incubation. Spawning habitat for CV spring-run Chinook salmon occurs on the mainstem Sacramento River between the RBDD and Keswick Dam and in tributaries, such as Mill, Deer, and Butte creeks, as well as the Feather and Yuba rivers and the Big Chico, Battle, Antelope, and Clear creeks (NMFS 2014a). Even in degraded reaches, spawning habitat has a high value for the conservation of the species because its function directly affects the spawning success and reproductive potential of listed salmonids.

1.2.2.2 Freshwater Rearing Habitat

The PBFs for CV spring-run Chinook salmon critical habitat include freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions that support juvenile growth and mobility; water quality and forage supporting juvenile salmonid development; and natural cover such as shade, submerged and overhanging LWM, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids (NMFS 2014a). Some complex, productive habitats with floodplains remain in the system (e.g., the lower Cosumnes River, Sacramento River reaches with setback levees [i.e., primarily located upstream of the City of Colusa]) and flood bypasses (i.e., Yolo and Sutter bypasses) (Summer et al. 2004; Jeffries et al. 2008). However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento-San Joaquin system typically have low habitat complexity, low abundance of food organisms, and offer little protection from piscivorous fish and birds (NMFS 2014a). Freshwater rearing habitat also has a high intrinsic value for the conservation of the species even if the current conditions are significantly degraded from their natural state.

1.2.2.3 Freshwater Migration Corridors

The PBFs for CV spring-run Chinook salmon critical habitat include freshwater migration corridors free of obstruction and excess predation with water quantity and quality conditions and natural cover such as submerged and overhanging LWM, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. Migratory corridors are downstream of the spawning areas and include the lower mainstems of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream passage of adults and the downstream emigration of juveniles. Migratory habitat condition is strongly affected by the presence of barriers, which can include dams (i.e., hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration (NMFS 2014a). For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage. Stranding of adults has been known to occur in flood bypasses and associated weir structures (Vincik and Johnson 2013), and a number of challenges exist on many tributary streams. For juveniles, unscreened or inadequately screened water diversions throughout their migration corridors and a scarcity of complex in-river cover have degraded this PBF (NMFS 2014a). However, since the primary migration corridors are used by numerous populations, and are essential for connecting early rearing habitat with the ocean, even the degraded reaches are considered to have a high intrinsic value for the conservation of the species.

1.2.2.4 Estuarine Areas

The PBFs for CV spring-run Chinook salmon critical habitat include estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater and natural cover—such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and juvenile and adult forage, including aquatic invertebrates and fishes— supporting growth and maturation (50 CFR 226.211(c)).

The remaining estuarine habitat for these species is severely degraded by altered hydrologic regimes, poor water quality, reductions in habitat complexity, and competition for food and space with exotic species (NMFS 2014a). Regardless of the condition, the remaining estuarine areas are of high value for the conservation of the species because they provide factors that function to provide predator avoidance, as rearing habitat, and as an area of transition to the ocean environment.

1.2.2.5 Summary of the Physical or Biological Features of Central Valley Spring-run Chinook Salmon Critical Habitat

Currently, many of the PBFs of CV spring-run Chinook salmon critical habitat are degraded and provide limited high-quality habitat. Factors that lessen the quality of migratory corridors for juveniles include unscreened or inadequately screened diversions, altered flows in the Delta, scarcity of complex in-river cover, and the lack of floodplain habitat. Although the current conditions of CV spring-run Chinook salmon critical habitat are significantly degraded, the spawning habitat, migratory corridors, and rearing habitat that remain are considered to have high intrinsic value for the conservation of the species.

1.2.3 Life History

1.2.3.1 Adult Migration and Holding

Chinook salmon runs are designated based on adult migration timing. Adult CV spring-run Chinook salmon leave the ocean to begin their upstream migration in late January and early February (CDFG 1998) and enter the Sacramento River beginning in March (Yoshiyama et al. 1998). Spring-run Chinook salmon move into tributaries of the Sacramento River (e.g., Butte, Mill, Deer creeks) beginning as early as February in Butte Creek and typically mid-March in Mill and Deer creeks (Lindley et al. 2004). Adult migration peaks around mid-April in Butte Creek, and mid- to end of May in Mill and Deer creeks, and is complete by the end of July in all three tributaries (Lindley et al. 2004) (Table B-2). Typically, spring-run Chinook salmon utilize mid- to high-elevation streams that provide appropriate temperatures and sufficient flow, cover, and pool depth to allow over-summering while conserving energy and allowing their gonadal tissue to mature (Yoshiyama et al. 1998).

During their upstream migration, adult Chinook salmon require stream flows sufficient to provide olfactory and other orientation cues used to locate their natal streams. Adequate stream flows are necessary to allow adult passage to upstream holding habitat. The preferred temperature range for upstream migration is 38ºF (3ºC) to 56ºF (13ºC) (Bell 1990, CDFG 1998).

Boles (1988) recommends water temperatures below 65ºF (18ºC) for adult Chinook salmon migration, and Lindley et al. (2004) report that adult migration is blocked when temperatures reach 70ºF (21ºC), and that fish can become stressed as temperatures approach 70ºF (21ºC). Reclamation reports that spring-run Chinook salmon holding in upper watershed locations prefer water temperatures below 60ºF (15.6ºC), although salmon can tolerate temperatures up to 65ºF (18ºC) before they experience an increased susceptibility to disease (Williams 2006).

1.2.3.2 Adult Spawning

Spring-run Chinook salmon spawning occurs in September and October (Moyle 2002). Chinook salmon typically mature between 2 and 6 years of age (Myers et al. 1998b), but primarily at age 3 (Fisher 1994). Between 56 and 87 percent of adult spring-run Chinook salmon that enter the Sacramento River basin to spawn are 3 years old (Fisher 1994); spring-run Chinook salmon tend to enter freshwater as immature fish, migrate far upriver, and delay spawning for weeks or months.

Spring-run Chinook salmon spawning typically occurs in gravel beds that are located at the tails of holding pools (USFWS 1995, NMFS 2007). Spawning Chinook salmon require clean, loose gravel in swift, relatively shallow riffles or along the margins of deeper runs, and suitable water temperatures, depths, and velocities for redd construction and adequate oxygenation of incubating eggs. The range of water depths and velocities in spawning beds that Chinook salmon find acceptable is very broad. Velocity typically ranging from 1.2 feet per second to 3.5 feet per second, and water depths greater than 0.5 feet (HDR/Surface Water Resources Inc. 2007). The upper preferred water temperature for spawning Chinook salmon is 55 to 57°F (13 to 14ºC) (Smith 1973, Bjornn and Reiser 1991, CDFG 2001). Chinook salmon are semelparous (die after spawning).

1.2.3.3 Eggs and Fry Incubation to Emergence

The CV spring-run Chinook salmon embryo incubation period encompasses the time period from egg deposition through hatching as well as the additional time while alevins remain in the gravel while absorbing their yolk sac before emergence. A compilation of data from multiple surveys has shown that Chinook salmon prefer a range of substrate sizes between approximately 22 millimeters (mm) and 48 mm (Kondolf and Wolman 1993). The length of time for CV spring-run Chinook salmon embryos to develop depends largely on water temperatures. In well-oxygenated intergravel environs where water temperatures range from about 41 to 55.4°F (5 to 13ºC), embryos hatch in 40 to 60 days and remain in the gravel as alevins for another 4 to 6 weeks, usually after the yolk sac is fully absorbed (NMFS 2014a). In Butte and Big Chico creeks, emergence occurs from November through January; in the colder waters of Mill and Deer creeks, emergence typically occurs from January through as late as May (Moyle 2002). Incubating eggs require sufficient concentrations of dissolved oxygen. (Coble 1961) noted that a positive correlation exists between dissolved oxygen levels and flow within redd gravel, and Geist et al. (2006) observed an emergence delay of 6 to 10 days at 4 milligrams per liter (mg/L) dissolved oxygen relative to water with complete oxygen saturation.

Incubating eggs are vulnerable to adverse effects from floods, siltation, desiccation, disease, predation, poor gravel permeability, and poor water quality. Studies of Chinook salmon egg survival to emergence conducted by Shelton (1955) indicated 87 percent of fry emerged successfully from large gravel with adequate subgravel flow. The optimal water temperature for egg incubation ranges from 41 to 56°F (5 to 14 ºC) (NMFS 1997, Rich 1997, Moyle 2002). A significant reduction in egg viability occurs at water temperatures above 57.5ºF (14ºC), and total embryo mortality can occur at temperatures above 62°F (17ºC) (NMFS 1997). Alderdice and Velsen (1978) found that the upper and lower temperatures resulting in 50 percent pre-hatch mortality were 61°F and 37°F (16ºC and 3ºC), respectively, when the incubation temperature was held constant. As water temperatures increase, the rate of embryo malformations also increases as well as the susceptibility to fungus and bacterial infestations. The length of development for Chinook salmon embryos is dependent on the ambient water temperature surrounding the redd egg pocket. Colder water necessitates longer development times as metabolic processes are slowed. Within the appropriate water temperature range for embryo incubation, embryos hatch in 40 to 60 days, and the alevins remain in the gravel for an additional 4 to 6 weeks before emerging from the gravel.

During the 4- to 6-week period when alevins remain in the gravel, they use their yolk-sac to nourish their bodies. As their yolk-sac is depleted, fry begin to emerge from the gravel to begin exogenous feeding in their natal stream. The newly emerged fry disperse to the margins of their natal stream, seeking out shallow waters with slower currents, finer sediments, and bank cover, such as overhanging and submerged vegetation, root wads, and fallen woody debris, and begin feeding on zooplankton, small insects, and small invertebrates. As they switch from endogenous nourishment to exogenous feeding, the fry’s yolk-sac is reabsorbed, and the belly suture closes over the former location of the yolk-sac (button-up fry). Fry typically range from 25 to 40 mm during this stage. Some fry may take up residence in their natal stream for several weeks to a year or more, while others migrate downstream to suitable habitat. Once started downstream, fry may continue downstream to the estuary and rear, or may take up residence in river reaches farther downstream for a period of time ranging from weeks to a year (Healey 1991).

1.2.3.4 Juvenile Rearing and Outmigration

Once juveniles emerge from the gravel, they initially seek areas of shallow water and low velocities while they finish absorbing the yolk sac and transition to exogenous feeding (Moyle 2002). Many also will disperse downstream during high-flow events. As is the case in other salmonids, there is a shift in microhabitat use by juveniles to deeper faster water as they grow larger. Microhabitat use can be influenced by the presence of predators, which can force fish to select areas of heavy cover and suppress foraging in open areas (Moyle 2002).

When juvenile Chinook salmon reach a length of 50 to 57 mm, they move into deeper water with higher current velocities, but still seek shelter and velocity refugia to minimize energy expenditures. In the mainstems of larger rivers, juveniles tend to migrate along the margins and avoid the elevated water velocities found in the thalweg of the channel. When the channel of the river is greater than 9 to 10 feet deep, juvenile salmon tend to inhabit the surface waters (Healey 1982). Migrational cues, such as increasing turbidity from runoff, increased flows, changes in day length, or intraspecific competition from other fish in their natal streams, may spur outmigration of juveniles when they have reached the appropriate stage of development (Kjelson et al. 1982, Brandes and McLain 2001).

As fish begin their emigration, they are displaced by the river's current downstream of their natal reaches. Similar to adult movement, juvenile salmonid downstream movement is primarily crepuscular. The daily migration of juveniles passing RBDD is highest in the 4-hour period before sunrise (Martin et al. 2001). Juvenile Chinook salmon migration rates vary considerably depending on the physiological stage of the juvenile and hydrologic conditions. Kjelson et al. (1982) found that Chinook salmon fry travel as fast as 30 kilometers per day in the Sacramento River. As Chinook salmon begin the smolt stage, they prefer to rear further downstream where ambient salinity is up to 1.5 to 2.5 parts per thousand (Healey 1979, Levy and Northcote 1981).

Spring-run Chinook salmon fry emerge from the gravel from November to March (Moyle 2002a), and the emigration timing is highly variable because they may migrate downstream as young-of-the-year (YOY) or as juveniles or yearlings.

The modal size of fry migrants at approximately 40 mm between December and April in Mill, Butte, and Deer creeks reflects a prolonged emergence of fry from the gravel (Lindley et al. 2004). Studies in Butte Creek (Ward et al. 2003, McReynolds et al. 2007) found the majority of CV spring-run Chinook salmon migrants to be fry that emigrated primarily during December, January, and February and that these movements appeared to be influenced by increased flow. Small numbers of CV spring-run Chinook salmon were observed to remain in Butte Creek to rear and migrated as yearlings later in the spring.

Juvenile emigration patterns in Mill and Deer creeks are very similar to patterns observed in Butte Creek, with the exception that Mill and Deer creek juveniles typically exhibit a later YOY migration and an earlier yearling migration (Lindley et al. 2004). The CDFG (1998) observed the emigration period for spring-run Chinook salmon extending from November to early May, with up to 69 percent of the YOY fish outmigrating through the lower Sacramento River and Delta during this period. Peak movement of juvenile CV spring-run Chinook salmon in the Sacramento River at Knights Landing occurs in December and again in March and April. However, juveniles also are observed between November and the end of May (Snider and Titus 2000).

Fry and parr may rear within riverine or estuarine habitats of the Sacramento River, the Delta, and their tributaries. Also, CV spring-run Chinook salmon juveniles have been observed rearing in the lower reaches of non-natal tributaries and intermittent streams in the Sacramento Valley during the winter months (Maslin et al. 1997, CDFG 2001). Within the Delta, juvenile Chinook salmon forage in shallow areas with protective cover such as intertidal and subtidal mudflats, marshes, channels, and sloughs (McDonald 1960, Dunford 1975). Cladocerans, copepods, amphipods (*Corophium*), and larvae of *Diptera*, as well as small arachnids and ants, are common prey items (Kjelson et al. 1982, Sommer et al. 2001, MacFarlane and Norton 2002). Shallow water habitats are more productive than the main river channels, supporting higher growth rates, partially due to higher prey consumption rates as well as favorable environmental temperatures (Sommer et al. 2001). Optimal water temperatures for the growth of juvenile Chinook salmon in the Delta are between 54 to 57ºF (12 to 14ºC) (Brett 1952).

1.2.3.5 Estuarine Rearing

Within the estuarine habitat, juvenile Chinook salmon movements are dictated by the tidal cycles, following the rising tide into shallow water habitats from the deeper main channels and returning to the main channels when the tide recedes (Levy and Northcote 1981, Levings 1982, Levings et al. 1986, Healey 1991). As juvenile Chinook salmon increase in length, they tend to school in the surface waters of the main and secondary channels and sloughs, following the tides into shallow water habitats to feed (Allen and Hassler 1986). In Suisun Marsh, Moyle et al. (1989) reported that Chinook salmon fry tend to remain close to the banks and vegetation, near protective cover, and in dead-end tidal channels. Kjelson et al. (1982) reported that juvenile Chinook salmon demonstrated a diel migration pattern, orienting themselves to nearshore cover and structure during the day, but moving into more open, offshore waters at night. The fish also distributed themselves vertically in relation to ambient light. During the night, juveniles were distributed randomly in the water column, but would school up during the day into the upper 3 meters of the water column. Available data indicate that juvenile Chinook salmon use Suisun Marsh extensively both as a migratory pathway and rearing area as they move downstream to the Pacific Ocean (O'Rear and Moyle 2012).

1.2.3.6 Ocean Rearing

Once in the ocean, juvenile Chinook salmon tend to stay along the California coast (Moyle 2002). This is likely due to the high productivity caused by the upwelling of the California current. These food-rich waters are important to ocean survival, as indicated by a decline in survival during years when the current does not flow as strongly and upwelling decreases (Moyle 2002, Lindley et al. 2009). After entering the ocean, juveniles become voracious predators on small fish and crustaceans and invertebrates such as crab larvae and amphipods. As they grow larger, fish increasingly dominate their diet. They typically feed on whatever pelagic plankton is most abundant, usually herring, anchovies, juvenile rockfish, and sardines. The ocean stage of the Chinook life cycle lasts 1 to 5 years. Information on salmon abundance and distribution in the ocean is based upon CWT recoveries from ocean fisheries. For more than 30 years, the marine distribution and relative abundance of specific stocks, including ESA-listed ESUs, have been estimated using a representative CWT hatchery stock (or stocks) to serve as proxies for the natural and hatchery-origin fish within ESUs. One extremely important assumption of this approach is that hatchery and natural stock components are similar in their life histories and ocean migration patterns (Knudsen et al 1999).

Ocean harvest of CV Chinook salmon is estimated using an abundance index called the Central Valley Index (CVI). The CVI is the ratio of Chinook salmon harvested south of Point Arena (where 85 percent of Central Valley Chinook salmon are caught) to escapement (adult spawner populations that have "escaped" the ocean fisheries and made it into the rivers to spawn). The CWT returns indicate that Sacramento River Chinook salmon congregate off the California coast between Point Arena and Morro Bay (NMFS 2013).

Table B-2 shows the temporal occurrence of adult (a) and juvenile (b) CV spring-run Chinook salmon in the Sacramento River. Darker shades indicate months of greatest relative abundance.

Table B-2. The Temporal Occurrence of Adult (a) and Juvenile (b) Central Valley Spring-run Chinook Salmon in the Sacramento River.

(a) Adult migration																								
Location	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**		**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Sac. River basin[a,b]					Medium	Medium	Medium	Medium	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low					
Sac. River Mainstem[b,c]		Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low								
Mill Creek[d]					Low	Low	Medium	High	High	High	High	Medium	Medium	Low	Low									
Deer Creek[d]					Low	Low	Medium	High	High	High	High	Medium	Medium											
Butte Creek[d,g]			Low	Medium	Medium	Medium	Medium	High	High	High	High	Medium	Low											
(b) Adult Holding[a,b]				Low	Low	Medium	Medium	High	High	High	High	High	High	High	High	Medium	Medium	Low	Low					
(c) Adult Spawning[a,b,c]															Low	Medium	High	High	Medium	Low				
(b) Juvenile migration																								
Location	**Jan**		**Feb**		**Mar**		**Apr**		**May**		**Jun**		**Jul**		**Aug**		**Sep**		**Oct**		**Nov**		**Dec**	
Sac. River Tribs[e]	Medium	Medium	Medium	Medium	Medium	Medium													Medium	Medium	High	High	High	High
Upper Butte Creek[f,g]	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low							Low	Low	Low	Low	High	High
Mill, Deer, Butte Creeks[d,g]	High	High	High	High	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low							Low	Low	Low	Low	Low	Low
Sac. River at RBDD[c]	High	High	Low	Low	Low	Low	Low	Low	Low												High	High	High	High
Sac. River at KL[h]	Medium	Medium	Medium	Medium	High	High	High	High	Medium	Medium											Medium	Medium	High	High

Relative Abundance: = High = Medium = Low

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

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

1.2.4 Description of Viable Salmonid Population Parameters

As an approach to evaluate the likelihood of viability of the CV spring-run Chinook salmon ESU and determine the extinction risk of the ESU, NMFS uses the VSP concept. In this section, we evaluate the VSP parameters of abundance, productivity, spatial structure, and diversity. These specific parameters are important to consider because they are predictors of extinction risk, and the parameters reflect general biological and ecological processes that are critical to the growth and survival of salmon (McElhany et al. 2000).

1.2.4.1 Abundance

Historically spring-run Chinook salmon were the second most abundant salmon run in the Central Valley and one of the largest on the west coast (CDFG 1990). These fish occupied the upper and middle elevation reaches (1,000 to 6,000 feet) of the San Joaquin, American, Yuba, Feather, Sacramento, McCloud and Pit rivers, with smaller populations in most tributaries with sufficient habitat for over-summering adults (Stone 1872, Rutter 1904, Clark 1929).

The Central Valley drainage as a whole is estimated to have supported spring-run Chinook salmon runs as large as 600,000 fish between the late 1880s and 1940s (CDFG 1998). The San Joaquin River historically supported a large run of spring-run Chinook salmon, suggested to be one of the largest runs of any Chinook salmon on the West Coast with estimates averaging 200,000 to 500,000 adults returning annually (CDFG 1990). Construction of Friant Dam on the San Joaquin River began in 1939 and when completed in 1942 blocked access to all upstream habitat.

The FRFH spring-run Chinook salmon population represents the only remaining evolutionary legacy of the spring-run Chinook salmon populations that once spawned above Oroville Dam, and has been included in the ESU based on its genetic linkage to the natural spawning population and the potential development of a conservation strategy for the hatchery program. On the Feather River, significant numbers of spring-run Chinook salmon, as identified by run timing, return to the FRFH. Since 1954, spawning escapement has been estimated using combinations of in-river estimates and hatchery counts, with estimates ranging from 2,908 in 1964 to two fish in 1978 (CDWR 2001). However, after 1981, CDFG (now CDFW) ceased to estimate in-river spawning spring-run Chinook salmon because spatial and temporal overlap with fall-run Chinook salmon spawners made it impossible to distinguish between the two races. Spring-run Chinook salmon estimates after 1981 have been based solely on salmon entering the hatchery during the month of September. The 5-year moving averages from 1997 to 2006 had been more than 4,000 fish, but from 2007 to 2011, the 5-year moving averages have declined each year to a low of 1,742 fish in 2011, and 2012 through 2015 were back up slightly to just over 2,000 fish (CDFW 2016) (Table B-3).

Genetic testing has indicated that substantial introgression has occurred between fall-run and spring-run Chinook salmon populations within the Feather River system due to temporal overlap and hatchery practices (CDWR 2001). Because Chinook salmon have not always been spatially separated in the FRFH, spring-run and fall-run Chinook salmon have been spawned together, thus compromising the genetic integrity of the spring-run Chinook salmon stock (Good et al. 2005, Cavallo et al. 2011).

In addition, coded-wire tag (CWT) information from these hatchery returns has indicated that fall-run and spring-run Chinook salmon have overlapped, providing further evidence that the two runs have been interbred in the hatchery (CDWR 2001). For the reasons discussed above, the FRFH spring-run Chinook salmon numbers are not included in the following discussion of ESU abundance trends.

Monitoring the Sacramento River mainstem during spring-run Chinook salmon spawning timing indicates that some spawning occurs in the river. The lack of physical separation of spring-run Chinook salmon from fall-run Chinook salmon is complicated by overlapping migration and spawning periods. Significant hybridization with fall-run Chinook salmon makes identification of spring-run Chinook salmon in the mainstem very difficult, but counts of Chinook salmon redds in September are typically used as an indicator of spring-run Chinook salmon abundance. Less than 15 Chinook salmon redds per year were observed in the Sacramento River from 1989 to 1993 during September aerial redd counts (USFWS2003).

Redd surveys conducted in September between 2001 and 2011 have observed an average of 36 Chinook salmon redds from Keswick Dam downstream to the RBDD, ranging from 3 to 105 redds; 2012 observed zero redds; and 2013 observed 57 redds in September (California Department Fish and Wildlife, unpublished data, 2014).

Therefore, even though physical habitat conditions can support spawning and incubation, spring-run Chinook salmon depend on spatial segregation and geographic isolation from fall-run Chinook salmon to maintain genetic diversity. With the onset of fall-run Chinook salmon spawning occurring in the same time and place as potential spring-run Chinook salmon spawning, it is likely extensive introgression between the populations has occurred (CDFG 1998). For these reasons, Sacramento River mainstem spring-run Chinook salmon are not included in the following discussion of ESU abundance trends.

Sacramento River tributary populations in Mill, Deer, and Butte creeks are likely the best trend indicators for the CV spring-run Chinook salmon ESU as a whole because these streams contain the majority of the abundance and are currently the only independent populations within the ESU. Generally, these streams have shown a positive escapement trend since 1991, displaying broad fluctuations in adult abundance. All tributaries combined, shown in Table B-3, are dominated by returns in Mill, Deer, and Butte creeks. Combined tributary returns from 1988 to 2015 have ranged from 1,013 in 1993 to 23,787 in 1998 (Table B-3). Escapement numbers are dominated by Butte Creek returns (Good et al. 2005), which averaged more than 7,000 fish from 1995 to 2005 but then declined in years 2006 through 2011, with an average of just over 3,000 fish. During this same period, adult returns on Mill and Deer creeks have averaged over 2,000 fish total and just over 1,000 fish total, respectively. Although trends were generally positive during this time, annual abundance estimates displayed a high level of fluctuation, and the overall number of CV spring-run Chinook salmon remained well below estimates of historic abundance.

Additionally, in 2002 and 2003, mean water temperatures in Butte Creek exceeded 21°C (69.8°F) for 10 or more days in July (Williams 2006). These persistent high water temperatures, coupled with high fish densities, precipitated an outbreak of *Columnaris* (*Flexibacter columnaris*) and *Ichthyophthiriasis* (*Ichthyophthirius multifiis*) diseases in the adult spring-run Chinook salmon over-summering in Butte Creek. In 2002, this contributed to a pre-spawning mortality of approximately 20 to 30 percent of the adults. In 2003, approximately 65 percent of the adults succumbed, resulting in a loss of an estimated 11,231 adult spring-run Chinook salmon in Butte Creek due to the diseases. In 2015, Butte Creek again experienced severe temperature conditions, with nearly 2,000 fish entering the creek, only 1,081 observed during the snorkel survey, and only 413 carcasses observed, which indicates a large number of pre-spawn mortality.

Declines in abundance from 2005 to 2016 placed the Mill Creek and Deer Creek populations in the high extinction risk category due to the rates of decline, and in the case of Deer Creek, also the level of escapement (NMFS 2016b). Butte Creek has sufficient abundance to retain its low extinction risk classification, but the rate of population decline in years 2006 through 2016 was nearly sufficient to classify it as a high extinction risk based on these criteria. Nonetheless, the watersheds identified as having the highest likelihood of success for achieving viability/low risk of extinction include Butte, Deer, and Mill creeks (NMFS 2016b). Some other tributaries to the Sacramento River, such as Clear Creek and Battle Creek, have seen population gains in the years from 2001 to 2014, but the overall abundance numbers have remained low. 2012 was a good return year for most of the tributaries, with some, such as Battle Creek, having the highest return on record (799). Additionally, 2013 escapement numbers increased in most tributary populations, which resulted in the second highest number of spring-run Chinook salmon returning to the tributaries since 1998. However, 2014 escapement numbers appear to be lower at just over 5,000 fish for the tributaries combined, which indicates a highly fluctuating and unstable ESU abundance. Even more concerning were returns for 2015, which were record lows for some populations. The next several years are anticipated to remain quite low as the effects of the 2012 to 2015 drought are fully realized (NMFS 2016b).

1.2.4.2 Productivity

The productivity of a population (i.e., production over the entire life cycle) can reflect conditions (e.g., environmental conditions) that influence the dynamics of a population and determine abundance. In turn, the productivity of a population allows an understanding of the performance of a population across the landscape and habitats in which it exists and its response to those habitats (McElhany et al. 2000). In general, declining productivity equates to declining population abundance. McElhany et al. (2000) suggested criteria for a population's natural productivity should be sufficient to maintain its abundance above the viable level (a stable or increasing population growth rate). In the absence of numeric abundance targets, this guideline is used. CRRs are indications of whether a cohort is replacing itself in the next generation.

From 1993 to 2007, the 5-year moving average of the tributary population (Mill, Deer, and Butte creeks) CRR remained over 1.0, but then declined to a low of 0.47 in years 2007 through 2011 (see Table B-3 for CV spring-run Chinook salmon population estimates with corresponding CRRs from 1986 to 2015). The productivity of the Feather River and Yuba River populations and contribution to the CV spring-run Chinook salmon ESU currently is unknown; however, the FRFH currently produces 2,000,000 juveniles each year. The CRR for the 2012 combined tributary population was 3.84 and 8.68 in 2013, due to increases in abundance for most populations. Although 2014 returns were lower than the previous 2 years, the CRR was still positive (1.85). However, 2015 returns were very low, with a CRR of 0.14 when using Butte Creek snorkel survey numbers—the lowest on record. Using the Butte Creek carcass surveys, the 2015 CRR for just Butte Creek was only 0.02.

Table B-3. Central Valley Spring-run Chinook Salmon Population Estimates from CDFW Grand Tab (2015) with Corresponding Cohort Replacement Rates for Years Since 1986.

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR
1986	3,638	1,433	2,205						
1987	1,517	1,213	304						
1988	9,066	6,833	2,233						
1989	7,032	5,078	1,954		0.89			1.93	

Year	Sacramento River Basin Escapement Run Size[a]	FRFH Population	Tributary Populations	5-Year Moving Average Tributary Population Estimate	Trib CRR[b]	5-Year Moving Average of Trib CRR	5-Year Moving Average of Basin Population Estimate	Basin CRR	5-Year Moving Average of Basin CRR
1990	3,485	1,893	1,592	1,658	5.24		4,948	2.30	
1991	5,101	4,303	798	1,376	0.36		5,240	0.56	
1992	2,673	1,497	1,176	1,551	0.60		5,471	0.38	
1993	5,685	4,672	1,013	1,307	0.64	1.55	4,795	1.63	1.22
1994	5,325	3,641	1,684	1,253	2.11	1.79	4,454	1.04	1.18
1995	14,812	5,414	9,398	2,814	7.99	2.34	6,719	5.54	1.83
1996	8,705	6,381	2,324	3,119	2.29	2.73	7,440	1.53	2.03
1997	5,065	3,653	1,412	3,166	0.84	2.77	7,918	0.95	2.14
1998	30,533	6,746	23,787	7,721	2.53	3.15	12,888	2.06	2.23
1999	9,838	3,731	6,107	8,606	2.63	3.26	13,791	1.13	2.24
2000	9,201	3,657	5,544	7,835	3.93	2.44	12,669	1.82	1.50
2001	16,865	4,135	12,730	9,916	0.54	2.09	14,300	0.55	1.30
2002	17,212	4,189	13,023	12,238	2.13	2.35	16,730	1.75	1.46
2003	17,691	8,662	9,029	9,287	1.63	2.17	14,161	1.92	1.43
2004	13,612	4,212	9,400	9,945	0.74	1.79	14,916	0.81	1.37
2005	16,096	1,774	14,322	11,701	1.10	1.23	16,295	0.94	1.19
2006	10,828	2,061	8,767	10,908	0.97	1.31	15,088	0.61	1.21
2007	9,726	2,674	7,052	9,714	0.75	1.04	13,591	0.71	1.00
2008	6,162	1,418	4,744	8,857	0.33	0.78	11,285	0.38	0.69
2009	3,801	989	2,812	7,539	0.32	0.69	9,323	0.35	0.60
2010	3,792	1,661	2,131	5,101	0.30	0.53	6,862	0.39	0.49
2011	5,033	1,969	3,064	3,961	0.65	0.47	5,703	0.82	0.53
2012	14,724	3,738	10,986	4,747	3.91	1.10	6,702	3.87	1.16
2013	18,384	4,294	14,090	6,617	6.61	2.36	9,147	4.85	2.06
2014	8,434	2,776	5,658	7,186	1.85	2.66	10,073	1.68	2.32
2015	3,074	1,586	1,488	7,057	0.14	2.63	9,930	0.21	2.28
Median	9,775	3,616	6,159	6,541	1.97	1.89	10,220	1.00	1.46

a Sacramento River Basin run size is the sum of the escapement numbers from the FRFH and the tributaries.

b Abbreviations: CRR = Cohort Replacement Rate, Trib = tributary

1.2.4.3 Spatial Structure

Spatial structure refers to the arrangement of populations across the landscape, the distribution of spawners within a population, and the processes that produce these patterns. Species with a restricted spatial distribution and few spawning areas are at a higher risk of extinction from catastrophic environmental events (e.g., a single landslide) than are species with more widespread and complex spatial structure. Species or population diversity concerns the phenotypic (morphology, behavior, and life-history traits) and genotypic (DNA) characteristics of populations. Phenotypic diversity allows more populations to use a wider array of environments and protects populations against short-term temporal and spatial environmental changes. Genotypic diversity, on the other hand, provides populations with the ability to survive long-term changes in the environment. To meet the objective of representation and redundancy, diversity groups need to contain multiple populations to survive in a dynamic ecosystem subject to unpredictable stochastic events such as pyroclastic events or wild fires (McElhany et al 2000).

The Central Valley Technical Review Team (TRT) estimated that historically there were 18 or 19 independent populations of CV spring-run Chinook salmon, along with a number of dependent populations, all within four distinct geographic regions, or diversity groups (Figure B-6) (Lindley et al. 2004). Of these populations, only three independent populations currently exist (Mill, Deer, and Butte creeks tributary to the upper Sacramento River), and they represent only the northern Sierra Nevada diversity group. Additionally, smaller populations are currently persisting in Antelope and Big Chico creeks and the Feather and Yuba rivers in the northern Sierra Nevada diversity group (CDFG 1998). All historical populations in the basalt and porous lava diversity group and the southern Sierra Nevada diversity group have been extirpated, except Battle Creek in the basalt and porous lava diversity group has had a small persistent population since 1995; the upper Sacramento River may have a small persisting population spawning in the mainstem-river as well. The northwestern California diversity group did not historically contain independent populations; it currently contains two small persisting populations, in Clear Creek and Beegum Creek (tributary to Cottonwood Creek), that are likely dependent on the northern Sierra Nevada diversity group populations for their continued existence. Construction of low elevation dams in the foothills of the Sierras on the San Joaquin, Mokelumne, Stanislaus, Tuolumne, and Merced rivers has been thought to have extirpated CV spring-run Chinook salmon from these watersheds of the San Joaquin River as well as on the American River of the Sacramento River basin. However, observations in the last decade suggest that spring-running populations may currently occur in the Stanislaus and Tuolumne rivers (Franks 2014).

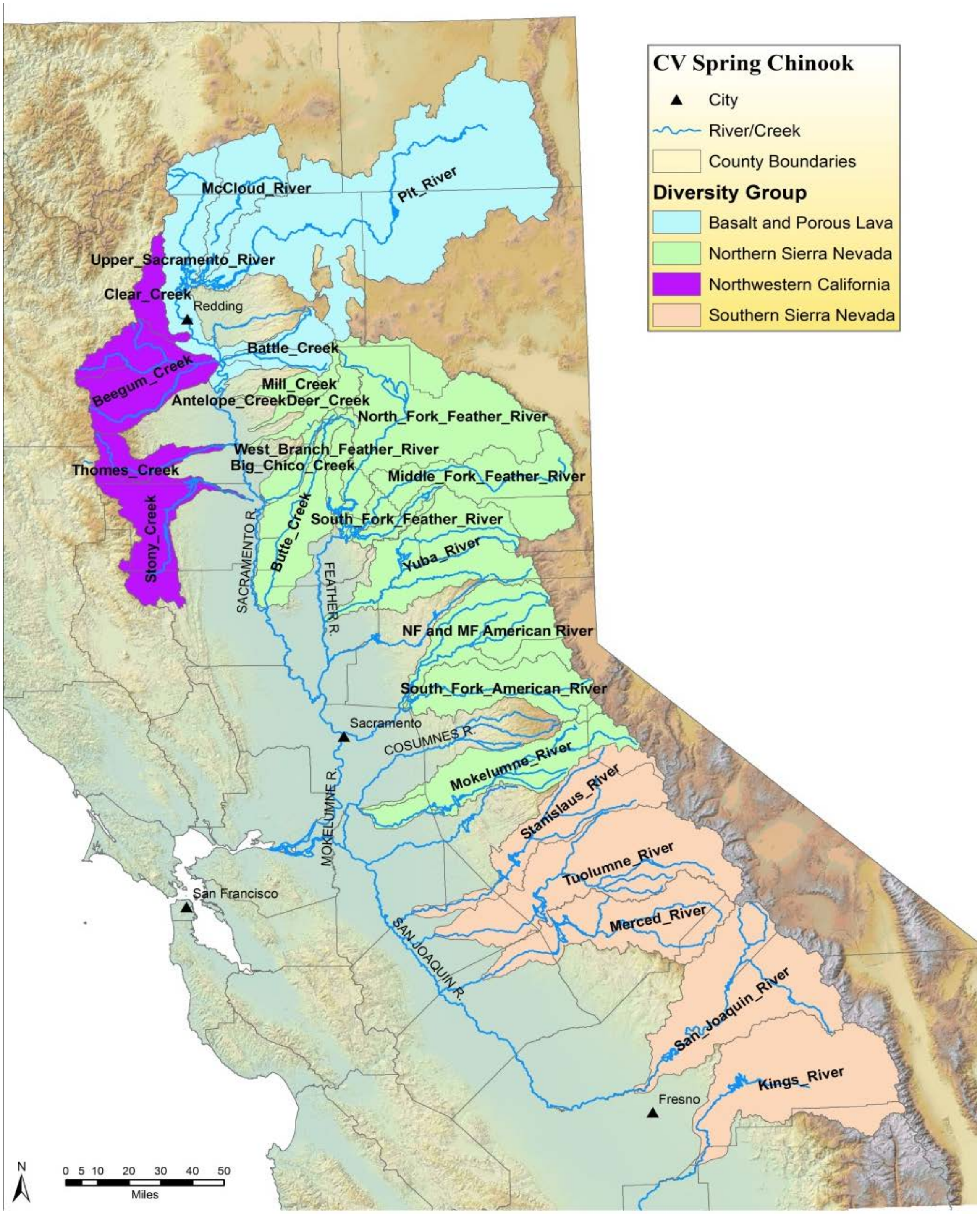

Figure B-6. Diversity Groups for the Central Valley Spring-run Chinook Salmon Evolutionarily Significant Unit.

With only one of four diversity groups currently containing viable independent populations, the spatial structure of CV spring-run Chinook salmon is severely reduced. Butte Creek spring-run Chinook salmon adult returns are currently utilizing all available habitat in the creek; it is unknown if individuals have opportunistically migrated to other systems. The persistent populations in Clear Creek and Battle Creek, with habitat restoration projects completed and more underway, are anticipated to add to the spatial structure of the CV spring-run Chinook salmon ESU if they can reach viable status in the basalt and porous lava and northwestern California diversity group areas. The spatial structure of the spring-run Chinook salmon ESU would still be lacking due to the extirpation of all San Joaquin River basin spring-run Chinook salmon populations; however, recent information suggests that perhaps a self-sustaining population of spring-run Chinook salmon is occurring in some of the San Joaquin River tributaries, most notably the Stanislaus and the Tuolumne rivers.

A final rule was published to designate a nonessential experimental population of CV spring-run Chinook salmon in the San Joaquin River from Friant Dam downstream to its confluence with the Merced River to allow reintroduction of the species below Friant Dam as part of the San Joaquin River Restoration Program (SJRRP) (78 FR 79622; December 31, 2013). Pursuant to ESA section 10(j), with limited exceptions, each member of an experimental population shall be treated as a threatened species. However, the rule includes protective regulations under ESA section 4(d) that provide specific exceptions to prohibitions for taking CV spring-run Chinook salmon within the experimental population area, and in specific instances elsewhere. The first release of CV spring-run Chinook salmon juveniles into the San Joaquin River occurred in April 2014. A second release occurred in 2015, and future releases are planned to continue annually during the spring. The 2016 release included the first generation of spring-run Chinook salmon reared entirely in the San Joaquin River in over 60 years. The nonessential experimental population's contribution to the viability of the CV spring-run Chinook salmon ESU will be determined in future status assessments.

Snorkel surveys (Kennedy and Cannon 2005) conducted between October 2002 and October 2004 on the Stanislaus River identified adults in June 2003 and 2004, as well as observed Chinook fry in December 2003, which would indicate spring-run Chinook salmon spawning timing. In addition, monitoring on the Stanislaus River since 2003 and on the Tuolumne River since 2009 have indicated upstream migration of adult spring-run Chinook salmon (Anderson et al. 2007), and 114 adult were counted on the video weir on the Stanislaus River between February and June in 2013, with only seven individuals without adipose fins (FISHBIO LLC 2015).

Finally, rotary screw trap (RST) data provided by the Stockton USFWS corroborates the spring-run Chinook salmon adult timing by indicating that there are a small number of fry migrating out of the Stanislaus and Tuolumne rivers at a period that would coincide with spring-run Chinook salmon juvenile emigration (Franks 2014). Although there have been observations of spring-run Chinook salmon returning to the San Joaquin tributaries in recent years, there is insufficient information to determine the specific origin of these fish and whether they are straying into the basin or returning to natal streams. Genetic assessment or natal stream analyses of hard tissues could inform managers' understanding of the relationship of these fish to the ESU.

Lindley et al. (2007) described a general criterion for "representation and redundancy" of spatial structure, which was for each diversity group to have at least two viable populations. More specific recovery criteria for the spatial structure of each diversity group have been laid out in the NMFS Central Valley Salmon and Steelhead Recovery Plan (NMFS 2014a). According to the criteria, one viable population in the Northwestern California diversity group, two viable populations in the basalt and porous lava diversity group, four viable populations in the northern Sierra Nevada diversity group, and two viable populations in the southern Sierra Nevada diversity group, in addition to maintaining dependent populations, are needed for recovery. It is clear that further efforts will need to involve more than restoration of currently accessible watersheds to make the ESU viable. The NMFS Central Valley Salmon and Steelhead Recovery Plan calls for re-establishing populations into historical habitats currently blocked by large dams, such as the reintroduction of a population upstream of Shasta Dam, and to facilitate passage of fish upstream of Englebright Dam on the Yuba River (NMFS 2014a).

1.2.4.4 Diversity

Diversity, both genetic and behavioral, is critical to success in a changing environment. Salmonids express variation in a suite of traits such as anadromy, morphology, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, and physiology and molecular genetic characteristics (including rate of gene-flow among populations). Criteria for the diversity parameter are that human-caused factors should not alter variation of traits. The more diverse these traits (or the more these traits are not restricted), the more adaptable a population is, and the more likely that individuals, and therefore the species, would survive and reproduce in the face of environmental variation (McElhany et al. 2000). However, when this diversity is reduced due to loss of entire life-history strategies or to loss of habitat used by fish exhibiting variation in life-history traits, the species is in all probability less able to survive and reproduce given environmental variation.

The CV spring-run Chinook salmon ESU is comprised of two known genetic complexes. Analysis of natural and hatchery spring-run Chinook salmon stocks in the Central Valley indicates that the northern Sierra Nevada diversity group spring-run Chinook salmon populations in Mill, Deer, and Butte creeks retain genetic integrity as opposed to the genetic integrity of the Feather River population, which has been somewhat compromised. The Feather River spring-run Chinook salmon have introgressed with the Feather River fall-run Chinook salmon, and it appears that the Yuba River spring-run Chinook salmon population may have been impacted by FRFH fish straying into the Yuba River (and likely introgression with wild Yuba River fall-run has occurred) (Garza et al 2008). Additionally, the diversity of the spring-run Chinook salmon ESU has been further reduced with the loss of the majority, if not all, of the San Joaquin River basin spring-run Chinook salmon populations. Efforts underway, such as the San Joaquin River Restoration Project to reintroduce a spring-run Chinook salmon population below Friant Dam, are necessary to improve the diversity of CV spring-run Chinook salmon (NMFS 2014a).

1.2.4.5 Summary of Evolutionarily Significant Unit Viability

Because the populations in Butte, Deer and Mill creeks are the best trend indicators for ESU viability, we can evaluate risk of extinction based on VSP parameters in these watersheds. Lindley et al. (2007) indicated that the spring-run Chinook salmon populations in the Central Valley had a low risk of extinction in Butte and Deer creeks according to their population viability analysis (PVA) model and other population viability criteria (i.e., population size, population decline, catastrophic events, and hatchery influence, which correlate with VSP parameters abundance, productivity, spatial structure, and diversity). The Mill Creek population of spring-run Chinook salmon was at moderate extinction risk according to the PVA model, but appeared to satisfy the other viability criteria for low-risk status. However, the CV spring-run Chinook salmon ESU failed to meet the “representation and redundancy rule” since there are only demonstrably viable populations in one diversity group (northern Sierra Nevada) out of the three diversity groups that historically contained them, or out of the four diversity groups as described in the NMFS Central Valley Salmon and Steelhead Recovery Plan. Over the long term, these three remaining populations are considered to be vulnerable to catastrophic events, such as volcanic eruptions from Mount Lassen or large forest fires, due to the close proximity of their headwaters to each other. Drought is also considered to pose a significant threat to the viability of the spring-run Chinook salmon populations in these three watersheds due to their close proximity to each other. One large event could eliminate all three populations.

Until 2012, the status of CV spring-run Chinook salmon ESU had deteriorated on balance since the 2005 status review and the Lindley et al. (2007) assessment, with two of the three extant independent populations (Deer and Mill creeks) of spring-run Chinook salmon slipping from low or moderate extinction risk to high extinction risk. Additionally, Butte Creek remained at low risk, although it was on the verge of moving towards high risk, due to rate of population decline. In contrast, spring-run Chinook salmon in Battle and Clear creeks had increased in abundance since 1998, reaching levels of abundance that place these populations at moderate extinction risk. Both of these populations have likely increased at least in part due to extensive habitat restoration. The Southwest Fisheries Science Center concluded in their viability report that the status of CV spring-run Chinook salmon ESU has probably deteriorated since the 2005 status review and that its extinction risk has increased (Williams et al. 2011). The degradation in status of the three formerly low- or moderate-risk independent populations is cause for concern.

The viability assessment of CV spring-run Chinook salmon conducted during NMFS’ 2010 status review (NMFS 2011a) found that the biological status of the ESU had worsened since the last status review (2005) and recommended that its status be reassessed in 2 to 3 years as opposed to waiting another 5 years if the decreasing trend continued and the ESU did not respond positively to improvements in environmental conditions and management actions. In 2012 and 2013, most tributary populations increased in returning adults, averaging over 13,000. However, 2014 returns were lower again, just over 5,000 fish, indicating the ESU remains highly fluctuating. The most recent status review, conducted in 2015 (NMFS 2016b), looked at promising increasing populations in 2012 to 2014. However, the 2015 returning fish were extremely low (1,488), with additional pre-spawn mortality reaching record lows. Because the effects of the 2012 to 2015 drought have not been fully realized, we anticipate at least several more years of very low returns, which may reach severe rates of decline (NMFS 2016b).

In summary, the extinction risk for the CV spring-run Chinook salmon ESU remains at moderate risk of extinction (NMFS 2016b). Based on the severity of the drought and the low escapements, as well as increased pre-spawn mortality in Butte, Mill, and Deer creeks in 2015, there is concern that these CV spring-run Chinook salmon strongholds will deteriorate into high extinction risk in the coming years based on the population size or rate of decline criteria (NMFS 2016b).

1.3 California Central Valley Steelhead Distinct Population Segment

- Originally listed as threatened (63 FR 13347; March 19, 1998), reaffirmed as threatened (71 FR 834; January 5, 2006)
- Designated critical habitat (70 FR 52488; September 2, 2005)

The Federally listed DPS of California Central Valley (CCV) steelhead and designated critical habitat occur in the action area and may be affected by the PA.

1.3.1 Species Listing and Critical Habitat Designation History

CCV steelhead were originally listed as threatened on March 19, 1998 (63 FR 13347). Following a new status review (Good et al. 2005) and after application of the agency's hatchery listing policy, NMFS reaffirmed the status of CCV steelhead as threatened and also listed the FRFH and Coleman NFH artificial propagation programs as part of the DPS on January 5, 2006 (71 FR 834). In doing so, NMFS applied the DPS policy to the species because the resident and anadromous life forms of steelhead remain "markedly separated" as a consequence of physical, ecological, and behavioral factors, and may therefore warrant delineation as separate DPSs (71 FR 834; January 5, 2006). On May 5, 2016, NMFS completed another 5-year status review of CCV steelhead and recommended that the CCV steelhead DPS remain classified as a threatened species (NMFS 2016c). Critical habitat was designated for CCV steelhead on September 2, 2005 (70 FR 52488).

1.3.2 Critical Habitat and Physical or Biological Features for California Central Valley Steelhead

Critical habitat for CCV steelhead includes stream reaches such as those of the Sacramento, Feather, and Yuba rivers and the Deer, Mill, Battle, and Antelope creeks in the Sacramento River basin; the San Joaquin River, including its tributaries; and the waterways of the Delta (Figure B-7). Currently, the CCV steelhead DPS and critical habitat extends up the San Joaquin River to the confluence with the Merced River. Critical habitat includes the stream channels in the designated stream reaches and the lateral extent as defined by the ordinary high-water line. In areas where the ordinary high-water line has not been defined, the lateral extent will be defined by the bankfull elevation (defined as the level at which water begins to leave the channel and move into the floodplain; it is reached at a discharge that generally has a recurrence interval of 1 to 2 years on the annual flood series) (Bain and Stevenson 1999) (70 FR 52488; September 2, 2005). The following subsections describe the status of the PBFs of CCV steelhead critical habitat, which are listed in the critical habitat designation (70 FR 52488; September 2, 2005).

1.3.2.1 Spawning Habitat

The PBFs of CCV steelhead critical habitat include freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, egg incubation, and larval development. Most of the available spawning habitat for steelhead in the Central Valley is located in areas directly downstream of dams due to inaccessibility to historical spawning areas upstream and the fact that dams are typically built at high gradient locations. These reaches are often impacted by the upstream impoundments, particularly over the summer months, when high temperatures can have adverse effects upon salmonids spawning and rearing below the dams (NMFS 2014a). Even in degraded reaches, spawning habitat has a high value for the conservation of the species as its function directly affects the spawning success and reproductive potential of listed salmonids.

1.3.2.2 Freshwater Rearing Habitat

The PBFs of CCV steelhead critical habitat include freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging LWM, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. Both spawning areas and migratory corridors comprise rearing habitat for juveniles, which feed and grow before and during their outmigration. Non-natal, intermittent tributaries also may be used for juvenile rearing. Rearing habitat condition is strongly affected by habitat complexity, food supply, and the presence of predators of juvenile salmonids (NMFS 2014a). Some complex, productive habitats with floodplains remain in the system (e.g., the lower Cosumnes River, Sacramento River reaches with setback levees [i.e., primarily located upstream of the City of Colusa]) and flood bypasses (i.e., Yolo and Sutter bypasses) (Summer et al 2004; Jeffries 2008). However, the channelized, leveed, and riprapped river reaches and sloughs that are common in the Sacramento-San Joaquin system typically have low habitat complexity, low abundance of food organisms, and offer little protection from either fish or avian predators (NMFS 2014a). Freshwater rearing habitat also has a high value for the conservation of the species even if the current conditions are significantly degraded from their natural state. Juvenile life stages of salmonids are dependent on the function of this habitat for successful survival and recruitment.

1.3.2.3 Freshwater Migration Corridors

The PBFs of CCV steelhead critical habitat include freshwater migration corridors free of obstruction and excessive predation with water quantity and quality conditions and natural cover such as submerged and overhanging LWM aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. Migratory corridors are downstream of the spawning areas and include the lower mainstems of the Sacramento and San Joaquin rivers and the Delta. These corridors allow the upstream and downstream passage of adults and the emigration of smolts. Migratory habitat condition is strongly affected by the presence of barriers, which can include dams *(*i.e., hydropower, flood control, and irrigation flashboard dams), unscreened or poorly screened diversions, degraded water quality, or behavioral impediments to migration (NMFS 2014a). For successful survival and recruitment of salmonids, freshwater migration corridors must function sufficiently to provide adequate passage. Stranding of adults has been known to occur in flood bypasses and associated weir structures (Vincik and Johnson 2013), and a number of challenges exist on many tributary streams. For juveniles, unscreened or complex in-river cover have degraded this PBF (NMFS 2014a). However, since the primary freshwater migration corridors are used by numerous listed fish populations, and are essential for connecting early rearing habitat with the ocean, even the degraded reaches are considered to have a high intrinsic value for the conservation of the species.

1.3.2.4 Estuarine Areas

The PBFs for CCV steelhead critical habitat include estuarine areas free of obstruction and excessive predation with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh and saltwater; natural cover such as submerged and overhanging LWM, aquatic vegetation, large rocks and boulders, side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation (50 CFR 226.211(c)).

The remaining estuarine habitat for this species is severely degraded by altered hydrologic regimes, poor water quality, reductions in habitat complexity, and competition for food and space with exotic species (NMFS 2014a). Regardless of the conditions, the remaining estuarine areas are considered to have a high value for the conservation of the species because they provide features that function to provide predator avoidance, as rearing habitat, and as a transitional zone to the ocean environment.

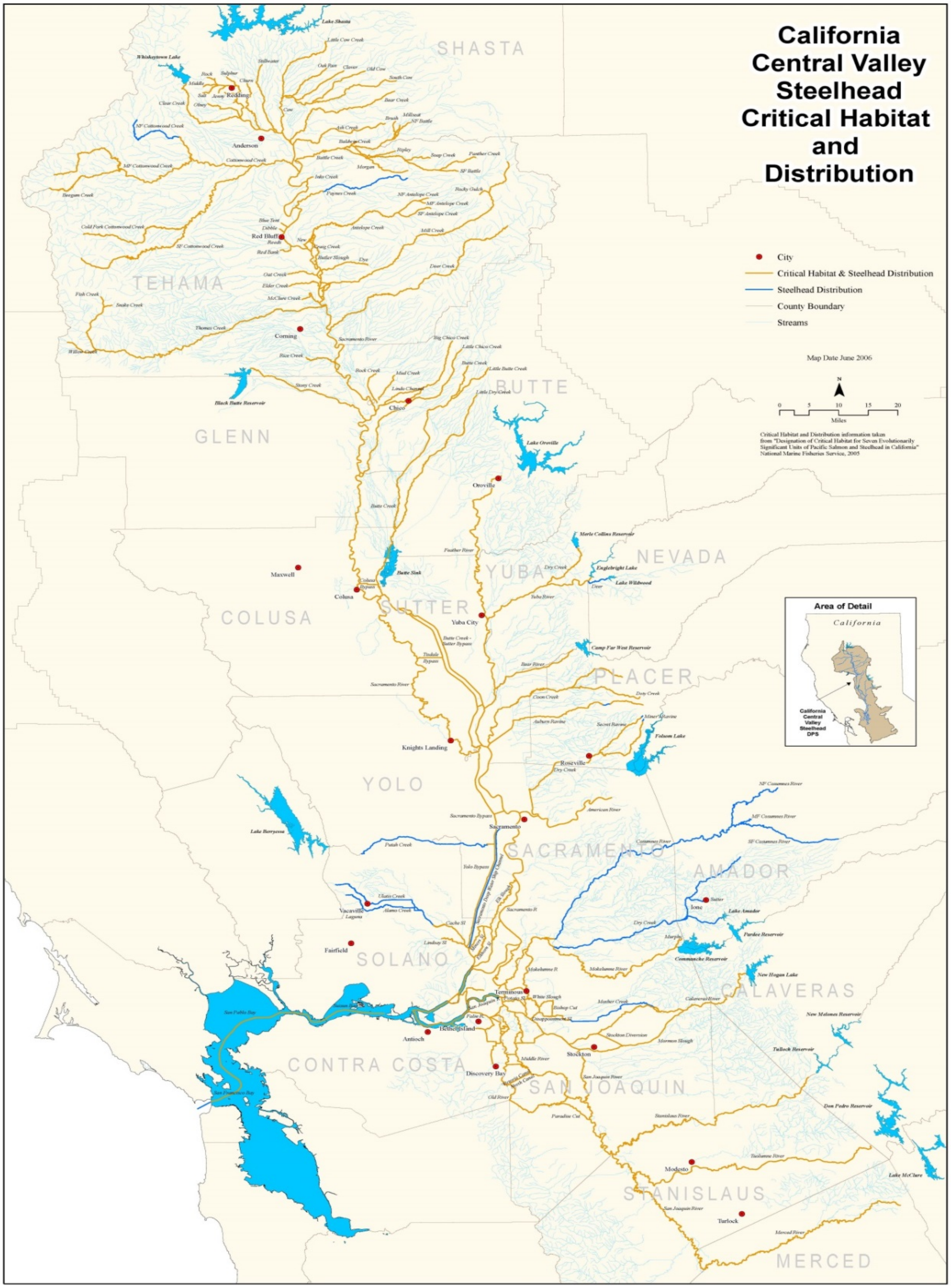

Figure B-7. California Central Valley Steelhead Designated Critical Habitat.

1.3.3 Life History

1.3.3.1 Egg to Parr

The length of time it takes for eggs to hatch depends mostly on water temperature. Steelhead eggs hatch in 3 to 4 weeks at 50°F (10°C) to 59°F (15°C) (Moyle 2002). After hatching, alevins remain in the gravel for an additional 2 to 5 weeks while absorbing their yolk sacs and emerge in spring or early summer (Barnhart 1986). A compilation of data from multiple surveys has shown that steelhead prefer a range of substrate sizes between approximately 18 and 35 mm (Kondolf and Wolman 1993). Fry emerge from the gravel usually about 4 to 6 weeks after hatching, but factors such as redd depth, gravel size, siltation, and temperature can speed or retard this time (Shapovalov and Taft 1954). Coble (1961) noted that a positive correlation exists between dissolved oxygen levels and flow within redd gravel, and Rombough (1988) observed a critical threshold for egg survival between 7.5 and 9.7 mg/L. Upon emergence, fry inhale air at the stream surface to fill their air bladders, absorb the remains of their yolks in the course of a few days, and start to feed actively, often in schools (Barnhart 1986, NMFS 1996).

The newly emerged juveniles move to shallow, protected areas associated within the stream margin (McEwan and Jackson 1996). As steelhead parr increase in size and their swimming abilities improve, they increasingly exhibit a preference for higher velocity and deeper mid-channel areas (Hartman 1965, Everest and Chapman 1972, Fontaine 1988). Growth rates have been shown to be variable and are dependent on local habitat conditions and seasonal climate patterns (Hayes et al. 2008).

Productive juvenile rearing habitat is characterized by complexity, primarily in the form of cover, which can be deep pools, woody debris, aquatic vegetation, or boulders. Cover is an important habitat component for juvenile steelhead both as velocity refugia and as a means of avoiding predation (Meehan and Bjornn 1991). Optimal water temperatures for growth range from 59°F (15°C) to 68°F (20°C) (McCullough et al. 2001, Spina et al. 2006). Cherry et al. (1975) found preferred temperatures for rainbow trout (*O. mykiss*) ranged from 51.8°F (11°C) to 69.8°F (21°C) depending on acclimation temperatures (Myrick and Joseph J. Cech 2001).

1.3.3.2 Smolt Migration

Juvenile steelhead will often migrate downstream as parr in the summer or fall of their first year of life, but this is not a true smolt migration (Loch et al. 1988). Smolt migrations occur in the late winter through spring, when juveniles have undergone a physiological transformation to survive in the ocean, and become slender in shape, bright silvery in coloration, with no visible parr marks. Emigrating CCV steelhead smolts use the lower reaches of the Sacramento River and the Delta primarily as a migration corridor to the ocean. Some rearing behavior is thought to occur in tidal marshes, non-tidal freshwater marshes, and other shallow water habitats in the Delta before the fish enter the ocean (NMFS 2014a).

1.3.3.3 Ocean Behavior

Unlike Pacific salmon, steelhead do not appear to form schools in the ocean (Behnke 1992). Steelhead in the southern part of their range appear to migrate close to the continental shelf, while more northern populations may migrate throughout the northern Pacific Ocean (Barnhart 1986). It is possible that CCV steelhead may not migrate to the Gulf of Alaska region of the North Pacific as commonly as more northern populations such as those in Washington and

British Colombia. Burgner (1993) reported that no CWT steelhead from California hatcheries were recovered from the open ocean surveys or fisheries that were sampled for steelhead between 1980 and 1988. Only a small number of disk-tagged fish from California were captured. This behavior might explain the small average size of CCV steelhead relative to populations in the Pacific Northwest, as food abundance in the nearshore coastal zone may not be as high as in the Gulf of Alaska.

Pearcy et al. (1990) found that the diets of juvenile steelhead caught in coastal waters of Oregon and Washington were highly diverse and included many species of insects, copepods, and amphipods, but by biomass the dominant prey items were small fishes (including rockfish and greenling) and euphausids.

There are no commercial fisheries for steelhead in California, Oregon, or Washington, with the exception of some tribal fisheries in Washington waters.

1.3.3.4 Spawning

CCV steelhead generally enter freshwater from August to November (with a peak in September) (Hallock et al. 1961), and spawn from December to April (with a peak in January through March) in rivers and streams where cold, well-oxygenated water is available (Table B-2) (Hallock et al. 1961, McEwan and Jackson 1996, Williams 2006). The timing of upstream migration is correlated with high flow events, such as freshets, and the associated change in water temperatures (Workman et al. 2002). Adults typically spend a few months in freshwater before spawning (Williams 2006), but very little is known about where they hold between entering freshwater and spawning in rivers and streams. The threshold of a 56°F (13.3°C) maximum water temperature that is commonly used for Chinook salmon is often extended to steelhead, but temperatures for spawning steelhead are not usually a concern as this activity occurs in the late fall and winter months when water temperatures are low. Female steelhead construct redds in suitable gravel and cobble substrate, primarily in pool tailouts and heads of riffles.

Few direct counts of fecundity are available for CCV steelhead populations, but because the number of eggs laid per female is highly correlated with adult size, adult size can be used to estimate fecundity with reasonable precision. Adult steelhead size depends on the duration of and growth rate during their ocean residency (Meehan and Bjornn 1991). CCV steelhead generally return to freshwater after 1 or 2 years at sea (Hallock et al. 1961), and adults typically range in size from 2 to 12 pounds (Reynolds et al. 1993). Steelhead about 55 cm (fork length) long may have fewer than 2,000 eggs, whereas steelhead 85 cm (FL) long can have 5,000 to 10,000 eggs, depending on the stock (Meehan and Bjornn 1991). The average for Coleman NFH since 1999 is about 3,900 eggs per female (USFWS2011).

Unlike Pacific salmon, steelhead are iteroparous, meaning they are capable of spawning multiple times before death (Busby et al. 1996). However, it is rare for steelhead to spawn more than twice before dying; and repeat spawners tend to be biased towards females (Busby et al. 1996). Iteroparity is more common among southern steelhead populations than northern populations (Busby et al. 1996). Although one-time spawners are the great majority, Shapovalov and Taft (1954) reported that repeat spawners were relatively numerous (17.2 percent) in Waddell Creek. Null (2013) found between 36 percent and 48 percent of kelts released from Coleman NFH in 2005 and 2006 survived to spawn the following spring, which is in sharp contrast to what

Hallock (1989) reported for Coleman NFH in the 1971 season, where only 1.1 percent of adults were fish that had been tagged the previous year. Most populations have never been studied to determine the percentage of repeat spawners. Hatchery steelhead are typically less likely than wild fish to survive to spawn a second time (Leider et al. 1986).

1.3.3.5 Kelts

Post-spawning steelhead (kelts) may migrate downstream to the ocean immediately after spawning, or they may spend several weeks holding in pools before outmigrating (Shapovalov and Taft 1954). Recent studies have shown that kelts may remain in freshwater for an entire year after spawning (Teo et al. 2011), but that most return to the ocean (Null 2013).

Table B-4 shows the temporal occurrence of (a) adult and (b) juvenile CCV steelhead at locations in the Central Valley. Darker shades indicate months of greatest relative abundance.

Table B-4. The Temporal Occurrence of (a) Adult and (b) Juvenile California Central Valley Steelhead at Locations in the Central Valley.

(a) Adult Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
[1]Sacramento R. at Fremont Weir	Low / Low	Low / Low	Low /	/	/	/ Low	Low / Low	Low / Medium	High / High	High / Medium	Low / Low	Low / Low
[2]Sacramento R. at RBDD	Low / Low	Low / Low	Low / Low	Low / Low	Low / Low	Low / Low	Low / Low	Low / Low	Medium / Medium	High / Medium	Low / Low	Low / Low
[3]Mill & Deer Creeks	Medium / Medium	High / Medium	Medium / Low	Low / Low	Low / Low	Low / Low	/	/	/	Medium / High	High / Low	Low / Low
[4]Mill Creek at Clough Dam	Low / Low	Medium / High	Medium / Medium	Low / Low	/	/	/	/	/ Low	Medium / High	High / High	Medium / Medium
[5]San Joaquin River	High / High	Medium / Medium	Low / Low	/	/	/	Low / Low	Low / Low	Medium / Medium	Medium / Medium	Medium / Medium	High / High
(b) Juvenile Migration												
Location	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
[1,2]Sacramento R. near Fremont Weir	Low / Low	Low / Low	Medium / Medium	Medium / Medium	Medium / Medium	Medium / Medium	Low / Low	Low / Low	Low / Low	Medium / Medium	Medium / Medium	Low / Low
[6]Sacramento R. at Knights Landing	High / High	High / High	Medium / Medium	Medium / Medium	Low / Low	Low / Low	/	/	/	/	Low / Low	Low / Low
[7]Mill & Deer Creeks (silvery parr/smolts)	Low / Low	Low / Low	Medium / High	High / High	High / High	Low / Low	/	/	/	Low / Low	Low / Low	Low / Low
[7]Mill & Deer Creeks (fry/parr)	Low / Low	Low / Low	Low / Low	Medium / Medium	High / High	High / High	/	/	/	Medium / Medium	Medium / Medium	Medium / Medium
[8]Chipps Island (clipped)	Medium / Medium	High / High	Medium / Medium	Low / Low	Low / Low	/	/	/	/	/	/	Low / Low
[8]ChippsIsland (unclipped)	Medium / Medium	Medium / Medium	High / High	High / High	High / High	Medium / Medium	Low / Low	/	/	/	/	Low / Low
[9]San Joaquin R. at Mossdale	/	Low / Low	Medium / Medium	High / High	High / High	Low / Low	/	/	/	Low / Low	/	/
[10]Mokelumne R. (silvery parr/smolts)	Low / Low	Medium / Medium	Medium / Medium	High / High	High / High	Medium / Medium	Medium / Medium	/	/	/	/	/
[10]Mokelumne R. (fry/parr)	/	Low / Low	Low / Low	Low / Low	Medium / Medium	High / High	Medium / Medium	/	/	/	/	/
[11]Stanislaus R. at Caswell	Low / Low	Medium / Medium	High / High	Medium / Medium	Medium / Medium	Low / Low	/	/	/	/	/	/
[12]Sacramento R. at Hood	Low / Low	High / High	High / High	High / High	High / High	High /	/	/	/	/	Low / Low	Low / Low

Relative Abundance: [black] = High [dark grey] = Medium [light grey] = Low

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

1.3.4 Description of Viable Salmonid Population Parameters

As an approach to determining the conservation status of salmonids, NMFS has developed a framework for identifying attributes of a VSP. The intent of this framework is to provide parties with the ability to assess the effects of management and conservation actions and ensure their actions promote the listed species' survival and recovery. This framework is known as the VSP concept (McElhany et al. 2000). The VSP concept measures population performance in terms of four key parameters: abundance, population growth rate, spatial structure, and diversity.

1.3.4.1 Abundance

Historic CCV steelhead run sizes are difficult to estimate given the paucity of data, but may have approached one to two million adults annually (McEwan 2001). By the early 1960s, the CCV steelhead run size had declined to about 40,000 adults (McEwan 2001). Hallock et al. (1961) estimated an average of 20,540 adult steelhead through the 1960s in the Sacramento River upstream of the Feather River. Steelhead counts at the RBDD declined from an average of 11,187 from 1967 to 1977, to an average of approximately 2,000 through the early 1990s, with an estimated total annual run size for the entire Sacramento-San Joaquin system, based on RBDD counts, to be no more than 10,000 adults (McEwan and Jackson 1996, McEwan 2001). Steelhead escapement surveys at RBDD ended in 1993 due to changes in dam operations. Comprehensive steelhead population monitoring has not taken place in the Central Valley since then, despite 100 percent marking of hatchery steelhead smolts since 1998. Efforts are underway to improve this deficiency, and a long-term adult escapement monitoring plan is being formulated (Eilers et al. 2010).

Current abundance data are limited to returns to hatcheries and redd surveys conducted on a few rivers. The hatchery data are the most reliable, as redd surveys for steelhead are often made difficult by high flows and turbid water usually present during the winter-spring spawning period.

Coleman NFH operates a weir on Battle Creek, where all upstream fish movement is blocked August through February, during the hatchery spawning season. Counts of steelhead captured at and passed above this weir represent one of the better data sources for the CCV DPS. However, changes in hatchery policies and transfer of fish complicate the interpretation of these data. In 2005, per NMFS request, Coleman NFH stopped transferring all adipose-fin clipped steelhead above the weir, resulting in a large decrease in the overall numbers of steelhead above the weir in recent years. In addition, in 2003, Coleman NFH transferred about 1,000 clipped adult steelhead to Keswick Reservoir, and these fish are not included in the data. The result is that the only unbiased time series for Battle Creek is the number of unclipped (wild) steelhead since 2001, which have declined slightly since that time, mostly because of the high returns observed in 2002 and 2003.

Prior to 2002, hatchery- and natural-origin steelhead in Battle Creek were not differentiable, and all steelhead were managed as a single, homogeneous stock, although USFWS believes the majority of returning fish in years prior to 2002 were hatchery-origin. Abundance estimates of natural-origin steelhead in Battle Creek began in 2001. These estimates of steelhead abundance include all steelhead, including resident and anadromous fish (Figure B-8).

Steelhead returns to Coleman NFH increased from 2011 to 2014 (Figure B-8). After hitting a low of only 790 fish in 2010, 2013 and 2014 have averaged 2,895 fish (Figure B-8). Since 2003, adults returning to the hatchery have been classified as wild (unclipped) or hatchery-produced (adipose fin clipped). Wild adults counted at the hatchery each year represent a small fraction of overall returns, but their numbers have remained relatively steady, typically 200 to 300 fish each year. Numbers of wild adults returning each year have ranged from 252 to 610 from 2010 to 2014 (Figure B-8).

Redd counts are conducted in the American River and in Clear Creek (Shasta County). An average of 143 redds have been counted on the American River from 2002 to 2015 (Figure B-9; data from (Hannon et al. 2003, Hannon and Deason 2008, Chase 2010). Surveys were not conducted in some years on the American River due to high flows and low visibility. An average of 178 redds have been counted in Clear Creek from 2001 to 2015 (Figure B-10; data from USFWS). The Clear Creek steelhead population appears to have increased in abundance since Saeltzer Dam was removed in 2000, as the number of redds observed in surveys conducted by the USFWS has steadily increased since 2001 (Figure B-10). The average redd index from 2001 to 2011 is 178, representing a range of approximately 100 to 1,023 spawning adult steelhead on average each year, based on an approximate observed adult-to-redd ratio in Clear Creek (USFWS2015). The vast majority of these steelhead are wild fish, as no hatchery steelhead are stocked in Clear Creek.

The East Bay Municipal Utilities District (EBMUD) has included steelhead in their redd surveys on the Lower Mokelumne River since the 1999-2000 spawning season, and the overall trend is a slight increase. However, it is generally believed that most of the steelhead spawning in the Mokelumne River are resident fish (Satterthwaite et al. 2010), which are not part of the CCV steelhead DPS. In the most recent 5-year status review, NMFS did not include the Mokelumne River steelhead population in the DPS (NMFS 2016c).

The returns of CCV steelhead to the FRFH experienced a sharp decrease from 2003 to 2010, with only 679, 312, and 86 fish returning in 2008, 2009, and 2010, respectively (Figure B-11). In recent years, however, returns have experienced an increase with 830, 1,797, and 1,505 fish returning in 2012, 2013, and 2014, respectively. Almost all these fish are hatchery fish, and stocking levels have remained fairly constant, suggesting that smolt and/or ocean survival was poor for age classes that showed poor returns in the late 2000s.

Catches of steelhead at the fish collection facilities in the southern Delta are another source of information on the relative abundance of the CCV steelhead DPS, as well as the proportion of wild steelhead relative to hatchery steelhead (CDFG) (ftp.delta.dfg.ca.gov/salvage). The overall catch of steelhead at these facilities has been highly variable since 1993 (Figure B-13). Variability in catch is likely due to differences in water year types as Delta exports fluctuate. The percentage of unclipped steelhead in salvage has also fluctuated, but has generally declined since 100 percent clipping started in 1998. The number of stocked hatchery steelhead has remained relatively constant overall since 1998, even though the number stocked in any individual hatchery has fluctuated.

The years 2009 and 2010 showed poor returns of steelhead to the FRFH and Coleman NFH, probably due to three consecutive drought years in 2007 to 2009, which would have impacted parr and smolt growth and survival in the rivers, and possibly due to poor coastal upwelling conditions in 2005 and 2006, which strongly impacted fall-run Chinook salmon post-smolt survival (Lindley et al. 2009). Wild (unclipped) adult counts appear not to have decreased as greatly in those same years, based on returns to the hatcheries and redd counts conducted on Clear Creek, and the American and Mokelumne rivers. This may reflect greater fitness of naturally produced steelhead relative to hatchery fish, and certainly merits further study.

Overall, steelhead returns to hatcheries have fluctuated so much from 2001 to 2015 that no clear trend is present, other than the fact that the numbers are still far below those seen in the 1960s and 1970s, and only a tiny fraction of the historical estimate. Returns of natural origin fish are very poorly monitored, but the little data available suggest that the numbers are very small, though perhaps not as variable from year to year as the hatchery returns.

Figure B-8 depicts steelhead returns to Coleman NFH from 1988 to 2014. It is important to note that starting in 2001, fish were classified as either wild (unclipped) or hatchery-produced (clipped). Figure B-9 shows steelhead redd counts from surveys on the American River from 2002 to 2015, where surveys could not be conducted in some years due to high flows and low visibility. Figures A-10 and A-11 show redd counts from USFWS surveys on Clear Creek from 2001 to 2015 and steelhead returns to the FRFH from 1964 to 2015, respectively.

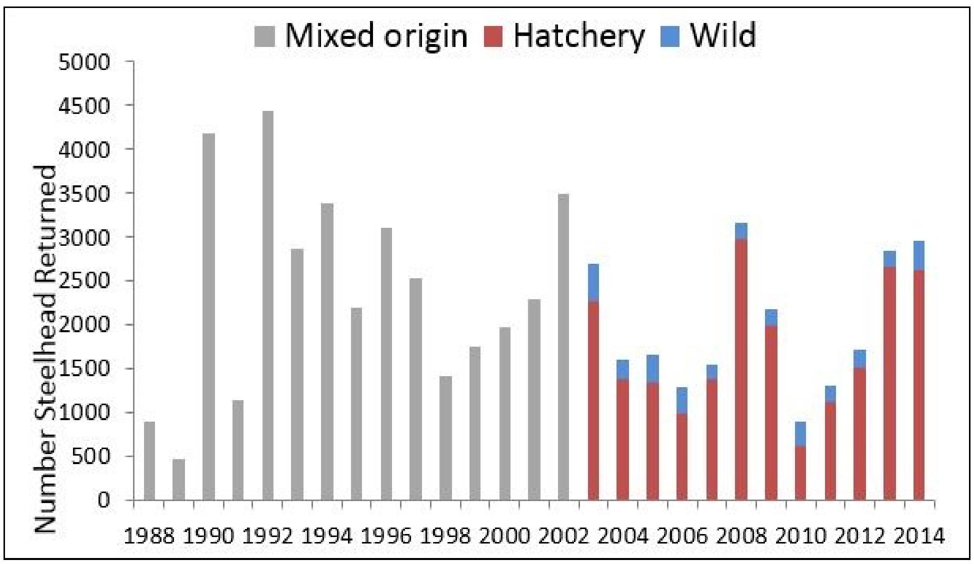

Figure B-8. Steelhead Returns to Coleman National Fish Hatchery from 1988 to 2014.

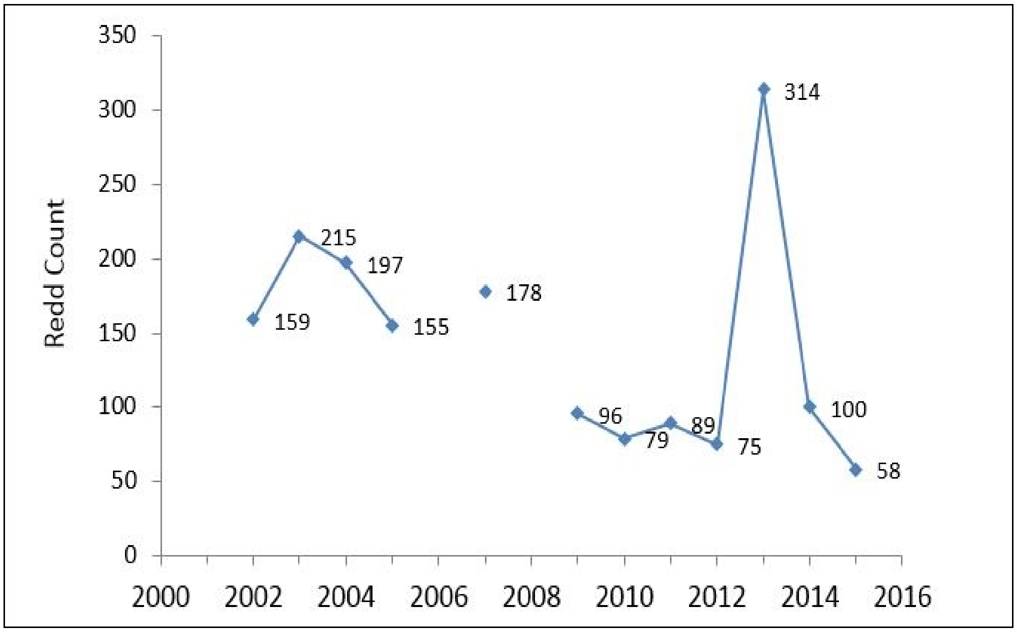

Figure B-9. Steelhead Redd Counts from Surveys on the American River from 2002 to 2015.

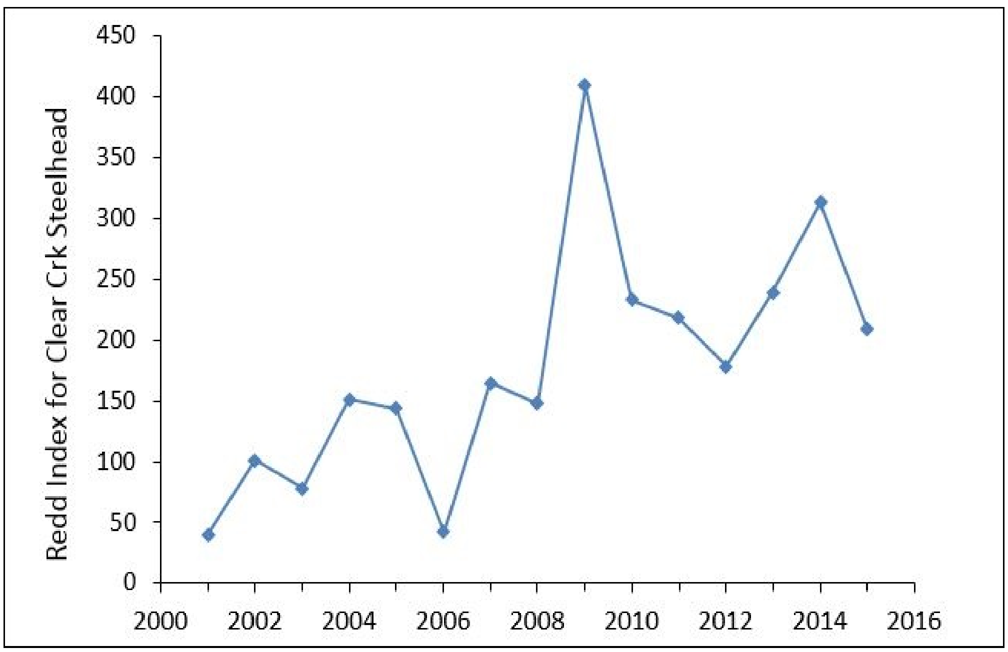

Figure B-10. Redd Counts from USFWSSurveys on Clear Creek from 2001 to 2015.

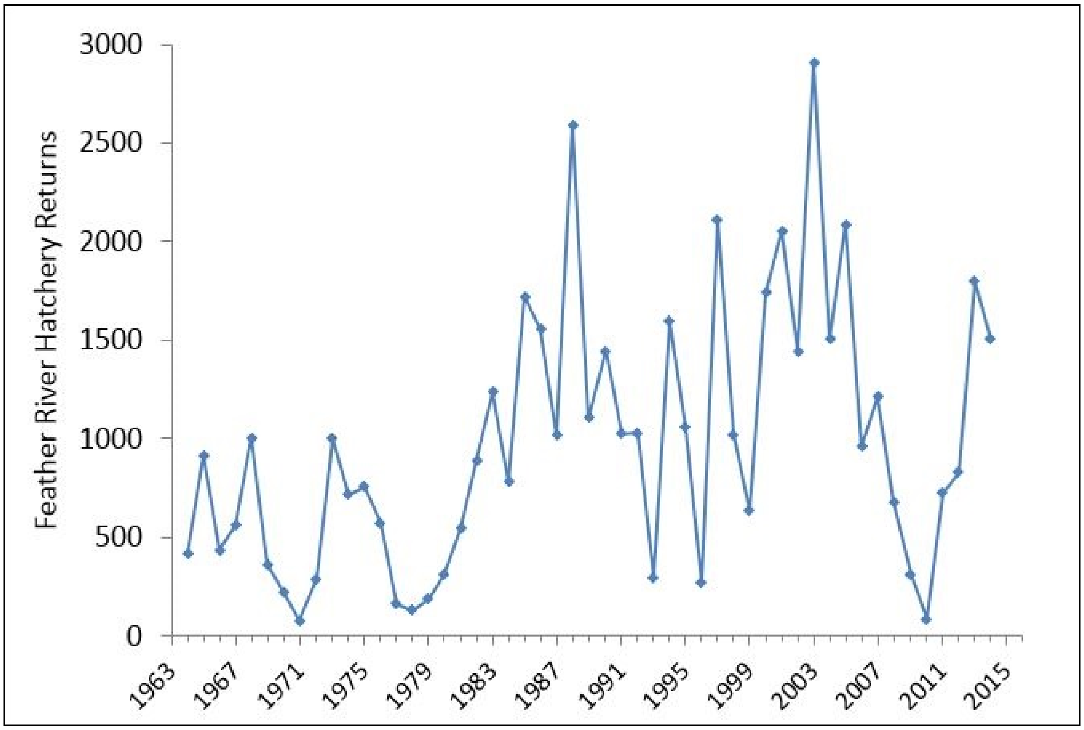

Figure B-11. Steelhead Returns to the Feather River Fish Hatchery from 1964 to 2015.

1.3.4.2 Productivity

An estimated 100,000 to 300,000 naturally produced juvenile steelhead are estimated to leave the Central Valley annually, based on rough calculations from sporadic catches in trawl gear (Good et al. 2005). The Mossdale trawls on the San Joaquin River conducted annually by CDFW and USFWS capture steelhead smolts, although usually in very small numbers. These steelhead recoveries, which represent migrants from the Stanislaus, Tuolumne, and Merced rivers, suggest that the productivity of CCV steelhead in these tributaries is very low. Also, the Chipps Island midwater trawl dataset from the USFWS provides information on the trend (Williams et al. 2011).

Nobriga and Cadrett (2001) used the ratio of adipose fin-clipped (hatchery) to unclipped (wild) steelhead smolt catch ratios in the Chipps Island trawl from 1998 through 2000 to estimate that about 400,000 to 700,000 steelhead smolts are produced naturally each year in the Central Valley. Good et al. (2005) made the following conclusion based on the Chipps Island data.

> *If we make the fairly generous assumptions (in the sense of generating large estimates of spawners) that average fecundity is 5,000 eggs per female, 1 percent of eggs survive to reach Chipps Island, and 181,000 smolts are produced (the 1998-2000 average), about 3,628 female steelhead spawn naturally in the entire Central Valley. This can be compared with McEwan (2001) estimate of 1 million to 2 million spawners before 1850, and 40,000 spawners in the 1960s.*

The Chipps Island midwater trawl dataset maintained by the USFWS provides information on the trend in abundance for the CCV steelhead DPS as a whole. Updated through 2014, the trawl data indicate that the level of natural production of steelhead has remained very low since the 2011 status review (Figure B-12). Catch per unit effort (CPUE) has fluctuated but remained relatively constant over the past decade, but the proportion of the catch that is adipose-clipped (100 percent of hatchery steelhead production has been adipose fin-clipped starting in 1998) has risen, exceeding 90 percent in some years and reaching a high of 95 percent in 2010 (Williams et al. 2011). Because hatchery releases have been fairly constant, this implies that natural production of juvenile steelhead has been declining in the Central Valley.

The top of Figure B-12 shows the catch of steelhead at Chipps Island by the USFWS midwater trawl survey. The middle section shows the fraction of the catch bearing an adipose fin clip. One hundred percent of steelhead production has been marked starting in 1998, denoted with the vertical gray line. The bottom section shows CPUE in fish per million m^3 swept volume. CPUE is not easily comparable across the entire period of record, as over time, sampling has occurred over more of the year and catches of juvenile steelhead are expected to be low outside of the primary migratory season.

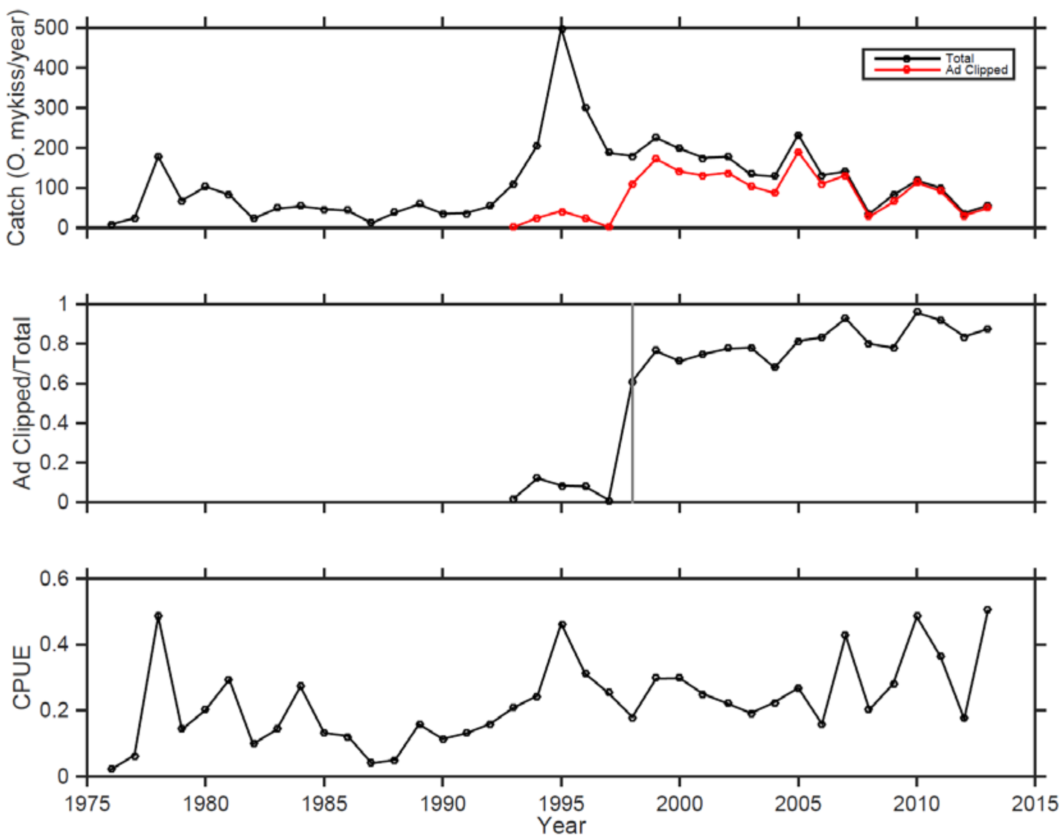

Figure B-12. Steelhead Catch at Chipps Island Midwater Trawl (USFWS unpublished data).

In the Mokelumne River, East Bay Municipal Utilities District (EBMUD) has included steelhead in their redd surveys on the Lower Mokelumne River since the 1999 to 2000 spawning season (NMFS 2011b). Based on data from these surveys, the overall trend suggests that redd numbers have slightly increased over the years (2000 to 2010). However, according to Satterthwaite et al. (2010), it is likely that most of the steelhead spawning in the Mokelumne River are nonanadromous (or resident) fish rather than steelhead. The Mokelumne River steelhead population is supplemented by Mokelumne River Hatchery production. In the past, this hatchery received fish imported from the Feather River and Nimbus hatcheries (Merz 2002). This practice was discontinued, however, for Nimbus stock after 1991 and discontinued for Feather River stock after 2008. Genetic studies show that the Mokelumne River Hatchery steelhead are closely related to Feather River fish, suggesting that there has been little carry-over of genes from the Nimbus stock (Pearse and Garza 2015).

Additionally, on the Mokelumne River, it appears that many fish can reach a size large enough to smolt at age 1, but the slower-growing fish are better served to mature as YOY and spawn at age 1 rather than risk the extra freshwater mortality associated with waiting to smolt at age 2 (because much less time must elapse before the age 1 spawning opportunity compared to age 2 emigration). Slow-growing fish are large enough to have a moderate chance of survival in the ocean. Additional freshwater residence time exposes fish to risk of freshwater mortality, to grow to a large enough size to spawn with much success as a resident female at an even older age (Satterthwaite et al. 2010).

These results suggest that restoration activities for CCV steelhead should focus on habitat improvements that both increase parr survival and growth in natal rivers, especially in the summer and fall, and improve smolt survival in the lower river reaches, the Delta, and bays.

Catches of steelhead at the fish collection facilities in the southern Delta are another source of information on the relative abundance of the CCV steelhead DPS as well as the production of wild steelhead relative to hatchery steelhead (ftp.delta.dfg.ca.gov/salvage). The overall catch of steelhead has declined dramatically since the early 2000s, with an overall average of 2,705 from 2004 to 2014, as measured by expanded salvage (Figure B-13). The percentage of wild (unclipped) fish in salvage has fluctuated, but has leveled off to an average of 36 percent since a high of 93 percent in 1999. The number of stocked hatchery steelhead has remained relatively constant overall since 1998, even though the number stocked in any individual hatchery has fluctuated. This relatively constant hatchery production, coupled with the dramatic decline in hatchery-origin steelhead catch at the south Delta fish collection facilities suggests that either stocked hatchery fish from the Sacramento basin are using a more natural outmigration path and are not being pulled into the south Delta fish facilities or the immediate survival of those stocked fish has decreased. With respect to wild steelhead, the data shown in Figure B-12 indicate that from 2011 to 2014 fewer adults are spawning (fewer eggs deposited), survival of early life stages has decreased, and/or wild steelhead are experiencing reduced exposure to the south Delta fish facilities.

Figure B-13 depicts steelhead salvaged in the Delta fish collection facilities from 1993 to 2014. All hatchery steelhead have been adipose fin-clipped since 1998. Data are from CDFW, at ftp.delta.dfg.ca.gov/salvage.

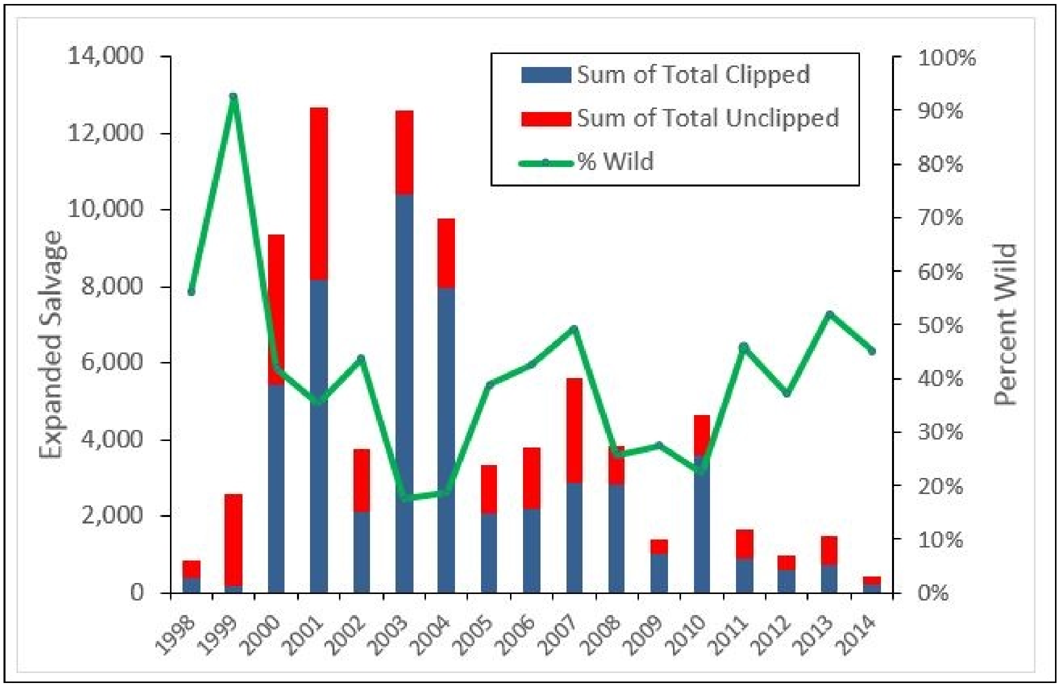

Figure B-12. Steelhead Salvaged in the Delta Fish Collection Facilities.

Since 2003, fish returning to the Coleman NFH have been identified as wild (adipose fin intact) or hatchery-produced (ad-clipped). Returns of wild fish to the hatchery have remained fairly steady at 200 to 300 fish per year, but represent a small fraction of the overall hatchery returns. Numbers of hatchery-origin fish returning to the hatchery have fluctuated much more widely, ranging from 624 to 2,968 fish per year (Figure B-8).

1.3.4.3 Spatial Structure

About 80 percent of the historical spawning and rearing habitat once used by anadromous steelhead in the Central Valley is now upstream of impassible dams (Lindley et al. 2006). The extent of habitat loss for steelhead most likely was much higher than that for salmon because steelhead were undoubtedly more extensively distributed. Due to their superior jumping ability, the timing of their upstream migration, which coincided with the winter rainy season, and their less restrictive preferences for spawning gravels, steelhead could have utilized at least hundreds of miles of smaller tributaries not accessible to the earlier-spawning salmon (Yoshiyama et al. 1996). Many historical populations of CCV steelhead are entirely above impassable barriers and may persist as resident or adfluvial rainbow trout, although they are presently not considered part of the DPS. Steelhead were found as far south as the Kings River (and possibly Kern River systems in wet years) (McEwan 2001). Native American groups, such as the Chunut people, have had accounts of steelhead in the Tulare Basin (Latta 1977).

Steelhead are well-distributed throughout the Central Valley below the major rim dams (Good et al. 2005, NMFS 2016c). Zimmerman et al. (2009) used otolith microchemistry to show that steelhead of anadromous parentage occur in all three major San Joaquin River tributaries, but at low levels, and that these tributaries have a higher percentage of resident steelhead compared to the Sacramento River and its tributaries.

Monitoring has detected small numbers of steelhead in the Stanislaus, Mokelumne, and Calaveras rivers and other streams previously thought to be devoid of steelhead (McEwan 2001). On the Stanislaus River, steelhead smolts have been captured in RSTs at Caswell State Park and Oakdale each year since 1995 (S.P. Cramer & Associates 2000). A counting weir has been in place in the Stanislaus River since 2002 and in the Tuolumne River since 2009 to detect adult salmon; these weirs have also detected steelhead passage. In 2012, 15 adult steelhead were detected passing the Tuolumne River weir and 82 adult steelhead were detected at the Stanislaus River weir (FISHBIO LLC 2012, FISHBIO LLC 2013a). Also, RST sampling has occurred since 1995 in the Tuolumne River, but only one juvenile steelhead was caught during the 2012 season (FISHBIO LLC 2013b). RSTs are well known to be very inefficient at catching steelhead smolts, so the actual numbers of smolts produced in these rivers could be much higher. RST on the Merced River has occurred since 1999. A fish counting weir was installed on this river in 2012. Since installation, one adult steelhead has been reported passing the weir. Juvenile steelhead were not reported captured in the RSTs on the Merced River until 2012, when a total of 381 were caught (FISHBIO LLC 2013c). The unusually high number of steelhead captured may be attributed to a flashy storm event that rapidly increased flows over a 24-hour period. Annual Kodiak trawl surveys are conducted on the San Joaquin River at Mossdale by CDFW. A total of 17 steelhead were caught during the 2012 season (CDFW 2013).

Most of the steelhead populations in the Central Valley have a high hatchery component, including Battle Creek (adults intercepted at the Coleman NFH weir), the American River, Feather River, and Mokelumne River. This is confounded, of course, by the fact that most of the dedicated monitoring programs in the Central Valley occur on rivers that are annually stocked. Clear Creek and Mill Creek are the exceptions.

Implementation of CDFW’s Steelhead Monitoring Program began during the fall of 2015. Important components of the program include a mainstem Sacramento River Steelhead Mark-Recapture Program and an Upper Sacramento River Basin Adult Steelhead Video/DIDSON Monitoring Program. The monitoring program will use a temporally stratified mark-recapture survey design in the lower Sacramento River, employing wire fyke traps to capture, mark, and recapture upstream migrating adult steelhead to estimate adult steelhead escapement from the Delta. Data collected from recaptured adult steelhead will provide additional information on tributary escapement, survival, population structure, population distribution, and spatial and temporal behavior of both hatchery- and natural-origin steelhead.

The low adult returns to the San Joaquin tributaries and the low numbers of juvenile emigrants typically captured suggest that existing populations of CCV steelhead on the Tuolumne, Merced, and lower San Joaquin rivers are severely depressed. The loss of these populations would severely impact CCV steelhead spatial structure and further challenge the viability of the CCV steelhead DPS.

Efforts to provide passage of salmonids over impassable dams have the potential to increase the spatial diversity of Central Valley steelhead populations if the passage programs are implemented for steelhead. In addition, the SJRRP calls for a combination of channel and structural modifications along the San Joaquin River below Friant Dam, releases of water from Friant Dam to the confluence of the Merced River, and the reintroduction of spring-run and fall-run Chinook salmon. If the SJRRP is successful, habitat improved for spring-run Chinook salmon could also benefit CCV steelhead (NMFS 2016c).

1.3.4.4 Diversity

1.3.4.4.1 Genetic Diversity

The CCV steelhead abundance and growth rates continue to decline, largely the result of a significant reduction in the amount and diversity of habitats available to these populations (Lindley et al. 2006). Recent reductions in population size are also supported by genetic analysis (Nielsen et al. 2003).

Garza and Pearse (2008) analyzed the genetic relationships among CCV steelhead populations and found that unlike the situation in coastal California watersheds, fish below barriers in the Central Valley were often more closely related to below barrier fish from other watersheds than to steelhead above barriers in the same watershed. This pattern suggests the ancestral genetic structure is still relatively intact above barriers, but may have been altered below barriers by stock transfers.

The genetic diversity of CCV steelhead is also compromised by hatchery-origin fish, which likely comprise the majority of the annual spawning runs, placing the natural population at a high risk of extinction (Lindley et al. 2007). There are four hatcheries (Coleman NFH, FRFH, Nimbus Fish Hatchery, and Mokelumne River Fish Hatchery) in the Central Valley which combined release approximately 1.6 million yearling steelhead smolts each year. These programs are intended to mitigate for the loss of steelhead habitat caused by dam construction, but hatchery-origin fish now appear to constitute a major proportion of the total abundance in the DPS. Two of these hatchery stocks (Nimbus and Mokelumne River Hatcheries) originated from outside the DPS (primarily from the Eel and Mad rivers) and are not presently considered part of the DPS. However, during the recent NMFS 5-year status review for CCV steelhead, NMFS recommended including the Mokelumne River Hatchery steelhead population in the CCV Steelhead DPS due to the close genetic relationship with FRFH steelhead that are considered part of the native Central Valley stock (NMFS 2016c).

1.3.4.4.2 Life-history Diversity

Steelhead in the Central Valley historically consisted of both summer-run and winter-run Chinook salmon migratory forms, based on their state of sexual maturity at the time of river entry and the duration of their time in freshwater before spawning. As stated in Gerstung (1971):

> *Between 1944 and 1947, annual counts of summer-run steelhead passing through the Old Folsom Dam fish ladder during May, June, and July ranged from 400 to 1,246 fish. After 1950, when the fish ladder at Old Folsom Dam was destroyed by flood flows, summer-run steelhead were no longer able to access their historic spawning areas, and perished in the warm water downstream of Old Folsom Dam (Gerstung 1971).*

Only winter-run (ocean-maturing) steelhead currently are found in CCV rivers and streams (McEwan and Jackson 1996, Moyle 2002). Summer-run steelhead have been extirpated due to a lack of suitable holding and staging habitat, such as cold water pools in the headwaters of CV streams, presently located above impassible dams (Lindley et al. 2006).

Juvenile steelhead (parr) rear in freshwater for 1 to 3 years before migrating to the ocean as smolts (Moyle 2002). The time that parr spend in freshwater is inversely related to their growth rate, with faster-growing members of a cohort smolting at an earlier age but a smaller size

(Seelbach 1993, Peven et al. 1994). Hallock et al. (1961) aged 100 adult steelhead caught in the Sacramento River upstream of the Feather River confluence in 1954 and found that 70 had smolted at age-2, 29 at age-1, and one at age-3. Seventeen of the adults were repeat spawners, with three fish on their third spawning migration, and one on its fifth. Age at first maturity varies among populations. In the Central Valley, most steelhead return to their natal streams as adults at a total age of 2 to 4 years (Hallock et al. 1961, McEwan and Jackson 1996).

Deer and Mill creeks were monitored from 1994 to 2010 by the CDFW using RSTs to capture emigrating juvenile steelhead (Johnson and Merrick 2012). Fish in the fry stage averaged 34 and 41 mm FL in Deer and Mill creeks, respectively, while those in the parr stage averaged 115 mm FL in both streams. Silvery parr averaged 180 and 181 mm in Deer and Mill creeks, while smolts averaged 210 and 204 mm. Most silvery parr and smolts were caught in the spring months from March through May, while fry and parr peaked later in the spring (May and June) and were fairly common in the fall (October through December) as well.

In contrast to the upper Sacramento River tributaries, Lower American River juvenile steelhead have been shown to smolt at a very large size (270 to 350 mm FL), and nearly all smolt at age-1 (Sogard et al. 2012).

1.3.4.5 Summary of Distinct Population Segment Viability

All indications are that natural CCV steelhead have continued to decrease in abundance and in the proportion of natural fish over the past 25 years (Good et al. 2005, NMFS 2016c); the long-term trend remains negative. Hatchery production and returns are dominant over natural fish, and one of the four hatcheries is dominated by Eel/Mad River-origin steelhead stock.

The ratio between naturally produced juvenile steelhead to hatchery juvenile steelhead in fish monitoring efforts indicates that the wild population abundance has remained at a relatively steady state since the 2011 status review and remains much lower than percentages observed in previous decades. Hatchery releases (100 percent adipose fin-clipped fish since 1998) have remained relatively constant over the past decade, yet the proportion of adipose fin-clipped hatchery smolts to unclipped naturally produced smolts has steadily increased over the past decade.

Although there have been recent restoration efforts in the San Joaquin River tributaries, CCV steelhead populations in the San Joaquin Basin continue to show an overall very low abundance and fluctuating return rates. Lindley et al. (2007) developed viability criteria for Central Valley salmonids. Using data through 2005, Lindley et al. (2007) found that data were insufficient to determine the status of any of the naturally spawning populations of CCV steelhead, except for those spawning in rivers adjacent to hatcheries, which were likely to be at high risk of extinction due to extensive spawning of hatchery-origin fish in natural areas.

The widespread distribution of wild steelhead in the Central Valley provides the spatial structure necessary for the DPS to survive and avoid localized catastrophes. However, most wild CCV populations are very small and may lack the resiliency to persist for protracted periods if subjected to additional stressors, particularly widespread stressors such as climate change. The genetic diversity of CCV steelhead has likely been impacted by low population sizes and high numbers of hatchery fish relative to wild fish. The life-history diversity of the DPS is mostly unknown because very few studies have been published on traits such as age structure, size at age, or growth rates in CCV steelhead.

The most recent status review of the CCV steelhead DPS (NMFS 2016c) found that the status of the DPS appears to have remained unchanged since the 2011 status review (Good et al. 2005), and the DPS is likely to become endangered within the foreseeable future throughout all or a significant portion of its range.

1.4 Southern Distinct Population Segment of North American Green Sturgeon

- Listed as threatened (71 FR 17757; April 7, 2006)
- Designated critical habitat (74 FR 52300; October 9, 2009)

1.4.1 Species Listing and Critical Habitat Designation History

Two DPS of North American green sturgeon have been identified—a northern DPS (nDPS) and a southern DPS (sDPS). While individuals from the two DPSs are visually indistinguishable and have significant geographical overlap, current information indicates that they do not interbreed or utilize the same natal streams (68 FR 4433; January 29, 2003) (Adams et al. 2002; Israel et al. 2004). This section discusses the sDPS green sturgeon, which is listed under the ESA, and its designated critical habitat. The sDPS green sturgeon consists of green sturgeon originating from the Sacramento River basin and from coastal rivers south of the Eel River (71 FR 17757; April 7, 2006). When necessary to fill in knowledge gaps, we use available life-history information for white sturgeon (*A. transmontanus)* and other sturgeon species, noting the use of other species life-history information as a surrogate.

In June of 2001, NMFS received a petition to list green sturgeon and designate their critical habitat under the ESA. After completion of a status review (Adams et al. 2002), NMFS found that the species was comprised of two DPSs that qualify as species under the ESA, but that neither DPS warranted listing (68 FR 4433; January 29, 2003). Several entities challenged our determination that listing was not warranted in Federal district court, and the court issued an order setting aside and remanding our determination. Following a status review update in 2005, NMFS listed the sDPS as threatened based on the reduction of potential spawning habitat, the severe threats to the single remaining spawning population (in the Sacramento River), the inability to alleviate these threats with the conservation measures in place, and the decrease in observed numbers of juvenile green sturgeon collected in the past two decades before listing compared to those collected historically (71 FR 17757; April 7, 2006). Since the 2006 listing decision, new information has become available regarding the many threats to the species from entrainment, flow operations, reservoir operations, habitat loss, water quality, toxics, invasive species, and population dynamics, reaffirming NMFS' concerns that sDPS green sturgeon face substantial threats to their viability and recovery (Israel and Klimley 2008).

1.4.2 Critical Habitat Physical or Biological Features for Southern Distinct Population Segment Green Sturgeon

Critical habitat for sDPS green sturgeon include the following:

1. The Sacramento River from the Sacramento I-Street Bridge to Keswick Dam, including the Sutter and Yolo Bypasses and the lower American River from the confluence with the mainstem Sacramento River upstream to the highway 160 bridge
2. The Feather River from its confluence with the Sacramento River upstream to the Fish Barrier Dam

3. The Yuba River from the confluence with the Feather River upstream to Daguerre Point Dam
4. The Sacramento-San Joaquin Delta (as defined by California Water Code section 12220, except for listed excluded areas)
5. San Francisco, San Pablo, Suisun, and Humboldt bays in California
6. Coos, Winchester, Yaquina, and Nehalem bays in Oregon
7. Willapa Bay and Grays Harbor in Washington
8. The lower Columbia River estuary from the mouth to river kilometer (RK) 74
9. All United States coastal marine waters out to the 60-fathom-depth bathymetry line, from Monterey Bay, California, north and east to include the Strait of Juan de Fuca, Washington (74 FR 52300; October 9, 2009) (Figure B-13)

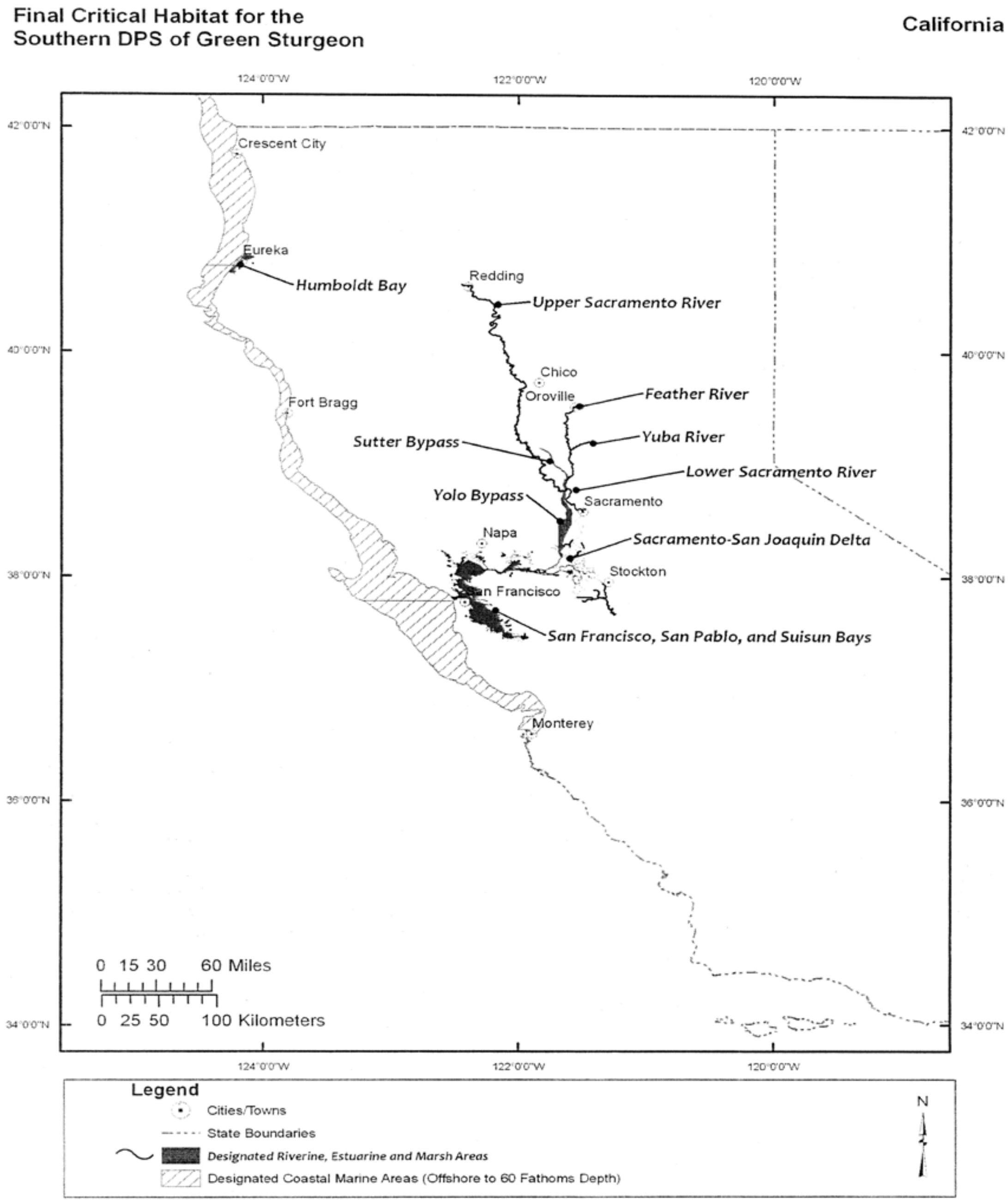

Figure B-13. Green Sturgeon Critical Habitat in California (Source: 74 FR 52300; October 9, 2009).

The following subsections describe the status of the PBFs of sDPS green sturgeon critical habitat, which are listed in the critical habitat designation (74 FR 52300; October 9, 2009).

1.4.2.1 Food Resources

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include food resources (i.e., abundant prey items for larval, juvenile, subadult, and adult life stages). Green sturgeon food resources likely include drifting and benthic invertebrates, forage fish, and fish eggs. In a stomach content analysis, Radtke (1966) found that the diet of juvenile green sturgeon consisted primarily of mysid shrimp (*Neomysis awatschensis*) and amphipods. Although little specific information on food resources is available for green sturgeon at various lifecycle stages within freshwater riverine systems, they are presumed to be opportunistic feeders with a diet similar to other sturgeon, such as white sturgeon, which also occupy the Sacramento River basin (Israel and Klimley 2008). Seasonally abundant drifting and benthic invertebrates have been shown to be the major food items for white sturgeon in the lower Columbia River (Muir et al. 2000). Increasing size of prey items in white sturgeon has also been positively correlated with increasing sizes of individual fish (Muir et al. 2000). The establishment of non-native species of plants and invertebrates (e.g., mussels, clams), which is occurring in the Delta, has the potential to alter food resources for the sDPS and those effects could be exacerbated by climate change. Research conducted on white sturgeon and to a lesser extent, green sturgeon, has shown that many of their non-native food resources, including the overbite clam (*Corbula amurensis*), have become a common food source for sturgeon and are either non-digestible (Kogut 2008) or, if digested, may be exposing green sturgeon to high levels of selenium (CDFG 2002; Linville et al. 2002). Bioaccumulation of selenium has known impacts on fish viability and reproduction.

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include food resources (i.e., abundant prey items within estuarine habitats and substrates for juvenile, subadult, and adult life stages). Prey species for juvenile, subadult, and adult green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fish, including crangonid shrimp, callianassid shrimp, burrowing thalassinidean shrimp, amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies. These prey species are critical for rearing, foraging, growth, and development of juvenile, subadult, and adult green sturgeon within bays and estuaries. As discussed above, non-native species are impacting the prey availability for sDPS in estuarine areas. The extent and severity of this impact is unknown.

The PBFs of sDPS green sturgeon critical habitat in nearshore coastal marine areas include abundant prey items for subadults and adults, which may include benthic invertebrates and fishes. Little is known about the prey base of sDPS in these areas.

1.4.2.2 Substrate Type or Size

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include substrate type or size (i.e., structural features of substrates)—substrates suitable for egg deposition and development (e.g., bedrock sills and shelves, cobble and gravel, or hard clean sand, with interstices or irregular surfaces to “collect” eggs and provide protection from predators, and free of excessive silt and debris that could smother eggs during incubation), larval development (e.g., substrates with interstices or voids providing refuge from predators and from high flow conditions), and subadults and adults (e.g., substrates for holding and spawning). Green sturgeon eggs are found in pockets of sand and gravel (2.0 to 64.0 mm in size) and in the interstitial spaces of larger substrate such as cobble and boulders (Poytress et al. 2011). Eggs are likely to adhere to sand and gravel after settling into spaces between larger substrates (Van Eenennaam et al. 2001, Deng et al. 2002). Larvae utilize benthic structure (Van Eenennaam et al. 2001, Deng et al. 2002, Kynard et al. 2005) and seek refuge within crevices, but will forage over hard surfaces (Nguyen and Crocker 2006). The creation of upstream dams and impoundments can reduce sediment delivery to rivers, bays, and estuaries and impact the quality and quantity of spawning substrates. The degree to which green sturgeon spawning habitats have been impacted in the CCV is not well-understood, but we would expect an impact commensurate with the demonstrated impacts to listed salmonid spawning habitats as described earlier in Sections 1.1, 1.2, and 1.3.

1.4.2.3 Water Flow

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include water flow, which is a flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages. Sufficient flow is necessary to reduce the incidence of fungal infestations of eggs, to flush fine material from feeding and rearing substrates, and to facilitate access to spawning grounds for spawning adults. On the Sacramento River, flow regimes are largely dependent on releases from Shasta Dam, thus the operation of this dam could have profound effects upon sDPS green sturgeon habitat. The majority of adult outmigration is thought to occur in the fall months when flows increase. Heublein et al. (2008) found that some tagged individuals outmigrated in the fall, and timing was correlated with the first winter pulse flow. However, others outmigrated in the late summer in which no known flow- or temperature-related cues could be correlated. The nDPS green sturgeon have exhibited similar behavior. In the Rogue River, adult green sturgeon have been shown to emigrate to the ocean during the autumn and winter when water temperatures dropped below 50°F (10°C) and flows increased (Erickson et al. 2002). On the Klamath River, the fall outmigration of green sturgeon has been shown to coincide with a significant increase in discharge resulting from the onset of the rainy season (Benson et al. 2007).

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include water flow within bays and estuaries adjacent to the Sacramento River (i.e., the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds. Water flows in the estuary have been altered by channel control structures, impoundments, and upstream diversions, which have changed flow patterns, channel morphology, and water depth/presence and salinity in certain areas. These changes have likely impacted habitat quality, migration, and movement of juvenile, subadult, and adult green sturgeon, although the extent and magnitude of impact is uncertain.

In the Columbia River basin, impoundments holding water back in the summer months significantly alter water flows throughout the estuary, especially at low tide when sDPS green sturgeon are known to congregate there (Lindley et al. 2008, 2011). Seasonally reduced flows can alter saltwater intrusion and create salinity levels unsuitable to green sturgeon; the Columbia River estuary is impacted by saltwater intrusion more than other bays and estuaries within the range of sDPS green sturgeon.

1.4.2.4 Water Quality

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include water quality, such as temperature, salinity, oxygen content, and other chemical characteristics, which are necessary for normal behavior, growth, and viability of all life stages. Suitable water temperatures, salinities, and dissolved oxygen levels are discussed in detail in the life history section.

Summer water temperatures in the upper Sacramento River have typically ranged between or below 15 to 19^{o}C, which is within the laboratory-based optima for green sturgeon egg development and below lab-based optima for larval and juvenile growth (Van Eenennaam et al. 2005; Mayfield and Cech 2004; Allen et al. 2006). Notably, the water temperatures in the Sacramento River were substantially higher than these “optima” during the drought of 2014 and 2015; the impacts to green sturgeon from these higher temperatures are not well understood.

Salinity in the Sacramento River is projected to increase by 33 percent on average in the 21st century, and water temperatures could also increase (CH2MHill 2014). These changes will result in declining habitat quality and food web productivity for green sturgeon. Laboratory experiments confirm the potential negative impacts to green sturgeon from salinity and prey base changes predicted for the San Francisco Bay Delta (Sardella and Kulz 2014; Haller et al. 2015; Vaz et al. 2015).

Green sturgeon are exposed to non-point and point source contaminants in the Sacramento River from agriculture runoff, urban development, discharge from industry, and legacy contaminants from mining activities. In addition, land use practices continue to deposit mercury, heavy metals, polychlorinated biphenyls, and organochlorine pesticides throughout Central Valley watersheds. Contaminants currently found in the Sacramento River pose a threat to several life stages of green sturgeon: (1) eggs, larvae, and juveniles resulting in reduced growth, injury, or mortality; and (2) female adults during spawning resulting in negative reproductive capacity.

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include water quality, such as temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages. Altered water temperatures are primarily a concern for the Columbia River Estuary as the other coastal bays and estuaries are not as influenced by input from large rivers with impoundments. The Columbia River estuary is impacted by saltwater intrusion more than other bays and estuaries within the range of sDPS. Non-point source contaminants enter the San Francisco Bay Estuary as runoff from urban sites, forests, agricultural lands, landfills, pastures, mines, nurseries, wastewater treatment, etc. and have the potential to impact juvenile growth and reproductive capacity of females.

The PBFs of sDPS green sturgeon critical habitat in nearshore coastal marine areas include nearshore marine waters with adequate dissolved oxygen levels and acceptably low levels of contaminants (e.g., pesticides, organochlorines, elevated levels of heavy metals) that may disrupt the normal behavior, growth, and viability of subadult and adult green sturgeon. Not a lot is known about the marine habitat usage of green sturgeon or the water quality conditions in those areas.

1.4.2.5 Migratory Corridor

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include a migratory corridor, which is a migratory pathway necessary for the safe and timely passage of sDPS fish within riverine habitats and between riverine and estuarine habitats (e.g., an unobstructed river or dammed river that still allows for safe and timely passage). Safe and unobstructed migratory pathways are necessary for adult green sturgeon to access spawning habitats and for larval and juvenile green sturgeon to migrate downstream from spawning/rearing habitats in freshwater rivers to estuarine rearing habitats. This PBF is highly degraded compared to its historical condition because of fabricated barriers and alteration of habitat. The ACID Dam, at RM 297, forms a barrier to any potential sturgeon migration. Downstream of this point, good spawning and rearing habitat exists, primarily in the river reach between Keswick Dam and RBDD (RM 242). The Feather River and Yuba River also offer potential green sturgeon spawning habitat, but those rivers contain fabricated barriers to migration and are highly altered environments.

Two key areas of concern are the Yolo and Sutter bypasses. These leveed floodplains are engineered to convey floodwaters of the greater Sacramento Valley, and they include concrete weir structures (Fremont and Tisdale Weirs) that allow flood flows to escape into the bypass channels. Adult sturgeon are attracted to the bypasses by these high flows. The weirs can act as barriers, however, impeding fish passage. Fish can also be trapped in the bypasses as floodwaters recede (USFWS 1995, DWR 2005). Some of the weir structures include fish ladders intended to provide upstream passage for adult salmon, but have shown to be ineffective for providing upstream passage for adult sturgeon (Department of Water Resources and Bureau of Reclamation 2012). Also, there are irregularities in the splash basins at the foot of these weirs and multiple road crossings and agricultural impoundments in the bypasses that block hydraulic connectivity, further impeding fish passage. As a result, sturgeon may become stranded in the bypasses, delaying migration. They also may face lethal and sub-lethal effects from poaching, high water temperatures, low dissolved oxygen, and desiccation.

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include migratory corridor, which is a migratory pathway necessary for the safe and timely passage of sDPS fish within estuarine habitats and between estuarine and riverine or marine habitats. The sDPS green sturgeon are known to use the Sacramento River and the Delta as a migratory corridor. Additionally, certain bays and estuaries throughout Oregon and Washington and into Canada are utilized for rearing and holding, and these areas must also offer safe and unobstructed migratory corridors (Lindley et al. 2011).

The PBFs of sDPS green sturgeon critical habitat in nearshore coastal marine areas include migratory corridor, which is a migratory pathway necessary for the safe and timely passage of sDPS fish within marine and between estuarine and marine habitats. There are no physical marine barriers or barriers between marine and estuarine habitats that prevent green sturgeon from migrating. Poor water quality conditions, such as anoxic conditions or acidified pulp mill effluent in the Columbia River estuary, may prevent or delay green sturgeon migration into and out of estuarine habitats but the extent of this impact is unknown.

1.4.2.6 Water Depth

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include water depth—deep (greater than or equal to 5 meters [m]) holding pools for both upstream and downstream holding of adult or subadult fish, with adequate water quality and flow to maintain the physiological needs of the holding adult or subadult fish. Deep pools (greater than 5 m depth) are critical for adult green sturgeon spawning and for summer holding within the Sacramento River. Summer aggregations of green sturgeon have been observed in deep pools above the Glen Colusa Irrigation District (GCID) diversion in the Sacramento River. The significance and purpose of these aggregations are unknown, but may be a behavioral characteristic of green sturgeon occurring elsewhere in the Delta and Sacramento River. Approximately 54 pools with adequate depth have been identified in the Sacramento River above the GCID location (Thomas et al. 2013). Adult green sturgeon in the Klamath and Rogue rivers also occupy deep holding pools for extended periods of time, presumably for feeding, energy conservation, and/or refuge from high water temperatures (Erickson et al. 2002, Benson et al. 2007).

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include depth—a diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Habitat complexity is necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages. Subadult and adult green sturgeon occupy deep (more than 5 m) holding pools within bays, estuaries, and freshwater rivers. These deep holding pools may be important for feeding and energy conservation, or may serve as thermal refugia (Benson et al. 2007). Tagged adults and subadults within the San Francisco Bay estuary primarily occupied waters with depths of less than 10 m, either swimming near the surface or foraging along the bottom (Kelly et al. 2007). In a study of juvenile green sturgeon in the Delta, relatively large numbers of juveniles were captured primarily in shallow waters from 0.9 m to 2.4 m (3 ft to 8 ft) feet deep, indicating juveniles may require shallower depths for rearing and foraging (Radtke 1966).

1.4.2.7 Sediment Quality

The PBFs of sDPS green sturgeon critical habitat in freshwater riverine systems include sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of contaminants (e.g., elevated levels of heavy metals such as mercury, copper, zinc, cadmium, and chromium; selenium; polycyclic aromatic hydrocarbons [PAHs]; and organochlorine pesticides) that can result in negative effects on any life stage of green sturgeon and/or their prey. Metals have been shown to bio-accumulate in *Acipenserids* (taxonomic family containing green sturgeon), although less is known about its effects on their behavior at any given life stage (Kruse and Scarnecchia 2002). PAHs found in oil-based products are known to bioaccumulate in fish and have carcinogenic, mutagenic, and cytotoxic effects (Johnson et al. 2002). This PBF is highly degraded within the freshwater riverine systems of the green sturgeon.

The PBFs of sDPS green sturgeon critical habitat in estuarine habitats include sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages. This includes sediments free of contaminants (e.g., elevated levels of selenium, heavy metals, PAHs, and organochlorine pesticides) that can cause negative effects on all life stages of green sturgeon. Poor agricultural practices in and around the estuary result in a lowered ability for the soil to hold water, which causes high runoff rates of pesticides, petroleum hydrocarbons, and other contaminants during rains events. Because these contaminants have increased permanence in the estuarine environment holding within the sediment, they likely impact green sturgeon through uptake of these contaminants when feeding. Bioaccumulation of contaminants in white sturgeon is well-documented (Feist et al. 2005) and because green sturgeon occupy the same habitats and share the same prey, contaminant bioaccumulation is also likely occurring in green sturgeon.

1.4.3 Green Sturgeon Life History

1.4.3.1 General Information

Green sturgeon belong to the family *Acipenseridae*, an ancient lineage of fish with a fossil record dating back approximately 200 million years. They are known to be long lived; green sturgeon captured in Oregon have been aged up to 52 years old, using a fin-spine analysis (Farr and Kern

2005). Green sturgeon are highly adapted to benthic environments, spending the majority of their lifespan residing in bays, estuaries, and near coastal marine environments. They are anadromous, migrating into freshwater riverine habitats to spawn, and iteroparous, as individuals are able to spawn multiple times throughout their lifespan. Further details of their life history can be found in various literature sources such as Moyle (2002), Adams et al. (2007), Beamesderfer et al. (2007), and Israel and Klimley (2008).

A general timeline of green sturgeon development is given in Table B-5. There is considerable variability across categories such as size or age at maturity.

1.4.3.2 Adult Migration and Spawning

Green sturgeon reach sexual maturity between 15 and 17 years old (Beamesderfer et al. 2007).

Based on data from acoustic tags (Heublein et al. 2008), adult sDPS green sturgeon leave the ocean and enter San Francisco Bay between January and early May. Migration through the bay/Delta takes about 1 week, and progress upstream is fairly rapid to their spawning sites (Heublein et al. 2008). The majority of adult green sturgeon abundance occurs in the Sacramento River, suggesting that the majority of spawning activity occurs there as well. In a recent survey, three observed sites on the Sacramento River accounted for more than 50 percent of observed green sturgeon spawning (Mora, ongoing research). However, in 2011, spawning was confirmed in the Feather River by the California Department of Water Resources (CDWR) (Seesholtz et al. 2014) and was suggested in the Yuba River (Bergman et al. 2011). Spawning activity is concentrated in the mid-April to mid-June time period (Poytress et al. 2013). Figure B-15 indicates known spawning locations on the Sacramento River.

Various studies of spawning site characteristics (Poytress et al. 2011) agree that spawning sDPS green sturgeon typically favor deep, turbulent holes over 5 m deep, featuring sandy, gravel, and cobble type substrates. Spawning depth may be variable, however, for spawning has been documented in depths as shallow as 2 m (Poytress et al. 2011). Substrate type is likely constrained as the interstices of the cobble and gravel catch and hold eggs, allowing them to incubate without being washed downstream. Under laboratory conditions, green sturgeon larvae (0 to 15 days post hatch [DPH]) have been shown to utilize cobble and gravel for shelter, even after commencing exogenous feeding (Kynard et al. 2005). Adequate flows are required to create the deep, turbulent habitat that green sturgeon favor for spawning. Successful egg development requires a water temperature range between 51.8°F and 66.2°F (11° and 19°C). As larvae and juveniles mature, their range of temperature tolerance increases (Table B-6).

Table B-5. General Green Sturgeon Life History from Egg to Adult Including Length and Life Stage Information.

Timeline	Life stage, Length-age relationship
Fertilization of eggs (spawning)	Spawning occurs primarily in deep water (> 5m) pools[1] at very few select sites,[2] predominantly in the Sacramento River, predominantly in time period mid-April to mid-June[3]
144–192 hours (6-8 days) after fertilization of eggs	Newly hatched larvae emerge. Larvae are 12.6–14.5 mm long.[4]
6 days post hatch (dph)	Nocturnal swim up, hide by day behavior observed[4]
10 dph	Exogenous feeding begins between 10–15 dph.[4] Larvae begin to disperse downstream
2 weeks old	Larvae appear in rotary screw traps at the RBDD at lengths of 24 to 31 mm.
45 dph	Larval to juvenile metamorphosis complete. Begin juvenile life stage. Juveniles are 63–94 mm in length.
45 days to 1.5 years	Juveniles migrate downstream and into the Delta or the estuary and rear to the sub-adult phase. Juveniles range in size from around 70 mm to 90 cm. Little information available about this life stage.
1.5–4 years	Juveniles migrate to sea for the first time, thereby entering the sub-adult phase. Subadults are 91 to 149 cm.
1.5 years to 15–17 years	Subadults enter the ocean where they grow and develop, reaching maturity between 15–17 years old*
15–17 years*	Green sturgeon reach sexual maturity and become adults, with males maturing around 120 cm and females maturing around 145 cm[5]
15 years to 50+ years	Green sturgeon have a lifespan that can reach 50 or more years and can grow to a total length of over 2 meters

Sources: 1. Thomas et al. (2013) 2. Mora unpublished data. 3. Poytress et al. (2013) 4. Deng et al. (2002) 5. Nakamoto et al. 1995

*Green sturgeon in the Klamath River might reach sexual maturity as early as 13 years for females and 9 years for males. More research is needed to determine the typical age and size of sDPS green sturgeon at maturity.

Green sturgeon fecundity is approximately 50,000 to 80,000 eggs per adult female (Van Eenennaam et al. 2001), and they have the largest egg size of any sturgeon. The outside of the eggs are mildly adhesive and are denser than those of white sturgeon (Kynard et al. 2005, Van Eenennaam et al. 2008).

Poytress et al. (2012) conducted spawning site and larval sampling in the upper Sacramento River from 2008 to 2012 that identified a number of spawning locations (Figure B-15). After spawning, adults have been observed to leave the system rapidly or to hold in deep pools and migrate downriver in winter after the first storms. From 2002 to 2004, Benson et al. (2007) conducted a study in which 49 adult green sturgeon were tagged with radio and/or sonic telemetry tags and tracked manually or with receiver arrays. Tagged individuals exhibited four movement patterns: upstream spawning migration, spring outmigration to the ocean, summer holding, and outmigration after summer holding. sDPS green sturgeon that hold over the summer typically re-enter the ocean from November through January (Lindley et al. 2008). Benson et al. (2007) also observed outmigration to the ocean in the spring.

1.4.3.3 Juvenile Migration

Larval green sturgeon hatch in the late spring or summer (peak in July) (Adams 2002) and presumably progress downstream towards the Delta as they develop into juveniles. It is uncertain when juvenile green sturgeon enter the Delta or how long they rear before entering the ocean. Ocean entry marks the transition from juvenile to sub-adults.

1.4.3.4 Egg and Larval Stages

Green sturgeon larvae have been observed hatching from fertilized eggs after approximately 169 hours at a water temperature of 59°F (15°C) (Van Eenennaam et al. 2001, Deng et al. 2002). Studies conducted at the University of California, Davis (UC Davis) by Van Eenennaam et al. (2005) indicated that an optimum range of water temperature for egg development ranged between 57.2°F (14°C) and 62.6°F (17.5°C). Eggs incubated at water temperatures between 63.5°F (17.5°C) and 71.6°F (22°C) resulted in elevated mortalities and an increased occurrence of morphological abnormalities in those eggs that did hatch (Van Eenennaam et al. (2005). Temperatures over 73.4°F (23°C) resulted in 100 percent mortality of fertilized eggs before hatching (Van Eenennaam et al. (2005). Further research is needed to identify the lower temperature limits for eggs and larvae. Table B-6 shows temperature tolerance by life stage for all stages of green sturgeon development.

Information about the life history and behavior of larval sDPS green sturgeon in the wild is very limited. The USFWS conducts annual sampling for eggs and larvae in the mainstem Sacramento River. Larval green sturgeon appear in USFWS RSTs at the RBDD from May through August (Poytress et al. 2010) at lengths ranging from 24 to 31 mm fork length, indicating they are approximately 2 weeks old (CDFG 2002b, USFWS2002).

This data provides limited information about green sturgeon larvae, including time and date of capture, and corresponding river conditions such as temperature and flow parameters.

Little is known about diet, distribution, and outmigration timing of larvae. Laboratory studies have provided some information about larval behavior, but the relevance to in-situ behavior is unknown.

Table B-6. Green Sturgeon Temperature Tolerance Range by Life Stage.

temperature °C	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
temperature °F	46.4	48.2	50.0	51.8	53.6	55.4	57.2	59.0	60.8	62.6	64.4	66.2	68.0	69.8	71.6	73.4	75.2	77.0	78.8	80.6	82.4
egg				b	b	b	b	b	b	b	b	b	b	b	b,f	b,f	b,f	b,f	b,f	b	b
larvae							e	e	e	c	f	dd,f	dd,f	dd,f	dd,f	dd,f	dd,f	dd,c,f	f	f	f
juvenile				a	a	a	a	a	a	a	a	a	a	a	a	a	a,d	a	a	a	a
spawning adult			g	g	g	g	g	g	g,h	g,h											

- optimal temperature (green)
- acceptable temperature (yellow)
- impaired fitness; avoid prolonged exposure; increasing chance of lethal effects (orange)
- likely lethal (red)
- lethal (black)
- unknown effect upon survival and fitness (light blue)

NOTES: Life stage definitions can be found within the life stage sections of this report. Lab studies involving nDPS green sturgeon from Klamath River broodstock (a, b, c, d, dd, f) were used to rate water temperatures for the eggs, larvae, and juveniles. Water temperatures recorded during sDPS green sturgeon egg and larvae collection on the upper Sacramento and Feather rivers (e,g, and h) were used to establish 'acceptable temperature' for spawning adults and larvae.

a = Mayfield and Cech 2004
b = Van Eenennaam *et al.* 2005
c = Werner *et al.* 2006
d = Allen *et al.* 2006a
e = Poytress *et al.* 2012
f = Linares-Casenave *et al.* 2013
g = Poytress *et al.* 2015
h = Seesholtz *et al.* 2014
dd = Allen *et al.* 2006b

The figure below shows green sturgeon spawning locations in the Sacramento River from 2008 to 2012. [Source: Poytress et al. (2012)]. Unconfirmed sites indicate an area where sturgeon have been known to congregate, but where evidence of spawning was not obtained in the study.

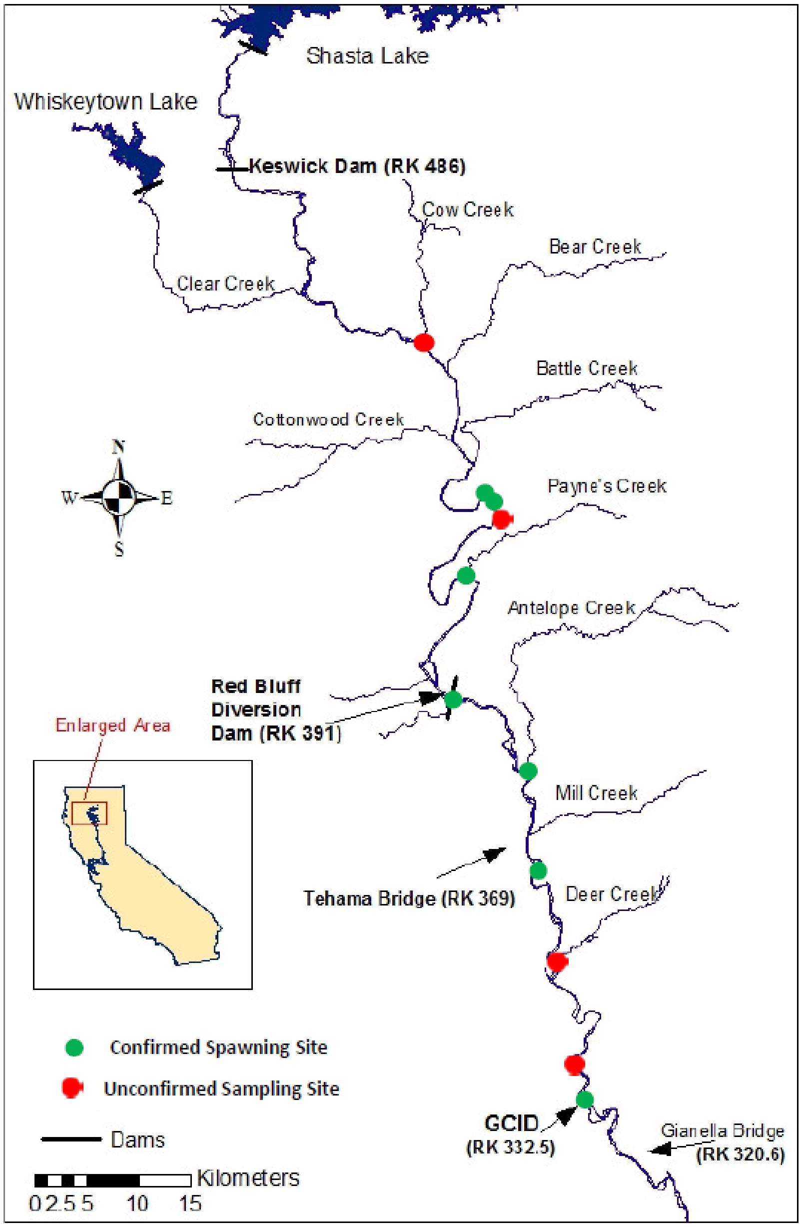

Figure B-15. Green Sturgeon Spawning Locations in the Sacramento River from 2008 to 2012.

1.4.3.5 Juvenile Development and Outmigration

Juvenile green sturgeon are defined as individuals that have completed metamorphosis or are greater than 45 DPH according to Deng et al. (2002). They appear to spend their first 1 to 2 months rearing in the Sacramento River (CDFG 2002). Little is known about juvenile growth rates in the sDPS. Juvenile sDPS green sturgeon have been salvaged at the Federal and State pumping facilities in the southern region of the Delta and collected in sampling studies by CDFW during all months of the year (CDFG 2002). Salvage data have been updated through

2015, and the majority of juveniles were between 200 and 500 mm (Figure B-16). It is important to note that few have been sampled there since 2001, and that sampling has only occurred during high water years. USWFS has sampled juvenile green sturgeon in the mainstem Sacramento River and found that some individuals reach approximately 300 mm total length (TL) in 6 months (W. Poytress, USFWS, unpublished data). The lack of any records of juveniles smaller than approximately 200 mm in the Delta may suggest that smaller individuals are rearing in the Sacramento River or its tributaries. Juvenile green sturgeon captured in the Delta by Radtke (1966) ranged in size from 200 to 580 mm, supporting the hypothesis that juvenile green sturgeon enter the Delta after 10 months or when they are greater than 200 mm in size.

Radtke (1966) inspected the stomach contents of juvenile green sturgeon (range: 200 to 580 mm) in the Delta and found food items to include mysid shrimp, amphipods, and other unidentified shrimp. In the northern estuaries of Willapa Bay, Grays Harbor, and the Columbia River, green sturgeon have been found to feed on a diet consisting primarily of benthic prey and fish common to the estuary. For example, burrowing thalassinid shrimp (mostly *Neotrypaea californiensis*) were important food items for green sturgeon taken in Willapa Bay, Washington (Dumbauld et al. 2008).

1.4.3.6 Estuarine Rearing

The age of first ocean entry in sDPS green sturgeon is poorly understood. Juvenile green sturgeon in the nDPS may spend 2 to 3 years in fresh or brackish water before making their first migration to sea. Nakamoto et al. (1995) found that, on average, green sturgeon on the Klamath River migrated to sea by age 3 and no later than age 4. On the Klamath River (nDPS), Allen et al. (2009) devised a technique to estimate the timing of transition from fresh water to seawater by taking a bone sample from the leading edge of the pectoral fin and analyzing the strontium to calcium ratios. The results of this study indicate that nDPS green sturgeon move from freshwater to brackish water at 0.5 to 1.5 years old and then move into seawater at 2.5 to 3.5 years old. Moyle (2002) suggests that sDPS green sturgeon migrate out to sea before the end of their second year and perhaps as YOY. Laboratory experiments indicate that green sturgeon juveniles may occupy fresh to brackish water at any age, but they gain the physiological ability to transition to saltwater at approximately 1.5 years old (Allen and Cech 2007).

1.4.3.7 Ocean Rearing

Once green sturgeon juveniles make their first entry into sea, they enter the sub-adult phase and spend multiple years migrating along the coastal zones, bays, and estuaries (Lindley et al. 2008). Sub-adult green sturgeon have not been observed in freshwater spawning areas. Green sturgeon mature at approximately 15 to 20 years old, and an individual may spawn once every 2 to 4 years and live for 50 years or more (Moyle 2002, Israel and Klimley 2008).

In the summer months, multiple rivers and estuaries throughout the sDPS range are visited by dense aggregations of adult green sturgeon (Moser and Lindley 2006, Lindley et al. 2011). Genetic studies on green sturgeon stocks indicate that the green sturgeon in the San Francisco Bay ecosystem belong exclusively to the sDPS (Israel et al. 2009). Capture of green sturgeon as well as tag detections in tagging studies have shown that green sturgeon are present in San Pablo Bay and San Francisco Bay at all months of the year (Kelly et al. 2006, Heublein et al. 2008, Lindley et al. 2011). An increasing amount of information is becoming available regarding green sturgeon habitat use in estuaries and coastal ocean and why they aggregate episodically (Lindley et al. 2008, Lindley et al. 2011).

Table B-7 shows the temporal occurrence of Southern DPS green sturgeon.

Table B-7. The Temporal Occurrence of (a) Spawning Adult, (b) Larval, (c) Young Juvenile, (d) Juvenile, and (e) Sub-adult and Non-spawning Adult Southern DPS Green Sturgeon. Locations emphasize the Central Valley of California. Darker shades indicate months of greatest relative abundance.

(a) Adult-sexually mature (≥145 cm TL females, ≥ 120 cm TL males), including pre- and post-spawning individuals.

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (rkm 332.5-451)	Low	Low	Low	Low	Medium	Medium	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	Medium	Medium	Medium
Sac River (< rkm 332.5)	Low	Low	Low	Medium	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Sac-SJ-SF Estuary	Low	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Low	Low

(b) Larval

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (> rkm 332.5)						Low	Medium	Medium	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Low	Low				

(c) Juvenile (≤5 months old)

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (> rkm 332.5)								Low	Medium	Medium	Medium	Medium	High	High	High	High	High	High	High	Medium	Medium	Medium	Medium	Medium

(d) Juvenile (≥5 months)

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
Sac River (< rkm 391)	Medium	Medium	Medium	Medium	Low	Low	Low	Low	Low	Low	Low	Medium	Medium	Medium	Medium	High	High	High	High	High	High	High	High	Medium
Sac-SJ Delta, Suisun Bay	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium

(e) Sub-Adults and Non-spawning adults

Location	Jan		Feb		Mar		Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec	
SAC-SJ-SF Estuary	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High	High	High	High	High	High	High	Medium	Medium
Pacific Coast	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Coastal Bays & Estuaries[1]	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	Medium	High	High	High	High	High	High	High	High	High	High	High	High	Medium	Medium

Relative Abundance: ■ = High ■ = Medium ■ = Low

Sources: (a) Heublein et al. 2008; Klimley et al. 2015; Poytress et al. 2015; Mora et al. 2015; (b) Poytress et al. 2015; Heublein et al. in review; (c) Heublein et al. in review, B. Poytress, unpublished; (d) Radtke 1966; CDFG 2002, Heublein et al. in review, B. Poytress, unpublished; (e) Erickson and Hightower 2007; Moser and Lindley 2006; Lindley et al. 2008, Lindley et al. 2011; Huff et al. 2011. Outside of Sac-SJ-SF estuary (e.g. Columbia R., Grays Harbor, Willapa Bay).

1.4.4 Green Sturgeon Viable Salmonid Population Parameters

As an approach to determining the conservation status of salmonids, NMFS has developed a framework for identifying attributes of a VSP. The intent of this framework is to provide parties with the ability to assess the effects of management and conservation actions and to ensure their actions promote the listed species' survival and recovery. This framework is known as the VSP concept (McElhany et al. 2000). The VSP concept measures population performance in terms of four key parameters: abundance, population growth rate, spatial structure, and diversity. Although the VSP concept was developed for Pacific salmonids, the underlying parameters are general principles of conservation biology and can therefore be applied more broadly. Here, we adopt the VSP parameters for analyzing sDPS green sturgeon viability.

1.4.4.1 Abundance

Trends in abundance of sDPS green sturgeon have been estimated from two long-term data sources: (1) salvage numbers at the State and Federal pumping facilities (see below); and (2) by incidental catch of green sturgeon by the CDFW's white sturgeon sampling/tagging program.

Historical estimates from these sources are likely unreliable as sDPS green sturgeon were likely not taken into account in incidental catch data, and salvage does not capture range-wide abundance in all water year types. Recently, more rigorous scientific inquiry has been undertaken to generate abundance estimates (Israel and May 2010, Mora et al. 2015).

A decrease in sDPS green sturgeon abundance has been inferred from the amount of take observed at the south Delta pumping facilities: the Skinner Delta Fish Protection Facility (SDFPF) and the Tracy Fish Collection Facility (TFCF). This data should be interpreted with some caution; operations and practices at the facilities have changed over the decades, which may affect the salvage data shown below (Figure B-16). The salvage data likely indicate a high production year versus a low production year qualitatively, but cannot be used to rigorously quantify abundance. Despite the potential pitfalls of using salvage data to estimate trends in abundance for sDPS green sturgeon, Figure B-16 indicates a steep decline in abundance.

Since 2010, more robust estimates of sDPS green sturgeon have been generated. As part of a doctoral thesis at UC Davis, Ethan Mora has been using acoustic telemetry as well as DIDSON (dual-frequency identification sonar) to locate green sturgeon in the Sacramento River and to derive an adult spawner abundance estimate (Mora et al. 2015). Results of these surveys estimate an average annual spawning run of 223 (DIDSON) and 236 (telemetry) fish. This estimate does not include the number of spawning adults in the lower Feather River, where green sturgeon spawning was recently confirmed (Seesholtz et al. 2014).

The image below shows annual salvage of green sturgeon for the SDFPF and the TFCF 1981 to 2015.

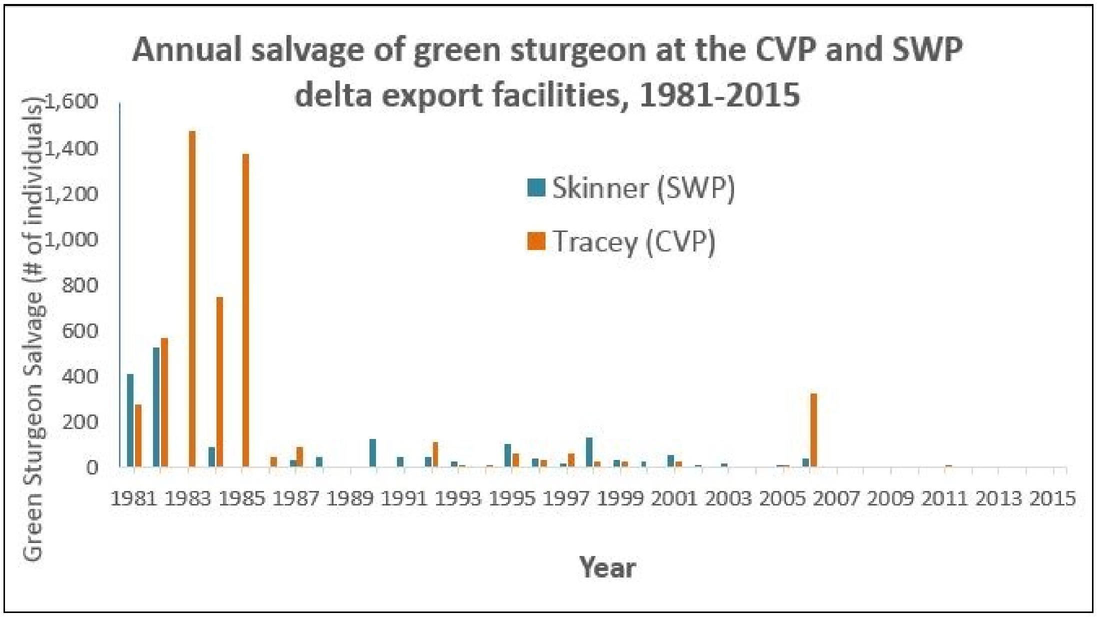

Figure B-14. Annual Salvage of Green Sturgeon for the Skinner Delta Fish Protection Facility and the Tracy Fish Collection Facility from *1981 to 2015. Data source: http://www.dfg.ca.gov/delta/apps/salvage/Default.aspx*

1.4.4.2 Productivity

The parameters of green sturgeon population growth rate and carrying capacity in the Sacramento Basin are poorly understood. Larval count data are available from RSTs set seasonally near Red Bluff and Glen Colusa irrigation diversions. This data shows enormous variance among years with the greatest number of larval green sturgeon occurring in 2011 when 3,700 larvae were captured (Poytress et al. 2012). In other years, larval counts were an order of magnitude lower. In general, sDPS green sturgeon year class strength appears to be highly variable with overall abundance dependent upon a few successful spawning events (NMFS 2010b). Other indicators of productivity, such as data for cohort replacement ratios and spawner abundance trends, are not currently available for sDPS green sturgeon. The long lifespan of the species and long age to maturity makes trend detection dependent upon datasets spanning decades. The acoustic telemetry work begun by Mora (UC Davis) on the Sacramento River and by Seesholtz et al. (2014) (CDWR) on the Feather River, as well as larval and juvenile studies by Poytress et al. (2011) (USFWS), may eventually produce a more statistically robust analysis of productivity.

1.4.4.3 Spatial Structure

Green sturgeon are known to range from Baja California to the Bering Sea along the North American continental shelf. During late summer and early fall, subadults and non-spawning adult green sturgeon can frequently be found aggregating in estuaries along the Pacific coast (Emmett et al. 1991, Moser and Lindley 2006). Using polyploid microsatellite data, Israel et al. (2009) found that green sturgeon within the Central Valley of California belong to the sDPS. Additionally, acoustic tagging studies have found that green sturgeon found spawning within the Sacramento River are exclusively sDPS green sturgeon (Lindley et al. 2011).

In waters inland from the Golden Gate Bridge in California, sDPS green sturgeon are known to range through the estuary and the Delta and up the Sacramento, Feather, and Yuba rivers (Israel et al. 2009; S.P. Cramer & Associates 2011; Seesholtz et al. 2014). The minimum northern-most extent of this range is thought to be Cow Creek (Mora, unpublished data). In the Yuba River, green sturgeon have been documented up to Daguerre Point Dam (Bergman et al. 2011), which currently impedes access to areas upriver. Similarly, in the Feather River, green sturgeon have been observed by CDWR staff up to the Fish Barrier Dam. Adult green sturgeon were detected up to the confluence with Cow Creek (RK 450) in 2005, and spawning was confirmed at the confluence with Ink's Creek (RK 426) in 2011 (Poytress et al. 2012). Adams et al. (2007) summarizes information that suggests green sturgeon may have been distributed above the locations of present-day dams on the Sacramento and Feather rivers. Mora et al. (2009) analyzed and characterized known green sturgeon habitat and used that characterization to identify potential green sturgeon habitat within the Sacramento and San Joaquin River basins, which now lies behind impassable dams. This study concludes that approximately 9 percent of historically available habitat is now blocked by impassible dams. It is likely that this blocked habitat was of high quality for spawning.

Studies conducted at UC Davis (Mora, unpublished data) have shown that green sturgeon spawning sites are concentrated in just a handful of locations. Mora (found that in the Sacramento River, just three sites accounted for over 50 percent of the green sturgeon documented in June of 2010, 2011, and 2012. This finding has important implications for the application of the spatial structure VSP parameter, which is largely concerned with spatial structuring of spawning habitat. Given the high density of individuals within a few spawning sites, extinction risk due to stochastic events is expected to have increased since the onset of dam construction and habitat loss in Central and Northern California.

Green sturgeon have been historically captured and are regularly detected within the Delta area of the lower San Joaquin River. Anglers have reported catching a small number of green sturgeon at various locations in the San Joaquin River upriver of the Delta (Gleason et al. 2008; DuBois et al. 2009, 2010, 2011, 2012). However, there is no known modern usage of the upper San Joaquin River, and adult green sturgeon spawning has not been documented (Jackson and Van Eenennaam 2013). Based on this information, it is unlikely that green sturgeon utilize areas of the San Joaquin River upriver of the Delta with regularity, and spawning events are thought to be limited to the upper Sacramento River and its tributaries.

Recent research indicates that the sDPS is composed of a single, independent population, which principally spawns in the mainstem Sacramento River (Israel et al. 2009), and also breeds opportunistically in the Feather River and possibly even the Yuba River (S.P. Cramer & Associates 2011; Seesholtz et al. 2014). Concentration of adults into a very few select spawning locations makes the species highly vulnerable to poaching and catastrophic events. The apparent, but unconfirmed, extirpation of spawning populations from the San Joaquin River narrows the available habitat within their range, offering fewer habitat alternatives.

1.4.4.4 Diversity

Diversity, as defined in the VSP concept in (McElhany et al. 2000), includes purely genetically driven traits, such as DNA sequence variation, and traits that are driven by a combination of genetics and the environment such as ocean behavior, age at maturity, and fecundity. Variation is important to the viability of a species for several reasons. First, it allows a species to utilize a wide array of environments. Second, diversity protects a species from short-term spatial and temporal changes in the environment by increasing the likelihood that at least some individuals will persist in spite of changing environmental conditions. Third, genetic diversity facilitates adaptation to changing environmental conditions over the long term.

Whether sDPS green sturgeon display these diversity traits and if there is sufficient diversity to buffer against long term extinction risk is not well-understood. It is likely that the diversity of sDPS green sturgeon is low, given recent abundance estimates. Human alteration of the environment is pervasive in the CCV. As a result, many aspects of sDPS green sturgeon diversity, such as run timing and behavior, have likely been adversely influenced through mechanisms such as altered flow and temperature regimes.

1.4.4.5 Summary of Distinct Population Segment viability

The viability of sDPS green sturgeon is constrained by factors such as a small population size, lack of multiple populations, and concentration of spawning sites into just a few locations. The risk of extinction is believed to be moderate (NMFS 2010b). Although threats due to habitat alteration are thought to be high and indirect evidence suggests a decline in abundance, there is much uncertainty regarding the scope of threats and the viability of population abundance indices (NMFS 2010b). Viability is defined as an independent population having a negligible risk of extinction due to threats from demographic variation, local environmental variation, and genetic diversity changes over a 100-year timeframe (McElhany et al. 2000).

Although the population structure of sDPS green sturgeon is still being refined, it is currently believed that only one population of sDPS green sturgeon exists. Lindley et al. (2008), in discussing winter-run Chinook salmon, states that an ESU represented by a single population at moderate risk of extinction is at high risk of extinction over a large timescale. This concern applies to any DPS or ESU represented by a single population, suggesting that sDPS green sturgeon face a high extinction risk in the future. NMFS determined, upon weighing all available information (and lack of information), that the extinction risk to sDPS green sturgeon is moderate (NMFS 2010b).

There is a strong need for additional information about sDPS green sturgeon, especially with regards to a more robust estimate of abundance and population trends, and a greater understanding of biology and habitat needs. The most recent 5-year status review for sDPS green sturgeon found that some threats to the species have recently been eliminated such as take from commercial fisheries and removal of some passage barriers (NMFS 2015). Since many of the threats cited in the original listing still exist, the threatened status of the DPS is still applicable (NMFS 2015). The 2015 5-year status review calls for the following future actions to be taken to contribute to the recovery of this species:

1. Continue monitoring and studying key life-history stages and modeling population abundance;
2. Achieve a comprehensive understanding of annual take of sDPS green sturgeon; and
3. Improve spawning habitat availability and quality (NMFS 2015).

1.5 Climate Change

One major factor affecting the range-wide status of the threatened and endangered anadromous fish in the Central Valley, and aquatic habitat at large is climate change. Lindley et al. (2007) summarized several studies (Hayhoe et al. 2004; Dettinger et al. 2004; Dettinger 2005; VanRheenen et al. 2004; Knowles and Cayan 2002) on how anthropogenic climate change is expected to alter the Central Valley, and based on these studies, described the possible effects to anadromous salmonids. Climate models for the Central Valley are broadly consistent in that temperatures in the future will warm significantly, total precipitation may decline, the variation in precipitation may substantially increase (i.e., more frequent flood flows and critically dry years), and snowfall will decline significantly (Lindley et al. 2007). Climate change is having, and will continue to have, an impact on salmonids throughout the Pacific Northwest and California (Battin et al. 2007).

Warmer temperatures associated with climate change reduce snowpack and alter the seasonality and volume of seasonal hydrograph patterns (Cohen et al. 2000). Central California has shown trends toward warmer winters since the 1940s (Dettinger and Cayan 1995). An altered seasonality results in runoff events occurring earlier in the year due to a shift in precipitation falling as rain rather than snow (Roos 1991; Dettinger et al. 2004). Specifically, the Sacramento River basin annual runoff amount for April- to July has been decreasing since about 1950 (Roos 1987, 1991). Increased temperatures influence the timing and magnitude patterns of the hydrograph.

The magnitude of snowpack reductions is subject to annual variability in precipitation and air temperature. The large spring snow water equivalent (SWE) percentage changes, late in the snow season, are due to a variety of factors including reduction in winter precipitation and temperature increases that rapidly melt spring snowpack (VanRheenen et al. 2004). Factors modeled by VanRheenen et al. (2004) show that the melt season shifts to earlier in the year, leading to a large percent reduction of spring SWE (up to 100 percent in shallow snowpack areas). Additionally, an air temperature increase of 3.8°F (2.1°C) is expected to result in a loss of about half of the average April snowpack storage (VanRheenen et al. 2004). The decrease in spring SWE (as a percentage) would be greatest in the region of the Sacramento River watershed, at the north end of the Central Valley, where snowpack is shallower than in the San Joaquin River watersheds to the south.

Modeling indicates that stream habitat for cold water species declined with climate warming and remaining habitat suitable may only exist at higher elevations (Null et al 2013). Climate warming is projected to cause average annual stream temperatures to exceed 24°C (75.2°F) slightly earlier in the spring, but notably later into August and September. The percentage of years that stream temperatures exceeded 24°C (for at least 1 week) is projected to increase, so that if air temperatures rise by 6°C, most Sierra Nevada rivers would exceed 24°C for some weeks every year.

Warming is already affecting CV Chinook salmon. Because the runs are restricted to low elevations as a result of impassable rim dams, if climate warms by 9°F (5°C), it is questionable whether any CV Chinook salmon populations can persist (Williams 2006). Based on an analysis of an ensemble of climate models and emission scenarios and a reference temperature from 1951 to 1980, the most plausible projection for warming over Northern California is 4.5°F (2.5°C) by 2050 and 9°F (5°C) by 2100, with a modest decrease in precipitation (Dettinger 2005). Chinook salmon in the Central Valley are at the southern limit of their range, and warming will shorten the period in which the low elevation habitats used by naturally producing Chinook salmon are thermally acceptable. This should particularly affect fish that emigrate as fingerlings, mainly in May and June, and especially those in the San Joaquin River and its tributaries.

Central Valley salmonids are highly vulnerable to drought conditions. The increased in-river water temperature resulting from drought conditions is likely to reduce the availability of suitable holding, spawning, and rearing conditions in Clear Creek and in the Sacramento, Feather, and Yuba rivers. During dry years, the availability of thermally suitable habitats in spring-run Chinook salmon river systems without major storage reservoirs (e.g., Mill, Deer, and Butte creeks) is also likely to be reduced. Multiple dry years in a row could potentially devastate Central Valley salmonids. Prolonged drought due to lower precipitation, shifts in snowmelt runoff, and greater climate extremes could easily render most existing spring-run Chinook salmon habitat unusable, either through temperature increases or lack of adequate flows. The drought that occurred from 2007 to 2009 was likely a factor in the recent widespread decline of all Chinook salmon runs (including spring-run Chinook salmon) in the Central Valley (Williams et al. 2011).

The increase in the occurrence of critically dry years also would be expected to reduce abundance, as, in the Central Valley, low flows during juvenile rearing and outmigration are associated with poor survival (Kjelson and Brandes 1989; Baker and Morhardt 2001; Newman and Rice 2002). In addition to habitat effects, climate change may also impact Central Valley salmonids through ecosystem effects. For example, warmer water temperatures would likely increase the metabolism of predators, reducing the survival of juvenile salmonids (Vigg and Burley 1991). In summary, climate change is expected to exacerbate existing stressors and pose new threats to Central Valley salmonids, including the CV spring-run Chinook salmon, by reducing the quantity and quality of inland habitat (Lindley et al. 2007).

Since 2005, there has been a period of widespread decline in all CV Chinook salmon stocks. An analysis by Lindley et al. (2009) that examined fall-run Chinook salmon found that unusual oceanic conditions led to poor growth and survival for juvenile salmon entering the ocean from the Central Valley during the spring of 2005 and 2006 and most likely contributed to low returns in 2008 and 2009. This reduced survival was attributed to weak upwelling, warm sea surface temperatures, low prey densities, and poor feeding conditions in the ocean. When poor ocean conditions are combined with drought conditions in the freshwater environment, the productivity of salmonid populations can be significantly reduced. Although it is unclear how these unusual ocean conditions affected CCV steelhead, it is highly likely they were adversely impacted by a combination of poor ocean conditions and drought (NMFS 2011b).

For Sacramento River winter-run Chinook salmon, the embryonic and larval life stages that are most vulnerable to warmer water temperatures occur during the summer, so this run is particularly at risk from climate warming. The only remaining population of winter-run Chinook salmon relies on the cold water pool in Shasta Reservoir, which buffers the effects of warm temperatures in most years. The exception occurs during drought years, which are predicted to occur more often with climate change (Yates et al. 2008). The long-term projection of how the CVP and SWP will operate incorporates the effects of potential climate change in three possible forms: less total precipitation; a shift to more precipitation in the form of rain rather than snow; or earlier spring snow melt (Reclamation 2008). Additionally, air temperature appears to be increasing at a greater rate than what was previously analyzed (Lindley 2008; Beechie et al.

2012; Dimacali 2013). These factors will compromise the quantity and/or quality of winter-run Chinook salmon habitat available downstream of Keswick Dam. It is imperative for additional populations of winter-run Chinook salmon to be re-established into historical habitat in Battle Creek and above Shasta Dam for long-term viability of the ESU (NMFS 2014a).

Spring-run Chinook salmon adults are vulnerable to climate change because they over-summer in freshwater streams before spawning in autumn (Thompson et al. 2011). CV spring-run Chinook salmon spawn primarily in the tributaries to the Sacramento River, and those tributaries without cold water refugia (usually input from springs) will be more susceptible to impacts of climate change. Even in tributaries with cool water springs, in years of extended drought and warming water temperatures, unsuitable conditions may occur. Additionally, juveniles often rear in the natal stream for one to two summers prior to emigrating and would be susceptible to warming water temperatures (NMFS 2016b). In Butte Creek, fish are limited to low elevation habitat that is currently thermally marginal, as demonstrated by high summer mortality of adults in 2002 and 2003, and will become intolerable within decades if the climate warms as expected. Ceasing water diversion for power production from the summer holding reach in Butte Creek resulted in cooler water temperatures, more adults surviving to spawn, and extended population survival time (Mosser et al. 2013).

Although CCV steelhead will experience similar effects of climate change to Chinook salmon, as they are also blocked from the vast majority of their historic spawning and rearing habitat, the effects may be even greater in some cases, as juvenile CCV steelhead need to rear in the stream for one to two summers prior to emigrating as smolts. In the Central Valley, summer and fall temperatures below the dams in many streams already exceed the recommended temperatures for optimal growth of juvenile steelhead, which range from 57°F to 66°F (14°C to 19°C). Several studies have found that steelhead require colder water temperatures for spawning and embryo incubation than salmon (McCullough et al. 2001). In fact, McCullough et al. (2001) recommended an optimal incubation temperature at or below 52°F to 55°F (11°C to 13°C). Successful smoltification in steelhead may be impaired by temperatures above 54°F (12°C), as reported in Richter and Kolmes (2005). As stream temperatures warm due to climate change, the growth rates of juvenile steelhead could increase in some systems that are currently relatively cold, but potentially at the expense of decreased survival due to higher metabolic demands and greater presence and activity of predators. Stream temperatures that are currently marginal for spawning and rearing may become too warm to support wild steelhead populations.

The sDPS green sturgeon spawn primarily in the Sacramento River in the spring and summer. ACID is considered the upriver extent of CCV green sturgeon migration in the Sacramento River (71 FR 17757; April 7, 2006). The upriver extent of CCV green sturgeon spawning, however, is approximately 30 kilometers downriver of ACID because water temperatures in this section of the river are too cold for spawning. Thus, if water temperatures increase with climate change, temperatures adjacent to ACID may remain within tolerable levels for the embryonic and larval life stages of green sturgeon, but temperatures at spawning locations lower in the river may be more affected. It is uncertain, however, if green sturgeon spawning habitat exists closer to ACID, which could allow spawning to shift upstream in response to climate change effects. Successful spawning of CCV green sturgeon in other accessible habitats in the Central Valley (i.e., the Feather River) is limited, in part, by late spring and summer water temperatures (NMFS 2015). Similar to salmonids in the Central Valley, CCV green sturgeon spawning in tributaries to the

Sacramento River is likely to be further limited if water temperatures increase and higher elevation habitats remain inaccessible.

In summary, observed and predicted climate change effects are generally detrimental to all of the species addressed in this appendix (McClure 2011; Wade et al. 2013), so unless offset by improvements in other factors, the status of the species and critical habitat is likely to decline over time. The climate change projections referenced above cover the time period between the present and approximately 2100. While there is uncertainty associated with projections, which increase over time, the direction of change is relatively certain (McClure et al. 2013).

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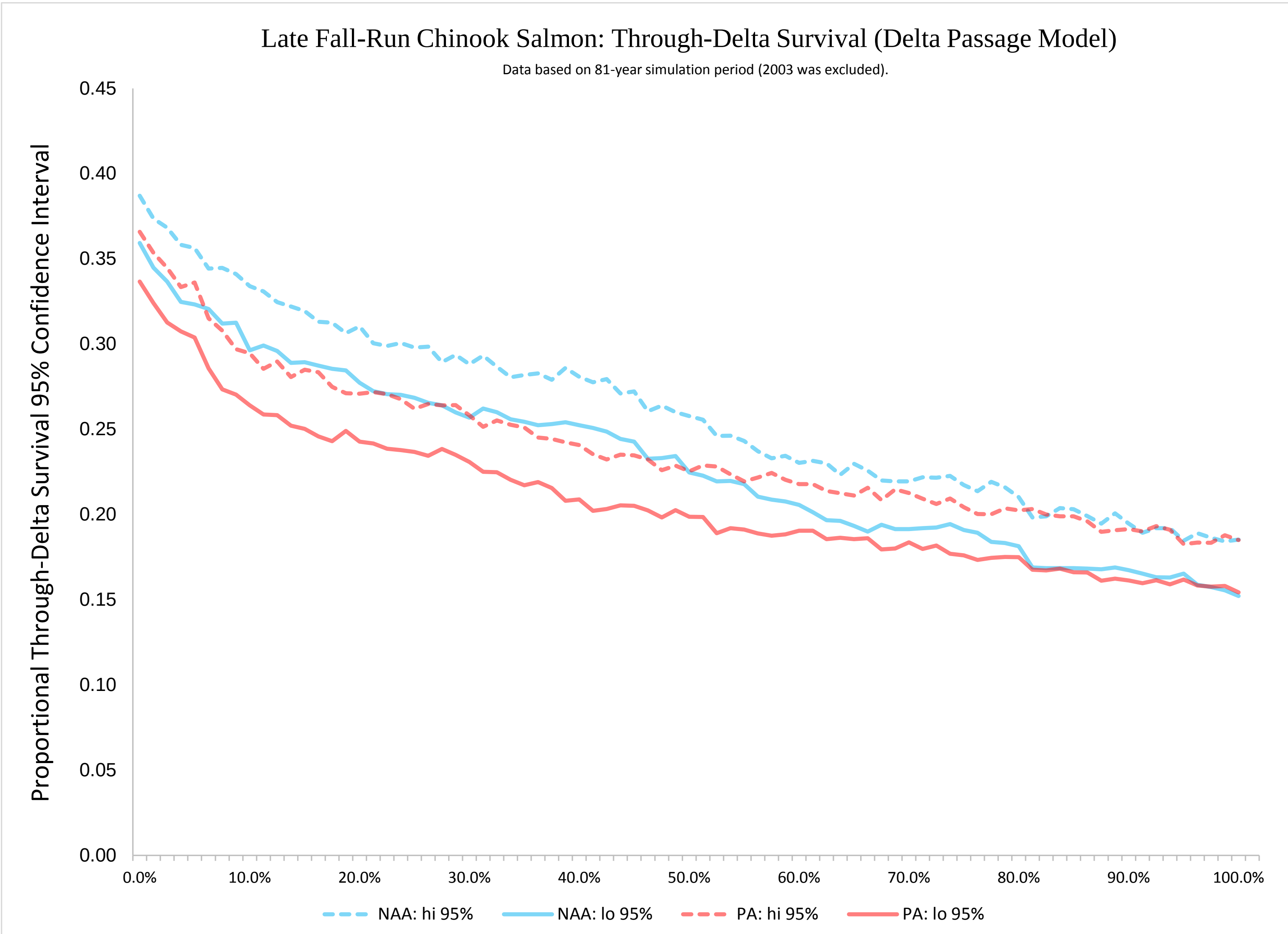
Appendix C

Section 2.5.1

Supporting Tables and Figures



Note: Data are sorted by mean estimate, with only 95% confidence intervals shown.

Figure 5.E-20. Exceedance Plot of Late Fall-Run Chinook Salmon Annual Through-Delta Survival Estimated from the Delta Passage Model.

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Table 5.C.7-7. Sacramento River at Bend Bridge, Monthly Temperature

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	60.8	59.7	-1.1	-2%	55.8	55.5	-0.3	-1%	51.1	50.9	-0.2	0%	48.2	48.2	0.1	0%	48.9	49.0	0.1	0%	52.2	51.8	-0.3	-1%
20%	57.7	57.4	-0.3	-1%	55.2	54.8	-0.4	-1%	50.4	50.3	-0.1	0%	47.6	47.5	0.0	0%	48.5	48.5	0.0	0%	51.7	51.6	0.0	0%
30%	57.1	57.0	-0.1	0%	54.6	54.4	-0.2	0%	49.5	49.3	-0.2	0%	47.0	47.1	0.1	0%	48.0	48.1	0.1	0%	51.3	51.3	0.0	0%
40%	56.7	56.5	-0.3	0%	54.2	53.9	-0.2	0%	49.0	49.0	0.0	0%	46.8	46.9	0.1	0%	47.7	47.7	0.0	0%	50.9	50.9	0.0	0%
50%	56.3	56.3	0.1	0%	53.9	53.6	-0.3	-1%	48.8	48.8	0.0	0%	46.6	46.6	0.0	0%	47.4	47.4	0.0	0%	50.2	50.2	0.0	0%
60%	56.0	56.2	0.1	0%	53.3	53.1	-0.2	0%	48.4	48.4	0.0	0%	46.4	46.5	0.1	0%	47.2	47.2	0.0	0%	49.8	49.8	0.0	0%
70%	55.9	55.8	-0.1	0%	52.9	52.9	-0.1	0%	48.1	48.1	0.0	0%	46.2	46.2	0.0	0%	46.5	46.5	0.0	0%	49.1	49.1	0.0	0%
80%	55.6	55.6	0.0	0%	52.8	52.5	-0.2	0%	47.7	47.8	0.1	0%	46.0	45.9	0.0	0%	46.3	46.3	0.0	0%	48.5	48.5	0.0	0%
90%	55.3	55.4	0.1	0%	52.0	51.9	-0.2	0%	47.4	47.5	0.1	0%	45.6	45.6	0.0	0%	46.0	46.0	0.0	0%	47.8	47.8	0.0	0%
Long Term Full Simulation Period[b]	57.0	57.0	0.0	0%	53.9	53.7	-0.2	0%	49.0	48.9	0.0	0%	46.7	46.8	0.1	0%	47.4	47.4	0.0	0%	50.2	50.1	-0.1	0%
Water Year Types[c]																								
Wet (32%)	55.8	56.0	0.2	0%	54.2	53.9	-0.3	-1%	49.4	49.4	0.0	0%	47.0	47.1	0.1	0%	46.7	46.7	0.0	0%	48.8	48.8	0.0	0%
Above Normal (16%)	55.9	55.8	0.0	0%	53.6	53.1	-0.5	-1%	48.9	48.8	-0.1	0%	47.0	47.0	0.0	0%	46.8	46.8	0.0	0%	49.6	49.5	-0.1	0%
Below Normal (13%)	56.4	56.2	-0.3	0%	53.6	53.4	-0.1	0%	49.0	49.0	-0.1	0%	46.8	46.8	0.0	0%	47.7	47.7	0.0	0%	50.9	50.8	-0.2	0%
Dry (24%)	56.8	56.8	-0.1	0%	53.1	53.2	0.1	0%	48.6	48.6	0.0	0%	46.4	46.4	0.0	0%	47.9	48.0	0.0	0%	51.0	51.0	0.0	0%
Critical (15%)	61.7	61.4	-0.3	0%	54.8	54.9	0.1	0%	48.5	48.6	0.0	0%	46.2	46.3	0.1	0%	48.4	48.5	0.2	0%	51.6	51.5	-0.2	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	55.2	55.3	0.0	0%	58.0	57.9	-0.1	0%	58.3	58.3	0.0	0%	58.7	58.9	0.3	0%	60.4	60.0	-0.4	-1%	63.0	62.5	-0.5	-1%
20%	54.7	54.6	-0.1	0%	56.8	56.9	0.1	0%	57.5	57.4	-0.2	0%	57.8	57.9	0.1	0%	59.5	59.0	-0.5	-1%	60.4	60.8	0.4	1%
30%	54.0	54.0	0.0	0%	56.6	56.6	0.0	0%	56.9	56.8	-0.1	0%	57.3	57.3	0.1	0%	58.7	58.4	-0.3	0%	59.7	60.1	0.3	1%
40%	53.6	53.6	0.0	0%	56.2	56.2	0.0	0%	56.5	56.5	-0.1	0%	56.8	56.9	0.1	0%	58.1	58.0	-0.1	0%	58.9	59.4	0.5	1%
50%	53.5	53.4	0.0	0%	55.9	55.9	0.0	0%	56.0	56.0	-0.1	0%	56.4	56.3	-0.2	0%	57.5	57.7	0.2	0%	57.9	58.3	0.4	1%
60%	53.2	53.2	0.0	0%	55.7	55.7	0.0	0%	55.7	55.5	-0.2	0%	55.8	55.8	0.0	0%	57.3	57.3	0.0	0%	56.3	57.0	0.6	1%
70%	52.7	52.7	-0.1	0%	55.2	55.2	0.0	0%	55.4	55.0	-0.4	-1%	55.5	55.5	0.1	0%	57.0	57.1	0.1	0%	55.3	55.5	0.2	0%
80%	52.0	52.1	0.1	0%	54.8	54.8	-0.1	0%	55.0	54.7	-0.4	-1%	55.1	55.2	0.1	0%	56.6	56.7	0.1	0%	54.7	55.0	0.3	0%
90%	51.4	51.3	0.0	0%	54.3	54.1	-0.2	0%	54.5	54.2	-0.3	-1%	54.5	54.7	0.2	0%	56.0	56.2	0.2	0%	54.1	54.2	0.1	0%
Long Term Full Simulation Period[b]	53.3	53.3	0.0	0%	56.0	56.0	0.0	0%	56.3	56.0	-0.2	0%	56.5	56.6	0.1	0%	58.2	58.2	0.0	0%	58.2	58.5	0.3	0%
Water Year Types[c]																								
Wet (32%)	52.5	52.5	0.0	0%	55.7	55.7	0.0	0%	56.5	56.4	-0.1	0%	56.3	56.3	0.0	0%	57.3	57.2	0.0	0%	54.7	54.8	0.1	0%
Above Normal (16%)	53.2	53.2	0.0	0%	55.9	55.9	0.0	0%	55.4	55.1	-0.3	0%	54.9	55.0	0.1	0%	56.7	56.7	0.1	0%	55.7	56.3	0.5	1%
Below Normal (13%)	53.7	53.8	0.1	0%	55.5	55.8	0.3	0%	55.6	55.3	-0.2	0%	55.8	55.8	0.0	0%	57.2	57.7	0.5	1%	58.9	59.5	0.6	1%
Dry (24%)	54.2	54.1	-0.1	0%	56.1	55.9	-0.3	0%	55.8	55.4	-0.4	-1%	56.6	56.7	0.1	0%	58.7	58.5	-0.2	0%	59.9	60.2	0.3	0%
Critical (15%)	53.6	53.5	-0.1	0%	56.9	56.8	-0.1	0%	58.1	57.8	-0.2	0%	59.4	59.6	0.2	0%	62.1	62.0	-0.2	0%	65.0	65.0	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Table 5.C.7-8. Sacramento River at Red Bluff Diversion Dam, Monthly Temperature

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	61.2	60.3	-0.9	-1%	55.9	55.5	-0.4	-1%	50.9	50.7	-0.2	0%	48.2	48.2	0.0	0%	49.2	49.2	0.0	0%	52.9	52.7	-0.3	-1%
20%	58.3	58.0	-0.3	-1%	55.3	54.8	-0.5	-1%	50.2	50.0	-0.2	0%	47.5	47.5	0.0	0%	48.8	48.9	0.0	0%	52.3	52.2	-0.1	0%
30%	57.6	57.6	-0.1	0%	54.7	54.4	-0.3	-1%	49.3	49.2	-0.1	0%	47.1	47.1	0.1	0%	48.4	48.4	0.0	0%	51.9	51.7	-0.2	0%
40%	57.1	57.0	-0.2	0%	54.2	53.9	-0.3	-1%	48.9	48.9	-0.1	0%	46.9	46.9	0.0	0%	47.9	47.9	0.0	0%	51.5	51.4	0.0	0%
50%	56.8	56.8	0.0	0%	53.9	53.6	-0.3	-1%	48.7	48.7	-0.1	0%	46.6	46.7	0.0	0%	47.6	47.6	0.0	0%	50.6	50.6	0.0	0%
60%	56.5	56.6	0.1	0%	53.3	53.2	-0.1	0%	48.4	48.4	0.1	0%	46.4	46.5	0.0	0%	47.3	47.3	0.0	0%	50.3	50.3	-0.1	0%
70%	56.4	56.3	0.0	0%	53.0	52.9	-0.1	0%	47.9	48.1	0.2	0%	46.3	46.3	0.0	0%	46.7	46.8	0.0	0%	49.5	49.5	0.0	0%
80%	56.0	56.1	0.0	0%	52.8	52.6	-0.2	0%	47.8	47.8	0.0	0%	46.0	46.0	0.0	0%	46.5	46.5	0.0	0%	48.8	48.8	0.0	0%
90%	55.7	55.9	0.2	0%	52.1	52.0	-0.1	0%	47.4	47.5	0.1	0%	45.6	45.6	0.0	0%	46.1	46.1	0.0	0%	48.1	48.2	0.1	0%
Long Term Full Simulation Period[b]	57.5	57.5	0.0	0%	53.9	53.7	-0.2	0%	48.9	48.9	0.0	0%	46.7	46.8	0.0	0%	47.6	47.7	0.0	0%	50.7	50.6	-0.1	0%
Water Year Types[c]																								
Wet (32%)	56.3	56.5	0.2	0%	54.2	53.9	-0.3	-1%	49.3	49.3	-0.1	0%	47.1	47.2	0.1	0%	46.9	46.9	0.0	0%	49.1	49.2	0.0	0%
Above Normal (16%)	56.4	56.4	0.0	0%	53.6	53.1	-0.5	-1%	48.9	48.8	-0.1	0%	46.9	46.9	0.0	0%	47.0	47.0	0.0	0%	50.1	49.9	-0.1	0%
Below Normal (13%)	56.9	56.7	-0.3	0%	53.6	53.5	-0.1	0%	49.0	48.9	-0.1	0%	46.8	46.8	0.0	0%	48.0	48.0	0.0	0%	51.5	51.4	-0.2	0%
Dry (24%)	57.4	57.3	-0.1	0%	53.2	53.2	0.1	0%	48.6	48.6	0.0	0%	46.4	46.4	0.0	0%	48.2	48.2	0.0	0%	51.5	51.5	0.0	0%
Critical (15%)	62.1	61.8	-0.2	0%	54.9	54.9	0.1	0%	48.5	48.5	0.0	0%	46.3	46.4	0.1	0%	48.8	49.0	0.2	0%	52.4	52.2	-0.2	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	56.2	56.2	0.0	0%	59.2	59.2	0.0	0%	60.1	60.1	0.0	0%	60.2	60.7	0.5	1%	62.0	61.9	-0.1	0%	64.5	64.2	-0.3	0%
20%	55.5	55.5	0.0	0%	58.2	58.1	0.0	0%	59.0	58.9	-0.1	0%	59.7	59.6	-0.1	0%	61.2	60.7	-0.6	-1%	62.3	62.6	0.3	0%
30%	54.9	54.9	-0.1	0%	57.8	57.9	0.1	0%	58.6	58.4	-0.2	0%	59.2	59.1	-0.1	0%	60.2	60.0	-0.2	0%	61.4	61.7	0.3	1%
40%	54.6	54.5	0.0	0%	57.4	57.5	0.0	0%	58.1	57.9	-0.2	0%	58.4	58.5	0.1	0%	59.8	59.7	-0.1	0%	60.6	61.0	0.4	1%
50%	54.2	54.2	-0.1	0%	57.1	57.1	0.0	0%	57.7	57.6	-0.2	0%	58.1	57.9	-0.1	0%	59.3	59.4	0.1	0%	59.5	60.0	0.5	1%
60%	54.0	54.0	0.0	0%	56.9	56.9	-0.1	0%	57.4	57.2	-0.2	0%	57.4	57.5	0.1	0%	58.9	59.0	0.1	0%	57.6	58.4	0.8	1%
70%	53.5	53.5	0.0	0%	56.5	56.4	-0.1	0%	57.1	56.6	-0.6	-1%	57.2	57.1	0.0	0%	58.6	58.7	0.1	0%	56.4	56.7	0.2	0%
80%	52.6	52.7	0.0	0%	56.0	55.9	-0.1	0%	56.6	56.2	-0.3	-1%	56.8	56.8	0.0	0%	58.2	58.4	0.2	0%	55.9	56.3	0.4	1%
90%	52.0	52.0	-0.1	0%	55.4	55.3	-0.1	0%	56.1	55.7	-0.4	-1%	56.1	56.4	0.3	1%	57.5	58.0	0.5	1%	55.1	55.1	0.1	0%
Long Term Full Simulation Period[b]	54.1	54.1	0.0	0%	57.2	57.1	0.0	0%	57.9	57.6	-0.3	0%	58.2	58.3	0.1	0%	59.9	59.9	0.0	0%	59.6	59.9	0.3	0%
Water Year Types[c]																								
Wet (32%)	53.1	53.1	0.0	0%	56.8	56.8	0.0	0%	58.1	58.0	-0.1	0%	58.0	58.0	0.0	0%	59.0	58.9	0.0	0%	55.8	55.9	0.1	0%
Above Normal (16%)	53.9	53.9	0.0	0%	57.2	57.1	0.0	0%	57.1	56.8	-0.3	-1%	56.6	56.7	0.1	0%	58.4	58.4	0.1	0%	57.0	57.7	0.6	1%
Below Normal (13%)	54.6	54.7	0.1	0%	56.7	57.0	0.2	0%	57.2	56.9	-0.3	-1%	57.4	57.4	0.0	0%	58.8	59.3	0.6	1%	60.5	61.2	0.6	1%
Dry (24%)	55.1	55.0	-0.1	0%	57.4	57.1	-0.3	0%	57.5	57.0	-0.4	-1%	58.3	58.4	0.1	0%	60.4	60.2	-0.2	0%	61.6	61.9	0.3	0%
Critical (15%)	54.6	54.5	-0.1	0%	58.2	58.1	-0.1	0%	59.7	59.4	-0.3	-1%	61.1	61.3	0.2	0%	63.6	63.5	-0.2	0%	66.2	66.3	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Table 5.C.7-14. American River at Hazel Ave, Monthly Temperature

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	66.3	66.1	-0.2	0%	58.2	58.0	-0.2	0%	53.3	52.7	-0.6	-1%	47.9	48.1	0.1	0%	48.4	48.7	0.2	0%	52.3	52.4	0.0	0%
20%	65.4	65.1	-0.3	0%	57.9	57.8	-0.1	0%	51.9	51.7	-0.2	0%	47.3	47.3	0.0	0%	47.8	47.8	0.0	0%	51.6	51.8	0.2	0%
30%	64.4	64.2	-0.2	0%	57.7	57.6	-0.1	0%	51.2	51.1	0.0	0%	46.9	47.0	0.1	0%	47.4	47.5	0.1	0%	50.6	50.6	0.0	0%
40%	63.8	63.4	-0.3	-1%	57.3	57.3	0.0	0%	50.7	50.7	0.0	0%	46.8	46.8	0.0	0%	46.9	46.9	0.0	0%	49.8	49.8	-0.1	0%
50%	63.3	63.1	-0.1	0%	57.1	57.0	-0.1	0%	50.3	50.1	-0.2	0%	46.1	46.2	0.1	0%	46.6	46.5	-0.1	0%	49.4	49.4	0.0	0%
60%	63.1	63.0	-0.1	0%	56.9	56.8	-0.1	0%	49.0	49.5	0.4	1%	45.8	45.8	0.0	0%	46.3	46.2	-0.1	0%	49.0	49.0	0.0	0%
70%	62.8	62.8	0.0	0%	56.7	56.6	-0.1	0%	48.5	48.6	0.2	0%	45.3	45.4	0.0	0%	46.0	46.0	0.0	0%	48.7	48.6	-0.1	0%
80%	62.7	62.7	0.0	0%	56.1	56.2	0.0	0%	48.1	48.3	0.2	0%	44.9	45.0	0.1	0%	45.8	45.7	0.0	0%	48.3	48.3	0.0	0%
90%	59.2	59.3	0.2	0%	55.7	55.4	-0.3	-1%	46.9	46.9	0.0	0%	44.5	44.4	-0.1	0%	45.4	45.4	0.0	0%	48.0	48.0	0.0	0%
Long Term Full Simulation Period[b]	63.4	63.3	-0.1	0%	57.0	56.9	-0.1	0%	50.0	50.0	-0.1	0%	46.2	46.2	0.0	0%	46.8	46.8	0.0	0%	49.9	49.8	0.0	0%
Water Year Types[c]																								
Wet (32%)	61.6	61.6	0.0	0%	57.0	56.9	-0.1	0%	50.7	50.8	0.0	0%	46.5	46.5	0.0	0%	46.0	45.9	-0.1	0%	48.6	48.5	-0.1	0%
Above Normal (16%)	63.1	63.3	0.2	0%	56.7	56.7	0.0	0%	50.0	50.1	0.1	0%	46.4	46.6	0.1	0%	46.5	46.5	0.0	0%	49.0	48.9	0.0	0%
Below Normal (13%)	63.8	63.8	-0.1	0%	57.3	57.0	-0.3	0%	50.4	50.1	-0.3	-1%	46.2	46.0	-0.2	0%	46.7	46.7	0.0	0%	50.0	50.0	0.0	0%
Dry (24%)	64.4	64.1	-0.3	0%	56.9	56.7	-0.3	0%	49.5	49.3	-0.2	0%	46.1	46.0	-0.1	0%	47.3	47.3	0.0	0%	50.6	50.6	0.0	0%
Critical (15%)	65.6	65.2	-0.4	-1%	57.5	57.4	-0.1	0%	49.0	49.1	0.1	0%	45.6	45.6	0.0	0%	48.0	48.0	0.0	0%	52.3	52.3	0.0	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	57.8	57.7	-0.1	0%	63.1	63.0	-0.1	0%	67.5	67.0	-0.5	-1%	68.9	68.7	-0.3	0%	67.2	67.3	0.1	0%	68.4	68.5	0.1	0%
20%	57.0	56.8	-0.2	0%	61.7	61.8	0.0	0%	65.7	65.8	0.1	0%	66.8	67.0	0.2	0%	66.7	66.8	0.1	0%	67.6	67.7	0.1	0%
30%	56.0	56.1	0.1	0%	60.8	60.6	-0.2	0%	64.5	64.7	0.2	0%	65.3	65.2	-0.1	0%	65.7	65.7	0.0	0%	66.4	66.6	0.2	0%
40%	55.3	55.3	0.0	0%	59.6	59.5	-0.1	0%	63.0	63.0	0.1	0%	64.9	64.7	-0.2	0%	65.0	65.1	0.1	0%	65.8	65.8	0.0	0%
50%	54.5	54.5	0.0	0%	58.3	58.3	0.0	0%	61.7	62.3	0.7	1%	64.6	64.5	-0.1	0%	64.3	64.3	0.0	0%	65.2	65.3	0.0	0%
60%	54.0	54.0	0.0	0%	57.8	57.8	0.0	0%	60.7	61.0	0.3	1%	64.5	64.2	-0.3	-1%	64.0	63.9	-0.1	0%	64.9	64.9	0.0	0%
70%	53.4	53.4	0.0	0%	57.0	57.0	0.0	0%	59.7	59.9	0.2	0%	64.4	63.8	-0.6	-1%	63.4	63.4	0.0	0%	64.3	64.3	0.0	0%
80%	52.4	52.4	0.0	0%	56.5	56.5	0.0	0%	59.3	59.3	0.0	0%	63.8	63.6	-0.2	0%	63.1	62.8	-0.2	0%	64.1	64.0	0.0	0%
90%	51.9	51.7	-0.2	0%	54.9	54.9	0.1	0%	59.0	59.0	0.0	0%	63.5	63.4	-0.1	0%	62.2	62.3	0.0	0%	63.1	63.1	0.0	0%
Long Term Full Simulation Period[b]	54.7	54.7	-0.1	0%	59.0	58.9	-0.1	0%	62.5	62.4	0.0	0%	65.3	65.2	-0.1	0%	64.6	64.7	0.1	0%	65.5	65.5	0.0	0%
Water Year Types[c]																								
Wet (32%)	52.8	52.7	-0.1	0%	56.6	56.6	0.0	0%	59.9	59.8	-0.1	0%	63.8	63.8	-0.1	0%	62.8	62.9	0.1	0%	63.8	63.7	-0.1	0%
Above Normal (16%)	54.2	54.2	0.0	0%	58.3	58.3	0.0	0%	61.8	62.1	0.4	1%	64.5	64.2	-0.3	0%	64.1	64.1	-0.1	0%	64.9	65.0	0.1	0%
Below Normal (13%)	56.1	56.1	0.0	0%	60.2	60.1	0.0	0%	63.7	63.0	-0.7	-1%	65.1	64.9	-0.2	0%	65.2	64.9	-0.3	0%	65.6	65.8	0.3	0%
Dry (24%)	55.5	55.3	-0.1	0%	60.2	60.0	-0.2	0%	63.7	63.9	0.1	0%	65.9	65.8	-0.1	0%	65.5	65.6	0.1	0%	66.4	66.5	0.1	0%
Critical (15%)	57.1	57.0	-0.1	0%	62.0	62.0	0.0	0%	65.6	65.6	0.0	0%	68.8	68.9	0.1	0%	66.8	67.8	0.9	1%	68.1	67.9	-0.2	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Table 5.C.7-15. American River at Watt Ave, Monthly Temperature

Statistic	Monthly Temperature (Deg-F)																							
	October				November				December				January				February				March			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	67.2	66.9	-0.3	0%	58.3	58.3	0.0	0%	52.5	52.1	-0.5	-1%	48.3	48.5	0.1	0%	50.0	50.1	0.1	0%	56.2	56.3	0.1	0%
20%	65.7	65.6	-0.2	0%	58.0	57.9	-0.1	0%	51.6	51.3	-0.3	-1%	47.8	47.8	0.0	0%	49.5	49.5	0.0	0%	54.7	55.0	0.3	0%
30%	64.9	64.8	-0.1	0%	57.6	57.5	-0.1	0%	50.8	50.8	0.1	0%	47.4	47.5	0.1	0%	48.6	48.6	0.0	0%	52.9	52.9	0.0	0%
40%	64.5	64.5	0.0	0%	57.3	57.3	0.0	0%	50.5	50.4	0.0	0%	47.1	47.2	0.0	0%	48.3	48.2	-0.1	0%	51.9	51.9	0.0	0%
50%	64.1	64.0	-0.1	0%	57.1	57.1	0.0	0%	50.0	49.9	-0.1	0%	46.7	46.7	0.0	0%	47.8	47.7	-0.1	0%	51.3	51.3	0.0	0%
60%	63.8	63.6	-0.2	0%	56.8	56.7	-0.1	0%	49.0	49.5	0.5	1%	46.3	46.3	0.0	0%	47.2	47.3	0.1	0%	50.4	50.4	0.0	0%
70%	63.3	63.3	0.0	0%	56.5	56.4	-0.1	0%	48.5	48.7	0.1	0%	45.7	45.7	-0.1	0%	46.9	46.8	-0.1	0%	50.0	49.9	-0.1	0%
80%	63.1	63.0	-0.1	0%	56.1	56.1	0.0	0%	48.0	48.3	0.2	0%	45.2	45.3	0.1	0%	46.5	46.4	0.0	0%	49.7	49.6	0.0	0%
90%	61.0	61.3	0.3	1%	55.8	55.5	-0.3	-1%	47.3	47.1	-0.2	0%	44.9	44.7	-0.2	-1%	46.1	45.9	-0.2	0%	49.2	49.0	-0.2	0%
Long Term Full Simulation Period[b]	64.1	64.1	-0.1	0%	57.0	56.9	-0.1	0%	49.8	49.8	0.0	0%	46.7	46.6	0.0	0%	48.0	48.0	-0.1	0%	52.0	51.9	0.0	0%
Water Year Types[c]																								
Wet (32%)	62.5	62.6	0.1	0%	57.0	56.9	-0.1	0%	50.5	50.5	0.0	0%	46.8	46.8	0.0	0%	46.7	46.6	-0.1	0%	49.9	49.8	-0.1	0%
Above Normal (16%)	63.8	63.9	0.2	0%	56.6	56.6	0.0	0%	49.8	49.9	0.1	0%	46.8	46.9	0.1	0%	47.5	47.4	-0.1	0%	50.4	50.4	0.0	0%
Below Normal (13%)	64.4	64.3	0.0	0%	57.2	57.0	-0.2	0%	50.0	49.8	-0.2	0%	46.5	46.3	-0.1	0%	47.8	47.7	-0.1	0%	52.5	52.5	0.0	0%
Dry (24%)	65.0	64.8	-0.2	0%	56.9	56.7	-0.2	0%	49.4	49.2	-0.2	0%	46.6	46.4	-0.1	0%	48.8	48.8	0.0	0%	53.2	53.1	-0.1	0%
Critical (15%)	66.4	66.0	-0.4	-1%	57.5	57.5	0.0	0%	49.1	49.1	0.1	0%	46.6	46.5	0.0	0%	50.5	50.5	0.0	0%	55.5	55.7	0.2	0%

Statistic	Monthly Temperature (Deg-F)																							
	April				May				June				July				August				September			
	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.	NAA	PA	Diff.	Perc. Diff.
Probability of Exceedance[a]																								
10%	62.7	62.3	-0.4	-1%	67.6	67.9	0.2	0%	72.8	71.5	-1.3	-2%	73.2	73.9	0.8	1%	73.0	73.5	0.5	1%	71.3	72.0	0.6	1%
20%	60.2	60.4	0.2	0%	66.5	66.1	-0.4	-1%	70.1	69.2	-1.0	-1%	69.8	70.1	0.2	0%	71.8	71.8	0.1	0%	70.3	70.5	0.2	0%
30%	59.0	59.1	0.1	0%	65.3	65.2	-0.1	0%	68.7	68.0	-0.7	-1%	68.7	69.0	0.3	0%	69.7	69.7	0.0	0%	68.9	69.2	0.4	1%
40%	57.7	57.6	-0.2	0%	63.8	63.8	0.0	0%	66.7	66.6	-0.1	0%	68.2	68.1	-0.2	0%	69.2	69.3	0.1	0%	68.5	68.3	-0.2	0%
50%	57.0	57.0	0.0	0%	62.3	62.3	0.1	0%	66.0	65.8	-0.2	0%	67.8	67.6	-0.3	0%	68.6	68.7	0.1	0%	67.7	67.8	0.1	0%
60%	56.4	56.5	0.0	0%	61.0	61.0	0.0	0%	64.8	64.3	-0.5	-1%	67.6	67.4	-0.2	0%	68.0	68.1	0.1	0%	67.2	67.2	0.0	0%
70%	55.0	55.0	0.0	0%	59.7	59.8	0.0	0%	63.7	63.7	0.0	0%	67.4	67.1	-0.2	0%	67.7	67.7	0.0	0%	66.4	66.6	0.1	0%
80%	54.2	54.2	0.0	0%	59.1	59.1	0.0	0%	62.9	62.9	0.0	0%	67.0	66.7	-0.3	0%	66.8	66.7	-0.1	0%	65.9	66.0	0.0	0%
90%	53.4	53.0	-0.4	-1%	57.1	57.0	-0.1	0%	61.9	62.0	0.1	0%	66.5	66.4	-0.1	0%	65.7	65.6	-0.1	0%	65.0	65.0	0.0	0%
Long Term Full Simulation Period[b]	57.4	57.4	0.0	0%	62.6	62.5	-0.1	0%	66.5	66.1	-0.3	0%	68.9	68.9	0.0	0%	69.1	69.2	0.2	0%	68.0	68.1	0.1	0%
Water Year Types[c]																								
Wet (32%)	54.7	54.6	-0.1	0%	59.3	59.3	0.0	0%	63.4	63.1	-0.3	0%	67.4	67.2	-0.2	0%	66.9	66.9	0.1	0%	65.7	65.7	0.0	0%
Above Normal (16%)	56.3	56.4	0.0	0%	61.9	62.0	0.0	0%	65.9	65.8	-0.1	0%	67.2	67.2	0.0	0%	68.2	68.1	-0.1	0%	67.1	67.3	0.2	0%
Below Normal (13%)	59.1	59.1	0.0	0%	64.0	63.9	-0.1	0%	67.9	66.6	-1.3	-2%	67.9	68.1	0.2	0%	70.1	69.5	-0.5	-1%	68.7	68.9	0.2	0%
Dry (24%)	58.5	58.4	-0.1	0%	64.2	64.1	-0.2	0%	67.8	67.4	-0.4	-1%	69.5	69.5	0.0	0%	70.3	70.6	0.3	0%	69.3	69.4	0.1	0%
Critical (15%)	61.4	61.4	0.0	0%	66.6	66.6	0.0	0%	70.2	70.6	0.4	1%	74.2	74.2	0.0	0%	72.0	73.0	1.0	1%	71.5	71.5	0.0	0%

a Exceedance probability is defined as the probability a given value will be exceeded in any one year.

b Based on the 82-year simulation period.

c As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB D-1641, 1999); projected to Year 2030. WYT for a given water year is applied from Feb through Jan consistent with CALSIM II.

d There are 26 wet years, 13 above normal years, 11 below normal years, 20 dry years, and 12 critical years projected for 2030 under Q5 climate scenario.

Table 5.E-10. Delta Passage Model: Sacramento River Basin Fall-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.39	0.38	-0.01 (-2%)	0.43	0.41	-0.02 (-5%)	0.08	0.08	0.00 (0%)	0.47	0.47	0.00 (0%)
AN	0.29	0.28	-0.01 (-3%)	0.31	0.29	-0.02 (-5%)	0.04	0.05	0.00 (6%)	0.47	0.47	0.00 (0%)
BN	0.24	0.24	0.00 (-1%)	0.26	0.26	-0.01 (-2%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)
D	0.24	0.23	0.00 (-1%)	0.25	0.25	0.00 (-2%)	0.03	0.03	0.00 (-5%)	0.47	0.47	0.00 (0%)
C	0.20	0.20	0.00 (-1%)	0.22	0.21	0.00 (-1%)	0.03	0.03	0.00 (-2%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.31	0.31	0.00 (-1%)	0.47	0.45	-0.02 (-4%)	0.26	0.26	0.00 (1%)	0.20	0.23	0.03 (14%)
AN	0.30	0.30	-0.01 (-2%)	0.35	0.33	-0.01 (-4%)	0.28	0.28	0.00 (2%)	0.16	0.17	0.01 (4%)
BN	0.29	0.29	0.00 (0%)	0.30	0.29	-0.01 (-2%)	0.29	0.29	0.00 (0%)	0.14	0.14	0.00 (2%)
D	0.29	0.29	0.00 (0%)	0.29	0.29	0.00 (-2%)	0.30	0.30	0.00 (0%)	0.13	0.14	0.00 (3%)
C	0.26	0.26	0.00 (0%)	0.26	0.26	0.00 (-1%)	0.32	0.32	0.00 (0%)	0.12	0.12	0.00 (1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.

Table 5.E-13. Delta Passage Model: Late Fall-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.27	-0.03 (-10%)	0.33	0.29	-0.04 (-13%)	0.05	0.06	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.25	0.23	-0.02 (-9%)	0.29	0.26	-0.04 (-12%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)
BN	0.25	0.21	-0.03 (-13%)	0.29	0.24	-0.05 (-16%)	0.02	0.02	0.00 (6%)	0.47	0.47	0.00 (0%)
D	0.21	0.20	-0.02 (-8%)	0.25	0.22	-0.03 (-11%)	0.02	0.02	0.00 (5%)	0.47	0.47	0.00 (0%)
C	0.19	0.18	-0.01 (-3%)	0.22	0.21	-0.01 (-5%)	0.02	0.02	0.00 (0%)	0.47	0.47	0.00 (0%)

WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.27	-0.02 (-6%)	0.38	0.34	-0.04 (-10%)	0.30	0.32	0.02 (7%)	0.12	0.13	0.01 (11%)
AN	0.28	0.26	-0.02 (-6%)	0.34	0.31	-0.03 (-10%)	0.32	0.34	0.02 (6%)	0.11	0.12	0.01 (9%)
BN	0.28	0.26	-0.02 (-8%)	0.33	0.28	-0.04 (-13%)	0.32	0.35	0.03 (9%)	0.11	0.11	0.01 (9%)
D	0.26	0.24	-0.02 (-6%)	0.29	0.26	-0.03 (-9%)	0.35	0.37	0.02 (5%)	0.10	0.10	0.01 (8%)
C	0.24	0.23	-0.01 (-2%)	0.26	0.25	-0.01 (-4%)	0.38	0.38	0.00 (1%)	0.09	0.10	0.00 (5%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.

Table 5.E-37. Mean Annual Fall-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[1]																	
NAA	5,144,855	809,484	5,954,338	1,451,660	511,012	1,962,672	7,917,010	150	4,296	6,055	10,501	4,694,051	266,976	40,366	5,001,393	5,011,894	12,928,904
PA	5,022,884	660,993	5,683,877	1,477,164	550,222	2,027,386	7,711,263	160	3,305	5,350	8,814	4,716,470	267,867	41,632	5,025,968	5,034,783	12,746,046
Difference	-121,970	-148,491	-270,461	25,504	39,210	64,714	-205,747	10	-991	-705	-1,687	22,419	891	1,265	24,575	22,889	-182,859
Percent Difference[3]	-2	-18	-5	2	8	3	-3	6	-23	-12	-16	0	0	3	0	0	-1
Water Year Types[2]																	
Wet (32.5%)																	
NAA	224,282	724,794	949,076	4,013,334	1,304,607	5,317,941	6,267,017	419	4,344	1,216	5,980	5,142,369	77,086	14,964	5,234,419	5,240,399	11,507,415
PA	81,977	213,648	295,625	4,066,702	1,436,450	5,503,152	5,798,777	472	4,231	1,943	6,645	5,194,728	75,562	16,386	5,286,676	5,293,321	11,092,098
Difference	-142,305	-511,146	-653,451	53,368	131,843	185,212	-468,240	52	-113	726	666	52,359	-1,525	1,422	52,256	52,922	-415,318
Percent Difference	-63	-71	-69	1	10	3	-7	13	-3	60	11	1	-2	10	1	1	-4
Above Normal (12.5%)																	
NAA	9,090,676	497,965	9,588,640	63,475	688,815	752,290	10,340,930	20	2,720	987	3,726	5,001,065	116,203	25,093	5,142,361	5,146,087	15,487,018
PA	9,476,226	106,985	9,583,211	94,913	675,539	770,452	10,353,663	19	2,397	1,086	3,502	5,134,558	124,860	26,228	5,285,646	5,289,147	15,642,810
Difference	385,550	-390,980	-5,430	31,439	-13,276	18,162	12,732	-1	-322	99	-224	133,493	8,656	1,135	143,284	143,060	155,792
Percent Difference	4	-79	0	50	-2	2	0	-5	-12	10	-6	3	7	5	3	3	1
Below Normal (17.5%)																	
NAA	57,594	127,629	185,223	306,984	0	306,984	492,207	0	571	872	1,443	5,201,156	404,885	55,474	5,661,515	5,662,958	6,155,165
PA	57,234	124,986	182,221	303,758	0	303,758	485,979	0	514	911	1,426	5,188,265	397,816	61,171	5,647,252	5,648,678	6,134,656
Difference	-360	-2,643	-3,003	-3,226	0	-3,226	-6,228	0	-56	39	-18	-12,890	-7,070	5,697	-14,263	-14,281	-20,509
Percent Difference	-1	-2	-2	-1	0	-1	-1	0	-10	4	-1	0	-2	10	0	0	0
Dry (22.5%)																	
NAA	4,432,070	732,312	5,164,382	364,687	0	364,687	5,529,069	65	2,706	1,662	4,434	4,607,491	443,967	57,263	5,108,721	5,113,155	10,642,224
PA	4,421,190	1,145,829	5,567,018	374,597	0	374,597	5,941,615	38	1,957	841	2,837	4,464,993	455,957	56,178	4,977,128	4,979,965	10,921,580
Difference	-10,880	413,517	402,637	9,910	0	9,910	412,546	-27	-749	-821	-1,597	-142,498	11,990	-1,086	-131,593	-133,190	279,356
Percent Difference	0	56	8	3	0	3	7	-41	-28	-49	-36	-3	3	-2	-3	-3	3
Critical (15%)																	
NAA	17,301,522	2,051,093	19,352,615	363,933	0	363,933	19,716,548	0	11,836	33,277	45,112	3,132,461	391,949	66,552	3,590,961	3,636,073	23,352,621
PA	16,417,771	1,830,250	18,248,020	377,779	0	377,779	18,625,799	0	7,087	28,295	35,382	3,288,656	378,908	67,477	3,735,041	3,770,423	22,396,222
B Difference	-883,752	-220,843	-1,104,595	13,846	0	13,846	-1,090,749	0	-4,748	-4,982	-9,730	156,195	-13,040	926	144,080	134,350	-956,399
Percent Difference	-5	-11	-6	4	0	4	-6	0	-40	-15	-22	5	-3	1	4	4	-4

1 Mortality values do not include base mortality
2 Based on the 80-year simulation period
3 Relative difference of the Annual average
4 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB 1995). Water years may not correspond to the biological years in SALMOD.
5 NA = Unable to calculate because dividing by 0

Table 5.E-54. Mean Annual Late Fall-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types[1]																	
NAA	0	9,621	9,621	170,413	310,055	480,468	490,089	3,759	68,139	38,185	110,083	1,776,744	14,419	567	1,791,729	1,901,812	2,391,902
PA	0	9,608	9,608	172,486	316,959	489,444	499,052	4,467	73,593	37,878	115,939	1,782,912	13,171	524	1,796,606	1,912,545	2,411,597
Difference	0	-14	-14	2,072	6,904	8,976	8,962	708	5,454	-306	5,856	6,168	-1,248	-43	4,877	10,733	19,695
Percent Difference[3]	0	0	0	1	2	2	2	19	8	-1	5	0	-9	-8	0	1	1
Water Year Types[2]																	
Wet (32.5%)																	
NAA	0	11,882	11,882	482,104	814,510	1,296,614	1,308,495	64	16	11	91	1,524,182	4,222	69	1,528,473	1,528,563	2,837,059
PA	0	11,880	11,880	486,545	824,230	1,310,775	1,322,656	63	20	5	88	1,502,838	3,095	69	1,506,002	1,506,090	2,828,746
Difference	0	-1	-1	4,441	9,720	14,162	14,160	-1	4	-6	-3	-21,344	-1,128	1	-22,471	-22,473	-8,313
Percent Difference	0	0	0	1	1	1	1	-1	28	-57	-3	-1	-27	1	-1	-1	0
Above Normal (12.5%)																	
NAA	0	7,815	7,815	22,967	370,137	393,103	400,918	110	37	19	166	1,843,097	1,583	28	1,844,708	1,844,874	2,245,792
PA	0	7,340	7,340	23,302	395,912	419,214	426,554	108	9	0	117	1,776,429	2,595	36	1,779,061	1,779,178	2,205,732
Difference	0	-475	-475	335	25,775	26,110	25,636	-2	-28	-19	-48	-66,668	1,012	8	-65,647	-65,696	-40,060
Percent Difference	0	-6	-6	1	7	7	6	-2	-75	-100	-29	-4	64	28	-4	-4	-2
Below Normal (17.5%)																	
NAA	0	1,186	1,186	30,443	0	30,443	31,630	0	872	2,684	3,556	1,958,331	16,897	713	1,975,940	1,979,496	2,011,126
PA	0	3,836	3,836	30,838	0	30,838	34,674	2	2,136	5,243	7,380	2,076,131	10,865	707	2,087,704	2,095,084	2,129,758
Difference	0	2,649	2,649	395	0	395	3,044	2	1,264	2,558	3,824	117,800	-6,032	-5	111,763	115,588	118,632
Percent Difference	0	223	223	1	0	1	10	0	145	95	108	6	-36	-1	6	6	6
Dry (22.5%)																	
NAA	0	10,840	10,840	29,324	0	29,324	40,163	137	4,347	8,912	13,396	1,868,390	9,467	824	1,878,681	1,892,076	1,932,240
PA	0	10,538	10,538	30,352	0	30,352	40,890	101	4,144	8,692	12,937	1,898,772	13,579	938	1,913,290	1,926,227	1,967,117
Difference	0	-301	-301	1,028	0	1,028	727	-36	-203	-220	-459	30,383	4,112	114	34,609	34,151	34,878
Percent Difference	0	-3	-3	4	0	4	2	-26	-5	-2	-3	2	43	14	2	2	2
Critical (15%)																	
NAA	0	12,420	12,420	31,960	0	31,960	44,380	24,592	446,147	237,209	707,948	1,917,364	54,477	1,579	1,973,420	2,681,368	2,725,748
PA	0	10,879	10,879	34,110	0	34,110	44,990	29,370	481,708	233,221	744,298	1,910,995	46,172	1,099	1,958,266	2,702,564	2,747,554
Difference	0	-1,541	-1,541	2,151	0	2,151	610	4,779	35,560	-3,989	36,350	-6,369	-8,305	-481	-15,154	21,196	21,806
Percent Difference	0	-12	-12	7	0	7	1	19	8	-2	5	0	-15	-30	-1	1	1

1 Based on the 80-year simulation period
2 As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (SWRCB 1995). Water years may not correspond to the biological years in SALMOD.
3 Relative difference of the Annual average
4 Mortality values do not include base mortality

Table 5.4-9. Median 15-minute Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% More than NAA and Red Shading Indicating PA is ≥ 5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.263	0.264	0.001 (0%)	0.378	0.433	0.054 (14%)	0.473	0.533	0.060 (13%)	0.482	0.548	0.066 (14%)	0.428	0.493	0.065 (15%)	0.407	0.462	0.055 (13%)	0.330	0.355	0.025 (8%)
		AN	0.182	0.185	0.003 (2%)	0.239	0.295	0.056 (23%)	0.308	0.371	0.064 (21%)	0.295	0.368	0.073 (25%)	0.271	0.351	0.081 (30%)	0.254	0.331	0.078 (31%)	0.152	0.196	0.045 (30%)
		BN	0.115	0.119	0.004 (4%)	0.131	0.202	0.071 (54%)	0.265	0.318	0.053 (20%)	0.169	0.251	0.082 (49%)	0.199	0.286	0.087 (44%)	0.166	0.245	0.079 (47%)	0.097	0.118	0.022 (22%)
		D	0.087	0.089	0.002 (3%)	0.112	0.171	0.059 (52%)	0.167	0.223	0.057 (34%)	0.172	0.228	0.056 (32%)	0.167	0.234	0.067 (40%)	0.155	0.217	0.061 (39%)	0.090	0.110	0.020 (22%)
		C	0.085	0.086	0.001 (1%)	0.087	0.128	0.041 (47%)	0.120	0.167	0.048 (40%)	0.104	0.142	0.038 (37%)	0.099	0.134	0.035 (35%)	0.092	0.128	0.035 (38%)	0.076	0.083	0.008 (11%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.240	0.251	0.011 (4%)	0.432	0.488	0.056 (13%)	0.471	0.554	0.083 (18%)	0.452	0.550	0.098 (22%)	0.439	0.474	0.034 (8%)	0.394	0.430	0.036 (9%)	0.232	0.293	0.061 (27%)
		AN	0.140	0.155	0.015 (11%)	0.269	0.300	0.031 (11%)	0.334	0.368	0.034 (10%)	0.293	0.385	0.092 (31%)	0.298	0.324	0.026 (9%)	0.247	0.270	0.022 (9%)	0.142	0.171	0.030 (21%)
		BN	0.061	0.081	0.020 (34%)	0.131	0.191	0.060 (45%)	0.237	0.260	0.023 (10%)	0.168	0.197	0.029 (17%)	0.213	0.222	0.009 (4%)	0.172	0.186	0.014 (8%)	0.130	0.139	0.008 (6%)
		D	0.068	0.076	0.008 (11%)	0.118	0.149	0.031 (27%)	0.184	0.198	0.013 (7%)	0.192	0.203	0.011 (6%)	0.195	0.208	0.014 (7%)	0.158	0.172	0.014 (9%)	0.134	0.143	0.010 (7%)
		C	0.085	0.087	0.002 (2%)	0.092	0.111	0.020 (21%)	0.148	0.150	0.002 (1%)	0.152	0.161	0.010 (6%)	0.144	0.148	0.004 (3%)	0.122	0.126	0.004 (3%)	0.124	0.124	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.250	-0.175	0.075 (30%)	0.004	0.227	0.224 (5831%)	0.036	0.448	0.412 (1138%)	0.052	0.505	0.454 (877%)	0.350	0.486	0.136 (39%)	0.296	0.453	0.157 (53%)	-0.110	0.170	0.279 (255%)
		AN	-0.358	-0.272	0.087 (24%)	-0.121	0.008	0.129 (107%)	-0.062	0.087	0.149 (240%)	-0.146	0.265	0.411 (282%)	0.189	0.230	0.041 (22%)	0.164	0.197	0.032 (20%)	-0.181	-0.061	0.120 (66%)
		BN	-0.446	-0.363	0.083 (19%)	-0.200	0.003	0.203 (101%)	-0.108	-0.051	0.057 (53%)	-0.171	-0.100	0.071 (42%)	0.109	0.061	-0.048 (-44%)	0.088	0.061	-0.027 (-30%)	-0.131	-0.077	0.054 (41%)
		D	-0.368	-0.321	0.046 (13%)	-0.213	-0.134	0.079 (37%)	-0.133	-0.086	0.047 (35%)	-0.097	-0.074	0.024 (24%)	0.067	0.047	-0.020 (-30%)	0.039	0.043	0.004 (11%)	-0.112	-0.043	0.069 (61%)
		C	-0.266	-0.222	0.044 (16%)	-0.214	-0.190	0.023 (11%)	-0.107	-0.108	0.000 (0%)	-0.019	-0.016	0.003 (16%)	0.056	0.034	-0.022 (-39%)	0.045	0.029	-0.015 (-35%)	0.035	0.052	0.017 (48%)
212	Old River upstream of the south Delta export facilities	W	0.682	0.701	0.018 (3%)	0.946	0.867	-0.079 (-8%)	1.120	1.036	-0.084 (-8%)	1.199	1.075	-0.124 (-10%)	1.171	1.074	-0.097 (-8%)	1.161	1.069	-0.093 (-8%)	0.666	0.621	-0.045 (-7%)
		AN	0.574	0.558	-0.016 (-3%)	0.705	0.578	-0.127 (-18%)	0.794	0.689	-0.105 (-13%)	0.818	0.754	-0.064 (-8%)	0.814	0.640	-0.174 (-21%)	0.805	0.612	-0.193 (-24%)	0.301	0.159	-0.142 (-47%)
		BN	0.493	0.465	-0.028 (-6%)	0.503	0.362	-0.141 (-28%)	0.713	0.555	-0.158 (-22%)	0.583	0.350	-0.234 (-40%)	0.657	0.387	-0.269 (-41%)	0.589	0.327	-0.262 (-44%)	0.132	0.047	-0.085 (-64%)
		D	0.445	0.428	-0.017 (-4%)	0.452	0.287	-0.165 (-36%)	0.541	0.378	-0.162 (-30%)	0.575	0.387	-0.188 (-33%)	0.584	0.363	-0.221 (-38%)	0.546	0.346	-0.200 (-37%)	0.113	0.037	-0.076 (-67%)
		C	0.418	0.394	-0.024 (-6%)	0.393	0.248	-0.145 (-37%)	0.467	0.300	-0.167 (-36%)	0.410	0.251	-0.159 (-39%)	0.378	0.235	-0.143 (-38%)	0.359	0.200	-0.160 (-44%)	0.009	-0.011	-0.020 (-229%)
365	Delta Cross Channel	W	0.016	0.016	0.000 (0%)	0.013	0.013	0.000 (1%)	0.014	0.014	0.000 (0%)	0.015	0.015	0.000 (1%)	0.016	0.016	0.000 (2%)	0.016	0.016	0.000 (2%)	0.422	0.471	0.049 (12%)
		AN	0.025	0.027	0.001 (6%)	0.014	0.014	0.000 (1%)	0.015	0.015	0.000 (1%)	0.015	0.015	0.000 (2%)	0.014	0.014	0.000 (2%)	0.013	0.013	0.000 (2%)	0.662	0.576	-0.087 (-13%)
		BN	0.036	0.037	0.001 (3%)	0.011	0.012	0.001 (5%)	0.013	0.013	0.000 (1%)	0.012	0.012	0.000 (1%)	0.012	0.013	0.000 (1%)	0.011	0.011	0.000 (2%)	0.667	0.613	-0.053 (-8%)
		D	0.043	0.043	0.000 (-1%)	0.011	0.011	0.000 (2%)	0.012	0.012	0.000 (0%)	0.013	0.013	0.000 (0%)	0.012	0.012	0.000 (0%)	0.010	0.011	0.000 (2%)	0.675	0.609	-0.065 (-10%)
		C	0.040	0.039	-0.001	0.010	0.010	0.000	0.011	0.011	0.000	0.010	0.011	0.000	0.010	0.010	0.000	0.008	0.009	0.000	0.535	0.518	-0.017

DSM2 Channel	Location	Water Year Type	December NAA	December PA	December PA vs. NAA	January NAA	January PA	January PA vs. NAA	February NAA	February PA	February PA vs. NAA	March NAA	March PA	March PA vs. NAA	April NAA	April PA	April PA vs. NAA	May NAA	May PA	May PA vs. NAA	June NAA	June PA	June PA vs. NAA
					(-1%)			(1%)			(0%)			(2%)			(0%)			(2%)			(-3%)
379	Sutter Slough	W	1.691	1.478	-0.214 (-13%)	2.573	2.270	-0.304 (-12%)	3.045	2.765	-0.280 (-9%)	2.536	2.208	-0.327 (-13%)	1.763	1.648	-0.116 (-7%)	1.687	1.543	-0.143 (-8%)	1.036	0.807	-0.229 (-22%)
		AN	1.101	1.012	-0.089 (-8%)	1.866	1.578	-0.288 (-15%)	2.564	2.305	-0.259 (-10%)	2.052	1.769	-0.283 (-14%)	1.345	1.270	-0.075 (-6%)	1.022	0.958	-0.065 (-6%)	0.799	0.656	-0.143 (-18%)
		BN	0.996	0.902	-0.094 (-9%)	1.079	1.015	-0.064 (-6%)	1.327	1.192	-0.134 (-10%)	1.146	0.992	-0.154 (-13%)	0.937	0.922	-0.015 (-2%)	0.856	0.832	-0.023 (-3%)	0.763	0.681	-0.082 (-11%)
		D	0.875	0.823	-0.052 (-6%)	1.008	0.939	-0.069 (-7%)	1.202	1.090	-0.112 (-9%)	1.236	1.052	-0.185 (-15%)	0.956	0.946	-0.010 (-1%)	0.821	0.799	-0.022 (-3%)	0.758	0.659	-0.099 (-13%)
		C	0.766	0.721	-0.046 (-6%)	0.932	0.892	-0.040 (-4%)	1.006	0.909	-0.097 (-10%)	0.846	0.805	-0.041 (-5%)	0.751	0.734	-0.017 (-2%)	0.649	0.607	-0.042 (-6%)	0.610	0.562	-0.048 (-8%)
383	Steamboat Slough	W	1.972	1.789	-0.183 (-9%)	2.932	2.617	-0.315 (-11%)	3.448	3.120	-0.328 (-10%)	2.868	2.495	-0.373 (-13%)	2.021	1.903	-0.118 (-6%)	1.888	1.742	-0.146 (-8%)	1.346	1.140	-0.206 (-15%)
		AN	1.394	1.313	-0.081 (-6%)	2.161	1.916	-0.245 (-11%)	2.937	2.632	-0.305 (-10%)	2.346	2.042	-0.304 (-13%)	1.581	1.538	-0.044 (-3%)	1.275	1.206	-0.070 (-5%)	1.026	0.930	-0.095 (-9%)
		BN	1.235	1.156	-0.079 (-6%)	1.362	1.276	-0.086 (-6%)	1.631	1.518	-0.113 (-7%)	1.397	1.239	-0.158 (-11%)	1.169	1.140	-0.030 (-3%)	1.089	1.062	-0.027 (-2%)	0.972	0.941	-0.031 (-3%)
		D	1.115	1.066	-0.049 (-4%)	1.272	1.196	-0.076 (-6%)	1.493	1.384	-0.109 (-7%)	1.483	1.307	-0.177 (-12%)	1.204	1.177	-0.027 (-2%)	1.032	1.012	-0.020 (-2%)	0.964	0.918	-0.046 (-5%)
		C	0.987	0.936	-0.051 (-5%)	1.175	1.121	-0.054 (-5%)	1.249	1.143	-0.106 (-8%)	1.083	1.019	-0.064 (-6%)	0.960	0.942	-0.018 (-2%)	0.816	0.808	-0.008 (-1%)	0.779	0.776	-0.003 (0%)
418	Sacramento River downstream of proposed NDD	W	2.224	1.901	-0.323 (-15%)	3.416	2.884	-0.532 (-16%)	4.052	3.484	-0.568 (-14%)	3.347	2.775	-0.571 (-17%)	2.305	2.070	-0.235 (-10%)	2.191	1.939	-0.252 (-12%)	1.524	1.162	-0.362 (-24%)
		AN	1.494	1.351	-0.143 (-10%)	2.473	2.019	-0.453 (-18%)	3.409	2.918	-0.491 (-14%)	2.700	2.240	-0.460 (-17%)	1.752	1.615	-0.137 (-8%)	1.343	1.225	-0.119 (-9%)	1.206	0.982	-0.224 (-19%)
		BN	1.365	1.219	-0.145 (-11%)	1.432	1.312	-0.120 (-8%)	1.744	1.538	-0.206 (-12%)	1.508	1.279	-0.229 (-15%)	1.240	1.186	-0.054 (-4%)	1.140	1.081	-0.060 (-5%)	1.157	1.017	-0.140 (-12%)
		D	1.222	1.131	-0.091 (-7%)	1.349	1.227	-0.122 (-9%)	1.594	1.411	-0.183 (-11%)	1.623	1.353	-0.269 (-17%)	1.265	1.218	-0.047 (-4%)	1.096	1.041	-0.055 (-5%)	1.149	0.992	-0.157 (-14%)
		C	1.081	0.993	-0.088 (-8%)	1.245	1.163	-0.082 (-7%)	1.333	1.182	-0.151 (-11%)	1.134	1.059	-0.075 (-7%)	1.019	0.977	-0.042 (-4%)	0.885	0.814	-0.071 (-8%)	0.928	0.826	-0.102 (-11%)
421	Sacramento River upstream of Georgiana Slough	W	1.858	1.672	-0.186 (-10%)	2.737	2.445	-0.292 (-11%)	3.191	2.903	-0.288 (-9%)	2.679	2.337	-0.342 (-13%)	1.897	1.773	-0.124 (-7%)	1.786	1.637	-0.149 (-8%)	1.407	1.115	-0.292 (-21%)
		AN	1.322	1.241	-0.081 (-6%)	2.031	1.773	-0.258 (-13%)	2.736	2.467	-0.269 (-10%)	2.210	1.921	-0.288 (-13%)	1.472	1.418	-0.055 (-4%)	1.154	1.074	-0.080 (-7%)	1.114	0.955	-0.159 (-14%)
		BN	1.194	1.113	-0.082 (-7%)	1.251	1.167	-0.084 (-7%)	1.501	1.374	-0.127 (-8%)	1.295	1.139	-0.156 (-12%)	1.076	1.053	-0.023 (-2%)	0.986	0.954	-0.032 (-3%)	1.067	0.980	-0.087 (-8%)
		D	1.087	1.040	-0.047 (-4%)	1.173	1.099	-0.073 (-6%)	1.372	1.263	-0.109 (-8%)	1.381	1.198	-0.183 (-13%)	1.103	1.084	-0.020 (-2%)	0.944	0.914	-0.030 (-3%)	1.058	0.955	-0.103 (-10%)
		C	0.956	0.902	-0.054 (-6%)	1.080	1.039	-0.041 (-4%)	1.147	1.053	-0.094 (-8%)	0.989	0.945	-0.045 (-5%)	0.885	0.867	-0.018 (-2%)	0.756	0.733	-0.024 (-3%)	0.852	0.814	-0.039 (-5%)
423	Sacramento River downstream of Georgiana Slough	W	1.713	1.578	-0.134 (-8%)	2.467	2.211	-0.256 (-10%)	2.857	2.593	-0.265 (-9%)	2.429	2.129	-0.300 (-12%)	1.755	1.670	-0.085 (-5%)	1.623	1.522	-0.102 (-6%)	1.147	0.975	-0.171 (-15%)
		AN	1.229	1.161	-0.067 (-5%)	1.857	1.680	-0.177 (-10%)	2.463	2.205	-0.259 (-11%)	2.015	1.764	-0.251 (-12%)	1.402	1.368	-0.034 (-2%)	1.127	1.072	-0.055 (-5%)	0.824	0.739	-0.086 (-10%)
		BN	1.063	0.993	-0.070 (-7%)	1.199	1.121	-0.077 (-6%)	1.458	1.359	-0.100 (-7%)	1.235	1.091	-0.144 (-12%)	1.020	0.998	-0.022 (-2%)	0.947	0.927	-0.020 (-2%)	0.767	0.743	-0.024 (-3%)
		D	0.949	0.903	-0.046 (-5%)	1.120	1.055	-0.065 (-6%)	1.328	1.228	-0.100 (-8%)	1.313	1.150	-0.162 (-12%)	1.058	1.032	-0.025 (-2%)	0.890	0.877	-0.013 (-2%)	0.759	0.723	-0.037 (-5%)
		C	0.829	0.784	-0.046 (-6%)	1.023	0.973	-0.050 (-5%)	1.095	0.999	-0.096 (-9%)	0.945	0.883	-0.062 (-7%)	0.824	0.810	-0.014 (-2%)	0.674	0.669	-0.005 (-1%)	0.596	0.594	-0.001 (0%)

Table 5.4-10. Median 15-minute Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% More than NAA and Red Shading Indicating PA is ≥ 5% Less than NAA.

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
21	San Joaquin River downstream of HOR	W	-0.298	-0.295	0.003 (1%)	-0.246	-0.194	0.052 (21%)	-0.182	-0.133	0.049 (27%)	-0.166	-0.121	0.045 (27%)	-0.154	-0.104	0.051 (33%)	-0.187	-0.124	0.063 (34%)	-0.222	-0.205	0.017 (7%)
		AN	-0.334	-0.332	0.002 (1%)	-0.284	-0.233	0.051 (18%)	-0.246	-0.187	0.059 (24%)	-0.225	-0.170	0.055 (25%)	-0.194	-0.132	0.062 (32%)	-0.215	-0.149	0.066 (31%)	-0.267	-0.249	0.017 (7%)
		BN	-0.321	-0.317	0.004 (1%)	-0.309	-0.251	0.058 (19%)	-0.281	-0.220	0.061 (22%)	-0.258	-0.198	0.060 (23%)	-0.229	-0.167	0.061 (27%)	-0.249	-0.190	0.059 (24%)	-0.299	-0.287	0.012 (4%)
		D	-0.333	-0.330	0.002 (1%)	-0.318	-0.259	0.059 (19%)	-0.306	-0.250	0.057 (18%)	-0.309	-0.254	0.054 (18%)	-0.277	-0.226	0.051 (18%)	-0.291	-0.239	0.052 (18%)	-0.312	-0.301	0.011 (4%)
		C	-0.338	-0.337	0.001 (0%)	-0.341	-0.294	0.047 (14%)	-0.317	-0.266	0.051 (16%)	-0.324	-0.282	0.042 (13%)	-0.327	-0.288	0.039 (12%)	-0.325	-0.284	0.041 (13%)	-0.322	-0.319	0.003 (1%)
45	San Joaquin River near the confluence with the Mokelumne River	W	-1.314	-1.307	0.008 (1%)	-1.223	-1.199	0.023 (2%)	-1.161	-1.118	0.043 (4%)	-1.196	-1.146	0.049 (4%)	-1.206	-1.188	0.018 (1%)	-1.231	-1.212	0.018 (1%)	-1.296	-1.264	0.032 (2%)
		AN	-1.343	-1.332	0.010 (1%)	-1.284	-1.268	0.016 (1%)	-1.255	-1.236	0.018 (1%)	-1.265	-1.219	0.045 (4%)	-1.285	-1.272	0.013 (1%)	-1.306	-1.297	0.010 (1%)	-1.340	-1.331	0.009 (1%)
		BN	-1.376	-1.364	0.012 (1%)	-1.341	-1.316	0.025 (2%)	-1.295	-1.283	0.012 (1%)	-1.321	-1.304	0.016 (1%)	-1.303	-1.297	0.005 (0%)	-1.316	-1.310	0.006 (0%)	-1.333	-1.330	0.003 (0%)
		D	-1.370	-1.365	0.005 (0%)	-1.348	-1.334	0.014 (1%)	-1.331	-1.321	0.010 (1%)	-1.323	-1.315	0.008 (1%)	-1.314	-1.310	0.004 (0%)	-1.328	-1.323	0.005 (0%)	-1.339	-1.336	0.003 (0%)
		C	-1.358	-1.355	0.002 (0%)	-1.351	-1.345	0.005 (0%)	-1.333	-1.329	0.004 (0%)	-1.337	-1.334	0.003 (0%)	-1.341	-1.339	0.002 (0%)	-1.336	-1.335	0.001 (0%)	-1.333	-1.334	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	-0.962	-0.953	0.009 (1%)	-0.895	-0.849	0.045 (5%)	-0.859	-0.775	0.084 (10%)	-0.873	-0.724	0.149 (17%)	-0.715	-0.706	0.009 (1%)	-0.733	-0.711	0.022 (3%)	-0.917	-0.815	0.102 (11%)
		AN	-0.977	-0.968	0.008 (1%)	-0.922	-0.884	0.038 (4%)	-0.910	-0.870	0.040 (4%)	-0.927	-0.812	0.115 (12%)	-0.821	-0.838	-0.017 (-2%)	-0.818	-0.834	-0.016 (-2%)	-0.963	-0.929	0.034 (4%)
		BN	-1.002	-0.996	0.006 (1%)	-0.956	-0.888	0.068 (7%)	-0.921	-0.889	0.031 (3%)	-0.940	-0.915	0.025 (3%)	-0.844	-0.877	-0.033 (-4%)	-0.843	-0.867	-0.024 (-3%)	-0.932	-0.923	0.009 (1%)
		D	-0.992	-0.987	0.006 (1%)	-0.965	-0.931	0.034 (4%)	-0.936	-0.919	0.017 (2%)	-0.929	-0.912	0.016 (2%)	-0.865	-0.882	-0.017 (-2%)	-0.851	-0.866	-0.014 (-2%)	-0.929	-0.917	0.012 (1%)
		C	-0.950	-0.952	-0.002 (0%)	-0.955	-0.943	0.012 (1%)	-0.916	-0.915	0.001 (0%)	-0.896	-0.905	-0.008 (-1%)	-0.888	-0.897	-0.009 (-1%)	-0.866	-0.878	-0.012 (-1%)	-0.898	-0.898	0.001 (0%)
212	Old River upstream of the south Delta export facilities	W	-0.451	-0.461	-0.010 (-2%)	-0.461	-0.698	-0.237 (-51%)	-0.377	-0.691	-0.314 (-83%)	-0.342	-0.661	-0.319 (-93%)	-0.418	-0.705	-0.288 (-69%)	-0.504	-0.766	-0.262 (-52%)	-0.261	-0.319	-0.058 (-22%)
		AN	-0.481	-0.465	0.016 (3%)	-0.531	-0.718	-0.187 (-35%)	-0.490	-0.678	-0.188 (-38%)	-0.431	-0.773	-0.342 (-79%)	-0.506	-0.767	-0.261 (-52%)	-0.550	-0.807	-0.257 (-47%)	-0.306	-0.348	-0.043 (-14%)
		BN	-0.433	-0.445	-0.012 (-3%)	-0.526	-0.761	-0.236 (-45%)	-0.501	-0.678	-0.177 (-35%)	-0.465	-0.675	-0.210 (-45%)	-0.548	-0.750	-0.202 (-37%)	-0.604	-0.798	-0.194 (-32%)	-0.369	-0.396	-0.027 (-7%)
		D	-0.472	-0.479	-0.008 (-2%)	-0.500	-0.699	-0.199 (-40%)	-0.544	-0.707	-0.163 (-30%)	-0.578	-0.723	-0.145 (-25%)	-0.620	-0.767	-0.147 (-24%)	-0.642	-0.793	-0.151 (-24%)	-0.400	-0.430	-0.030 (-8%)
		C	-0.591	-0.573	0.018 (3%)	-0.554	-0.700	-0.146 (-26%)	-0.596	-0.716	-0.121 (-20%)	-0.691	-0.797	-0.106 (-15%)	-0.735	-0.829	-0.094 (-13%)	-0.731	-0.830	-0.099 (-14%)	-0.473	-0.489	-0.016 (-3%)
365	Delta Cross Channel	W	-0.052	-0.052	0.000 (0%)	-0.050	-0.050	0.000 (0%)	-0.050	-0.049	0.000 (1%)	-0.051	-0.051	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.056	-0.060	-0.004 (-7%)
		AN	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (1%)	-0.052	-0.052	0.000 (0%)	-0.053	-0.053	0.000 (0%)	-0.059	-0.061	-0.002 (-3%)
		BN	-0.053	-0.053	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.057	-0.059	-0.002 (-3%)
		D	-0.054	-0.054	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.052	0.000 (0%)	-0.052	-0.052	0.000 (0%)	-0.058	-0.060	-0.002 (-3%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
		C	-0.055	-0.055	0.000 (-1%)	-0.052	-0.052	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.051	-0.051	0.000 (0%)	-0.099	-0.095	0.004 (4%)
379	Sutter Slough	W	-0.120	-0.127	-0.007 (-6%)	-0.077	-0.073	0.003 (5%)	-0.025	-0.022	0.003 (12%)	NA*	NA	NA	-0.111	-0.119	-0.008 (-7%)	-0.124	-0.122	0.002 (2%)	-0.147	-0.135	0.011 (8%)
		AN	-0.224	-0.209	0.015 (7%)	-0.099	-0.062	0.037 (37%)	-0.206	-0.177	0.029 (14%)	NA	-0.027	NA	-0.154	-0.150	0.003 (2%)	-0.140	-0.123	0.017 (12%)	-0.135	-0.104	0.032 (24%)
		BN	-0.218	-0.199	0.019 (9%)	-0.173	-0.162	0.010 (6%)	-0.295	-0.271	0.025 (8%)	-0.096	-0.094	0.002 (2%)	-0.154	-0.142	0.012 (8%)	-0.132	-0.136	-0.005 (-3%)	-0.139	-0.145	-0.005 (-4%)
		D	-0.194	-0.180	0.014 (7%)	-0.136	-0.128	0.008 (6%)	-0.153	-0.143	0.010 (7%)	-0.127	-0.115	0.013 (10%)	-0.172	-0.163	0.009 (5%)	-0.149	-0.136	0.013 (9%)	-0.143	-0.156	-0.013 (-9%)
		C	-0.231	-0.240	-0.010 (-4%)	-0.192	-0.121	0.071 (37%)	-0.149	-0.173	-0.024 (-16%)	-0.166	-0.145	0.021 (12%)	-0.146	-0.144	0.002 (2%)	-0.249	-0.248	0.001 (1%)	-0.222	-0.230	-0.008 (-3%)
383	Steamboat Slough	W	-0.404	-0.399	0.005 (1%)	-0.362	-0.364	-0.002 (-1%)	-0.185	-0.250	-0.065 (-35%)	-0.160	-0.347	-0.187 (-117%)	-0.372	-0.397	-0.025 (-7%)	-0.410	-0.438	-0.028 (-7%)	-0.550	-0.579	-0.029 (-5%)
		AN	-0.492	-0.516	-0.025 (-5%)	-0.345	-0.340	0.005 (2%)	-0.525	-0.461	0.064 (12%)	-0.246	-0.324	-0.078 (-32%)	-0.367	-0.393	-0.027 (-7%)	-0.431	-0.456	-0.025 (-6%)	-0.567	-0.594	-0.026 (-5%)
		BN	-0.484	-0.512	-0.028 (-6%)	-0.457	-0.470	-0.014 (-3%)	-0.419	-0.435	-0.015 (-4%)	-0.392	-0.419	-0.027 (-7%)	-0.434	-0.463	-0.029 (-7%)	-0.480	-0.490	-0.010 (-2%)	-0.578	-0.547	0.030 (5%)
		D	-0.541	-0.559	-0.018 (-3%)	-0.439	-0.474	-0.035 (-8%)	-0.376	-0.421	-0.045 (-12%)	-0.384	-0.409	-0.025 (-7%)	-0.471	-0.474	-0.003 (-1%)	-0.472	-0.476	-0.004 (-1%)	-0.582	-0.578	0.003 (1%)
		C	-0.625	-0.648	-0.023 (-4%)	-0.499	-0.494	0.005 (1%)	-0.419	-0.485	-0.066 (-16%)	-0.487	-0.516	-0.029 (-6%)	-0.503	-0.516	-0.014 (-3%)	-0.613	-0.621	-0.007 (-1%)	-0.691	-0.696	-0.005 (-1%)
418	Sacramento River downstream of proposed NDD	W	-0.120	-0.136	-0.017 (-14%)	-0.091	-0.092	-0.002 (-2%)	NA	-0.073	NA	NA	0.000	NA	-0.168	-0.160	0.008 (5%)	-0.145	-0.154	-0.008 (-6%)	-0.156	-0.175	-0.019 (-12%)
		AN	-0.250	-0.242	0.008 (3%)	-0.065	-0.064	0.001 (2%)	-0.265	-0.220	0.046 (17%)	NA	-0.036	NA	-0.200	-0.183	0.017 (8%)	-0.150	-0.140	0.010 (7%)	-0.202	-0.156	0.046 (23%)
		BN	-0.254	-0.231	0.023 (9%)	-0.187	-0.180	0.007 (4%)	-0.374	-0.359	0.015 (4%)	-0.126	-0.114	0.012 (9%)	-0.175	-0.178	-0.002 (-1%)	-0.150	-0.160	-0.010 (-7%)	-0.135	-0.135	0.000 (0%)
		D	-0.233	-0.200	0.032 (14%)	-0.141	-0.139	0.002 (1%)	-0.154	-0.149	0.005 (3%)	-0.115	-0.119	-0.004 (-3%)	-0.194	-0.182	0.012 (6%)	-0.168	-0.158	0.010 (6%)	-0.157	-0.152	0.005 (3%)
		C	-0.272	-0.266	0.006 (2%)	-0.224	-0.146	0.078 (35%)	-0.155	-0.188	-0.033 (-21%)	-0.183	-0.169	0.014 (8%)	-0.166	-0.162	0.004 (3%)	-0.285	-0.281	0.005 (2%)	-0.271	-0.263	0.009 (3%)
421	Sacramento River upstream of Georgiana Slough	W	-0.074	-0.080	-0.006 (-8%)	-0.061	-0.052	0.008 (14%)	NA	-0.104	NA	NA	-0.033	NA	-0.123	-0.123	0.001 (0%)	-0.111	-0.147	-0.036 (-33%)	-0.152	-0.158	-0.006 (-4%)
		AN	-0.190	-0.187	0.003 (2%)	-0.047	-0.084	-0.037 (-78%)	-0.179	-0.139	0.040 (22%)	NA	-0.058	NA	-0.156	-0.137	0.019 (12%)	-0.110	-0.142	-0.032 (-29%)	-0.186	-0.147	0.038 (21%)
		BN	-0.218	-0.179	0.038 (18%)	-0.141	-0.141	0.000 (0%)	-0.304	-0.278	0.025 (8%)	-0.088	-0.096	-0.008 (-9%)	-0.133	-0.161	-0.028 (-21%)	-0.115	-0.146	-0.031 (-27%)	-0.113	-0.133	-0.020 (-18%)
		D	-0.178	-0.161	0.017 (10%)	-0.103	-0.105	-0.002 (-2%)	-0.106	-0.118	-0.012 (-11%)	-0.077	-0.092	-0.014 (-18%)	-0.149	-0.157	-0.008 (-5%)	-0.125	-0.145	-0.020 (-16%)	-0.162	-0.142	0.020 (12%)
		C	-0.223	-0.223	0.000 (0%)	-0.163	-0.108	0.054 (33%)	-0.113	-0.152	-0.039 (-35%)	-0.134	-0.139	-0.004 (-3%)	-0.122	-0.139	-0.018 (-15%)	-0.219	-0.234	-0.015 (-7%)	-0.247	-0.256	-0.009 (-4%)
423	Sacramento River downstream of Georgiana Slough	W	-0.347	-0.343	0.005 (1%)	-0.310	-0.297	0.013 (4%)	-0.225	-0.217	0.008 (4%)	-0.144	-0.286	-0.142 (-98%)	-0.317	-0.338	-0.021 (-7%)	-0.356	-0.384	-0.028 (-8%)	-0.545	-0.580	-0.035 (-6%)
		AN	-0.448	-0.468	-0.020 (-4%)	-0.297	-0.285	0.012 (4%)	-0.467	-0.402	0.065 (14%)	-0.213	-0.268	-0.054 (-25%)	-0.312	-0.333	-0.021 (-7%)	-0.377	-0.403	-0.026 (-7%)	-0.576	-0.610	-0.034 (-6%)
		BN	-0.449	-0.479	-0.030 (-7%)	-0.396	-0.414	-0.017 (-4%)	-0.354	-0.372	-0.018 (-5%)	-0.329	-0.363	-0.034 (-10%)	-0.385	-0.412	-0.026 (-7%)	-0.434	-0.443	-0.008 (-2%)	-0.582	-0.585	-0.002 (0%)
		D	-0.505	-0.520	-0.015 (-3%)	-0.389	-0.426	-0.037 (-9%)	-0.329	-0.369	-0.039 (-12%)	-0.334	-0.348	-0.014 (-4%)	-0.417	-0.419	-0.002 (0%)	-0.430	-0.435	-0.005 (-1%)	-0.589	-0.600	-0.011 (-2%)
		C	-0.587	-0.608	-0.021	-0.438	-0.444	-0.006	-0.373	-0.432	-0.059	-0.435	-0.463	-0.028	-0.460	-0.472	-0.012	-0.566	-0.576	-0.010	-0.678	-0.682	-0.004

DSM2 Channel	Location	Water Year Type	December NAA	December PA	December PA vs. NAA	January NAA	January PA	January PA vs. NAA	February NAA	February PA	February PA vs. NAA	March NAA	March PA	March PA vs. NAA	April NAA	April PA	April PA vs. NAA	May NAA	May PA	May PA vs. NAA	June NAA	June PA	June PA vs. NAA
					(-4%)			(-1%)			(-16%)			(-6%)			(-3%)			(-2%)			(-1%)

Note: *NA denotes that there were no negative velocity estimates.

Table 5.4-11. Median Daily Proportion of Negative Velocity in Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% Less than NAA and Red Shading Indicating PA is ≥ 5% More than NAA.

DSM2 Channel	Location	Water Year Type	December NAA	December PA	December PA vs. NAA	January NAA	January PA	January PA vs. NAA	February NAA	February PA	February PA vs. NAA	March NAA	March PA	March PA vs. NAA	April NAA	April PA	April PA vs. NAA	May NAA	May PA	May PA vs. NAA	June NAA	June PA	June PA vs. NAA
21	San Joaquin River downstream of HOR	W	0.438	0.438	0.000 (0%)	0.365	0.250	-0.115 (-31%)	0.219	0.083	-0.135 (-62%)	0.167	0.063	-0.104 (-63%)	0.234	0.094	-0.141 (-60%)	0.292	0.135	-0.156 (-54%)	0.385	0.323	-0.063 (-16%)
		AN	0.469	0.458	-0.010 (-2%)	0.438	0.406	-0.031 (-7%)	0.406	0.333	-0.073 (-18%)	0.396	0.260	-0.135 (-34%)	0.396	0.292	-0.104 (-26%)	0.406	0.323	-0.083 (-21%)	0.448	0.438	-0.010 (-2%)
		BN	0.469	0.469	0.000 (0%)	0.458	0.427	-0.031 (-7%)	0.438	0.396	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.427	0.385	-0.042 (-10%)	0.438	0.396	-0.042 (-10%)	0.458	0.458	0.000 (0%)
		D	0.469	0.469	0.000 (0%)	0.458	0.438	-0.021 (-5%)	0.458	0.427	-0.031 (-7%)	0.458	0.438	-0.021 (-5%)	0.448	0.417	-0.031 (-7%)	0.448	0.427	-0.021 (-5%)	0.469	0.458	-0.010 (-2%)
		C	0.469	0.469	0.000 (0%)	0.469	0.448	-0.021 (-4%)	0.458	0.438	-0.021 (-5%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.469	0.469	0.000 (0%)
45	San Joaquin River near the confluence with the Mokelumne River	W	0.479	0.479	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.438	-0.010 (-2%)	0.448	0.448	0.000 (0%)	0.469	0.469	0.000 (0%)
		AN	0.490	0.490	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.448	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)
		BN	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.469	-0.010 (-2%)	0.479	0.479	0.000 (0%)
		D	0.500	0.490	-0.010 (-2%)	0.490	0.479	-0.010 (-2%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.469	0.469	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
		C	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)	0.479	0.479	0.000 (0%)
94	Old River downstream of the south Delta export facilities	W	0.583	0.573	-0.010 (-2%)	0.531	0.490	-0.042 (-8%)	0.531	0.448	-0.083 (-16%)	0.531	0.438	-0.094 (-18%)	0.448	0.438	-0.010 (-2%)	0.458	0.448	-0.010 (-2%)	0.531	0.479	-0.052 (-10%)
		AN	0.583	0.583	0.000 (0%)	0.531	0.510	-0.021 (-4%)	0.531	0.500	-0.031 (-6%)	0.542	0.469	-0.073 (-13%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.542	0.521	-0.021 (-4%)
		BN	0.667	0.604	-0.063 (-9%)	0.552	0.490	-0.063 (-11%)	0.521	0.521	0.000 (0%)	0.542	0.531	-0.010 (-2%)	0.479	0.490	0.010 (2%)	0.479	0.490	0.010 (2%)	0.531	0.521	-0.010 (-2%)
		D	0.594	0.583	-0.010 (-2%)	0.552	0.531	-0.021 (-4%)	0.531	0.531	0.000 (0%)	0.521	0.521	0.000 (0%)	0.490	0.500	0.010 (2%)	0.490	0.490	0.000 (0%)	0.521	0.510	-0.010 (-2%)
		C	0.542	0.542	0.000 (0%)	0.552	0.552	0.000 (0%)	0.521	0.521	0.000 (0%)	0.500	0.500	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)	0.490	0.490	0.000 (0%)
212	Old River upstream of the south Delta export facilities	W	0.344	0.354	0.010 (3%)	0.292	0.396	0.104 (36%)	0.125	0.354	0.229 (183%)	0.094	0.297	0.203 (217%)	0.177	0.365	0.188 (106%)	0.229	0.396	0.167 (73%)	0.188	0.385	0.198 (106%)
		AN	0.344	0.365	0.021 (6%)	0.365	0.427	0.063 (17%)	0.313	0.406	0.094 (30%)	0.271	0.417	0.146 (54%)	0.344	0.427	0.083 (24%)	0.365	0.438	0.073 (20%)	0.438	0.464	0.026 (6%)
		BN	0.333	0.365	0.031 (9%)	0.385	0.448	0.063 (16%)	0.365	0.427	0.063 (17%)	0.354	0.438	0.083 (24%)	0.375	0.438	0.063 (17%)	0.396	0.448	0.052 (13%)	0.469	0.490	0.021 (4%)
		D	0.375	0.375	0.000 (0%)	0.385	0.448	0.063 (16%)	0.385	0.448	0.063 (16%)	0.396	0.448	0.052 (13%)	0.406	0.448	0.042 (10%)	0.417	0.458	0.042 (10%)	0.479	0.500	0.021 (4%)
		C	0.396	0.406	0.010 (3%)	0.406	0.458	0.052 (13%)	0.396	0.448	0.052 (13%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.438	0.469	0.031 (7%)	0.500	0.500	0.000 (0%)
365	Delta Cross Channel	W	0.448	0.448	0.000 (0%)	0.427	0.427	0.000 (0%)	0.427	0.417	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.438	0.427	-0.010 (-2%)	0.427	0.427	0.000 (0%)	0.073	0.083	0.010 (14%)
		AN	0.458	0.458	0.000	0.448	0.448	0.000	0.438	0.438	0.000	0.438	0.438	0.000	0.448	0.448	0.000	0.458	0.458	0.000	0.031	0.063	0.031

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
					(0%)			(0%)			(0%)			(0%)			(0%)			(0%)			(100%)
		BN	0.458	0.448	-0.010 (-2%)	0.469	0.458	-0.010 (-2%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.458	-0.010 (-2%)	0.042	0.063	0.021 (50%)
		D	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.042	0.073	0.031 (75%)
		C	0.458	0.458	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.469	0.469	0.000 (0%)	0.146	0.156	0.010 (7%)
379	Sutter Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.083	0.063	-0.021 (-25%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.063	0.010 (20%)	0.104	0.083	-0.021 (-20%)
		D	0.000	0.063	0.063 (Inf.)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.052	0.052	0.000 (0%)	0.104	0.104	0.000 (0%)
		C	0.167	0.203	0.036 (22%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.021	0.021 (Inf.)	0.083	0.094	0.010 (13%)	0.167	0.188	0.021 (12%)	0.240	0.250	0.010 (4%)
383	Steamboat Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.198	0.302	0.104 (53%)
		AN	0.125	0.167	0.042 (33%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.188	0.229	0.042 (22%)	0.302	0.333	0.031 (10%)
		BN	0.167	0.229	0.063 (37%)	0.115	0.146	0.031 (27%)	0.000	0.094	0.094 (Inf.)	0.042	0.146	0.104 (250%)	0.219	0.250	0.031 (14%)	0.281	0.281	0.000 (0%)	0.313	0.313	0.000 (0%)
		D	0.260	0.281	0.021 (8%)	0.182	0.224	0.042 (23%)	0.021	0.125	0.104 (500%)	0.000	0.125	0.125 (Inf.)	0.224	0.229	0.005 (2%)	0.271	0.271	0.000 (0%)	0.313	0.323	0.010 (3%)
		C	0.333	0.344	0.010 (3%)	0.219	0.250	0.031 (14%)	0.146	0.214	0.068 (46%)	0.281	0.292	0.010 (4%)	0.302	0.302	0.000 (0%)	0.344	0.354	0.010 (3%)	0.375	0.375	0.000 (0%)
418	Sacramento River downstream of proposed NDD	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.031	0.052	0.021 (67%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.042	0.021 (100%)	0.000	0.000	0.000 (0%)
		C	0.141	0.156	0.016 (11%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.005	0.005 (Inf.)	0.073	0.083	0.010 (14%)	0.156	0.167	0.010 (7%)	0.130	0.135	0.005 (4%)
421	Sacramento River upstream of Georgiana Slough	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)
		AN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.031	0.031 (Inf.)	0.000	0.000	0.000 (0%)
		BN	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.042	0.073	0.031 (75%)	0.000	0.000	0.000 (0%)
		D	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.021	0.073	0.052 (250%)	0.000	0.000	0.000 (0%)
		C	0.135	0.156	0.021 (15%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.052	0.052 (Inf.)	0.083	0.104	0.021 (25%)	0.167	0.167	0.000 (0%)	0.125	0.135	0.010 (8%)
423	Sacramento River downstream	W	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.281	0.333	0.052 (19%)
		AN	0.146	0.188	0.042 (29%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.000	0.000 (0%)	0.000	0.063	0.063 (Inf.)	0.208	0.250	0.042 (20%)	0.344	0.365	0.021 (6%)

DSM2 Channel	Location	Water Year Type	December			January			February			March			April			May			June		
			NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	of Georgiana Slough	BN	0.188	0.250	0.063 (33%)	0.135	0.167	0.031 (23%)	0.000	0.115	0.115 (Inf.)	0.083	0.177	0.094 (113%)	0.240	0.250	0.010 (4%)	0.292	0.292	0.000 (0%)	0.354	0.354	0.000 (0%)
		D	0.281	0.302	0.021 (7%)	0.198	0.240	0.042 (21%)	0.083	0.146	0.063 (75%)	0.000	0.146	0.146 (Inf.)	0.229	0.240	0.010 (5%)	0.281	0.281	0.000 (0%)	0.354	0.365	0.010 (3%)
		C	0.344	0.354	0.010 (3%)	0.240	0.260	0.021 (9%)	0.177	0.229	0.052 (29%)	0.292	0.292	0.000 (0%)	0.302	0.313	0.010 (3%)	0.354	0.354	0.000 (0%)	0.396	0.396	0.000 (0%)

Table 5.4-12. Median Daily Proportion of Flow Entering Important Delta Channels, from DSM2-HYDRO Modeling, with Green Shading Indicating PA is ≥ 5% Less than NAA and Red Shading Indicating PA is ≥ 5% More than NAA(Except for Sutter/Steamboat Sloughs, where Entry is Considered Beneficial and the Color Scheme is Reversed).

Junction	Water Year Type	December			January			February			March			April			May			June		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
Sutter Slough (Entry is beneficial)	W	0.262	0.262	0.000 (0%)	0.264	0.263	-0.001 (0%)	0.267	0.265	-0.002 (-1%)	0.265	0.265	0.000 (0%)	0.263	0.263	0.000 (0%)	0.263	0.263	0.000 (0%)	0.219	0.193	-0.026 (-12%)
	AN	0.259	0.257	-0.002 (-1%)	0.261	0.261	0.000 (0%)	0.263	0.263	0.000 (0%)	0.262	0.263	0.001 (0%)	0.262	0.261	-0.001 (0%)	0.262	0.258	-0.004 (-2%)	0.181	0.174	-0.007 (-4%)
	BN	0.257	0.252	-0.005 (-2%)	0.259	0.258	-0.001 (0%)	0.261	0.261	0.000 (0%)	0.260	0.259	-0.001 (0%)	0.261	0.259	-0.002 (-1%)	0.240	0.238	-0.002 (-1%)	0.175	0.181	0.006 (3%)
	D	0.227	0.219	-0.008 (-4%)	0.256	0.254	-0.002 (-1%)	0.260	0.259	-0.001 (0%)	0.260	0.259	-0.001 (0%)	0.259	0.259	0.000 (0%)	0.242	0.239	-0.003 (-1%)	0.173	0.174	0.001 (1%)
	C	0.195	0.185	-0.010 (-5%)	0.254	0.247	-0.007 (-3%)	0.259	0.256	-0.003 (-1%)	0.249	0.239	-0.010 (-4%)	0.230	0.225	-0.005 (-2%)	0.199	0.195	-0.004 (-2%)	0.151	0.152	0.001 (1%)
Steamboat Slough (Entry is beneficial)	W	0.254	0.242	-0.012 (-5%)	0.278	0.272	-0.006 (-2%)	0.291	0.284	-0.007 (-2%)	0.277	0.270	-0.007 (-3%)	0.257	0.253	-0.004 (-2%)	0.252	0.249	-0.003 (-1%)	0.182	0.180	-0.002 (-1%)
	AN	0.207	0.203	-0.004 (-2%)	0.259	0.248	-0.011 (-4%)	0.279	0.272	-0.007 (-3%)	0.263	0.257	-0.006 (-2%)	0.238	0.229	-0.009 (-4%)	0.202	0.203	0.001 (0%)	0.164	0.169	0.005 (3%)
	BN	0.200	0.193	-0.007 (-4%)	0.213	0.209	-0.004 (-2%)	0.238	0.220	-0.018 (-8%)	0.218	0.205	-0.013 (-6%)	0.196	0.196	0.000 (0%)	0.192	0.194	0.002 (1%)	0.164	0.168	0.004 (2%)
	D	0.192	0.190	-0.002 (-1%)	0.199	0.197	-0.002 (-1%)	0.222	0.210	-0.012 (-5%)	0.232	0.212	-0.020 (-9%)	0.197	0.198	0.001 (1%)	0.192	0.194	0.002 (1%)	0.163	0.169	0.006 (4%)
	C	0.192	0.193	0.001 (1%)	0.198	0.196	-0.002 (-1%)	0.203	0.199	-0.004 (-2%)	0.193	0.194	0.001 (1%)	0.190	0.191	0.001 (1%)	0.191	0.193	0.002 (1%)	0.180	0.183	0.003 (2%)
Delta Cross Channel (Entry is adverse)	W	0.006	0.007	0.001 (17%)	0.004	0.004	0.000 (0%)	0.003	0.003	0.000 (0%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.006	0.006	0.000 (0%)	0.386	0.379	-0.007 (-2%)
	AN	0.009	0.010	0.001 (11%)	0.005	0.006	0.001 (20%)	0.004	0.004	0.000 (0%)	0.005	0.006	0.001 (20%)	0.007	0.008	0.001 (14%)	0.010	0.011	0.001 (10%)	0.432	0.426	-0.006 (-1%)
	BN	0.009	0.010	0.001 (11%)	0.009	0.009	0.000 (0%)	0.007	0.008	0.001 (14%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.437	0.430	-0.007 (-2%)
	D	0.011	0.011	0.000 (0%)	0.010	0.010	0.000 (0%)	0.008	0.009	0.001 (13%)	0.008	0.009	0.001 (13%)	0.010	0.010	0.000 (0%)	0.011	0.011	0.000 (0%)	0.442	0.429	-0.013 (-3%)
	C	0.013	0.013	0.000 (0%)	0.010	0.010	0.000 (0%)	0.009	0.010	0.001 (11%)	0.011	0.011	0.000 (0%)	0.011	0.011	0.000 (0%)	0.012	0.013	0.001 (8%)	0.389	0.379	-0.010 (-3%)
Georgiana Slough (Entry is adverse)	W	0.314	0.342	0.028 (9%)	0.293	0.295	0.002 (1%)	0.291	0.292	0.001 (0%)	0.292	0.293	0.001 (0%)	0.302	0.304	0.002 (1%)	0.307	0.311	0.004 (1%)	0.396	0.393	-0.003 (-1%)
	AN	0.395	0.401	0.006 (2%)	0.304	0.327	0.023 (8%)	0.292	0.293	0.001 (0%)	0.299	0.302	0.003 (1%)	0.336	0.360	0.024 (7%)	0.417	0.405	-0.012 (-3%)	0.420	0.402	-0.018 (-4%)
	BN	0.411	0.418	0.007 (2%)	0.396	0.400	0.004 (1%)	0.339	0.379	0.040 (12%)	0.391	0.417	0.026 (7%)	0.424	0.416	-0.008 (-2%)	0.433	0.422	-0.011 (-3%)	0.414	0.412	-0.002 (0%)
	D	0.415	0.419	0.004 (1%)	0.421	0.423	0.002 (0%)	0.382	0.400	0.018 (5%)	0.366	0.406	0.040 (11%)	0.416	0.411	-0.005 (-1%)	0.432	0.423	-0.009 (-2%)	0.415	0.403	-0.012 (-3%)
	C	0.387	0.384	-0.003 (-1%)	0.412	0.428	0.016 (4%)	0.418	0.416	-0.002 (0%)	0.431	0.429	-0.002 (0%)	0.440	0.434	-0.006 (-1%)	0.404	0.397	-0.007 (-2%)	0.363	0.347	-0.016 (-4%)
Head of Old River (Entry is adverse)	W	0.649	0.642	-0.007 (-1%)	0.580	0.322	-0.258 (-44%)	0.537	0.282	-0.255 (-47%)	0.534	0.323	-0.211 (-40%)	0.525	0.259	-0.266 (-51%)	0.527	0.259	-0.268 (-51%)	0.515	0.497	-0.018 (-3%)
	AN	0.663	0.661	-0.002 (0%)	0.616	0.349	-0.267 (-43%)	0.577	0.280	-0.297 (-51%)	0.560	0.264	-0.296 (-53%)	0.529	0.253	-0.276 (-52%)	0.537	0.252	-0.285 (-53%)	0.530	0.474	-0.056 (-11%)
	BN	0.679	0.667	-0.012 (-2%)	0.635	0.342	-0.293 (-46%)	0.602	0.353	-0.249 (-41%)	0.611	0.289	-0.322 (-53%)	0.559	0.264	-0.295 (-53%)	0.581	0.279	-0.302 (-52%)	0.504	0.412	-0.092 (-18%)
	D	0.667	0.662	-0.005 (-1%)	0.647	0.362	-0.285 (-44%)	0.634	0.371	-0.263 (-41%)	0.629	0.385	-0.244 (-39%)	0.597	0.322	-0.275 (-46%)	0.602	0.335	-0.267 (-44%)	0.467	0.377	-0.090 (-19%)

Junction	Water Year Type	December			January			February			March			April			May			June		
		NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
	C	0.642	0.639	-0.003 (0%)	0.638	0.405	-0.233 (-37%)	0.622	0.383	-0.239 (-38%)	0.594	0.398	-0.196 (-33%)	0.567	0.393	-0.174 (-31%)	0.580	0.383	-0.197 (-34%)	0.367	0.307	-0.060 (-16%)
	W	0.176	0.173	-0.003 (-2%)	0.176	0.181	0.005 (3%)	0.191	0.187	-0.004 (-2%)	0.197	0.190	-0.007 (-4%)	0.180	0.189	0.009 (5%)	0.177	0.187	0.010 (6%)	0.190	0.183	-0.007 (-4%)
	AN	0.171	0.169	-0.002 (-1%)	0.167	0.174	0.007 (4%)	0.175	0.185	0.010 (6%)	0.182	0.185	0.003 (2%)	0.170	0.188	0.018 (11%)	0.167	0.186	0.019 (11%)	0.173	0.173	0.000 (0%)
Turner Cut (Entry is adverse)	BN	0.177	0.172	-0.005 (-3%)	0.165	0.168	0.003 (2%)	0.169	0.181	0.012 (7%)	0.169	0.181	0.012 (7%)	0.164	0.182	0.018 (11%)	0.161	0.176	0.015 (9%)	0.163	0.164	0.001 (1%)
	D	0.168	0.167	-0.001 (-1%)	0.164	0.170	0.006 (4%)	0.161	0.170	0.009 (6%)	0.159	0.168	0.009 (6%)	0.157	0.170	0.013 (8%)	0.157	0.168	0.011 (7%)	0.160	0.160	0.000 (0%)
	C	0.161	0.161	0.000 (0%)	0.161	0.167	0.006 (4%)	0.158	0.166	0.008 (5%)	0.152	0.159	0.007 (5%)	0.150	0.157	0.007 (5%)	0.151	0.158	0.007 (5%)	0.153	0.153	0.000 (0%)
	W	0.169	0.166	-0.003 (-2%)	0.166	0.163	-0.003 (-2%)	0.171	0.161	-0.010 (-6%)	0.173	0.157	-0.016 (-9%)	0.155	0.157	0.002 (1%)	0.155	0.157	0.002 (1%)	0.169	0.161	-0.008 (-5%)
	AN	0.166	0.164	-0.002 (-1%)	0.161	0.162	0.001 (1%)	0.165	0.165	0.000 (0%)	0.166	0.158	-0.008 (-5%)	0.153	0.160	0.007 (5%)	0.151	0.159	0.008 (5%)	0.164	0.161	-0.003 (-2%)
Columbia Cut (Entry is adverse)	BN	0.171	0.167	-0.004 (-2%)	0.160	0.158	-0.002 (-1%)	0.162	0.165	0.003 (2%)	0.161	0.164	0.003 (2%)	0.151	0.160	0.009 (6%)	0.149	0.158	0.009 (6%)	0.157	0.156	-0.001 (-1%)
	D	0.164	0.163	-0.001 (-1%)	0.159	0.161	0.002 (1%)	0.156	0.160	0.004 (3%)	0.153	0.158	0.005 (3%)	0.149	0.156	0.007 (5%)	0.148	0.154	0.006 (4%)	0.154	0.152	-0.002 (-1%)
	C	0.158	0.157	-0.001 (-1%)	0.157	0.160	0.003 (2%)	0.152	0.158	0.006 (4%)	0.147	0.151	0.004 (3%)	0.144	0.148	0.004 (3%)	0.144	0.149	0.005 (3%)	0.147	0.147	0.000 (0%)
	W	0.189	0.186	-0.003 (-2%)	0.183	0.178	-0.005 (-3%)	0.185	0.174	-0.011 (-6%)	0.184	0.168	-0.016 (-9%)	0.167	0.168	0.001 (1%)	0.169	0.169	0.000 (0%)	0.186	0.176	-0.010 (-5%)
	AN	0.190	0.187	-0.003 (-2%)	0.180	0.178	-0.002 (-1%)	0.182	0.180	-0.002 (-1%)	0.183	0.173	-0.010 (-5%)	0.170	0.175	0.005 (3%)	0.170	0.174	0.004 (2%)	0.183	0.180	-0.003 (-2%)
Middle River (Entry is adverse)	BN	0.194	0.189	-0.005 (-3%)	0.182	0.175	-0.007 (-4%)	0.180	0.180	0.000 (0%)	0.181	0.179	-0.002 (-1%)	0.171	0.176	0.005 (3%)	0.170	0.175	0.005 (3%)	0.178	0.177	-0.001 (-1%)
	D	0.188	0.186	-0.002 (-1%)	0.181	0.180	-0.001 (-1%)	0.179	0.178	-0.001 (-1%)	0.177	0.178	0.001 (1%)	0.171	0.175	0.004 (2%)	0.170	0.174	0.004 (2%)	0.176	0.175	-0.001 (-1%)
	C	0.180	0.180	0.000 (0%)	0.179	0.179	0.000 (0%)	0.175	0.176	0.001 (1%)	0.171	0.172	0.001 (1%)	0.169	0.172	0.003 (2%)	0.169	0.172	0.003 (2%)	0.170	0.170	0.000 (0%)
	W	0.178	0.174	-0.004 (-2%)	0.177	0.172	-0.005 (-3%)	0.181	0.170	-0.011 (-6%)	0.177	0.164	-0.013 (-7%)	0.162	0.161	-0.001 (-1%)	0.163	0.161	-0.002 (-1%)	0.174	0.167	-0.007 (-4%)
	AN	0.174	0.172	-0.002 (-1%)	0.173	0.171	-0.002 (-1%)	0.175	0.172	-0.003 (-2%)	0.173	0.164	-0.009 (-5%)	0.159	0.162	0.003 (2%)	0.159	0.161	0.002 (1%)	0.171	0.169	-0.002 (-1%)
Mouth of Old River (Entry is adverse)	BN	0.177	0.173	-0.004 (-2%)	0.168	0.164	-0.004 (-2%)	0.169	0.169	0.000 (0%)	0.165	0.164	-0.001 (-1%)	0.158	0.162	0.004 (3%)	0.158	0.161	0.003 (2%)	0.167	0.167	0.000 (0%)
	D	0.171	0.170	-0.001 (-1%)	0.167	0.166	-0.001 (-1%)	0.165	0.165	0.000 (0%)	0.162	0.163	0.001 (1%)	0.158	0.161	0.003 (2%)	0.158	0.160	0.002 (1%)	0.166	0.164	-0.002 (-1%)
	C	0.166	0.165	-0.001 (-1%)	0.166	0.166	0.000 (0%)	0.163	0.163	0.000 (0%)	0.157	0.159	0.002 (1%)	0.155	0.156	0.001 (1%)	0.156	0.158	0.002 (1%)	0.161	0.161	0.000 (0%)

Table 5.4-13. Delta Passage Model: Winter-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.43	0.43	-0.01 (-2%)	0.48	0.46	-0.02 (-5%)	0.22	0.22	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.40	0.39	-0.01 (-2%)	0.44	0.42	-0.02 (-6%)	0.16	0.17	0.00 (1%)	0.47	0.47	0.00 (0%)
BN	0.31	0.29	-0.02 (-6%)	0.34	0.31	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
D	0.30	0.28	-0.02 (-7%)	0.33	0.30	-0.03 (-8%)	0.06	0.06	0.00 (2%)	0.47	0.47	0.00 (0%)
C	0.25	0.24	-0.01 (-4%)	0.27	0.26	-0.01 (-4%)	0.03	0.03	0.00 (0%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	-0.01 (-2%)	0.52	0.50	-0.02 (-4%)	0.26	0.26	0.00 (2%)	0.18	0.23	0.05 (28%)
AN	0.30	0.29	-0.01 (-2%)	0.49	0.46	-0.02 (-5%)	0.26	0.27	0.01 (2%)	0.17	0.20	0.03 (19%)
BN	0.31	0.30	-0.01 (-2%)	0.38	0.35	-0.03 (-7%)	0.27	0.28	0.01 (2%)	0.14	0.15	0.01 (5%)
D	0.30	0.30	-0.01 (-2%)	0.37	0.34	-0.03 (-8%)	0.27	0.28	0.01 (2%)	0.14	0.14	0.00 (0%)
C	0.29	0.29	0.00 (-1%)	0.31	0.30	-0.01 (-4%)	0.29	0.29	0.00 (1%)	0.13	0.12	0.00 (-1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.

Table 5.4-14. Delta Passage Model: Spring-Run Chinook Salmon Mean Through-Delta (Total) Survival, Mainstem Sacramento River survival, and Proportion Using and Surviving Other Migration Routes.

WY	Total Survival			Mainstem Sacramento River Survival			Yolo Bypass					
							Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.42	0.42	0.00 (-1%)	0.46	0.44	-0.02 (-4%)	0.19	0.19	0.00 (1%)	0.47	0.47	0.00 (0%)
AN	0.37	0.36	-0.01 (-2%)	0.39	0.37	-0.02 (-5%)	0.13	0.14	0.01 (5%)	0.47	0.47	0.00 (0%)
BN	0.27	0.26	-0.01 (-3%)	0.29	0.28	-0.01 (-4%)	0.04	0.04	0.00 (-2%)	0.47	0.47	0.00 (0%)
D	0.28	0.27	-0.01 (-4%)	0.30	0.28	-0.01 (-5%)	0.05	0.05	0.00 (-1%)	0.47	0.47	0.00 (0%)
C	0.22	0.22	0.00 (-1%)	0.24	0.23	0.00 (-1%)	0.03	0.03	0.00 (-2%)	0.47	0.47	0.00 (0%)
WY	Sutter/Steamboat Sloughs						Interior Delta (Via Georgiana Slough/DCC)					
	Proportion Using Route			Survival			Proportion Using Route			Survival		
	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA	NAA	PA	PA vs. NAA
W	0.29	0.28	0.00 (-1%)	0.50	0.48	-0.02 (-4%)	0.26	0.26	0.00 (1%)	0.21	0.25	0.04 (19%)
AN	0.29	0.29	-0.01 (-2%)	0.43	0.41	-0.02 (-4%)	0.27	0.27	0.00 (1%)	0.19	0.21	0.02 (11%)
BN	0.30	0.30	0.00 (-1%)	0.32	0.31	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (2%)
D	0.30	0.29	0.00 (-1%)	0.34	0.32	-0.01 (-4%)	0.28	0.28	0.00 (1%)	0.15	0.15	0.00 (1%)
C	0.28	0.28	0.00 (0%)	0.28	0.27	0.00 (-1%)	0.30	0.30	0.00 (0%)	0.13	0.13	0.00 (1%)

Note: Survival in Sutter/Steamboat Sloughs and Interior Delta routes includes survival in the Sacramento River prior to entering the channel junctions.

Table 5.4-38. Mean Annual Winter-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality			Life Stage Total	Temperature-Related Mortality				Flow-Related Mortality				Life Stage Total	Grand Total
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal		Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal		
All Water Year Types[2]																	
NAA	9,092	423,231	432,323	368,939	0	368,939	801,262	5,343	2,391	0	7,734	123,789	115	0	123,904	131,638	932,900
PA	9,119	391,450	400,568	430,651	0	430,651	831,220	5,495	2,125	0	7,620	120,680	104	0	120,784	128,404	959,624
Difference	27	-31,781	-31,755	61,712	0	61,712	29,958	152	-266	0	-114	-3,109	-11	0	-3,120	-3,234	26,723
Percent Difference[3]	0	-8	-7	17	0	17	4	3	-11	0	-1	-3	-10	0	-3	-2	3
Water Year Types[4]																	
Wet (32.5%)																	
NAA	8,774	806	9,580	167,602	0	167,602	177,182	0	0	0	0	173,745	36	0	173,781	173,781	350,962
PA	8,890	670	9,560	244,211	0	244,211	253,771	0	0	0	0	154,086	27	0	154,113	154,113	407,884
Difference	116	-136	-19	76,609	0	76,609	76,589	0	0	0	0	-19,659	-9	0	-19,667	-19,667	56,922
Percent Difference	1	-17	0	46	0	46	43	0	0	0	NA	-11	-25	0	-11	-11	16
Above Normal (12.5%)																	
NAA	9,001	457	9,459	316,112	0	316,112	325,570	0	0	0	0	159,631	24	0	159,655	159,655	485,225
PA	9,001	376	9,378	369,936	0	369,936	379,313	0	0	0	0	139,838	16	0	139,854	139,854	519,167
Difference	0	-81	-81	53,824	0	53,824	53,743	0	0	0	0	-19,793	-8	0	-19,801	-19,801	33,942
Percent Difference	0	-18	-1	17	0	17	17	0	0	0	NA	-12	-32	0	-12	-12	7
Below Normal (17.5%)																	
NAA	7,909	8,021	15,930	587,438	0	587,438	603,368	10	1	0	11	95,189	127	0	95,316	95,327	698,696
PA	8,455	12,730	21,184	714,331	0	714,331	735,515	11	1	0	12	105,939	117	0	106,056	106,068	841,584
Difference	545	4,709	5,254	126,893	0	126,893	132,147	1	0	0	1	10,749	-10	0	10,740	10,741	142,888
Percent Difference	7	59	33	22	0	22	22	15	-8	0	12	11	-8	0	11	11	20
Dry (22.5%)																	
NAA	9,789	29,678	39,467	610,519	0	610,519	649,986	24	6	0	30	106,542	246	0	106,788	106,818	756,803
PA	9,474	21,650	31,123	648,552	0	648,552	679,676	25	4	0	29	122,973	182	0	123,155	123,184	802,859
Difference	-316	-8,028	-8,344	38,034	0	38,034	29,690	1	-2	0	-1	16,431	-64	0	16,367	16,366	46,056
Percent Difference	-3	-27	-21	6	0	6	5	5	-33	0	-3	15	-26	0	15	15	6
Critical (15%)																	
NAA	9,853	2,764,994	2,774,847	275,207	0	275,207	3,050,054	35,573	15,929	0	51,502	33,235	160	0	33,395	84,897	3,134,950
PA	9,779	2,561,888	2,571,667	290,273	0	290,273	2,861,940	36,581	14,162	0	50,743	39,024	223	0	39,247	89,990	2,951,930
Difference	-74	-203,106	-203,180	15,066	0	15,066	-188,113	1,008	-1,767	0	-759	5,789	63	0	5,852	5,093	-183,021
Percent Difference	-1	-7	-7	5	0	5	-6	3	-11	0	-1	17	40	0	18	6	-6

[1] Mortality values do not include base mortality

[2] Based on the 80-year simulation period

[3] Relative difference of the Annual average

[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.

Table 5.4-54. Mean Annual Spring-Run Chinook Salmon Mortality[1] (# of Fish/Year) Predicted by SALMOD

	Spawning, Egg Incubation, and Alevins							Fry and Juvenile Rearing									
	Temperature-Related Mortality			Flow-Related Mortality				Temperature-Related Mortality				Flow-Related Mortality					
Analysis Period	Pre-Spawn	Eggs	Subtotal	Incubation	Super-imposition	Subtotal	Life Stage Total	Fry	Pre-smolt	Immature Smolt	Subtotal	Fry	Pre-smolt	Immature Smolt	Subtotal	Life Stage Total	Grand Total
All Water Year Types2																	
NAA	46,032	124,013	170,045	1,905	0	1,905	171,950	1	0	0	1	2,265	0	0	2,265	2,265	174,215
PA	50,462	107,473	157,935	2,118	0	2,118	160,053	0	0	0	0	2,273	0	0	2,273	2,273	162,325
Difference	4,431	-16,540	-12,110	212	0	212	-11,898	-1	0	0	-1	8	0	0	8	7	-11,890
Percent Difference[3]	10	-13	-7	11	0	11	-7	-100	0	0	-100	0	0	0	0	0	-7
Water Year Types4																	
Wet (32.5%)																	
NAA	116	6,530	6,646	1,336	0	1,336	7,983	0	0	0	0	2,614	0	0	2,614	2,614	10,597
PA	117	5,835	5,952	1,748	0	1,748	7,699	0	0	0	0	2,815	0	0	2,815	2,815	10,514
Difference	1	-695	-695	411	0	411	-283	0	0	0	0	200	0	0	200	200	-83
Percent Difference	0	-11	-10	31	0	31	-4	0	0	0	NA5	8	0	0	8	8	-1
Above Normal (12.5%)																	
NAA	78	4,181	4,258	1,162	0	1,162	5,420	0	0	0	0	2,703	0	0	2,703	2,703	8,124
PA	65	3,888	3,953	1,509	0	1,509	5,463	0	0	0	0	2,354	0	0	2,354	2,354	7,816
Difference	-12	-293	-305	347	0	347	42	0	0	0	0	-350	0	0	-350	-350	-307
Percent Difference	-16	-7	-7	30	0	30	1	0	0	0	NA	-13	0	0	-13	-13	-4
Below Normal (17.5%)																	
NAA	154	34,929	35,084	1,300	0	1,300	36,384	0	0	0	0	2,634	0	0	2,634	2,634	39,018
PA	309	41,242	41,551	1,711	0	1,711	43,262	0	0	0	0	2,591	0	0	2,591	2,591	45,853
Difference	155	6,313	6,467	411	0	411	6,878	0	0	0	0	-43	0	0	-43	-43	6,835
Percent Difference	100	18	18	32	0	32	19	0	0	0	NA	-2	0	0	-2	-2	18
Dry (22.5%)																	
NAA	1,093	66,312	67,406	3,652	0	3,652	71,058	0	0	0	0	2,468	0	0	2,468	2,468	73,526
PA	995	64,050	65,045	3,422	0	3,422	68,467	0	0	0	0	2,438	0	0	2,438	2,438	70,905
Difference	-98	-2,263	-2,361	-230	0	-230	-2,591	0	0	0	0	-30	0	0	-30	-30	-2,621
Percent Difference	-9	-3	-4	-6	0	-6	-4	0	0	0	NA	-1	0	0	-1	-1	-4
Critical (15%)																	
NAA	304,677	671,412	976,089	1,670	0	1,670	977,759	3	0	0	3	408	0	0	408	411	978,170
PA	334,238	560,737	894,976	1,835	0	1,835	896,811	0	0	0	0	463	0	0	463	463	897,274
Difference	29,562	-110,675	-81,113	165	0	165	-80,949	-3	0	0	-3	55	0	0	55	52	-80,897
Percent Difference	10	-16	-8	10	0	10	-8	-100	0	0	-100	14	0	0	14	13	-8

[1] Mortality values do not include base mortality
[2] Based on the 80-year simulation period
[3] Relative difference of the Annual average
[4] As defined by the Sacramento Valley 40-30-30 Index Water Year Hydrologic Classification (State Water Resources Control Board 1995). Water years may not correspond to the biological years in SALMOD.
[5] NA = Unable to calculate because dividing by 0

Appendix D

Modeling Analysis of Habitat Restoration

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

May 13, 2017

MEMORANDUM FOR: ARN: 151422-WCR2016-SA00204

FROM: Erin Strange, San Joaquin River Branch, California Central Valley Office, West Coast Region

REVIEWED BY: Maria Rea, Assistant Regional Administrator, California Central Valley Office, West Coast Region

SUBJECT: Technical memorandum regarding additional analysis of habitat restoration actions for enhancement of juvenile rearing habit and amelioration of reverse flows in the Delta for the California WaterFix Project (CWF).

Purpose of Analysis:

The purpose of this analysis is to determine: 1) the impact of fish routing and habitat restoration on the cohort replacement rate of winter-run Chinook salmon, and 2) how reverse flows in the Delta caused by proposed project can be ameliorated with Delta tidal habitat restoration.

Background:

Habitat restoration is proposed for two purposes: 1) to improve spawning and rearing habitat for listed salmonids; and 2) address potential undesirable hydrodynamic effects of NDD operations (e.g. reverse flows).

Upstream Habitat Restoration Actions. As a condition of the 2081(b) ITP, DFW is requiring DWR to improve spawning and rearing habitat for spring run chinook salmon (CHNSR), winter run chinook salmon (CHNWR) and steelhead, and contribute to establishment of additional populations of winter run, support adult spawning, egg incubation and juvenile production. The funding described above will be initially used specifically to establish a new population of CHNWR through introduction and reintroduction of fish into Sacramento River tributaries (which may include Battle Creek and/or upstream of Shasta Reservoir) and to support that population with associated habitat restoration and other measures prior to operation of the NDD or within 12 years of order issuance[1]. Consistent with the 2081(b) ITP, the goal of this action is to establish a new CHNWR population in the Sacramento River watershed within the term of this permit that meets the low extinction risk criteria identified by the Central Valley Technical Recovery Team (CVTRT) (Lindley et al.2007). As a condition of the 2081(b) ITP, DWR will fully fund and implement reintroduction and restoration action effectiveness monitoring and extinction risk monitoring to ensure that the goal is met. Additionally, the 2081(b) ITP requires that funding commitments will be sufficient to support creation and enhancement of Sacramento River spawning and instream and/or off-channel rearing habitat and measurable expansion of salmonid habitat capacity. Consistent with the 2081(b) ITP, the goal of this effort is to contribute to the quantity, quality, and diversity of important rearing habitat along the Sacramento River corridor for CHNWR, CHNSR, and steelhead, and may include use of mitigation bank(s) as appropriate. Initially efforts will be focused on restoring 80 acres of spawning and rearing habitat in the upper Sacramento River above the Red Bluff Diversion Dam (RBDD). Restoration of rearing habitat in particular above RBDD is targeted at reducing density dependent reductions in CHNWR survival above RBDD. The committed annual funds may also be used to restore habitat in the middle Sacramento River (e.g., in Sutter Bypass). DWR will coordinate with CDFW, NMFS, FWS, Reclamation and other entities undertaking restoration and enhancement actions to identify the highest priority projects for funding annually. Restoration opportunities will align with species recovery needs and be guided by information in the Salmon Resiliency Strategy. This measure may be terminated with written approval from CDFW and NMFS upon demonstration that the measure has offset the population level effects of the CWF operations.

Delta Habitat Restoration. DWR and Reclamation commit to improve and expand the diversity, quantity, and quality of rearing and refuge habitat in the tidal portions of the Delta and Suisun Marsh, including conservation measures discussed below in 3.4.3.1.2.1 *Tidal Perennial Habitat Restoration*. As described in this section, the PA includes conservation measures to provide restoration of at least 1,800 acres of tidal habitat prior to operation of the NDD, consistent with the multi-species benefits that exist with restoration associated with the delta smelt conservation measures described below and other restoration efforts, that will contribute to improved growth, survival, and migratory success of juvenile CHNWR, CHNSR, and steelhead, including potential use of mitigation banks as deemed appropriate. Implementation of these measures will be funded out of the project budget related to construction costs and not through the additional funds as described above, and is in addition to the 9,000 acres of restoration currently being implemented through the previously described Existing Commitments.

It is expected that through the measures described above, additional tidal restoration will be provided to sufficiently address potential undesirable hydrodynamic effects of NDD operations (e.g. reverse flows). DWR and Reclamation commit to ongoing analytical efforts as part of the CWF AMP to accurately characterize the conditions in the near future when benefits of in-progress restoration projects (e.g., Cache Slough and Suisun Marsh) have begun to be realized. DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA

[1] As stated previously, according to the draft DFW's 2081(b) ITP, permit terms become operative at issuance of the SWRCB order approving the change of point of diversion for DWR and Reclamation, consistent with the requirements of the Delta Reform Act of 2009.

standards for any project-related effects on the frequency, duration, and magnitude of reverse flows caused by NDD operations. Restoration opportunities will align with species recovery needs and be guided by information in the Salmon Resiliency Strategy. Furthermore, DWR and Reclamation commit as part of the AMP to a monitoring program to assess the performance of these actions and modify the mitigation approach as necessary to offset the effects of the project as they are better understood.

Description of Analysis and Results:

Reverse Flows

Analyses were provided on April 26, 2017 in email from Garner Jones (DWR) – Draft write-up entitled "TIDAL HABITAT RESTORATION EFFECTS ON SACRAMENTO RIVER REVERSE FLOWS AT GEORGIANA SLOUGH":

There is concern regarding the potential for water export by the proposed north Delta diversions (NDD) to increase the incidence of reverse flows in the Sacramento River at Georgiana Slough, thereby increasing the potential for downstream-migrating juvenile salmonid entry into the interior Delta, where survival is significantly reduced (Perry et al. 2010, 2012; Singer et al. 2013). Although real-time operations would aim to minimize such effects by ramping down NDD operations when pulses of juvenile salmonids are migrating through the Delta, concern remains as to this potential effect. As illustrated in the public draft Bay Delta Conservation Plan (BDCP), tidal habitat restoration's redirection of tidal energy away from the Sacramento River–Georgiana Slough junction has the potential to more than offset NDD effects on reverse flow relative to a baseline, no action alternative that does not include either the NDD or tidal habitat restoration (DWR 2013: Appendix 5.C *Flow, Passage, Salinity, and Turbidity*, Section 5C.5.3.8 *Sacramento River Reverse Flows Entering Georgiana Slough*). This ability of tidal marsh restoration in the Cache Slough complex to influence the tidal conditions in the Sacramento River near Georgiana Slough was documented in the BDCP discussions as early as 2009 (BDCP Integration Team Technical Studies). Several hypothetical restoration scenarios were considered as part of initial BDCP discussions, which included around 6,750 acres, 13,000 acres, and 20,000 acres of restoration in the Cache Slough complex.

The draft BDCP modeling included around 25,000 acres of tidal habitat restoration in the Delta and Suisun Marsh by 2025, with around 13,000 acres in the Cache Slough complex. DSM2-HYDRO modeling illustrated that tidal habitat restoration results in less reverse flow for a given Sacramento River bypass flow downstream of the NDD (Figure 1). The three scenarios depicted in Figure 1 include EBC2 (which represented existing climate and sea level, with operational criteria the same as the CWF NAA scenario), EBC2_ELT (same operating criteria, climate, and sea level as the CWF NAA scenario), and ESO_ELT (similar to the CWF PA scenario, but with tidal habitat restoration). As described by DWR (2013: Appendix 5.C Flow, Passage, Salinity, and Turbidity, Section 5C.5.3.8 Sacramento River Reverse Flows Entering Georgiana Slough), smoothed relationships between mean monthly bypass flow and the percentage of each month with reverse flows were created for each of these scenarios using generalized additive models (GAM with 4 degrees of freedom; Figure 2).

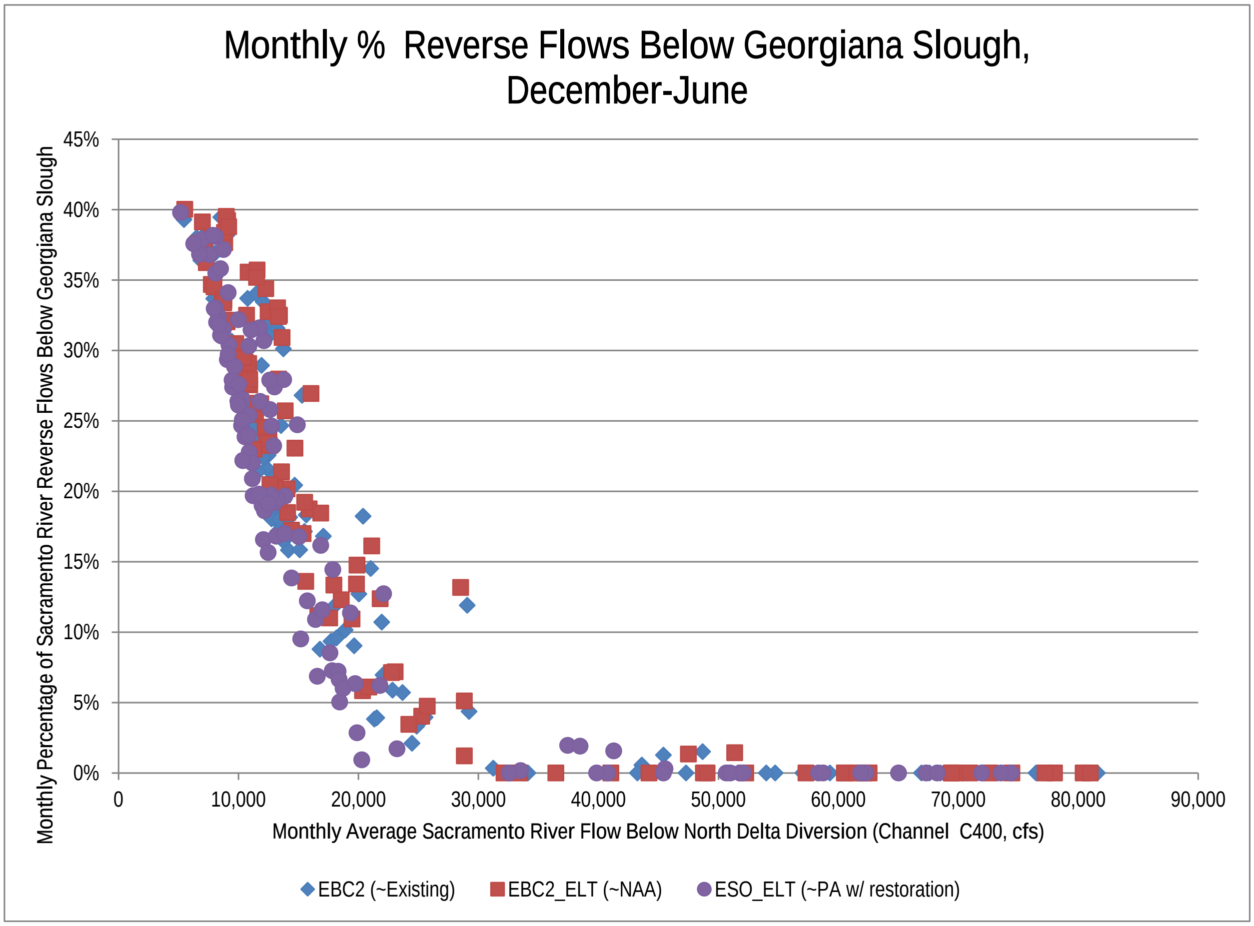

Figure 1. DSM2-HYDRO-Modeled Percentage of Each Month With Reverse Flows at Sacramento River Below Georgiana Slough (DSM2 Channel 423 at 1000 feet; SAC_37) Versus Mean Monthly Flow in the Sacramento River Below the North Delta Diversions (CALSIM Channel C-400), December–June 1976–1991

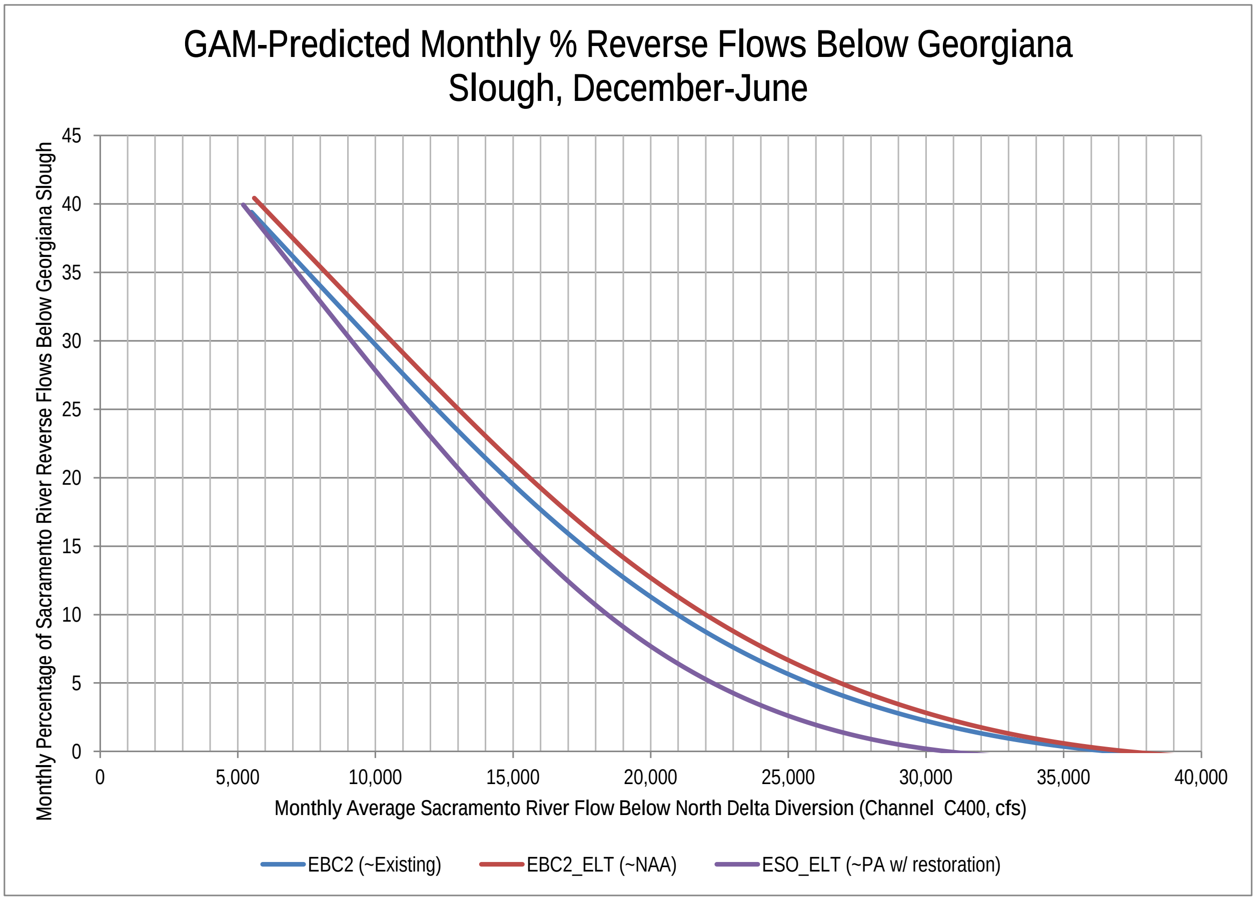

Figure 2. Generalized Additive Model Splines of DSM2-HYDRO-Modeled Percentage of Each Month With Reverse Flows at Sacramento River Below Georgiana Slough (DSM2 Channel 423 at 1000 feet; SAC_37) Versus Mean Monthly Flow in the Sacramento River Below the North Delta Diversions (CALSIM Channel C-400), December–June 1976–1991.

Using the GAM relationships illustrated in Figure 2, predictions of reverse flow percentage were created for 100-cfs bypass flow increments between ~5,500 cfs and 45,000 cfs. These were then related to mean monthly flow by water-year type for the CWF NAA, PP, and PP_{LFS} scenarios (see Table 4.D-4 in Appendix 4.D *Comparison of Key Hydrological Variables for Proposed Project with Longfin Smelt Spring Outflow Criteria to No Action Alternative and Proposed Project Scenarios* of the CWF ITP application), rounded to the nearest 100 cfs. This shows that for the months of December–June, which are the main months of interest for juvenile outmigrating salmonids, inclusion of several thousand acres of tidal habitat restoration in the Cache Slough complex generally would offset effects of less bypass flow under the PP, particularly when Delta outflow criteria for longfin smelt are included (PP_{LFS}) (Table 1).

Month	Year Type	Mean Flow (cfs) NAA	PP	PP_{LFS}	Predicted % Reversal NAA	PP	PP_{LFS}	Absolute % Difference PP - NAA	PP_{LFS} - NAA
Dec	W	36,300	33,100	33,200	0.2	0.0	0.0	-0.2	-0.2
	AN	24,700	22,500	22,500	7.0	4.7	4.7	-2.2	-2.2
	BN	15,800	14,200	14,200	19.6	18.0	18.0	-1.6	-1.6
	D	13,600	12,700	12,800	23.8	21.4	21.2	-2.5	-2.7
	C	11,200	10,300	10,300	28.7	27.1	27.1	-1.6	-1.6
Jan	W	49,300	42,900	43,000	0.0	0.0	0.0	0.0	0.0
	AN	38,600	33,000	33,000	0.0	0.0	0.0	0.0	0.0
	BN	18,300	16,400	16,500	15.3	13.6	13.4	-1.7	-1.9
	D	17,200	15,600	15,600	17.1	15.1	15.1	-2.0	-2.0
	C	14,100	13,300	13,300	22.9	20.0	20.0	-2.8	-2.8
Feb	W	56,600	48,800	48,700	0.0	0.0	0.0	0.0	0.0
	AN	46,700	40,000	40,100	0.0	0.0	0.0	0.0	0.0
	BN	30,300	26,300	26,300	2.6	1.8	1.8	-0.9	-0.9
	D	23,400	20,100	20,100	8.3	7.5	7.5	-0.8	-0.8
	C	16,000	14,200	14,200	19.3	18.0	18.0	-1.2	-1.2
Mar	W	48,000	40,100	40,400	0.0	0.0	0.0	0.0	0.0
	AN	40,800	34,100	35,400	0.0	0.0	0.0	0.0	0.0
	BN	18,500	15,100	16,100	15.0	16.1	14.1	1.2	-0.8
	D	21,300	17,300	17,900	10.9	11.9	10.9	1.0	0.0
	C	12,500	11,700	11,600	26.0	23.7	23.9	-2.3	-2.1
Apr	W	35,000	32,400	30,800	0.6	0.0	0.0	-0.6	-0.6
	AN	24,100	22,900	22,400	7.6	4.4	4.9	-3.2	-2.7
	BN	14,100	13,600	13,700	22.9	19.3	19.1	-3.5	-3.7
	D	14,900	14,300	14,200	21.3	17.8	18.0	-3.5	-3.3
	C	10,300	10,100	10,200	30.6	27.6	27.3	-3.0	-3.2
May	W	29,800	26,700	26,000	2.9	1.5	1.9	-1.4	-1.0
	AN	16,700	15,400	15,500	18.0	15.5	15.3	-2.5	-2.7
	BN	12,500	12,000	11,900	26.0	23.0	23.2	-3.0	-2.8
	D	11,600	11,400	11,300	27.9	24.4	24.7	-3.5	-3.2
	C	8,200	8,000	8,000	35.0	32.9	32.9	-2.1	-2.1
Jun	W	20,000	15,100	15,100	12.7	16.1	16.1	3.4	3.4
	AN	13,400	11,500	11,400	24.2	24.2	24.4	0.0	0.2
	BN	12,800	12,000	12,000	25.4	23.0	23.0	-2.4	-2.4
	D	12,600	11,500	11,900	25.8	24.2	23.2	-1.7	-2.6
	C	9,300	9,100	9,200	32.7	30.1	29.8	-2.6	-2.8

Red highlights indicate >0.5% more under PP or PP_{LFS} than NAA

Green highlights indicate >0.5% less under PP or PP_{LFS} than NAA

Rearing Habitat Restoration

NMFS used the WRLCM to evaluate the proposed habitat restoration from the Revised PA along with some fish routing actions (Figure 2-184). Scenario #1 was developed as a test-run for the model to implement the various proposed actions and evaluate how the model treated those additions. Scenario #2 captures the habitat restoration being proposed as part of the PA, as well habitat restoration that is being recommitted to in the Revised PA that was originally part of the NMFS 2009 BiOp RPA and/or EcoRestore.

Scenario	Benefit	Proposed Actions							
		Fish Routing				Habitat Restoration			
		Delta Cross Channel Gate Ops	Fremont Weir – Yolo Bypass	Georgiana Slough Barrier (non-physical)	Steamboat Slough Fish Guidance	Sutter Slough Fish Guidance	Upper Sac Convert to natural bank, Backwater/ Floodplain	Lower Sac Non-tidal wetland/ Floodplain	Delta Tidal Marsh
1	Low	NAA	15% more fish migrants into Yolo	Entrainment reduced by a relative 50%	Increase entrainment by 15%	Increase entrainment by 15%	Increase habitat capacity by 80 acres	Increase habitat capacity by 80 acres	Increase habitat capacity by 80 acres
2	Med	NAA	15% more fish migrants into Yolo	Entrainment reduced by a relative 50%	Increase entrainment by 15%	Increase entrainment by 15%	Increase habitat capacity by 80 acres	Increase habitat capacity by 9,000 acres	Increase habitat capacity by 11,000 acres
Model Representation	Current	PA	Proposed Fremont Weir	None	None	None	Existing habitat	Existing habitat	Existing habitat
	New	NAA	An additional percentage of fish enter Yolo	Reduce relative percentage of fish entering GS	Increase percentage of fish entering Steamboat Slough	Increase percentage of fish entering Sutter Slough	Add habitat	Add habitat	Add habitat
	Steps	DCC closure as NAA	Adjust LCM code	1. Adjust Hydrofile 2. ePTM run 3. LCM	1. Adjust Hydrofile 2. ePTM run 3. LCM	1. Adjust Hydrofile 2.ePTM run 3. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM	1. Alter HEC-RAS geometry to estimate increased habitat capacity 2. LCM

Figure 2-184. Habitat Restoration and Fish Routing Scenarios Evaluated with the Winter-run Life Cycle Model.

This analysis focused on the evaluation of change in cohort replacement rate between Scenario 2 and NAA as compared to the original analysis of the change in cohort replacement rate between the PA and NAA to demonstrate the population level benefits of the proposed habitat restoration and fish routing activities. The percent difference in mean cohort replacement rate under SA was approximately 1% better under all the scenarios when compared to the PA (Table 2-235 and Table 2-236). The restored habitat in the Lower River increased the proportion of fry rearing and subsequently smolting in this habitat; however, the Lower River smolts experienced through-delta survival rates that were affected by the north Delta diversions. The implementation of non-physical barriers at Georgiana Slough, Steamboat Slough, and Sacramento Slough under S2 did improve the survival rates of smolts originating in the Lower Sacramento River over the PA. These routing measures did not fully mitigate for the overall reduction in smolt survival due to operation of the North Delta Diversions under the PA, however.

Table 2-235. Percent Difference in Winter-run Chinook Salmon Cohort Replacement Rate Between Scenario Two (S2) and NAA.

CWF Alternative (S2, NAA) Comparison	Percent Difference in mean CRR (S2-NAA /NAA)	Percent Difference in median CRR (S2-NAA /NAA)	Pr (NAA > S2)
Scenario 1	-7.19%	-6.58%	0.999
Scenario 1A	-7.85%	-6.31%	0.999
Scenario 1B	-8.16%	-6.64%	0.998
Scenario 2	-8.37%	-6.70%	0.998
Scenario 2A	-6.98%	-5.36%	0.998
Scenario 2B	-7.80%	-6.16%	0.998

Table 2-236. Percent Difference in Winter-run Chinook Salmon Cohort Replacement Rate Between PA and NAA.

CWF Alternative (PA, NAA) Comparison	Percent Difference in mean CRR (PA-NAA /NAA)	Percent Difference in median CRR (PA-NAA /NAA)	Pr (NAA > PA)
Scenario 1	-8.72%	-7.72%	0.997
Scenario 1A	-8.51%	-7.53%	0.998
Scenario 1B	-8.92%	-7.92%	0.998
Scenario 2	-9.18%	-7.94%	0.998
Scenario 2A	-7.75%	-6.56%	0.998
Scenario 2B	-8.59%	-7.37%	0.998

Conclusions:

Reverse Flows

In the absence of specific information in the CWF Biological Assessment, the CWF Biological Opinion (Opinion) relies on the NDD bypass evaluation in the smolt entrainment model to evaluate the likelihood of reverse flows and proportion of daily reverse flows in the Sacramento River downstream of Georgiana Slough under the PA without extensive real-time operations adjustments. Unlimited pulse protections, which as described in the PA would be implemented through real-time operations at the NDD, cannot be modeled with the tools described here but are evaluated with a different level of analysis discussed in CWF Opinion Section 2.5.1.2.7.4 Delta Survival. In addition, in the June 2017 Revised PA, DWR committed to additional Delta habitat restoration that is expected to change the tidal prism so that the operational commitment of not exacerbating reverse flows in the north Delta can be met.

As illustrated in the public draft Bay Delta Conservation Plan (BDCP), tidal habitat restoration's redirection of tidal energy away from the Sacramento River–Georgiana Slough junction has the potential to more than offset NDD effects on reverse flow relative to a no action alternative (reflecting continuation of the environmental baseline) that does not include either the NDD or tidal habitat restoration (DWR 2013: Appendix 5.C Flow, Passage, Salinity, and Turbidity, Section 5C.5.3.8 Sacramento River Reverse Flows Entering Georgiana Slough). Several hypothetical restoration scenarios were considered as part of initial BDCP discussions, which included around 6,750 acres, 13,000 acres, and 20,000 acres of restoration in the Cache Slough complex (see Appendix G Habitat Restoration of this Opinion). The PA adds 1,800 acres of Delta tidal habitat restoration to the existing commitments for 9,000 acres of Delta tidal habitat restoration, which in total according to DSM2-HYDRO modeling will mute reverse flows to varying degrees depending on Sacramento River outflow (see Figures 1 and 2 in Appendix G Habitat Restoration of this Opinion).

In addition to the 1,800 acres, the PA states, " DWR and Reclamation also commit to providing the restoration type, location, and amount that, in combination with other changes to baseline, would be necessary to meet ESA and CESA standards for any project-related effects on the frequency, duration and magnitude of reverse flows caused by NDD operations…Furthermore, DWR and Reclamation commit as part of the AMP to a monitoring program to assess the performance of these actions and modify the mitigation approach as necessary to offset the effects of the project as they are better understood." Therefore, Reclamation and DWR are not only commiting to an additional 1,800 acres, but are also committing to a new program of Delta habitat restoration that will be driven by the PA objective of the project not exacerbating reverse flows in the North Delta/Lower Sacramento River area, and be based on science, monitoring and adaptive management.

NMFS expects that tidal habitat restoration (both the additional 1,800 acres and the new objective-driven program) in combination with reductions in NDD diversions due to real-time operation pulse protection actions will prevent the exacerbation of reverse flows in the north Delta. Therefore, the Calsim modeling for the PA represents a worst-case scenario analysis. The Calsim modeling for the PA does not account for the prevention of additional reverse flows in the north Delta that is expected with proposed NDD operations. Therefore, the analysis presented here, which is based on the Calsim modeling, includes an increase in flow reversals and the subsequent impacts to migrating salmonids, but the increase is expected to be prevented or reduced to some degree under the PA.

Habitat Restoration

NMFS expected the results to show more improvement in the winter-run Chinook salmon cohort replacement rate under S2. This moderate improvement is likely due to the population dynamics of the winter-run Chinook salmon (one population at low abundance) and how the different aspects of the species life-cycle are modeled relative to the fishes habitat use. The proposed Delta habitat restoration did not improve the cohort replacement rate under this scenario because the current low abundance of the winter-run population is not limited by Delta rearing habitat. As the population abundance increases because of recovery action implementation (such as newly reintroduced populations in Battle Creek and upper Sacramento River – above Shasta Reservoir) the availability of additional tidal Delta rearing habitats will become more important for the species.

Appendix E

Analysis of UPP

Using Perry Survival Model

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
West Coast Region
650 Capitol Mall, Suite 5-100
Sacramento, California 95814-4700

June 16, 2017

MEMORANDUM FOR: ARN: 151422-WCR2016-SA00204

FROM: Cathy Marcinkevage, California WaterFix Branch,
Erin Strange, San Joaquin River Basin Branch, California Central Valley Office, West Coast Region

REVIEWED BY: Maria Rea, Assistant Regional Administrator, California Central Valley Office, West Coast Region

SUBJECT: Technical memorandum regarding analysis of revised NDD real-time operations of the California WaterFix

Purpose of Analysis:

The purpose of this analysis is to identify change in annual mean through-Delta survival rates for migrating winter-run and spring-run Chinook salmon affected by the California WaterFix (CWF) proposed action (PA) based on analysis of the June 2, 2017, initial approach to the real-time operations of the north Delta diversions (NDD) using river flow data and Knights Landing catch index data from 2003-2012 and 2014 water years.

Background:

RTO for the NDD proposed in the August 2, 2016, BA submission were partially determined by the Knights Landing catch index (X_p), whereby the capture five or more winter-run-sized and spring-run-sized fish would trigger fish pulse protection operations downriver at the NDD (i.e., reduced water diversion flows). The operations included the implementation of pulse protection for a maximum of two pulses.

On June 2, 2017, Reclamation submitted a Revised PA that included revisions to the NDD RTO. The objective of these revisions are to lessen the adverse impacts of both PA and Level 1 Only (L1) operational scenarios identified in the January 21, 2017, Initial Draft Biological Opinion effects analysis.

The Revised PA Unlimited Pulse Protection scenario (UPP or Revised) includes revisions such that the real-time operations of the north Delta diversions are as described in BA Section 3.3.3.1 North Delta Diversion. Specifically,

> *"…Under RTOs, the NDD would be operated within the range of pulse protection, and Levels 1, 2, and 3, depending on risk to fish and with consideration for other factors such as water supply and other Delta conditions, and by implementing pulse protection periods when primary juvenile winter-run and spring-run Chinook salmon migration is occurring. Post-pulse bypass flow operations may remain at Level 1 pumping depending on fish presence, abundance, and movement in the north Delta; however, the exact levels will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping. The specific criteria for transitioning between and among pulse protection and post-pulse bypass flow operations will be based on real-time fish monitoring and hydrologic/ behavioral cues upstream of and in the Delta that will be studied as part of the PA's Collaborative Science and Adaptive Management Plan (Section 3.4.6)…."*

> *"The following operational framework serves as an example that is based on the recommended NDD RTO process (Marcinkevage and Kundargi 2016)…."*

- *A fish pulse is defined as combined catch of X_p winter-run and spring-run sized Chinook salmon in a single day at specified locations.*
- *Upon initiation of fish pulse, operations must reduce to low-level pumping.*
- *Pumping may not exceed low-level pumping for the duration of fish pulse. However, additional pumping above low-level may be allowed as long as a minimum of 35,000 cfs bypass flow is maintained during the period of pulse protection. A fish pulse is considered over after X consecutive days with daily combined catch of winter- and spring run-sized Chinook salmon less than X_p at or just downstream of the new intakes.*
- *Post-pulse bypass flow operations will be determined through initial operating studies evaluating the level of protection provided at various levels of pumping.*
- *All subsequent pulses of winter- and spring-run Chinook salmon will be afforded the same level of protection as the first pulse.*
- *Unlimited fish pulses are protected in any given year.*

Under the UPP scenario, flow operations are adjusted based on capture of winter-run and spring-run Chinook salmon in the Delta. Due to the high likelihood of non-discretionary conditions the pending CDFW California Fish and Game Code section 2081 permit, NMFS has used the permit conditions as initial catch and index values that would trigger operational adjustments for purposes of the analysis in this Opinion.

Catch or index values that would trigger the operational adjustments are not specifically defined in the revised PA; however, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition that triggers pulse protection based on a Knights Landing catch index (X_p) greater than or equal to 5 winter-run-sized and spring-run-sized fish.

The number of days pulse protection would be implemented once triggered are to be based on empirical Chinook smolt migration rates and are not specifically defined under the revised PA; however, CDFW's draft permit for the PA under California Fish and Game Code Section 2081 includes a condition related to pulse protection that considers a pulse to be over when Knights Landing catch index (X_p) is less than 5 for a duration (X) of 5 days. The effectiveness of this operation relies on a robust monitoring program coupled with efficient and expedient real-time operations adjustments.

Description of Analysis:

The following analysis was conducted by evaluating through-Delta survival for previously determined RTO (L1) and revised real time operations (UPP or Revised) based on observed Knights Landing Catch Index for the 2003-2012 and 2014 water years using the Perry Survival Model (Perry 2017). Through-Delta survival for each day of WY 2003-2013 and 2014 was calculated for: 1) No diversion (i.e., bypass discharge = Freeport discharge); 2) L1 real time operations; and 3) Revised real time operations. Daily through-Delta survival was calculated for each draw of the joint-posterior distribution to represent uncertainty in survivability. In addition to daily survival, posterior distributions were calculated for the difference in daily survival of each scenario relative to no diversion. Posterior distributions of annual survival was calculated by weighting each daily survival by the fraction of the total Knights Landing Catch Index for each day. In addition, posterior distributions were calculated for the difference in annual survival of each scenario relative to no diversion.

Assumption #1: Annual survivals were calculated by weighting each daily survival by the fraction of the total Knights Landing Catch Index for each day. In addition, the difference in annual survival of each scenario relative to NAA (i.e., no diversion from the new NDD facility) were calculated. Because this analytical method is bound by the frequency of monitoring and capture efficiency at Knights Landing, the reliance on the existing Knights Landing monitoring data could underestimate both the abundance and the temporal extent of winter-run and spring-run Chinook salmon presence during the migration season. As described in PA, the final development of the trigger values and monitoring location would depend on: 1) operation of a new or additional monitoring station(s) closer to the NDD, 2) the method used to identify winter-run and spring-run Chinook salmon, and 3) the collection of sufficient fish monitoring data collected during the appropriate time of year with a large enough sample size with appropriate sampling gear to estimate fish abundance not just presence.

Assumption #2: The violin plots used to describe mean annual survival are not inclusive of all daily survival probabilities that could occur during the winter-run and spring-run Chinook salmon migration window for any given year. These only include survival probabilities for those days when winter-run and spring-run Chinook salmon were captured at Knights Landing. If no catch occurred, the daily survival rates were not included in the estimate of mean annual survival because the proportion of total annual catch for those days was zero. Therefore, the results may underestimate the survival reductions experienced in any given year since fish presence is solely dependent on fish catch at Knights Landing. In other words, this modeling exercise assumes any fish present would be captured with 100 percent accuracy, which is an overestimate given that 100 percent catch is extremely unlikely. Furthermore, UPP would cease when capture of fish is fewer than 5 winter-run or spring-run Chinook sized fish for five consecutive days, thereby exposing any fish still present near or downstream of the intakes to the more adverse L1, L2, or L3 operating scenarios

Assumption #3: Fish passing Knights Landing on a given day experience the calculated bypass flows on that day. This means that for the purposes of this analysis: 1) no lag time was applied to the weighted survival values to account for fish travel time from Knights Landing to the north Delta diversion, and 2) no travel times were applied to different reaches within the Delta to account for flow variation over a given cohort of fish. When real-time operations are implemented, new/additional monitoring locations and information from baseline studies are expected to allow a better characterization of the typical travel time, and therefore lag time, from monitoring stations to the diversion locations. This would allow better resolution of fish presence and abundance to coordinate operations.

Results:

Compared to the previously-proposed operations, the survival analysis of the application of the revised initial approach to NDD real-time operations to river flow and Knights Landing catch index data from 2003-2012 and 2014 shows either a general improvement or no difference in annual mean survival. As seen in the panel plots below (all odd-numbered figures; see in particular, the third panel of each plot), survival increases during the migration pulses (as characterized by the catch index data) in the UPP scenario compared to the L1 scenario due to the general increase in bypass flow during those pulses. When viewing results, the time series of daily trends in survival (summarized in the panel plots), are more informative than the seasonal average (summarized in the violin plots; all even-numbered figures). For example, even when there was little difference in mean annual survival between scenarios, the daily trends often revealed that survival was more frequently higher under revised operations compared to the L1 scenario. Last, we caution that the mean annual survivals are generated using catch at the Knights Landing rotary screw traps as an index of abundance and run timing, but given very low capture probabilities (likely 1% or less), the annual mean survival likely under-represents survival on days when catch was zero during times where true abundance is expected to be greater than zero.

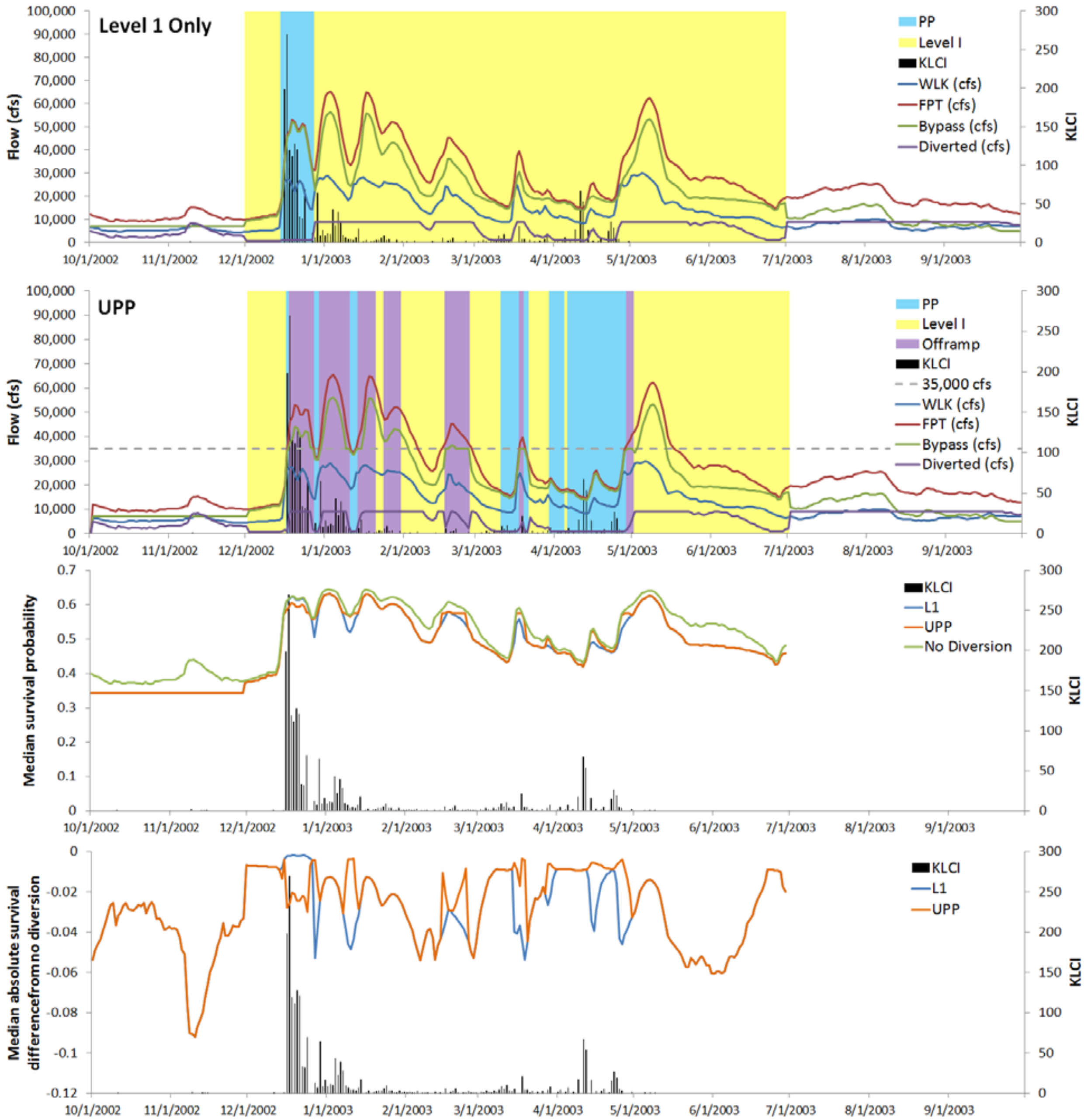

Figure 1. Summary for Water Year 2003 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

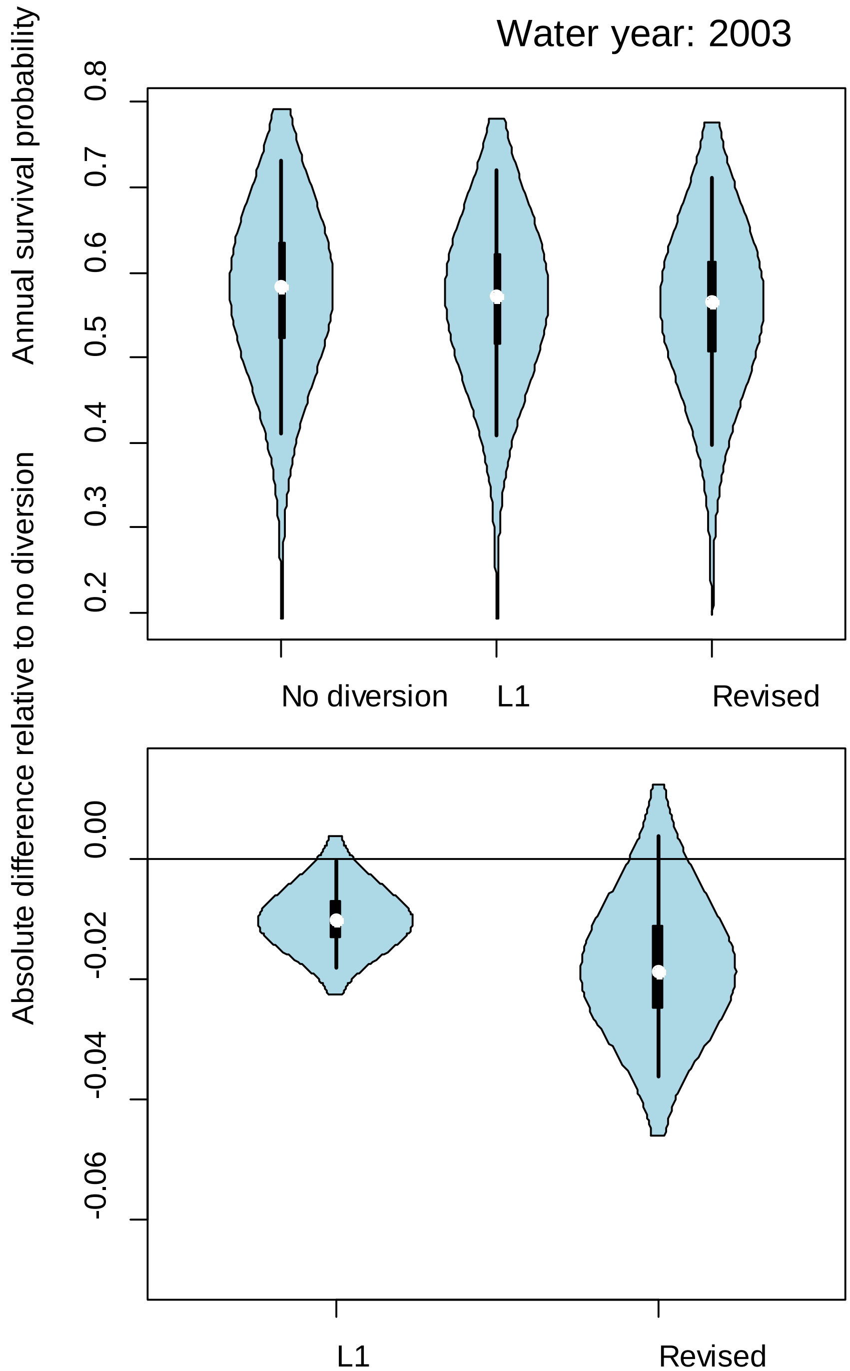

Figure 2. Violin plots for Water Year 2003 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

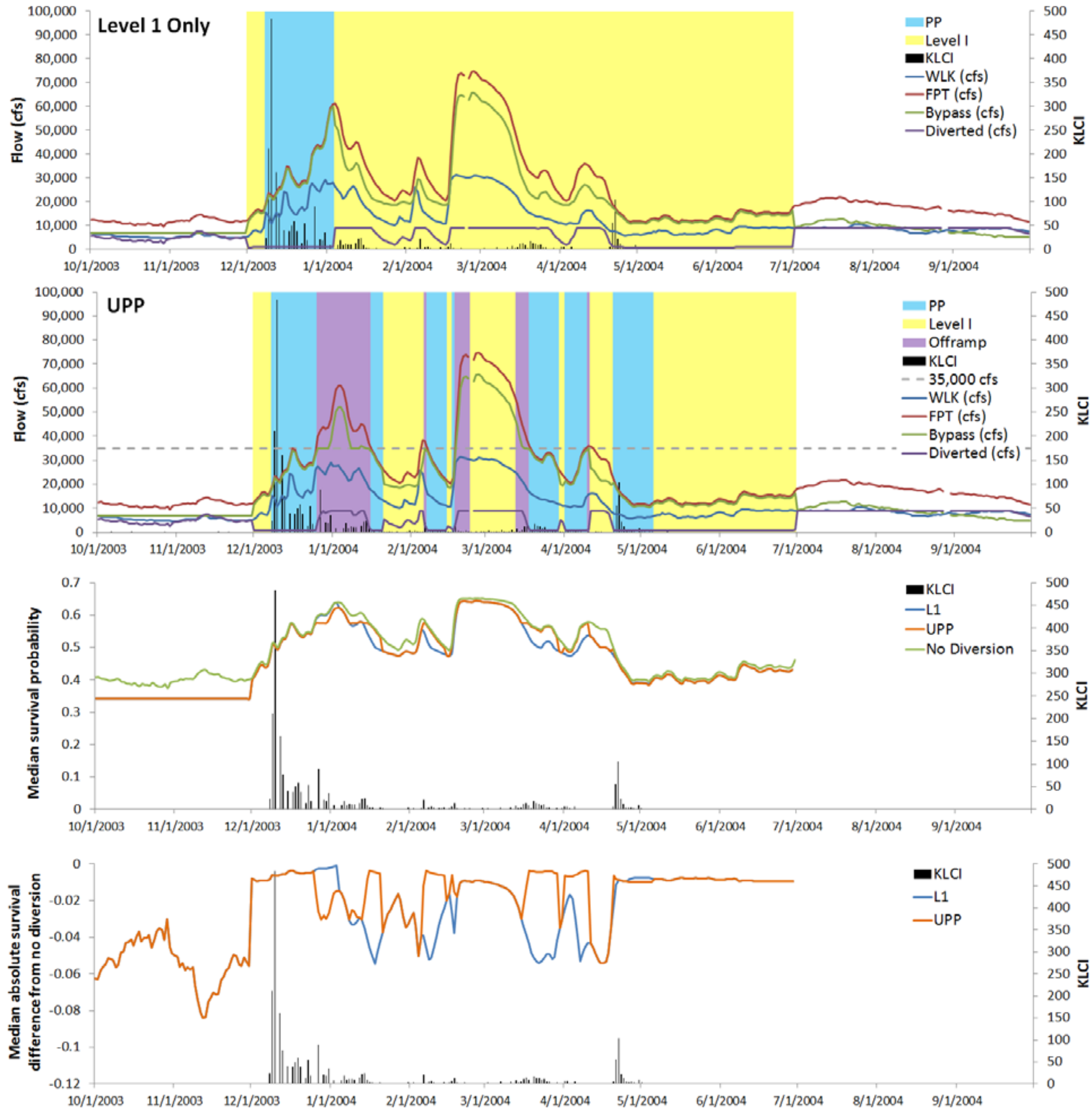

Figure 3. Summary for Water Year 2004 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

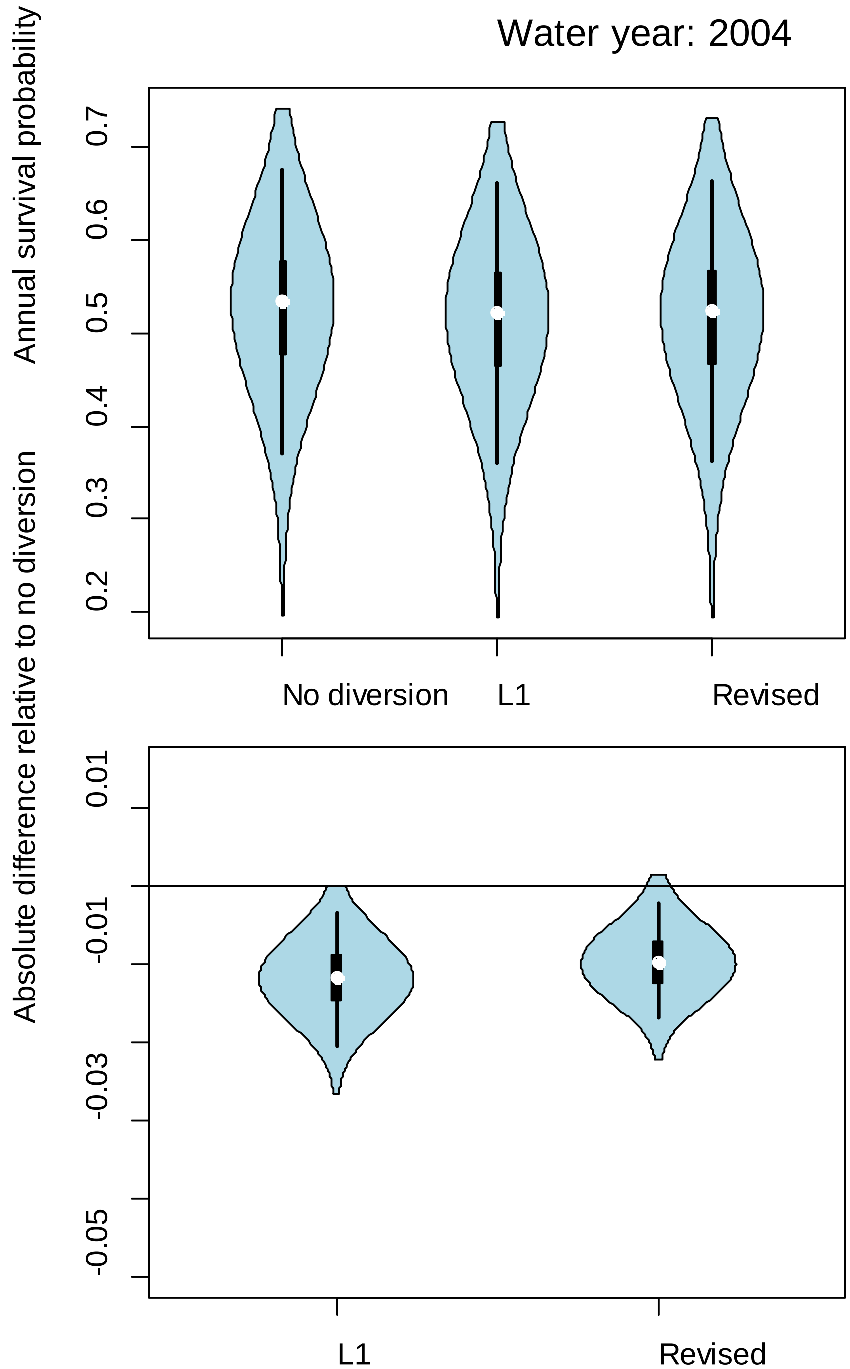

Figure 4. Violin plots for Water Year 2004 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

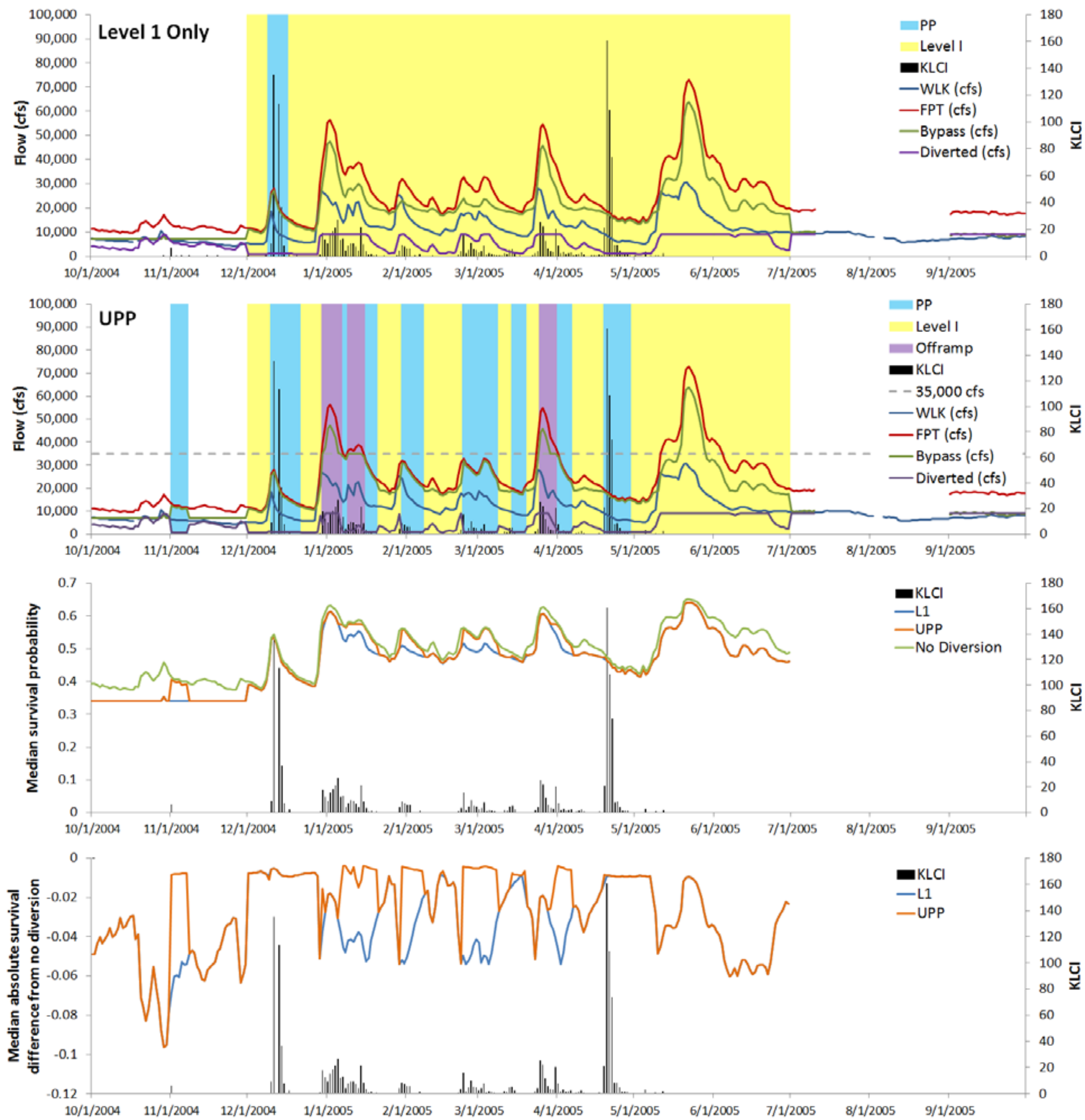

Figure 5. Summary for Water Year 2005 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

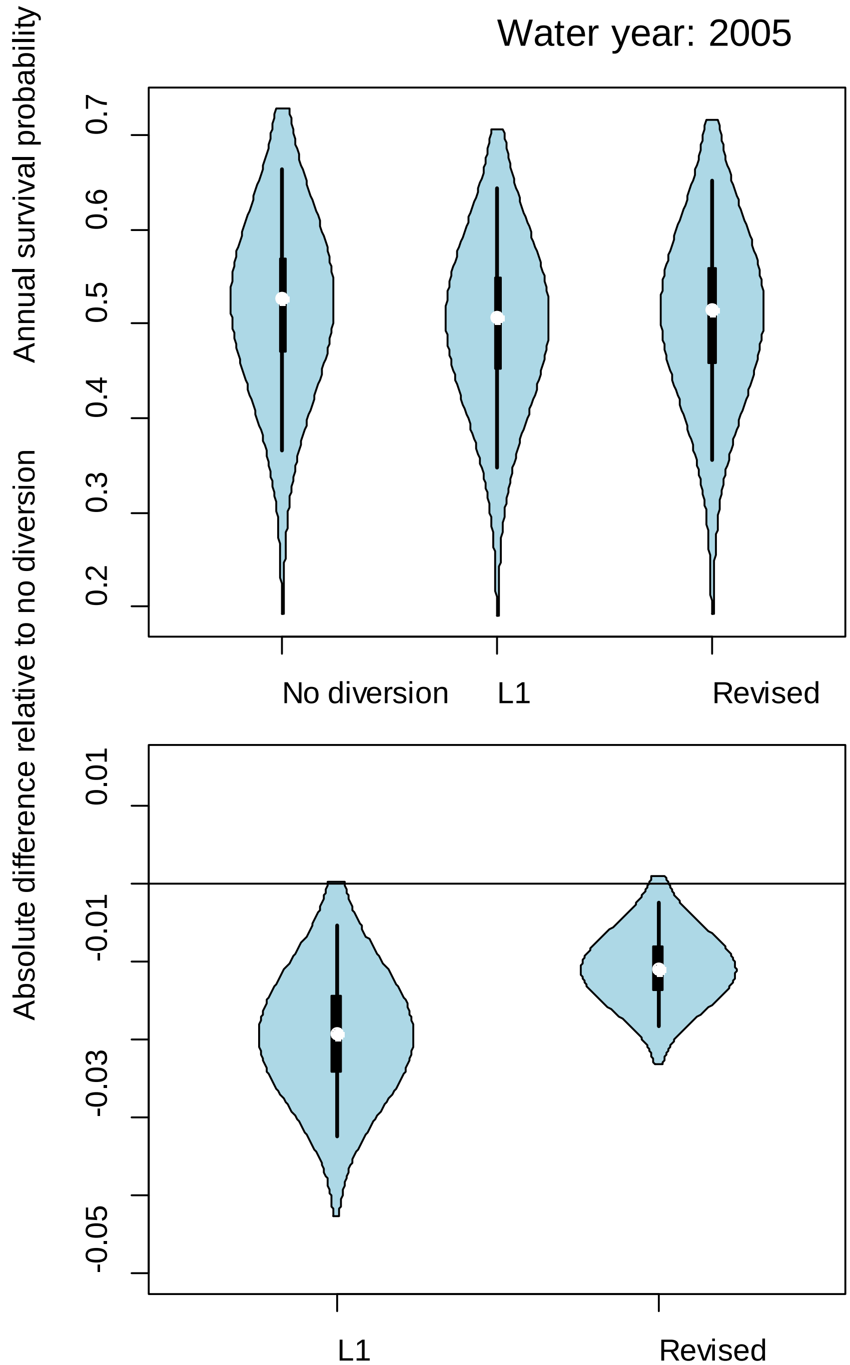

Figure 6. Violin plots for Water Year 2005 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

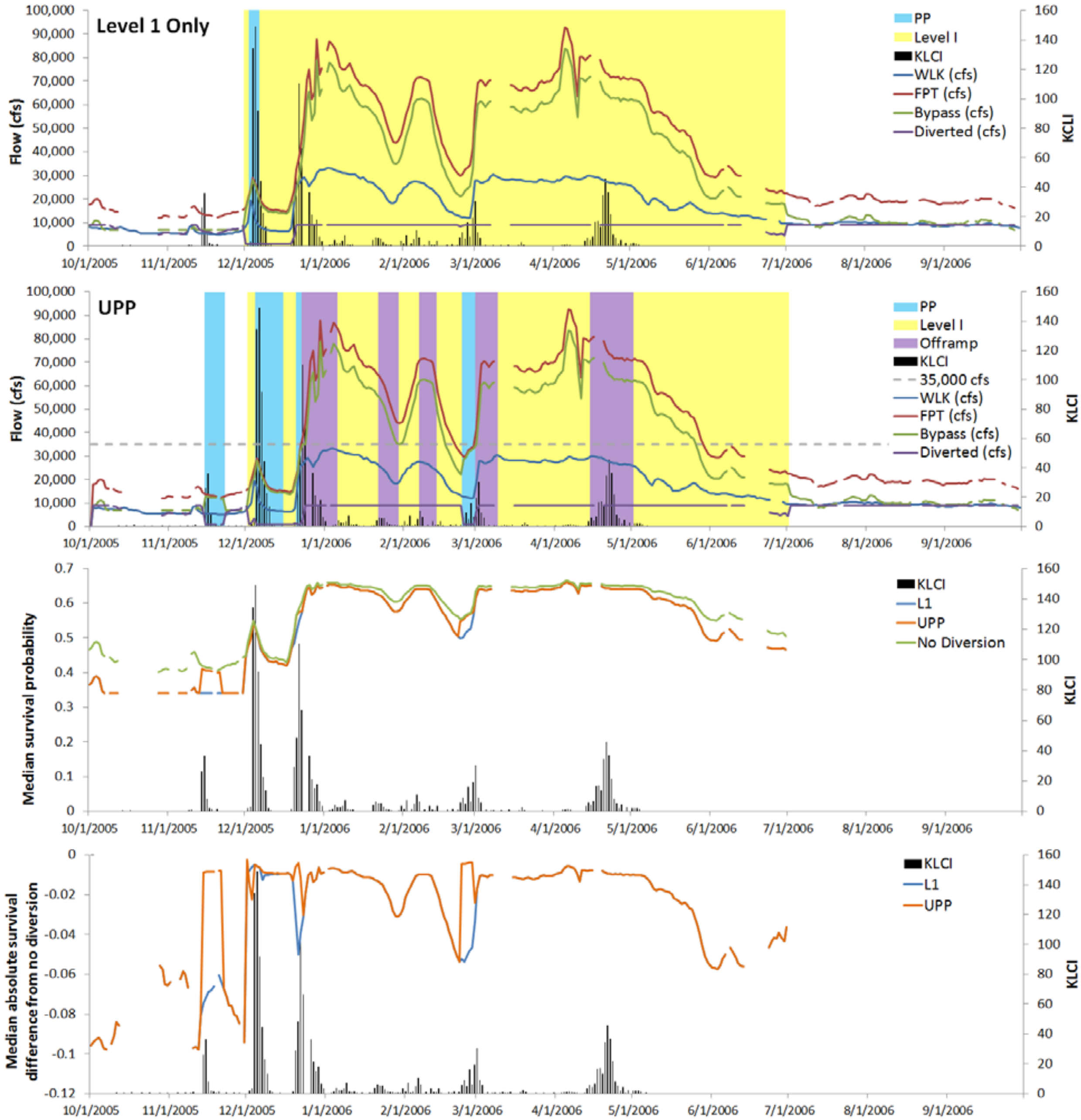

Figure 7. Summary for Water Year 2006 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

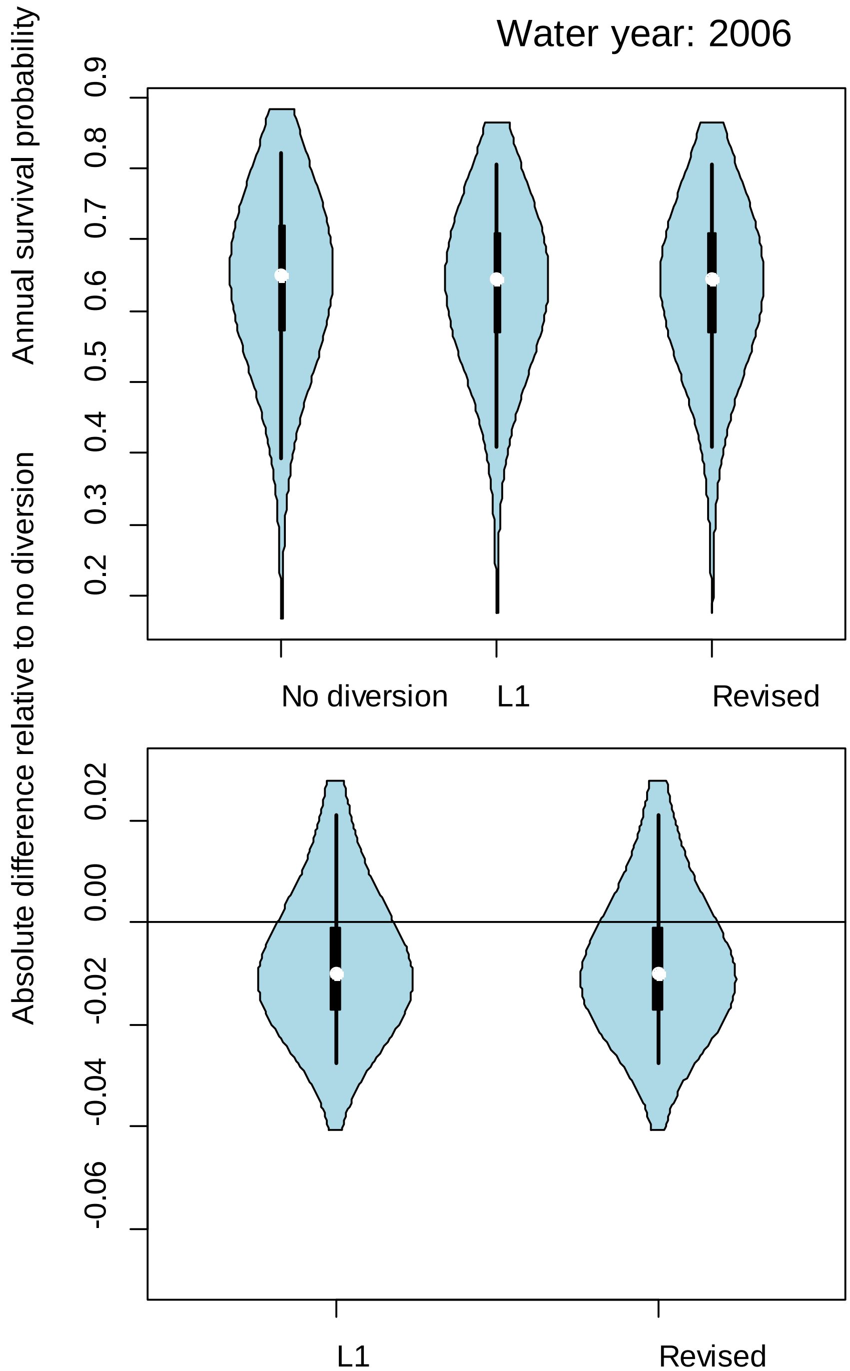

Figure 8. Violin plots for Water Year 2006 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

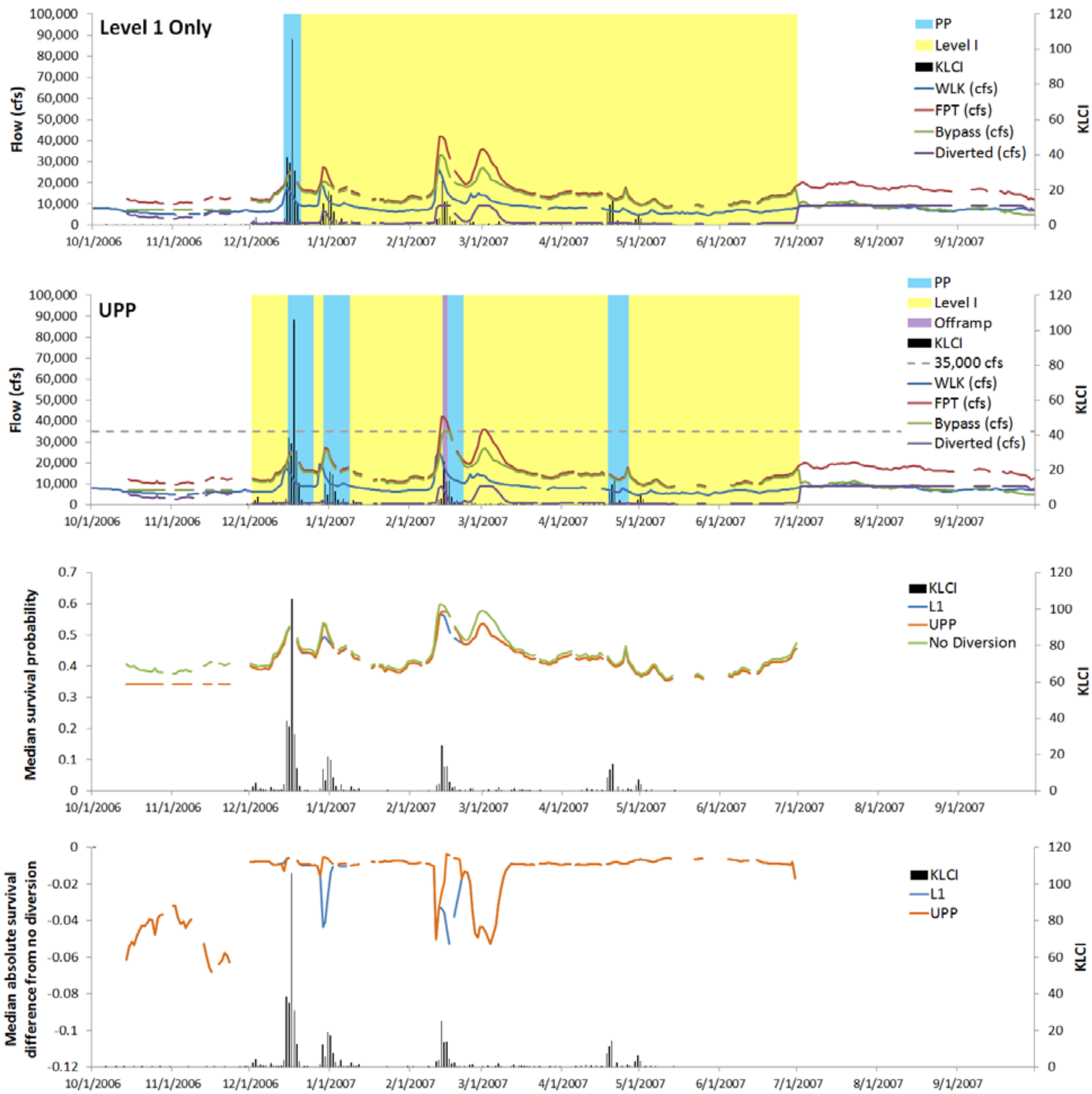

Figure 9. Summary for Water Year 2007 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2^{nd} panel), median daily through-Delta survival (3^{rd} panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

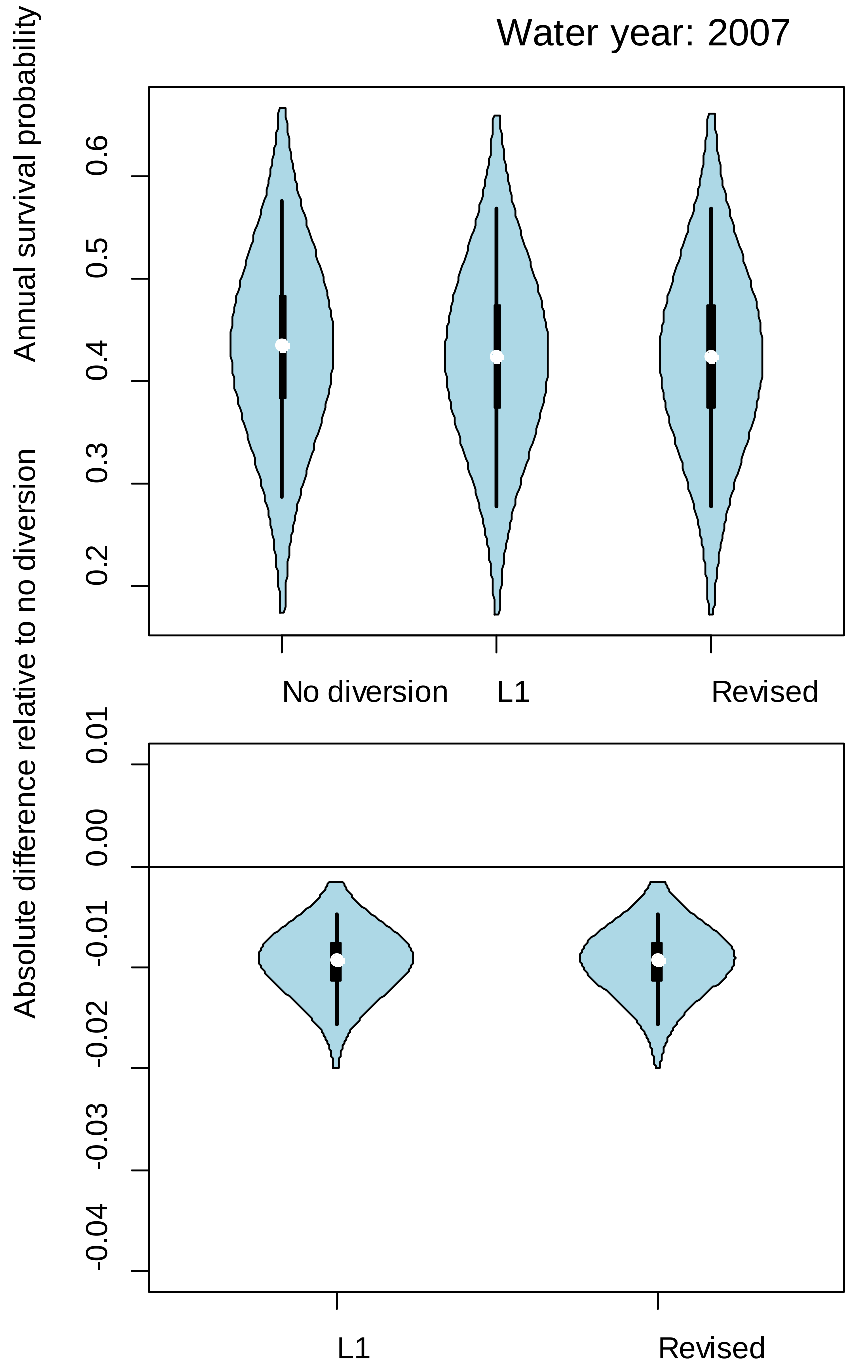

Figure 10. Violin plots for Water Year 2007 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

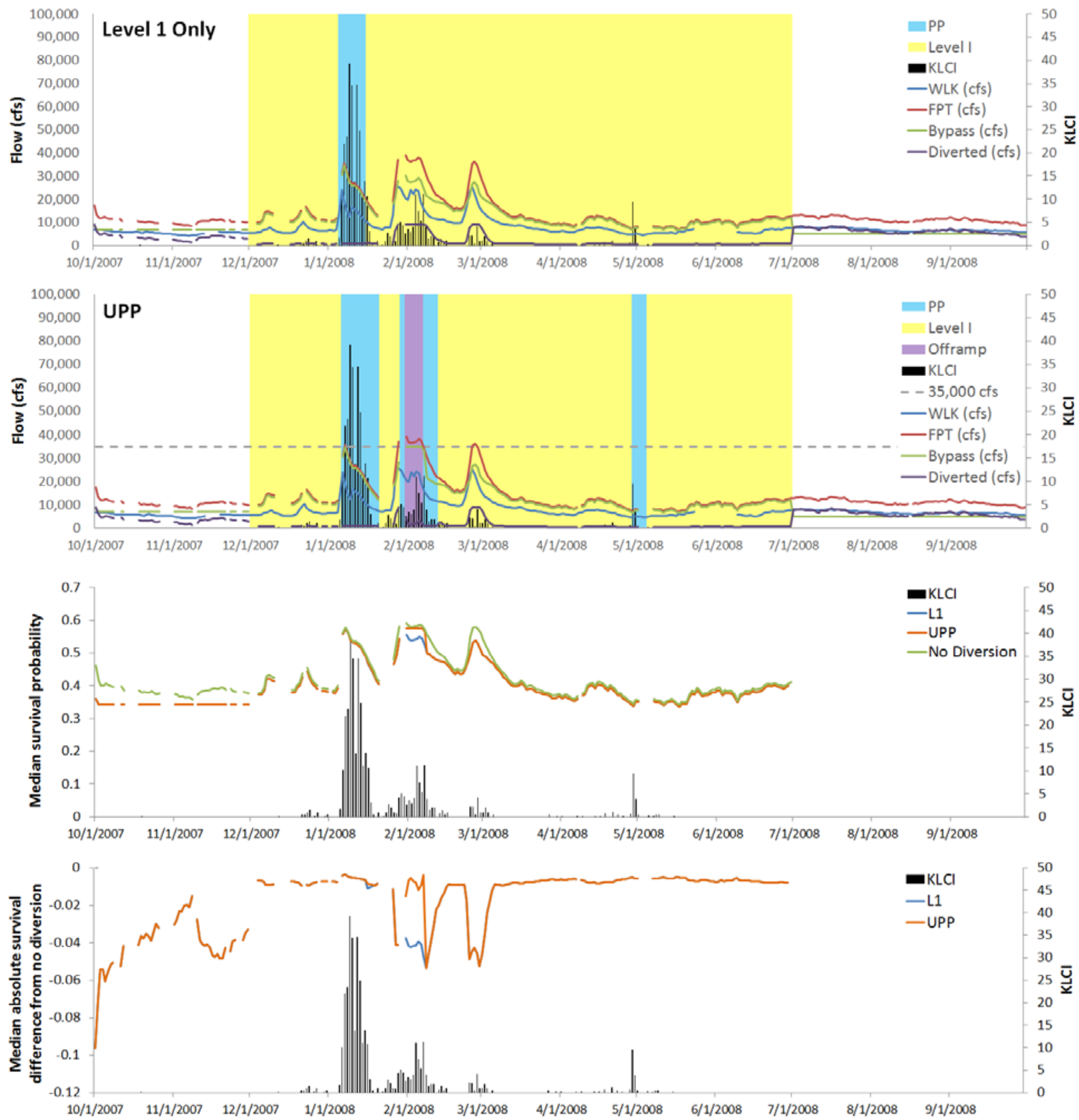

Figure 11. Summary for Water Year 2008 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

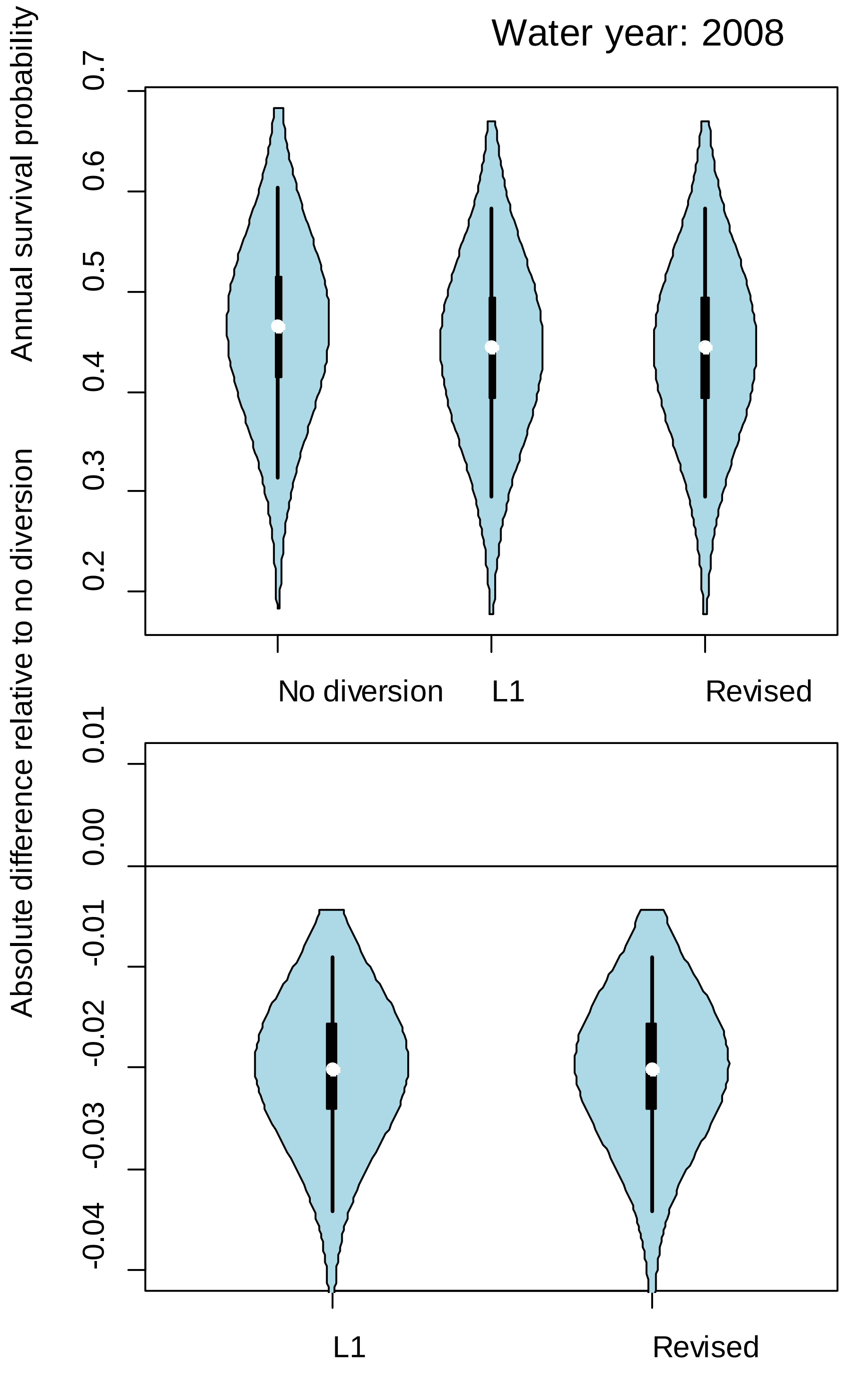

Figure 12. Violin plots for Water Year 2008 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

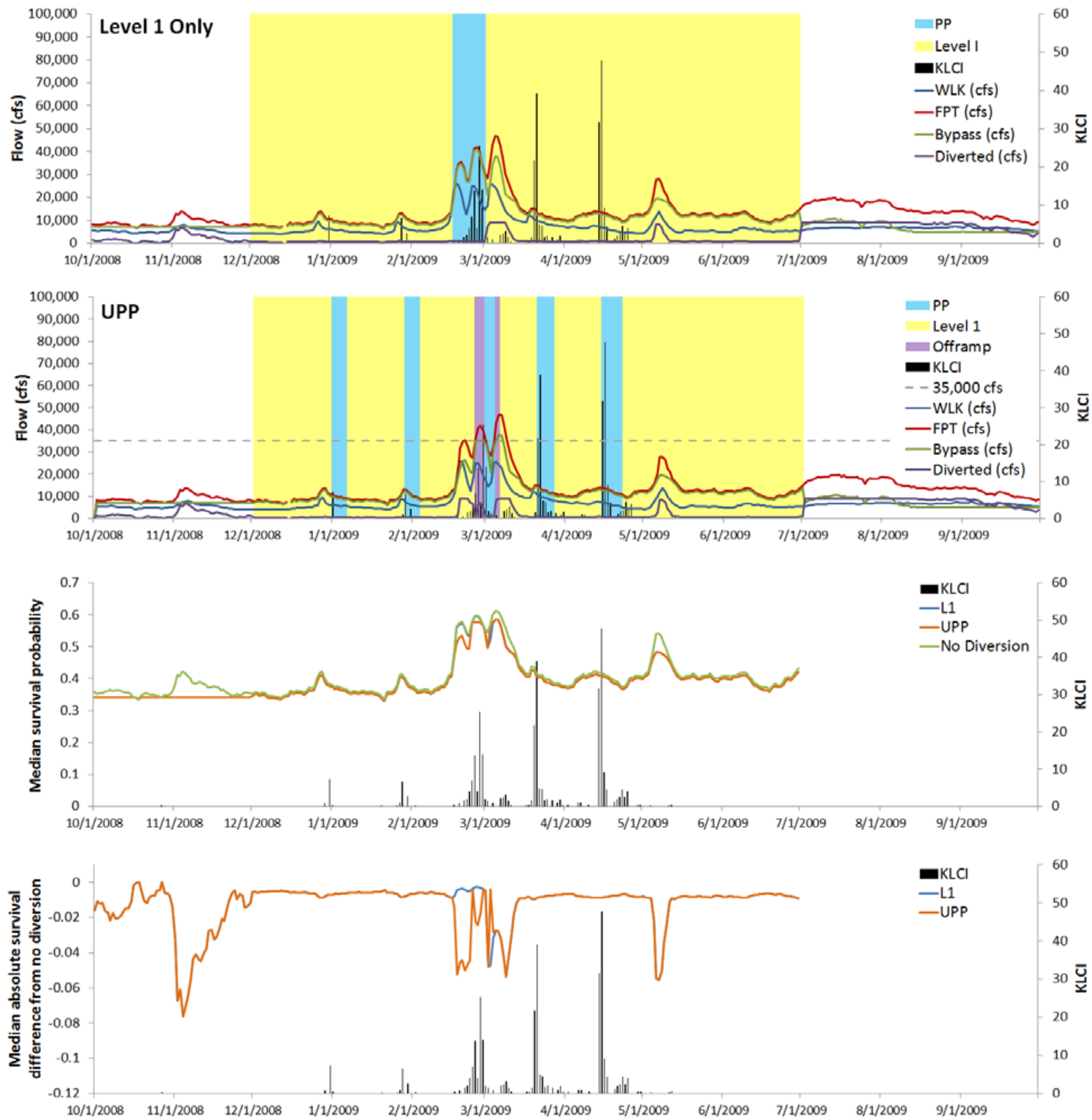

Figure 13. Summary for Water Year 2009 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

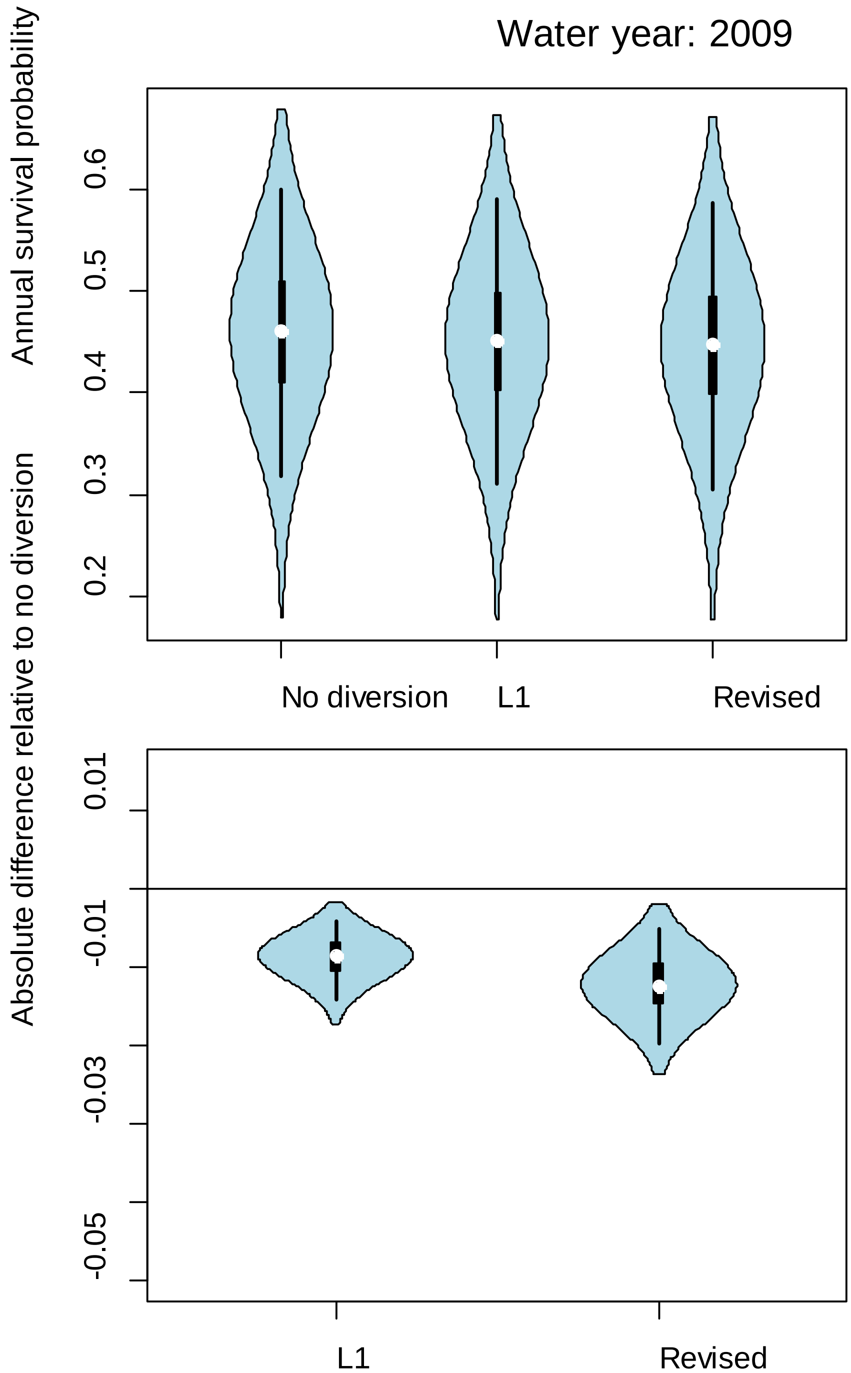

Figure 14. Violin plots for Water Year 2009 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

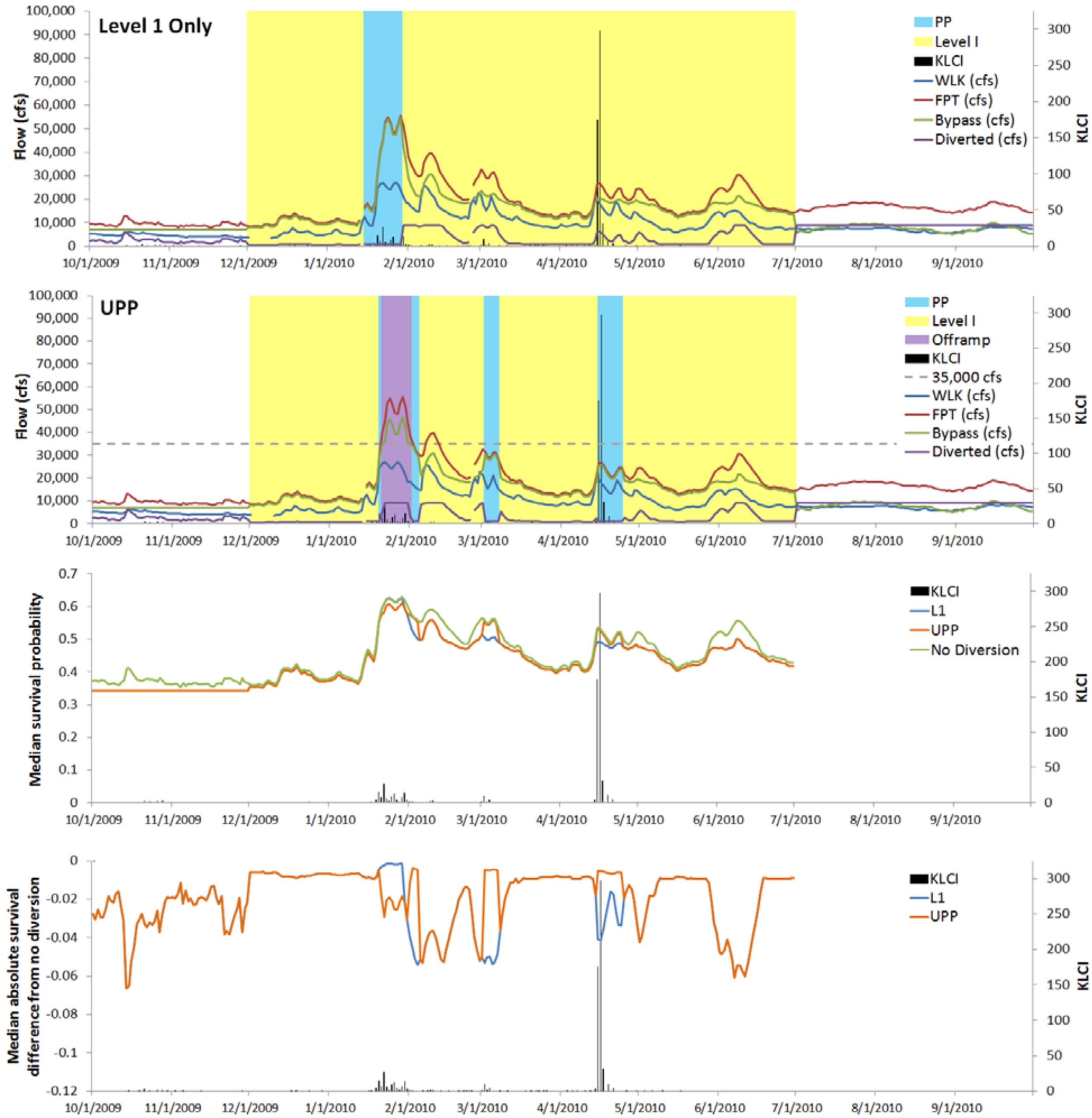

Figure 15. Summary for Water Year 2010 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

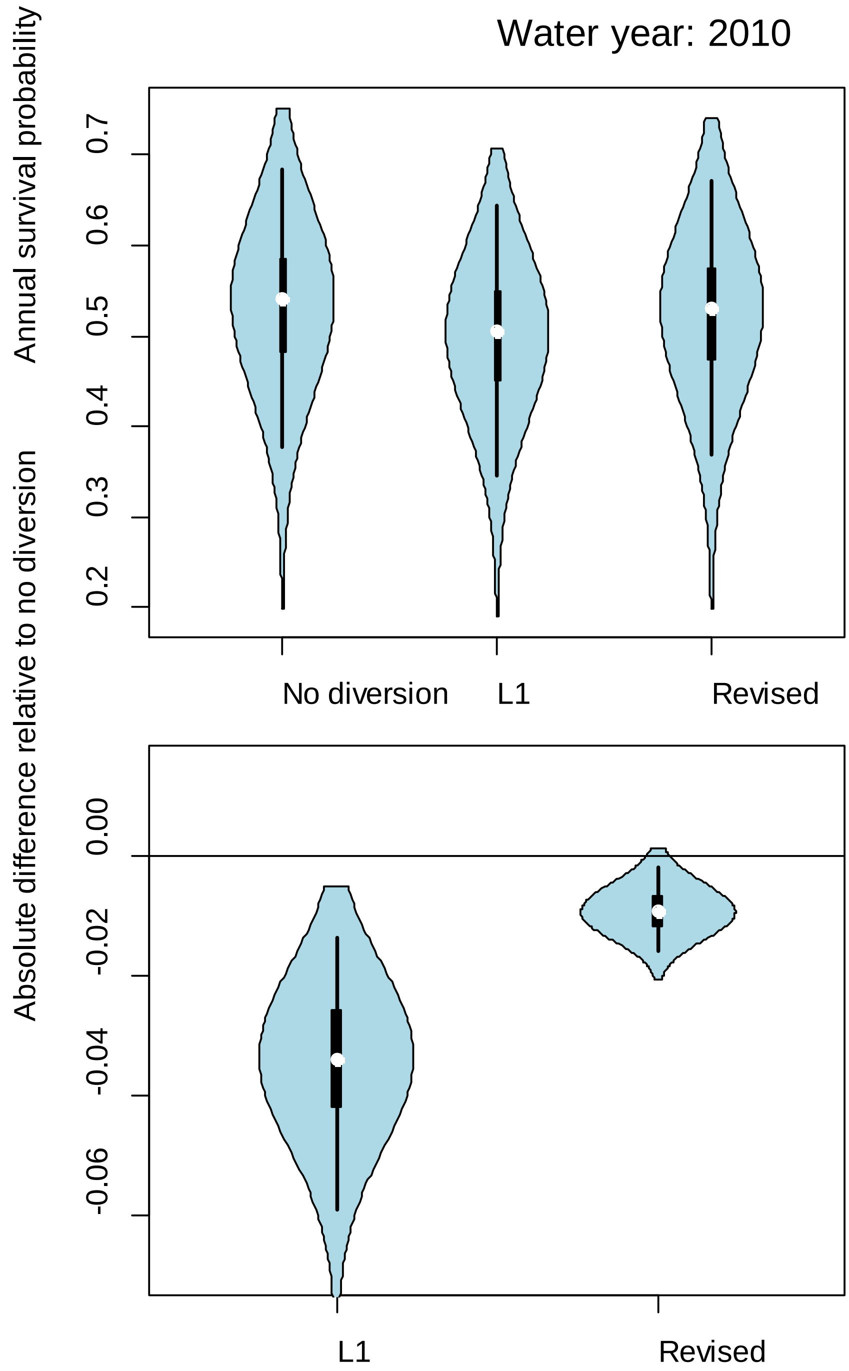

Figure 16. Violin plots for Water Year 2010 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

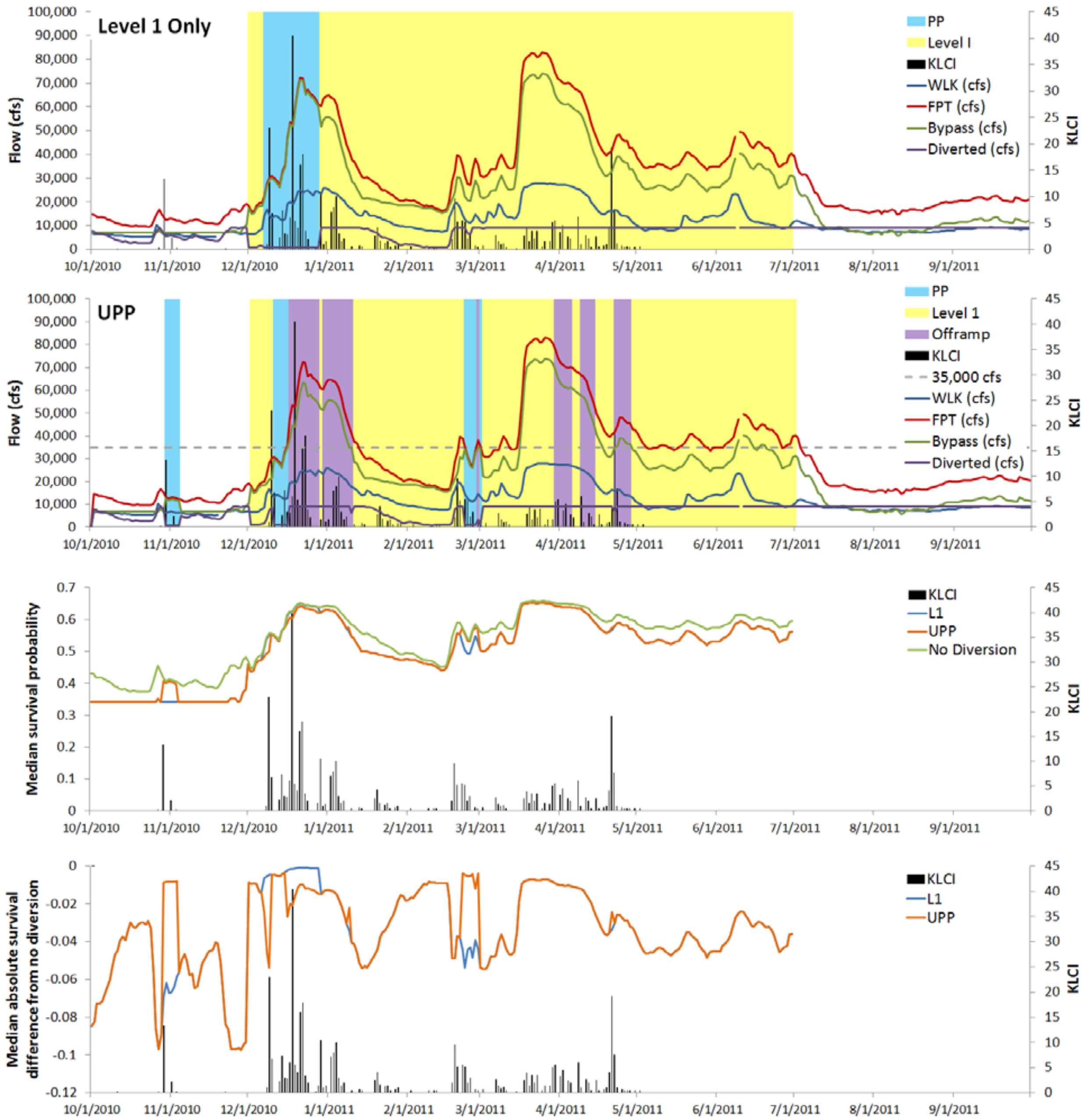

Figure 17. Summary for Water Year 2011 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

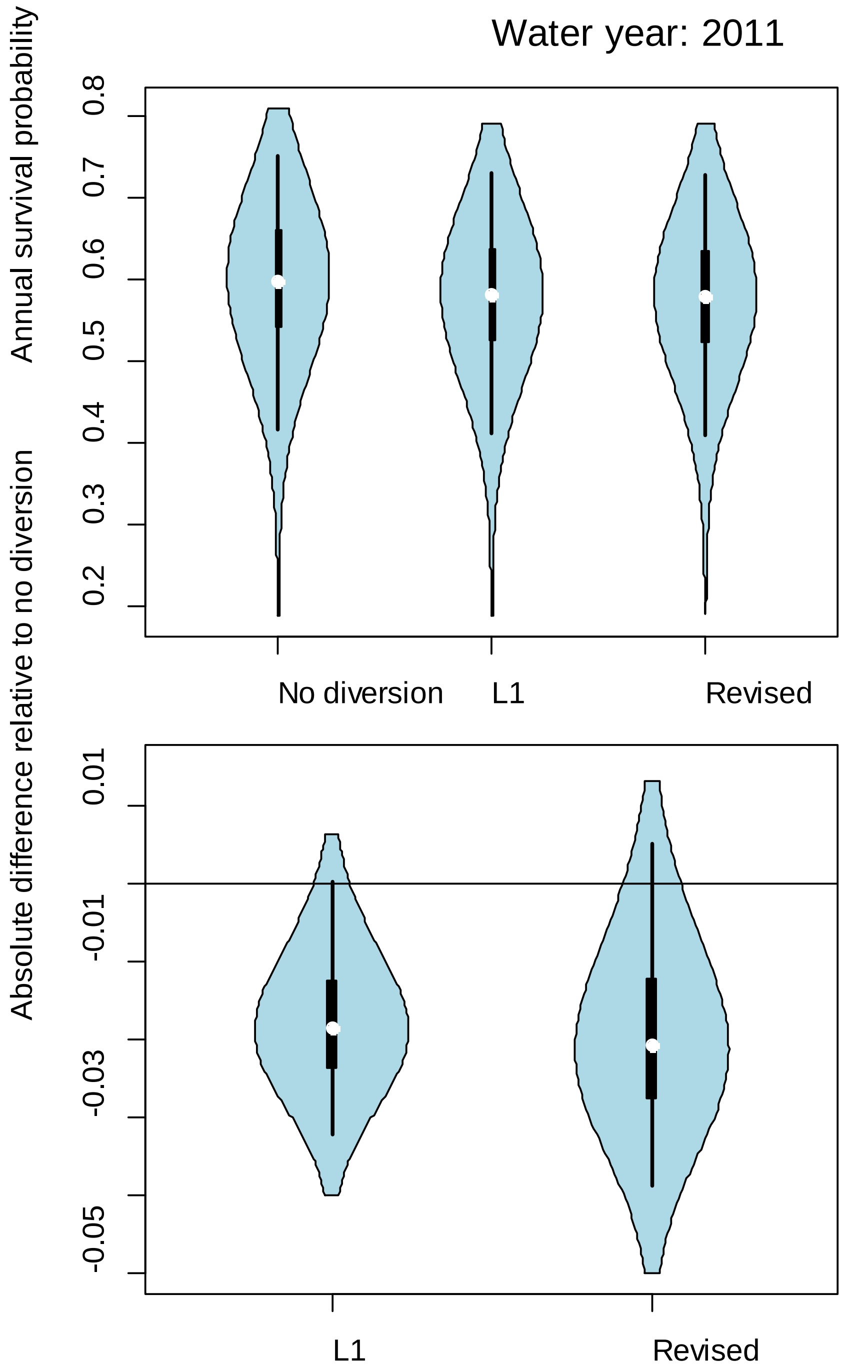

Figure 18. Violin plots for Water Year 2011 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25^{th}-75^{th} percentile, and the white dot shows the median.

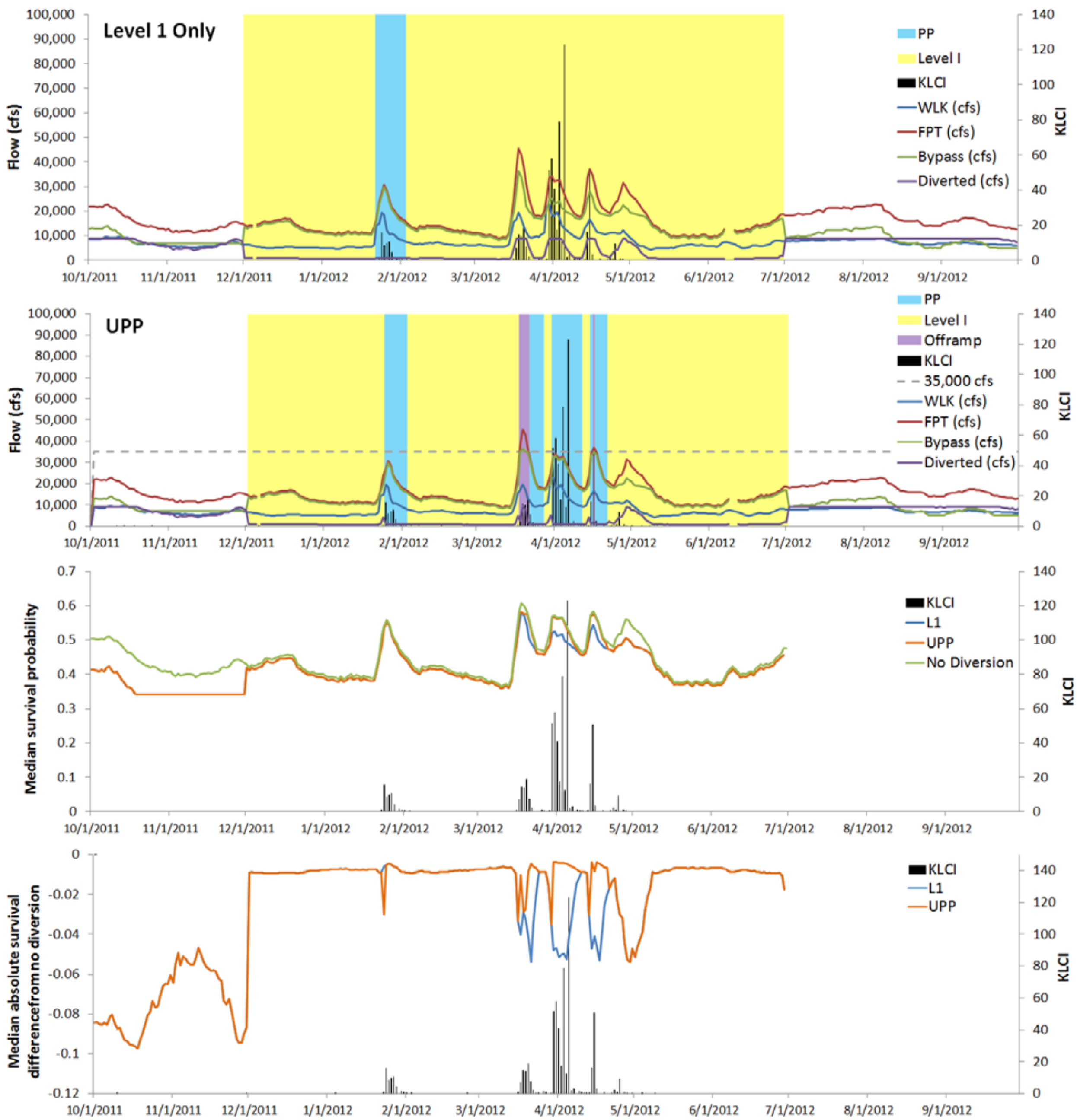

Figure 19. Summary for Water Year 2012 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

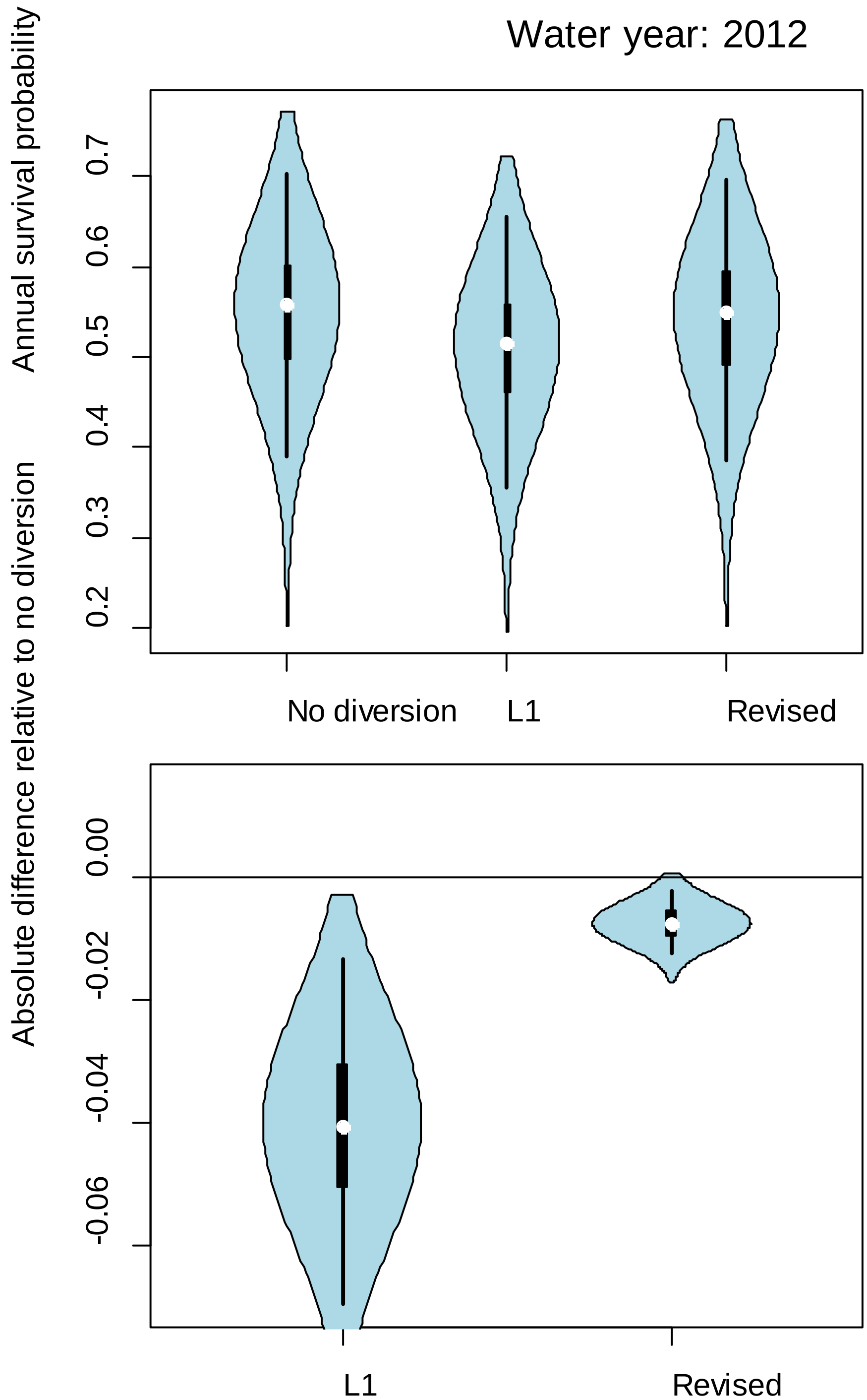

Figure 20. Violin plots for Water Year 2012 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

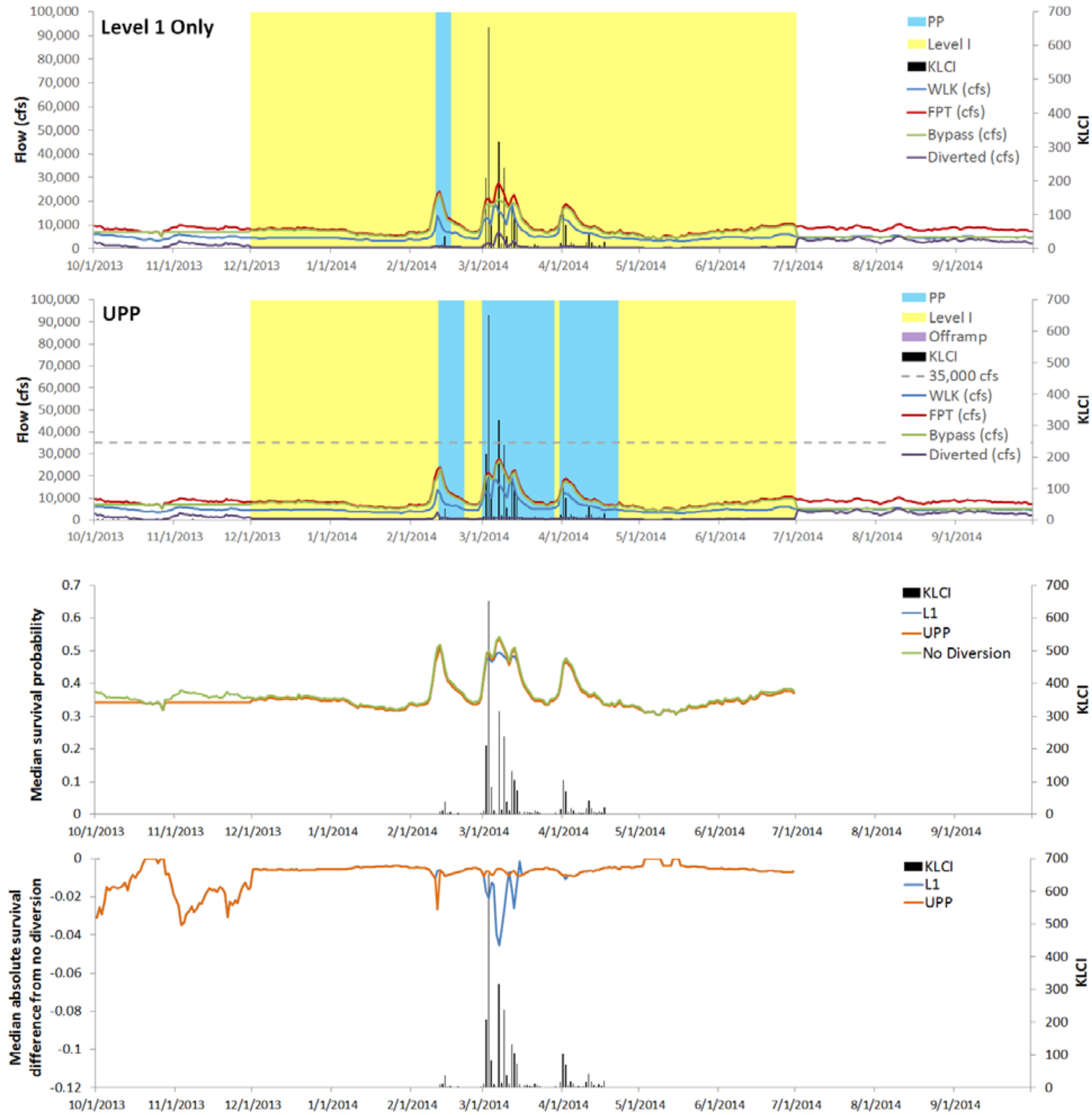

Figure 21. Summary for Water Year 2014 of Level 1 (L1) real time operations (top panel), revised Unlimited Pulse Protection (UPP) real time operations (2nd panel), median daily through-Delta survival (3rd panel), and median daily difference in survival of the L1 and UPP scenarios relative to the no diversion scenario (bottom panel). All flows, including flows at Wilkins Slough (WLK) and Freeport (FPT) are plotted along the left vertical axis. The Knights Landing Catch Index (KLCI) is plotted along the right vertical axis. Yellow shading indicates periods of Level 1 pumping; blue shading indicates periods of pulse protection based on the KLCI, and purple shading indicates pulse protection offramp periods.

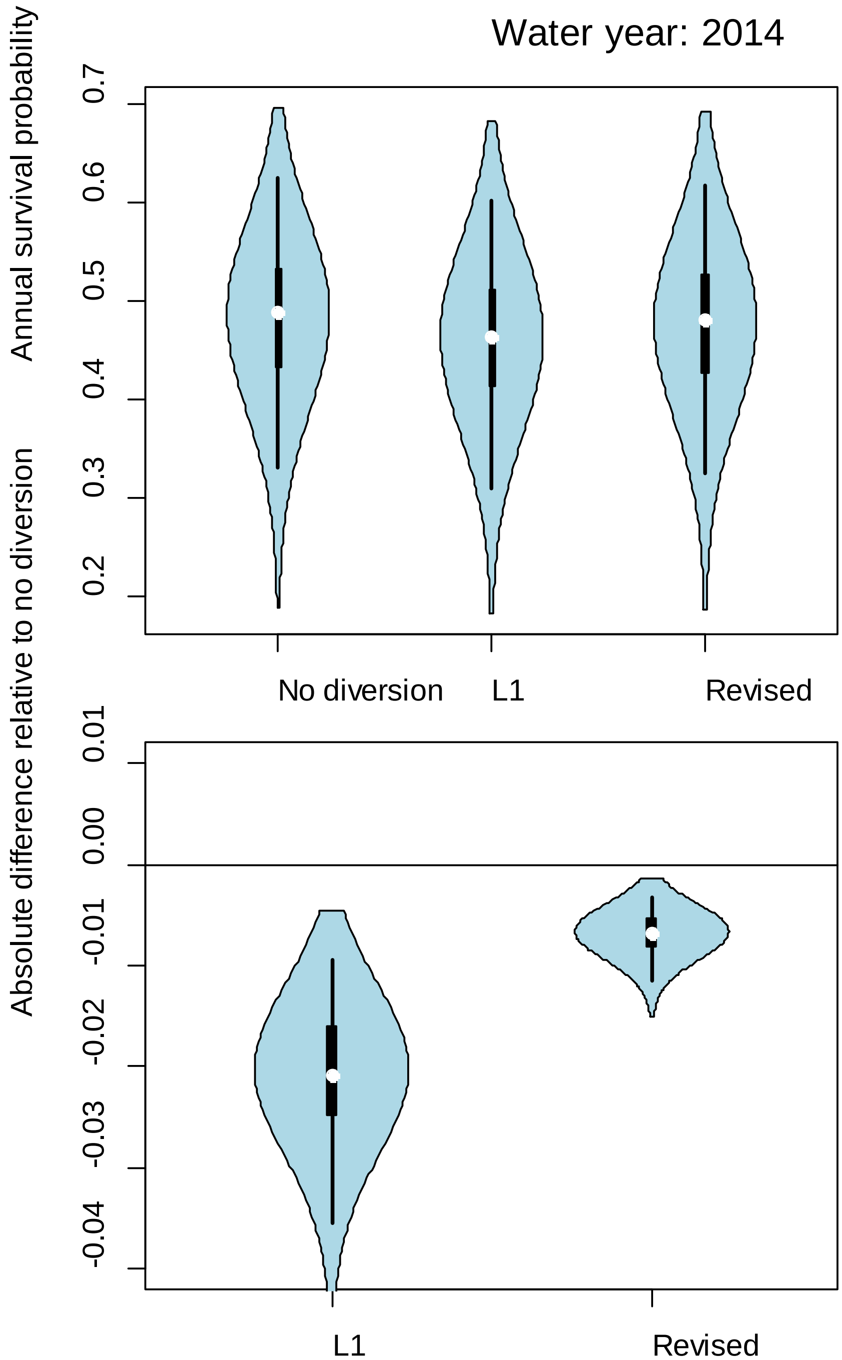

Figure 22. Violin plots for Water Year 2014 showing posterior distributions of annual survival probability for Level 1 (L1) real time operations and revised Unlimited Pulse Protection (Revised) real time operations (top panel) and difference in annual survival of the L1 and Revised scenarios relative to the no diversion scenario (bottom panel). The violin displays a non-parametric kernel density estimate of the full posterior distributions, the thin black line represent the 95% credible intervals, the thick line displays the 25th-75th percentile, and the white dot shows the median.

Appendix F

Evaluating the Effect of the North Delta Diversion on Flow Reversals and Entrainment of Juvenile Chinook Salmon into Georgiana Slough and the Delta Cross Channel

Prepared in cooperation with National Atmospheric and Oceanic Administration, National Marine Fisheries Service

Evaluating the Effect of the North Delta Diversion on Flow Reversals and Entrainment of Juvenile Chinook Salmon into Georgiana Slough and the Delta Cross Channel

By Russell W. Perry, Jason G. Romine, Adam C. Pope, and Scott D. Evans

Open File Report 2016–XXXX

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Figures

Tables

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	0.4047	square hectometer (hm^2)
acre	0.004047	square kilometer (km^2)
square foot (ft^2)	0.09290	square meter (m^2)
square mile (mi^2)	259.0	hectare (ha)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
cubic foot (ft^3)	0.02832	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Vertical Datum of 1988 (NAVD 88).”

Horizontal coordinate information is referenced to the insert datum name (and abbreviation) here for instance, “North American Datum of 1983 (NAD 83).”

Altitude, as used in this report, refers to distance above the vertical datum.

Evaluating the Effect of the North Delta Diversion on Flow Reversals and Entrainment of Juvenile Chinook Salmon into Georgiana Slough and the Delta Cross Channel

By Russell W. Perry, Jason G. Romine, Adam C. Pope, and Scott D. Evans

Executive Summary

The California Department of Water Resources and US Bureau of Reclamation propose new water intake facilities on the Sacramento River that would route water through tunnels rather than through the Sacramento-San Joaquin Delta. The collection of water intakes, tunnels, pumping facilities, associated structures, and proposed operations are collectively referred to as California Water Fix (ICF International, 2016). The water intake facilities, referred to here as the North Delta Diversion (NDD), are proposed to be located on the Sacramento River downstream of the city of Sacramento but upstream of the first major river junction where Sutter Slough branches from the Sacramento River. The North Delta Diversion can divert a maximum discharge of 9,000 ft^3/s from the Sacramento River, which reduces the amount of inflow into the Delta.

In this report, we conduct two analyses to investigate the effect of the North Delta Diversion and its proposed operation on entrainment of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Georgiana Slough and the Delta Cross Channel. Fish that enter the interior Delta (the network of channels to the south of the Sacramento River) via Georgiana Slough and the Delta Cross Channel survive at lower rates than fish that use other migration routes (Sacramento River, Sutter Slough, and Steamboat Slough; Perry and others 2010). Therefore, of concern is the extent to which operation of the North Delta Diversion increases the proportion of the population entering the interior Delta, which would lower overall survival through the Delta by increasing the fraction of the population subject to lower survival rates.

In the first analysis, we evaluate the effect of the NDD bypass rules on flow reversals of the Sacramento River below Georgiana Slough. The NDD bypass rules are a set of operational criteria designed to minimize upstream transport of fish into Georgiana Slough and Delta Cross Channel, and were developed based on previous studies showing that the magnitude and duration of flow reversals increase the proportion of fish entering Georgiana Slough and the Delta Cross Channel (Perry and others, 2015; Perry, 2010). We estimated the frequency and duration of reverse-flow conditions of the Sacramento River downstream of Georgiana Slough under each of the prescribed minimum bypass flows described in the NDD bypass rules. To accommodate adaptive levels of protection during different times of year when juvenile salmon are migrating through the Delta, the NDD bypass rules prescribe a series of minimum allowable bypass flows that vary depending on 1) month of the year and 2) progressively decreasing levels of protection following a pulse flow event.

We found that the NDD bypass rules increased the frequency and duration of reverse flows of the Sacramento River downstream of Georgiana Slough, with the magnitude of increase varying among scenarios. Constant low-level pumping, the most protective bypass rule that limits diversion to 10% of the maximum diversion and is implemented following a pulse-flow event, led to the smallest increase in

frequency and duration of flow reversals. In contrast, we found that some scenarios led to sizeable increases in the fraction of the day with reverse flow. The conditions under which the proportion of the day with reverse flow can increase by ≥10 percentage points between October and June, when juvenile salmon are present in the Delta, include October–November bypass rules and level 3 post-pulse operations from December through June. These conditions would be expected to increase the proportion of juvenile salmon entering the interior Delta via Georgiana Slough.

In the second analysis, we evaluated the effect of the North Delta Diversion on the daily probability of fish entering Georgiana Slough and Delta Cross Channel. We applied the entrainment probability model of Perry and others (2015) to 15-minute flow data for an 82-year time series of flows simulated by DSM2 (Delta Simulation Model 2) under the Proposed Action (PA) and the No Action Alternative (NAA). To estimate the daily fraction of fish entering each river channel, entrainment probabilities were averaged over each day. To evaluate the two scenarios, we then compared mean annual entrainment probabilities by month, water year classification, and three different assumed run timings.

Effect of the North Delta Diversion Bypass Rules on Flow Reversal of the Sacramento River below Georgiana Slough

Introduction

This analysis investigates the effects of the North Delta Diversion (NDD) bypass rules (Table 3.4.1–2 in DWR, 2013) on the frequency and duration of reverse flows of the Sacramento below Georgiana Slough. One goal of the NDD bypass rules is to provide bypass flows that prevent an increase in upstream transport of fish into Georgiana Slough and the Delta Cross Channel (DCC). Bypass flows are defined as flow remaining in the Sacramento River downstream of the North Delta Diversion. These rules were developed based on previous research and understanding of reverse-flow hydrodynamics at this river junction. Research has shown that the entrainment probability of juvenile Chinook salmon (*Oncorhynchus tshawytscha*) into Georgiana Slough and the Delta Cross Channel is highest during reverse-flow flood tides (Perry and others, 2015). Furthermore, the daily proportion of fish entrained into Georgiana Slough increases with the fraction of the day in a reverse flow condition at the Sacramento River downstream of Georgiana Slough (Perry, 2010). Consequently, diverting water from the Sacramento River could increase the frequency and duration of reverse-flow conditions, thereby reducing survival by increasing the proportion of fish entrained into the interior Delta where survival probabilities are lower than in the Sacramento River (Perry and others, 2010, 2013).

The NDD bypass rules are also designed to provide more protection during times of the year when juvenile salmon populations are actively migrating through the Delta (primarily December through June) and during pulse flow events when endangered winter-run Chinook salmon are likely to initiate downstream migration into the Delta (del Rosario and others, 2013). To accommodate adaptive levels of protection, the NDD bypass rules prescribe a series of minimum allowable bypass flows that vary depending on 1) month of the year and 2) progressively decreasing levels of protection following a pulse flow event. For modeling purposes, pulse-events are defined based on discharge of the Sacramento River at Wilkins Slough, and minimum bypass levels are based on varying fractions of discharge of the Sacramento River arriving at the North Delta Diversion (see Table 3.4.1–2 in DWR, 2013 for details). For operational purposes, pulse events will be based on monitoring for the presence of winter-run sized fish entering the reach.

Our goal was to estimate the frequency and duration of reverse-flow conditions of the Sacramento River downstream of Georgiana Slough under each of the prescribed minimum bypass flows described in the NDD bypass rules Table 3.4.1–2. First, we used historical flow data of the Sacramento River downstream of Georgiana Slough (WGB; USGS Gage 11447905) to estimate the effect of discharge of the Sacramento River at Freeport (FPT; USGS Gage 11447650) on 1) the daily probability of a flow reversal, and 2) the daily proportion of each day with reverse flow. We then used these relationships to calculate the change in the probability of a flow reversal and the proportion of the day with reverse flow under each of the prescribed bypass flows described in the NDD bypass rules. This analysis assumes that 1) the NDD bypass rules are applied based on mean daily discharge at Freeport, and 2) that water is diverted at a constant discharge over an entire day such that the bypass flow is constant over the day. In other words, we assume that the bypass is operated as strictly defined by the NDD bypass rules. We do not attempt to simulate "real time management" such as varying diversion flow at hourly timescales in response to in situ tidal conditions to prevent reverse flows. Such real-time management criteria have yet to be defined, and we therefore expand on this topic in the discussion.

Methods

We used logistic regression to quantify the relationship between Sacramento River inflows to the Delta and reverse flows of the Sacramento River downstream of Georgiana Slough. Mean daily discharge at Freeport, 15-min discharge data at station WGB, and the daily position of the Delta Cross Channel (DCC) gate for the period October 2007 to March 2015 were used in the analysis. The 15-min data at WGB was summarized to two daily statistics: 1) a binary indicator value that was set to one if reverse flow occurred at any point on a given day and set to zero if all 15-min flows were positive, and 2) the number of 15-min flow observations for each day that were negative. The position of the DCC gate was coded as a binary indicator variable (1 = open, 0 = closed) for inclusion in the analysis. Dates without a complete record of 15-min flows at WGB or where the DCC gate was not open or closed for the entire day were excluded from the analysis.

To estimate the probability of a flow reversal occurring on a given day, we fit a logistic regression model to the binary indicator variable described above as a function of daily flow at Freeport:

$$\mathrm{P(reverse)} = \mathrm{logit}^{-1}(\alpha_0 + \alpha_1 Q_{\mathrm{FPT}})$$

where logit^{-1} is the inverse logit function, Q_{FPT} is mean daily discharge at Freeport, α_0 is the intercept, and α_1 is the slope. We excluded the DCC gate position from this analysis because we found that flow reversals always occurred for some part of the day when the DCC was open (i.e., P(reverse) = 1 for DCC open). Therefore, the analysis was restricted to days when the DCC was closed.

To estimate the proportion of the day with reverse flow as a function of Freeport flow, we fit a logistic regression model to the number of 15-min reverse flows on each day relative to the total number 15-min flow observations each day:

$$\mathrm{P_{day}(reverse)} = \mathrm{logit}^{-1}(\beta_0 + \beta_1 Q_{\mathrm{FPT}})$$

where β_0 is the intercept and β_1 is the slope. This analysis was conducted separately for periods with the DCC gate open and closed.

Given the relationships estimating the effect of Freeport discharge on the frequency (P(reverse)) and duration ($\mathrm{P_{day}}$(reverse)) of flow reversals, we applied the bypass rules over a range of Freeport discharge from 5,000 to 35,000 ft^3/s, which bracketed flows under which we observed a 100% probability of a flow reversal to a 0% probability of a flow reversal. We compared the probability of flow reversal and the proportion of the day with flow reversals assuming no diversion and diversion under the NDD bypass rules with the DCC closed. We then calculated the difference in these statistics between no diversion and that prescribed under the NDD bypass rules to assess the magnitude of increase in the frequency and duration of reverse flows. Specifically, we performed this comparison for the 12 scenarios described under the NDD bypass rules:

1) Constant low-level pumping
2) October–November bypass rules
3) Level 1, 2, and 3 post-pulse operations for December–April
4) Level 1, 2, and 3 post-pulse operations for May
5) Level 1, 2, and 3 post-pulse operations for June
6) July–September bypass rules

Results

We found the probability of a flow reversal declined from one at about 12,500 ft^3/s to zero at about 22,500 ft^3/s (fig. 1). We found that the proportion of day with negative flow was about 45 percent at a Freeport discharge of about 6,000 ft^3/s regardless of the DCC gate position (fig. 2). However, DCC gate position had a strong effect on the rate of change in the proportion of the day with reverse flows (table 1). As Freeport discharge increased over 6,000 ft^3/s, the fraction of the day with reverse flows decreased much more sharply with the DCC closed relative to open (fig. 2).

Table 1. Parameter estimates for the three logistic regression models used to estimate frequency and duration of flow reversals of the Sacramento River downstream of Georgiana Slough as a function of mean daily discharge at Freeport.

[DCC, Delta Cross Channel; SE, standard error; P, probability]

Response variable	DCC position	Intercept (SE)	Slope (SE)
P(reverse)	Closed	17.92 (1.567)	-1.017e-03 (9.001e-05)
P_{day}(reverse)	Closed	0.13 (0.022)	-5.837e-05 (1.600e-06)
	Open	1.37 (0.027)	-2.409e-04 (2.477e-06)

We found that the NDD bypass rules, as implemented under the assumptions of our simulation, increased the frequency and duration of reverse flows of the Sacramento River downstream of Georgiana Slough, with the magnitude of increase varying among scenarios (figs. 2–13). Constant low-level pumping, the most protective bypass rule, led to the smallest increase in frequency and duration of flow reversals (fig. 2). For example, the probability of a flow reversal increased by a maximum of 22 percentage points at a Freeport discharge of 18,000 ft^3/s, but the maximum increase in the proportion of the day with reverse flow increased by only 2.9 percentage points at a Freeport discharge of 10,000 ft^3/s. In contrast, in December–April when most populations of juvenile salmon are migrating through the Delta, level 3 post-pulse operations led to sizeable increases in the frequency and duration of flow reversals (fig. 6). Under these conditions, the probability of a flow reversal occurring increased from a 1 percent chance to a 99 percent chance at Freeport flows of 22,000 ft^3/s. More importantly, at this discharge, the proportion of each day with reverse flow increased by 12 percentage points from 0.019 to 0.146 (fig. 6). These conditions would be expected to increase the proportion of juvenile salmon entering Georgiana Slough.

Juvenile salmon are also present in the Delta, albeit at lower abundances, during other periods with less restrictive bypass rules (e.g., May, and October–November). Under October–November bypass rules, the proportion of the day with reverse flow increased by a maximum of 34 percentage points at a Freeport discharge of 16,000 ft^3/s (fig. 3). Under level 3 post-pulse operations in May, the proportion of the day with reverse flow is expected to increase by a maximum of 14.3 percentage points at a Freeport discharge of 21,400 ft^3/s.

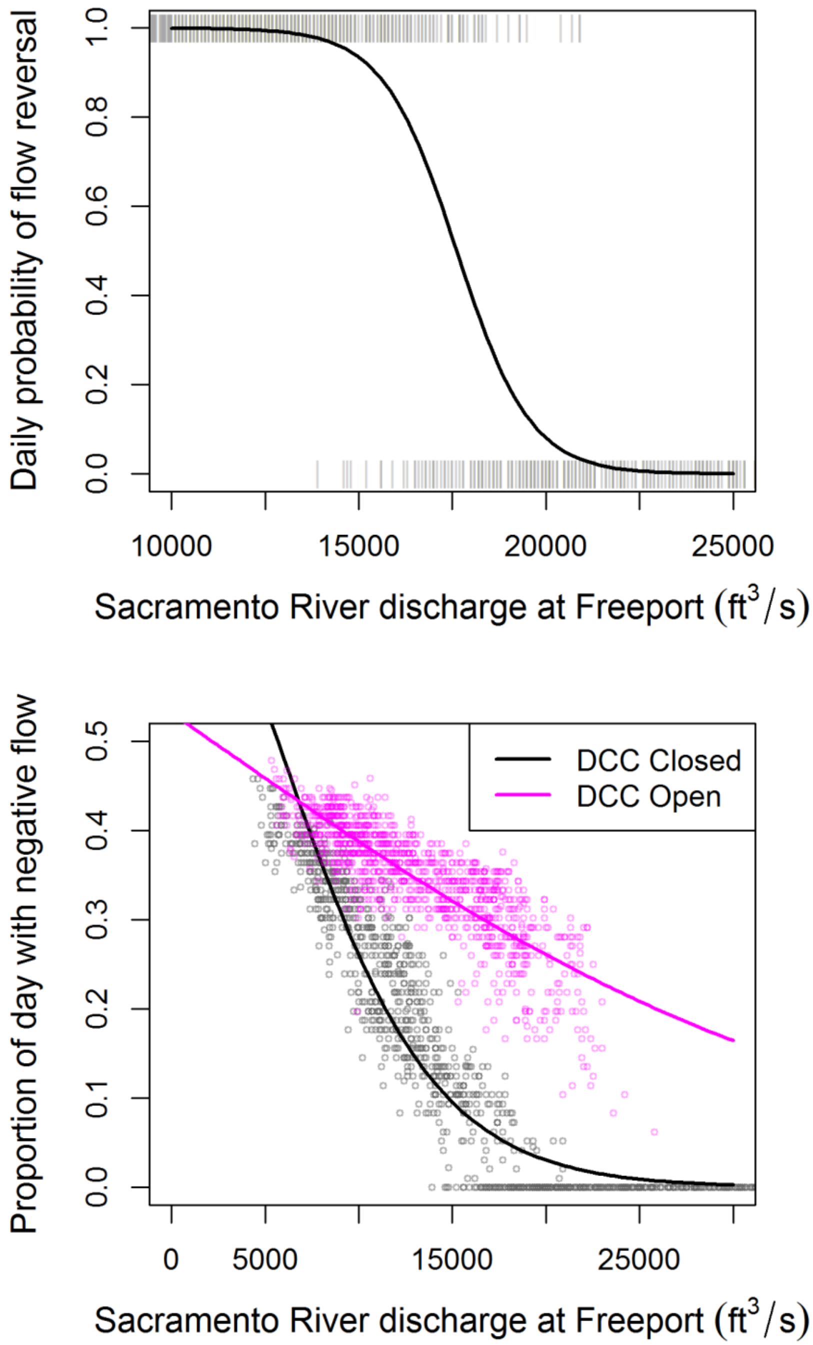

Figure 1. Effect of discharge at Freeport on frequency and duration of flow reversals. Top panel shows the effect of the mean daily discharge (cfs; cubic feet per second) at Freeport on the probability of a flow reversal occurring on a given day at the USGS gage in the Sacramento River just downstream of Georgiana Slough with the Delta Cross Channel (DCC) gate closed. The bottom panel shows the fraction of each day with reversing flow as a function of DCC gate position and mean daily discharge at Freeport.

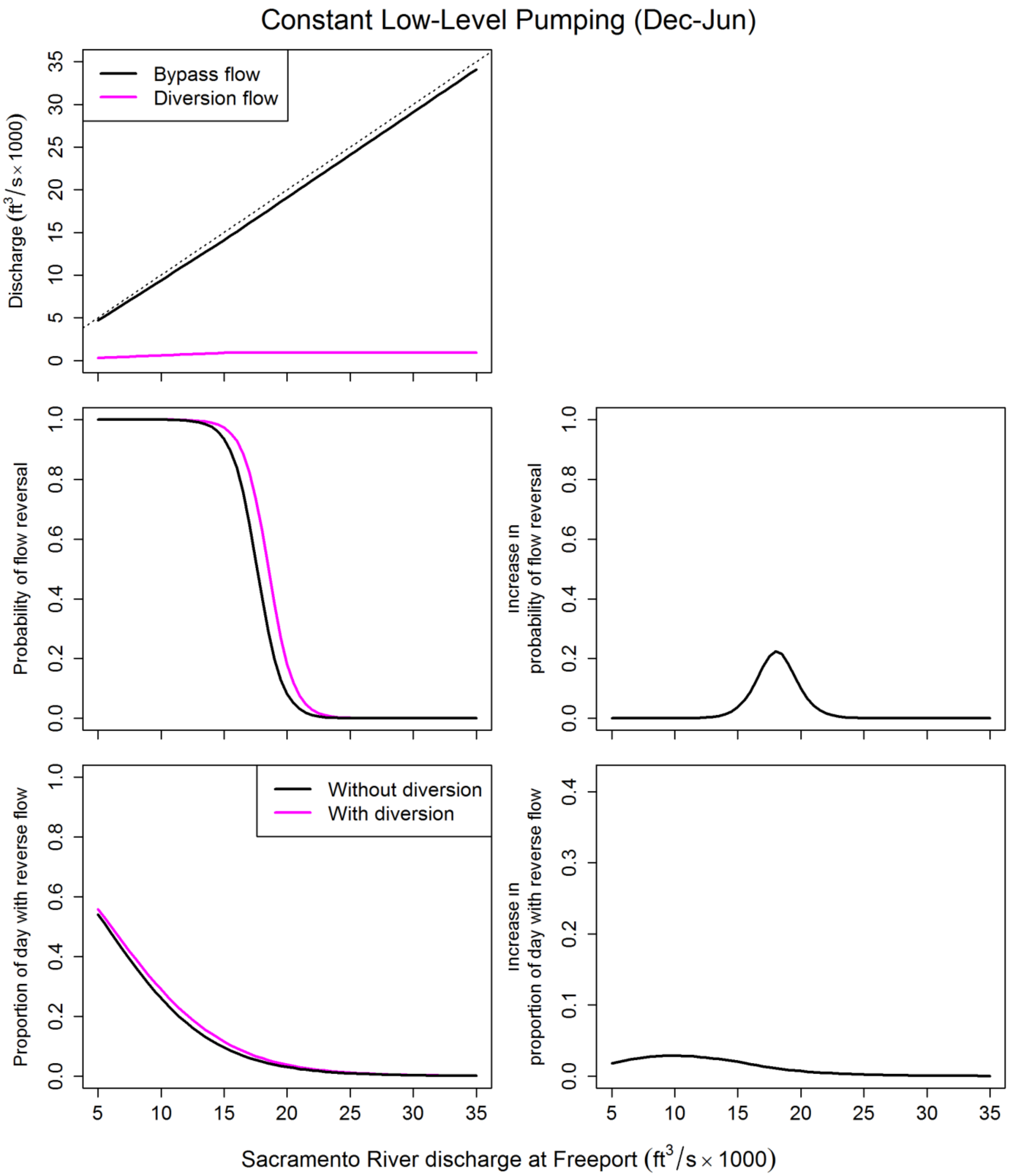

Figure 2. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for constant low-level pumping as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

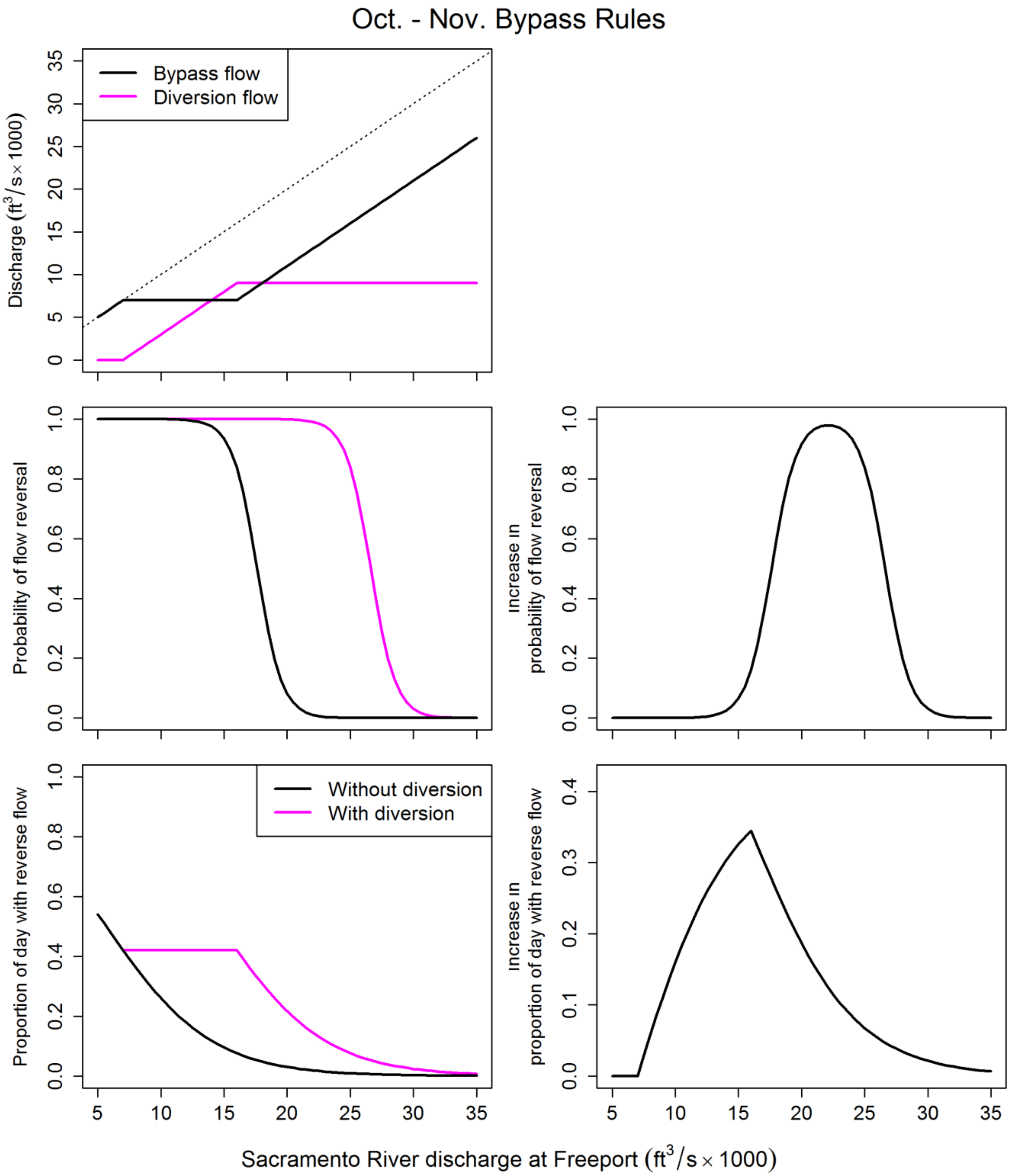

Figure 3. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for October–November as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

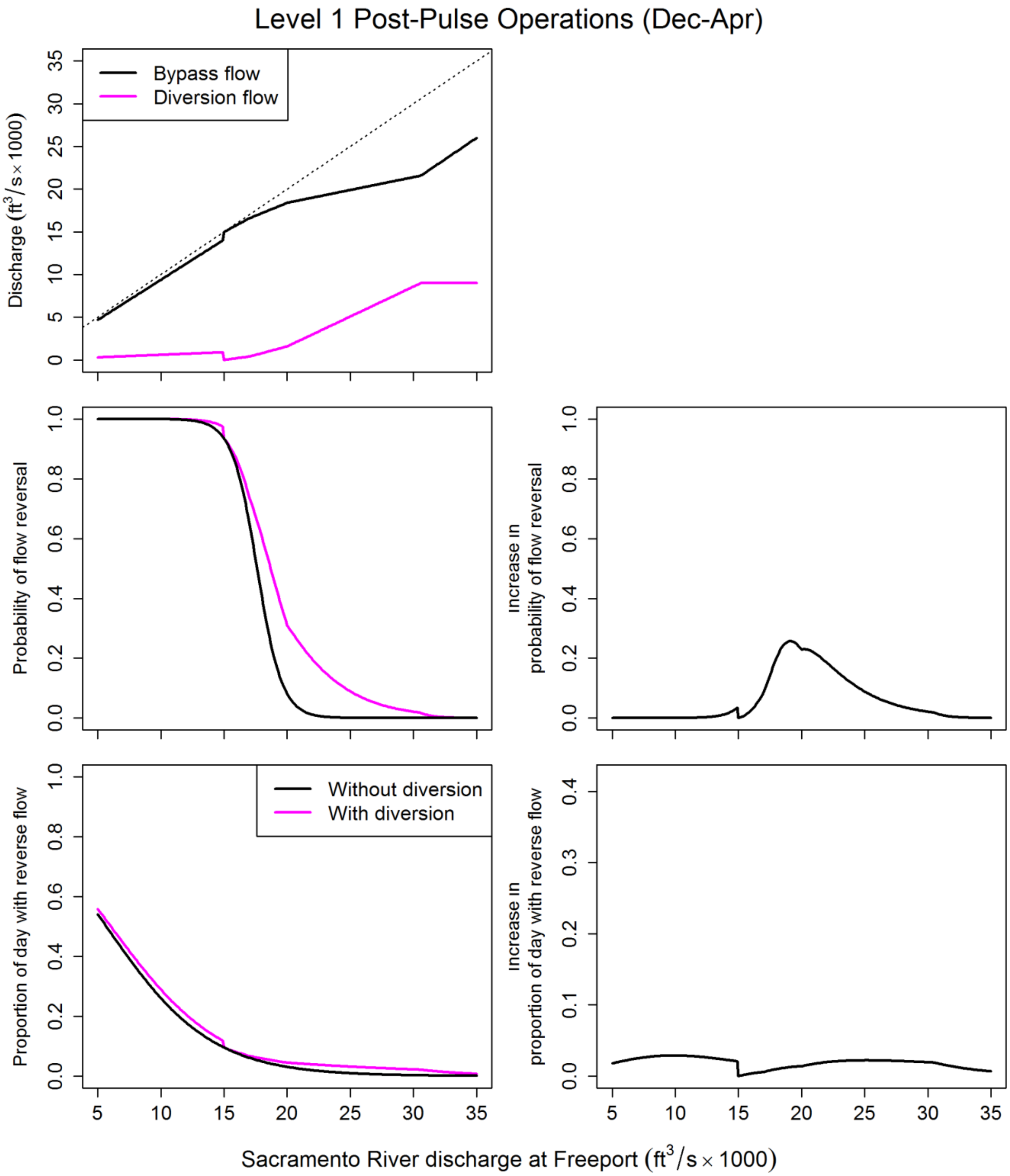

Figure 4. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 1 post-pulse operations in December–April as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

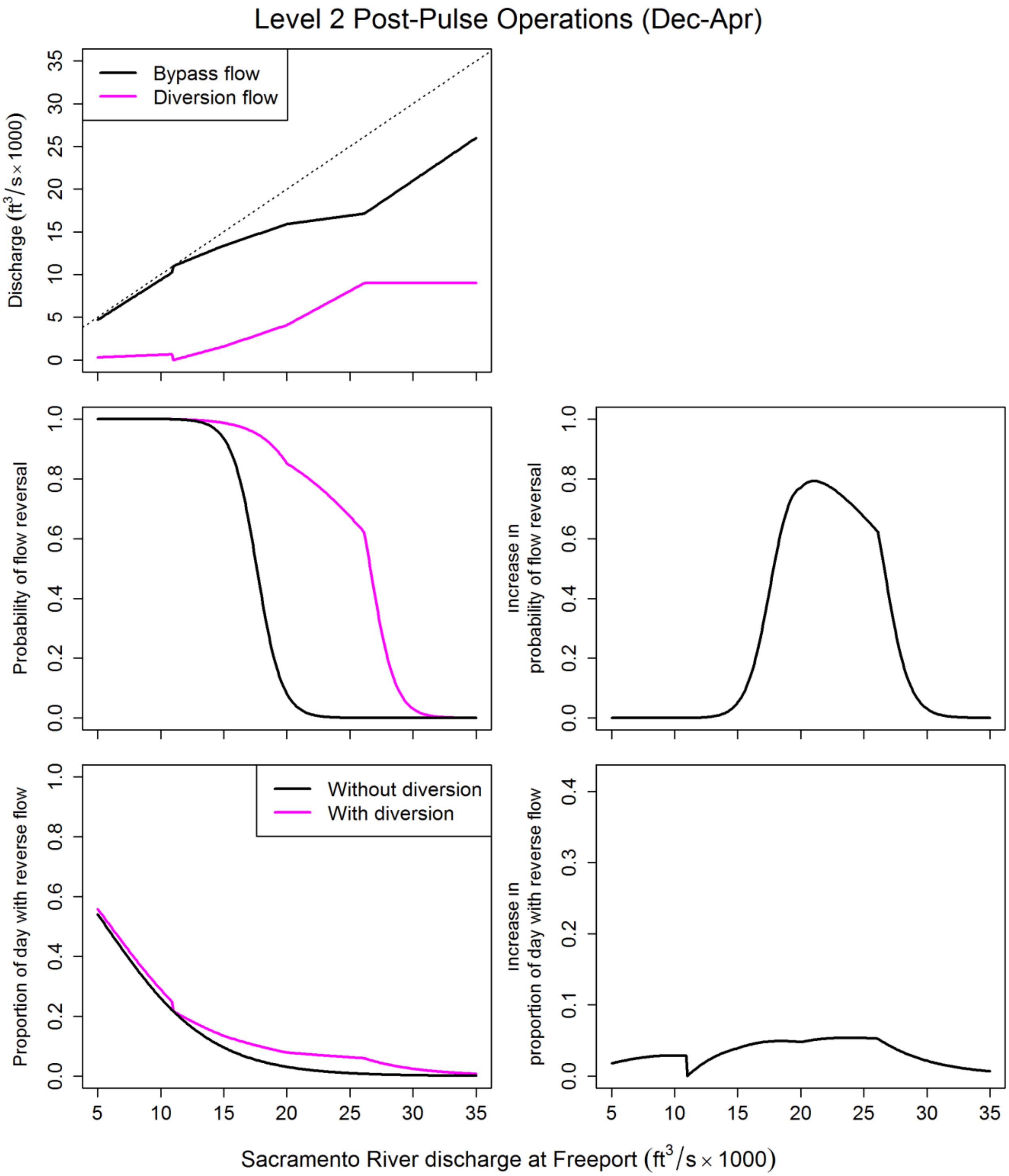

Figure 5. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 2 post-pulse operations in December–April as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

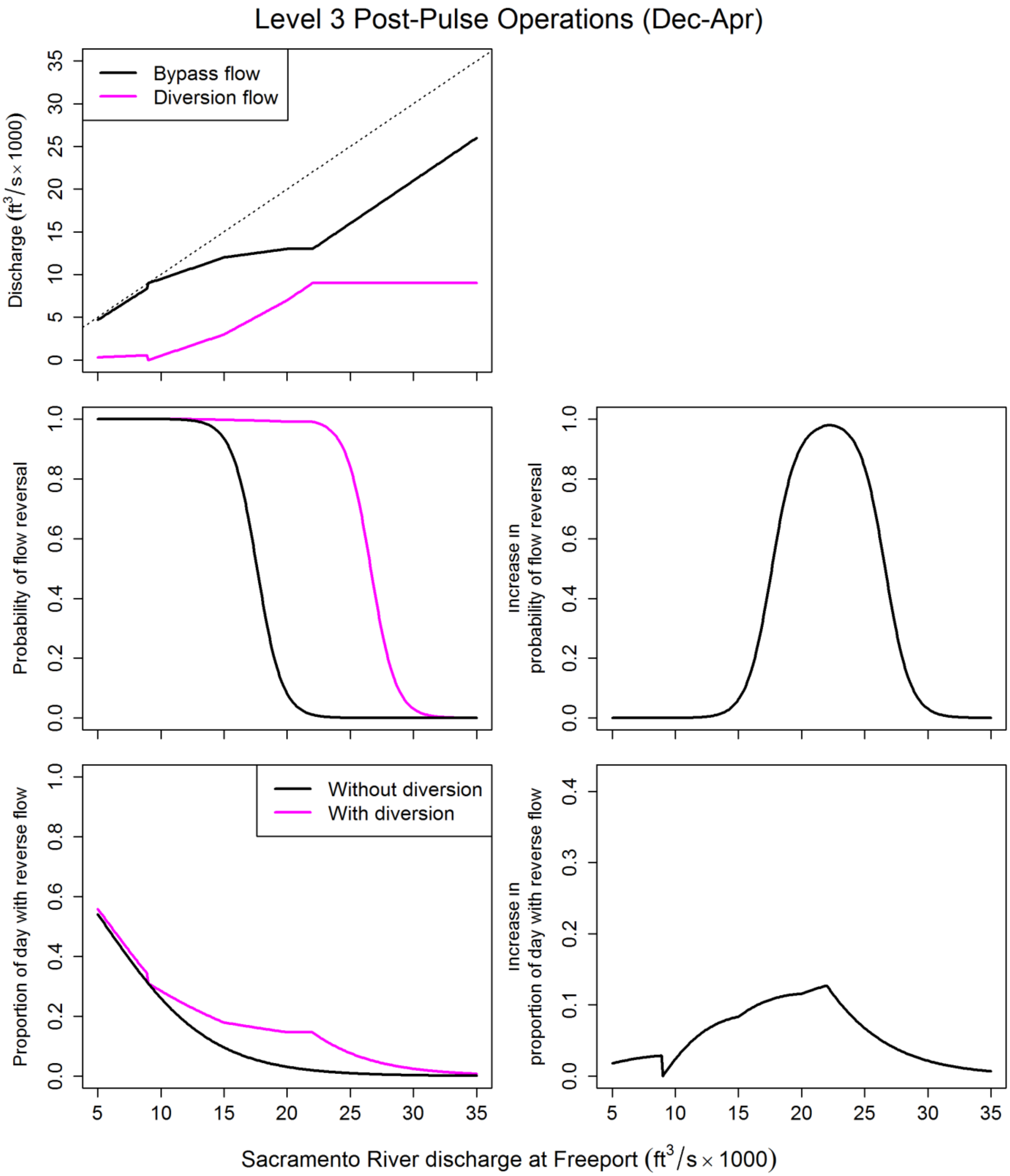

Figure 6. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 3 post-pulse operations in December–April as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

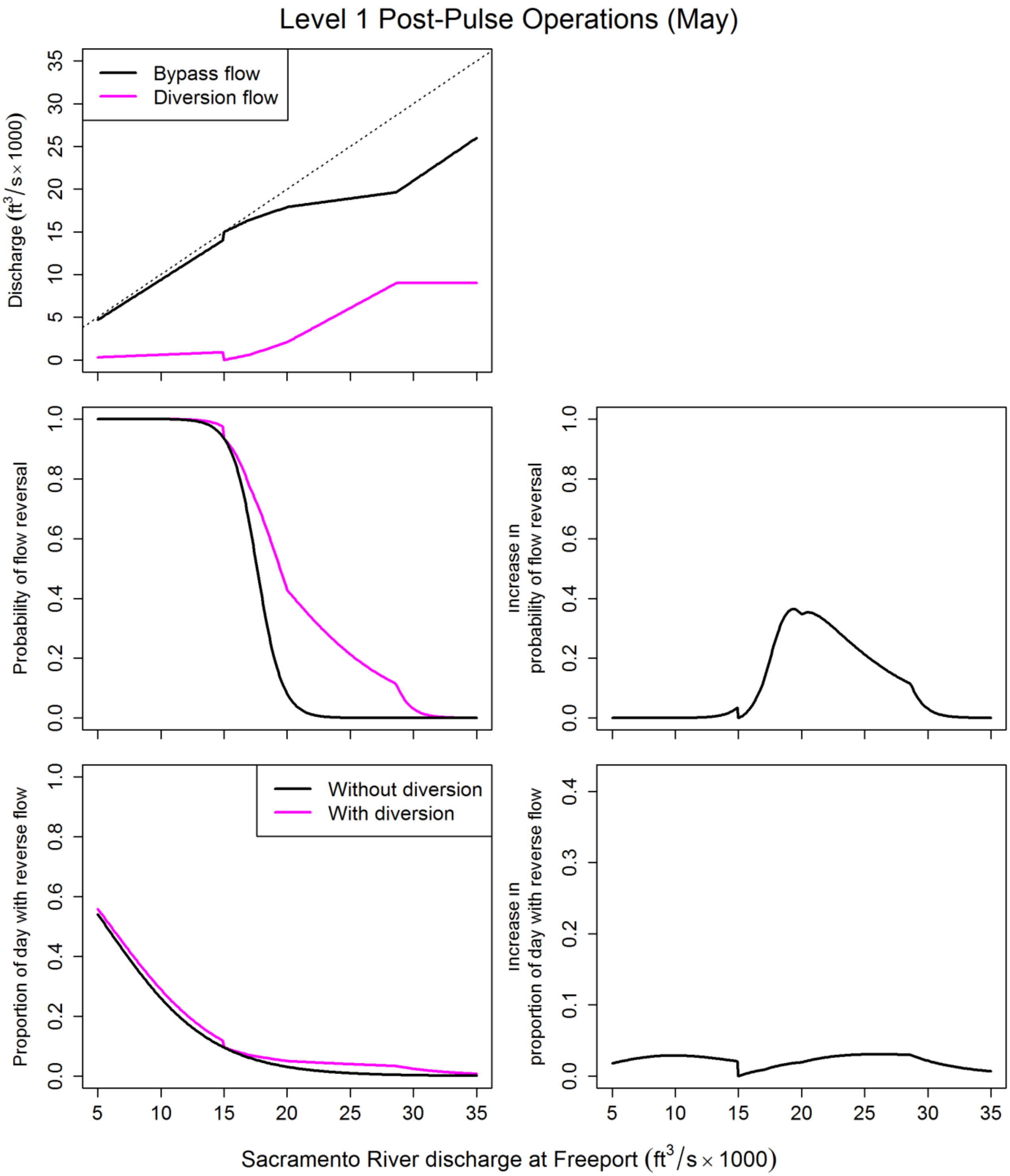

Figure 7. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 1 post-pulse operations in May as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

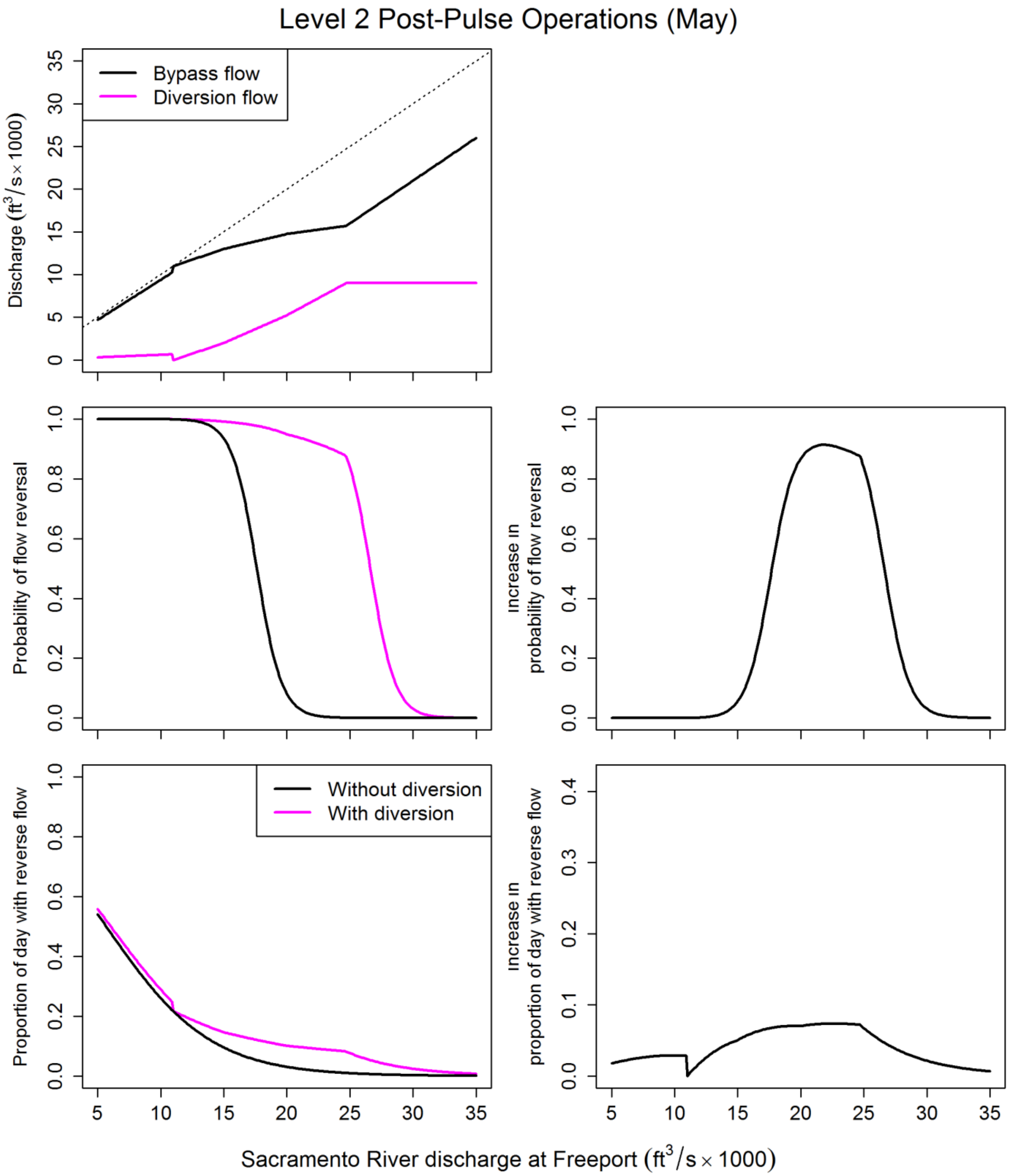

Figure 8. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 2 post-pulse operations in May as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

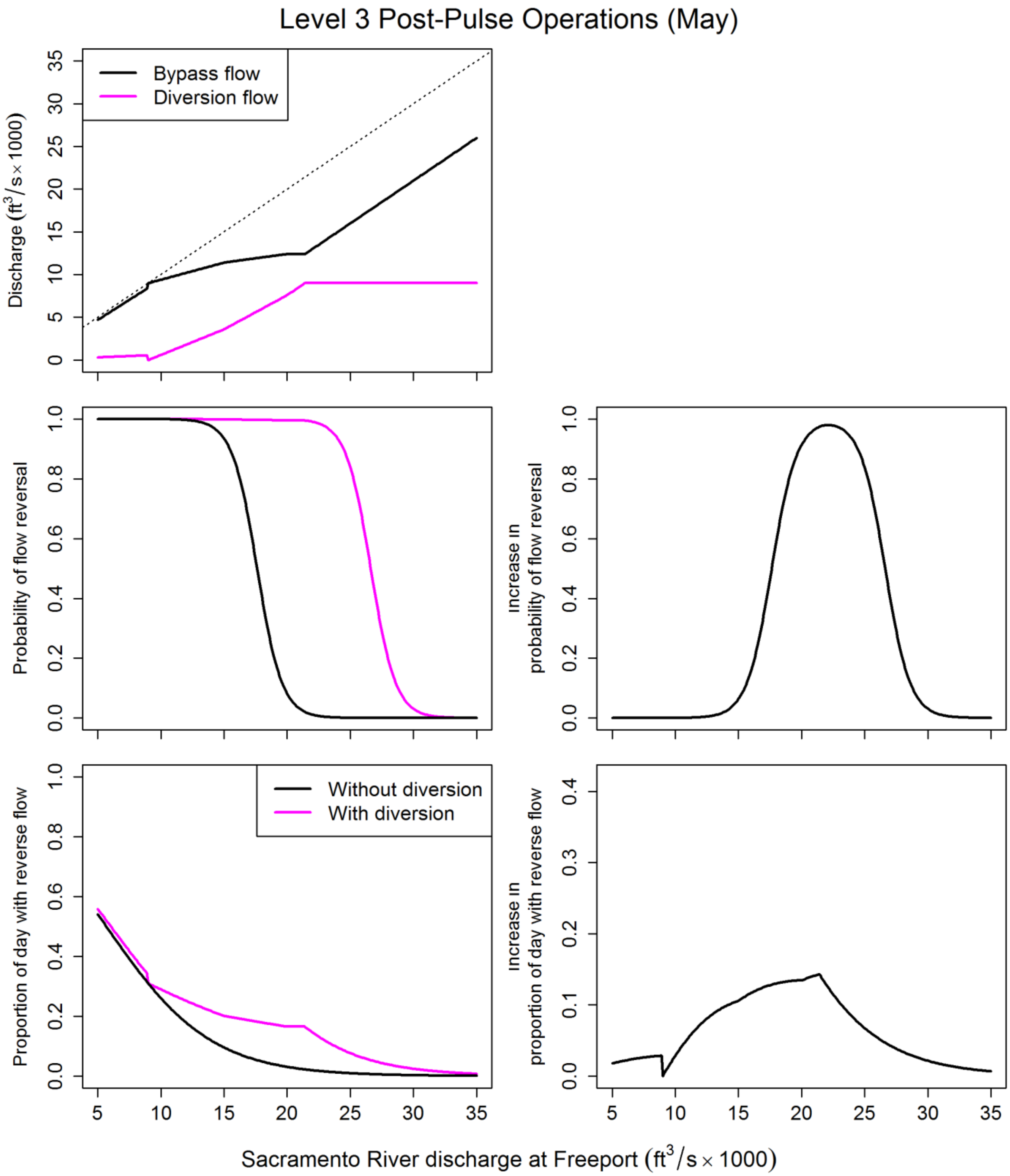

Figure 9. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 3 post-pulse operations in May as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

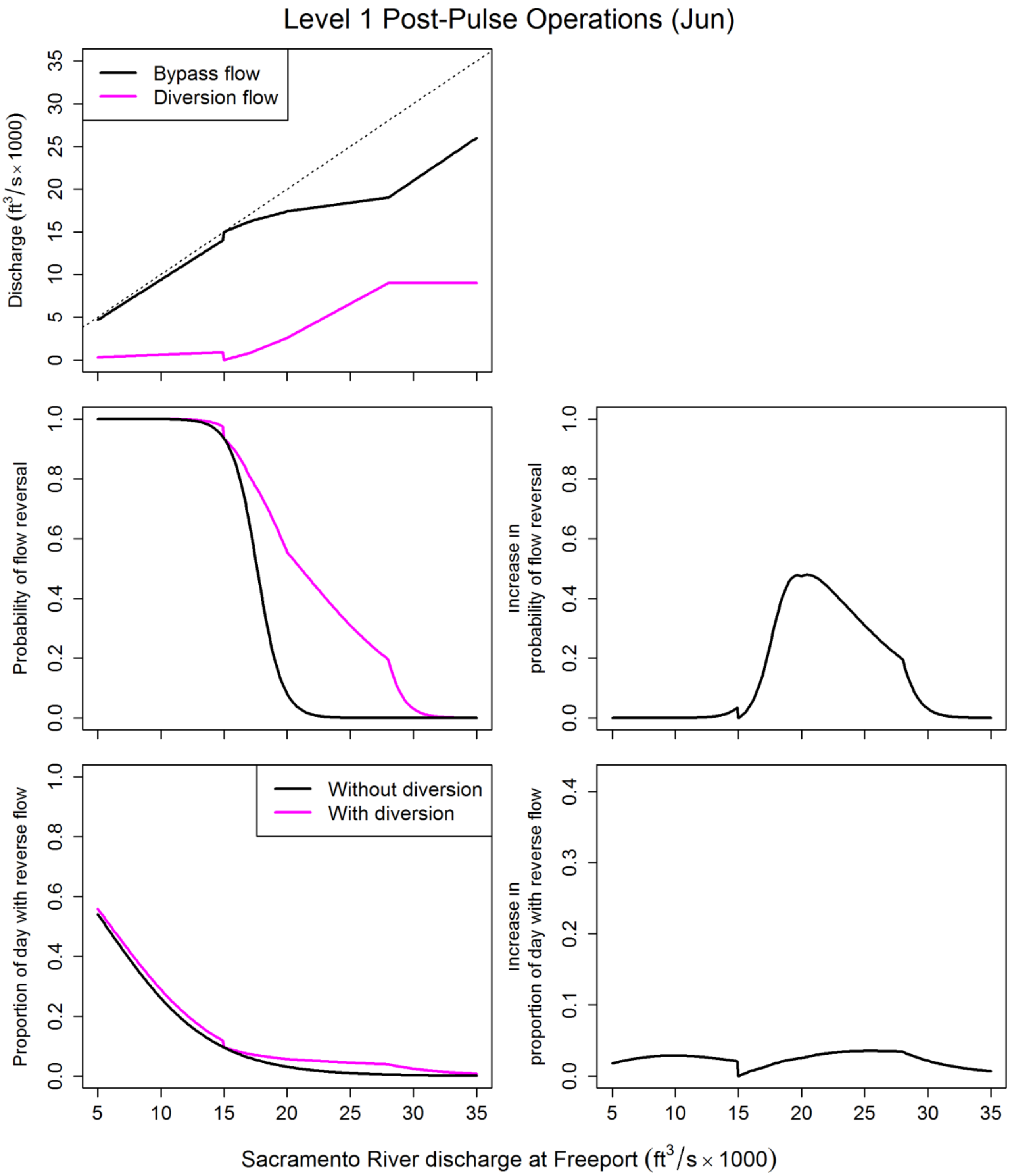

Figure 10. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 1 post-pulse operations in June as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

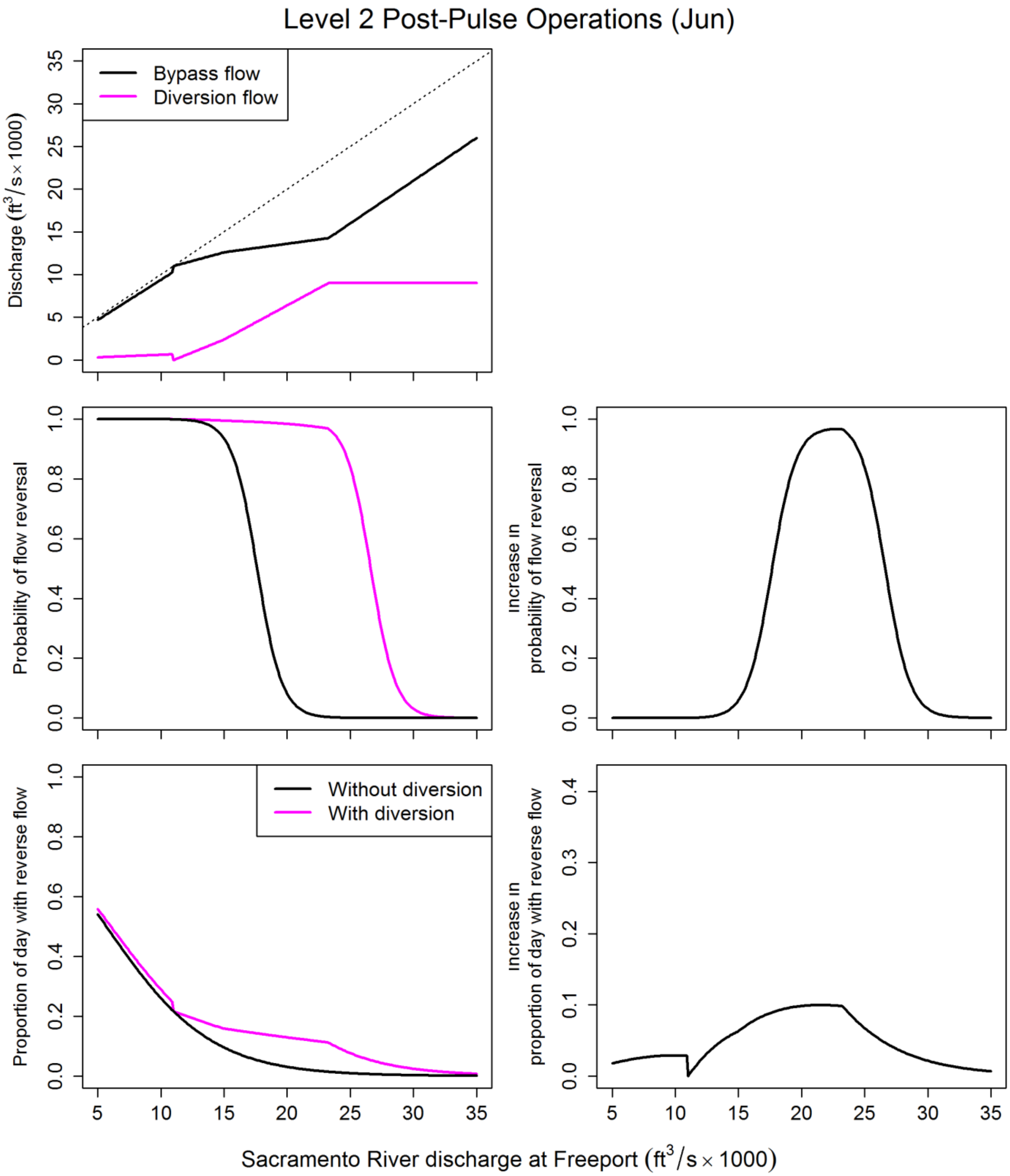

Figure 11. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 2 post-pulse operations in June as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

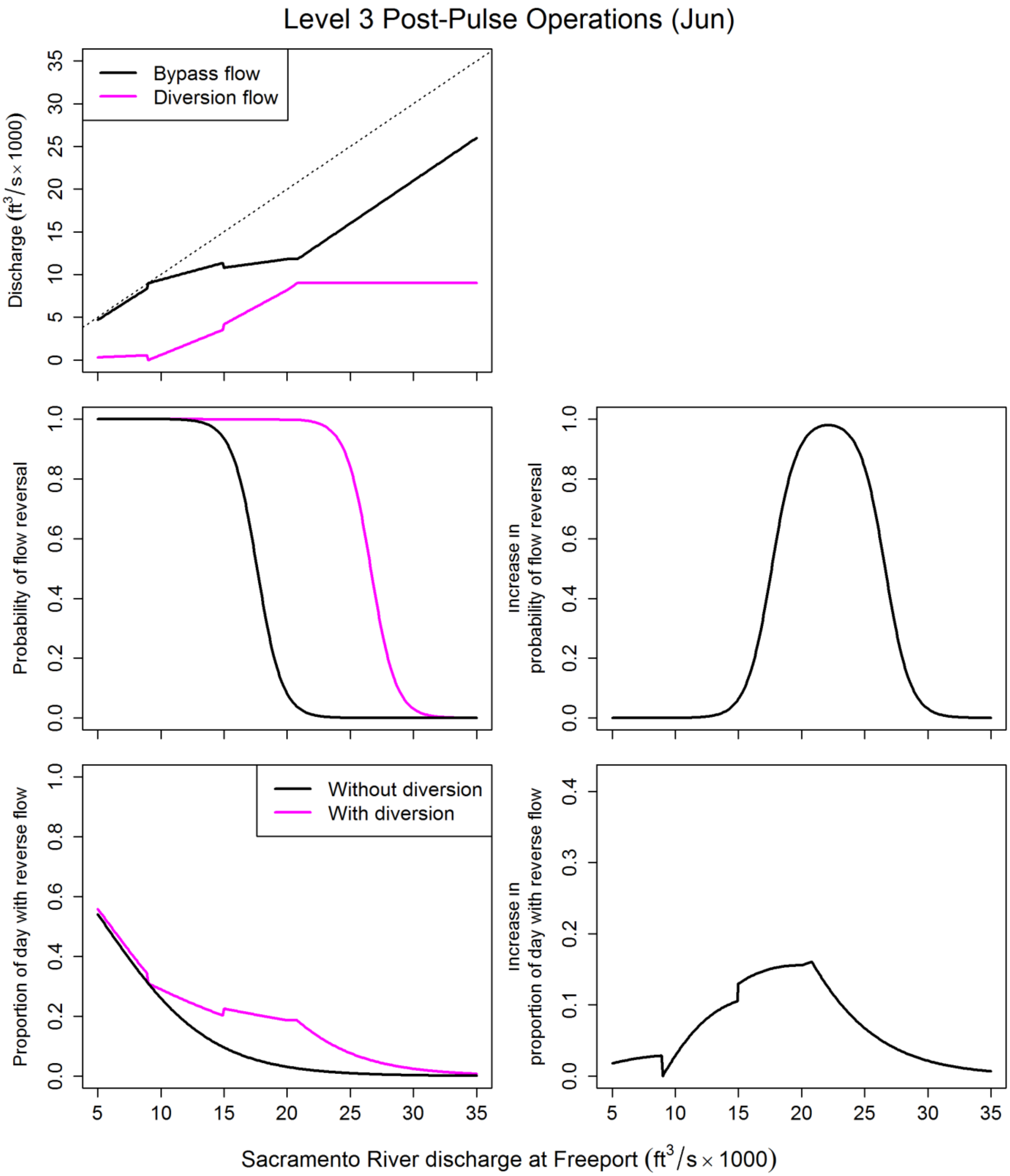

Figure 12. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for Level 3 post-pulse operations in June as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

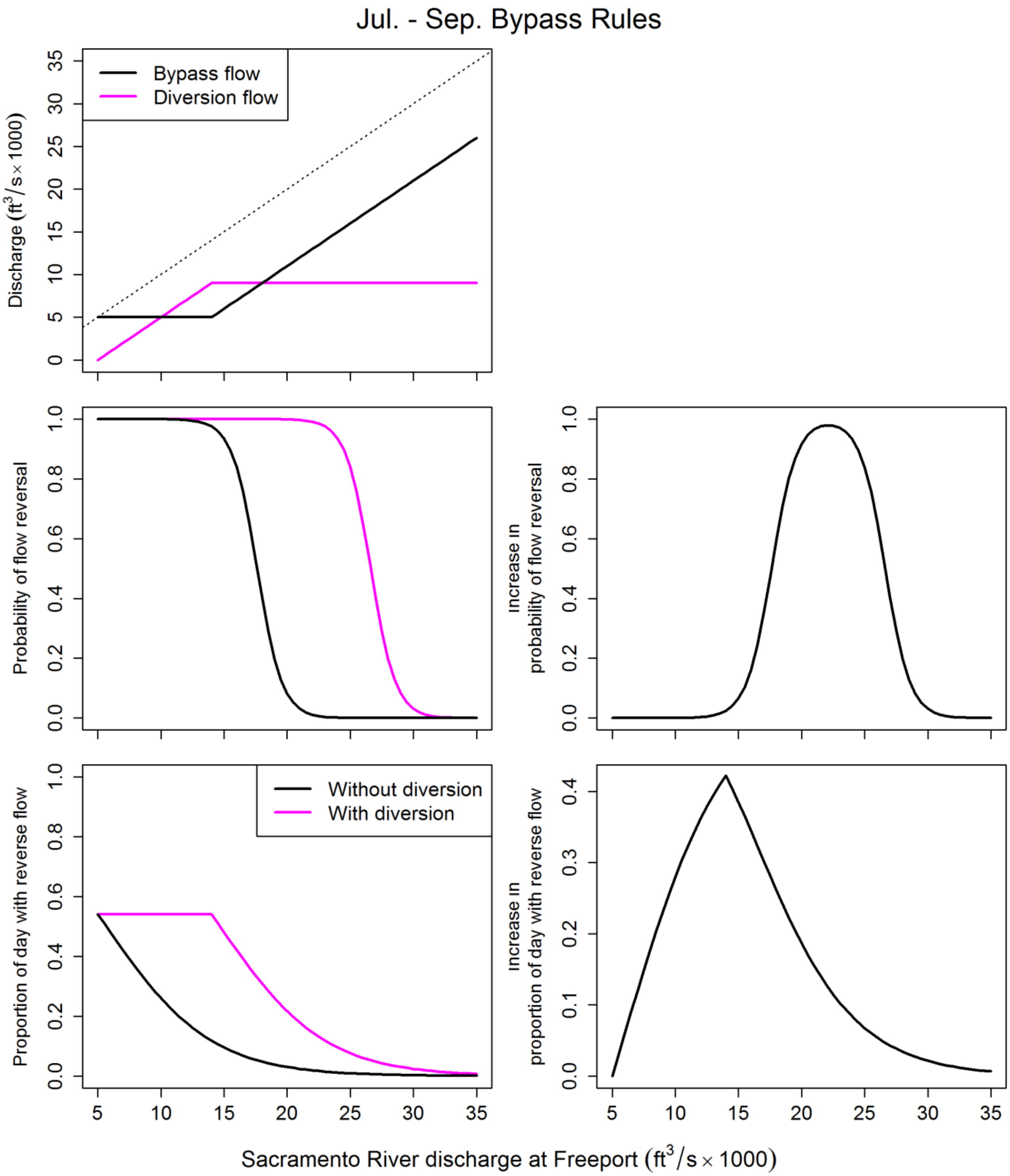

Figure 13. Effect of North Delta Diversion (NDD) on bypass discharge, probability of flow reversal, and proportion of the day with reverse flow for July–December as defined in the NDD bypass rules. In the top panel, the dotted line shows bypass discharge when diversion discharge is zero.

Discussion

The NDD bypass rules are designed to allow for diversion of water from the Sacramento River while providing fish protection during peak migration periods into the Delta. Low level pumping, which is initiated following flow pulses that have been shown to initiate migration of juvenile winter-run Chinook salmon (del Rosario and others, 2013), limits diversion to 10% of the maximum diversion capacity (9,000 ft^3/s). Under this criterion, we found little increase in the proportion of day with reverse flow (fig. 2), and therefore we expect little increase in entrainment of juvenile salmon into Georgiana Slough. In contrast, we found that the duration of flow reversal could be increased considerably during periods when juvenile salmon are likely to be migrating past Georgiana Slough. The conditions under which the P_{day}(reverse) can increase by ≥10 percentage points between October and June include October–November bypass rules and level 3 post-pulse operations from December through June (see lower right panels of fig. 3, 6, 9, and 12).

We performed our analysis under the assumption that the North Delta Diversion was operated at a constant rate for an entire day and followed the NDD bypass rules based on daily mean flows of the Sacramento River at Freeport. It is generally understood that the diversion would be operated "in real time" to prevent reverse flows at Georgiana Slough. However, to evaluate the effect of "real time" operations on flow reversal requires clear definition of control rules governing how the diversion would be operated to control flow reversals. To our knowledge, such control rules have yet to be developed and evaluated using tools such as DSM2. Consequently, our analysis evaluates the effect of the NDD bypass rules on flow reversals based on the how the rules were explicitly written according to readily available information on a daily basis (i.e., Sacramento River flows at Freeport).

Although it is unclear how real-time operations would be implemented, it is conceivable that the diversion could be operated on an hourly basis, in concert with the tides, to increase diversion during ebb tides but restrict diversion during flood tides. Such operations would likely require detailed real-time predictions of tides and tidally varying river flow in order to account for variation in tidal cycles that affect the frequency, magnitude, and duration of reverse flows at a given Freeport discharge. The relationship between Sacramento River inflows with the probability of flow reversal and proportion of the day with reverse flow is driven by tidal cycles that vary on hourly and biweekly time scales. Spring and neap cycles cause variation in the strength of the tides, which drives variation in the mean river flows at which the Sacramento River reverses downstream of Georgiana Slough. For example, at a Freeport discharge of 7,500 ft^3/s the proportion of the day with reverse flow ranges from about 0.12 to 0.35. This variation is driven by spring and neap tides that vary on biweekly scales, with strong spring tides corresponding with longer duration of reverse flows and weak neap tides corresponding with shorter duration of reverse flow. Based on these considerations, if real-time operations are to be used to control flow reversals, we strongly encourage development of explicit control rules for real-time management and testing of these controls through simulation models such as DSM2.

Bias Correction of DSM2 Discharge Predictions at the Junction of Sacramento River with the Delta Cross Channel and Georgiana Slough

Introduction

We used the fish entrainment model described in Perry and others (2015) to simulate the probability of fish entering Georgiana Slough and the Delta Cross Channel under the California Water Fix scenarios simulated by DSM2 (Delta Simulation Model 2), a one dimensional hydrodynamic simulation model of the Delta (http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm). Because the model of Perry and others (2015) used USGS gage flows in the Sacramento River and Georgiana slough to predict routing of juvenile salmon, we evaluated how well DSM2 predicted USGS gage flows. The concern was that bias in DSM2 flow predictions would induce bias in the predicted routing probabilities.

We found evidence of bias when DSM2 flow predictions at USGS gages at Georgiana Slough (GEO; USGS Gage 11447903) and Sacramento River below Georgiana Slough (WGB; USGS Gage 11447905) was compared to the observed flows data. Therefore, we used observed discharge data collected at these sites from November 2006 to December 2011 to correct discharge values predicted by DSM2. Discharge over this time period ranged from -8,440 to 21,000 ft^3/s at WGB and -534 to 8,300 ft^3/s at GEO. It is important to note that although DSM2 version 8.1.2 is the current release version, DSM2 simulations for the California Water Fix used DSM2 version 8.0.6 to maintain consistency with the simulations conducted under the Bay Delta Conservation Plan. Although not presented here, we found DSM2 version 8.1.2 exhibited less bias when used to predict discharge at these gaging stations. By using observed flow data to correct DSM2 flow predictions, we eliminated any potential bias in routing probabilities that would result from using biased flow predictions to predict routing probabilities.

Methods

We developed two multiple linear regression models to predict observed flow at GEO and WGB as a function of DSM2 flows at WGA (Sacramento River Above the Delta Cross Channel), DCC (Delta Cross Channel), GEO, and WGB. Two indicator variables were evaluated; first, an indicator variable (I_{WGB}) was used to provide the direction of flow at WGB (upstream flow=1; downstream flow=0) and second, DCC_{gate} was used to indicate the status of the DCC gates (open=1, closed=0). Interactions between covariates were also included within the model. The model that resulted in the highest coefficient of determination (R^2) and met all assumptions of linear regression (i.e. homogeneity of residuals, low skew and kurtosis etc.) was selected as the best fit model. Lagged DSM2 flows were used to improve tidal phase shift. Alternative models were assessed to evaluate whether lagged flow variables improved model fit. Variables were lagged by 15 minute time steps from 15 minutes to 150 minutes.

Results

The best fit model for the GEO gaging station included flow at all four flow gages (WGA,WGB, GEO, and DCC) lagged by two time steps or 30 minutes (table 2). The indicator variable I_{WGB} and DCC gate position parameter (DCCgate) were included in the final model as main effects. The final model also included two- and three-way interactions. Two- and three-way interactions included the interactions between lagged flow at each flow station and DCC gate operation (DCCgate) and the interactions between lagged flow at each flow station and the flow indicator parameter I_{WGB}. The interaction between the indicator variable I_{WGB} and DCC gate position was also retained in the final model. Three-way interactions consisted of the interactions between lagged flow at each flow station, DCC gate position, and the flow indicator variable I_{WGB}. The model fit the observed data reasonably well (fig. 14). Residuals between predicted and observed discharge at GEO were normally distributed and centered near zero. Coefficient of determination (R^2) was 0.949.

The model for the WGB gaging station was similar to the model used to correct flows at GEO, however flows were lagged by three time steps or 0.75 hour (i.e., $Q_{GEO,3}$; table 3). All flow stations, the flow indicator parameter, and the DCC_{gate} indicator were included as main effects in the model (table 2).

Two- and three-way interactions were also included in the final model. Two-way interactions retained in the final model consisted of the interactions between flow at each flow station and DCC gate position. The interaction between flow at WGA, WGB, and GEO and the flow indicator variable I_{WGB} was also retained. The flow indicator variable interacted with gate operations was also retained in the final model. Three-way interactions consisted of flow at WGA, WGB, and GEO interacted with the DCC gate operations and the flow indicator parameter. The model provided a good fit to the data (R^2=0.962) and residuals between corrected flow and observed flow were normally distributed and had a mean of approximately zero for all model fits (fig. 15).

Table 2. Parameter estimates for correction of flow at GEO. Parameters were lagged by 2 time steps or 30 minutes. The second subscript in each parameter indicates the number of lag steps.
[Q, discharge; GEO, Georgiana Slough; WGB, Sacramento River below Walnut Grove; WGA, Sacramento River above Walnut Grove; DCCgate, indicator variable for position of the Delta Cross Channel gate position (1 = open, 0 = closed); I, indicator variable for flow direction at WGB (1 = upstream, 0 = downstream)]

	Parameter	Estimate	Std. Error
Main Effects	(Intercept)	-81.800	4.616
	$Q_{GEO,2}$	0.568	0.009
	$Q_{WGB,2}$	-0.099	0.007
	$Q_{WGA,2}$	0.238	0.007
	$Q_{DCC,2}$	-0.152	0.010
	I_{WGB}	894.100	21.910
	DCCgate	219.600	8.072
Two-way interactions	$Q_{GEO,2}$*DCCgate	-0.731	0.016
	$Q_{WGB,2}$*DCCgate	-0.296	0.011
	$Q_{WGA,2}$*DCCgate	0.330	0.012
	$Q_{DCC,2}$ *DCCgate	-0.195	0.014
	I_{WGB} *DCCgate	-483.200	24.150
	$Q_{GEO,2}$ * I_{WGB}	-0.148	0.026
	$Q_{WGB,2}$ * I_{WGB}	-0.050	0.020
	$Q_{WGA,2}$ * I_{WGB}	-0.015	0.022
	$Q_{DCC,2}$ * I_{WGB}	-0.111	0.024
Three-way interactions	$Q_{GEO,2}$ * I_{WGB} * DCCgate	0.220	0.032
	$Q_{WGB,2}$ * I_{WGB} * DCCgate	0.203	0.023
	$Q_{WGA,2}$ * I_{WGB} * DCCgate	-0.209	0.025
	$Q_{DCC,2}$ * I_{WGB} * DCCgate	0.333	0.027

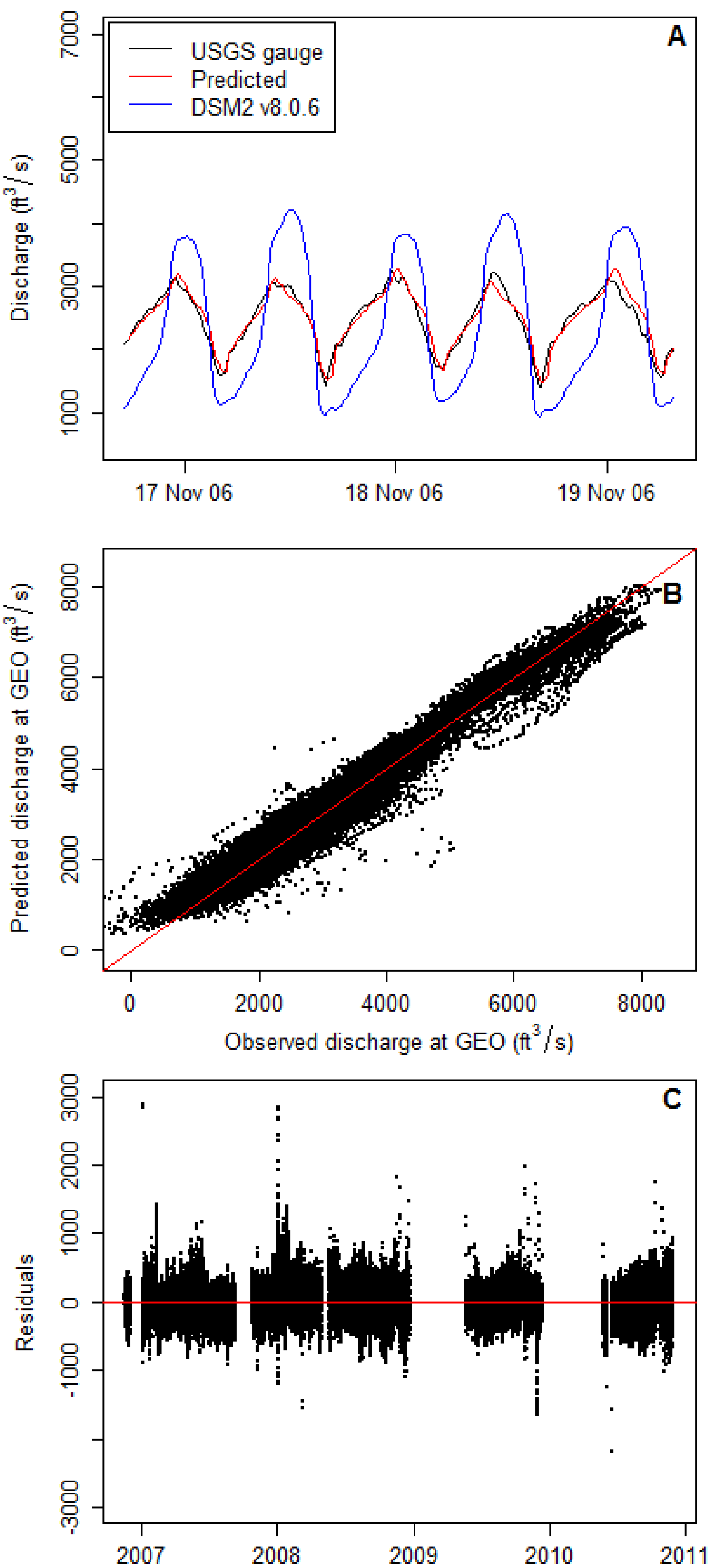

Figure 14. Comparison of observed, DSM2v8.0.6, and regression-corrected (predicted) discharge at the Georgiana Slough (GEO) USGS flow gage (*A*). Panel B compares observed and predicted discharge. The

diagonal line has slope of 1 and an intercept of zero. Residuals of the predicted and observed discharge for GEO (*C*).

Table 3. Parameter estimates for correcting DSM2v8.0.6 predicted flow at WGB. Parameters were lagged by 3 times steps or 0.75 hour. The second subscript in each parameter indicates the number of lag steps.
[Q, discharge; GEO, Georgiana Slough; WGB, Sacramento River below Walnut Grove; WGA, Sacramento River above Walnut Grove; DCCgate, indicator variable for position of the Delta Cross Channel gate position (1 = open, 0 = closed); I, indicator variable for flow direction at WGB (1 = upstream, 0 = downstream)]

	Parameter	Estimate	Std. Error
Main Effects	(Intercept)	-2317	22
	$Q_{GEO,3}$	2.326	0.039
	$Q_{WGB,3}$	2.173	0.030
	$Q_{WGA,3}$	-1.283	0.033
	$I_{WGB,3}$	1392	87
	DCCgate,3	722	38
	$Q_{DCC,3}$	1.447	0.042
Two-way interactions	$Q_{GEO,3}$ * DCCgate,3	0.678	0.065
	$Q_{WGB,3}$ * DCCgate,3	1.002	0.042
	$Q_{WGA,3}$ * DCCgate,3	-1.055	0.045
	I_{WGB} * DCCgate,3	-394	99
	$Q_{GEO,3}$ * $I_{WGB,3}$	-0.314	0.052
	$Q_{WGB,3}$ * $I_{WGB,3}$	0.017	0.038
	$Q_{WGA,3}$ * $I_{WGB,3}$	-0.349	0.041
	$Q_{DCC,3}$ * DCCgate,3	1.219	0.051
Three-way interactions	$Q_{GEO,3}$ * I_{WGB}*DCCgate,3	-0.491	0.082
	$Q_{WGB,3}$ * I_{WGB}*DCCgate,3	-0.263	0.042
	$Q_{WGA,3}$ * I_{WGB}*DCCgate,3	0.256	0.045

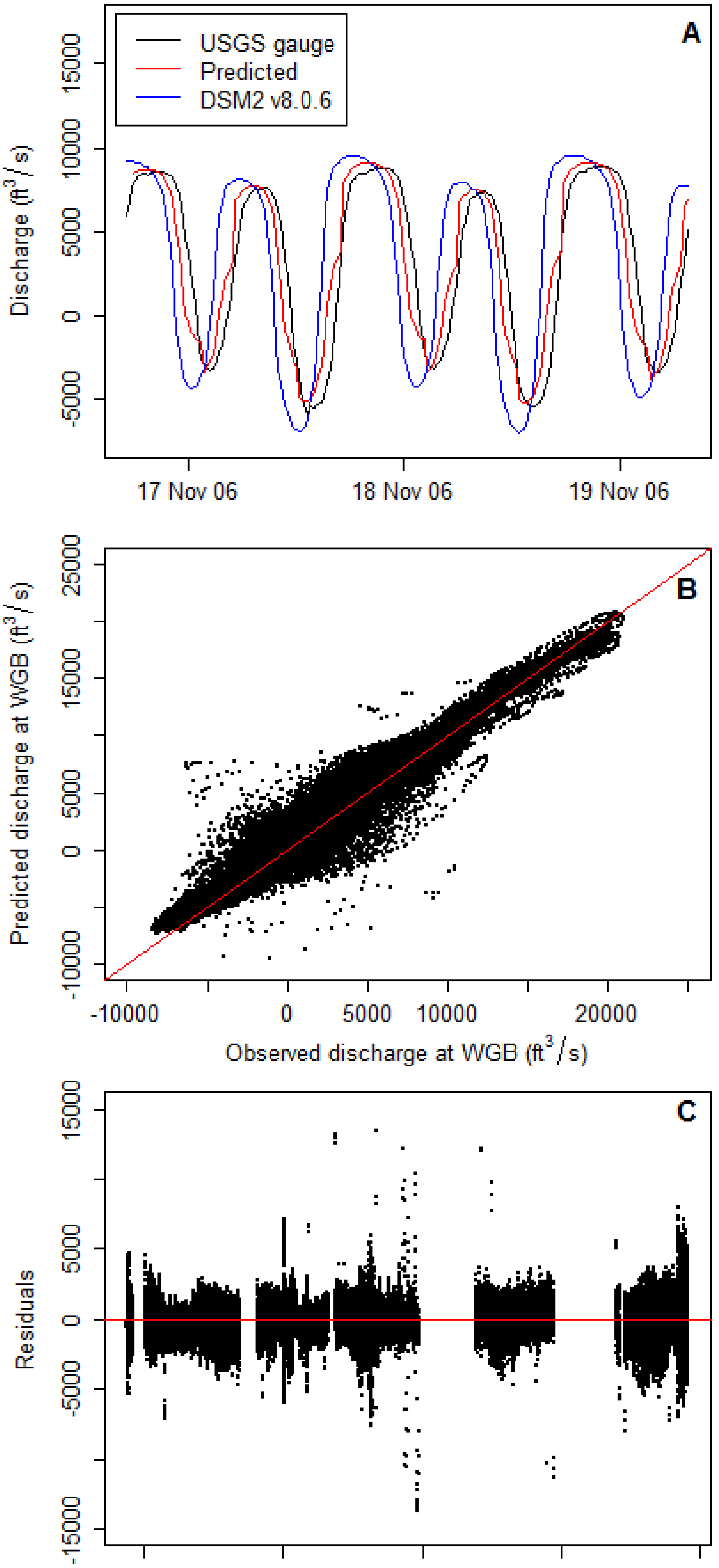

Figure 15. Comparison of observed, DSM2v8.0.6, and regression-corrected (predicted) discharge at the

Sacramento River below Walnut Grove (WGB) USGS flow gage (A). Panel B compares observed and predicted discharge. The diagonal line has slope of 1 and an intercept of zero. Panel (C) illustrates the residuals of the predicted and observed discharge for WGB.

Discussion

We used lagged flow variables in conjunction with indicator variables to create models to adjust DSM2 predicted flows at both GEO and WGB. Our models provide a good adjustment for correcting the DSM2 output; however the predictive power of our model is limited to the range of flows used for the correction. Empirical data were only available for the 2006–2011 time period. Therefore, one should use caution in applying the model to predict flows outside of the range of flows used in the model development.

Interestingly, lags in the model covariates improved model fits, suggesting that DSM2 8.0.6 does not adequately predicting tidal phasing at this location. Given the time lags it appears that DSM2 is predicting water pulses to arrive later than observed at WGB and earlier than observed at GEO. In addition DSM2 routinely overestimated the magnitude of flow at WGB. In contrast, DSM2 did accurately estimate the magnitude of flow at GEO. This suggests the complex hydrodynamics at this junction are not fully captured by DSM2.

Simulating the Effect of the North Delta Diversion on Daily Entrainment Probability of Juvenile Chinook Salmon into Georgiana Slough and the Delta Cross Channel

Introduction

This analysis investigates the effect of the proposed North Delta Diversion on entrainment of juvenile Chinook salmon into Georgiana Slough and the Delta Cross Channel. Specifically, we used the entrainment probability model of Perry and others (2015) to predict entrainment probabilities from flows simulated by DSM2 under the California Water Fix No Action Alternative (NAA) and Proposed Action (PA) from October to June for each water year in the 82-year simulation period (ICF International 2016). The entrainment model is based on a multinomial regression analysis that estimated the probability (π) of individual fish entering the Delta Cross Channel (π_{DCC}), Georgiana Slough (π_{GEO}), and the Sacramento River (π_{SAC}) from three variables: 1) instantaneous river discharge (i.e., measured every 15 minutes) entering Georgiana Slough (GEO), 2) instantaneous discharge of the Sacramento River below Georgiana Slough (WGB), and 3) Delta Cross Channel gate position (1 = open, 0 = closed). The entrainment model was based on acoustic telemetry data collected between 2006 and 2009 from 919 juvenile late-fall Chinook salmon that passed the river junction over rivers flows of the Sacramento River at Freeport ranging from 6,802 ft^3/s to 40,700 ft^3/s. A complete description of the model, including model equations, estimated parameters, and goodness-of-fit, can be found in Perry and others (2015) and Perry (2010).

Methods

To apply the entrainment model of Perry and others (2015) to DSM2 output, we 1) corrected DSM2 discharge simulations at WGB and GEO using the regression correction described in the previous section, 2) formed covariates required for the entrainment model from the corrected DSM2 discharge simulations, and 3) simulated route entrainment probabilities for the entire 82-year time series of 15-minute flows simulated under the NAA and PA scenarios. We then tabulated daily entrainment probabilities as the mean of 15-minute entrainment probabilities for each day. Daily entrainment probabilities represent the expected fraction of fish entering each channel on a particular date under the assumption that fish migrate past this river junction uniformly over the diel period.

The entrainment model was based on data collected at a maximum Freeport discharge of 40,700 ft^3/s, whereas the DSM2 simulations include Freeport flows up to about 80,000 ft^3/s. Therefore, we evaluated the model's behavior at flows >40,000 ft^3/s because we were concerned about using the entrainment model outside the range of data used to inform the model. Simulated daily entrainment probabilities based on DSM2 output increased from about 0.35 to 0.50 as Freeport discharge increased from about 40,000 ft^3/s to 80,000 ft^3/s (fig. 16). We compared these predictions to estimates from Perry and others (2014), who quantified the effect of a non-physical barrier on entrainment into Georgiana Slough when Freeport flows were approximately 80,000 ft^3/s. At this flow level, Perry and others (2014) estimated a mean entrainment probability into Georgiana Slough of about 0.30 with the non-physical barrier off, as opposed to 0.50 simulated using the Perry and others (2015) model. This finding suggests that entrainment probabilities remain relatively constant at flows between 40,000 ft^3/s and 80,000 ft^3/s rather than increasing as the model of Perry and others (2015) would predict. Because the Perry and others (2015) model appears to over-estimate entrainment at high flows, we restricted our analysis of simulated daily entrainment probabilities to flows at Freeport ≤ 41,000 ft^3/s.

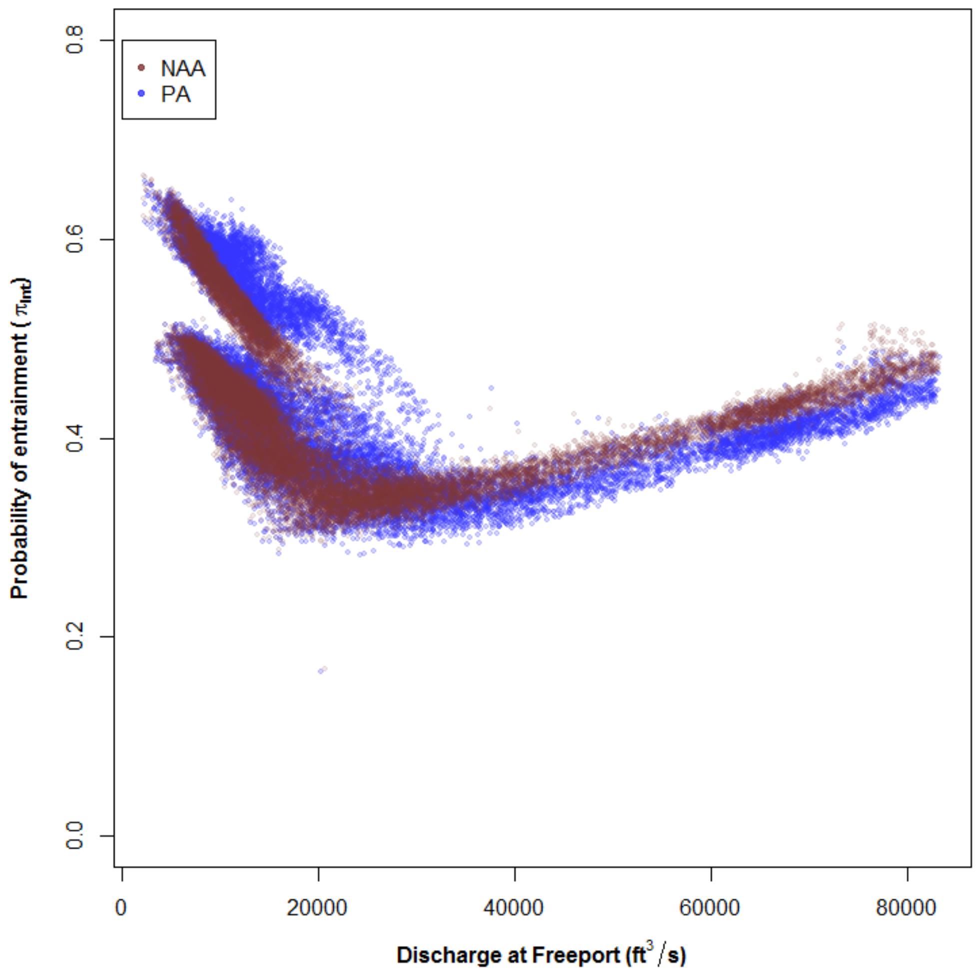

Figure 16. Daily probability of entering the interior Delta ($\pi_{Int} = \pi_{GEO} + \pi_{DCC}$) as a function of Sacramento River discharge at Freeport for the No Action Alternative (NAA) and Proposed Action (PA) simulations conducted with DSM2 (Delta Simulation Model 2).

Ideally, if daily inflows to the Delta were the same between NAA and PA scenarios, then daily entrainment probabilities could be compared directly among common dates that employ different management alternatives between scenarios. However, daily inflows to the Delta vary between scenarios owing to upstream flow management that differs between scenarios, making direct comparison of daily entrainment probabilities problematic. Therefore, we compared scenarios by summarizing daily entrainment probabilities within each year by averaging daily entrainment probabilities over 1) each year, 2) each month within years, and 3) over three alternative run-timing distributions. Summary statistics included days when Freeport flows were ≤41,000 ft^3/s and excluded days when flows were >41,000 ft^3/s. The three run-timings were: 1) a uniform distribution, where an equal proportion of fish out-migrated each month; 2) an early run timing representing winter-run Chinook in years when flow conditions trigger an early migration into the Delta and 3) a late run timing representing winter-run Chinook in years when the migration begins in December (fig. 17). Estimates of annual entrainment probability for the different run timings were calculated as a weighted average of the daily entrainment probability weighted by the proportion of the run migrating on a given day. Run timing distributions were based on juvenile trapping data from Knight's landing (Yvette Redler, written commun. January 7, 2016). We then categorize these annual statistics according to California Department of Water Resources water-year classification and compare box plots of annual entrainment probabilities for different water year types. CDWR uses five classifications for water year type in the Sacramento Valley that are based on water year index value (WYI): W=Wet, WYI ≥ 9.2; AN=above normal, 7.8 ≤ WYI ≤ 9.2; BN=Below Normal, 6.5≤ WYI ≤7.8; D=Dry, 5.4≤ WYI ≤6.5; C=Critical, WYI ≤ 5.4.

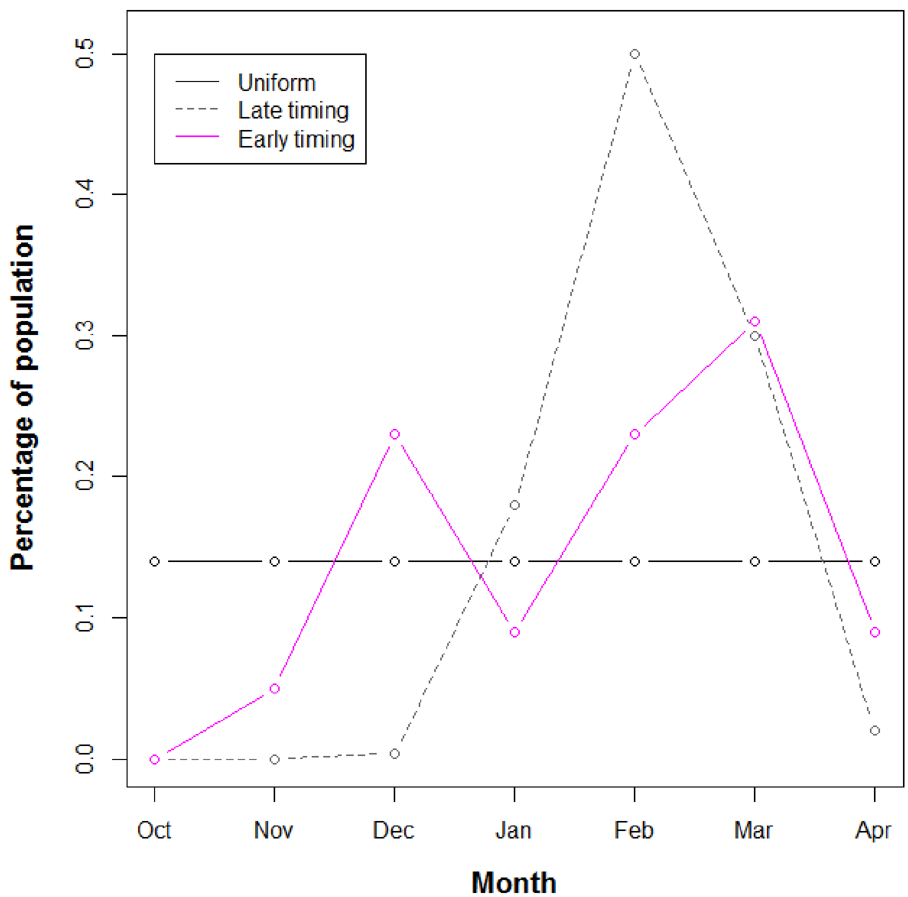

Figure 17. Migration timing scenarios used to estimate mean annual entrainment probabilities, with the early and late timings representing two scenarios for winter-run Chinook salmon in the Sacramento River.

Results

We estimated entrainment probabilities for NAA and PA under three run timing distributions over an 82-year period. In general, the mean annual entrainment probabilities differed little between PAA and NA (table 4); however, we found small but consistent differences in entrainment between scenarios that varied across years (figs. 18 and 19). For example, under uniform run timing, the annual probability of fish remaining in the Sacramento River for the PA scenario was 0 to 4 percentage points lower than under the NAA scenario, indicating higher entrainment into the interior Delta (fig. 18). Mean annual entrainment into the Delta Cross Channel was consistently higher under the PA scenario, but differences in mean annual entrainment into Georgiana Slough exhibited both positive and negative deviations (fig. 18). These findings indicate that the increased entrainment into the Delta Cross Channel was responsible for the lower probability of fish remaining in the Sacramento River.

Table 4. Mean (SD) predicted annual entrainment probabilities under different run-timing scenarios for No Action Alternative (NAA) and Proposed Action (PA) simulations conducted with DSM2.

	Sacramento River		Georgiana Slough		Delta Cross Channel	
Run-timing	**NAA**	**PA**	**NAA**	**PA**	**NAA**	**PA**
Uniform	0.571 (0.031)	0.556 (0.028)	0.349 (0.017)	0.346 (0.017)	0.072 (0.03)	0.089 (0.024)
Late	0.555 (0.132)	0.547 (0.129)	0.344 (0.09)	0.352 (0.094)	0 (0)	0 (0)
Early	0.558 (0.085)	0.549 (0.082)	0.346 (0.061)	0.352 (0.063)	0.018 (0.018)	0.021 (0.018)

The differences in entrainment under the early run timing revealed a slightly higher (by about 1 percentage point) mean annual probability of entering the Delta Cross Channel (fig. 19). However, for the late run timing, we found little difference in entrainment between the NA and PAA scenarios (fig. 19). The differences in annual entrainment among the run timing scenarios suggested that daily entrainment probabilities varied seasonally, thereby affecting annual entrainment differentially for the alternative run timings.

Examination of the distribution of mean monthly entrainment probabilities revealed seasonal patterns that varied among water year types (fig. 20). In all but critically dry years, median π_{SAC} (the probability of fish remaining in the Sacramento River) under the PA scenario was up to 5 percentage points lower than under the NAA scenario for October and November (fig. 20). This difference was also apparent for June in wet years. Because the early and late run timings had zero probability of migrating in October and low (early) or zero (late) probability of migrating in November, these run timing distributions had little exposure to the differences in operation between PA and NAA during these months, leading to little difference in mean annual entrainment probabilities (figs. 18 and 19).

For the months of October, November, and June, fish had a lower probability of remaining in the Sacramento owing primarily to a higher probability of entering the Delta Cross Channel. We also found that the Delta Cross Channel gates were open more frequently in October and November (fig. 21), which likely contributed to the higher mean monthly probability of entering the Delta Cross Channel. For example, we identified days when the Delta Cross Channel was open under PA but closed under NAA (fig. 22). Under NAA the DCC remained closed owing to NDD Bypass flows > 25,000 ft^3/s, a trigger that causes closure of the DCC (fig. 22). However, under PA, water diversion reduced bypass flows below 25,000 ft^3/s, which allowed the DCC gates to remain open (fig. 22). In turn, opening the Delta Cross Channel gates substantially reduced the instantaneous probability of fish remaining in the Sacramento River by increasing the probability of fish entering the Delta Cross Channel (fig. 22).

We found that much of the interannual variation in mean annual entrainment probabilities could be attributed to water year classification. For example, mean annual π_{SAC} for the uniform run timing decreased from a median of about 0.60 to 0.52 as water year type transitioned from wet to critically dry years (fig. 23). In contrast, both mean annual π_{GEO} and π_{DCC} increased as water years transitioned from wet to critically dry (fig. 23). Between scenarios, π_{SAC} under PA was less than under the NAA scenario for all water year types for a uniform run timing (fig. 24). For the early and late run timings, we observed little difference between PA and NAA for π_{SAC} for wet and above normal water years, but π_{SAC} was consistently lower for PA relative NAA (fig. 24). Although we found some consistent differences between PA and NAA among water year types, the median difference between scenarios was <2 percentage points for all mean annual entrainment probabilities.

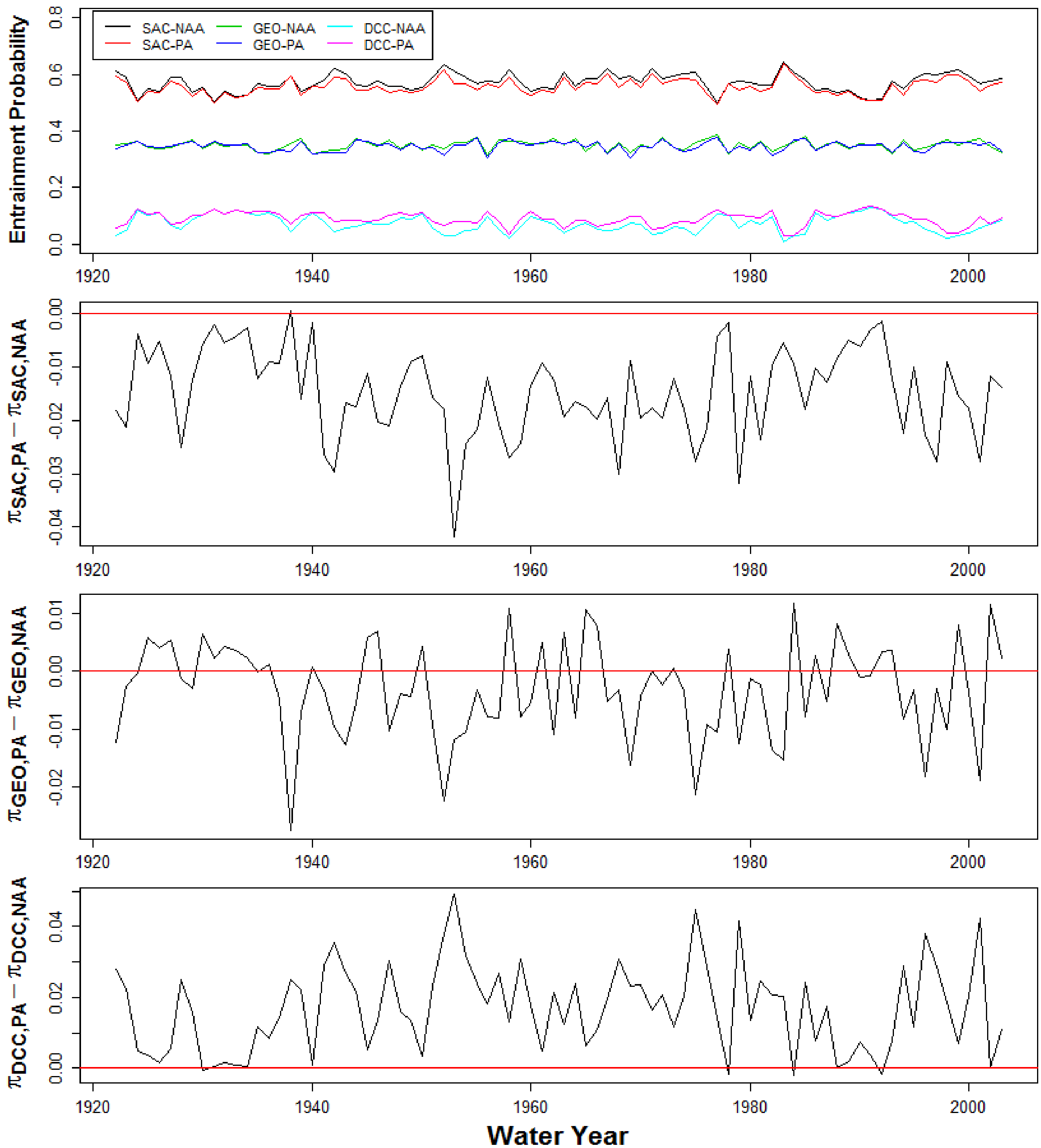

Figure 18. Comparison of predicted mean annual entrainment probability assuming uniform run timing for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the Proposed Action (PA) and No Action Alternative (NAA). Shown are the mean annual entrainment probabilities (top panel) and the difference in entrainment between scenarios for SAC, GEO, and DCC (lower panels). Values above the horizontal red line indicate greater entrainment under the PA scenario.

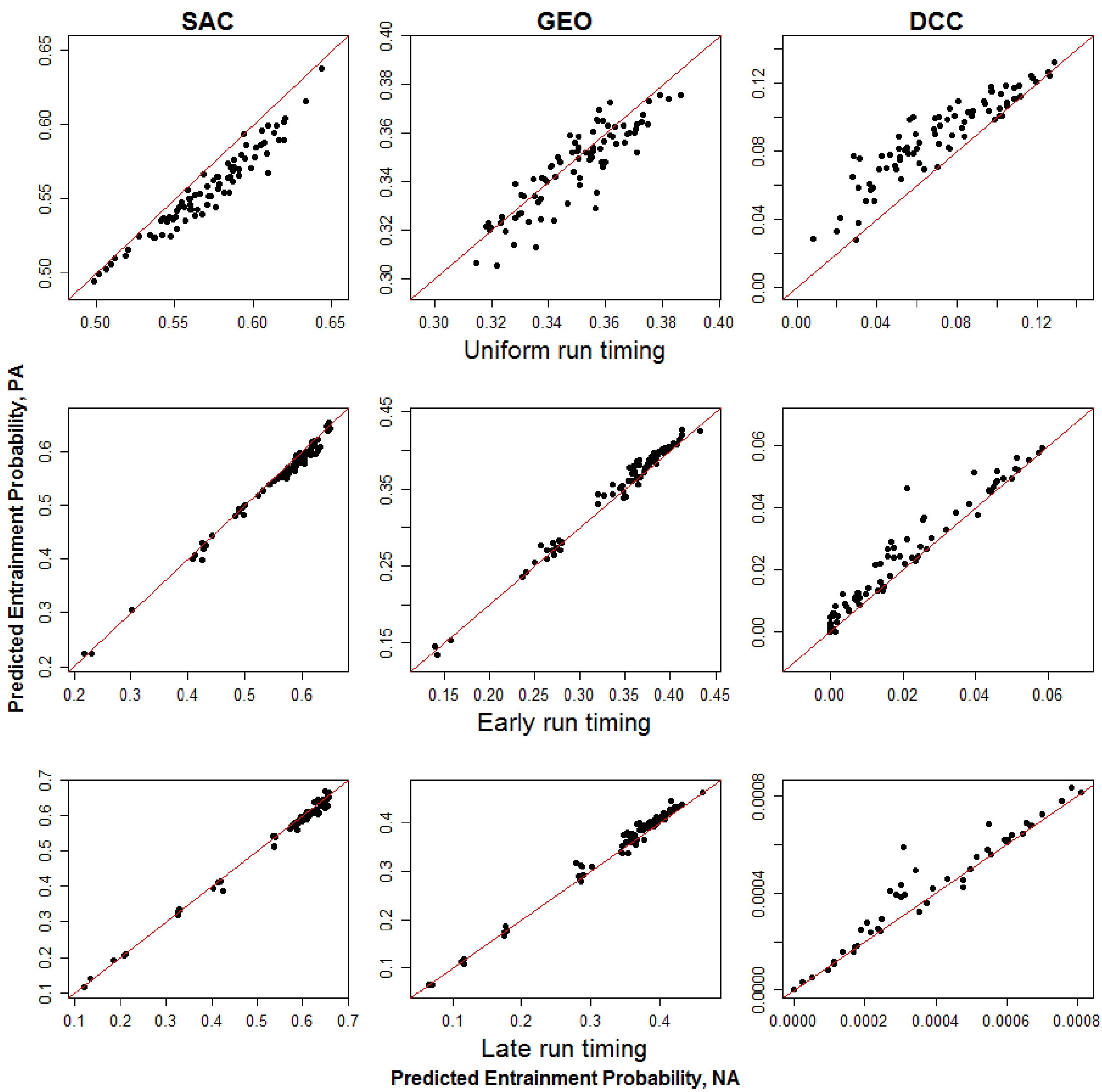

Figure 19. Comparison of predicted mean entrainment probability for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the Proposed Action (PA) and No Action Alternative (NAA) for uniform arrival and two different run timings for winter run Chinook salmon. The data points are paired by year, and the diagonal line has slope of one and an intercept of zero.

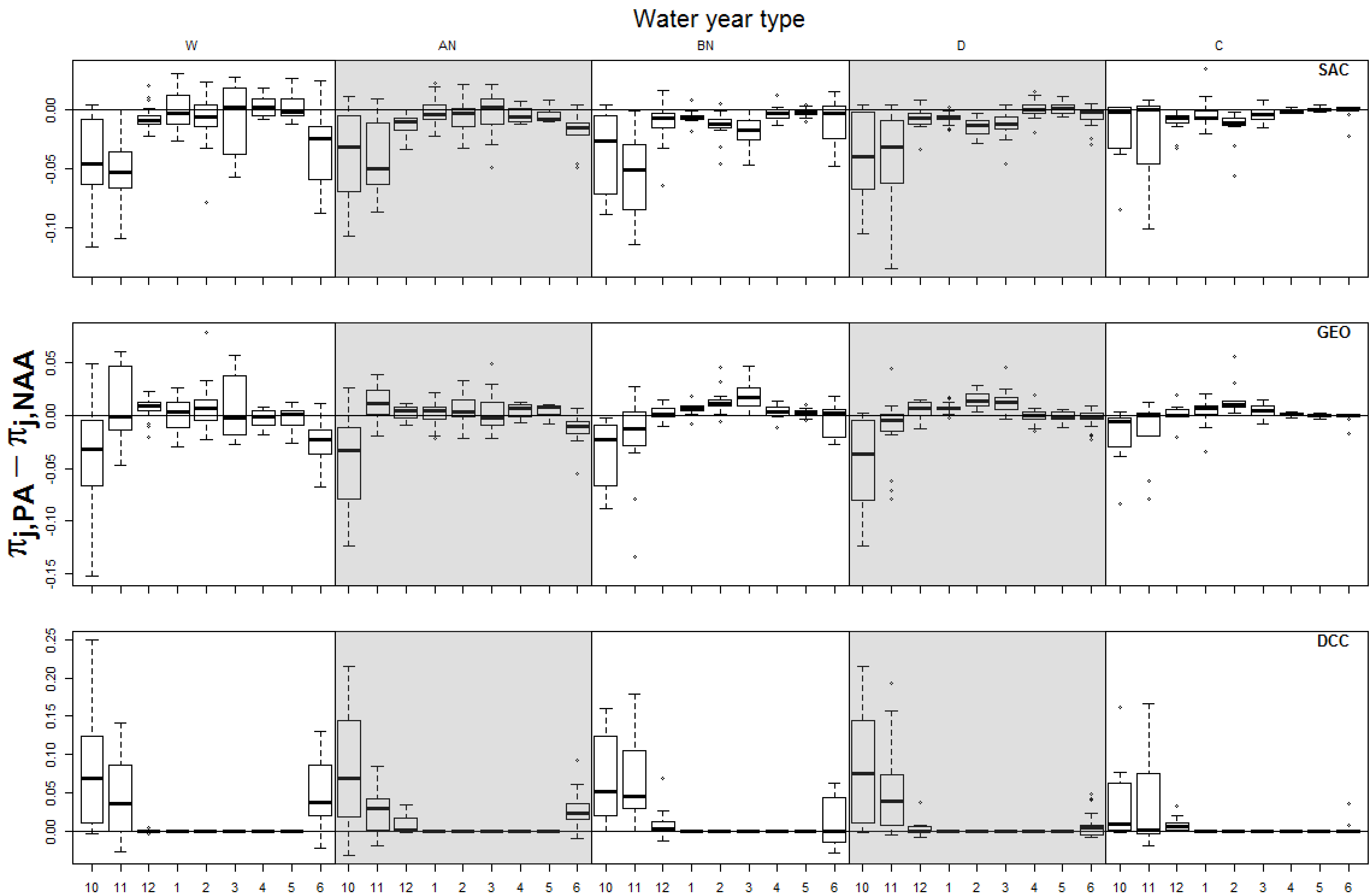

Figure 20. Boxplot of the difference predicted entrainment probability between the Proposed Action (PA) and No Action Alternative (NAA) by water year type and month assuming a uniform run timing (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical). Boxes range from the 25th to the 75th percentiles with a line indicating the median, whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers.

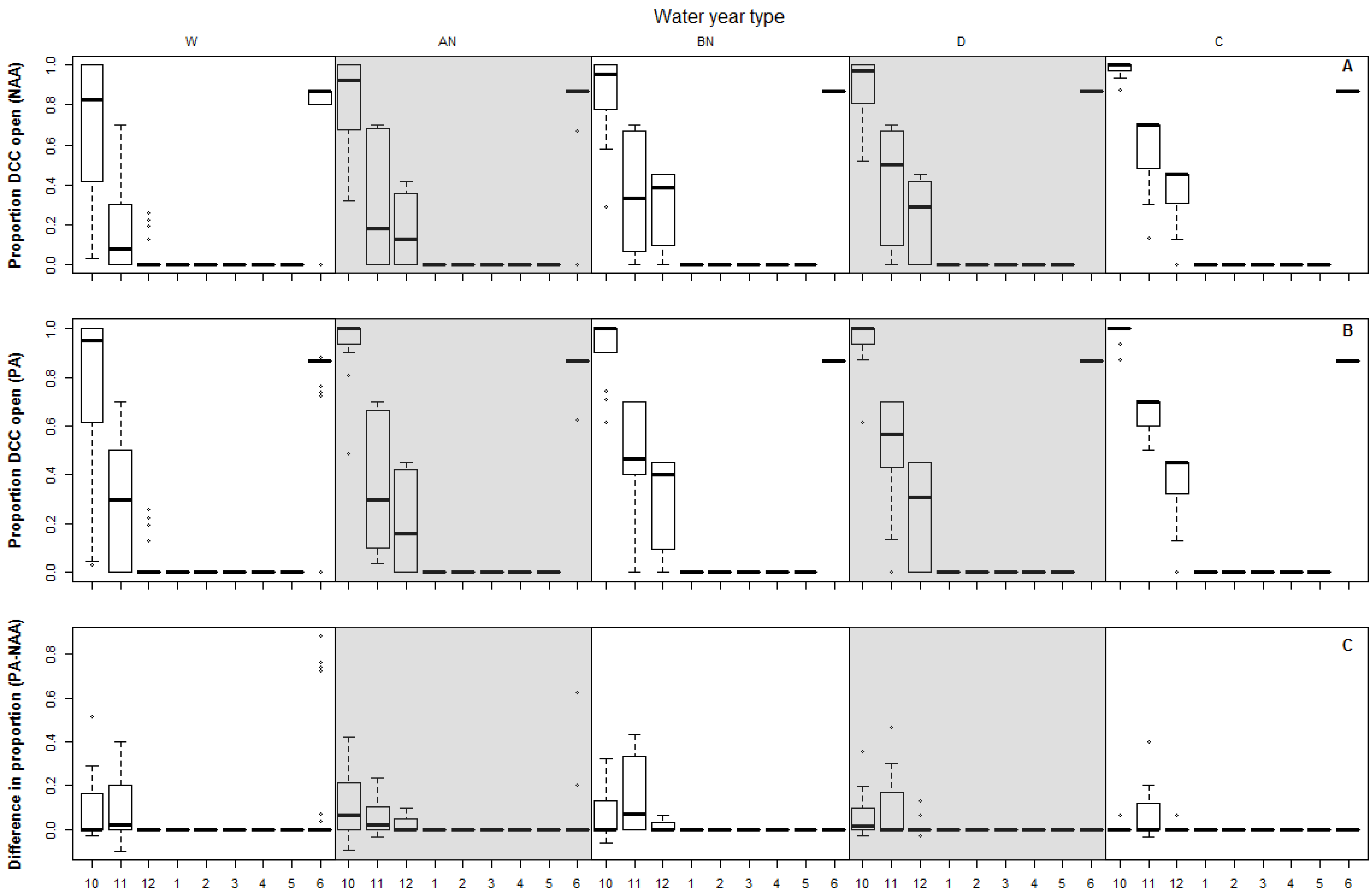

Figure 21. Boxplot of the proportion of each month that the DCC was open for the No Action Alternative (NAA, panel A), Proposed Action (PA, panel B), and the difference between PA and NAA (panel C) by water year type (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical). Boxes range from the 25th to the 75th percentiles with a line indicating the median, whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers.

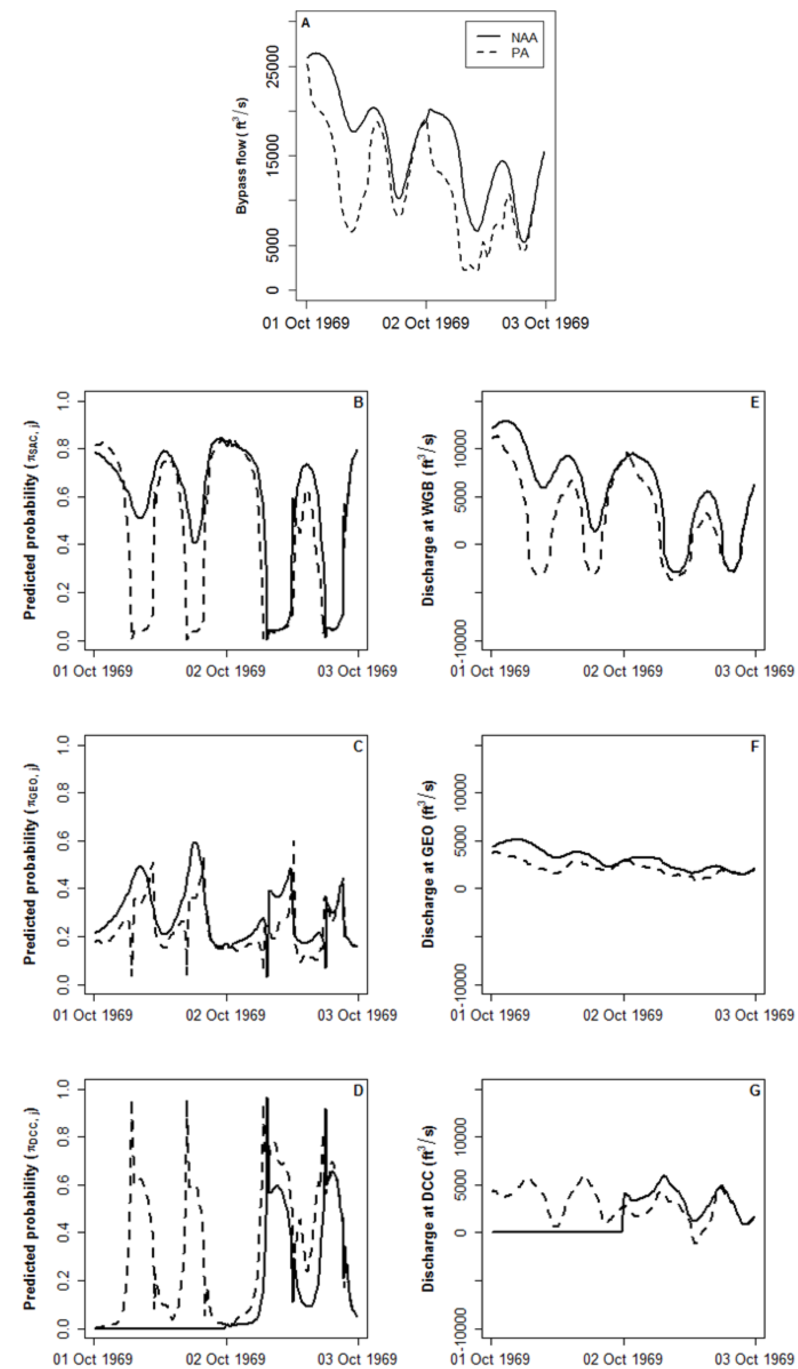

Figure 22. Comparison of bypass flows (A), predicted probability of entrainment into Sacramento River (B), Georgiana Slough (C), and the Delta Cross Channel (D) for the Proposed Action (PA) and No Action Alternative (NAA) during dates when the DCC was open under PA but closed under NAA. Discharge entering each route for NAA and PA are also shown (E, F, G).

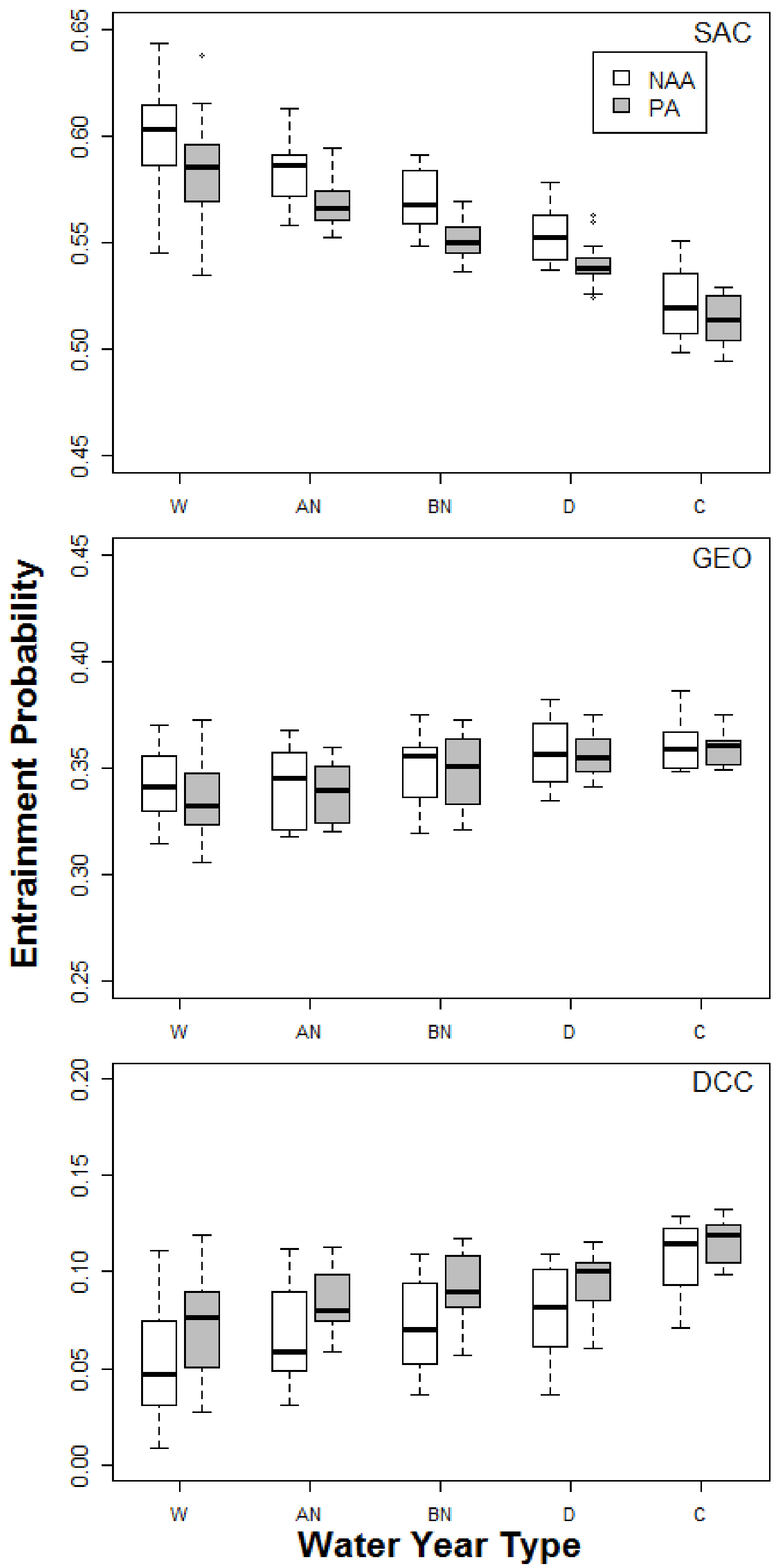

Figure 23. Boxplot of predicted mean annual entrainment probability for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the No Action Alternative (NAA) and Proposed Action (PA) by water year type based on a uniform run timing distribution (W=Wet, AN=Above Normal, BN=Below Normal,

D=Dry, C=Critical). Boxes range from the 25th to the 75th percentiles with a line indicating the median, whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers.

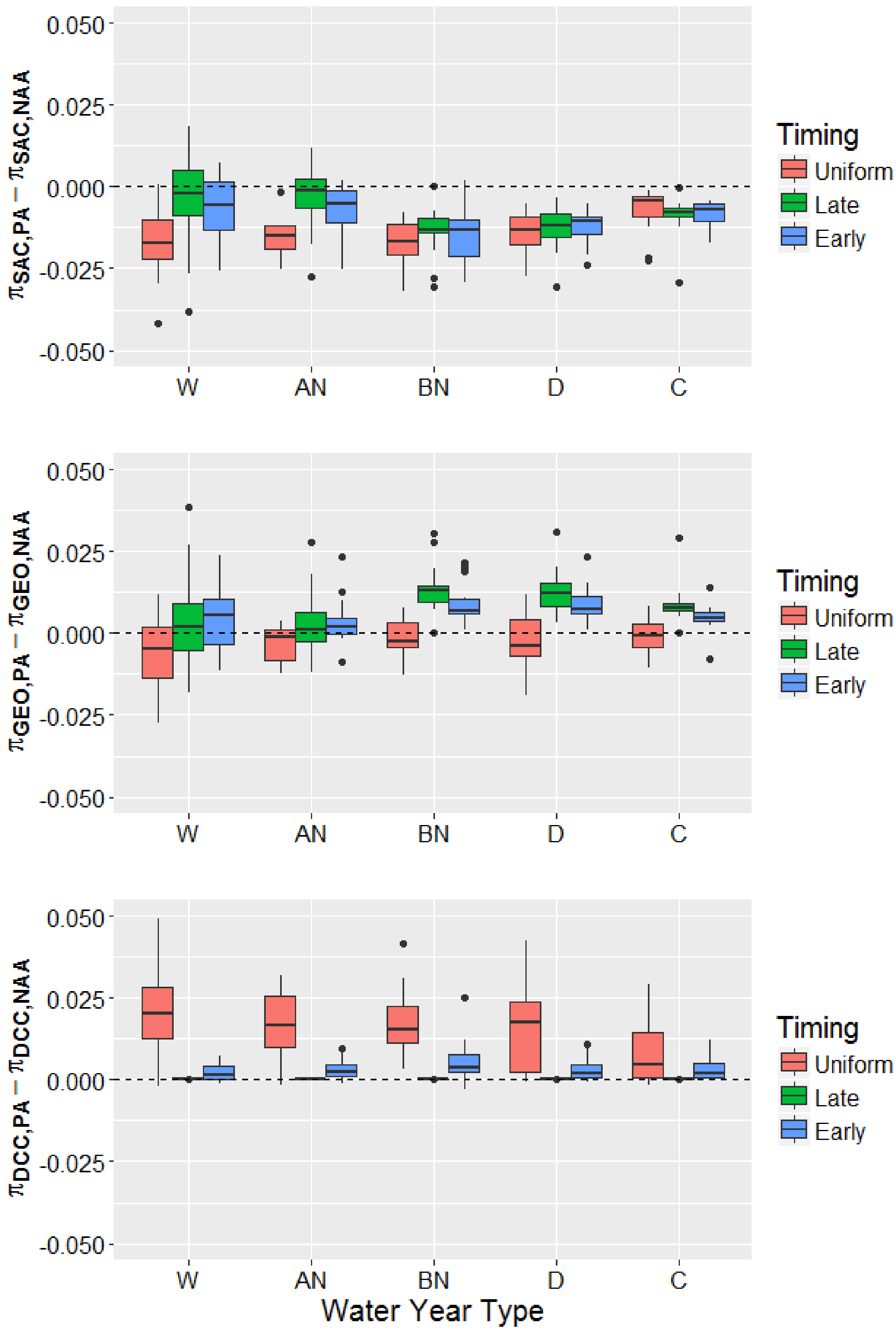

Figure 24. Boxplots of the difference between No Action Alternative (NAA) and Proposed Action (PA) for each

route (SAC = Sacramento River, GEO = Georgiana Slough, DCC = Delta Cross Channel) by water year type (W=Wet, AN=Above Normal, BN=Below Normal, D=Dry, C=Critical) and run timing scenario. Boxes range from the 25th to the 75th percentiles with a line indicating the median, whiskers extend 1.5 times past the length of the box, and dots represent data points that fall beyond the whiskers.

Discussion

We used previously developed entrainment models to predict the probability of fish entrainment into the interior Delta via Georgiana Slough and the Delta Cross Channel under the PA and NAA scenarios for different run timings and water year types. Overall the probability of remaining in the Sacramento River was lower under the PA scenario, but the magnitude of the difference was small. However, when run timing was assumed to occur between December and April, this difference was even less because fish were less exposed to periods when we observed the largest difference in entrainment between scenarios (October and November).

Although we observed relatively small differences in entrainment, we restricted our analysis to flows <41,000 ft^3/s to avoid potential bias in predicted entrainment probabilities at higher flows. When the entrainment model of Perry and others (2015) was used to predict entrainment at higher flows, the model predicted that entrainment increased with increasing river flow up to about 50% entrainment at flows of 80,000 ft^3/s at Freeport (fig. 16). However, comparison to estimates of entrainment from Perry and others (2014) at similar flows indicated entrainment into Georgiana Slough of only about 30%. The entrainment model was fit to data that encompassed the range of flows where the Sacramento River transitions from strongly reversing to non-reversing flows. Thus, the model's parameterization captures changes in entrainment owing to the strength of reversing flows, and revealed that highest entrainment occurred at the lowest flows where tidal forcing increases the magnitude and duration of reverse flows. The available empirical evidence suggests that entrainment stabilizes as inflows increase above the level at which reverse flows cease, but more data is needed to substantiate this observation. Assuming this pattern holds true, excluding the high-flow observations from our analysis would tend to weight the mean annual entrainment probabilities more towards the higher daily entrainment probabilities that occur at lower discharges. Therefore, we may have observed even less difference in mean annual entrainment probabilities between PA and NAA had we used a model that predicted daily entrainment probabilities are relatively constant at flows >41,000 ft^3/s.

The difference in entrainment between scenarios was primarily driven by the difference in operation of the DCC between PA and NAA. Under the PA scenario, the DCC was open more frequently, thus exposing more fish to being entrained into the interior Delta via the DCC. Two triggers require the DCC to close: 1) Flow below the NDD exceeding 25,000 ft^3/s and 2) flow at Wilkins Slough on the Sacramento River exceeding 7,500 ft^3/s. Water diversions have no effect on flow at Wilkins Slough, which leaves the flow below the diversion as the primary driver of the differences between entrainment under the PA and NAA scenarios. Diversions under the PA reduced the flow to below 25,000 ft^3/s, thus increasing the number of days the DCC could remain open. This was particularly evident in October and November during wet and above normal water year types when discharge above the diversion was greater than 25,000 ft^3/s. For example, under PA in October during wet years the DCC was open for about three more days than under the NAA scenario. During drier water year types, the DCC was operated similarly between PA and NAA since flows in those years rarely exceeded 25,000 ft^3/s. When the DCC was operated in a similar manner between scenarios (drier years), entrainment to the interior was higher due to the general relationship between flow and entrainment to the interior delta. Under lower flows entrainment to the interior delta is higher due to tidal forcing at the Georgiana Slough divergence.

Perry and others (2013) explored the sensitivity of overall survival of emigrating juvenile Chinook salmon to changes in entrainment into the interior Delta. This analysis found that completely eliminating entrainment to the interior Delta resulted in a 2–7 percentage point increase in overall survival through Delta, under the assumption of no change in route-specific survival. Thus, we expect that a 3-5 percentage point difference in the probability of being entrained to the interior Delta between PA and NAA would contribute relatively little to the change in overall survival. However, it is important to recognize that reduced inflows to the Delta owing to the NDD may simultaneously influence both route-specific survival and migration routing. Such simultaneous changes may result in larger expected changes in survival than the effect of routing alone on overall survival.

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Appendix

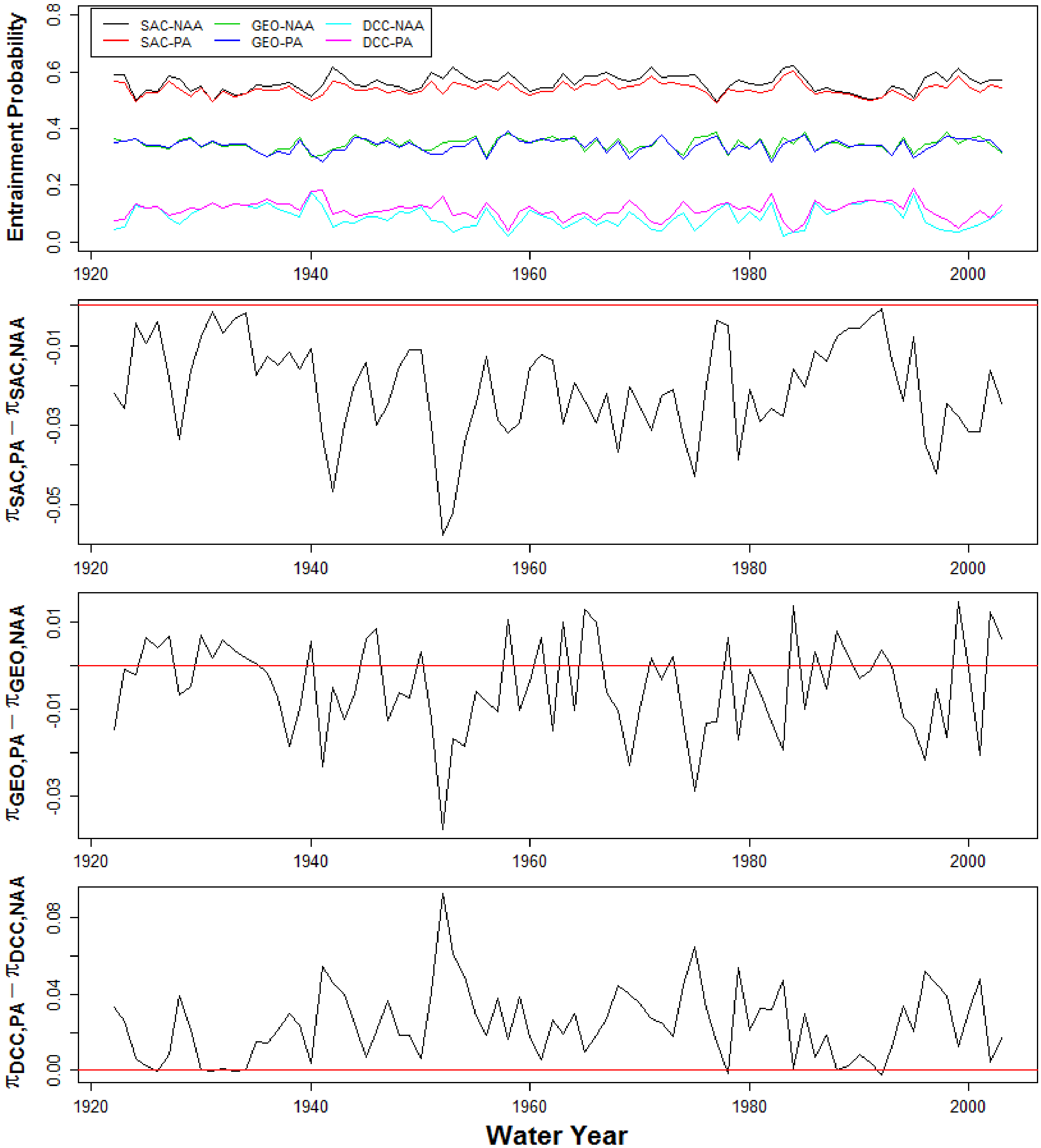

Figure 25. Comparison of predicted mean annual entrainment probability during daytime hours assuming uniform run timing for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the Proposed Action (PA) and No Action Alternative (NAA). Shown are the mean annual entrainment probabilities (top panel) and the difference in entrainment between scenarios for SAC, GEO, and DCC (lower panels). Values above the horizontal red line indicate greater entrainment under the PA scenario.

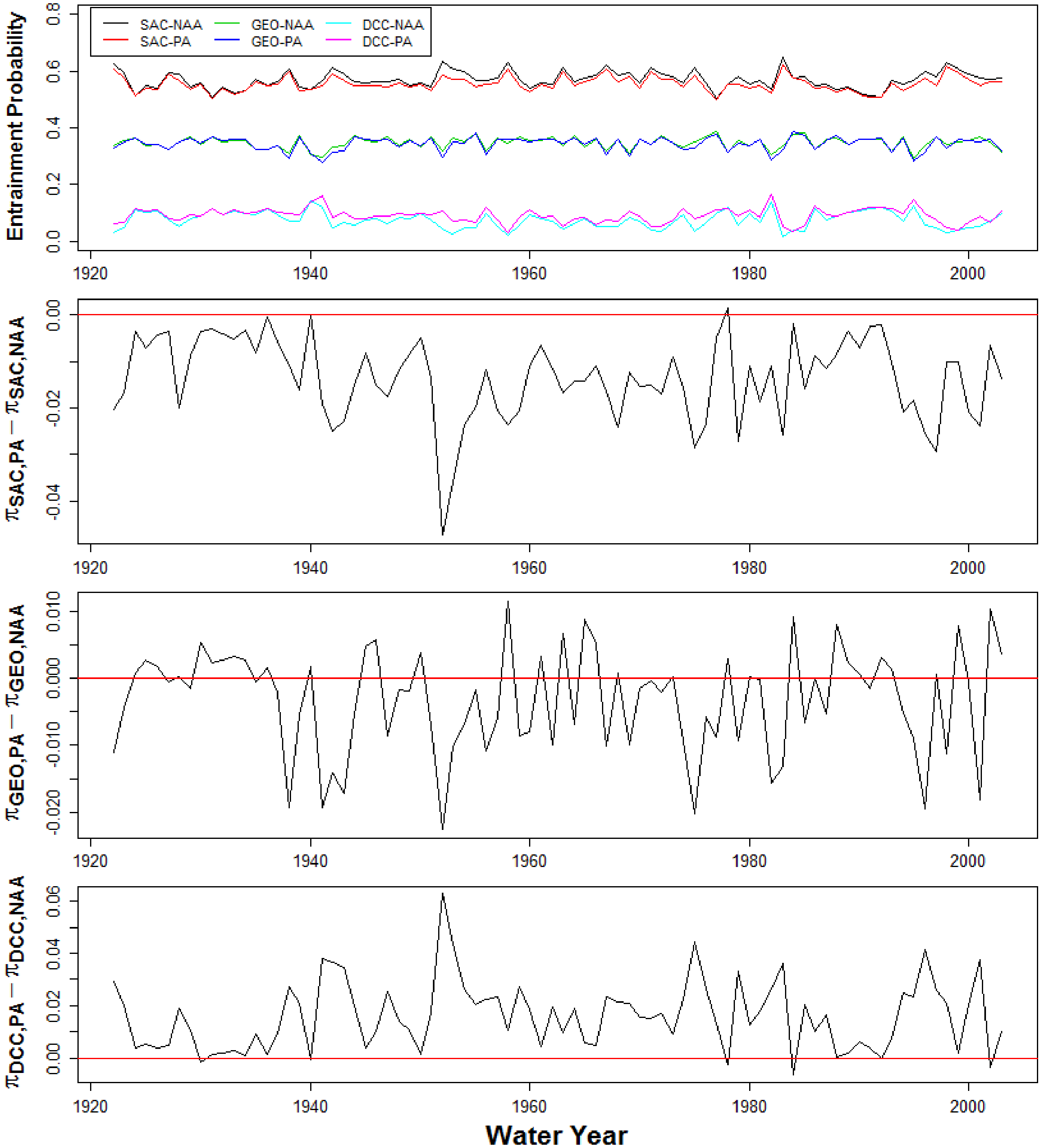

Figure 26. Comparison of predicted mean annual entrainment probability during nighttime hours assuming uniform run timing for the Sacramento River (SAC), Georgiana Slough (GEO), and Delta Cross Channel (DCC) between the Proposed Action (PA) and No Action Alternative (NAA). Shown are the mean annual entrainment probabilities (top panel) and the difference in entrainment between scenarios for SAC, GEO, and DCC (lower panels). Values above the horizontal red line indicate greater entrainment under the PA scenario.

Appendix G

Summary of Survival Methods

Draft summary of methods used to simulate travel time, survival, and routing of juvenile Chinook salmon for the California WaterFix effects analysis.

R. Perry, USGS, Western Fisheries Research Center
19 December 2016

Here I provide a brief overview of the methods used to produce the draft results presented to the Independent Peer Review Panel's review for Phase 2B of the California Water Fix consultation. In summary, we combined equations from statistical models that estimate the relationship of Sacramento River inflows (measured at Freeport) on reach-specific travel time, survival, and routing of acoustic-tagged juvenile late-fall Chinook salmon. Given these equations, we simulated daily cohorts of juvenile Chinook salmon migrating through the Delta under the CalSim simulations of the Proposed Action (PA) and No Action Alternative (NAA). We also included daily Delta Cross Channel gate operations from the DSM2 simulations of PA and NAA.

Survival and Travel Time

Fitted models from a joint statistical analysis of travel time and survival in eight discrete reaches of the Delta (Figure 1, Perry et al. in prep.) was used for the assessing travel time and survival under the PA and NAA scenarios. The data for the analysis consisted of 2,170 acoustic-tagged late-fall Chinook salmon released during a five-year period (2007-2011) over a wide range of Sacramento River inflows (6,800 – 77,000 ft^3/s at Freeport). This analysis was based on acoustic telemetry data from several published studies where details of each study can be found (Perry et al. 2010, 2013; Michel et al. 2015).

Although a number of studies have identified a relationship between Delta inflows and survival at the Delta-wide scale, the goal of the Perry et al. (in prep.) analysis was quantify how the flow-survival relationship varies spatially among different regions of the Delta. To quantify the reach-specific relation between river inflows and survival, the analysis used time-varying individual covariates where an individual's covariate value was defined as the flow of the Sacramento River at Freeport on the day that *i*th fish entered the *m*th reach. Owing to missing covariate values for undetected fish, the analysis implemented the multistate mark-recapture model of Perry et al. (2010) using a complete data likelihood approach in a Bayesian framework (King et al. 2010). To cope with missing covariate values, the analysis jointly modeled both reach-specific travel times and survival. Estimated parameters of a log-normal travel time distribution for each reach were used to impute travel times of undetected fish, which in turn, allowed missing covariate values to be defined based on the imputed arrival time in a given reach. Markov Chain Monte Carlo techniques were used to integrate over the missing covariate values by drawing missing travel times on each iteration of the Markov chain.

Reach-specific survival and median travel time were modeled as functions of river inflow and DCC gate position:

$$\text{logit}\left(S_{i,m}\right) = \beta_{0,m} + \beta_{1,m} Q_{i,m,d} + \beta_{2,m} I\left(\text{DCC}_{i,m,d} = \text{open}\right) + \varepsilon_{S,g,m}$$

where *m* indexes reaches 0, …, 8 (Figure 1), logit(·) is the logit link function, $\beta_{0,m}$ is the intercept, $\beta_{1,m}$ is the slope for the effect of discharge on survival, $\beta_{2,m}$ is the effect of Delta Cross Channel position on survival, $Q_{i,m,d}$ is the discharge of the Sacramento River at Freeport on day *d* that individual *i* entered reach *m*, $I\left(\text{DCC}_{i,m,d} = \text{open}\right)$ is an indicator function resolving to 1 if the DCC is open on day *d* that individual *i* entered reach *m*, and $\varepsilon_{S,g,m}$ is a normally distributed deviation for the *g*th release group in reach *m* with mean zero and standard deviation $\xi_{S,m}$.

Median travel time was expressed as a function of covariates in a similar manner as survival:

$$\mu_{i,m} = \alpha_{0,m} + \alpha_{1,m} Q_{i,m,d} + \alpha_{2,m} I\left(\text{DCC}_{i,m,d} = \text{open}\right) + \varepsilon_{\mu,g,m}$$

where $\mu_{i,m}$ is the mean of log-normal travel time distribution for the *i*th individual in the *m*th reach, exp($\mu_{i,m}$) is the median travel time, and $\alpha_{i,m}$ are slope and intercept coefficients.

In this model, survival is constant among individuals that enter a given reach on a particular day but varies among release groups according to the random effect term ε. Travel time influences survival only through its effect on arrival times to a given telemetry station, which determines the discharge that individuals experienced when they entered a given reach. The standard deviation of the random effects, ξ, estimates variation in mean travel time and survival among release groups over that explained by covariates. This term can be thought of as a measure of process error for unmeasured factors that vary among release groups migrating through a given reach (e.g., predator density). The DCC gate position is included as a covariate since the effect of opening the DCC gate is to reduce discharge in downstream reaches. Therefore, $\alpha_{2,m}$ and $\beta_{2,m}$ was set to zero for reaches located upstream of the of the Delta Cross Channel (i.e., for m = 0, ..., 3).

The Perry et al. (in prep.) analysis found a relationship between river inflows and median travel times in all reaches of the Delta (Figures 2 and 3). In contrast, their analysis found considerable variation in the flow-survival relationship among reaches (Figures 2 and 3). In the upper reaches of the Delta (Reaches 1 and 2; Figure 1), survival was consistently high regardless of inflows , whereas in the strongly tidal reaches (reaches 7 and 8) there was no significant relationship between river inflows and reach-specific survival despite a relationship between inflow and travel time. The strongest flow-survival relationships were identified in the three reaches that transition from river-driven to tidally-driven flows (Reaches 3, 4, and 5).

The product of reach-specific survival for a given migration pathway between Freeport (Site A_2 in Figure 1) and Chipps Island (Site A_6 in Figure 1) yields the probability of surviving through each migration route at a given river discharge. Route-specific survival for all routes increased with river discharge but approach an asymptote, leveling off at about 0.7 for the Sacramento River and Sutter and Steamboat Sloughs and about 0.35 for fish entering Georgiana Slough when river discharges increases beyond 30,000 – 40,000 ft^3/s (Figure 4). The reach-specific survival relationships indicate that the asymptote in route-specific survival was driven by the survival in the strongly tidal reaches (Reaches 7 and 8) since survival for all other reaches approached 1 as flow increased, but remained constant with flow for the strongly tidal reaches (Figure 3). Expected travel time distributions through each migration route decreased as river flow increased, with migration routes leading to the interior Delta (Georgiana Slough and the Delta Cross Channel) having longer travel times than other routes (Figure 5).

Migration Routing

To simulate overall survival through the Delta as a function of inflows requires a model for how river inflows affect the proportion of fish using each of the four primary migration routes through the Delta. Fish first enter Sutter and Steamboat Sloughs at its junction with the Sacramento River (Site B_1 and A_3 in Figure 1). Fish that remain in the Sacramento River may then enter the DCC (Site C_1) and Georgiana Slough (Site D_1) further downstream. For each migration route, we related daily proportions of fish entering each route to daily river discharge at Freeport.

For Sutter and Steamboat Slough, we analyzed acoustic telemetry on late-fall Chinook salmon from a study conducted in 2014 (DWR, in review). During this study, 3,418 acoustic tagged fish were detected at this river junction over a 58-day period. We conducted a logistic regression analysis that related the daily fraction of discharge entering Sutter and Steamboat Slough to the daily proportion of fish entering this route. Because fish were released daily at Sacramento, daily sample sizes averaged 58 fish (interquartile range = 43-83 fish), providing adequate sample sizes for the analysis. Daily river discharge varied from 9,146 – 28,051 ft^3/s over the 58-day period. Although initial analysis revealed a direct relation between discharge at Freeport and the probability of entering Sutter and Steamboat Slough, extending this relationship beyond the range of flow observed in the study suggested that entrainment increased in a linear fashion with flow. In contrast, the fraction of discharge entering Sutter and Steamboat increases at low flows owing to tidal forcing, but then stabilizes to a constant fraction as river inflow dampens tidal forcing. Thus, by using the ratio of Sutter and Steamboat discharge relative to Freeport discharge as a covariate, extending this relationship beyond the range of observed flows leads to an asymptotic relationship of entrainment with respect to discharge at Freeport (Figure 6). Although empirical data at higher flows is required to substantiate this relationship, we feel that this approach is consistent with the hypothesis that entrainment is related to the relative quantity of discharge entering this route rather than the absolute amount. The analysis suggests that the proportion of fish entering Sutter and Steamboat Slough increase from about 0.1 at 5,000 ft3/s to about 0.4 at 80,000 ft^3/s (Figure 6).

We summarize results of the multinomial model of Perry et al. (2015) to predict daily entrainment probabilities into Georgiana Slough and the Delta Cross Channel. This river junction experiences tidally reversing flows when inflows at Freeport are less than approximately 23,000 ft^3/s at Freeport. Perry et al. (2015) showed that entrainment into these migration routes depended on the tidal conditions when fish arrived at the river junction. Since the model predicts the probability of an individual entering each route as a function of the "instantaneous" river discharge (i.e., discharge measured at 15-minute intervals) at the time of fish arrival, we used this model to calculate entrainment probabilities based on 15-minute discharge records occurring during the time period the study was conducted (December through February of 2007 – 2009). We then related the mean daily entrainment probability to daily discharge at Freeport. Specifically, we used a segmented linear regression to relate the daily probability of entering Georgiana Slough with the DCC gate closed to Freeport discharge. For the DCC gate open, we used linear regression to relate the daily probability entering the DCC and Georgiana Slough to Freeport discharge. The segmented regression indicates that daily entrainment probabilities into Georgiana Slough initially decline with increasing discharge, but then change little as discharge increases above about 20,000 ft^3/s (Figure 7). Although the maximum discharge for this analysis was about 40,000, the expected entrainment into Georgiana Slough at 80,000 was 0.33 and is consistent with empirical evidence that showed entrainment into Georgiana Slough ranged from 0.244 to 0.299 at a Freeport discharge of 80,000 ft^3/s (Perry et al. 2014).

Simulating Survival under the PA and NAA Scenarios

To understand the effect of the North Delta Diversion on survival and travel time of juvenile late-fall Chinook salmon, we used the analysis of Perry et al (in prep.) to simulate travel time, survival, and migration routing using the CalSim model runs for the No Action Alternative (NAA) and Proposed Action (PA). The simulation produces a Delta-wide (Freeport to Chipps Island) survival probability and travel time distributions for a cohort of fish entering the Delta at Freeport on each day of the 82 year daily time series of Delta inflows. For each day of the 82 year time series, travel time and survival was simulated as follows:

1) Initiate the simulation with 10,000 fish at Freeport on day *t*.
2) Calculate survival in Reach 1 given Freeport discharge on day *t*. Survival was calculated based on the median of the posterior distributions of the parameters relating survival to inflows at Freeport.
3) Draw individual travel times through Reach 1 from a log-normal distribution where the mean of the distribution depends on the river flow on day *t*. This yields a distribution of arrival times at the junction of Sutter and Steamboat Slough with the Sacramento River.
4) Draw the route taken by each fish from a Bernoulli distribution where the probability of entering Sutter and Steamboat Slough is a function of Bypass discharge on the day each fish arrives at the junction.

5) Calculate the survival probability of each individual for the next reach downstream (Sacramento River or Sutter and Steamboat Sloughs) given the river flow on day each fish entered the reach.
6) Draw travel times for each individual for the next downstream reach given the flows on the day each fish entered the reach.
7) For fish remaining in the Sacramento River, draw the route taken by fish at the junction of the Sacramento River with the Delta Cross Channel (DCC) and Georgiana Slough from a multiple Bernoulli distribution where the probability of entering each route depends on the position of the DCC gates and Freeport flows on the day each fish arrived at the junction.
8) Repeat steps 5 and 6 for all remaining reaches.

Thus, the simulation yields reach-specific expected survival probabilities, reach-specific travel times, and routing histories for a cohort of 10,000 individuals entering the Delta at Freeport on each day of the 82-year time series of CalSim output. By using this approach, our simulation emulates the effect of daily flow variation on through-Delta survival and travel time for a cohort of fish that enter the Delta on a given day. For example, although two cohorts may enter the Delta under identical flows at Freeport, survival and travel time of these cohorts would differ if one cohort entered under an ascending hydrograph and one entered during a descending hydrograph.

The simulation output for each day was then summarized to provide a number of useful statistics for each daily cohort:

- The proportion of fish using each unique migration route.
- The mean survival for each unique migration route, calculated by first taking the product of reach-specific survival between Freeport and Chipps Island for each individual and then taking the mean survival over all individuals.
- Overall survival through the Delta, calculated as the mean survival over all individuals. Since routing for each individual was a randomly drawn at each river junction, the mean survival is implicitly weighted by the proportion of fish that used each route.
- Median travel time by route and over all routes. Median travel time was calculate by first summing reach-specific travel times for each individual between Freeport and Chipps

Island and then taking the mean of the logarithm of travel times (by route and over all routes).

- Daily difference in survival and median travel time between PA and NAA scenarios.

We summarize the difference in daily through-Delta survival between PA and NAA with boxplots that display the distribution of survival differences among years for a given date or for given months. To understand how these differences arise, it is useful to examine how the individual components of migration routing, survival, and travel time contribute to overall survival in a particular year. In Figures 8-13, we illustrate detailed model output for 1943, a wet water year that exhibited bypass flows (flow remaining in the Sacramento River below the North Delta Diversion) ranging from <5,000 ft^3/s to > 50,000 ft^3/s.

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This document is in draft form, for the purposes of soliciting feedback from independent peer review.

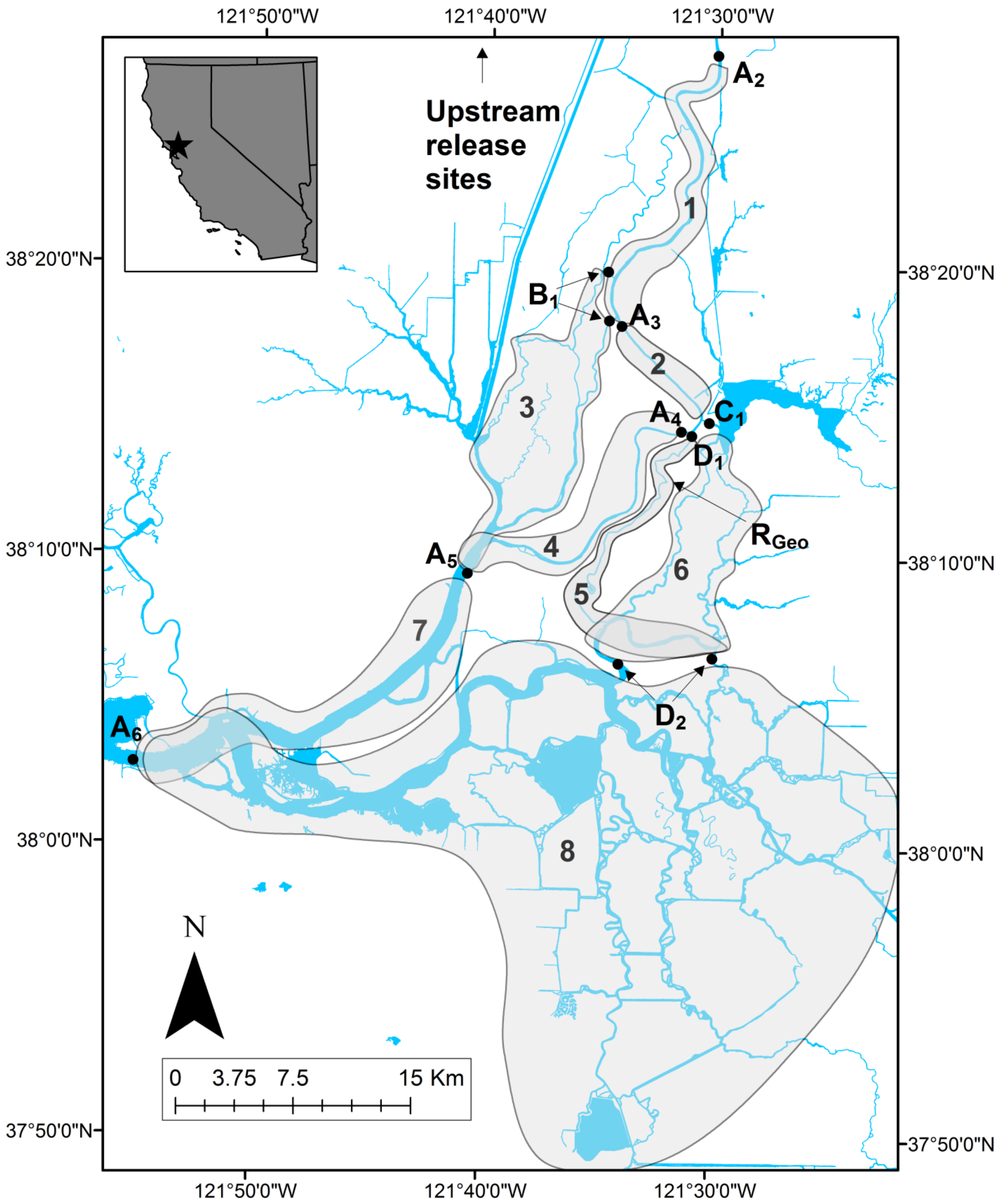

Figure 1. Map of the Delta with dots showing location of telemetry stations and shaded regions highlighting the eight reaches in which reach-specific survival and travel times were estimated. Telemetry stations are coded by the *i*th telemetry station in the *h*th route (A = Sacramento River, B = Sutter and Steamboat Slough, C = Delta Cross Channel, D = Georgiana Slough). Reach 0 from Sacramento to Freeport (A_2) was considered an "acclimation" reach to allow fish to resume nominal migration behavior after release. RGeo indicates a release site in Georgiana Slough to increase the sample size of fish migrating through the interior Delta (Reach 8).

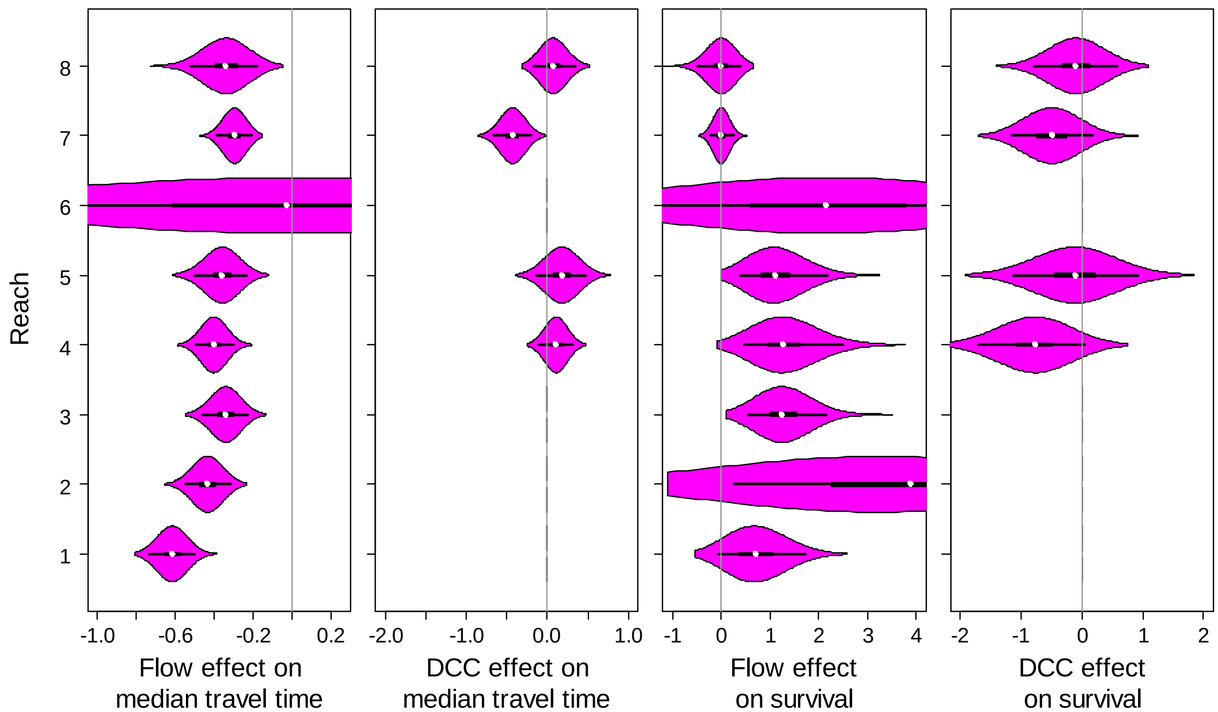

Figure 2. Violin plots showing the posterior distributions of slope parameters for the effect of Sacramento River discharge at Freeport on survival and median travel time. The white dot shows the median, the heavy bar displays the interquartile range, and the thin bar shows the 2.5th to 97.5th percentile of the posterior distribution.

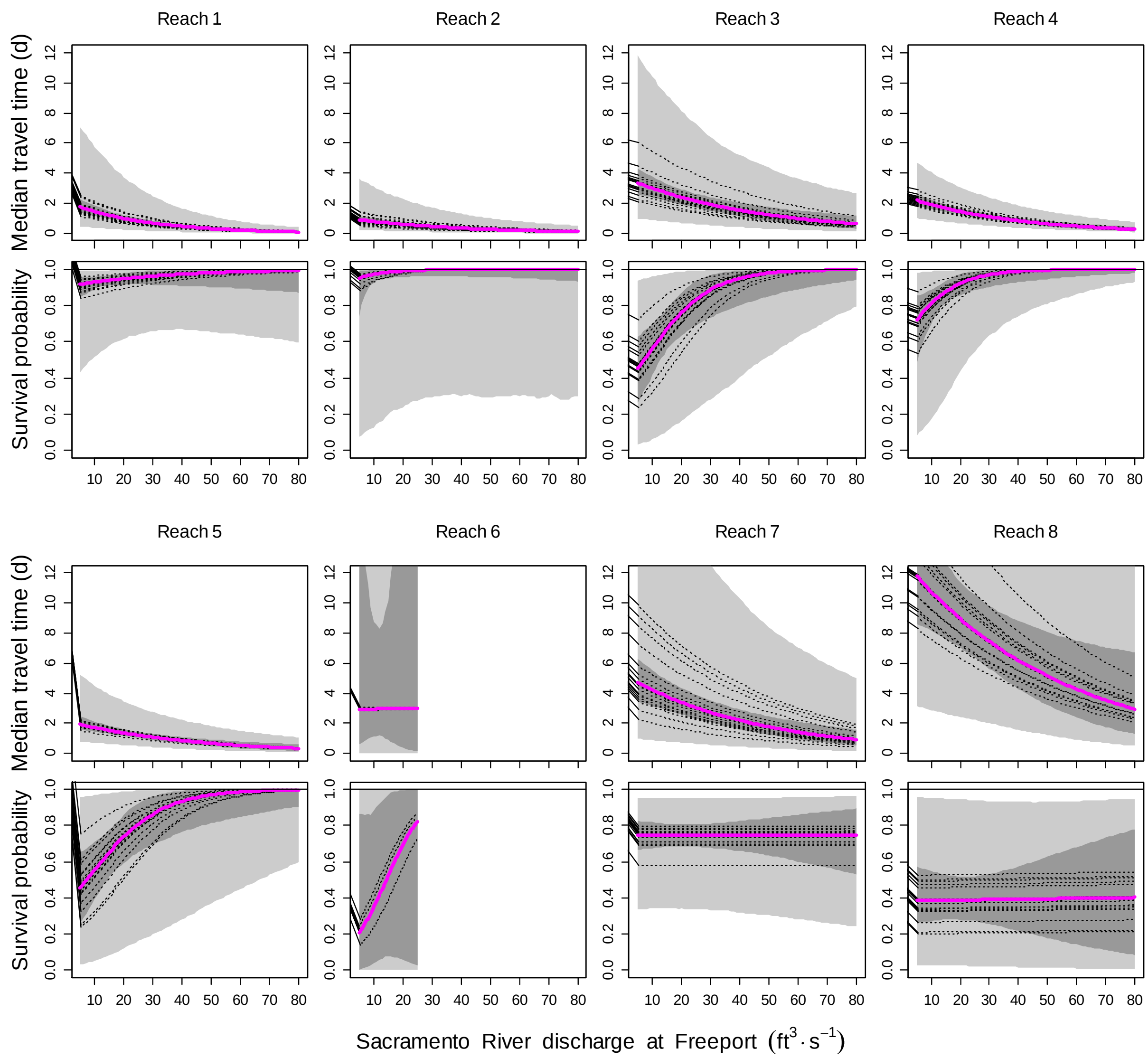

Figure 3. Reach-specific relationships of survival and travel time with Sacramento River discharge at Freeport (ft^3/s x 1000). The heavy magenta line shows the relationship plotted at the median of the posterior distribution of the parameters. The thin dotted lines show variation in the relationship among 17 release groups. The dark gray region shows 95% credible intervals about the median relationship. The light gray region shows 95% credible intervals including both parameter uncertainty and uncertainty in the estimate of the variation among release groups.

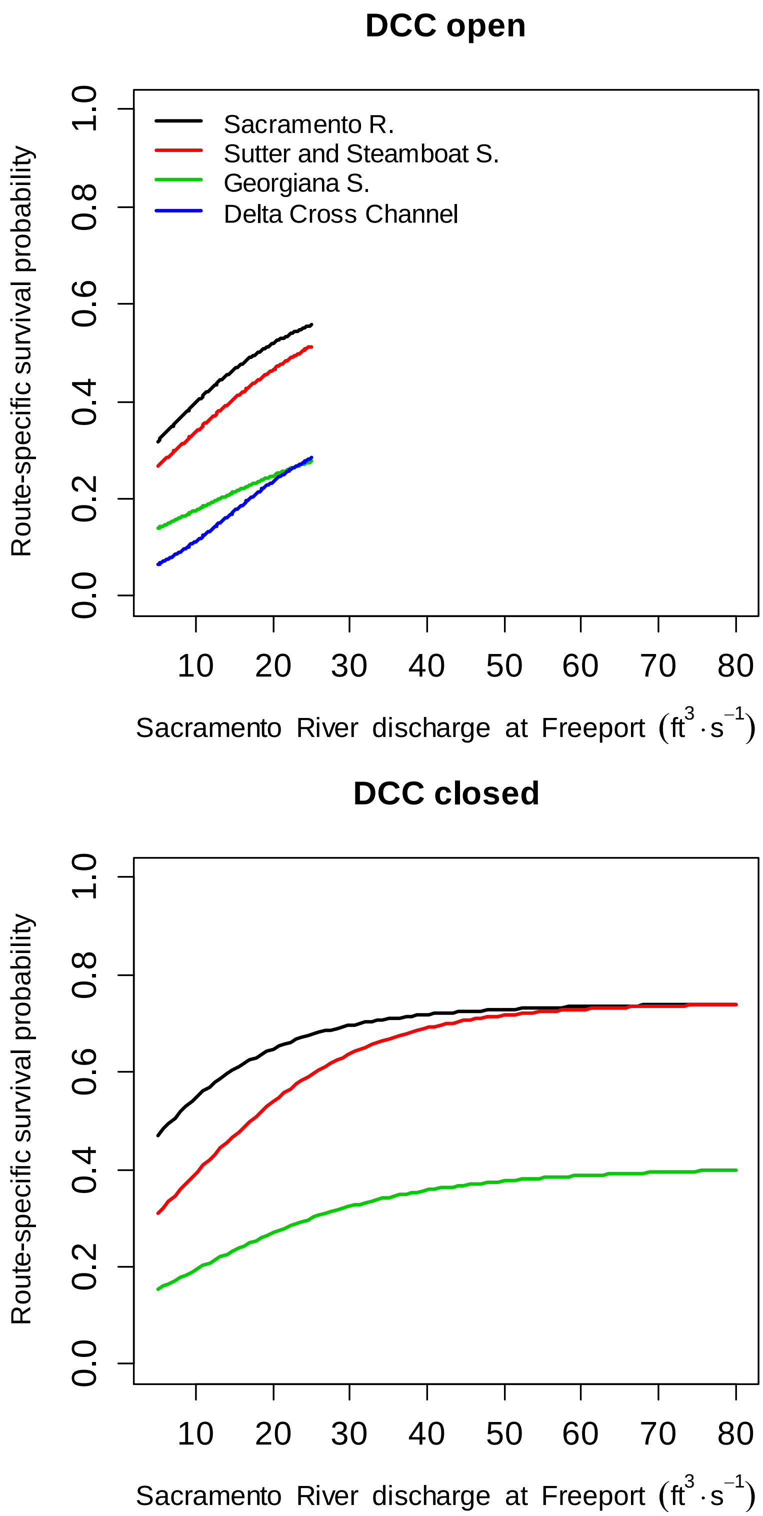

Figure 4. Route-specific survival between Freeport and Chipps Island as a function of Sacramento River discharge at Freeport. Route-specific survival was calculated as the product of reach-specific survival based on the posterior medians of the parameters.

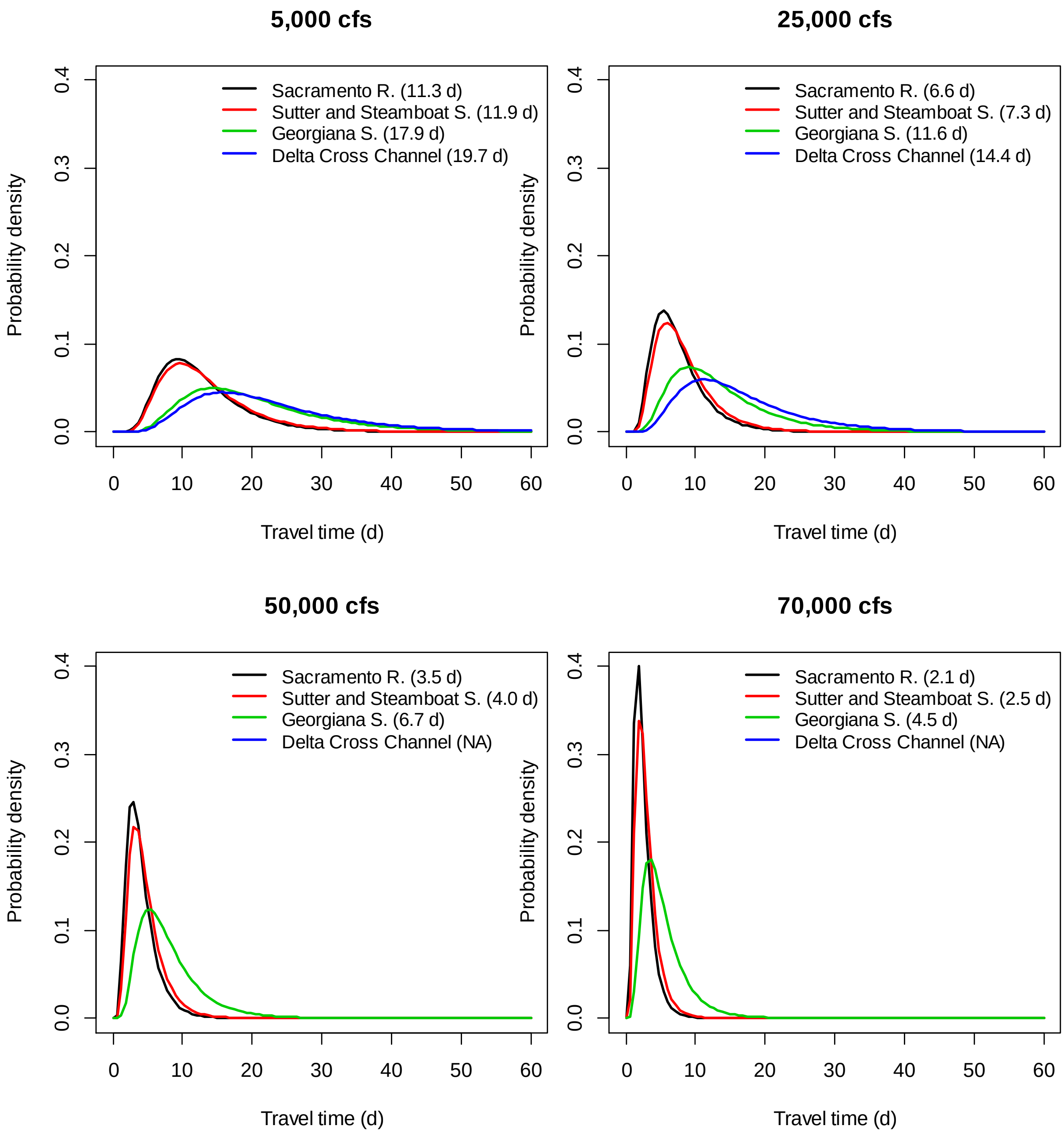

Figure 5. Route-specific travel time distributions between Freeport and Chipps Island for a range of Sacramento River discharge at Freeport. The median travel times for each route is given in the legend. Travel time distributions were based on posterior medians of parameters for reach-specific travel time distributions. Distributions are shown assuming closed Delta Cross Channel gates.

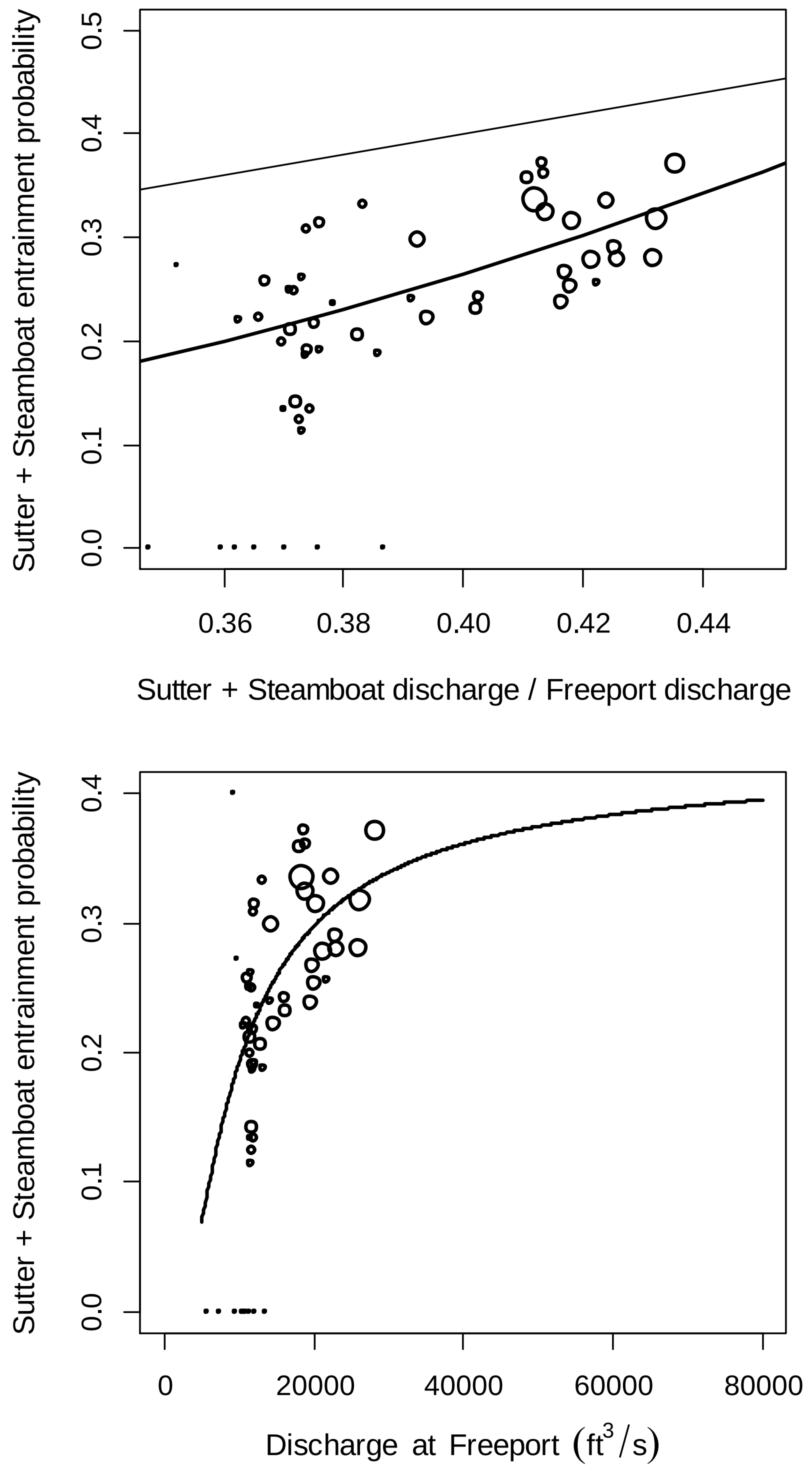

Figure 6. Logistic regression model (heavy line) showing the probability of entering Sutter and Steamboat Slough as a function of the ratio of Sutter + Steamboat discharge to Freeport discharge (top panel) and discharge of the Sacramento River at Freeport (bottom panel). In the top panel, the thin line shows where the proportion of fish entering Sutter and Steamboat sloughs is equal to the proportion of flow enter the sloughs. Data were obtained from acoustically tagged late-fall Chinook salmon collected in 2014 during the Georgiana Slough non-physical barrier study. The size of the symbols are scaled proportionately to the daily sample size of fish passing the river junction each day.

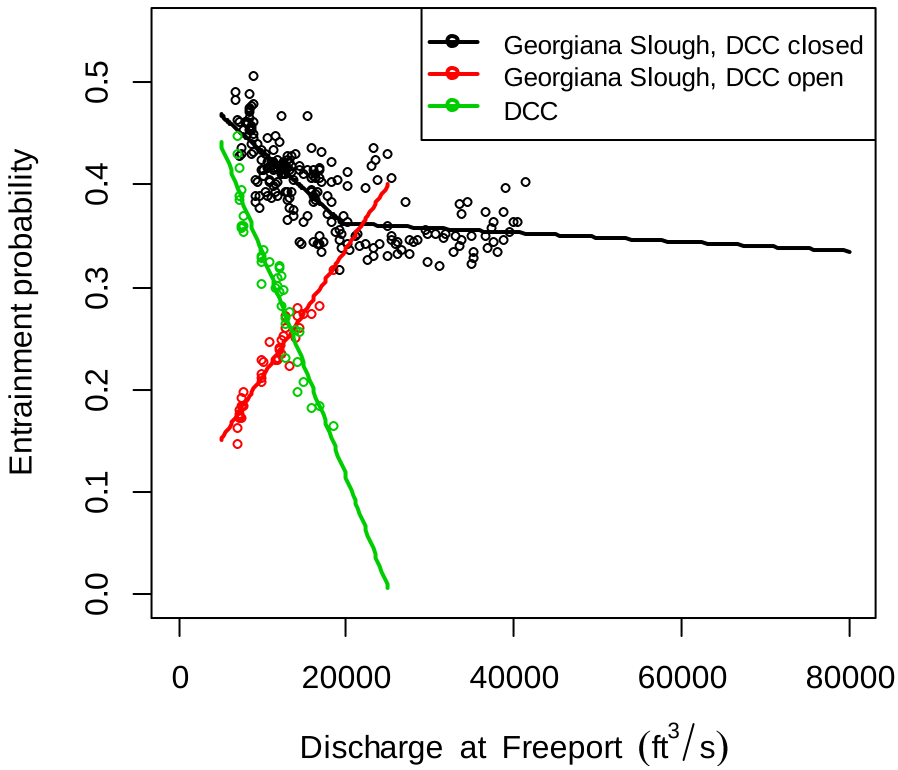

Figure 7. Daily entrainment probability into Georgiana Slough and the Delta Cross Channel as a function of discharge of the Sacramento River at Freeport. Daily routing probabilities were estimated by fitting linear models to daily entrainment probabilities that were calculated using the entrainment model of Perry et al. (2015).

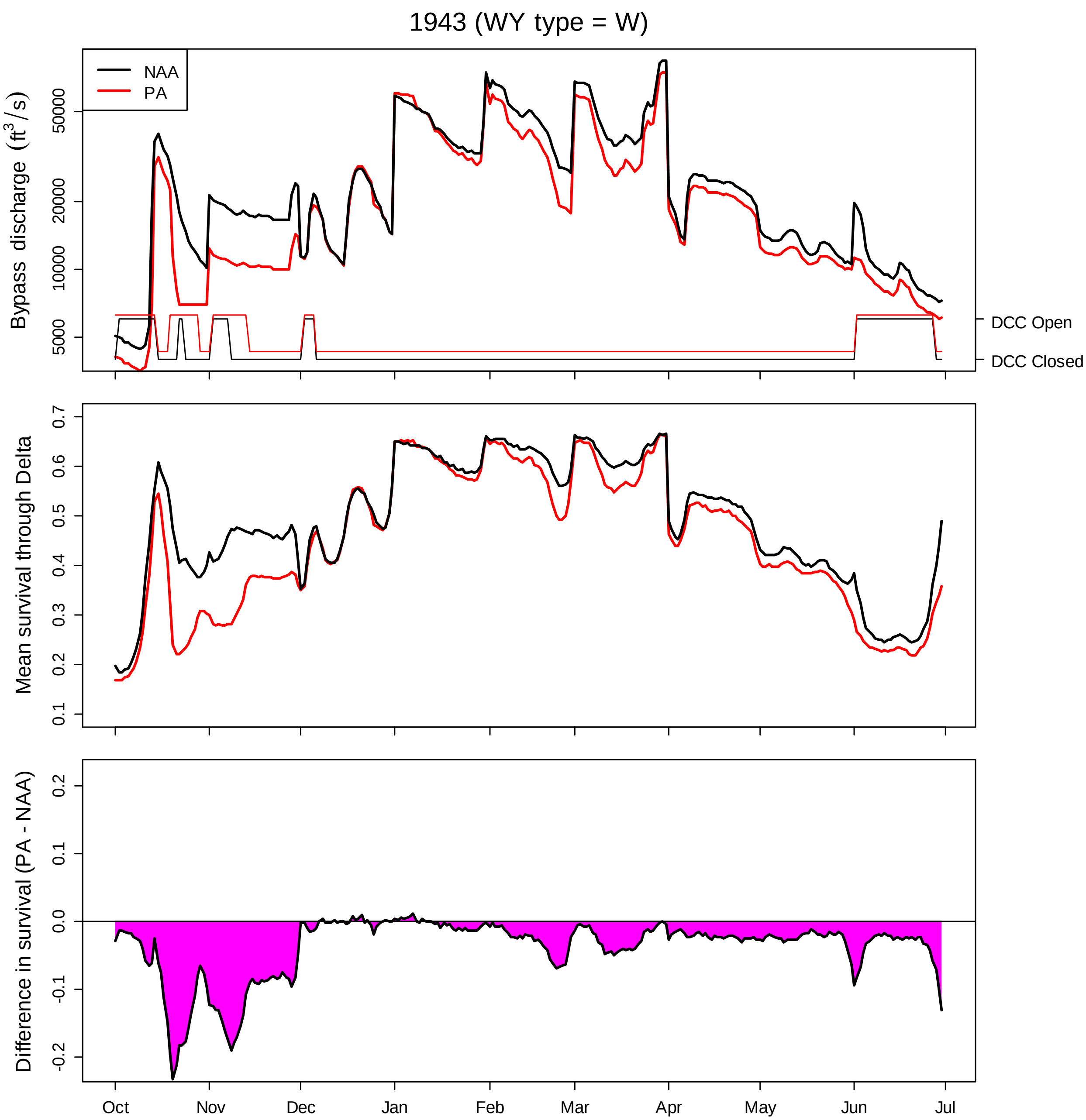

Figure 8. Mean daily survival through the Delta simulated for the Proposed Action (PA) and No Action Alternative (NAA, middle panel). Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. The bottom panel shows the difference in daily survival between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

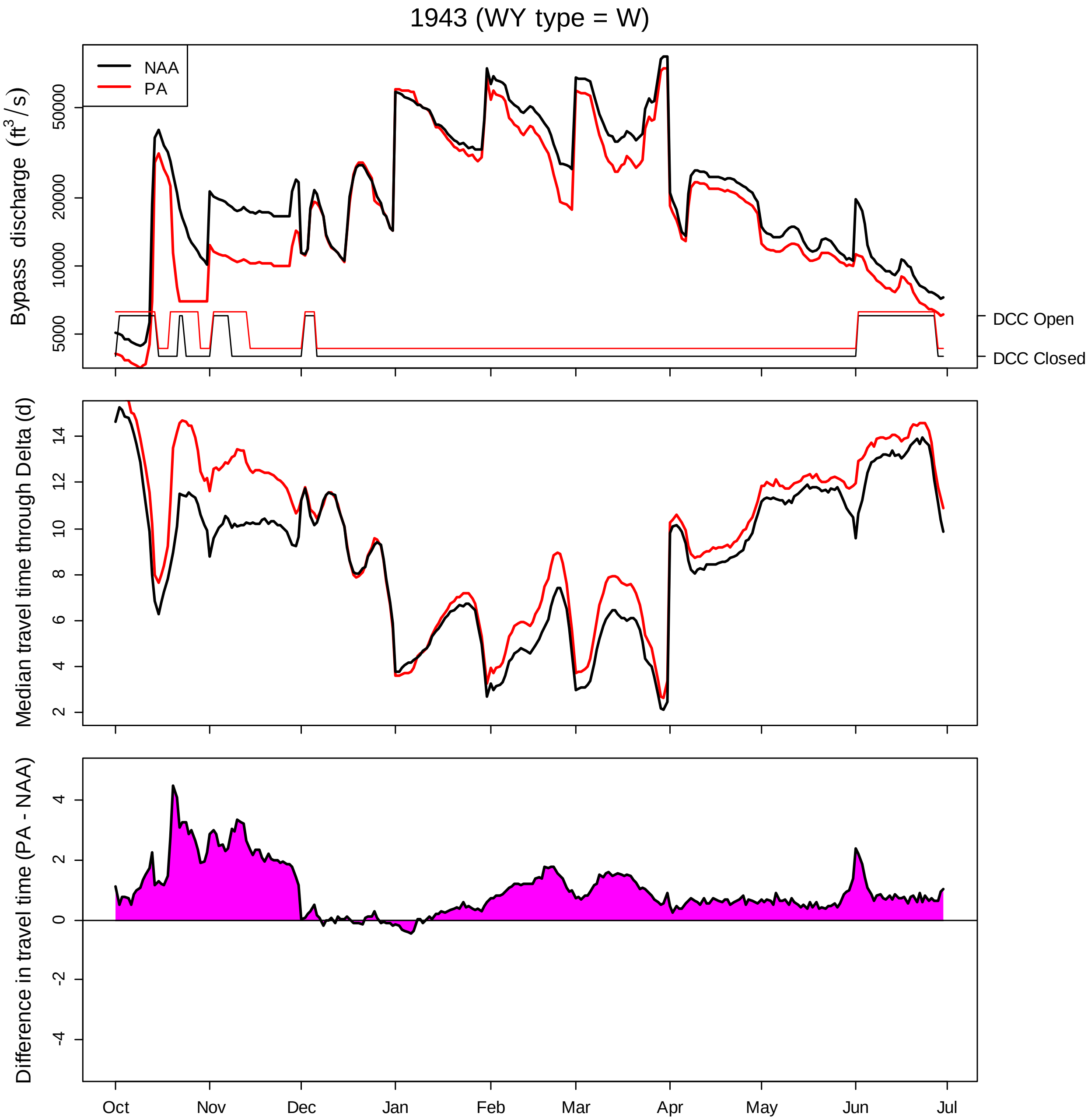

Figure 9. Median daily travel time through the Delta simulated for the Proposed Action (PA) and No Action Alternative (NAA, middle panel). Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. The bottom panel shows the difference in median travel time between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

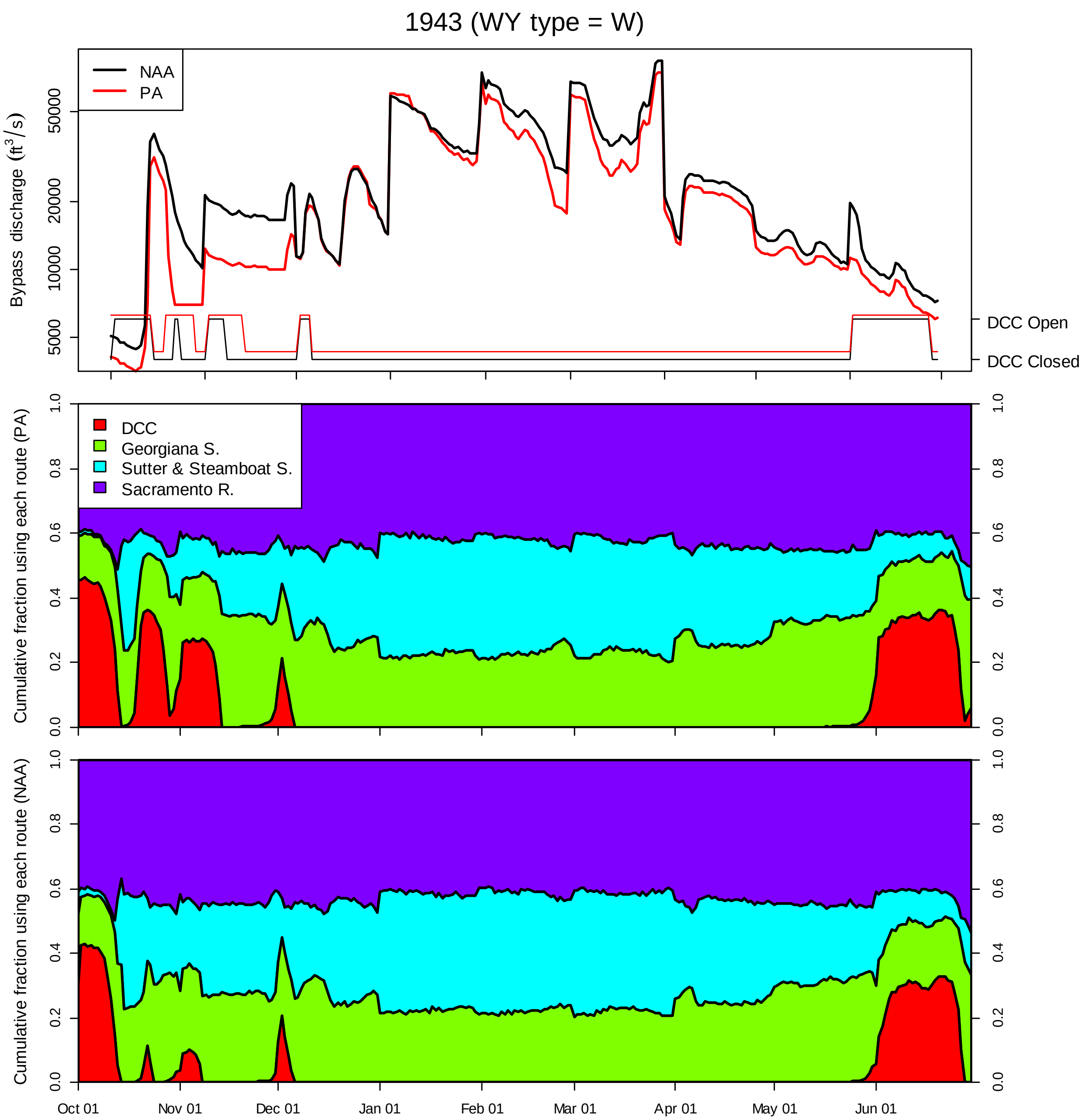

Figure 10. Stacked line plots showing the daily cumulative migration route probabilities for the Proposed Action (PA, middle panel) and No Action Alternative (NAA, bottom panel). Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. The bottom panel shows the difference in median travel time between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

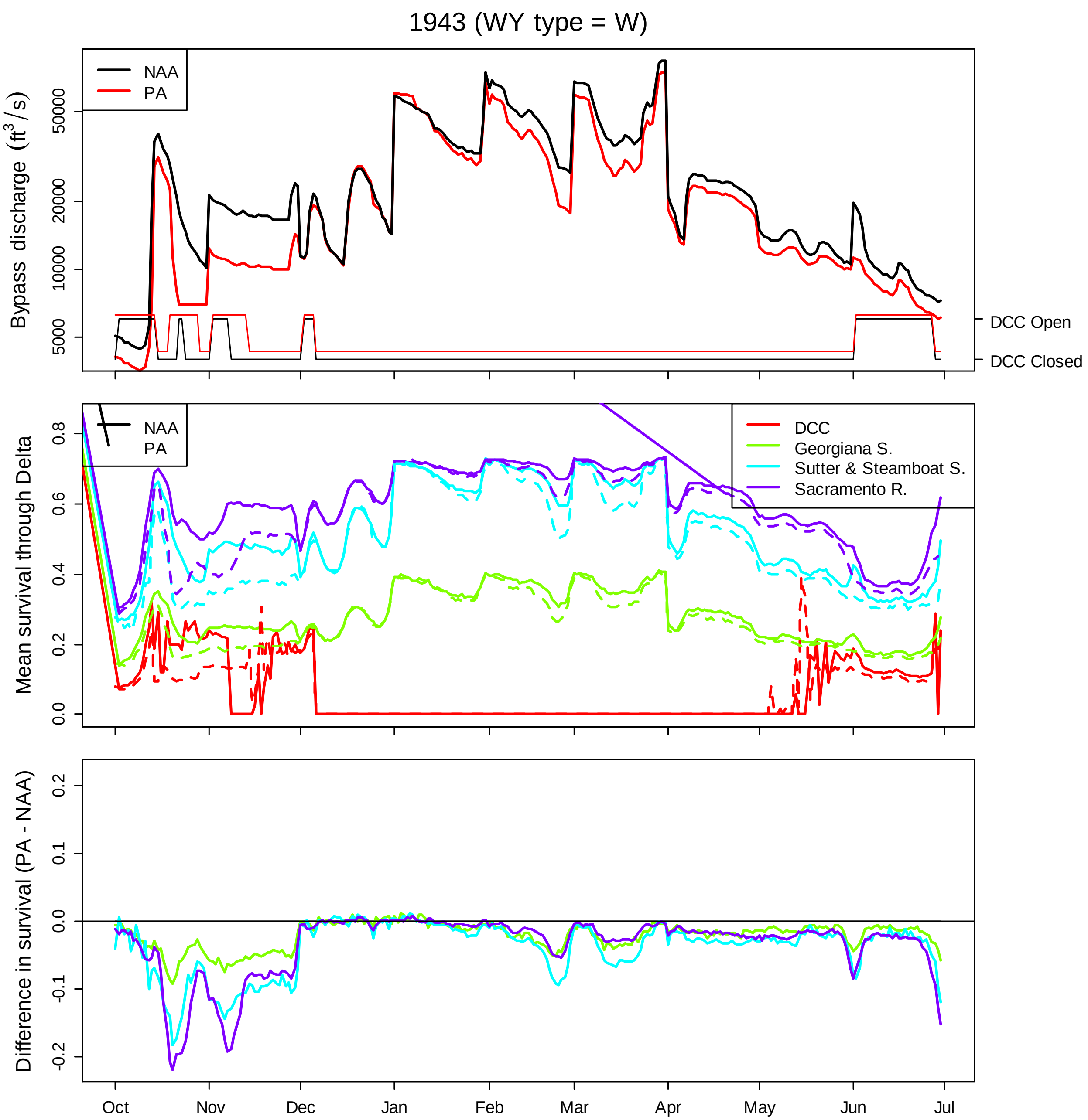

Figure 11. Mean daily route-specific survival through the Delta simulated for the Proposed Action (PA) and No Action Alternative (NAA, middle panel). Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. The bottom panel shows the difference in daily route-specific survival between scenarios. Differences in Delta Cross Channel survival is not shown owing to difference in daily operations of the DCC between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

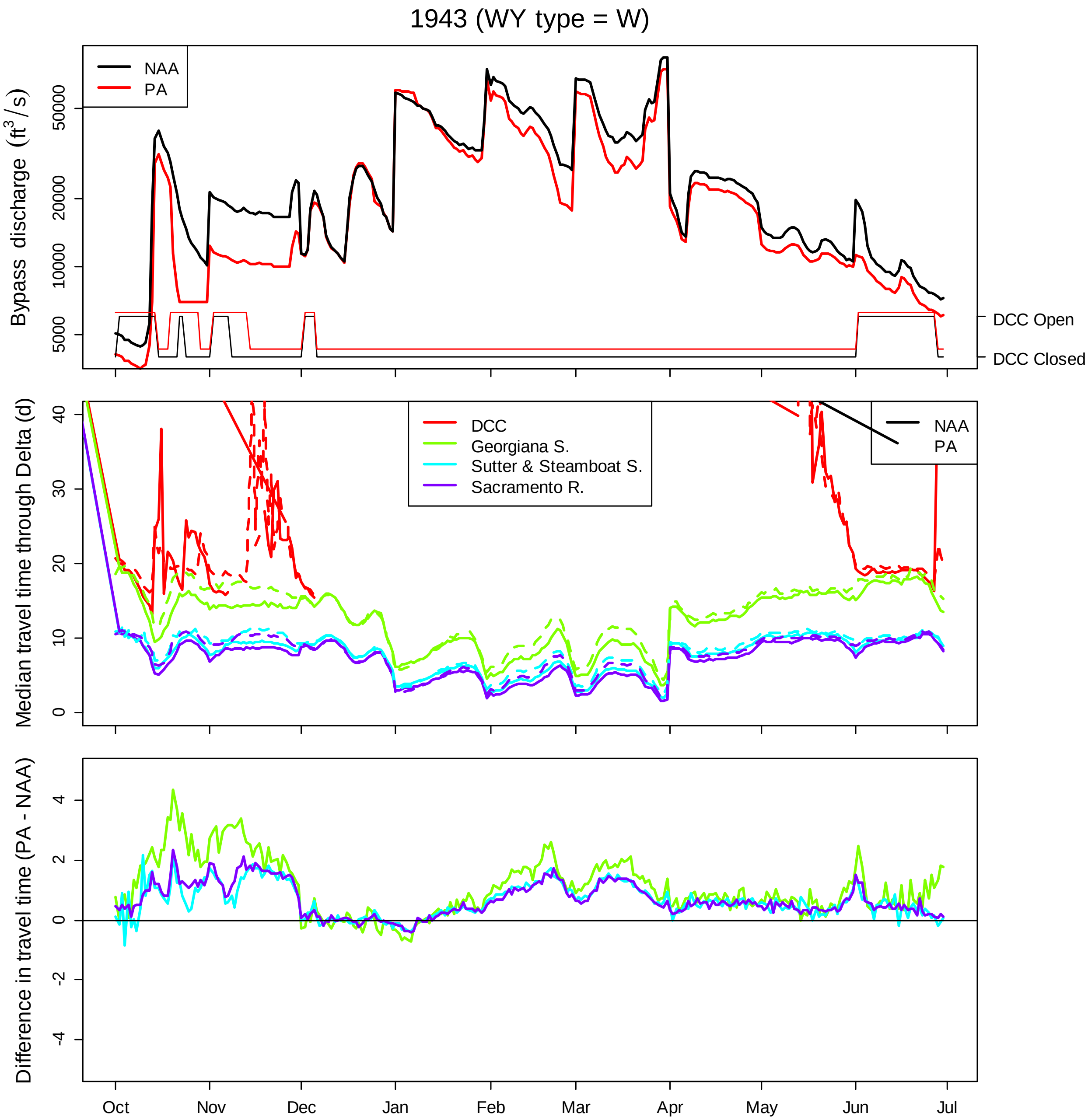

Figure 12. Median daily route-specific travel time through the Delta simulated for the Proposed Action (PA) and No Action Alternative (NAA, middle panel). Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. The bottom panel shows the difference in daily route-specific travel time between scenarios. Differences in Delta Cross Channel survival is not shown owing to difference in daily operations of the DCC between scenarios. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

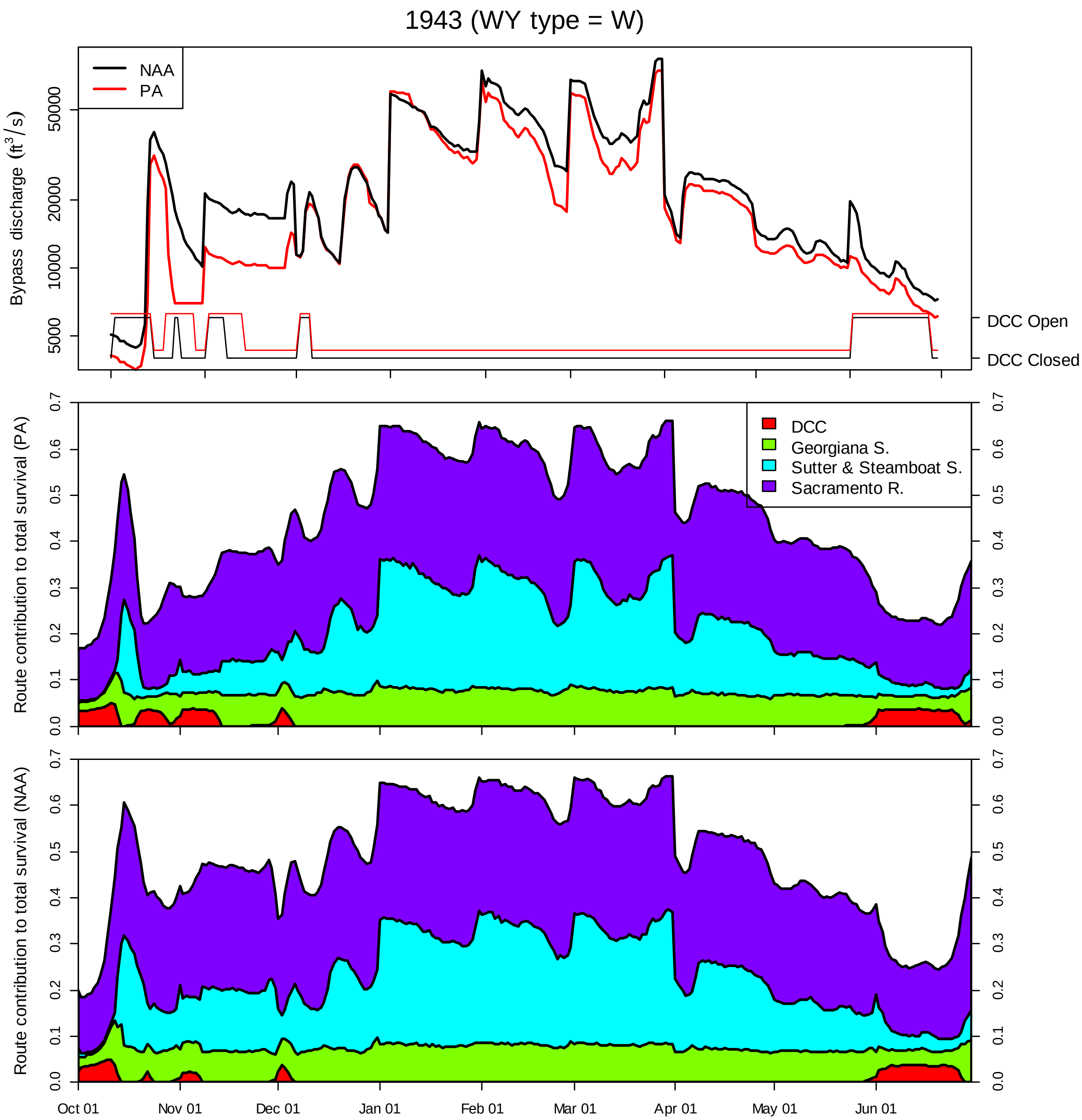

Figure 13. Stacked line plot showing each route's contribution to total survival simulated for the Proposed Action (PA, middle panel) and NAA (No Action Alternative, bottom panel). The width of each bar is the product of the probability of surviving a given migration route and the probability of migrating through that route such that the top line is the total survival through the Delta. Heavy lines in the top panel shows bypass discharge and thin lines show DCC operation of open or closed on the second *y*-axis. Discharge in the top panel is shown on a logarithmic scale to highlight variation in discharge when discharge is low.

Appendix H

Model Description for the Sacramento River Winter-run Chinook Salmon Life Cycle Model

Model Description for the Sacramento River Winter-run Chinook Salmon Life Cycle Model

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I. Background and Model Structure

Given the goals of improving the reliability of water supply and improving the ecosystem health in California's Central Valley, NMFS-SWFSC is developing simulation models to evaluate the potential effects of water project operations and habitat restoration on the dynamics of Chinook salmon populations in the Central Valley. These life cycle models (LCMs) couple water planning models (CALSIM II), physical models (HEC-RAS, DSM2, DSM2-PTM, USBR river temperature model, etc.) and Chinook salmon life cycle models to predict how various salmon populations will respond to suites of management actions, including changes to flow and export regimes, modification of water extraction facilities, and large-scale habitat restoration. In this document, we describe a winter-run Chinook salmon life cycle model (WRLCM). In the following sections, we provide the general model structure, the transition equations that define the movement and survival throughout the life cycle, the life cycle model inputs that are calculated by external models for capacity and smolt survival, and the steps to calibrate the WRLCM.

Winter-run Life Cycle Model (WRLCM)

The WRLCM is structured spatially to include several habitats for each of the life history stages of spawning, rearing, smoltification (physiological and behavioral process of preparing for seaward migration as a smolt), outmigration, and ocean residency. We use discrete geographic regions of Upper River, Lower River, Floodplain, Delta, Bay, and Ocean (Figure 1). The temporal structure of winter-run Chinook is somewhat unique, with spawning occurring in the late spring and summer, the eggs incubating over the summer, emerging in the fall, rearing through the winter and outmigrating in the following spring (Figure 2). We capture these life-history stages within the WRLCM by using developmental stages of eggs, fry, smolts, ocean sub-adults, and mature adults (spawners). The goal of the WRLCM is consistent with that of Hendrix et al. (2014); that is, to quantitatively evaluate how Federal Central Valley Project (CVP) and California State Water Project (SWP) management actions affect Central Valley Chinook salmon populations.

In 2015, the WRLCM was reviewed by the Center for Independent Experts (CIE). In response to recommendations from the CIE, the following modifications were implemented in the WRLCM: 1) divided the River habitat to encompass above Red Bluff Diversion Dam (Upper River) and below Red Bluff Diversion Dam (Lower River); 2) incorporated hatchery fish into the WRLCM; 3) used 95% of observed density as an upper bound for calculation of habitat capacity; 4) re-parameterized the Beverton-Holt function; 5) used appropriate spawner sex-ratios for model calibration to account for bias in Keswick trap capture; 6) modified the WRLCM to a state-space form to incorporate measurement error and process noise; and 7) designed metrics and simulation studies to evaluate model performance. In addition, Hendrix et al. (2014) indicated that future work would use DSM2's enhanced particle tracking model to track salmon survival, which has now been implemented.

Additional comments received in the CIE review that have not been incorporated yet include: 1) expanding spatial structure for spring and fall-run; 2) tracking additional categories of juveniles (e.g., yearling) for applying an LCM to spring-run Chinook; 3) implementing shared capacity for fall and spring-run Chinook; 5) tracking monthly cohorts through the model; and 6) evaluating multiple model structural forms. We are actively working on improving the WRLCM and developing the spring-run LCM (SRLCM) and fall-run LCM (FRLCM). Many of the CIE recommendations will be implemented with subsequent versions of these models.

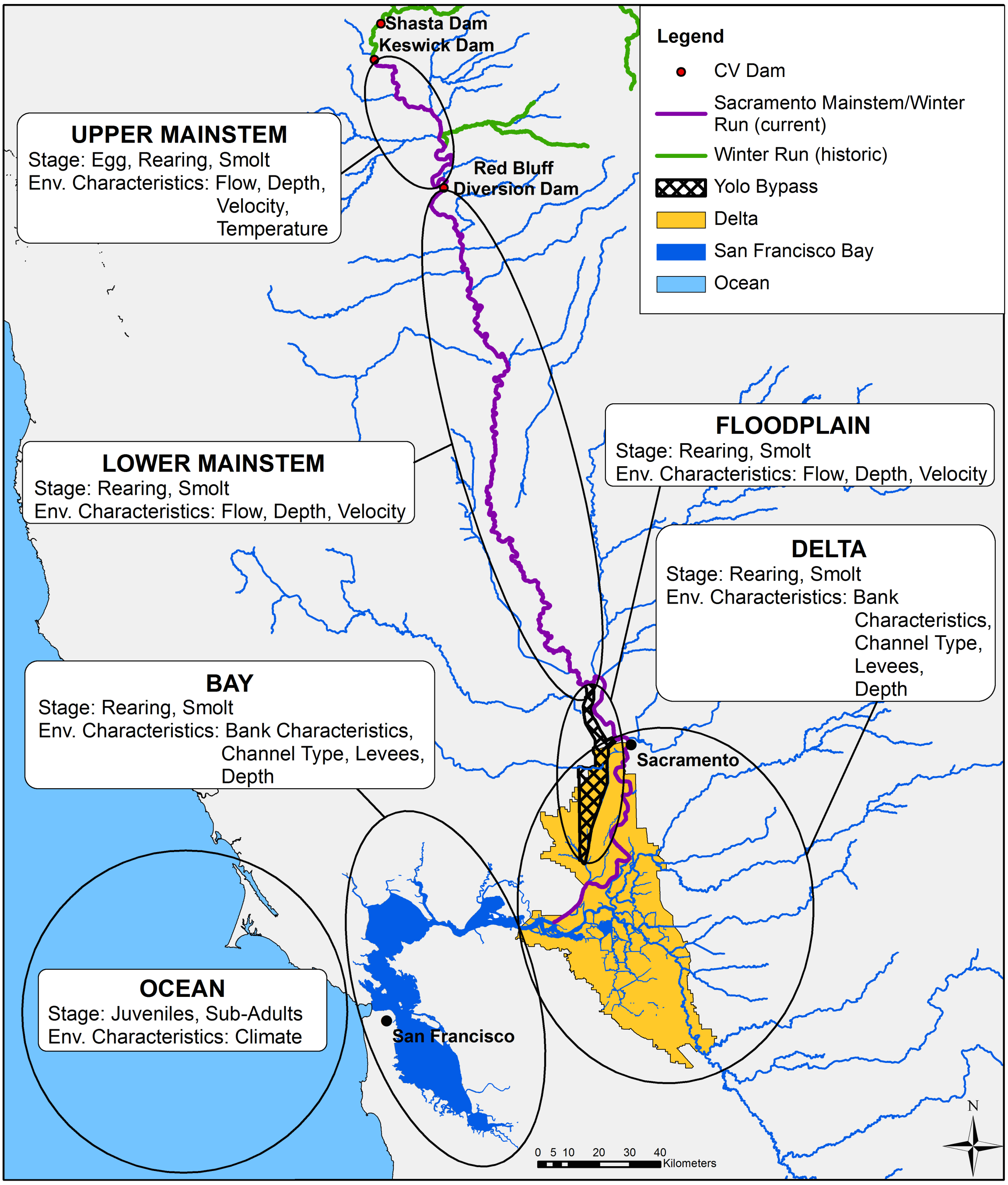

Figure 1. Geographic distribution of Chinook life stages and examples of environmental characteristics that influence survival.

The quantity and quality of rearing and migratory habitat are viewed as key drivers of reproduction, survival, and migration of freshwater life stages. Various life stages have velocity, depth, and temperature preferences and tolerances, and these factors are influenced by water project operations and climate.

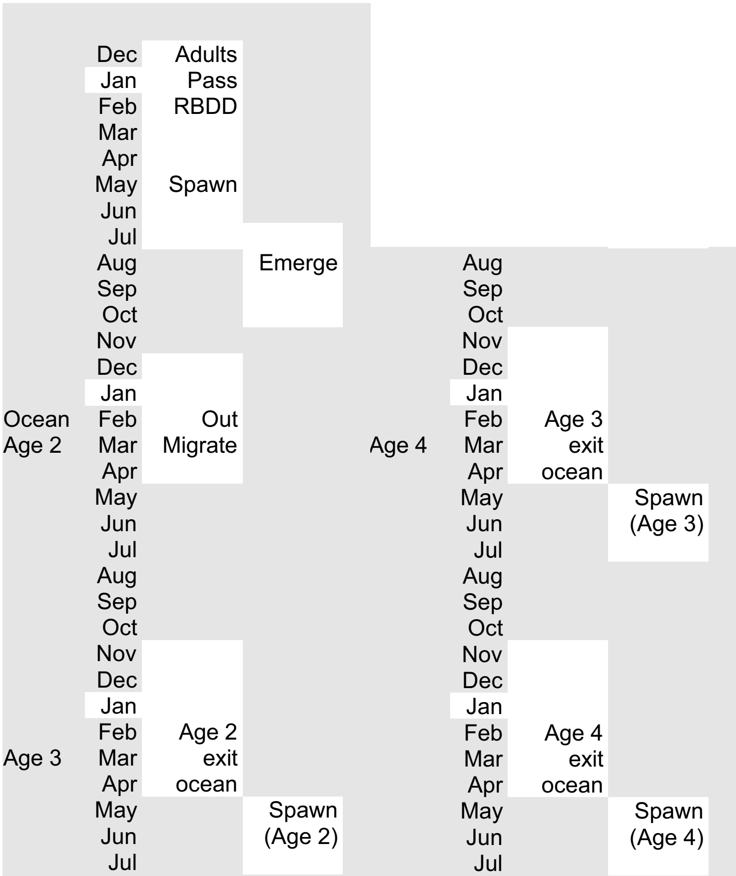

Figure 2. Temporal structure of the winter-run Chinook salmon, each cohort begins in March of the brood year. Figure from Grover et al. (2004).

Hydrology (the amount and timing of flows) is modeled with the California Simulation Model II (CALSIM II). Hydraulics (depth and velocity) and water quality is modeled with the Delta Simulation Model II (DSM2) and its water quality sub-model QUAL, the Hydrologic Engineering Centers River Analysis System (HEC-RAS), the U.S. Bureau of Reclamation's (USBR) Sacramento River Water Quality Model (SRWQM), and other temperature models. The enhanced particle tracking model (ePTM) makes use of many of these DSM2 related products to calculate survival of outmigrating smolts originating from Lower River, Delta, and Floodplain habitats. Many of the stage transition equations describing the salmon life cycle are directly or indirectly functions of water quality, depth, or velocity, thereby linking management actions to the salmon life cycle. The combination of models and the linkages among them form a framework for analyzing alternative management scenarios (Figure 3).

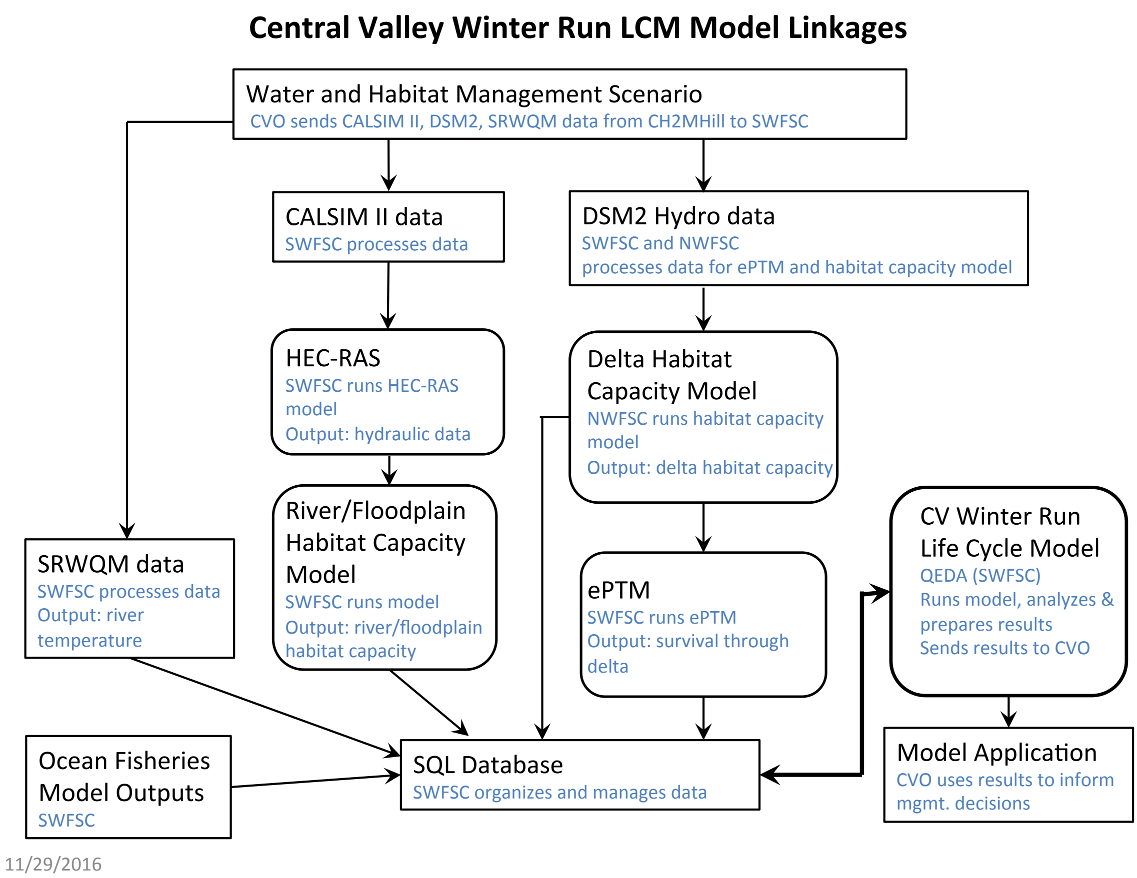

Figure 3. Submodels that support and provide parameter inputs that feed into the life cycle model.

The life cycle model is a stage-structured, stochastic life cycle model. Stages are defined by development and geography (Figure 1), and each stage transition is assigned a unique number (Figure 4).

II. Model Transition Equations

This section is divided into two parts. In the first part, we explain each of the transitions for the natural origin winter-run Chinook, which are described by the life cycle diagram (Figure 4). In the second part, we explain the transitions for hatchery origin fish. The transitions are described for an annual cohort; however, in most cases we have not included a subscript for the cohort brood year to simplify the equations. For those transitions in which there are multiple cohorts, such as the production of eggs in transition 22, a subscript to distinguish cohort is included in the equation.

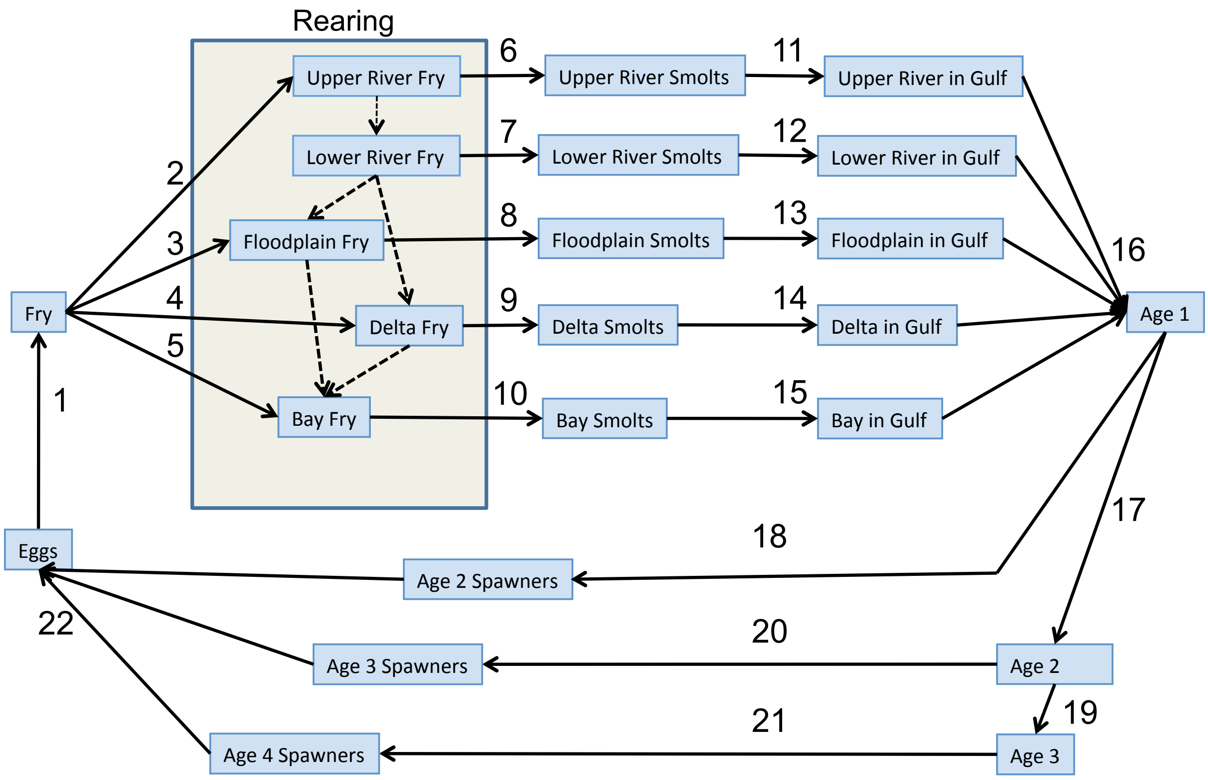

Figure 4. Central Valley Chinook transition stages. Each number represents a transition equation through which we can compute the survival probability of Chinook salmon moving from one life stage in a particular geographic area to another life stage in another geographic area.

Natural Origin Chinook

Transition 1

Definition: Survival from Egg to Fry

$Fry_{m+2} = Eggs_m * S_{eggs,\, m}$

$$logit(S_{eggs,m}) = \begin{cases} B0_1\,, & TEMP \;\le t.crit \\ B0_1 + B1_1(TEMP_m - t.crit), & TEMP > t.crit \end{cases}$$

where $S_{eggs,m}$ is the survival rate of fry as a function of the coefficients $B0_1$, $B1_1$ and $t.crit$ (model parameter representing the critical temperature at which egg survival begins to be decline), the covariate $TEMP_m$ (the average of the month of spawning m and the following 2 months), logit(x) = log(x/[1-x]) is a function that ensures that the survival rate is within the interval [0,1], for months m = (2, ..., 6) corresponding to April to August.

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Transitions 2 - 5

Definition: Dispersal from fry in the natal reaches as tidal fry to the h habitats = Lower River (LR), Floodplain (FP), Delta (DE), and Bay (BA) in months m = (5, ..., 10) corresponding to July to December. Remaining fry as rearing fry in the Upper River (UR).

Tidal Fry and Upper River Rearing Fry (Transition 2)

$TidalFry_{m,} = P_{TF,} * Fry_m$

$RearFry_{UR,m} = (1 - P_{TF}) * Fry_m$

where P_{TF} is the proportion of fry moving out of the Upper River as tidal fry, and $RearFry_{UR,m}$ are the number remaining in the Upper River habitat (*UR*) as rearing fry.

Floodplain Tidal Fry (Transition 3)

Whenever there are flows into the Yolo Bypass, a proportion of the Tidal Fry move into the floodplain habitat:

$TidalFry_{FP,m} = S_{TF,FP} * TidalFry_m * P_{FP,m}$

where $P_{FP,m}$ is the proportion of fry that move into the Floodplain habitat, and $S_{TF,FP}$ is the monthly survival of tidal fry in the floodplain. The $P_{FP,m}$ is modeled as a function of the expected flow onto the Floodplain habitat due to proposed modifications of the Fremont Weir.

$$P_{FP,m} = \begin{cases} min.p\,, & y.flow_m < 100 \\ min.p + \dfrac{(y.flow_m - 100) * (0.5 - min.p)}{5900}\,, & 100 \leq y.flow_m \leq 6000 \\ inv.logit\left(\dfrac{p.rate * (y.flow_m - 6000)}{1000}\right), & y.flow_m > 6000 \end{cases}$$

where $P_{FP,m}$ is the proportion of fry moving into the Floodplain as a function of the coefficients *min.p* (0.05) and *p.rate* (1.1), and the covariate $y.flow_m$. The function inv.logit(x) = $e^x/(1+ e^x)$ ensures that the proportion of fry moving into the Floodplain is within the interval [0,1]. The covariate $y.flow_m$ represents the monthly average flow rate (cfs) at the entrance to Yolo Bypass (CALSIM node D160). The relationship between $P_{FP,m}$ and flow is depicted in Figure 5.

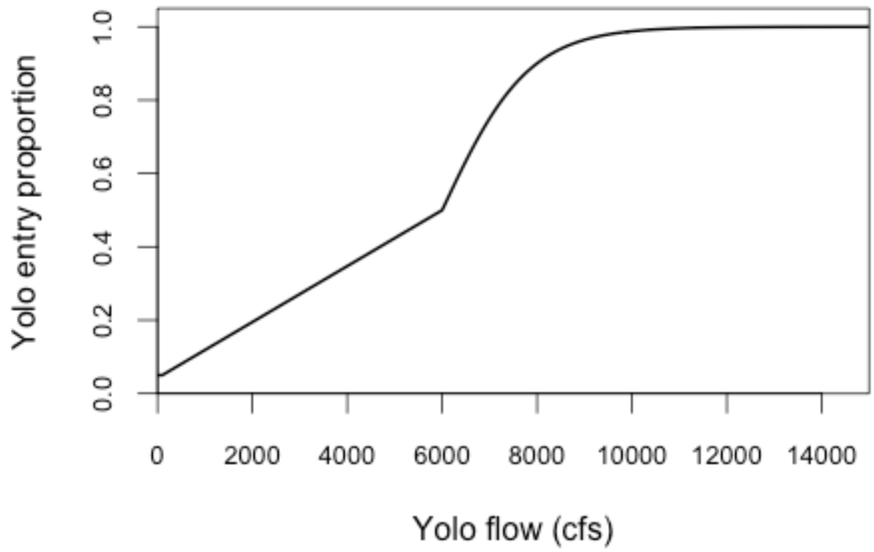

Figure 5. The relationship of Floodplain entry (Yolo bypass) entry proportion (P_{FP}) as a function of Yolo flow.

Delta and Bay Tidal Fry (Transition 4 and 5)

$TidalFry_{DE,m} = TidalFry_m * (1- P_{FP,m}) * (1 - P_{TF, BA,m}) * S_{TF,DE,m}$

$TidalFry_{BA,m} = TidalFry_m * (1- P_{FP, m}) * P_{TF, BA,m} * S_{TF,DE,m} * S_{TF,DE-BA}$

where $S_{TF,DE,m}$ is the survival to the Delta by Tidal Fry.

$\text{logit}(S_{TF,DE,m}) = B0_4 + B1_4*DCC_m$

where $B0_4$ and $B1_4$ are model parameters, and DCC_m is the proportion of the transition month that the DCC gate is open.

$P_{TF,Bay,m}$ is the proportion of fish moving to the Bay from the Delta

$\text{logit}(P_{TF,Bay,m}) = B0_5 + B1_5*Q_{RioVista,m}$

where $B0_5$ and $B1_5$ are model parameters, and $Q_{RioVista,m}$ is the flow anomaly (subtract mean and divide by standard deviation). The mean and standard deviation were calculated from 1970-2014 data at Rio Vista, which was the period of model calibration.

Rearing

Definition: Fry rear among Upper River, Lower River, Floodplain, Delta, and Bay habitats according to a density dependent movement function in months m = (5, …, 10) corresponding to July to December.

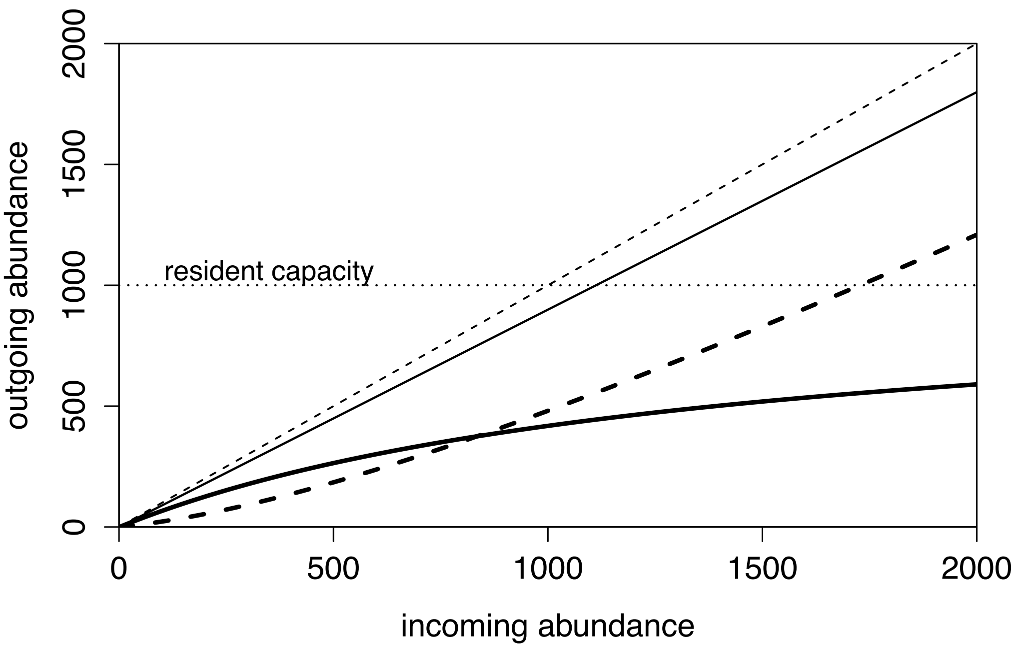

Figure 6. Example of the Beverton-Holt movement function in which the outgoing abundance (thin solid black line) is split between migrants (thick dashed line) and residents (solid dark line), that are affected by the resident capacity (thin dotted line). The 1:1 line (thin dashed line) is also plotted for reference. Parameter values used in the plotted relationship are survival, *S* = 0.90; migration, *m* = 0.2; and capacity, *K*= 1000.

The number of residents in the month is calculated from the following equation (Figure 6):

$Residents_{h,m} = S_{FRY,h,m} * (1 - mig_{h,m}) * N_{h,m} / (1 + S_{FRY,h,m} * [1 - mig_{h,m}] * N_{h,m}/K_{h,m})$

$Migrants_{h,m} = S_{FRY,h,m} * N_{h,m} - Residents_{h,m}$

where $S_{FRY,h,m}$ is the survival rate in the absence of density dependence, $N_{h,m}$ is the pre-transition abundance composed of *Migrants* from upstream habitats in *m-1* and *Residents* from the current habitat (Figure 7) in *m-1*, $K_{h,m}$ is the capacity for habitat type *h* and $mig_{h,m}$ is the migration rate in the absence of density dependence in month *m*.

The migration rate in the Lower River is modeled as a function of a flow threshold at Wilkins Slough

$\text{logit}(mig_{LR,m}) = B0_M + B1_M * I(Q_{Wilkins,\,m} > 400\ m^3 s^{-1})$

whereas in all other habitats and months the migration rate $mig_{h,m}$ is a constant value. Survival of resident and migrant fry $S_{FRY,h,m}$ are also constant over habitats and months.

Transitions 6 - 10

Definition: Smolting of *Residents* in the Upper River, Lower River, Floodplain, Delta, and Bay rearing habitats in months *m* = (11, … ,17) corresponding to January to July in the calendar year after spawning.

$Smolts_{h,m} = P_{SM,m} * Residents_{h,m-1}$

where $P_{SM,m}$ is the probability of smolting in month m which is assumed to be the same across habitats, by the *Residents* from the previous month (m-1) in that habitat.

The probability of smolting is modeled as a proportion ordered logistic regression model of the form:

$\text{logit}(P_{SM,\,m}) = Z_k$

where $-\infty < Z_1 < Z_2 \ldots < Z_k < \infty$ are the monthly rates of smoltification based on photoperiod (k = 1, …, 7 encomapassing January to July).

The model performs the following steps during the months in which smoltification occurs:

1. Smoltification of Resident fry
2. Survival and movement of the Migrant fry from the upstream habitats and remaining Resident fry after removing smolts from step 1

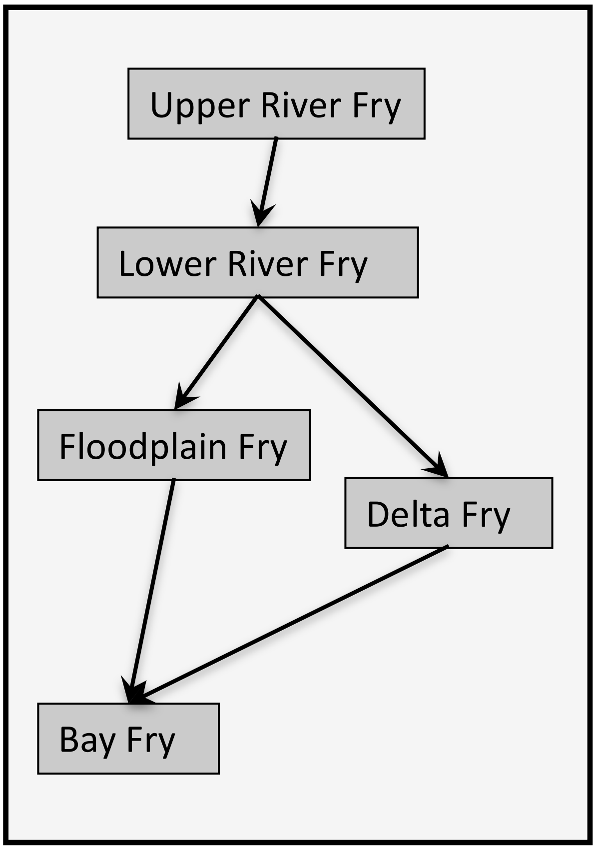

Figure 7. Connectivity among habitats for winter-run Chinook fry. Connections between the Lower River and Floodplain occur due to flooding of the Yolo bypass and are thus ephemeral.

Transitions 11 & 12

Definition: Smolts that reared in the Upper River and Lower River habitats migrate to the Gulf of the Farallones in months m = (12, … ,18) corresponding to February to August.

Upper River smolt outmigration (Transition 11)

$Gulf_{UR,m} = S_{11,UR,m} * S_{G1} * Smolts_{UR,m-1} * \exp(\varepsilon_y)$

Lower River smolt outmigration (Transition 12)

$Gulf_{LR,m} = S_{12,LR,m} * S_{G1} * Smolts_{LR,m-1} * \exp(\varepsilon_y)$

where survival $S_{T,h,m}$ is the smolt survival rate from transition T (11, ..., 15) in habitat h (UR, LR, FP, DE, BA) in month m. The rates $S_{11.UR,m}$ and $S_{12,LR,m}$ are composed of three components: A) survival rate from the Upper or Lower River to the Sacramento River near Sacramento; B) survival through the Delta to Chipps Island; and C) survival from Chipps Island to Golden Gate. The survival rate S_{G1} is the survival rate of smolts originating from the Upper River, Lower River, and Floodplain habitats during ocean entry at the Gulf of Farallones. Finally, the transition to the ocean from all habitats includes a random effect term ε_y that is specific to each year y and is distributed as a normal random variable, that is $\varepsilon_y \sim \mathrm{N}(0, \sigma_\varepsilon^2)$.

$S_{11.UR,m} = {}^{A}S_{11,UR,m} * {}^{B}S_{12,LR,m} * {}^{C}S_{11}$
$S_{12,LR,m} = {}^{A}S_{12,LR,m} * {}^{B}S_{12,LR,m} * {}^{C}S_{11}$

The first smolt survival component is modeled as a function of flow at Bend Bridge

$\mathrm{logit}({}^{A}S_{11,UR,m}) = B0_{11,UR} + B1_{11} * q.bb_m$
$\mathrm{logit}({}^{A}S_{12,LR,m}) = B0_{12,LR} + B1_{11} * q.bb_m$

where $B0_{11,UR}$, $B0_{12,LR}$ and $B1_{11}$ are model parameters, and $q.bb_m$ is monthly flow at Bend Bridge which is the closest station to the Red Bluff Diversion Dam standardized relative to historic Bend Bridge flows from 1970-2014.

${}^{B}S_{12.LR,m} = ptm_{LR,m}$

where $ptm_{LR,m}$ is a mean monthly survival rate for smolts originating from the Sacramento River through the Delta to Chipps Island as calculated by the enhanced Particle Tracking Model (ePTM, described below). The value ${}^{C}S_{11}$ is a model parameter representing survival from Chipps Island to Golden Gate and is applicable to smolts originating from all habitats.

Transition 13

Definition: Smolts that reared in the Floodplain migrate to the Gulf of the Farallones in months m = (12, … ,18) corresponding to February to August.

$Gulf_{FP,m} = S_{13,FP,m} * S_{G1} * Smolts_{FP,m-1} * \exp(\varepsilon_y)$

The rate $S_{13,FP,m}$ is composed of three components: A) survival rate from the Floodplain to the Delta; B) survival through the Delta to Chipps Island; and C) survival from Chipps Island to Golden Gate.

$S_{13,FP,m} = {}^{A}S_{13,FP,m} * {}^{B}S_{13,FP,m} * {}^{C}S_{11}$

where ${}^{A}S_{12,FP,m}$ is survival to insertion into the Floodplain nodes in the ePTM and

${}^{B}S_{13.FP,m} = ptm_{FP,m}$

where $ptm_{FP,m}$ is a mean monthly survival rate for smolts originating from the Floodplain through the Delta to Chipps Island as calculated by the ePTM.

Transition 14

Definition: Smolts that reared in the Delta migrate to the Gulf of the Farallones in months m = (12, … ,18) corresponding to February to August.

$Gulf_{DE,m} = S_{14,DE,m} * S_{G2} * Smolts_{DE,m-1}$

The rate $S_{13,DE,m}$ is composed of two components: A) survival through the Delta to Chipps Island; and B) survival from Chipps Island to Golden Gate. The survival rate S_{G2} is the survival rate of smolts in the nearshore from Delta and Bay habitats during ocean entry at the Gulf of Farallones.

$S_{G2} = \text{logit}(\text{inv.logit}(S_{G1}) + D_{G2})$

$S_{14,DE,m} = {}^{A}S_{14,FP,m} * {}^{C}S_{11}$

where ${}^{A}S_{14.FP,m} = ptm_{DE,m}$

Transition 15

Definition: Smolts that reared in the Bay migrate to the Gulf of the Farallones with an associated migration survival in months m = (12, … ,18) corresponding to February to August.

$Gulf_{BA,m} = S_{15,BA}\, S_{G2} Smolts_{BA,m-1}$

where $S_{\mathbf{15,BA}}$ is the survival from the Bay habitat to the Golden Gate.

Transition 16

The total number of Age 1 from all habitats arriving in a given month can be calculated by summing across each of the individual rearing areas. Furthermore, earlier arriving fish are retained in the Age 1 stage and an ocean survival rate is applied to those fish that were already in the Age 1 stage in the previous month. Fish arrive into the Age 1 stage in months m = (12, …, 21) corresponding to February through October.

$Age1_{m} = Age1_{UR,m} + Age\ 1_{LR,m} + Age\ 1_{FP,m} + Age\ 1_{DE,m} + Age\ 1_{BA,m} + Age1_{m-1} * S_{17}^{1/4}$

Transition 17

Definition: Survival in the ocean from Age 1 to Age 2 (for Chinook that remain in the ocean)

$Age2 = Age1_{m=21} * (1 - M_2) * S_{17}$

where S_{17} is a model parameter representing the survival rate of Age 1 fish in the ocean to Age 2 and M_2 is a model parameter representing the maturation rate that leads to 2 year old spawners. The model transitions from a monthly time step (used for months 1 through 20) to an annual time step (used for Age 2, Age 3 and Age 4 fish) in this transition, thus the S_{17} survival represents a 4-month survival rate from 21 months to 24 months.

Transition 18

Definition: Maturation and migration for Age 2 males and females that will spawn as 2 year olds

$Sp_{2,F} = Age1_{m=21} * S_{17} * M_2 * Fem_{Age2} * S_{sp2}$
$Sp_{2,M} = Age1_{m=21} * S_{17} * M_2 * (1 - Fem_{Age2}) * S_{sp2}$

where S_{17} and M_2 are model parameters for maturation and survival as described in Transition 17. Fem_{Age2} is a model parameter representing the proportion of Age 2 spawners that are female, and S_{sp2} is a model parameter representing the natural survival rate of Age 2 spawners from the ocean to the spawning grounds.

Transition 19

Definition: Survival in the ocean from Age 2 to Age 3 (for Chinook that remain in the ocean)

$Age3 = Age2 * (1 - I_3) * S_{19} * (1 - M_3)$

where I_3 is the fishery impact rate for Age 3 fish, S_{19} is a model parameter representing natural survival rate for fish between Age 2 and Age 3, and M_3 is a model parameter representing maturation rate of Age 3 fish.

Transition 20

Definition: Maturation and migration for Age 3 males and females that will spawn as 3 year olds

$Sp_{3,F} = Age2 * (1 - I_3) * S_{19} * M_3 * Fem_{Age3} * S_{sp3}$
$Sp_{3,M} = Age2 * (1 - I_3) * S_{19} * M_3 * (1 - Fem_{Age3}) * S_{sp3}$

where I_3 is the Age 3 fishery impact rate, and M_3 and S_{19} are the Age 3 maturation and survival rates as described in Transition 19. Fem_{Age3} is a model parameter representing the proportion of Age 3 and 4 spawners that are female, and S_{sp3} is a model parameter representing the natural survival rate of Age 3 spawners from the ocean to the spawning grounds.

Transition 21

Definition: Maturation and migration for Age 3 males and females that will spawn as 4 year olds

$Sp_{4,F} = Age3 * (1 - I_4) * S_{21} * Fem_{Age3} * S_{sp4}$
$Sp_{4,M} = Age3 * (1 - I_4) * S_{21} * (1 - Fem_{Age3}) * S_{sp4}$

where I_4 is the Age 4 fishery impact rate, S_{21} is a model parameter representing survival rate from Age 3 to Age 4, Fem_{Age3} is a model parameter representing the proportion of Age 3 and 4 spawners that are female, and S_{sp4} is a model parameter representing the natural survival rate of Age 4 spawners from the ocean to the spawning grounds.

Transition 22

Definition: Number of eggs produced by spawners of Ages 2 – 4 in months m = (2, …, 6) corresponding to April to August.

$$Eggs_m = \frac{\sum_{j=2}^{4} TSp_{j,F} * P_{SP,m} * V_{eggs,j}}{1 + \frac{\sum_{j=2}^{4} P_{SP,m} * TSp_{j,F} * V_{eggs,j}}{K_{Sp,m}}}$$

where TSp_j are the total number of female spawners of age j = 2, 3, 4 (composed of both natural and hatchery origin), $V_{eggs,j}$ is the number of eggs per spawner of age j = 2, 3, 4, $K_{Sp,m}$ is the capacity of eggs in the spawning grounds per month, and $P_{SP,m}$ is the proportion of spawning that occurs in month m and is a function of April average temperature at Keswick Dam. Because the April temperature can vary among years, the monthly distribution varies as well to reflect observed patterns in spawn timing among the years from 1999 to 2012. Please see Appendix A for description of the analysis of historical patterns in spawn timing.

$TSp_{2,F} = Sp_{2,F} + Sp_{2,F,Hatchery}$

$TSp_{3,F} = Sp_{3,F} + Sp_{3,F,Hatchery} - hat.f$

$TSp_{4,F} = Sp_{4,F} + Sp_{4,F,Hatchery}$

$hat.f = 0.15 * Sp_3$ (min = 10; max = 60)

where $hat.f$ is the number of spawning females removed for use as hatchery broodstock, and $Sp_{j,Hatchery}$ for j = (2,3,4) is the spawners of age j hatchery origin, which are described below in the *Hatchery Origin Chinook* section.

Hatchery Origin Chinook

Transition 1H

Definition: Survival of hatchery fish from eggs to Age 2

$Age2_{Hatchery} = hat.f * 3000 * H_{S1}$

$H_{S1} = 2.3 * Age2_{Natural} / Fry_{Natural}$

where H_{S1} is the hatchery-origin survival rate from pre-smolt at release to Age 2 in the ocean, $Age2_{Natural}$ is the number of natural-origin Chinook that survived to Age 2 and remained in the ocean, and $Fry_{Natural}$ is the number of natural origin emerging Fry (see Transition 1 for Natural Origin Chinook). The multiplier of 3000 hatchery smolts per spawner was obtained from Winship et al. (2014). The multiplier of 2.3 was used to equate hatchery origin survival to the end of age 2 to natural origin survival to the end of age 2 as described in Winship et al. (2014).

Transition 2H

Definition: Maturation and spawning for hatchery origin Age 2

$Sp_{2,F,Hatchery} = Age2_{Hatchery} * M_2 * Fem_{Age2} * S_{sp2}$
$Sp_{2,M,Hatchery} = Age2_{Hatchery} * M_2 * (1 - Fem_{Age2}) * S_{sp2}$

where the coefficients are described under Transition 18.

Transition 3H

Definition: Survival of hatchery origin fish in the ocean from Age 2 to Age 3 (for Chinook that remain in the ocean)

$Age3_{Hatchery} = Age2_{Hatchery} * (1 - I_3) * S_{19} * (1 - M_3)$

where the coefficients are described under Transition 19.

Transition 4H

Definition: Maturation and spawning for hatchery origin Age 3

$Sp_{3,F, Hatchery} = Age2_{Hatchery} * (1- I_3) * S_{19} * M_3 * Fem_{Age3} * S_{sp3}$
$Sp_{3,M, Hatchery} = Age2_{Hatchery} * (1- I_3) * S_{19} * M_3 * (1 - Fem_{Age3}) * S_{sp3}$

where the coefficients are described under Transition 20.

Transition 5H

Definition: Survival and maturation rate for hatchery origin Age 4

$Sp_{4,F, Hatchery} = Age3_{Hatchery} * (1- I_4) * S_{21} * Fem_{Age3} * S_{sp4}$
$Sp_{4,M, Hatchery} = Age_{Hatchery}\, 3\ (1- I_4) * S_{21} * (1 - Fem_{Age3}) * S_{sp4}$

where the coefficients are described under Transition 21.

Fishery Dynamics

To simulate the winter-run population dynamics under alternative hydrologic scenarios, we include fishery dynamics that are consistent with the current fishery control rule (NMFS 2012) (Figure 8). For each year of the simulation, the impact rate for age 3 (I_3) was calculated from the control rule by obtaining the 3-year trailing geometric average of spawner abundance. The age-4 impact rate (I_4) in that year was calculated as double the instantaneous age-3 impact rate (Winship et al. 2014).

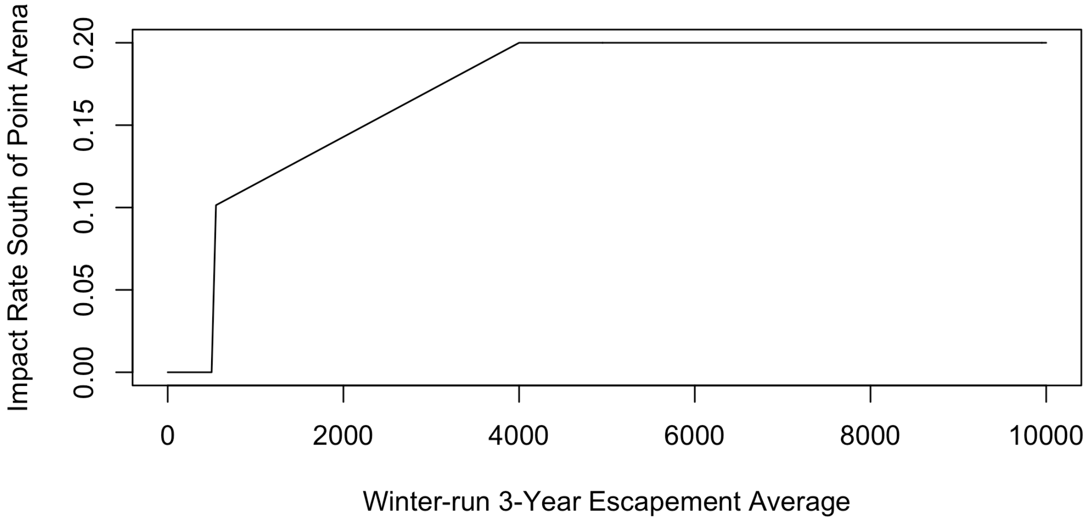

Figure 8. Fishery control rule determining the level of Age 3 impact rate as a function of trailing 3-year geometric mean in winter-run escapement.

III. Inputs to the Winter-run life-cycle model

Water Temperature

The life cycle model (LCM) incorporates monthly average temperature below Keswick Dam into the definition of egg to fry survival. The water temperature can be obtained from water quality gages on the Sacramento River (for model calibration) or from a forecasted water temperature model, such as the as the Sacramento River Water Quality Model (SRWQM).

Fisheries

Estimates of impact rates on vulnerable age classes of Chinook salmon are computed as part of the Pacific Fisheries Management Council (PFMC) annual forecast of harvest rates and review of previous years' observed catch rates. For runs that are not actively targeted, such as winter-run and spring-run Chinook, analyses of coded wire tag (CWT) groups are used to infer impact rates for these races (e.g., O'Farrell et al. 2012).

Habitat Capacity

Juvenile salmonids rear in the mainstem Sacramento River, delta, floodplain, and bay habitats (Figure 1). The model incorporates the dynamics of rearing by using density-dependent movement out of habitats as a function of capacity for juvenile Chinook. The capacities of each of the habitats are calculated in each month using a series of habitat-specific models that relate habitat quality to a spatial capacity estimate for rearing juvenile Chinook salmon. Habitat quality is defined uniquely for each habitat type (mainstem, delta, etc.) with the goal of reflecting the unique habitat attributes in that specific habitat type. For example, the mainstem habitat quality is a function of velocity and depth (Liermann et al. 2005). Higher quality habitats are capable of supporting higher densities of rearing Chinook salmon, with the range of densities being determined from studies in the Central Valley and in river systems in the Pacific Northwest where appropriate.

Defining habitat capacity. For each habitat type (mainstem, delta, and bay), capacity was calculated each month as:

$$K_i = \sum_{j=1}^{n} A_j d_j$$

where K_i is the capacity for a given habitat type i, n is the total number of categories describing habitat variation, A_j is the total habitat area for a particular category, and d_j is the maximum density attributable to a habitat of a specific category. Three variables were determined for each habitat, the ranges of each were divided into high and low quality, and all combinations were examined, resulting in a total of eight categories (2 x 2 x 2) of habitat quality for each habitat type (Table 1). The exception was mainstem habitats (Upper River and Lower River), which were subdivided into 4 (2x2) bins of habitat quality. Ranges of high and low habitat quality were based on published studies of habitat use by Chinook salmon fry across their range and examination of data collected by USFWS within the Sacramento-San Joaquin Delta and San Francisco Bay.

Defining maximum densities. Determining maximum densities for each combination of habitat variables is complicated by the fact that most river systems in the Central Valley are now hatchery-dominated with fish primed for outmigration. In addition, the Central Valley river system is at historically low natural abundance levels compared to expected or potential density levels. Because of this deficiency in the Central Valley system, salmon fry density data from the Skagit River system were used, which in contrast has very low hatchery inputs, has been monitored in mainstem, delta, and bay habitats, and exhibits evidence of reaching maximum density in years of high abundance (Greene et al. 2005; Beamer et al. 2005). These data from the Skagit River were compared with Central Valley density estimates calculated by USFWS. For each of these data sets, the upper 90 to 95 percentile levels of density defined a range of maximum density levels, assuming that the highest five percentile of density levels were sampling outliers. The comparison indicated that Skagit River values represented conservative estimates of maximum density (Figure 9).

Table 1. Habitat variables influencing capacity for each habitat type.

Habitat type	Variable	Habitat quality	Variable range
Mainstem	Velocity	High	<= 0.15 m/s
		Low	> 0.15 m/s
	Depth	High	> 0.2 m, <= 1 m
		Low	<= 0.2 m, > 1 m
Delta	Channel type	High	Blind channels
		Low	Mainstem, distributaries, open water
	Depth	High	> 0.2 m, <= 1.5 m
		Low	<= 0.2 m, > 1.5 m
	Cover	High	Vegetated
		Low	Not vegetated
Bay	Shoreline type	High	Beaches, marshes, vegetated banks, tidal flats
		Low	Riprap, structures, rocky shores, exposed habitats
	Depth	High	> 0.2 m, <= 1.5 m
		Low	<= 0.2 m, > 1.5 m
	Salinity	High	<= 10 ppt
		Low	> 10 ppt

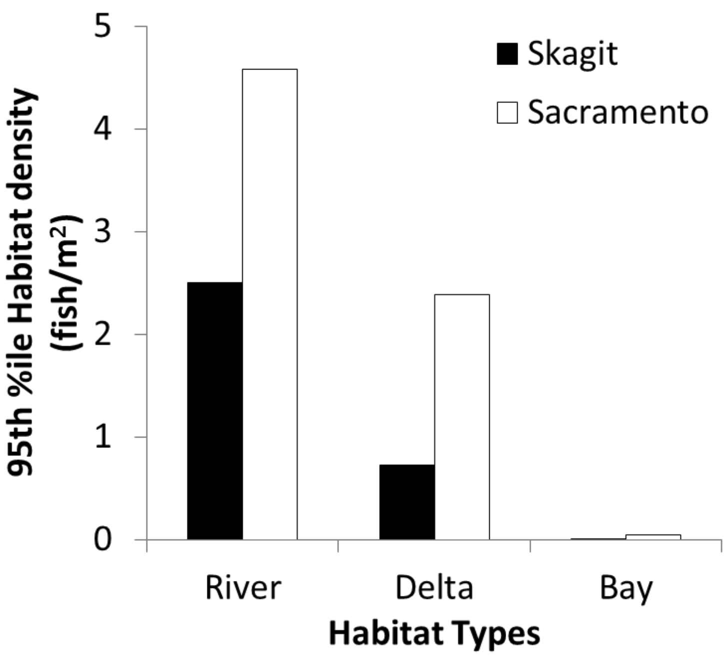

Figure 9. 95th percentile values of densities in river, delta, and bay habitats in the Skagit and Sacramento Rivers. Skagit data are based on electroshocking in mainstems and beach seining in delta and bay habitats (Beamer et al. 2005), while Sacramento data are based on beach seining across all habitat types (USFWS, 2005).

Determining habitat areas. Two approaches were used to map the spatial extents of different combinations of habitat variables. In the mainstem and floodplain, the HEC-RAS model divides the river into units based on multiple cross-sections defining depth ranges (Figure 10). Each unit defined by the cross-sections has velocity parameters associated with it. Different levels of flow in a given month or year change the distribution of velocity and depth. Total habitat area in each of the eight classes is calculated by integrating over the river channels modeled by HEC-RAS.

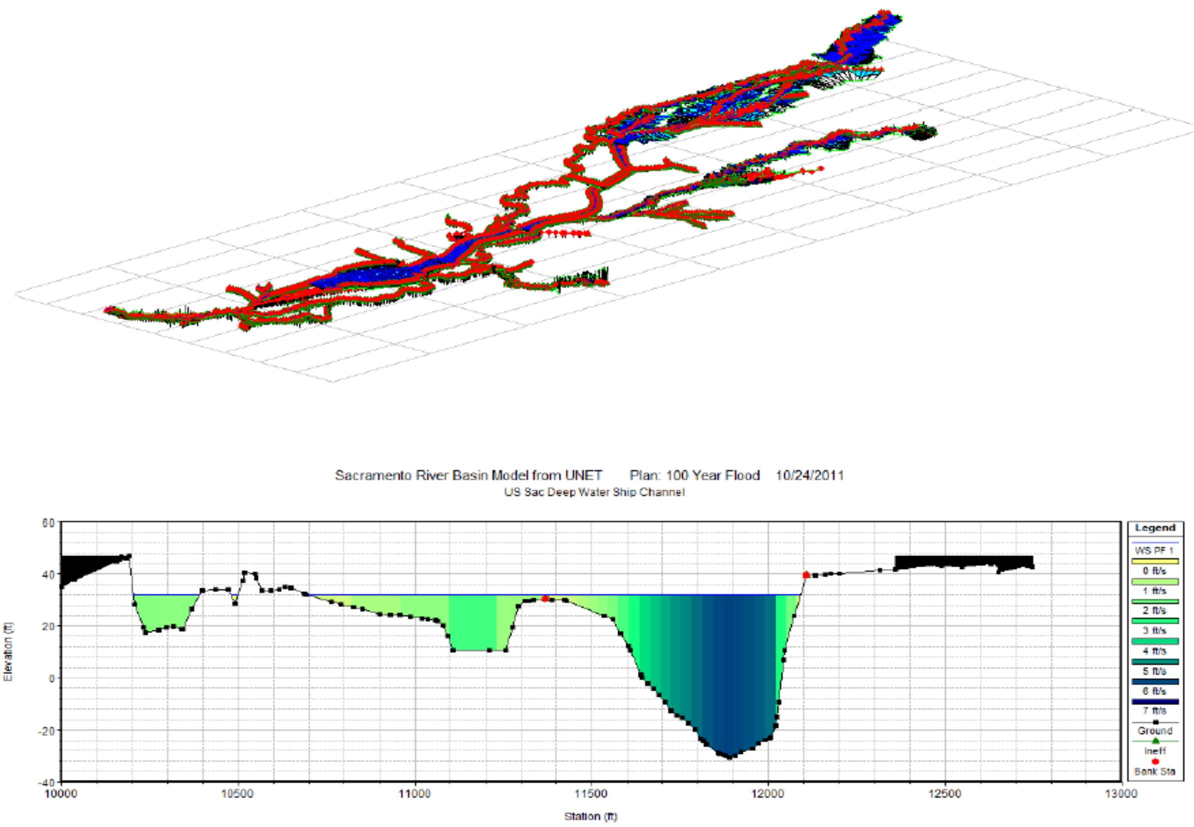

Figure 10. HEC-RAS model cross sections of the Sacramento River mainstem and floodplain (upper panel), and a visualization of a single cross-section, showing depth and velocity differences (lower panel).

For the delta and bay, channel type, depth, cover, salinity, and shoreline type were mapped from existing delta and bay Geographic Information Systems (GIS) products (Figure 11). Delta and bay polygons[1] were classified into high quality habitat types (blind tidal channels) and low quality habitat types (mainstem, distributaries, large water bodies, and bay). For the channel typing, several datasets comprised the base GIS layers, including National Wetlands Inventory (NWI) wetland polygons, San Francisco Estuary Institute's Bay Area Aquatic Resource Inventory's (BAARI) stream lines and polygons, Hydro24ca channel polygons (USBR 2006, Mid-Pacific Region GIS Service Center), aerial photos and Google Earth. The Hydro24ca channel data included channel types such as major river, slough, lake and several other types. When channel type could not be defined for a given reach, aerial photos and attributes from surrounding channels were used to estimate channel type. National Wetland Inventory (NWI) GIS data served as base channel and wetland data. NWI data provides comprehensive data coverage as well as detailed wetland categories that were required. However, NWI data did not have enough information to distinguish accessibility for juveniles. Thus, Bay Area Aquatic Resource Inventory (BAARI) data were used as a reference to identify accessible

[1] A closed shape used in GIS mapping that is defined by a connected sequence of x, y coordinate pairs, where the first and last coordinate pair are the same and all other pairs are unique.

wetlands from NWI polygons. For the areas that BAARI data did not cover, levee GIS layers were overlain to estimate accessible wetland habitat.

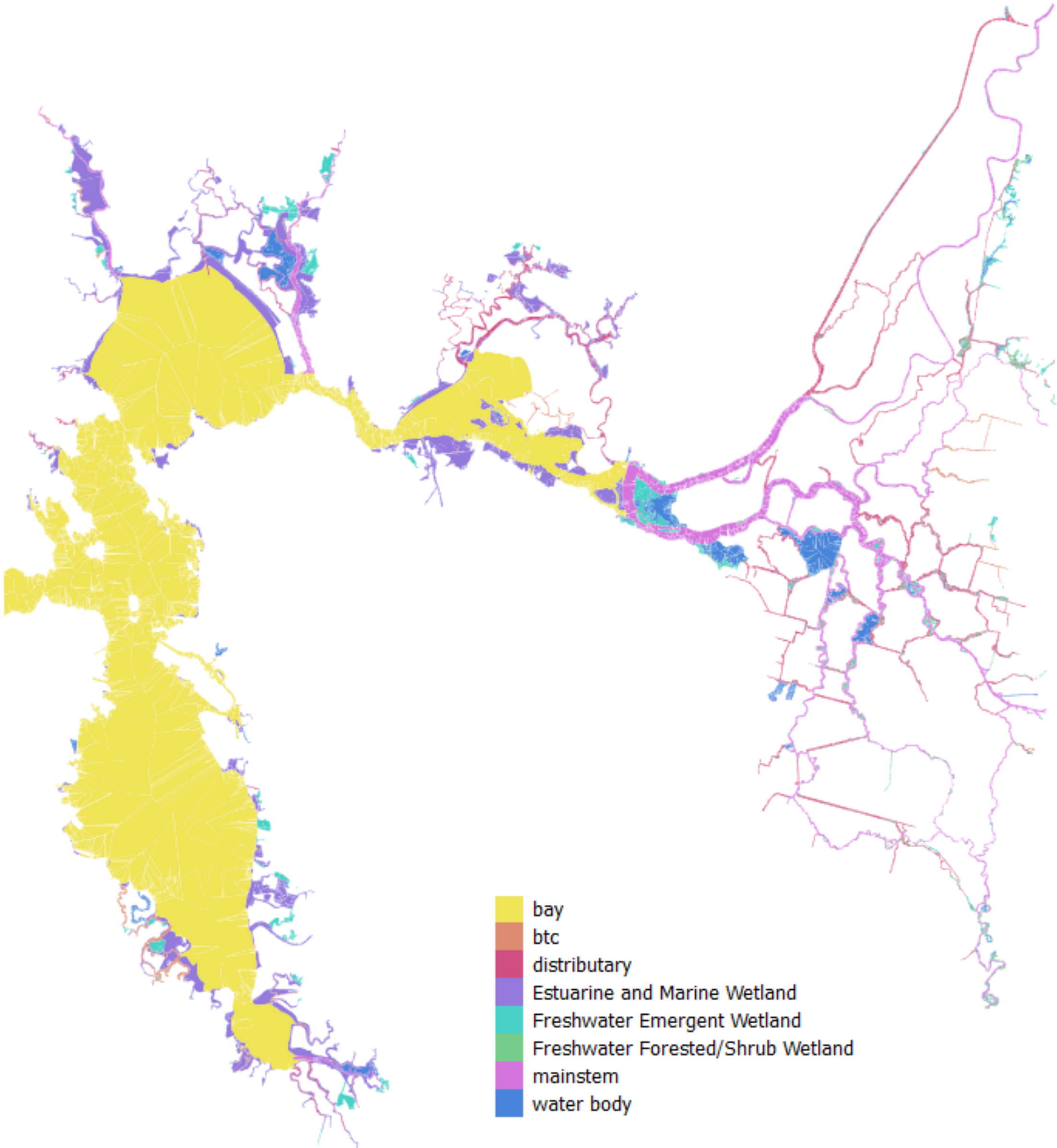

Figure 11. Habitat types delineated for the Sacramento Delta and San Francisco Bay. The abbreviation "btc" stands for blind tidal channel.

Most channel types could be mapped using these datasets except for the blind tidal channels. Instead of directly mapping blind tidal channels, we estimated these areas using allometric relationships between wetland areas and blind tidal channel areas. We tested allometric equations developed in the Skagit River by Beamer et al. (2005) and Hood (2007) to determine which equations were best suited to apply to the Central Valley and chose an allometric equation that returned conservative estimation results:

BTC (ha) = 0.0024*Wetland(ha)^1.56

We also applied the minimum area requirement (0.94 ha) to form blind tidal channels in a wetland from Hood (2007).

Salinity is another factor influencing habitat availability for juvenile Chinook salmon that can vary with water flow. The X2 position describes the distance from Golden Gate Bridge to the 2 ppt isohaline position near the Sacramento Delta (Jassby et al. 1995). This distance predicts amount of suitable habitat for various fish and other organisms. Based on observations of high likelihood of fry presence in water with salinity of up to 10 ppt in both Skagit River and San Francisco Bay fish monitoring data, we defined the low-salinity zone for Chinook as salinity < 10 ppt (i.e., habitats upstream of X10). We calculated X10 values as 75 percent of X2 values (Monismith et al. 2002, Jassby et al. 1995), and mapped these across San Francisco Bay.

Another axis used to evaluate habitat is vegetated cover along river banks. Areas associated with cover were assumed to be higher quality habitats because they provide protection from predators (Semmens 2008) and offer subsidies of terrestrial insect prey. Such habitats are preferred in other systems by Chinook salmon (Beamer et al. 2005, Semmens 2008). The extent of these areas was estimated using Coastal Change Analysis Program (C-CAP) Land Use/Land Cover (LULC) layers. We defined sheltered habitat as forested or shrub covered areas and assumed that other areas, such as urban and bare land, did not provide sheltered habitat.

Restricting habitat areas based on connectivity. Our first analysis of habitat areas assumed all regions of the Delta were equally accessible to Chinook salmon fry. This assumption may be incorrect, however, because much of the fish monitoring has shown that fry do not inhabit certain areas in the Delta. Therefore, a spatial connectivity mask, or exclusion zone, was developed to exclude certain areas from the habitat mapping. This exclusion zone was produced using month- and year-specific fish monitoring data (Figure 12). Poisson regression models were used to predict fish counts based on the relationships between fish counts in beach seine datasets and several covariates including river system (Sacramento or San Joaquin), distance of sampling site to its mainstem (m), physical channel depth (m), physical channel width (m), and DSM2 water stage (m). We selected these parameters based on Akaike's Information Criterion (AIC) analysis of the Poisson regression models with various combinations of the parameters. The resulting Poisson model equation was used to produce a presence-absence map for the entire delta (Figure 12). Restricted capacity estimates were generated by summing habitat areas with predicted fry presence.

Modeling capacity for preferred and no action alternatives. The geospatial tools described above were used to make predictions of capacities of preferred and no action alternatives by routing Calsim2 runs of alternatives through HEC-RAS and DSM2 models. Model changes for these runs included the lowering of the diversion for the Yolo Bypass in HEC-RAS for both alternatives and the diversions and underground tunnels in DSM2 for the preferred alternative.

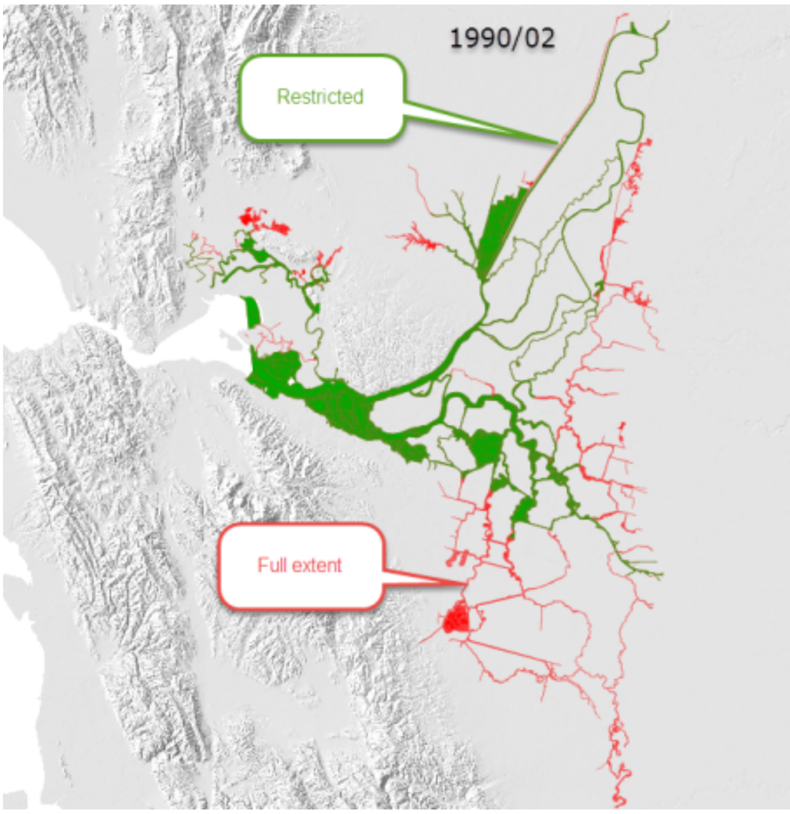

Figure 12. Example results of reduced connectivity applied to the February (02) 1990 map. The presence/absence prediction for connected habitat areas is designated as "Restricted" (green), a smaller area than the full extent of the Sacramento Delta (red).

Enhanced Particle Tracking Model

The survival rate of juvenile Chinook salmon within and migrating through the Delta is modeled using the Enhanced Particle Tracking Model (ePTM). This rate is defined as the survival at Chipps Island of simulated juvenile salmon (SJS) released at any location within the Delta. The ePTM survival computation includes swimming behavior and predation mortality (Sridharan et al., in prep.). The ePTM is based on the Delta Simulation Model II Particle Tracking Model (DSM2 PTM) developed by the Department of Water Resources (DWR), California.

DSM2

The DSM2 PTM transports particles on a one-dimensional network representation of the Delta, driven by the flows computed by HYDRO, the hydrodynamic module of DSM2 written in FORTRAN (Anderson and Mierzwa, 2002). The DSM2 HYDRO module computes the flow and stage at different locations in the Delta by solving the cross-sectionally averaged one-dimensional shallow water wave equations on a network of links, continuously stirred tank reactors (CSTR) and nodes which respectively represent channels, flooded and leveed islands, floodplains and forebays, and channel junctions (Figure 13). River inflows and in-delta consumptive use flows are estimated from DAYFLOW, an estimated account of net flows in and out of the Delta. Gate operations are provided by DWR. Details of the numerical solution method can be found in DeLong et al. (1997). DSM2 HYDRO is typically run with a timestep of 15 minutes to one hour.

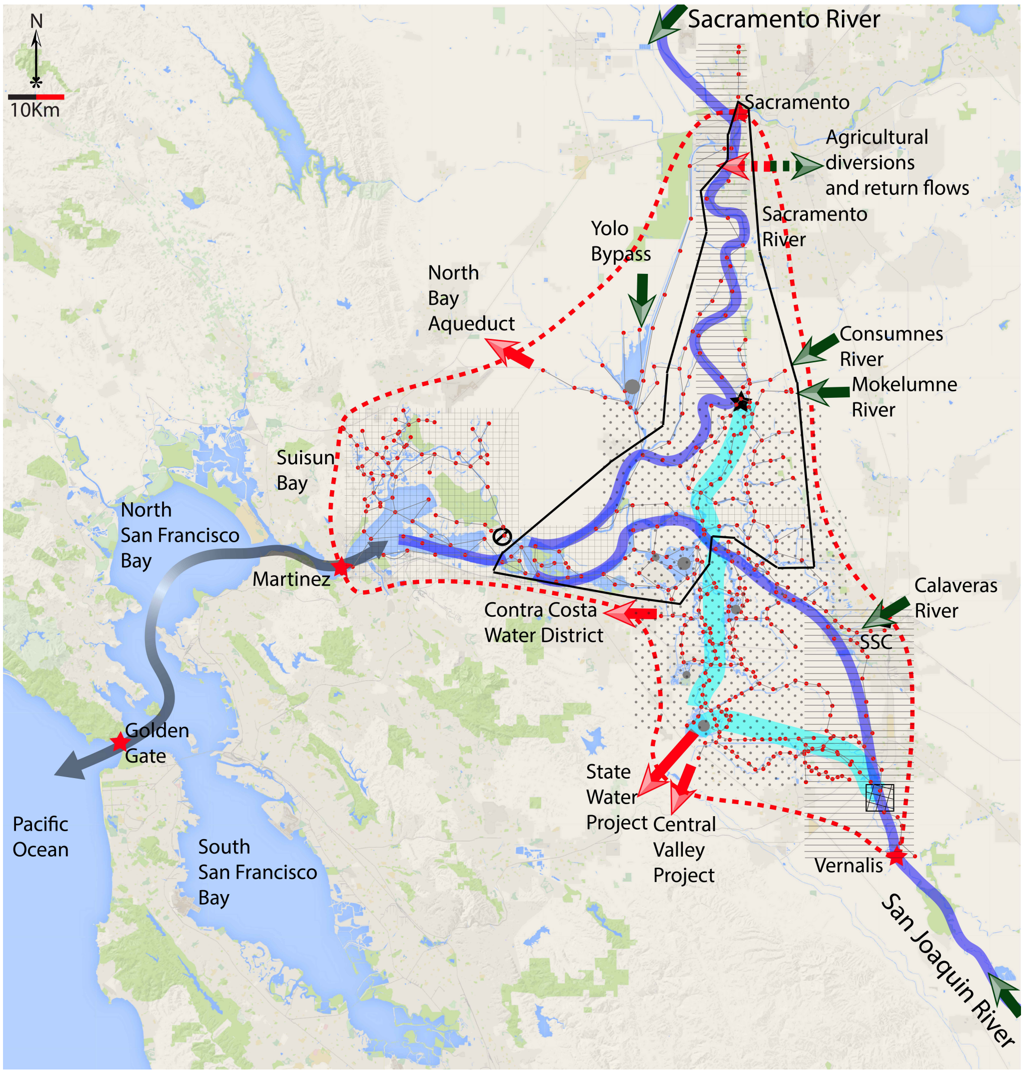

Figure 13. Sacramento-San Joaquin Delta and DSM2 grid. Dashed red line represents boundary of the Delta. Green arrows represent inflows, red arrows represent outflows, grey arrow represents tidal flow. Grey lines, grey circles and red dots respectively represent DSM2 links, reservoirs and nodes. Dark blue lines represent the mainstem Sacramento and San Joaquin Rivers. Light blue lines represent the canals and Old and Middle River Corridors. The black star represents the Delta Cross Channel, the black no pictogram represents the salinity control gate in Montezuma Slough. The black cross-hatched box represents the temporary barriers. The riverine, transitional and tidal ePTM behavioral reaches are represented respectively by the horizontal, dotted, and checkered hatches. The DSM2 nodes at which SJS are released to represent river, floodplain and Delta smolt and fry are represented respectively by the red star at Sacramento, the black circle at the Southern tip of the Yolo Bypass floodplain, and all the nodes within the black border.

The DSM2 PTM module, written in JAVA, is a pseudo three-dimensional model with a turbulent law of the wall logarithmic vertical velocity (Prandlt, 1935) and a fourth order polynomial transverse velocity profile (Wilbur, 2000) imposed onto the solved mean flows through a cross-section. The links are represented as rectangular prismoids whose cross-sections preserve the hydraulic radii and water column depth in the channels they represent. It uses constant cross-sectional eddy diffusivities in a zeroth-order turbulence closure to move particles laterally and vertically. Particles are advected in the streamwise direction with the hydrodynamic velocity at their locations and moved randomly in the lateral and vertical direction with the diffusivities at their locations using Forward Euler numerical integration. DSM2 PTM is capable of modeling about 5,000 particles (Kimmerer and Nobriga, 2008). It does not have any temporal interpolation of hydrodynamic quantities between DSM2 HYDRO timesteps, and randomizes particles arriving at nodes and assigns them to new links based on the flow splits at the nodes. Their new cross-sectional positions are also randomized. The ePTM builds on the basic framework of the DSM2 PTM.

ePTM

The ePTM adds juvenile salmon swimming behavior and predation mortality to the DSM2 PTM (Jackson et al., in prep.). Apart from these additions, the ePTM linearly interpolates all hydraulic and hydrodynamic quantities between DSM2 HYDRO timesteps to account for SJS movement within an ePTM time substep. Broadly, the scope of the ePTM can be summarized into its representation of the hydrodynamics, the fish behavior, and the mortality of SJS.

Hydrodynamics

SJS trajectories are given by the Weiner process (Visser, 1997)

$$\frac{dx}{dt} = u + u_S;\ \frac{dy}{dt} = R_y\sqrt{\frac{2}{r}\frac{\varepsilon_H}{\Delta t}};\frac{dz}{dt} = R_z\sqrt{\frac{2}{r}\frac{\varepsilon_V z}{\Delta t}}$$

where u is the hydrodynamic velocity at the particle position, u_s is the swimming velocity, ε_H and ε_V are the lateral and vertical eddy diffusivities, Δt is the ePTM timestep, R_Y and R_Z are uniform random variables between -1 and 1, r is the variance of a uniform distribution and is equal to 1/3.

The velocities and diffusivities in ePTM are given by

$$u = U f_V f_H$$

$$f_V = \begin{cases} 1 + \frac{\sqrt{C_D}}{\kappa}\left[1 + \ln\left(\frac{z}{H}\right)\right]; z > z_0;\ z_0 = 0.03m \\ 0 \qquad\qquad\qquad\qquad ; z \le z_0 \end{cases};\ C_D \approx 0.03$$

$$f_H = 1.2 + 0.3\left(\frac{2y-W}{W}\right)^2 - 1.5\left(\frac{2y-W}{W}\right)^4$$

where U is the mean velocity of flow, the linearization of the friction force has been performed with the bottom drag coefficient C_D (e.g., Wang et al., 2009), and the bed shear stress has been parameterized using a constant bottom roughness height z_0 (e.g. Kundu and Cohen, 2002).

and

$$\varepsilon_H = 0.6Hu_*; \varepsilon_V = 0.067Hu_*; u_* = \sqrt{C_D}U$$

where H is the depth of the water column and u_* is the friction velocity.

Time substeps are chosen as the time step required to limit particle displacement at any given timestep to within 10 percent of the smallest dimension of the channel. A particle leaves a given channel through its upstream or downstream end when its streamwise displacement during a timestep exceeds the distance between its current position and the end of the channel. The channel bottom, banks and free surface are treated as fully reflecting boundaries.

Currently, SJS are not allowed to enter reservoirs or flooded islands because the DSM2 PTM does not have a module for dealing with reservoirs. Also, the routing of SJS through junctions follows the randomization based on the flow splits of the DSM2 PTM. The next update of ePTM will include a CSTR model for flooded islands, as well as a parameterization of SJS movement at channel junctions based on fitting beta distributions to observed juvenile salmon distributions at key junctions in the Delta (Perry and Pope, p.c.).

Behavior

The ePTM incorporates behavior by adding a biological swimming velocity to the flow velocity at the location of the SJS. The SJS also hold position via Selective Tidal-Stream Transport (STST) (Gibson, 2003), a hypothesis for optimal energy expenditure while achieving average travel speeds greater than the average flow velocity in tidal regions. During the ebb phase of the tide, the SJS allow themselves to be advected. On a flood tide, when the upstream flow exceeds some threshold, they hold position (Liao, 2007). The ePTM also parameterizes diel swimming behavior (Chapman et al., 2013) by assigning a probability of swimming during the light hours. Lastly, ePTM includes phenomenological parameters of oceanward direction assessment, and confusion of SJS due to confounding flows such as exports due to pumping (Table 2).

Table 2. Behavior and habitat parameters in the ePTM.

Parameter	Value in riverine reach	Value in transition reach	Value in tidal reach
Swimming speed (m/s)	0.015 ± 0.31	0.23 ± 0.83	0.25 ± 1.91
Threshold oceanward directed velocity above which fish hold position (m/s)	0.28	0.05	0.41
Probability of swimming during the day	0.15	0.31	0.28
Probability of being confused about direction of flow	$0.5 - 0.25\left(\frac{\bar{Q}}{Q_{RMS}} - 3.99\right)$	$0.5 - 0.25\left(\frac{\bar{Q}}{Q_{RMS}} - 4.62\right)$	$0.5 - 0.25\left(\frac{\bar{Q}}{Q_{RMS}} - 2.91\right)$
Probability of assessing direction of flow at a given time step	0.01	0.01	0.01
Mean free path length between predator encounters (Km)	395	151.4	329.8
Random predator encounter speed which includes tidal fluctuations as well (m/s)	0.048	0.048	0.048

<u>Rationale behind the choice of behavior parameters</u>

As the advection due to the river flow decreases from the riverine to transition reaches, SJS have to rely greater on their swimming velocity to migrate than the river advection, and hence swimming speed increases.

The rationale behind the choice of mean free path length between predator encounters is that more time spent in a particular region is likely to increase the chance of predation within that region. This is elaborated subsequently. In the riverine reaches, the channels are long (~10Km) and there are very few multi-channel junctions. Therefore, SJS trajectories looped over many junctions (i.e., when a fish moves downstream and then back upstream again via the same or different channels during different phases of the tide) are unlikely, and the path length between predator encounters is very large. In the transition reach, the many channel junctions and very small channel lengths (~100-500m) are likely to induce an increased number of predator encounters due to looped SJS trajectories, and so the path length between predator encounters is small here. In the tidal reach, there are fewer channel junctions and longer channels (~1Km) but with greater likelihood of looped SJS trajectories than in the riverine reaches, and so the path length between predator encounters is larger than in the transition reach but smaller than in the riverine reaches.

The biological parameters of random predator-prey encounter speed and the probability of assessing the downstream direction are theoretically independent of the nature of the flow. We treat these variables as constant across all reaches in the ePTM. In reality, the random predator-prey encounter speed is likely to be spatially heterogeneous due to different interactions between predators and prey in different conditions (Anderson, p.c.). The probability of assessing the downstream direction is set to 0.01. This ensures that the recurrence interval of the assessment, which is the inverse of the probability of assessment, is approximately 24 hours. In other words, SJS are likely to assess the oceanward direction once every two tidal cycles. While there is little support for such a recurring assessment of the correct migration direction by juvenile salmon in literature, a diel assessment of flow conditions would at least allow for the filtering of the principle tidal constituents up to the longest periods that contribute to flow reversal in the San Francisco Bay-Delta system, i.e. K1, O1 and S1.

Chapman et al. (2013) observed that approximately 75-90% of tracked juveniles migrated during the dark hours in the Sacramento River, while about 60-70% migrated during the dark hours in the Delta and Suisun Bay. These values are qualitatively reflected in the probability of swimming during the day.

In the confusion parameterization, the probability of improper orientation is a logistic function of the signal-to-noise ratio (SNR) that saturates at a probability of 0.5 for low SNRs (simulated juveniles can only randomly assess the downstream direction) and at a probability of 0 for high SNRs (simulated juveniles can always assess the downstream direction accurately). The shape of the logistic function is defined by two parameters: the location of the half-saturation point, and the steepness of the logistic function. A slope of the logistic function of -0.25 captures the range of SNRs commonly observed in the Delta within the linear portion of the curve and the half-saturation point is higher in the riverine and transition reaches than the tidal reaches, reflecting larger likelihood of confusion with distance away from the ocean. The half-saturation point increases in the transition reach compared to the riverine reaches as the influence of the tides becomes strong compared to the mean river flow.

Predation Mortality

The ePTM adds predator-induced mortality according to the XT model (Anderson et al., 2005). The probability of a SJS surviving passage through a reach, S, is as follows:

$$S = e^{-\left(\frac{1}{\lambda}\sqrt{x^2+\omega^2 t^2}\right)}$$

where x is the distance traveled and t is the travel time. The mean free path, λ, is

$$\lambda = \frac{1}{\rho \pi r^2}$$

where ρ is the density of predators and r is the encounter distance. The term ω is the random component of prey speed. The implementation of the XT model in the ePTM involves recording the x and t for each channel that a SJS traverses in a given 15-minute time step. A survival probability for each of these sub time steps is then calculated using the λ values for the individual channels. The overall probability that the SJS survives the 15-minute time step is the product of the survival probabilities of the sub time steps, i.e.:

$$S = \prod_{i=1}^{n} e^{-\left(\frac{1}{\lambda_i}\sqrt{x_i^2+\omega_i^2 t_i^2}\right)}$$

where n is the number of channels that the SJS traversed during the time step, x_i is the distance traveled in channel i, t_i is the time spent in channel i, and λ_i and ω_i are the channel-specific mortality parameters. In the ePTM, only the parameters λ_i and ω_i are specified explicitly (Table 2).

$$\frac{\bar{Q}}{Q_{\mathrm{RMS}}} \geq 1; \quad \text{Riverine}$$

$$0.1 \leq \frac{\bar{Q}}{Q_{\mathrm{RMS}}} < 1; \quad \text{Transitional}$$

$$\frac{\bar{Q}}{Q_{\mathrm{RMS}}} < 0.1; \quad \text{Tidal}$$

where T_T is the duration of a tidal cycle, and $Q_{\mathrm{RMS}} = \sqrt{\frac{1}{T_T}\int_0^{T_T} Q^2 dt - \bar{Q}^2}$.

ePTM application

A minimum of 10000 SJS released from any location on the DSM2 grid is required to achieve statistically repeatable results. These releases are performed uniformly over a period of one month, which is the timestep size in the LCM. However, releasing 10000 simulated juveniles is computationally expensive. As a tradeoff between statistical repeatability and performance, for riverine and tidal salmon fry and smolt survival, 1000 SJS are released uniformly each month at Sacramento, and in the floodplain node (Figure 13). The survival probability of each SJS escaping the Delta at Chipps Island is resampled with replacement to produce 1000 survival probabilities, whose mean and standard deviation give a measure of the expected value of the survival and its variance. A similar exercise is carried out for Delta fry and smolt, with 100 particles released uniformly over all the nodes within the North and Central Delta corridor (Figure 13). In this case, a release of 100 particles per node is sufficient, as this results in more than 15,000 SJS released over the total number of release nodes. The net Delta survival is computed as

$$S_D = \frac{\sum_i^n N_i S_i}{\sum_i^n N_i}$$

where *n* is the number of resampled outcomes, or 1000, N_i is the number of times the i^{th} SJS arriving at Chipps Island is resampled, and S_i is the survival of the i^{th} SJS. Such a resampling procedure ensures that the net Delta survival is an average of contributions from all the nodes of the Delta weighted by the escapement from each node. It is to be noted that the definition of the Delta as shown in Figure 1 represents the likely passage of late-fall and winter-run Chinook salmon smolts. This can be readily modified to include other nodes in the Delta. The number of simulated salmon resampled from each release node are weighted by the relative maximum supported population at each node with respect to the total maximum supported population in the whole Delta by

$$N_m = \frac{\sum_{j=1}^{8} k_j A_j}{\sum_{i=1}^{m}\left(\sum_{j=1}^{8} k_j A_j\right)} \times n$$

where N_m is the number of particles contributing to the resampling from the release node m, A_j is area and k_j is the carrying capacity of the j^{th} type of habitat class associated with that node, in which habitat class is characterized into 8 classes by the velocity and depth of the flow, channel bottom roughness, type of shoreline, vegetation cover, salinity intrusion (X2), carrying capacity and available area (Hendrix et al., 2014).

There are certain months during which habitat information may be unavailable. In these cases, a lookup table was developed in MATLAB to interpolate survivals from ePTM results for those months. The lookup table was based on the ratio of export flow to inflow, ratio of the RMS tidal flow to the mean river flow through Carquinez Strait, ratio of time the Delta Cross Channel was open to the total duration of one month, and ratio of flow through the Delta Cross Channel to the flow in the Sacramento River. There is no correlation assumed between these parameters. Each parameter is assumed to have equal weight. The lookup table operation is performed by first choosing the year-month combination which minimizes the 4-dimensional Euclidean distance between the hydrology of the year-month, r, that does not have the habitat information,

$$M_{\mathrm{LOOKUP}} = min_{\forall i}\left\{\sqrt{\left[\left(\frac{Q_E}{Q_I}\right)_i - \left(\frac{Q_E}{Q_I}\right)_r\right]^2 + \left[\left(\frac{Q_{\mathrm{RMS}}}{\bar{Q}}\right)_i - \left(\frac{Q_{\mathrm{RMS}}}{\bar{Q}}\right)_r\right]^2 + \left[\left(\frac{T_{\mathrm{DXC\,OPEN}}}{T}\right)_i - \left(\frac{T_{\mathrm{DXC\,OPEN}}}{T}\right)_r\right]^2 + \left[\left(\frac{\overline{Q_{DXC}}}{\overline{Q_{SAC}}}\right)_i - \left(\frac{\overline{Q_{DXC}}}{\overline{Q_{SAC}}}\right)_r\right]^2}\right\}$$

Then, the habitat factor for MLOOKUP is computed as

$$S = \frac{N_{r,\mathrm{CHIPPS}}}{N_r} \times \frac{N_{\mathrm{LOOKUP}}}{N_{\mathrm{LOOKUP,CHIPPS}}} \times \frac{\overline{S_{\mathrm{LOOKUP}}}}{\overline{S_{\mathrm{LOOKUP,RESAMPLED}}}} \times S_{\mathrm{LOOKUP}}$$

where N_{LOOKUP} and N_r are the number of particles released in the lookup year-month and in month r respectively, $N_{\mathrm{LOOKUP,CHIPPS}}$ and $N_{r,CHIPPS}$ are the number of particles escaping the Delta in the lookup year-month and in month r, respectively, $\overline{S_{\mathrm{LOOKUP}}}$ is the mean survival before resampling, and $\overline{S_{\mathrm{LOOKUP,RESAMPLED}}}$ is the mean survival after resampling, and S_{LOOKUP} is an actual survival in the lookup year-month, where the factor $\frac{\overline{s_{\mathrm{LOOKUP}}}}{s_{\mathrm{LOOKUP,RESAMPLED}}}$ is included to correct for sampling bias from different nodes.

Alternative Scenario Applications

Currently, the ePTM can represent four scenarios: (i) the current geomorphology and hydrology of the Delta (Current), (ii) a historic representation of the Delta before Liberty Island flooded (Historic), (iii) operational scenarios due to the California Water Fix, in which canals are in place to divert freshwater from the Sacramento River upstream of the Delta Cross Channel to a forebay, but water is not pumped through these canals (No Action Alternative, NAA), and (iv) these diversion canals are actively withdrawing water, (Preferred Alternative, PA). These scenarios are represented as alternate DSM2 grids, which can be applied individually in the ePTM (BDCP, 2013; Figure 14).

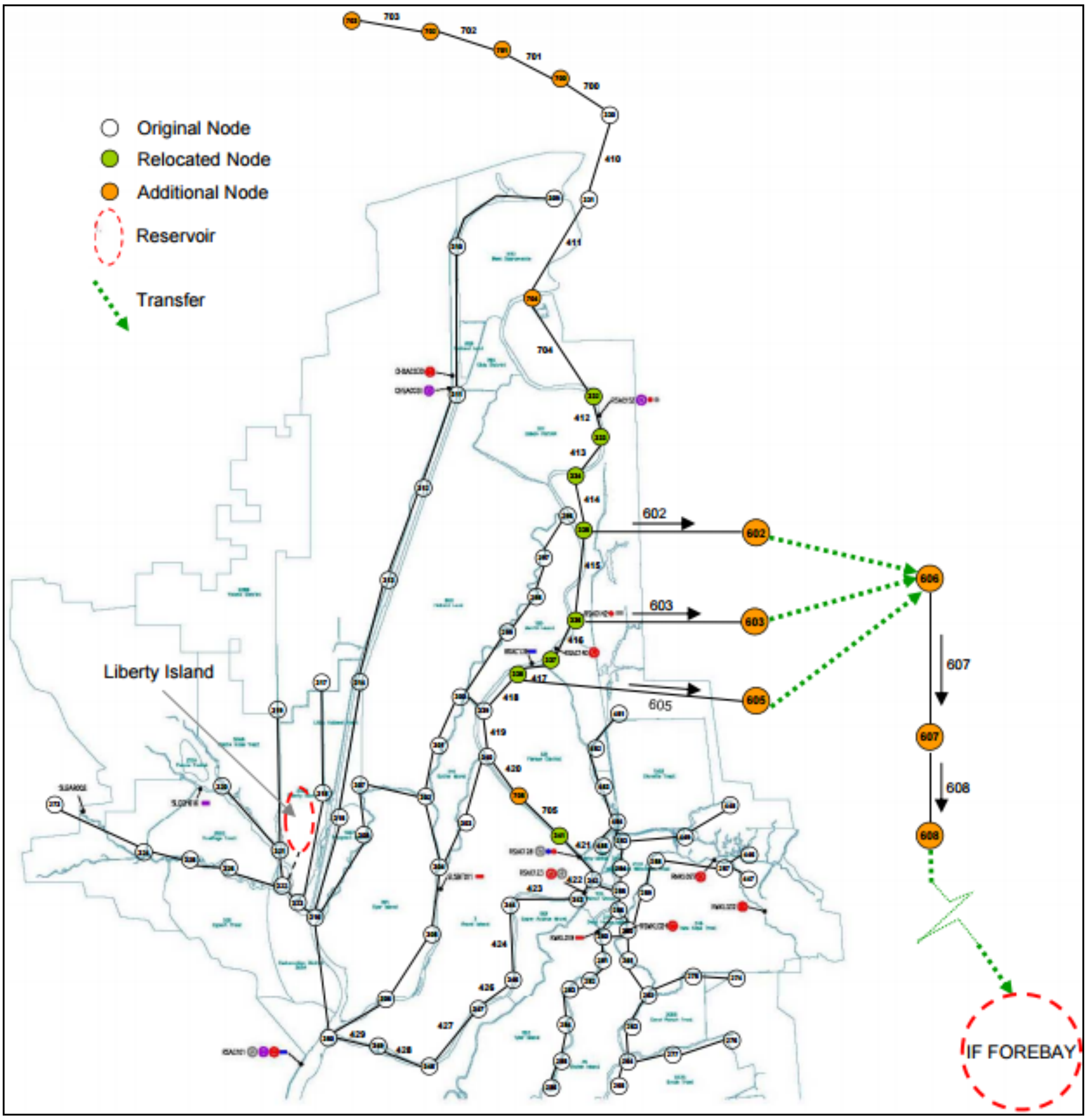

Figure 14. Changes to the DSM2 grid for the NAA and PA scenarios (BDCP, 2013).

The potential implications of the NAA scenario is that while active diversion of freshwater does not occur, the presence of screens may impact habitat quality near the diversion canals. These locations may also become predation hotspots. The habitat quality and area associated with this alternative can be modified accordingly.

The potential implications of the PA scenario is that when active diversion of freshwater occurs, a number of salmon fry and smolt may become entrained in this flow, and abrade against the screens, thereby reducing their survivability significantly. The locations of the intakes may also become predator hotspots. Finally, the reduced freshwater flow may reduce the quality of the habitat, and intensify the effect of predation, and migratory confusion. The ePTM accounts for water diversion automatically by intensifying the effect of confounding pumping and tidal flows, thereby increasing the confusion of SJS. Their routing through channel junctions is also adversely affected by the reduced flows. Reduced survivability due to screen abrasion could be incorporated by reducing the weight of each release in the Sacramento River location, so that the final river fry and smolt survival can be modified as

$$S = \alpha S_0$$

where S_0 is the original survival, S is the modified survival, and α represents the fraction of fish unaffected by abrasion with the screens. Further, reduced survival can also be incorporated by randomly assigning reduced swimming velocity and increased probability of confusion to some SJSs released in the Sacramento River location. The effect of predation hotspots can be incorporated by reducing the mean free path length between predator encounters, and increasing the predator encounter speed in the links near the diversion canals.

Caveats

The ePTM results are based on a simplified one-dimensional network representation of the Delta, and hence do not account for complex geo-morphological and hydrodynamic transport and mixing phenomena such as tide induced chaotic dispersion, wind generated transport and gravitational circulation. The ePTM results do not include the effects of environmental stressors such as water quality, temperature, nutrients, channel scale, temporal variability in predation dynamics, and foraging behavior or energy management dynamics. There is a significant data gap in addressing more complex spatio-temporal patterns in biological behavior and habitat interactions, as well as a need for easy model deployment and speed, so the ePTM parameterizes only simple hypothesis about these effects.

IV. Model Calibration

The WRLCM framework is flexible in that it may be used to generate many different trajectories of abundance and spatial patterns of habitat use by varying the parameters of the model. The WRLCM should reflect historical trends and spatial patterns in abundance, however. As a result, we calibrated the WRLCM to multiple winter-run abundance indices by fixing some model parameters and estimating other parameters with a statistical fitting algorithm.

One goal of the WRLCM was to construct a model that was sensitive to alternative hydromanagement actions in the Central Valley; thus the model was structured such that it is sensitive to hydrologic drivers. An unintended consequence of this approach is that the statistical properties of the model are not optimal. In particular, some model parameters are not uniquely identifiable; that is, the same abundance can occur through several different parameter combinations. Because this property of the LCM makes statistical estimation difficult, the values of some parameters must be constrained using biological information, previous studies, or expert opinion, so that other parameters can be estimated. We provide the parameters that were constrained and provide justification for their values before moving to the statistical estimation of the remaining parameters.

Fixed parameters and their justifications

Spawn timing parameters

Historically, the spawning of winter-run Chinook has not been uniform among the months April to August. Instead, higher proportions of winter-run spawned in June and July relative to April, May, and August. In addition, the proportions of winter-run that spawned in each month were not constant across years, but instead varied yearly. We analyzed the historical proportion spawning among each month from 2003 – 2014 using carcass counts (assuming a 2 week period between spawning and senescence), and estimated the proportion of winter-run spawning in each month as a function of April temperatures at Keswick (Appendix A). We compared this model to one that used a static proportion among years, and found that the model based on April temperatures outperformed the static model. The general relationship identified through this multinomial regression model was that hotter April temperatures caused later initiation of spawning in winter-run Chinook. This may be explained mechanistically if the female spawners were laying their eggs to target an emergence time. Hotter temperatures in April indicated that a shorter incubation window was needed, whereas cooler temperatures indicated a longer incubation window. Please see Appendix A for additional information on this analysis.

These equations provided a method of shifting spawning distribution among months as a function of April temperatures (Table 3 and Appendix A). The April water temperatures were standardized in the analysis and thus need to be standardized for use in the simulation model.

Table 3. Fixed parameter values related to monthly spawn timing.

Parameter	Value	Description
$B0_{Apr}$	-4.145	Intercept for proportion of spawners in April
$B1_{Apr}$	0.0538	Effect of temperature on proportion of spawners in April
$B0_{May}$	-1.796	Intercept for proportion of spawners in May
$B1_{May}$	-0.2031	Effect of temperature on proportion of spawners in May
$B0_{Jul}$	-0.332	Intercept for proportion of spawners in July
$B1_{Jul}$	0.3852	Effect of temperature on proportion of spawners in July
$B0_{Aug}$	-3.443	Intercept for proportion of spawners in August
$B1_{Aug}$	0.7921	Effect of temperature on proportion of spawners in August

Tidal fry related parameters

Winter-run Chinook generally have not had a high tidal fry proportion (on the order of less than 5%). Furthermore, the location of tidal fry has varied among years, and they have been susceptible to movement downstream in the Sacramento River under high flow conditions (Pat Brandes, USFWS *personal communication*). The WRLCM parameters for the fry stage reflected these assumptions (Table 4).

Table 4. Fixed parameter values related to the tidal fry stage.

Parameter	Value	Description
$P_{TF,\,m}$	0.047	Proportion tidal fry
$S_{TF,FP}$	0.731	Survival tidal fry in floodplain
$P_{FP,m}$	0.881	Proportion tidal fry to Floodplain if flooding
$B0_4$	0.5	Average survival tidal fry to delta intercept
$B1_4$	-1.0	Effect of DCC gate (value is in logit space)*
$B0_5$	0.5	Average proportion of tidal fry to bay intercept
$B1_5$	2.0	Effect of Rio Vista flow (value is in logit space)*

*Values in logit space are the untransformed values used in the logit function of the transition equation

Smoltification timing parameters

The timing of smoltification of winter-run Chinook salmon historically begins in January with a majority of winter-run sized smolts outmigrating by March (delRosario et al. 2013). In the WRLCM, all fry are assumed to have smolted by April and migrating in May (Table 5). The timing of smoltification in the WRLCM has been parameterized to coincide with winter-run sized Chinook salmon in Chipps Island trawl data (delRosario et al. 2013) and by using Chipps Island abundance indices as described below in the *Parameter Estimation* section.

Table 5. Smoltification timing parameters for winter-run Chinook.

Parameter	Value	Description
Z_1	0.269	January smolt probability
Z_2	0.5	February smolt probability
Z_3	0.953	March smolt probability
Z_4	1	April smolt probability
Z_5	1	May smolt probability
Z_6	1	June smolt probability
Z_7	1	July smolt probability

Maturation rate probabilities

The age-specific maturation probabilities for winter-run Chinook salmon were fixed to values based on analysis of coded wire tagged hatchery fish (Grover et al. 2004). The probability of maturation of age 2 fish was 0.10 (M_2), the conditional probability of maturation at age 3 was 0.90 (M_3), and the conditional probability of maturation at age 4 was 1.0.

Age-specific sex ratios were applied to obtain age and sex specific escapement values. Males dominate age-2 escapement, thus the female sex ratio for age-2 fish (Fem_{Age2}) was set at 0.01. Estimates of the proportion of age-3 female spawners (Fem_{Age3}) may vary among years, and we accounted for this historical annual variability by using an annual sex spawner ratio value calculated from Keswick trap counts 2001 – 2014 (mean = 0.595, sd = 0.077). These values were also used in the annual calculation of natural origin escapement from carcass surveys over the period 2001 – 2014 (Doug Killam, CDFW Redding, CA, *personal communication*). In the absence of an estimate of the age-3 sex ratio, a value of 0.5 was assumed for 1970 – 2000.

Egg production per age-2 female ($V_{eggs,2}$) was 3200 for age 2 females (Newman and Lindley, 2006) and production per age-3 and age-4 female ($V_{eggs,3}$ and $V_{eggs,4}$) was 5000 (Winship et al. 2014).

Smolt survival

The ePTM calculates month and year-specific smolt survival probabilities; however, some survival probabilities were needed to move the smolts from their areas of rearing to the location in which the ePTM survival rates were applied. Smolt survival from the Lower River to the Delta ($B0_{11,LR}$) was fixed at 0.8 (estimates of survival ranged from 0.73 - 0.875 Colusa to Sacramento in the 2012-2015 WR acoustic tag data, Arnold Ammann, SWFSC NMFS Santa Cruz *personal communication*). Smolt survival from the Upper River to the Delta ($B0_{10,UR}$) was fixed at 0.4 (estimates of survival averaged 0.456 from release to Sacramento in the 2012-2015 WR acoustic tag data, Arnold Ammann, SWFSC NMFS Santa Cruz *personal communication*). Smolt survival from the Yolo bypass to insertion into the DSM2 grid for incorporation into the ePTM (${}^{A}S_{13,FP}$) was assumed to be 0.924 per month.

Survival of smolts from Chipps Island to the Golden Gate bridge (${}^{c}S_{11}$) was assumed to be 0.82, and survival of smolts that reared in the Bay to the Golden Gate bridge ($S_{15,BA}$) was assumed to be 0.5.

Ocean survival

Survival of smolts that reared in the Upper River, Lower River, and Yolo habitats (S_{G1}) have the same gulf survival, which is estimated (see below in the *Parameter Estimation* section). The survival of smolts from the Delta and Bay habitats (S_{G2}) had survivals that were reduced slightly from those of the River and Yolo habitats to reflect lower quality rearing conditions affecting ocean entry survival (i.e., D_{G2} = -0.5 in the logit function for survival during entry into the gulf).

Survival during the first four months in the ocean (S_{17}) was assumed to have a rate of 0.79, which equates to an annual survival of 0.5, whereas annual survival in the ocean for age-3 and age-4 (S_{19} and S_{21}) was assumed to be 0.8. These annual natural survival rates are consistent with winter-run reconstruction conducted annually as part of the fishery management of Sacramento River salmon (Grover et al. 2004, O'Farrell et al. 2012). Annual impact rates of age-3 (I_3) and age-4 (I_4) were obtained from estimated harvest rates over the 1970- 2014 period (O'Farrell and Satterthwaite 2015). Survival of age-2 (S_{sp2}), age-3 (S_{sp3}), and age-4 (S_{sp4}) through the freshwater prior to spawning is assumed to be 0.9 to incorporate in-river harvest, which historically included levels of approximately 7 percent (Grover et al. 2004) and pre-spawn mortality.

Formulation of the Floodplain habitat access for calibration

To reflect the historical dynamics of access to the Floodplain habitat (Yolo bypass), the following transition equation was used to describe the proportion of Tidal Fry that enter the floodplain habitat ($P_{FP,m}$)

$$P_{FP,m} = B1_{FP} * \mathrm{I}(Q_{Verona,m} > 991.1\ \mathrm{m}^3\mathrm{s}^{-1})$$

where $Q_{Verona,m}$ was the Sacramento River flow at Verona in month m, I( ) is an indicator function that equates to 1 when the condition in the parenthesis is met, and $B1_{FP}$ is the proportion of fry that enter the Yolo under flooding conditions, which was 0.8.

Statistical estimation

One of our objectives is to ensure that the WRLCM is capable of reflecting the historical patterns in winter-run Chinook population dynamics in the Sacramento River. In order to meet this objective, we calibrated the LCM to observed winter-run indices of abundance throughout the life cycle (Table 6). Not all indices of abundance were available for the entire period of model calibration of 1970-2014. This data limitation is not a problem for fitting the WRLCM, however. The WRLCM can be fit to the specific indices of abundance for the period over which they were available by pairing observed indices of abundance with WRLCM predictions over the appropriate period. Then, the sampling distribution provided a likelihood function by which the model predictions were statistically evaluated given the observed data (Hilborn and Mangel 1997).

This type of model, in which multiple data sources are used to inform multiple life-history stages, is called an integrated population model and has notable advantages over piece-wise model composition (Newman et al. 2014). In particular, the model parameter estimates can utilize all of the available data simultaneously, which can improve the parameter estimates by allowing the model to “fill in the gaps” over portions of the life cycle that are unobserved (Newman et al. 2014).

Table 6. Indices of abundance used to calibrate the winter-run life cycle model.

Data	Date	Coefficient of Variation	Sampling Distribution	Data time step
Natural Escapement	1970-2014	0.15 (1970-1986) 0.5 (1987-2000) 0.15 (2001-2014)	lognormal	Annual
RBDD monthly juvenile counts	1996-1999, 2002-2014	0.85	lognormal	Monthly
Knights Landing monthly catches	1999 - 2008	NA	multinomial	Monthly
Chipps Island monthly juvenile abundance	2008 - 2011	1.5	lognormal	Monthly

Maximum Likelihood Estimation

Given the fixed parameter values described above, the remaining parameters were estimated in a statistical fitting framework. An initial evaluation of model complexity (not shown) indicated that approximately 10 parameters were identifiable in the mechanistic portion of the model, depending upon which parameters were chosen. We estimated 8 parameters in addition to 45 annual random effects (i.e, the ε_y) in the model calibration.

These parameters were estimated by maximizing the likelihood (the likelihood specified by the sampling distribution) of observing the winter-run abundance indices (Hilborn and Mangel 1997). That is, parameter combinations can be used to make predictions on the escapement in each year, the number of juveniles passing RBDD in each month, the catches at Knights Landing, and monthly abundance estimates at Chipps Island. Some parameter combinations provide predictions that are closer to the observed abundance indices than others. The parameter combination that provides the closest fit to the observed indices is the one that maximizes the likelihood, and is thus called the maximum likelihood estimate (MLE).

Model parameters were estimated using an Expectation-Maximization algorithm (Dempster et al. 1977). The specific implementation of the algorithm optimizes the fit across different dimensions and has also been termed a gradient search method (Neal et al. 1998; Hastie et al. 2011). In short, the algorithm obtains maximum likelihood estimates for different components of the parameters, cycling through the parameter list to maximize the likelihood in a piece-wise fashion. In our case we used two blocks of parameters: 1) parameters associated with the mechanistic population dynamics and 2) the annual random effects. The calibration used a statistical search algorithm in which lower and upper bounds were specified to maintain parameter values in biologically realistic ranges (optim using the BFGS fitting algorithm with box constraints in the R programming language – RCDT 2016).

Fits to abundance indices

Fits to the abundance indices generally followed patterns in the observed data. Annual patterns in natural origin escapement were well estimated by the model (Figure 15), as were monthly patterns in juvenile abundance estimates at RBDD (Figure 16).

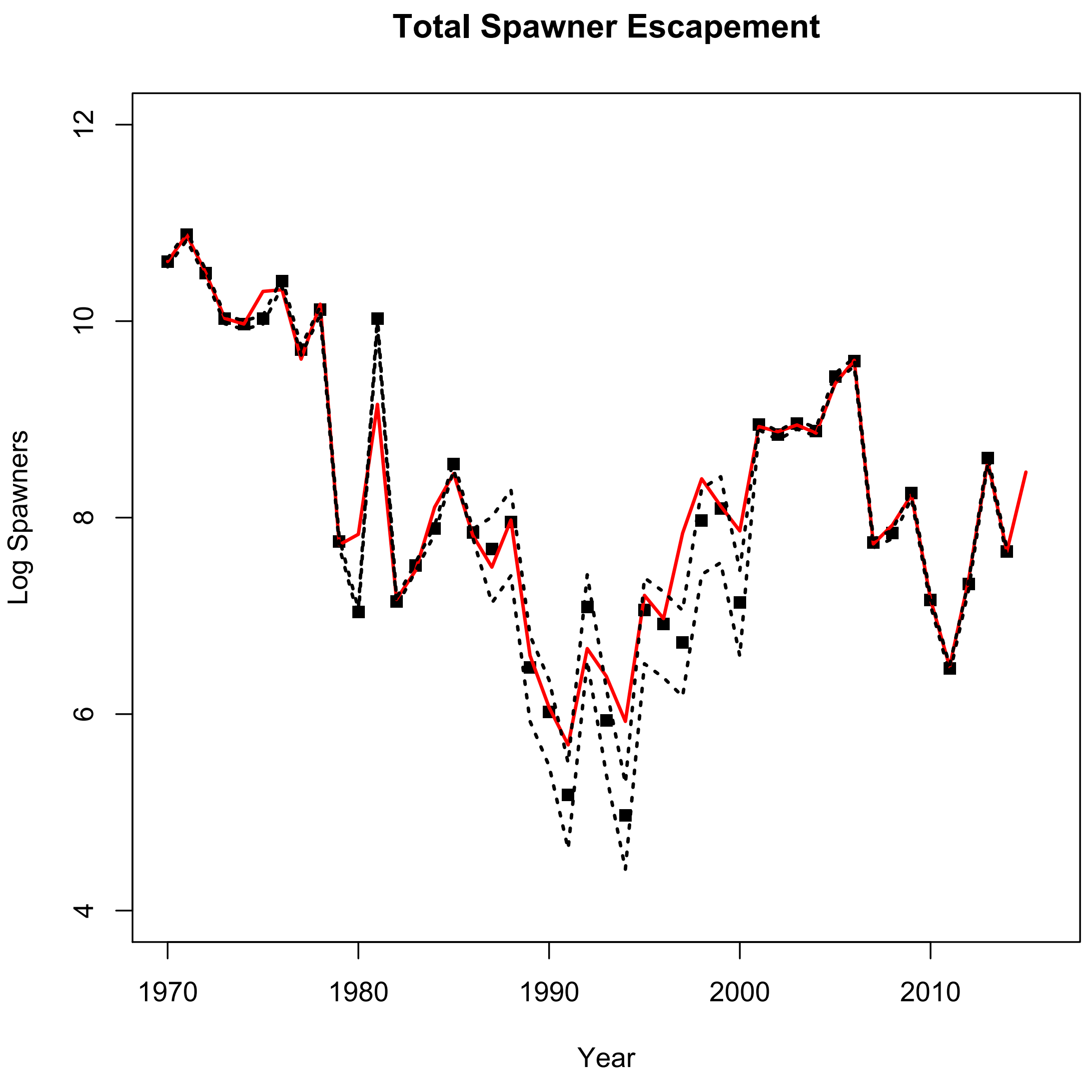

Figure 15. Model fit (red line) to log natural origin escapement data (squares) with 95% interval on measurement error (dashed lines).

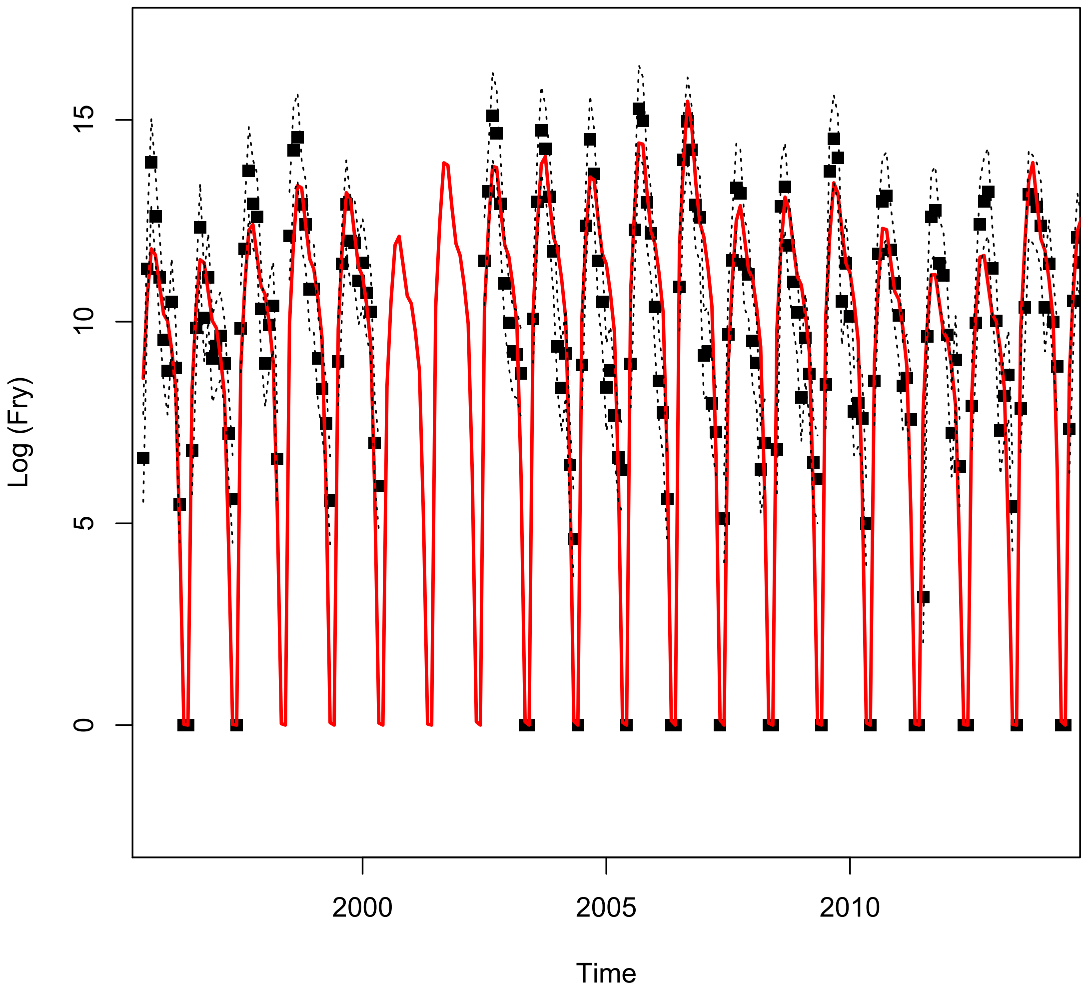

Figure 16. Model fit (red line) to monthly juvenile abundance estimates at Red Bluff Diversion Dam from 1996 to 2014 (squares) with 95% interval on measurement error (dashed lines).

Catches at Knights Landing were estimated by applying the proportion of fish predicted by the model to the observed total catches in a given year. The WRLCM used the flow triggers at Wilkins Slough (Rearing transition) of greater than 400 m^3s^{-1} to move fish past Knights Landing, and the model was able to capture the general patterns in movement among years as a function of the flow trigger (Figure 17 and 18).

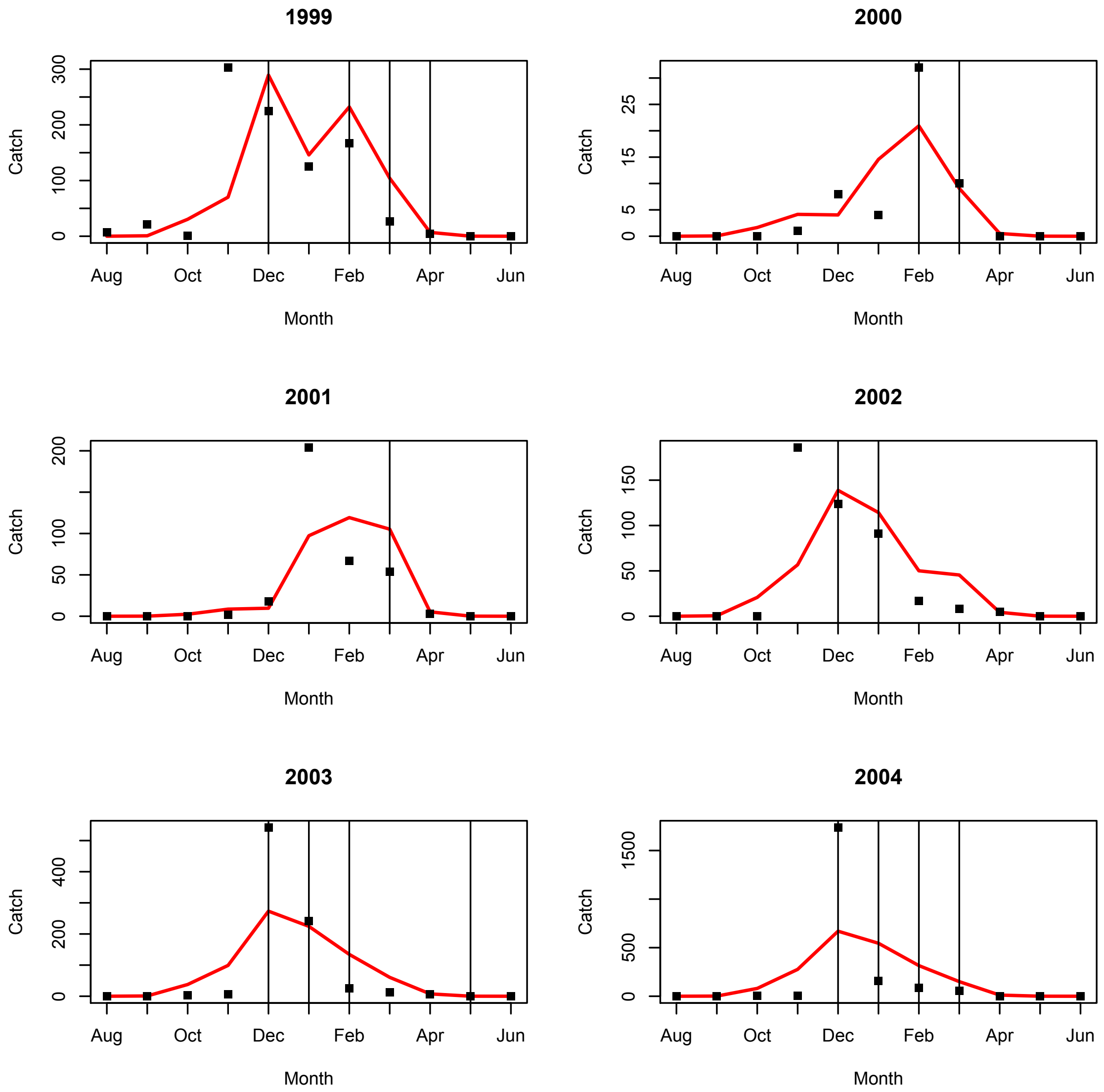

Figure 17. Model fits (red line) to Knights Landing catch data (black squares) from 1999 to 2004. Vertical lines indicate months in which the average flow at Wilkins Slough was greater than 400 m^3s^{-1}.

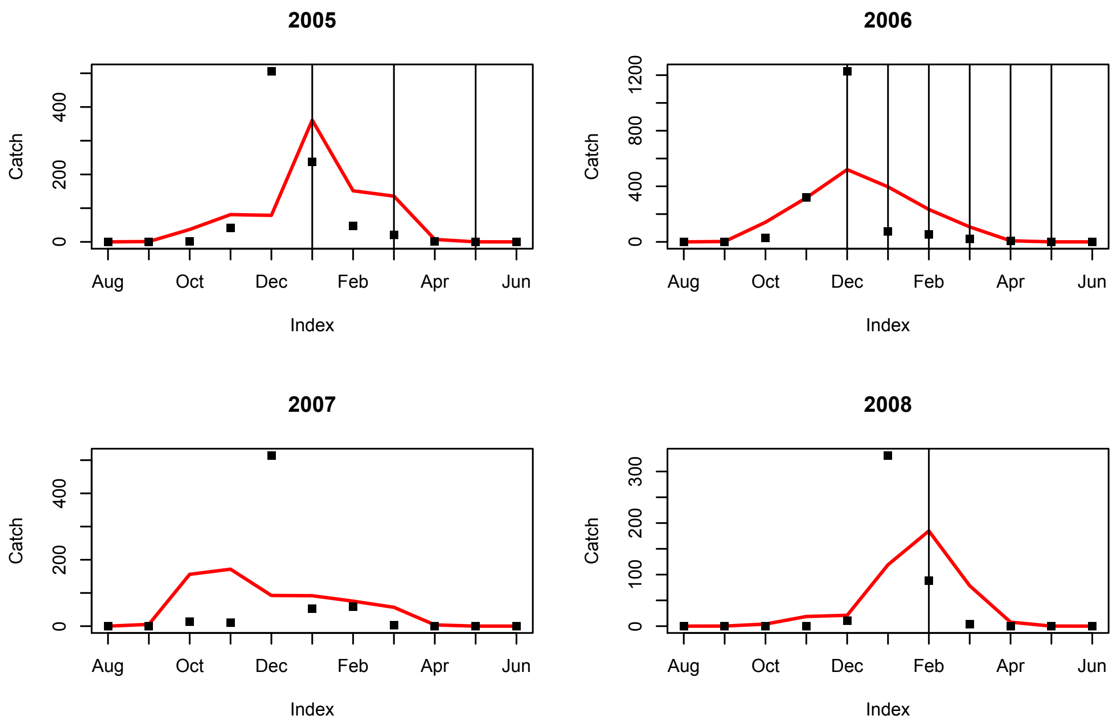

Figure 18. Model fits (red line) to Knights Landing catch data (black squares) from 2005 to 2008. Vertical lines indicate months in which the average flow at Wilkins Slough was greater than 400 m^3s^{-1}.

Finally, the WRLCM was able to capture the monthly patterns in Chipps Island abundance trends from 2008 – 2011, reflecting the outmigration patterns of winter-run from each of the rearing habitats (Figure 19).

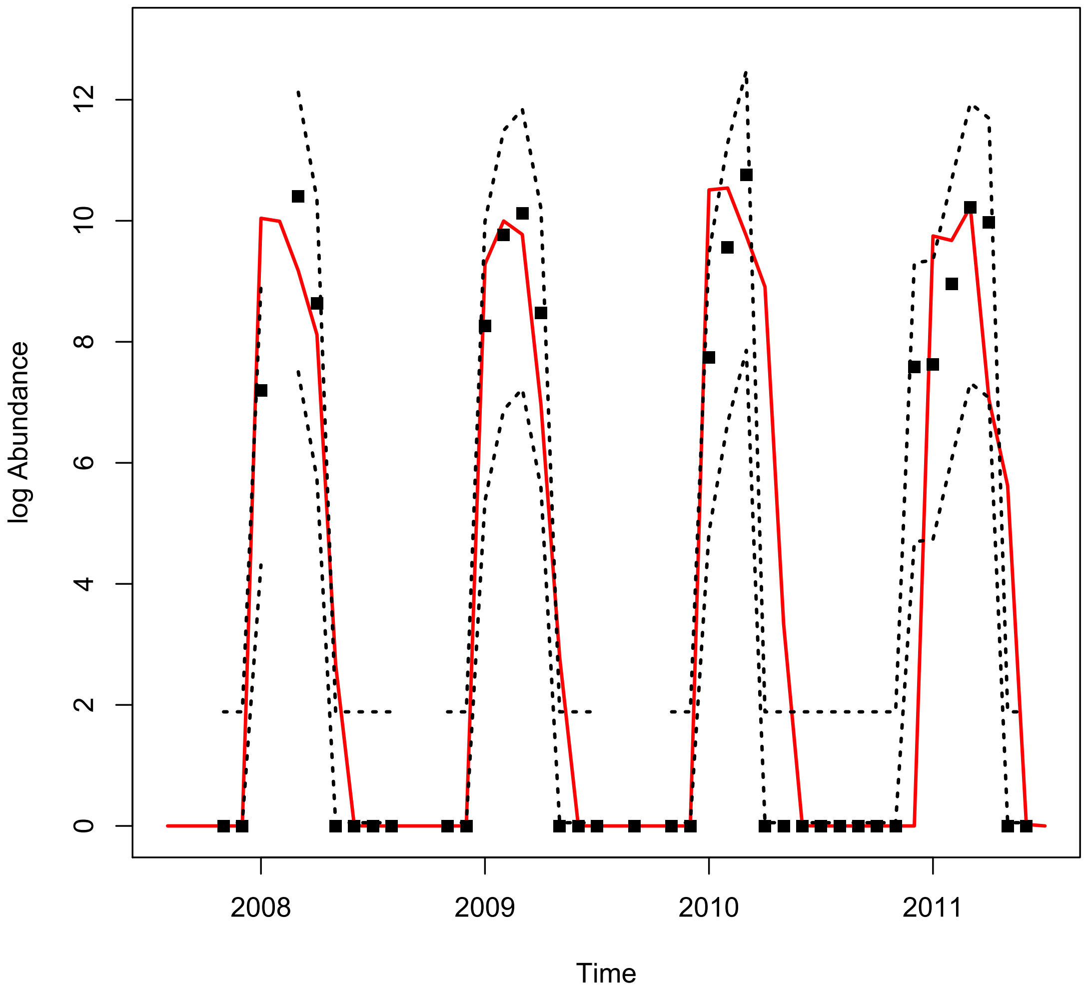

Figure 19. Model fits (red line) to monthly Chipps Island abundance estimates (black squares) from 2008 to 2011 with 95% interval on measurement error (dashed lines).

The estimated parameter values from the Expectation-Maximization algorithm are provided in Table 7. The table provides the parameter estimate, the standard deviation of the estimate (SD), a transformed value of the parameter estimate, and a note defining the parameter. We attempted to estimate all parameters of the survival of egg to fry as a function of temperature (Transition 1); however, there was strong correlation among the three parameters that caused problems with parameter identifiability. We assumed that the survival rate from egg to fry in the absence of thermal mortality was 0.321, which is consistent with historical estimates of egg to fry survival values (Poytress et al. 2014). The parameter estimates indicated that the 3-month trailing average (spawn month and trailing 2 months) of 13.4 ^{0}C (*t.crit*) was thermal threshold. Above the thermal threshold, the survival of egg to fry below this critical temperature the survival was 0.321 ($B0_1$) for the 3-month period, whereas above this threshold the survival was reduced ($B1_1$).

The other parameter value that was set was the variance on the random effect in process noise (σ_ε^2), and it was set to have a value of 1. This variance allowed the model to estimate the annual random effect parameters (ε_y) to have values of approximately ± 2. These parameter values corresponded to a range in annual variability in survival of (0.17, 7.4) due to the lognormal structure of the random effects.

Table 7. WRLCM parameter estimates from the model calibration to winter-run indices of abundance (Table 6).

Parameter	Estimate	SD	Transformed Value	Notes
$t.crit$	13.4	0.0521	13.4	Critical temperature (C) at which egg to fry survival is reduced
$B0_1$ *	-0.75	0	0.321	Survival below critical temperature value (logit space)
$B1_1$	-0.785	0.0213	NA	Rate of reduction in egg to fry survival (logit space)
S_{FRY}	1.25	0.0338	0.777	Winter run fry survival (logit space)
mig_{LH}	-0.604	0.0423	0.268	Proportion of fry in upper river migrating to lower river per month (logit space)
$B0_M$	-5.56	0.815	0.001	Wilkins slough movement without trigger (logit space)
$B1_M$	4.95	0.819	NA	Wilkins slough change in movement with flow trigger (logit space), proportion moving with flow effect is 0.35
$B1_{10}$	1.47	0.0526	NA	River smolt survival from flow effect
S_{G1}	-1.68	0.0441	0.157	Gulf entry for upper river, lower river, and floodplain
σ_ε^2 *	1	0		Variance of annual random effects in process noise

* parameters fixed in estimation but are relevant for the estimation portion of the model

Using the Hessian matrix (second derivative of parameter estimates with respect to the likelihood surface at the maximum likelihood estimate), we were able to calculate the Fisher information matrix, and obtain estimates of the standard deviation of the model parameters (Table 7) and the correlation among estimated model parameters (Table 8). Several parameters had high correlations. The estimated parameters of the egg to fry survival (Transition 1) had a strong negative correlation (-0.79). In addition, the parameters of the fry movement function from the

Lower River to the Delta (Rearing transition) as a function of Wilkins Slough flow had a high positive correlation (0.99). Finally, the survival at ocean entry was negatively correlated with the fry survival rate (-0.96) and the critical temperature (-0.68).

Table 8. Correlation matrix for estimated parameters in the WRLCM calibration.

	$t.crit$	$B1_1$	S_{FRY}	mig_{LH}	$B0_M$	$B1_M$	$B1_{10}$	S_{G1}
$t.crit$	1	-0.79	0.56	0.33	-0.02	-0.05	0.01	-0.68
$B1_1$	-0.79	1	-0.55	-0.46	0.03	0	-0.41	0.55
S_{FRY}	0.56	-0.55	1	0.26	0.08	-0.09	0.18	-0.96
mig_{LH}	0.33	-0.46	0.26	1	0.04	-0.04	0.41	-0.25
$B0_M$	-0.02	0.03	0.08	0.04	1	-0.99	0.03	-0.01
$B1_M$	-0.05	0	-0.09	-0.04	-0.99	1	0	0.05
$B1_{10}$	0.01	-0.41	0.18	0.41	0.03	0	1	0.01
S_{G1}	-0.68	0.55	-0.96	-0.25	-0.01	0.05	0.01	1

Developing parameter sets for Monte Carlo simulations

To compare alternative hydromanagement actions, Monte Carlo simulations should be run under each of the actions. We have obtained estimates of parameter uncertainty and correlation in the model calibration from the Hessian matrix (Table 8) to incorporate into the Monte Carlo simulation. For those parameters that were estimated, Monte Carlo parameter values were drawn from multivariate normal distribution centered on the maximum likelihood estimates (MLE) and using the covariance matrix estimated from the Hessian obtained at the MLE. The draws from the multivariate normal distribution incorporated the relative uncertainty in the estimated parameters and preserved the strong correlation among several of the life cycle model parameters that were identified in the correlation matrix of the parameter estimates (Table 7). For the random effects, iid normal N(0,1) random variables were drawn to reflect the annual random effects in the process noise. All other parameters were set to their fixed values as described above. Please see Appendix B for a list of all parameter values.

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Appendix A. Analysis of winter-run monthly spawn timing

To estimate the proportion of winter-run spawning among the months of April to August, we conducted an analysis of the numbers of winter-run carcasses detected in each of the months April to August. We were interested in understanding whether the proportions spawning among months were static across all years, or alternatively, whether the proportions varied among years due to the environmental conditions in that year. That is, whether there were some environmental conditions that caused shifts to earlier spawning in some years.

Data

Winter-run carcass observations by date were shifted two weeks earlier to generate "observed" number of fish spawning by date. These spawning numbers by date were coalesced by month to form $N.spawn_{m,t}$ the observed (based on carcass counts) number of winter-run Chinook spawning in month m in year t.

To evaluate annual variability in the proportion spawning in a given month, we calculated a spawning proportion anomaly as the standardized proportion of fish spawning each month ($SPr_{m,t}$). For example, the values of the standardized April values were

$$SP_{Apr,t} = \frac{P.spawn_{Apr,t} - mean(P.spawn_{Apr})}{std\ dev(P.spawn_{Apr})}$$

where the proportion spawning in each month for a given year t (subscript suppressed) was calculated as

$$P.spawn_m = \frac{N.spawn_m}{\sum_m N.spawn_m}.$$

To understand how these annual anomalies varied as a function of water temperature, we calculated the Pearson's correlation coefficient between mean monthly temperature below Keswick Dam between January and June and the standardized proportions (Figure A1).

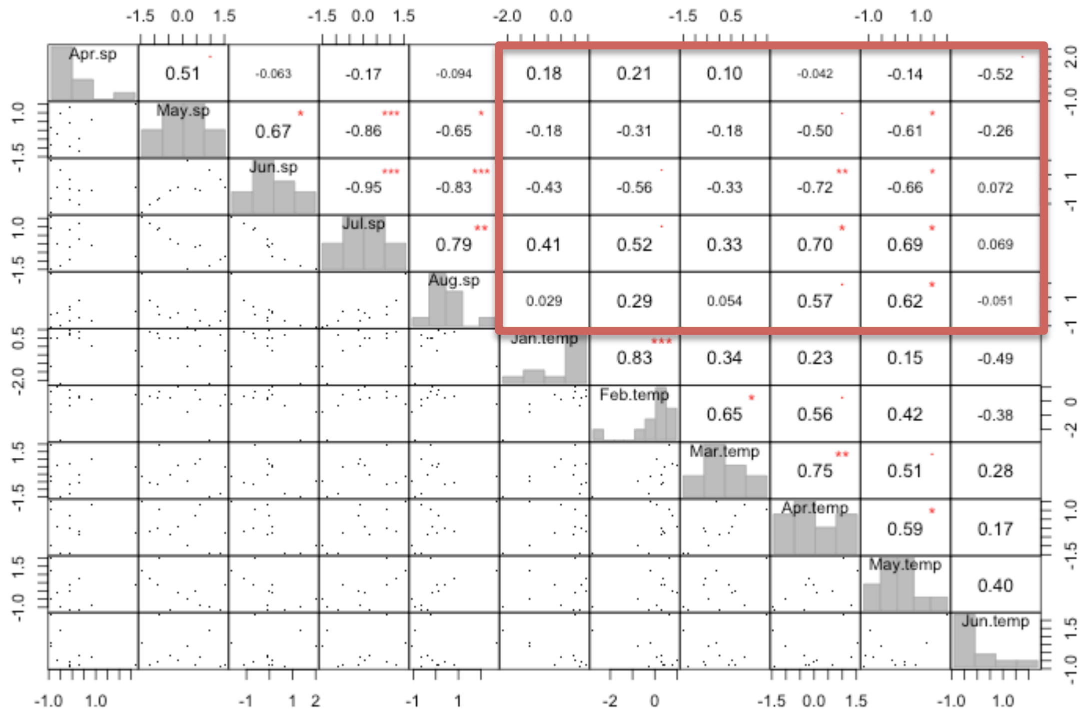

Figure A1. Pearson correlation coefficients (upper triangle), histograms (diagonal) and scatter plots (lower triangle) for all combinations of monthly spawning proportion anomalies and Keswick water temperatures. The red box indicates the month by temperature correlations, and red asterisks indicate significant correlation coefficients.

Statistical analysis

We fit a multinomial logistic regression using the *multinom* function from the *nnet* package in R to the number of winter-run Chinook spawning in each month, $N.spawn_{m,t}$. We evaluated the ability of April Keswick temperatures to explain annual variability in the spawning timing. We focused on April temperatures because April is the first month of spawning, and April would allow this physical variable to be used as a predictor of spawn timing for future years. The monthly average April temperatures at Keswick were standardized (subtracted mean and divided by standard deviation) for use in the multinomial model.

We fit a base model without the April temperature effect and we fit the model with the April effect and used Akaike Information Criterion (AIC) to compare the models. The AIC value for the base multinomial model was 75822, whereas the value for the multinomial model including April temperature as a covariate was 74209. The difference in AIC was 1613, providing strong support for the model with the April temperature covariate.

The model coefficients for the multinomial model with April covariate indicated increasing spawning in July and August (positive coefficient values) when April temperatures increased (Table A1 and Figure A2). The model coefficients (Table A1) can thus be used for making predictions of spawning proportions using standardized April temperatures as displayed in Figure A2.

Table A1. Coefficient estimates of the multinomial model including April covariate. The effect of the April covariate is reflected in the B1 coefficient estimate.

	Estimate		Standard Error	
Month	B0	B1	B0	B1
Apr	-4.145	0.054	0.06	0.062
May	-1.796	-0.203	0.02	0.02
Jul	-0.332	0.385	0.012	0.012
Aug	-3.443	0.792	0.044	0.045

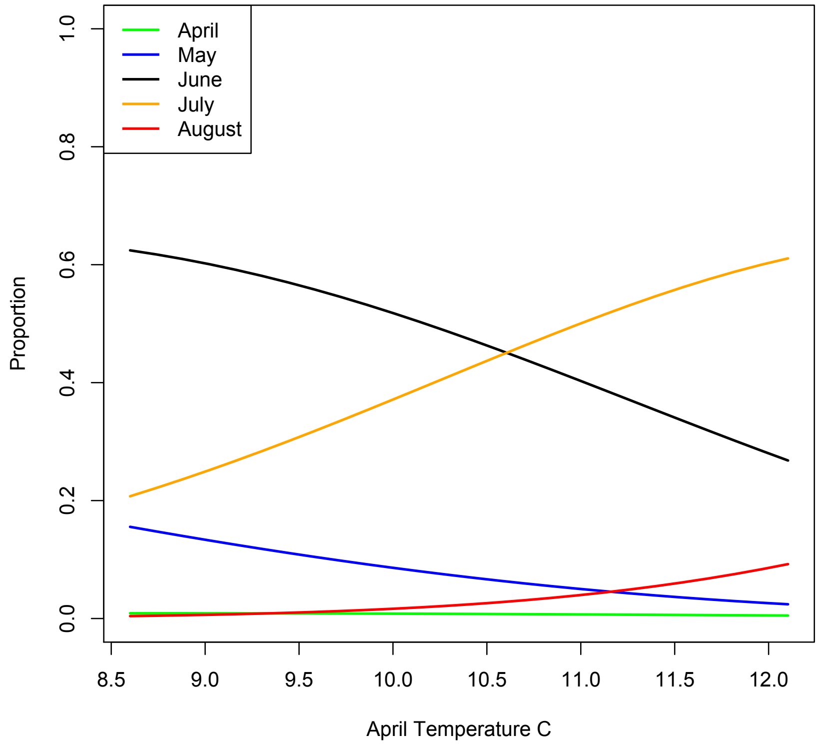

Figure A2. Predictions of the proportion of winter-run Chinook spawning from the multinomial regression model using April temperatures at Keswick Dam as a predictor variable.

Appendix B. Table of parameter values for WRLCM

Table B1. Parameter values, standard deviation (SD), transformed values, transition numbers in which parameters are found and brief description of parameter.

Name	Value	SD*	Transformed Value	Transition	Description
$t.crit$	13.40	0.052	13.40	1	Critical temperature (C) at which egg to fry survival is reduced
$B0_1$	-0.75	0	0.236	1	Survival below critical temperature value (logit space)
$B1_1$	-0.785	0.021	NA	1	Rate of reduction in egg to fry survival (logit space)
$P_{TF,\,m}$	-3	0	0.047	2	Proportion tidal fry
$S_{TF,FP}$	1	0	0.731	3	Survival tidal fry in floodplain
$min.p$	0.05	0	0.05	3	Minimum proportion entering Yolo bypass under flow < 100 cfs
$p.rate$	1.1	0	NA	3	Rate of increase in proportion entering Yolo bypass for flows > 6000 cfs
$B0_4$	0	0	0.5	4	Average survival tidal fry to delta intercept
$B1_4$	-1	0	NA	4	Effect of DCC gate (value is in logit space)*
$B0_5$	0	0	0.5	5	Average proportion of tidal fry to bay intercept
$B1_5$	2	0	NA	5	Proportion tidal fry to bay - flow at Rio Vista effect
$S_{TF,DE\text{-}BA}$	-1	0	0.269	5	Survival of tidal fry from delta to bay
S_{FRY}	1.25	0.034	0.777	Rearing	Winter run fry survival
mig_{LH}	-0.604	0.042	0.268	Rearing	Proportion of fry in upper river migrating to lower river per month
$B0_M$	-5.56	0.815	0.001	Rearing	Wilkins slough movement without trigger
$B1_M$	4.95	0.819	NA	Rearing	Wilkins slough change in movement with flow trigger, movement rate under flow trigger is 0.352
mig	-3	0	0.047	Rearing	Probability of migration from habitats
$S_{FRY,BA}$	-7	0	0.001	Rearing	Survival of bay rearing fry pushed to gulf
Z_1	-1	0	0.269	11 to 15	January smolt probability
Z_2	0	0	0.5	11 to 15	February smolt probability
Z_3	3	0	0.953	11 to 15	March smolt probability

Name	Value	SD*	Transformed Value	Transition	Description
Z_4	8	0	1	11 to 15	April smolt probability
Z_5	10	0	1	11 to 15	May smolt probability
Z_6	10	0	1	11 to 15	June smolt probability
Z_7	10	0	1	11 to 15	July smolt probability
$B0_{11,LR}$	1.39	0	0.801	12	Smolt survival lower river to delta
$B0_{10,UR}$	-0.4	0	0.401	11	Survival of upper river fish to lower river
$B1_{10}$	1.47	0.053	NA	11,12	River smolt survival from flow effect
${}^{C}S_{11}$	1.5	0	0.818	11 to 14	Survival smolt chipps to ocean - assume 0.8
${}^{A}S_{13,FP,m}$	2.5	0	0.924	13	survival from Yolo until Delta, assume 0.92 (at least until insertion point into PTM in Delta)
$S_{15,BA}$	0	0	0.5	15	Survival of smolts bay to ocean
S_{G1}	-1.68	0.044	0.157	11, 12, 13	Gulf entry for upper river, lower river, and floodplain
D_{G2}	-0.5	0	NA	14, 15	Gulf entry decrement for delta and bay (value in logit space)
σ_{ε}^2	1	0	1		Variance of annual random effects in process noise
S_{17}	1.35	0	0.794	17, 18	Probability of survival age 1 to age 2 over 4 months
M_2	-2.2	0	0.1	17,18	Probability of maturation age 2
S_{sp2}	2.2	0	0.9	18	Survival ocean exit to spawning ground age 2
S_{19}	1.4	0	0.802	19	Probability of survival age 2 to age 3
M_3	2.2	0	0.9	19, 20	Conditional probability of maturation at age 3
S_{sp3}	2.2	0	0.9	20	Survival ocean exit to spawning ground age 3
S_{21}	1.4	0	0.802	21	Survival age 3 to age 4
S_{sp4}	2.2	0	0.9	21	Survival ocean exit to spawning ground age 4
$V_{eggs,2}$	3200	0	3200	22	Eggs per spawner age 2
$V_{eggs,3}$	5000	0	5000	22	Eggs per spawner age 3
$V_{eggs,4}$	5000	0	5000	22	Eggs per spawner age 4
$B0_{Apr}$	-4.145	0	NA	22	Intercept for proportion of spawners in April

Name	Value	SD*	Transformed Value	Transition	Description
$B1_{Apr}$	0.0538	0	NA	22	Effect of temperature on proportion of spawners in April
$B0_{May}$	-1.796	0	NA	22	Intercept for proportion of spawners in May
$B1_{May}$	-0.2031	0	NA	22	Effect of temperature on proportion of spawners in May
$B0_{Jul}$	-0.332	0	NA	22	Intercept for proportion of spawners in July
$B1_{Jul}$	0.3852	0	NA	22	Effect of temperature on proportion of spawners in July
$B0_{Aug}$	-3.443	0	NA	22	Intercept for proportion of spawners in August
$B1_{Aug}$	0.7921	0	NA	22	Effect of temperature on proportion of spawners in August
Fem_{Age2}	0.01	0	0.01	18	Proportion of age 2 spanwers that are female
Fem_{Age3}	0.5	0	0.5	20	Proportion of age 3 and 4 that are female
$K_{Sp,m}$	50000	0	50000	22	Capacity in the spawning reaches by month

*Estimated parameter values have associated standard deviations (SD)