Attachment 5C.A
CALSIM and DSM2 Modeling Results for the Evaluated Starting Operations Scenarios

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5C.A.1 Introduction

The CALSIM operations model and the DSM2 Delta model were used as the primary tools for determining the physical flow changes resulting from the Bay Delta Conservation Plan (BDCP). This attachment provides detailed descriptions and summaries of the basic results from these models. The CALSIM II model was used to evaluate the Central Valley Project (CVP) and State Water Project (SWP) system operations for existing and future levels of water supply demands with expected climate change effects on runoff, potential future Sacramento–San Joaquin River Delta (Delta) facilities, and current or alternative operational requirements in the Delta. Key model outputs include reservoir storage levels, downstream river flows, water diversions, Delta exports, water deliveries, and Delta outflow. The DSM2 Delta model was used to simulate hydrodynamics, water quality (salinity), and particle tracking (water movement) within the Delta.

CALSIM II simulates CVP and SWP operations assuming a repeat of the historical (measured) monthly inflow hydrology for the Central Valley region for water years (WY) 1922–2003, with appropriate adjustments for current land use and water demands. The model uses an optimization algorithm to calculate SWP and CVP reservoir and Delta operations (exports, outflow) to meet assumed water demands on a monthly time step. Reservoir storage, releases, and Delta conditions are controlled by many different objectives. The model results are governed by specified "weights" for meeting (satisfying) the various regulatory and operational priorities. The Delta outflow–salinity response is approximated with Artificial Neural Network (ANN) "internal multiple regression equations." Delta exports and outflow, along with X2 position and electrical conductivity (EC) at a few key regulatory locations, are the major model outputs. The CALSIM II model is described in detail by Draper et al. (2004) and the California Department of Water Resources (DWR) (2002), and has been subjected to two peer reviews in the past 8 years (Close et al. 2003; Lund et al. 2006). Much more information on the CALSIM model can be found at this DWR website:

<http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSim/index.cfm>

The CALSIM model has been peer-reviewed by two technical panels; these peer reviews and DWR/U.S. Department of the Interior, Bureau of Reclamation (Reclamation) responses to questions and suggestions about the model methods, assumptions, and accuracy (calibration) are available at this DWR website:

<http://baydeltaoffice.water.ca.gov/modeling/hydrology/CalSimII/index.cfm>

DSM2 is a one-dimensional (with branched-channels) model used to simulate hydrodynamics, water quality, and particle tracking in the Delta (Anderson and Mierzwa 2002). DSM2 was used to describe the existing conditions in the Delta and to simulate expected changes with the BDCP and climate change (sea-level rise). The DSM2 model has three separate components: HYDRO, QUAL, and particle tracking models (PTM). HYDRO simulates tidal flows, tidal velocities, and tidal elevations for the specified Delta channel geometry and tidal boundary elevations at Martinez. QUAL simulates the concentrations of conservative (i.e., no decay or growth) and non-conservative (sources and sinks) water quality constituents given the tidal flows simulated by HYDRO. PTM simulates mixing and transport of neutrally buoyant particles based on the channel geometry and tidal flows simulated by HYDRO. A good introduction to the DSM2 model and results from the most recent calibration effort to match the tidal effects of the flooding of Liberty Island are presented by CH2MHill (2009).

Both the CALSIM model and the DSM2 model were used extensively for the 2008 Biological Assessment for the Operations Criteria and Plan (OCAP) for the CVP and SWP, prepared for the U.S. Fish and Wildlife Service (USFWS) and National Marine Fisheries Service (NMFS) (for their endangered species evaluations) by Reclamation and DWR. The CALSIM model is described in Appendix D and the DSM2 model is described in Appendix F of the 2008 Biological Assessment (BA). These documents are available at the Reclamation website:

<http://www.usbr.gov/mp/cvo/ocap_page.html>

5C.A.2 Modeling Scenarios

Ten scenarios have been simulated to support the BDCP effects analysis. Four of these CALSIM cases represent different bases for comparison and six are the simulated BDCP facilities and operation, and tidal wetlands restoration areas for the early long-term (ELT) and late long-term (LLT). Table C.A-1 lists the ten modeling cases. The subsequent analysis of the BDCP effects on aquatic species uses the CALSIM-simulated differences in reservoir operations, river flows, Delta channel flows (i.e., Delta outflow), and Delta exports (from the south Delta and at the proposed north Delta intakes). However, all of the CALSIM cases are generally controlled by the historical sequence of runoff from WY 1922–2003; many of the simulated differences in monthly reservoir operations,river flows, and Delta flows for the BDCP (at ELT or LLT) are relatively small compared to the differences between the monthly flows in a wet year, an above normal year, and a critical year. The assumed changes in runoff for the ELT and LLT timeframes are fully described and compared in Appendix 5.A.2, Section 5A.2.4, *Upstream Inflow Modeling Results*. The effects of changes in runoff together with assumed warming on water temperatures below the major reservoirs are described and compared in Appendix 5.A.2, Section 5A.2.5, *Upstream Water Temperatures Modeling Results*. There were some differences in the upstream and downstream demands between EBC1 (2005 demands) and EBC2 (2020 demands) [EBC = existing biological conditions]; and the EBC2 and BDCP cases included the Fall X2 actions, while EBC1 did not. Generally, all other reservoir operating rules and Delta operations objectives were the same for each of the EBC2 cases and BDCP cases; the higher outflow scenario (HOS) and lower outflow scenario (LOS) cases included specific changes in Delta outflow objectives, as described below in Section 5C.A.5, *Comparison of Higher Outflow Scenario and Lower Outflow Scenario*.

Table C.A-1 provides a complete listing of the CALSIM assumptions that were used to evaluate the existing biological conditions (EBC1), the No Action Alternative (EBC2; for current hydrology and for ELT and LLT), and the Evaluated Starting Operations (ESO) that were evaluated as the selected BDCP operations (for the ELT and LLT). The ESO corresponds to Alternative 4 in the BDCP EIS/EIR documentation. Also evaluated were the decision-tree outflow scenarios, including the HOS with higher March–May outflow in some years, and the LOS with State Water Resources Control Board (State Water Board) water right Decisions 1641 (D-1641) outflow in September–November.

The analysis below first describes changes modeled for the ESO cases (Section 5C.A.3 for upstream operations and Section 5C.A.4 for Delta operations).

Table C.A-1. CALSIM II Modeling Assumptions for Existing Conditions (EBC1), No Action Alternative (EBC2) and BDCP Operational Scenarios

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
General							
Planning horizon[a]	Year 2009/Year 2015	Year 2020/Year 2025/Year 2060	Same as No Action Alternative				Common Assumptions (CA) assumed 2004 and 2030; 2008 OCAP BA assumed 2005 and 2030
Demarcation date[a]	February 2009 (but with June 2009 NMFS BiOp included)	Same as Existing Conditions	Same as No Action Alternative				CA assumed June 2004; 2008 OCAP BA assumed 2005
Period of simulation	82 years (1922–2003)	Same as Existing Conditions	Same as No Action Alternative				
Hydrology							
Inflows/Supplies	Historical with modifications for operations upstream of rim reservoirs	Historical with modifications for operations upstream of rim reservoirs and with or without changed climate at Early Long Term (Year 2025) or Late Long Term (Year 2060)	Same as No Action Alternative				
Level of development	Projected 2005 level[b]	Projected 2030 level[c]	Same as No Action Alternative				
Demands, Water Rights, CVP/SWP Contracts							
Sacramento River Region—excluding American River							
CVP[d]	Land-use based, limited by contract amounts	Land-use based, full build-out of contract amounts	Same as No Action Alternative				Consistent with 2008 OCAP BA; 2008 OCAP BA included updates to CA assumptions
SWP (FRSA)[e]	Land-use based, limited by contract amounts	Same as Existing Conditions	Same as No Action Alternative				Consistent with 2008 OCAP BA; 2008 OCAP BA included updates to CA assumptions
Non-project	Land-use based, limited by water rights and SWRCB decisions for existing facilities	Same as Existing Conditions	Same as No Action Alternative				
Antioch	Pre-1914 water right	Same as Existing Conditions	Same as No Action Alternative				Not included in 2008 BA of CA assumptions
Federal refuges[f]	Recent historical Level 2 water needs	Firm Level 2 water needs	Same as No Action Alternative				
Sacramento River Region—American River[g]							
Water rights	Year 2005	Year 2025, full water rights	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed Sacramento Area Water Forum
CVP	Year 2005	Year 2025, full contracts, including Freeport Regional Water Project	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed Sacramento Area Water Forum; CA did not include Sacramento River Water Reliability Project
San Joaquin River Region[h]							
Friant Unit	Limited by contract amounts, based on current allocation policy	Same as Existing Conditions	Same as No Action Alternative				
Lower Basin	Land-use based, based on district level operations and constraints	Same as Existing Conditions	Same as No Action Alternative				Stockton Delta Water Supply project included from 2008 OCAP BA model
Stanislaus River[i]	Land-use based, Revised Operations Plan[r] and NFMS BiOp (Jun 2009) Actions III.1.2 and III.1.3[t]	Same as Existing Conditions	Same as No Action Alternative				2008 BA assumed draft Transitional Plan for Future; CA assumed Interim Operations Plan

			Alternative 4				
Parameter Category/ Study	**Existing Conditions**	**No Action Alternative**	**H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow**	**H2 Enhanced Spring Outflow, D-1641 Fall Outflow**	**H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2**	**H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2**	**Comments**
San Francisco Bay, Central Coast, Tulare Lake and South Coast Regions (CVP/SWP project facilities)							
CVP[d]	Demand based on contracts amounts	Same as Existing Conditions	Same as No Action Alternative				
Contra Costa Water District[j]	195 taf/yr CVP contract supply and water rights	Same as Existing Conditions	Same as No Action Alternative				
SWP[e,k]	Variable demand, of 3.0–4.1 maf/yr, up to Table A amounts including all Table A transfers through 2008	Demand based on full Table A amounts	Same as No Action Alternative				2008 OCAP BA assumed 3.1–4.2 maf/yr variable demand for Existing; CA assumed Table A transfers only up through 2004.
Article 56	Based on 2001–2008 contractor requests	Same as Existing Conditions	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed pattern based on 2002–2006 contractor requests
Article 21	MWD demand up to 200 taf/month from December to March subject to conveyance capacity, KCWA demand up to 180 taf/month and other contractor demands up to 34 taf/month in all months, subject to conveyance capacity	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA limited MWD Article 21 to 100 taf/mon; CA assumed 50 taf/yr for KCWA in Existing, 2,555 cfs max demand rate for KCWA in Future and unlimited for MWD in Future
North Bay Aqueduct	71 taf/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville and Benecia Settlement Agreement	77 taf/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville and Benecia Settlement Agreement	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed 48 taf/yr demand under SWP contracts and no Settlement Agreement
Federal refuges[f]	Recent historical Level 2 water needs	Firm Level 2 water needs	Same as No Action Alternative				
Facilities							
System-wide							
System-wide	Existing facilities	Same as Existing Conditions	Existing facilities and Isolated Facility				
Isolated Facility	None	Same as Existing Conditions	North Delta Diversion: maximum capacity of 9,000 cfs, diversion point near Hood				
Sacramento River Region							
Shasta Lake	Existing, 4,552 taf capacity	Same as Existing Conditions	Same as No Action Alternative				
Red Bluff Diversion Dam	Diversion dam operated gates out, except Jun 15–Aug 31 based on NMFS BiOp (Jun 2009) Action I.3.2[t]; assume interim/ temporary facilities in place	Diversion dam operated with gates out all year, NMFS BiOp (Jun 2009) Action I.3.1[t]; assume permanent facilities in place	Same as No Action Alternative				2008 OCAP BA used May 15–Sep 31 for Existing; modified to reflect NMFS BiOp (June 2009); CA assumed May 15–Sep 15 for Future
Colusa Basin	Existing conveyance and storage facilities	Same as Existing Conditions	Same as No Action Alternative				
Upper American River[g,l]	Placer County Water Agency American River Pump Station	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA document assumes permanent pump station in both conditions
Lower Sacramento River	None	Freeport Regional Water Project	Same as No Action Alternative				2008 OCAP BA did not include Sacramento River Water Reliability Project or Freeport Regional Water Project in existing; CA did not include Sacramento River Water Reliability Project

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
Freemont Weir / Yolo bypass	Exisiting weir	Same as Existing Conditions	**Seasonal Floodplain Inundation** • Period of inundation o Dec 1–Mar 31 (modeled as Dec 1 to Apr 30). o Operational gates at both 17.5 ft and 11.5 ft will be OPEN during this period. • Triggers for inundation o Spills over the Fremont Weir will be triggered based on the river flow. • Duration o Duration of event will be governed by the hydrologic conditions in the Sacramento River, restoring the natural synchrony of inundation timing and frequency with river flows. o While "desired" inundation is on the order of 30–45 days, no management of the gates will be implemented to limit to this range. • Target flows o Gates will be operated to limit maximum spill to 6,000 cfs until river stage reaches existing weir height **Fish Passage** • Period of concern o Sep 15–Jun 30 based on NMFS, CDFW, and USFWS anadromous fish surveys in Yolo Bypass (modeled as Sep 1 to Jun 30). o Low elevation gates (11.5 ft) will be OPEN during this period. • Target flows o Limit flows to 100 cfs as required for fish passage and flow continuity				
San Joaquin River Region							
Millerton Lake (Friant Dam)	Existing, 520 taf capacity	Same as Existing Conditions	Same as No Action Alternative				
Lower San Joaquin River	None	City of Stockton Delta Water Supply Project, 30 mgd capacity	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA did not include City of Stockton Delta Water Supply Project
Delta Region							
SWP Harvey O. Banks Pumping Plant (South Delta) (Banks PP)	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months up to 8,500 cfs during Dec 15–Mar 15 depending on Vernalis flow conditions[m]; additional capacity of 500 cfs (up to 7,180 cfs) allowed for Jul–Sep for reducing impact of NMFS BiOp (Jun 2009) Action IV.2.1[t] on SWP[u]	Same as Existing Conditions	10,300 cfs				Reducing impact of Vernalis Adaptive Management Program on SWP formerly known as limited-Environmental Water Account
CVP C.W. Bill Jones Pumping Plant (Jones PP)	Permit capacity is 4,600 cfs but exports limited to 4,200 cfs plus diversions upstream of DMC constriction	Permit capacity is 4,600 cfs in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same as No Action Alternative				
Upper Delta-Mendota Canal Capacity	Existing	Existing plus 400 cfs Delta-Mendota Canal–California Aqueduct Intertie	Same as No Action Alternative				
Contra Costa Water District Intakes	Los Vaqueros existing storage capacity, 100 taf, existing pump locations	Los Vaqueros existing storage capacity, 100 TAF, existing pump locations, Alternative Intake Project (AIP) included[n]	Same as No Action Alternative				2008 OCAP BA did not include the AIP in Existing; AIP was considered under a separate consultation

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
San Francisco Bay Region							
South Bay Aqueduct	Existing capacity	South Bay Aqueduct rehabilitation, 430 cfs capacity from junction with California Aqueduct to Alameda County Flood Control and Water Conservation District Zone 7 diversion point	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA did not include South Bay Aqueduct rehabilitation in Existing
South Coast Region							
California Aqueduct East Branch	Existing capacity	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not include rehabilitation of capacity at California Aqueduct pool 49 (2,875 cfs)
Regulatory Standards							
North Coast Region							
Trinity River							
Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369–815 taf/yr)	Same as Existing Conditions	Same as No Action Alternative				
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 taf as able)	Same as Existing Conditions	Same as No Action Alternative				
Sacramento River Region							
Clear Creek							
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 Reclamation Proposal to USFWS and NPS, predetermined CVPIA 3406(b)(2) flows[o], and NMFS BiOp (Jun 2009) Action I.1.1[t]	Same as Existing Conditions	Same as No Action Alternative				Predetermined flows based on Aug 08 2008 BA Studies; reflects Management Team direction regarding interpretation of NMFS BiOp (Jun 2009)
Upper Sacramento River							
Shasta Lake end-of-September minimum storage	NMFS 2004 Winter-Run Biological Opinion, (1,900 taf in non-critically dry years), and NMFS BiOp (Jun 2009) Action I.2.1[t]	Same as Existing Conditions	Same as No Action Alternative				Management Team direction regarding interpretation of NMFS BiOp (Jun 2009)
Minimum flow below Keswick Dam	SWRCB WR 90-5 temperature control, predetermined CVPIA 3406(b)(2) flows[o], and NMFS BiOp (Jun 2009) Action I.2.2[t]	Same as Existing Conditions	Same as No Action Alternative				Predetermined flows based on Aug 08 2008 OCAP BA Studies; reflects Management Team direction regarding interpretation of NMFS BiOp (Jun 2009)
Feather River							
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700 / 800 cfs)	Same as Existing Conditions	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed 1983 DWR, CDFW Agreement (600 cfs)
Minimum flow below Thermalito Afterbay outlet	1983 DWR, CDFW Agreement (750–1,700 cfs)	Same as Existing Conditions	Same as No Action Alternative	Requirements under No Action Alternative, and additional flow contribution for the enhanced spring outflow requirement[z]	Same as No Action Alternative	Requirements under No Action Alternative, and additional flow contribution for the enhanced spring outflow requirement[z]	

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	**H2 Enhanced Spring Outflow, D-1641 Fall Outflow**	**H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2**	**H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2**	
Yuba River							
Minimum flow below Daguerre Point Dam	SWRCB D-1644 Operations (Lower Yuba River Accord)[p]	Same as Existing Conditions	Same as No Action Alternative				Consistent with 2008 OCAP BA; CA assumed D-1644 (long-term, without Lower Yuba River Accord)
American River							
Minimum flow below Nimbus Dam	American River Flow Management[q] as required by NMFS BiOp (Jun 2009) Action II.1[t]	Same as Existing Conditions	Same as No Action Alternative				Modified to reflect NMFS BiOp; consistent with 2008 OCAP BA; CA did not include American River Flow Management
Minimum Flow at H Street Bridge	SWRCB D-893	Same as Existing Conditions	Same as No Action Alternative				
Lower Sacramento River							
Minimum Flow at Freeport	None	Same as Existing Conditions	Same as No Action Alternative				
North Delta Diversion Bypass Flow	None	Same as Existing Conditions	**Constant Low-Level Pumping:** Diversions up to 6% of river flow for flows greater than 5,000 cfs (No diversion if it would cause downstream flow less than 5,000 cfs). No more than 300 cfs at any one intake (combined limit of 900 cfs).				
	None	Same as Existing Conditions	**Initial Pulse Protection:** Low level pumping maintained through the initial pulse period. For the purpose of monitoring, the initiation of the pulse is defined by the following criteria: (1) Wilkins Slough flow changing by more than 45% over a five day period; and (2) Flow greater than 12,000 cfs. Low-level pumping continues until: (a) Wilkins Slough returns to prepulse flows (flow on first day of 5-day increase), (b) Wilkins Slough flows decrease for 5 consecutive days, or (c) Bypass flows are greater than 20,000 cfs for 10 consecutive days. After pulse period has ended, operations will return to the bypass flow table (SubTable A). If the first flush begins before Dec 1, a second pulse period will have the same protective operation.				
	None	Same as Existing Conditions	**Post-Pulse Operations:** After initial pulse(s), apply Level I post-pulse bypass rule (see SubTable A) until 15 total days of bypass flows above 20,000 cfs. Then apply Level II post-pulse bypass rule until 30 total days of bypass flows above 20,000 cfs. Then apply Level III post-pulse bypass rule.				
Minimum flow near Rio Vista	SWRCB D-1641	Same as Existing Conditions	Sep–Dec: SWRCB D-1641; Jan–Aug: minimum of 3,000 cfs				
San Joaquin River Region							
Mokelumne River							
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100–325 cfs)	Same as Existing Conditions	Same as No Action Alternative				
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25–300 cfs)	Same as Existing Conditions	Same as No Action Alternative				
Stanislaus River							
Minimum flow below Goodwin Dam	1987 Reclamation, CDFW agreement, and flows required for NMFS BiOp (Jun 2009) Action III.1.2 and III.1.3[t]	Same as Existing Conditions	Same as No Action Alternative				Reflects Management Team direction regarding interpretation of NMFS BiOp (Jun 2009); flow schedule to be provided
Minimum dissolved oxygen	SWRCB D-1422	Same as Existing Conditions	Same as No Action Alternative				

			Alternative 4				
Parameter Category/ Study	**Existing Conditions**	**No Action Alternative**	**H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow**	**H2 Enhanced Spring Outflow, D-1641 Fall Outflow**	**H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2**	**H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2**	**Comments**
Merced River							
Minimum flow below Crocker-Huffman Diversion Dam	Davis-Grunsky (180–220 cfs, Nov–Mar), and Cowell Agreement	Same as Existing Conditions	Same as No Action Alternative				
Minimum flow at Shaffer Bridge	FERC 2179 (25–100 cfs)	Same as Existing Conditions	Same as No Action Alternative				
Tuolumne River							
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94–301 taf/yr)	Same as Existing Conditions	Same as No Action Alternative				
San Joaquin River							
San Joaquin River below Friant Dam/ Mendota Pool	Water Year 2010 Interim Flows Project[s]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA document did not include San Joaquin River Restoration; CA did not include restoration flows
Maximum salinity near Vernalis	SWRCB D-1641	Same as Existing Conditions	Same as No Action Alternative				
Minimum flow near Vernalis	SWRCB D-1641, and NMFS BiOp (Jun 2009) Action IV.2.1[t]	Same as Existing Conditions	Same as No Action Alternative				2008 BA and CA assumed Vernalis Adaptive Management Program flows
Sacramento River–San Joaquin Delta Region							
Delta Outflow Index (Flow, NDOI)	SWRCB D-1641	Same as Existing Conditions	Same as No Action Alternative				2008 BA and CA assumed SWRCB D-1641 only. For the BDCP PROPOSED PROJECT EARLY LONG-TERM, proportional Reservoir release concept will continure to be evaluated to the extent that it provides similar response to outflow, inflow and upstream storage conditions
Delta Outflow Index (Salinity, X2)—Spring	SWRCB D-1641	Same as Existing Conditions	Same as No Action Alternative	Requirements under No Action Alternative, and additional flow for the enhanced spring outflow requirement[z]	Same as No Action Alternative	Requirements under No Action Alternative, and additional flow for the enhanced spring outflow requirement[z]	2008 BA and CA assumed SWRCB D-1641 only
Delta Outflow (Salinity, X2)—Fall	None	USFWS BiOp (Dec 2008) Action 4	None	None	Same as No Action Alternative	Same as No Action Alternative	
Delta Cross Channel gate operation	SWRCB D-1641 with additional days closed from Oct 1–Jan 31st based on NMFS BiOp (Jun 2009) Action IV.1.2[t] (closed during flushing flows from Oct 1–Dec 14 unless adverse water quality conditions)	Same as Existing Conditions	Same as No Action Alternative				2008 BA and CA assumed SWRCB D-1641 only
South Delta exports (Jones PP and Banks PP)	SWRCB D-1641, Vernalis flow-based export limits Apr 1–May 31 as required by NMFS BiOp (Jun 2009) Action IV.2.1[t] (additional 500 cfs allowed for Jul–Sep for reducing impact on SWP)[u]	Same as Existing Conditions	Physical Capacity				2008 BA and CA assumed discretionary use of CVPIA 3406(b)(2); 2008 BA also assumed limited Environmental Water Account

			Alternative 4				
Parameter Category/ Study	**Existing Conditions**	**No Action Alternative**	**H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow**	**H2 Enhanced Spring Outflow, D-1641 Fall Outflow**	**H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2**	**H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2**	**Comments**
Combined Flow in Old and Middle River	USFWS BiOp (Dec 2008) Actions 1 through 3 and NMFS BiOp (Jun 2009) Action IV.2.3[t]	Same as Existing Conditions	More positive of the No Action Alternative assumptions and the assumption noted below: • Jan: 0 (W), -3500 (AN), -4000 (BN), -5000 (D, C) • Feb: 0 (W), -3500 (AN), -4000 (BN, D, C) • Mar: 0 (W, AN), -3500 (AN, BN, D, C) • Apr–Jun: Varies based on San Joaquin inflow relationship to Old and Middle River povided below in SubTable B[w] • Jul–Sep: No Restrictions • Oct–Nov: Varies based San Joaquin River pulse flow condition[x] • Dec: -5000 when north Delta initial pulse flows are triggered or -2000 when delta smelt Action 1 triggers • HORB opening is restricted[y]				2008 BA and CA did not assume USFWS BiOp (Dec 2008) or other Old and Middle River restrictions
Delta Water Quality	SWRCB D-1641	Same as Existing Conditions	Existing SWRCB D-1641, EXCEPT moved compliance point from Emmaton to Three Mile Slough near Sacramento River.				Currently only operate for D-1641 standards
Operations Criteria: River-Specific							
Sacramento River Region							
Upper Sacramento River: Flow objective for navigation (Wilkins Slough)	NMFS BiOp (Jun 2009) Action I.4[t]; 3,500–5,000 cfs based on CVP water supply condition	Same as Existing Conditions	Same as No Action Alternative				
American River: Folsom Dam flood control	Variable 400/670 flood control diagram (without outlet modifications)	Same as Existing Conditions	Same as No Action Alternative				
Feather River: Flow at Mouth of Feather River (above Verona)	Maintain CDFW/DWR flow target of 2,800 cfs for Apr–Sep dependent on Oroville inflow and FRSA allocation	Same as Existing Conditions	Same as No Action Alternative				
San Joaquin River Region							
Stanislaus River: Flow below Goodwin Dami	Revised Operations Plan[t] and NMFS BiOp (Jun 2009) Action III.1.2 and III.1.3[t]	Same as Existing Conditions	Same as No Action Alternative				2008 BA assumed draft Transitional New Melones Operations Plan; CA assumed Interim Plan
San Joaquin River: Salinity at Vernalis	Grasslands Bypass Project (partial implementation)	Grasslands Bypass Project (full implementation)	Same as No Action Alternative				Existing condition assumptions to be determined Year 2010
OPERATIONS CRITERIA: SYSTEMWIDE							
North & South Delta Intakes Operation Criteria							
Water quality and residence time	None	Same as Existing Conditions	Jul–Sep: prefer sourth Delta pumping up to 3,000 cfs before diverting from North. Oct–Jun: prefer North Delta pumping (real-time operation flexibility) (No explicit implementation in the model).				Not explicitly included in model; model results with existing weight structure are consistent with intake preferences
CVP Water Allocation							
Settlement/Exchange	100% (75% in Shasta critical years)	Same as Existing Conditions	Same as No Action Alternative				
Refuges	100% (75% in Shasta critical years)	Same as Existing Conditions	Same as No Action Alternative				
Agriculture Service	100–0% based on supply, South-of-Delta allocations are additionally limited due to SWRCB D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[t]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
Municipal & Industrial Service	100–50% based on supply, South-of-Delta allocations are additionally limited due to SWRCB D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[t]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)
SWP Water Allocation							
North of Delta (FRSA)	Contract specific	Same as Existing Conditions	Same as No Action Alternative				
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between agricultural and municipal and industrial based on Monterey Agreement; allocations are additionally limited due to SWRCB D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[t]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)
CVP-SWP Coordinated Operations							
Sharing of responsibility for in-basin-use	1986 Coordinated Operations Agreement (Freeport Regional Water Project East Bay Municipal Utilities District and 2/3 of the North Bay Aqueduct diversions considered as Delta Export; 1/3 of the North Bay Aqueduct diversion considered as in-basin-use)	Same as Existing Conditions	Same as No Action Alternative	Same as No Action Alternative[z]	Same as No Action Alternative	Same as No Action Alternative[z]	CA included exchange of SWP to convey 50 taf/yr of Level 2 refuge supplies at Banks PP (Jul–Aug) and CVP to provide up to max of 37.5 taf/yr to meet SWP In-Basin-Use (released from Shasta)
Sharing of surplus flows	1986 Coordinated Operations Agreement	Same as Existing Conditions	Same as No Action Alternative				
Sharing of total allowable export capacity for project-specific priority pumping	Equal sharing of export capacity under SWRCB D-1641, USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009) export restrictions[t]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks PP over non-SWP users; LowerYuba River Accord included for SWP contractors[u]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA assumed transfer of LowerYuba River Accord acquisitions for reducing impact of Vernalis Adaptive Management Program on SWP, formerly known as limited-Environmental Water Account; CA assumed Sacramento Valley Water Management Agreement and short term temporary transfers
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 taf/yr), CALFED Record of Decision defined Joint Point of Diversion	Same as Existing Conditions	Same as No Action Alternative				
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 100 taf	Same as Existing Conditions	Same as No Action Alternative				
CVPIA 3406(b)(2)[t,o]							
Policy Decision	Per May 2003 Dept. of Interior Decision	Same as Existing Conditions	Same as No Action Alternative				Discretionary 3406(b)(2) operations being replaced by non-discretionary operations for USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009)
Allocation	800 taf, 700 taf in 40-30-30 dry years, and 600 taf in 40-30-30 critical years as a function of Ag allocation	Same as Existing Conditions	Same as No Action Alternative				

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
Actions	Pre-determined upstream fish flow objectives below Whiskeytown and Keswick Dams, non-discretionary NMFS BiOp (Jun 2009) actions for the American and Stanislaus Rivers, and NMFS BiOp (Jun 2009) and USFWS BiOp (Dec 2008) actions leading to export restrictions[t]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)
Accounting	Releases for non-discretionary USFWS BiOp (Dec 2008) and NMFS BiOp (Jun 2009)v actions may or may not always be deemed (b)(2) actions; in general, it is anticipated, that accounting of these actions using (b)(2) metrics, the sum would exceed the (b)(2) allocation in many years; therefore no additional actions are considered and no accounting logic is included in the model[o]	Same as Existing Conditions	Same as No Action Alternative				2008 OCAP BA and CA did not assume USFWS BiOp (Dec 2008) or NMFS BiOp (Jun 2009)
Water Management Actions							
Water Transfer Supplies (long-term programs)							
Lower Yuba River Accord[u]	Yuba River acquisitions for reducing impact of NMFS BiOp export restrictions[t] on SWP	Same as Existing Conditions	Same as No Action Alternative				2008 BA assumed Yuba River acquisitions for reducing impact of NMFS BiOp export restrictions, formerly known as limited-Environmental Water Account; CA did not include LowerYuba River Accord
Phase 8	None	None	None				
Water Transfers (short-term or temporary programs)							
Sacramento Valley acquisitions conveyed through Banks PP[v]	Post-analysis of available capacity	Post-analysis of available capacity	Post-analysis of available capacity				Consistent with 2008 OCAP BA; CA model outputs available capacity to support such analysis

BA = Biological Assessment.
BiOp = Biological Opinion.
CA = Common Assumptions.
CDFW = California Department of Fish and Wildlife.
cfs = cubic feet per second.
CVP = Central Valley Project.
CVPIA = Central Valley Project Improvement Act
D-1641 = water reight Decision 1641.
DWR = California Department of Water Resources.
FRSA = Feather River Service Area.
maf = million acre-feet.
mgd = milliong gallons per day.
MWD = The Metropolitan Water District of Southern California
NMFS = National Marine Fishereis Service.
OCAP = Operations Criteria and Plan.
Reclamation = U.S. Department of the Interior, Bureau of Reclamation.
SWP = State Water Project.
SWRCB = State Water Resources Control Board.
taf = thousand acre-feet
USFWS = U.S. Fish and Wildlife Service

CALSIM Notes:

[a] These assumptions have been developed under the direction of DWR and Reclamation management team for the BDCP HCP and EIR/EIS. Only operational components of 2008 USFWS and 2009 NMFS BiOps as of demarcation date of Existing Conditions and the No action Alternative assumptions are included. Restoration of at least 8,000 acres of intertidal and associated subtidal habitat in the Delta and Suisun Marsh required by the 2008 USFWS BiOp and restoration of at least 17,000 to 20,000 acres of floodplain rearing habitat for juvenile winter-run and spring-run Chinook salmon and Central Valley steelhead in the Yolo Bypass and/or suitable areas of the lower Sacramento River required by the NMFS 2009 BiOp are not included in the No Action Alternative assumptions because environmental documents of projects regarding these actions were not completed as of the publication date of the Notice of Preparation/Notice of Intent (February 13, 2009)

[b] The Sacramento Valley hydrology used in the Existing Conditions CALSIM II model reflects nominal 2005 land-use assumptions. The nominal 2005 land-use was determined by interpolation between the 1995 and projected 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects 2005 land-use assumptions developed by Reclamation. Existing-level projected land-use assumptions are being coordinated with the California Water Plan Update for future models.

[c] The Sacramento Valley hydrology used in the No Action Alternative CALSIM II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of Future-level projected land-use assumptions are being coordinated with the California Water Plan Update for future models.

[d] CVP contract amounts have been updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and municipal and industrial service contracts and Settlement Contract amounts are documented in the Delivery Specifications attachments.

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	
[e] SWP contract amounts have been updated as appropriate based on recent Table A transfers/agreements. Assumptions regarding SWP agricultural and municipal and industrial contract amounts are documented in the Delivery Specifications attachments.							
[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in the Delivery Specifications attachments. Refuge Level 4 (and incremental Level 4) water is not analyzed.							
[g] Assumptions regarding American River water rights and CVP contracts are documented in the Delivery Specifications attachments. The Sacramento Area Water Forum agreement, its dry year diversion reductions, Middle Fork Project operations and "mitigation" water is not included.							
[h] The new CALSIM II representation of the San Joaquin River has been included in this model package (CALSIM II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to groundwater overdraft problems. In addition a dynamic groundwater simulation is not yet developed for the San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.							
[i] The CALSIM II model representation for the Stanislaus River does not necessarily represent Reclamation's current or future operational policies. A suitable plan for supporting flows has not been developed for NMFS BiOp (Jun 2009) Action 3.1.3.							
[j] The actual amount diverted is operated in conjunction with supplies from the Los Vaqueros project. The existing Los Vaqueros storage capacity is 100 taf. Associated water rights for Delta excess flows are included.							
[k] Under Existing Conditions it is assumed that SWP Contractors demand for Table A allocations vary from 3.0 to 4.1 maf/yr. Under the No Action Alternative, it is assumed that SWP Contractors can take delivery of all Table A allocations and Article 21 supplies. Article 56 provisions are assumed and allow for SWP Contractors to manage storage and delivery conditions such that full Table A allocations can be delivered. Article 21 deliveries are limited in wet years under the assumption that demand is decreased in these conditions. Article 21 deliveries for the NBA are dependent on excess conditions only, all other Article 21 deliveries also require that San Luis Reservoir be at capacity and that Banks PP and the California Aqueduct have available capacity to divert from the Delta for direct delivery.							
[l] PCWA American River pumping facility upstream of Folsom Lake is included in both the Existing and No Action Alternative No Action Alternative. The diversion is assumed to be 35.5 taf/yr.							
[m] Current U.S. Army Corps of Engineers permit for Banks PP allows for an average diversion rate of 6,680 cfs in all months. Diversion rate can increase up to 1/3 of the rate of San Joaquin River flow at Vernalis during Dec 15–Mar 15 up to a maximum diversion of 8,500 cfs, if Vernalis flow exceeds 1,000 cfs.							
[n] The CCWD Alternate Intake Project (AIP), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir. This assumption is consistent with the future no-project condition defined by the Los Vaqueros Enlargement study team.							
[o] CVPIA (b)(2) fish actions are not dynamically determined in the CALSIM II model, nor is (b)(2) accounting done in the model. Since the USFWS BiOp and NMFS BiOp were issued, the Department of the Interior (Interior) has exercised its discretion to use (b)(2) in the delta by accounting some or all of the export reductions required under those biological opinions as (b)(2) actions. It is therefore assumed for modeling purposes that (b)(2) availability for other delta actions will be limited to covering the CVP's VAMP export reductions. Similarly, since the USFWS BiOp and NMFS BiOp were issued, Interior has exercised its discretion to use (b)(2) upstream by accounting some or all of the release augmentations (relative to the hypothetical (b)(2) base case) below Whiskeytown, Nimbus and Goodwin as (b)(2) actions. It is therefore assumed for modeling purposes that (b)(2) availability for other upstream actions will be limited to covering Sacramento releases, in the fall and winter. For modeling purposes, pre-determined timeseries of minimum instream flow requirements are specified. The timeseries are based on the Aug 2008 BA Study 7.0 and Study 8.0 simulations which did include dynamically determined (b)(2) actions.							
[p] SWRCB D-1644 and the Lower Yuba River Accord is assumed to be implemented for Existing and No Action Alternative No Action Alternative. The Yuba River is not dynamically modeled in CALSIM II. Yuba River hydrology and availability of water acquisitions under the Lower Yuba River Accord are based on modeling performed and provided by the Lower Yuba River Accord EIS/EIR study team.							
[q] Under Existing Conditions, the flow components of the proposed American River Flow Management are as required by the NMFS BiOp (June 4, 2009).							
[r] The model operates the Stanislaus River using a 1997 Interim Plan of Operation-like structure, i.e., allocating water for SEWD & CSJWCD, Vernalis water quality dilution and Vernalis D-1641 flow requirements based on the New Melones Index. OID & SSJID allocations are based on their 1988 agreement and Ripon DO requirements are represented by a static set of minimum instream flow requirements during Jun thru Sep. Instream flow requirements for fish below Goodwin are based on NMFS BiOp Action III.1.2. NMFS BiOp Action IV.2.1's flow component is not assumed to be in effect.							
[s] San Joaquin River Restoration Water Year 2010 Interim Flows Project are assumed, but are not input into the models; operation not regularly defined at this time							
[t] In cooperation with Reclamation, NMFS, USFWS, and CDFW, the DWR has developed assumptions for implementation of the USFWS BiOp (Dec 15, 2008) and NMFS BiOp (June 4, 2009) in CALSIM II.							
[u] Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks PP during Jul–Sep, are assumed to be used to reduce as much of the impact of the Apr–May Delta export actions on SWP contractors as possible.							
[v] Only acquisitions of Lower Yuba River Accord Component 1 water are included.							

Parameter Category/ Study	Existing Conditions	No Action Alternative	Alternative 4				Comments
			H1 (Low Outflow Scenario) D-1641 Spring X2 and D-1641 Fall Outflow	H2 Enhanced Spring Outflow, D-1641 Fall Outflow	H3 (Evaluated Starting Operations) D-1641 Spring X2, with Fall X2	H4 (High Outflow Scenario) Enhanced Spring Outflow, with Fall X2	

[w] SubTable B. San Joaquin Inflow Relationship to Old and Middle River (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
≤ 5,000 cfs	-2,000 cfs	≤ 3,500 cfs	-3,500 cfs
6,000 cfs	+1000 cfs	3,501 to 10,000 cfs	0 cfs
10,000 cfs	+2000 cfs		
15,000 cfs	+3000 cfs	10,001 to 15,000 cfs	+1000 cfs
≥30,000 cfs	+6000 cfs	>15,000 cfs	+2000 cfs

[x] Before the SWRCB D-1641pulse = HORB open, no Old and Middle River restrictions; during the SWRCB D-1641pulse = no south Delta exports (two weeks) and HORB closed; after the SWRCB D-1641 pulse = -5,000 cfs Old and Middle River (through November); HORB open 50% for 2 weeks.

[y] Head of Old River Operable Barrier (HORB) Operations/Modeling assumptions (% OPEN)1: Oct 50%, Nov 100%2, Dec 100%, Jan 50%3, Feb–Jun 15 50%, Jun 16–30 100%, Jul–Sep 100%

1. Percent of time the HORB is open. Agricultural barriers are in and operated consistent with current practices. HORB would be open 100% whenever flows are greater than 10,000 cfs at Vernalis.
2. For modeling assumption only. Action proposed:
   Before the SWRCB D-1641 pulse = no Old and Middle River restrictions (HORB open).
   During the SWRCB D-1641 pulse = no south Delta exports for two weeks (HORB closed).
   After the SWRCB D-1641 pulse = -5,000 cfs Old and Middle River through November (HORB open 50% for 2 weeks).
   Exact timing of the action will be based on hydrologic conditions.
3. The HORB becomes operational at 50% when salmon fry are immigrating (based on real time monitoring). This generally occurs when flood flow releases are being made.)

[z] Enhanced Spring Delta Outflow required during the Mar–May period. This additional Mar–May Delta Outflow requirement is determined based on 90% forecast of Mar–May Eight River Index (8RI). For modeling purposes the Mar–May 8RI was forecasted based on a correlation between the Jan–Feb 8RI and Mar–May 8RI at ELT and LLT. Each year in March, Spring Delta Outflow target for the Mar-May period is determined based on the forecasted Mar–May 8RI value and its exceedance probability, from SubTable C below, linearly interpolating for values in-between. This additional spring outflow is not considered as an “in-basin use” for CVP–SWP Coordinated Operations. This outflow requirement is met through first by curtailing Delta exports at Banks and Jones Pumping Plants by an amount needed to meet the outflow target, such that the minimum exports are at least 1,500 cfs. In wetter years (< 50% exceedance), if the outflow target is not achieved by export curtailments, then the additional flow needed to meet the outflow target is released from the Oroville reservoir as long as its projected end-of-May storage is at or above 2 maf.

SubTable C

Percent exceedance of forecasted March–May 8RI based on January–February 8RI values	10%	20%	30%	40%	50%	60%	70%	80%	90%
Proposed March–May Delta outflow target (cfs)	44,500	44,500	35,000	32,000	23,000	17,200	13,300	11,400	9,200

SubTable A. North Delta Diversion Bypass Flows

Level I			Level II			Level III		
If Sacramento River Flow is over (cfs)	But Not over (cfs)	The Bypass is	If Sacramento River Flow is over (cfs)	But Not over (cfs)	The Bypass is	If Sacramento River Flow is over (cfs)	But Not over (cfs)	The Bypass is
December–April			December–April			December–April		
0	15,000	100% of the amount over 0 cfs	0	11,000	100% of the amount over 0 cfs	0	9,000	100% of the amount over 0 cfs
15,000	17,000	15,000 cfs plus 80% of the amount over 15,000 cfs	11,000	15,000	11,000 cfs plus 60% of the amount over 11,000 cfs	9,000	15,000	9,000 cfs plus 50% of the amount over 9,000 cfs
17,000	20,000	16,600 cfs plus 60% of the amount over 17,000 cfs	15,000	20,000	13,400 cfs plus 50% of the amount over 15,000 cfs	15,000	20,000	12,000 cfs plus 20% of the amount over 15,000 cfs
20,000	No limit	18,400 cfs plus 30% of the amount over 20,000 cfs	20,000	No limit	15,900 cfs plus 20% of the amount over 20,000 cfs	20,000	No limit	13,000 cfs plus 0% of the amount over 20,000 cfs
May			May			May		
0	15,000	100% of the amount over 0 cfs	0	11,000	100% of the amount over 0 cfs	0	9,000	100% of the amount over 0 cfs
15,000	17,000	15,000 cfs plus 70% of the amount over 15,000 cfs	11,000	15,000	11,000 cfs plus 50% of the amount over 11,000 cfs	9,000	15,000	9,000 cfs plus 40% of the amount over 9,000 cfs
17,000	20,000	16,400 cfs plus 50% of the amount over 17,000 cfs	15,000	20,000	13,000 cfs plus 35% of the amount over 15,000 cfs	15,000	20,000	11,400 cfs plus 20% of the amount over 15,000 cfs
20,000	No limit	17,900 cfs plus 20% of the amount over 20,000 cfs	20,000	No limit	14,750 cfs plus 20% of the amount over 20,000 cfs	20,000	No limit	12,400 cfs plus 0% of the amount over 20,000 cfs
June			June			June		
0	15,000	100% of the amount over 0 cfs	0	11,000	100% of the amount over 0 cfs	0	9,000	100% of the amount over 0 cfs
15,000	17,000	15,000 cfs plus 60% of the amount over 15,000 cfs	11,000	15,000	11,000 cfs plus 40% of the amount over 11,000 cfs	9,000	15,000	9,000 cfs plus 30% of the amount over 9,000 cfs
17,000	20,000	16,200 cfs plus 40% of the amount over 17,000 cfs	15,000	20,000	12,600 cfs plus 20% of the amount over 15,000 cfs	15,000	20,000	10,800 cfs plus 20% of the amount over 15,000 cfs
20,000	No limit	17,400 cfs plus 20% of the amount over 20,000 cfs	20,000	No limit	13,600 cfs plus 20% of the amount over 20,000 cfs	20,000	No limit	11,800 cfs plus 0% of the amount over 20,000 cfs

5C.A.3 CALSIM Reservoir Operations and Downstream Flows for the ESO

The following sections describe the CALSIM-simulated changes for each upstream reservoir and associated downstream river flows. The reservoir inflows assumed for CALSIM were adjusted for the ELT and LLT timeframes. These adjustments are described and compared in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

The basic presentation of the CALSIM results will be tables of the monthly cumulative distributions of reservoir storage and flows; the table format shows the monthly ranges with the 0% (minimum), 10%, 20%, 30%, 40%, 50% (median), 60%, 70%, 80%, 90%, and 100% (maximum) and the average at the bottom of each monthly column. For flows (cfs units), the distribution of annual flow volumes (taf units) is given in the last column. This format provides a good summary of the seasonal distribution of reservoir storages or flows that would be observed over the 82-year sequence of WY 1922–2002. Because runoff is highly variable from year to year, these cumulative distributions of monthly storage and flows are the probability distribution of storages and flows. There is a 10% probability of monthly flows falling within each 10% interval of the monthly cumulative distribution. The overall changes from one CALSIM run to another can be summarized by the shifts in the monthly cumulative distributions of the reservoir storages or the river flows. The method of presentation focuses on the patterns of change in reservoir operations and release flows, rather than the monthly difference in the 82-year sequence. Although some months of a few years will have relatively large changes (because of crossing thresholds for storage limits or minimum flow conditions) the overall shifts in the monthly distributions of storages or flows are the more fundamental differences between two operational scenarios.

5C.A.3.1 Simulated Changes in Trinity Reservoir Operations for the ESO

The inflows to Trinity Reservoir averaged about 1,275 thousand acre-feet per year (taf/yr). The Trinity River monthly flows are specified in the Trinity River Restoration Plan as a function of the Trinity Reservoir inflows (runoff) and these were simulated to average about 700 taf/yr. The Trinity River flows are therefore about 55% of the Trinity Reservoir inflows.

Table C.A-2 shows the Trinity Reservoir end-of-month storage patterns for 1922–2003 for the four EBC cases as well as the two ESO cases. The maximum storage of about 2,500 thousand acre-feet (taf) was achieved only once in June over the period of simulation for each of the cases. In all other months the maximum storage is controlled by flood control rules (i.e., safety of dam overtopping limits) as indicated by the maximum monthly values that were simulated in 20–30% of the years. For example, the maximum storage in October–December was 1,850 taf and the maximum storage in January was 1,900 taf. Operation of Trinity Reservoir is controlled by the maximum storage, the required river releases, and exports through the Carr tunnel and powerhouse to the Sacramento River. Spills are generally rare for the Trinity Reservoir. The EBC2_ELT and EBC2_LLT cases showed lower median storage values than the EBC2, reflecting the shift to increased runoff in the winter months (with increased spils), and slightly less inflow during the summer and fall. Lower storage at the end of April, with high Trinity River flows required in May, resulted in lower storage throughout the summer and fall. There was a similar drawdown of summer storage (carryover storages) for the ESO cases in ELT and LLT compared to the EBC2_ELT and EBC2_LLT; each of these cases require the Fall X2 conditions specified in the 2008 USFWS BiOp.

Figure C.A-1 shows the simulated Trinity Reservoir monthly storage for the four EBC cases as well as the two ESO cases for the 1963–2003 sequence (second half of the full CALSIM sequence). The second half of the CALSIM sequence has the full range of hydrological conditions (including the 1976–1977 and 1987–1992 drought), allows the historical operations data for most reservoirs to be compared, and allows the seasonal variations to be identified.The historical Trinity Reservoir storage is shown for comparison. The major difference between EBC1 and EBC2 is that EBC2 requires more Delta outflow releases in September and October following above normal or wet years for the Fall X2. EBC1 is the only case that does not include this Fall X2 requirement. Although the monthly minimum storage was reduced by about 100 taf in many years, the carryover storage (i.e., end of September storage) under ESO_ELT and ESO_LLTwas reduced by 100 taf to 300 taf in several years when the EBC1 carryover storage was between 500 taf and 1,500 taf. For years with storage below the Trinity target carryover storage of 600 taf (specified in the 2009 NMFS BiOp and Trinity River Restoration), the carryover storage was similar. The differences in Trinity Reservoir storage between the EBC2 cases and the ESO cases for the ELT and LLT conditions were slight.

Figure C.A-2 shows the simulated monthly Trinity Reservoir storage for the four EBC cases and the two ESO cases for the 1994–2003 sequence (most recent 10 years in CALSIM). This 10-year sequence is shown because the operating rules were similar to existing operations criteria (i.e., Central Valley Project Improvement Act [CVPIA] and D-1641, beginning in about 1995), and allows the seasonal variations between wet years and dry years to be fully resolved. Although these 10 years were relatively wet, the additional simulated drawdown for the ELT and LLT cases in WY 2000 and WY 2001 reduced the Trinity storage and there was not enough inflow for the storage to recover to the EBC1 (or historical) levels in 2002 or 2003. The simulated effects of climate change on the ELT and LLT inflows appeared to have some effect on the Trinity storage.

Table C.A-3 shows the Trinity River flows for the six cases. The monthly flows were nearly identical, with only a few months of simulated spills being slightly different in these six CALSIM cases. Monthly flow requirements increase in the spring months depending on the runoff, but remain at 300 cubic feet per second (cfs) from November through March in all years, except for uncontrolled spills. The Trinity River prescribed baseline flows are increased slightly in April to 500 cfs and are increased dramatically in May and June, according to runoff conditions. Flows in July are about 1,000 cfs in most years and flows in August through October are about 500 cfs. Because the Trinity River flows are specified as a function of runoff (year-type), they do not change with the different EBC or ESO cases (climate change in runoff did not shift Trinity year-type classification).

Figure C.A-3 shows the simulated Trinity River flows for the four EBC and two ESO cases for the 1963–2003 sequence. The monthly flows are all between 300 cfs and 6,000 cfs (flood control maximum). The specified flows are highest in May. The highest specified monthly flow in May is 4,700 cfs in years with the highest inflow. Figure C.A-4 shows the simulated monthly Trinity River flows at Lewiston for the six cases for the 1994–2003 sequence. The only changes in Trinity River flows were caused by slightly different reservoir spills caused by the different inflow sequences assumed for the existing and the ELT and LLT conditions.

Table C.A-4 shows the Trinity exports through the Carr tunnel for the six cases. The Trinity River exports are generally controlled by Trinity Reservoir storage, Shasta Reservoir storage (balancing rules), Trinity Reservoir inflows, and the CVP Western Area Power Association (WAPA) power demands. The annual average exports were not changed substantially from the EBC cases to the ESO cases. The annual average exports were 535 taf for the EBC1 case, 522 taf for the ESO_ELT case, and 557 taf for the ESO_LLT case. The three EBC2 (with Fall X2) cases were 539 taf, 527 taf and 554 taf. The assumed Trinity Reservoir inflows were shifted into the winter months and were slightly higher for the ELT and LLT timeframes, allowing slightly different exports for each case. The monthly Trinity export flows were highest in July–October with a lower export flow in January–March and much lower exports in the other months. This monthly export pattern was similar for the six cases.

The Trinity Reservoir operations will have effects on aquatic resources (fish) by changing the reservoir storage levels (drawdown) and affecting the cold-water pool (volume) remaining at the end of each water year. The Trinity Reservoir operations will also affect the Trinity River flows and the release temperatures at Lewiston and downstream in the Trinity River. The effects of Trinity Reservoir operations on Trinity River water temperatures for existing runoff and air temperature conditions and with climate change assumptions are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

Table C.A-2. CALSIM-Simulated Monthly Distributions of Trinity Reservoir Storage (taf)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	240	240	264	327	361	482	603	619	638	555	412	240
10%	641	689	675	674	814	890	1,041	1,028	1,009	820	697	651
20%	917	884	969	1,054	1,121	1,233	1,364	1,339	1,271	1,133	1,031	950
30%	1,196	1,188	1,234	1,297	1,387	1,500	1,650	1,637	1,611	1,495	1,360	1,247
40%	1,271	1,274	1,314	1,359	1,537	1,699	1,869	1,832	1,773	1,601	1,409	1,295
50%	1,353	1,364	1,440	1,584	1,718	1,834	1,981	1,912	1,840	1,694	1,532	1,408
60%	1,469	1,510	1,668	1,750	1,868	2,006	2,159	2,090	2,017	1,853	1,695	1,551
70%	1,744	1,796	1,846	1,848	1,965	2,098	2,215	2,206	2,143	2,006	1,872	1,770
80%	1,850	1,847	1,850	1,900	2,000	2,100	2,264	2,290	2,270	2,184	2,083	1,970
90%	1,850	1,850	1,850	1,900	2,000	2,100	2,299	2,329	2,366	2,270	2,150	1,975
Max	1,850	1,850	1,850	1,900	2,208	2,100	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,326	1,336	1,385	1,447	1,557	1,679	1,827	1,822	1,787	1,650	1,513	1,393
B. ESO_ELT												
Min	240	240	245	262	271	419	530	535	527	307	240	240
10%	534	583	584	595	733	908	1,000	959	916	738	591	548
20%	860	897	936	1,022	1,081	1,197	1,303	1,257	1,227	1,067	964	888
30%	1,039	1,053	1,134	1,178	1,320	1,445	1,602	1,551	1,510	1,350	1,184	1,068
40%	1,153	1,163	1,215	1,261	1,496	1,686	1,750	1,718	1,631	1,463	1,295	1,184
50%	1,243	1,244	1,377	1,522	1,644	1,792	1,938	1,876	1,724	1,526	1,390	1,275
60%	1,356	1,405	1,564	1,655	1,834	1,973	2,115	2,020	1,897	1,725	1,555	1,419
70%	1,546	1,560	1,717	1,802	1,946	2,070	2,210	2,159	2,061	1,906	1,760	1,617
80%	1,777	1,807	1,850	1,900	2,000	2,100	2,247	2,239	2,158	2,006	1,859	1,740
90%	1,850	1,850	1,850	1,900	2,000	2,100	2,270	2,344	2,277	2,180	2,083	1,966
Max	1,850	1,850	1,850	1,952	2,314	2,181	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,233	1,255	1,320	1,399	1,523	1,647	1,786	1,764	1,693	1,541	1,396	1,280
C. ESO_LLT												
Min	191	202	234	240	240	320	380	401	365	240	216	184
10%	308	359	495	484	657	837	855	815	774	663	509	352
20%	629	685	691	808	938	1,068	1,230	1,103	1,072	892	767	663
30%	806	787	860	931	1,125	1,226	1,374	1,353	1,245	1,064	951	868
40%	904	923	1,089	1,146	1,353	1,509	1,569	1,534	1,436	1,253	1,081	972
50%	1,090	1,100	1,173	1,346	1,531	1,708	1,858	1,762	1,628	1,404	1,231	1,127
60%	1,202	1,241	1,358	1,563	1,688	1,894	2,043	1,957	1,802	1,603	1,433	1,309
70%	1,355	1,374	1,520	1,633	1,836	1,998	2,144	2,085	1,915	1,737	1,586	1,431
80%	1,580	1,595	1,661	1,820	1,994	2,100	2,228	2,183	2,018	1,866	1,736	1,616
90%	1,764	1,769	1,847	1,900	2,000	2,100	2,268	2,306	2,172	2,051	1,917	1,775
Max	1,850	1,850	1,850	2,030	2,447	2,245	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,072	1,089	1,171	1,278	1,425	1,565	1,704	1,656	1,548	1,380	1,235	1,125

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	240	240	243	256	278	431	521	545	557	515	313	240
10%	629	689	679	694	786	857	1,038	1,051	1,006	847	724	637
20%	890	891	958	1,017	1,090	1,196	1,317	1,306	1,253	1,106	994	908
30%	1,091	1,112	1,169	1,224	1,364	1,437	1,575	1,540	1,552	1,405	1,241	1,128
40%	1,214	1,220	1,306	1,328	1,518	1,645	1,823	1,794	1,708	1,551	1,374	1,263
50%	1,356	1,345	1,396	1,561	1,694	1,826	1,975	1,924	1,827	1,682	1,502	1,391
60%	1,429	1,470	1,653	1,739	1,825	1,942	2,117	2,035	1,952	1,790	1,622	1,481
70%	1,646	1,720	1,759	1,820	1,935	2,100	2,218	2,185	2,124	1,989	1,868	1,731
80%	1,850	1,827	1,850	1,900	2,000	2,100	2,263	2,292	2,265	2,176	2,055	1,968
90%	1,850	1,850	1,850	1,900	2,000	2,100	2,300	2,330	2,367	2,270	2,150	1,975
Max	1,850	1,850	1,850	1,900	2,208	2,100	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,302	1,312	1,364	1,428	1,538	1,662	1,813	1,808	1,772	1,634	1,493	1,372
E. EBC2_ELT												
Min	212	240	240	252	270	418	530	534	527	318	240	200
10%	502	588	585	598	699	906	970	916	854	731	609	513
20%	806	854	872	945	1,051	1,136	1,315	1,224	1,167	1,050	921	833
30%	1,000	1,007	1,059	1,103	1,214	1,366	1,473	1,448	1,385	1,244	1,127	1,040
40%	1,141	1,162	1,218	1,265	1,477	1,681	1,784	1,743	1,653	1,467	1,279	1,171
50%	1,222	1,274	1,388	1,505	1,639	1,776	1,922	1,863	1,722	1,549	1,378	1,264
60%	1,394	1,415	1,584	1,662	1,802	1,936	2,139	2,036	1,912	1,748	1,541	1,429
70%	1,577	1,598	1,666	1,786	1,943	2,068	2,212	2,145	2,062	1,916	1,767	1,622
80%	1,808	1,787	1,799	1,900	2,000	2,100	2,251	2,237	2,187	2,056	1,894	1,780
90%	1,850	1,844	1,850	1,900	2,000	2,100	2,284	2,345	2,302	2,183	2,114	1,946
Max	1,850	1,850	1,850	1,952	2,314	2,181	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,223	1,237	1,301	1,378	1,506	1,633	1,775	1,752	1,681	1,535	1,391	1,274
F. EBC2_LLT												
Min	211	240	240	240	246	326	386	407	352	240	240	200
10%	296	319	473	613	651	815	834	763	750	641	500	444
20%	700	721	759	914	1,001	1,100	1,226	1,130	1,104	980	875	756
30%	808	857	939	1,031	1,161	1,373	1,510	1,409	1,325	1,140	996	883
40%	1,050	1,068	1,100	1,169	1,312	1,533	1,640	1,580	1,468	1,314	1,144	1,071
50%	1,107	1,154	1,245	1,433	1,582	1,744	1,867	1,806	1,644	1,430	1,245	1,111
60%	1,309	1,300	1,422	1,562	1,721	1,943	2,097	1,982	1,863	1,703	1,513	1,368
70%	1,406	1,425	1,520	1,677	1,897	2,070	2,191	2,063	1,929	1,775	1,632	1,456
80%	1,577	1,540	1,642	1,790	2,000	2,100	2,216	2,196	2,018	1,868	1,720	1,576
90%	1,762	1,707	1,814	1,900	2,000	2,100	2,279	2,311	2,243	2,102	1,977	1,849
Max	1,850	1,850	1,850	2,026	2,447	2,245	2,300	2,420	2,447	2,270	2,150	1,975
Avg	1,110	1,118	1,203	1,312	1,460	1,601	1,737	1,685	1,583	1,433	1,283	1,163

Table C.A-3. CALSIM-Simulated Monthly Distributions of Trinity River Flows (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	0	300	300	300	300	300	427	1,498	783	450	450	450	369
10%	373	300	300	300	300	300	460	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	743
80%	373	300	300	300	300	300	540	4,709	2,526	1,102	450	450	817
90%	373	300	300	1,118	1,194	1,112	600	4,709	4,626	1,102	450	450	1,009
Max	373	5,201	6,000	6,000	6,000	6,000	2,920	4,709	6,000	3,274	450	450	1,885
Avg	368	360	545	671	634	611	584	3,779	2,108	923	450	450	696
B. ESO_ELT													
Min	0	0	300	300	300	300	427	1,498	783	450	0	0	274
10%	373	300	300	300	300	300	427	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	810
80%	373	300	300	300	300	300	540	4,709	2,526	1,102	450	450	839
90%	373	300	300	1,405	2,099	300	600	4,709	4,626	1,102	450	450	1,110
Max	373	4,475	6,000	6,000	6,000	6,000	2,937	4,709	6,000	2,103	450	450	1,967
Avg	350	340	642	714	739	677	590	3,753	2,226	890	445	439	715
C. ESO_LLT													
Min	0	0	0	0	300	300	427	1,498	783	450	0	0	237
10%	373	300	300	300	300	300	427	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	521	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	798
80%	373	300	300	300	300	300	540	4,709	4,626	1,102	450	450	855
90%	373	300	300	300	2,357	300	600	4,709	4,626	1,102	450	450	1,094
Max	373	2,001	6,000	6,000	6,000	6,000	4,066	4,709	4,626	1,133	450	450	1,876
Avg	344	302	494	650	804	676	622	3,766	2,286	872	428	420	706

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	0	0	300	300	300	300	427	1,498	783	450	450	450	369
10%	373	300	300	300	300	300	460	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	745
80%	373	300	300	300	300	300	540	4,709	2,526	1,102	450	450	817
90%	373	300	300	486	1,194	560	600	4,709	4,626	1,102	450	450	987
Max	373	5,261	5,139	6,000	6,000	6,000	2,920	4,709	6,000	3,274	450	450	1,889
Avg	368	357	529	650	642	590	584	3,779	2,108	923	450	450	692
E. EBC2_ELT													
Min	0	0	300	300	300	300	427	1,498	783	450	0	0	274
10%	373	300	300	300	300	300	427	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	813
80%	373	300	300	300	300	300	600	4,709	2,526	1,102	450	450	847
90%	373	300	300	839	2,195	331	600	4,709	4,626	1,102	450	450	1,053
Max	373	5,755	6,000	6,000	6,000	6,000	2,937	4,709	6,000	2,103	450	450	2,019
Avg	354	354	611	703	702	654	605	3,753	2,226	890	445	436	710
F. EBC2_LLT													
Min	0	0	0	147	300	300	427	1,498	783	0	0	0	269
10%	373	300	300	300	300	300	427	1,498	783	450	450	450	370
20%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
30%	373	300	300	300	300	300	460	2,924	783	450	450	450	453
40%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	648
50%	373	300	300	300	300	300	493	4,189	2,120	1,102	450	450	649
60%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	702
70%	373	300	300	300	300	300	540	4,570	2,526	1,102	450	450	776
80%	373	300	300	300	300	300	540	4,709	4,626	1,102	450	450	817
90%	373	300	300	559	2,181	300	600	4,709	4,626	1,102	450	450	1,064
Max	373	3,263	6,000	6,000	6,000	6,000	4,066	4,709	4,626	1,133	450	450	1,905
Avg	344	318	466	684	795	676	630	3,766	2,286	866	434	423	707

Table C.A-4. CALSIM-Simulated Monthly Distributions of Trinity River Exports (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	0	0	0	0	0	0	0	0	0	0	42	0	150
10%	250	0	0	0	0	0	0	0	0	1,273	1,239	250	288
20%	250	0	0	0	0	0	0	0	7	1,500	1,500	1,000	361
30%	750	5	4	0	0	0	100	0	58	1,500	1,500	1,293	409
40%	750	100	100	100	0	98	144	0	247	1,500	1,545	1,500	468
50%	750	133	102	100	93	100	249	0	250	1,500	1,750	1,500	530
60%	750	444	250	115	100	100	300	0	750	1,750	2,000	2,000	578
70%	1,250	500	250	250	100	187	406	100	750	2,000	2,000	2,000	636
80%	1,772	500	353	603	104	248	497	250	764	2,221	2,500	2,500	704
90%	1,956	911	923	1,815	250	821	1,267	250	1,281	3,300	2,944	2,596	829
Max	3,300	2,082	1,754	2,592	1,002	3,300	2,624	2,388	3,203	3,300	3,300	3,300	1,169
Avg	994	343	282	448	97	268	404	163	512	1,783	1,875	1,630	535
B.ESO_ELT													
Min	0	0	0	0	0	0	0	0	0	15	250	40	150
10%	195	0	0	0	0	0	0	0	0	551	1,415	750	296
20%	250	7	0	0	0	0	90	0	0	1,500	1,500	1,000	365
30%	250	100	0	0	0	0	100	0	78	1,500	1,500	1,500	406
40%	724	100	66	100	0	12	170	0	250	1,500	1,720	1,500	463
50%	750	124	100	100	0	100	250	0	260	1,500	1,779	1,500	493
60%	750	500	100	100	100	100	307	0	750	2,000	2,000	1,589	554
70%	1,214	500	142	250	100	187	373	100	750	2,000	2,250	2,000	639
80%	1,250	500	250	511	100	248	435	245	750	2,508	2,500	2,000	717
90%	1,768	502	290	1,728	238	614	608	250	1,478	3,300	2,897	2,671	799
Max	3,300	2,965	2,135	3,109	782	3,021	2,049	2,039	3,121	3,300	3,300	3,300	948
Avg	812	339	173	424	74	252	334	162	604	1,804	1,982	1,626	522
C. ESO_LLT													
Min	0	0	0	0	0	0	0	0	0	0	111	118	67
10%	108	0	0	0	0	0	0	0	0	1,025	1,167	697	288
20%	250	100	0	0	0	0	0	0	0	1,500	1,500	1,000	362
30%	250	100	52	0	0	0	108	0	180	1,500	1,500	1,000	440
40%	361	100	100	100	0	100	206	0	250	1,500	1,850	1,500	471
50%	750	145	100	100	18	100	250	0	250	1,875	2,000	1,500	531
60%	1,000	500	118	209	100	112	330	0	750	2,000	2,250	2,000	610
70%	1,250	500	250	250	100	189	397	71	750	2,510	2,313	2,004	661
80%	1,323	500	250	801	100	250	458	184	1,250	2,982	2,506	2,520	731
90%	1,749	775	250	1,925	102	786	635	250	1,500	3,300	3,235	2,950	847
Max	3,300	2,623	3,260	3,300	1,274	3,300	2,308	2,371	3,170	3,300	3,300	3,300	1,154
Avg	845	370	200	476	74	294	362	166	685	1,989	1,989	1,712	557

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	0	0	0	0	0	0	0	0	0	0	250	201	150
10%	250	0	0	0	0	0	0	0	0	1,091	1,168	831	280
20%	250	1	0	0	0	0	9	0	2	1,500	1,500	1,000	356
30%	750	100	69	0	0	0	100	0	58	1,500	1,500	1,500	399
40%	750	100	100	100	0	51	144	0	207	1,500	1,545	1,500	474
50%	750	287	102	100	100	100	249	0	250	1,500	1,750	1,500	541
60%	1,150	500	234	103	100	100	300	0	634	1,750	2,000	2,000	581
70%	1,558	500	250	250	100	187	392	100	750	2,000	2,000	2,000	621
80%	1,787	500	250	566	104	248	441	250	750	2,480	2,700	2,425	705
90%	2,014	579	574	1,699	250	710	974	250	1,362	3,300	3,169	2,605	814
Max	3,300	2,082	2,641	3,300	843	3,300	2,297	2,388	3,203	3,300	3,300	3,123	1,041
Avg	1,057	333	251	425	95	259	362	166	528	1,797	1,928	1,674	539
E. EBC2_ELT													
Min	0	0	0	0	0	0	0	0	0	0	0	250	138
10%	11	0	0	0	0	0	0	0	0	526	1,323	596	296
20%	250	5	0	0	0	0	90	0	0	1,500	1,500	1,000	370
30%	250	100	64	0	0	0	100	0	59	1,500	1,500	1,167	402
40%	664	100	100	100	0	100	167	0	250	1,500	1,602	1,500	450
50%	750	151	101	100	0	100	250	0	250	1,500	1,750	1,500	494
60%	750	500	196	125	100	100	293	0	750	1,750	2,000	1,500	569
70%	1,250	500	250	250	100	190	370	100	750	2,000	2,333	2,000	641
80%	1,250	500	250	652	104	250	437	245	750	2,501	2,744	2,000	734
90%	1,836	616	440	1,728	238	650	705	250	1,362	3,284	3,068	2,622	817
Max	3,095	2,743	2,316	3,300	926	3,300	2,322	2,039	3,121	3,300	3,300	3,300	1,075
Avg	832	362	245	471	79	265	334	169	588	1,770	1,961	1,593	527
F. EBC2_LLT													
Min	0	0	0	0	0	0	0	0	0	0	0	0	61
10%	96	0	0	0	0	0	0	0	0	495	1,260	720	296
20%	250	100	0	0	0	0	85	0	0	1,500	1,500	1,000	379
30%	250	100	71	1	0	0	116	0	86	1,500	1,500	1,000	423
40%	675	100	100	100	0	0	241	0	250	1,500	1,750	1,500	482
50%	750	145	100	100	100	100	256	0	250	1,500	2,000	1,555	503
60%	750	415	211	174	100	102	337	0	750	1,750	2,000	2,000	571
70%	1,212	500	250	250	100	189	407	100	750	2,000	2,445	2,000	663
80%	1,361	500	250	471	104	250	537	245	837	2,250	2,757	2,494	731
90%	1,856	1,469	341	2,005	250	786	967	250	1,487	3,238	3,300	2,744	894
Max	3,300	3,300	2,584	3,300	1,361	3,300	2,309	2,409	3,300	3,300	3,300	3,300	1,102
Avg	880	489	223	478	113	285	402	173	632	1,742	2,036	1,665	554

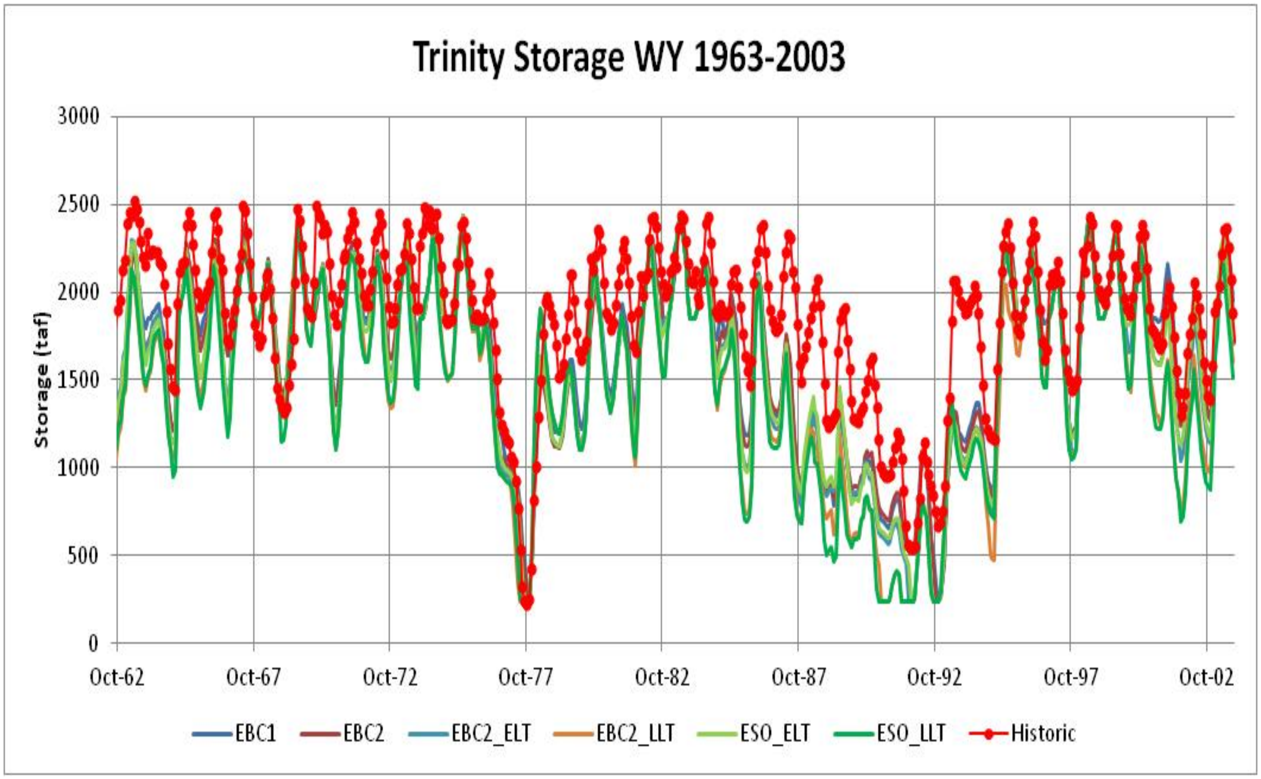


Figure C.A-1. CALSIM-Simulated Monthly Trinity Reservoir Storage for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

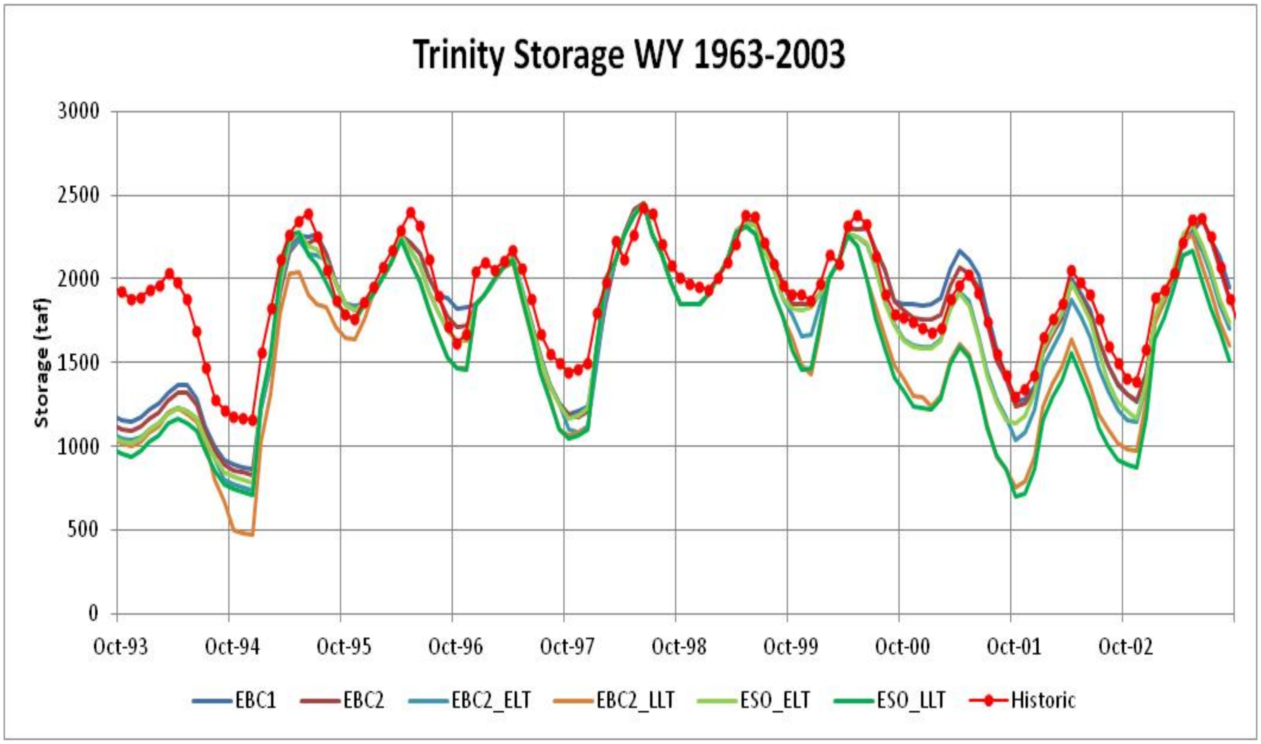


Figure C.A-2. CALSIM-Simulated Monthly Trinity Reservoir Storage for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

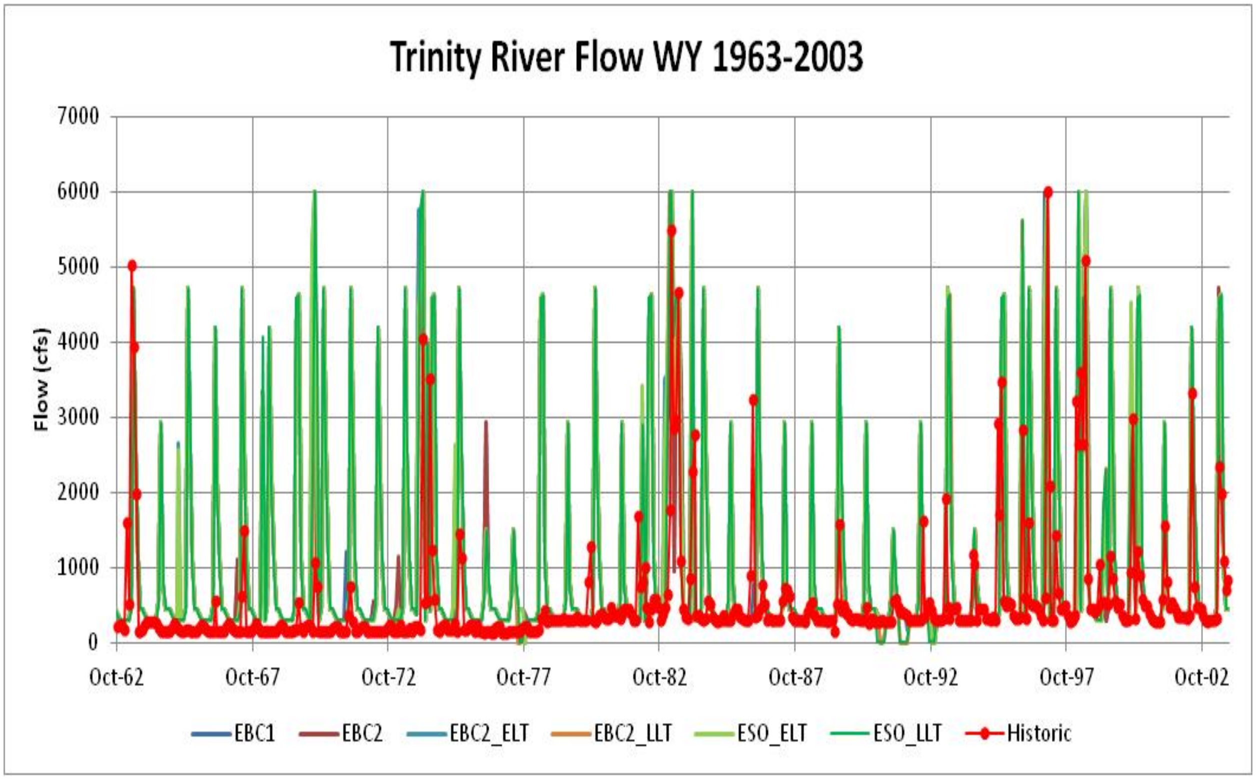


Figure C.A-3. CALSIM-Simulated Monthly Trinity River Flow at Lewiston for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

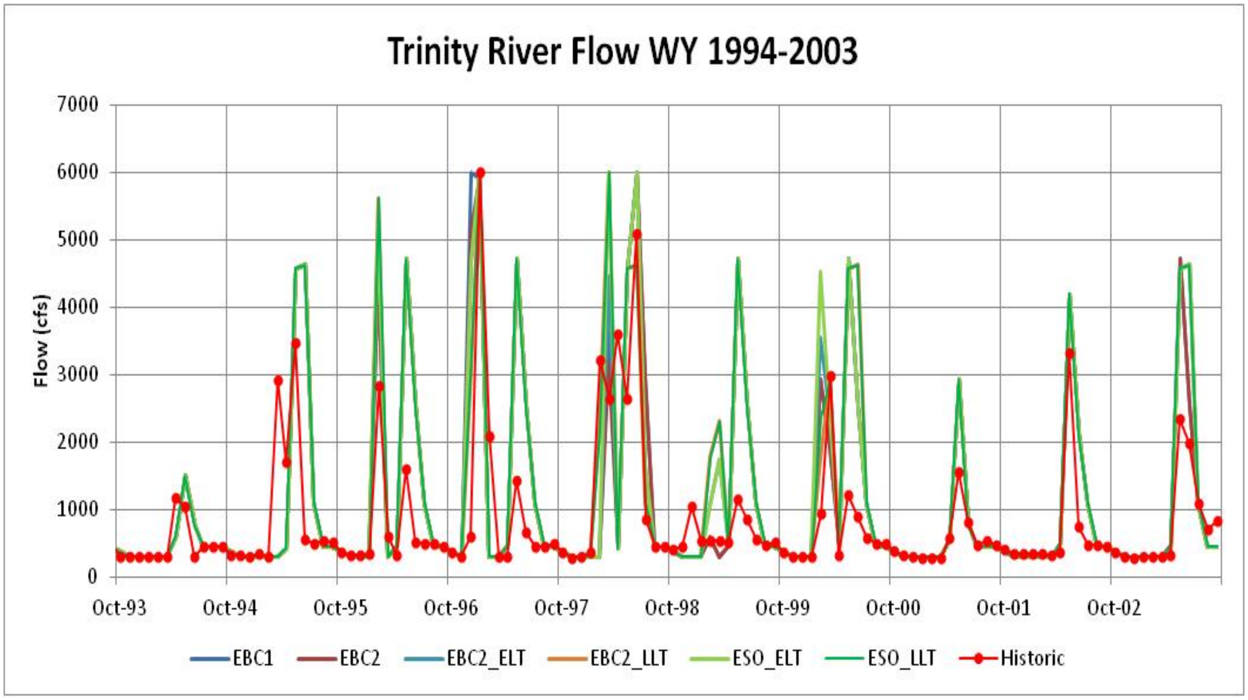


Figure C.A-4. CALSIM-Simulated Monthly Trinity River Flow at Lewiston for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.3.2 Simulated Changes in Shasta Reservoir Operations for the ESO

The simulated Shasta Reservoir operations generally depend on the Shasta inflows, the Shasta flood control rules, the minimum required Keswick flows, and the downstream water diversions (along the Sacramento River and in the Delta). Because Shasta operations are coordinated with other CVP reservoirs (Trinity and Folsom) as well as with the SWP Oroville Reservoir and Delta operations, major changes in the operations of these upstream reservoirs are not expected with the BDCP. Because the ESO would not change the basic Delta outflow or export/inflow ratio (E/I) objectives, only relatively small changes in upstream reservoir operations are expected.

Table C.A-5 shows the monthly distributions of the CALSIM-simulated Shasta Reservoir storage patterns for the six CALSIM cases. The maximum flood control storage (indicated as the maximum monthly values) is about 3,250 taf in October and November, and increases from about 4,300 taf in December to about 4,250 taf in March. The maximum storage of about 4,550 taf was simulated only in April, May, and June of wet years. The EBC1 median storage volumes were less than 3,000 taf in October and November; about 3,250 taf in December and January; 3,500 taf in February; about 4,000 taf in March; about 4,250 in April and May; about 3,900 taf in June; 3,400 in July; and about 3,000 taf in August and September. The simulated median storage levels for the three EBC2 scenarios were slightly less than the EBC1 in September and October because these are the months when additional outflow is required to meet the Fall X2 requirements under the EBC2 scenario. Some of this additional outflow is supplied from increased releases from Shasta Reservoir. The median storage levels were reduced by about 100 taf to 150 taf from EBC1 to EBC2, and were further reduced by the effects of climate change for the EBC2_ELT and EBC2_LLT. The median monthly storage levels for the ESO cases for ELT and LLT conditions were very similar to the corresponding EBC2 cases, suggesting that the BDCP facilities and restoration activities would not have a large effect on Shasta Reservoir storage levels.

Figure C.A-5 shows the simulated monthly Shasta Reservoir storage for the six CALSIM cases for the 1963–2003 sequence. The historical Shasta Reservoir storages are shown for comparison. The simulated carryover storages (end-of-September storage) for all of the three EBC2 cases and the two ESO cases were reduced in many years compared to the EBC1 (and historical) storage, because of the additional releases for Fall X2 outflow (in about half of the years). The carryover storage was reduced by 250 taf to 500 taf in several years when the EBC1 carryover storage was between 1,500 taf and 3,500 taf. For several years with EBC1 storage below the Shasta target carryover storage of 1,900 taf (specified in the 2009 NMFS BiOp), the EBC2_ELT and EBC2_LLT carryover storages were reduced further below the target carryover storage. The ESO cases were similar to the corresponding EBC2 cases. Figure C.A-6 shows the simulated monthly Shasta Reservoir storage for the three EBC2 cases (existing hydrology, ELT hydrology, and LLT hydrology) for the 1963–2003 sequence. This comparison isolates the effects of climate change on Shasta Reservoir operations. Because of the shift in runoff to the winter months, there are some years when Shasta Reservoir does not quite fill (less snowmelt) and many years when the drawdown was lower with ELT and LLT hydrology. Figure C.A-7 shows the simulated monthly Shasta Reservoir storage for the EBC2_LLT and ESO_LLT cases for the 1963–2003 sequence. There were very few changes in Shasta Reservoir operations caused by the ESO (full facilities and restoration activities).

Figure C.A-8 shows the simulated monthly Shasta Reservoir storage for the six CALSIM cases for the 1994–2003 sequence. The additional drawdown simulated for the EBC2 and ESO cases was usually recovered in the subsequent spring inflow (maximum storage). There were no large differences between the ESO cases and the corresponding EBC2 cases in these years.

Table C.A-6 shows the CALSIM-simulated Sacramento River flows at Keswick for each of the modeled cases. The simulated changes in Shasta Reservoir and Trinity Reservoir operations are combined in the monthly Keswick flows. The Sacramento River at Keswick flow includes all of the Shasta runoff (there are no substantial diversions upstream) and an average of about 525 taf/yr of Trinity River runoff that is exported to the Sacramento River for hydropower production. The total flow simulated at Keswick was nearly the same for the six cases; the EBC1 flow averaged 6,253 taf/yr, the EBC2 flow averaged 6,259 taf/yr, the EBC2_ELT flow averaged 6,300 taf/yr, and the EBC2_LLT flow averaged 6,385 taf/yr. The ESO_ ELT Keswick flow averaged 6,295 taf/yr, and the ESO_ LLT Keswick flow averaged 6,906 taf/yr, nearly identical to the EBC2 cases. The CALSIM-simulated Keswick flows in almost all months were regulated to remain above the 3,250 cfs minimum flow for fish habitat in the fall and winter months (October–March). All flows during the summer months were regulated to remain less than the Keswick hydropower turbine capacity of 15,000 cfs. The peak summer flows of 15,000 cfs were simulated in July of most years. The EBC1 median (50%) flows were between 4,000 cfs and 6,000 cfs from September through April, and increased to about 7,500 cfs in May, about 10,000 cfs in June, about 13,000 cfs in July, and about 10,500 in August. These monthly median flows at Keswick were not changed substantially from the EBC2 cases for the ESO cases. The monthly median flows for EBC2, EBC2_ELT, and EBC2_LLT cases also were similar. Although the monthly distribution of Keswick flows was similar for all six CALSIM cases, about half of the years had increased releases that caused a greater drawdown of the Trinity and Shasta storage levels for the Fall X2 outflow requirements. For example, the median Shasta storage at the end of Octover about 150 taf less for EBC2 than for EBC1, and the median Trinity storage was about 25 taf less for EBC2 than for EBC1.

Figure C.A-9 shows the simulated Sacramento River flows at Keswick Dam for the six CALSIM cases for the 1963–2003 sequence. The monthly flows are generally between 3,250 cfs (minimum flow requirement) and 15,000 cfs (Keswick powerhouse capacity). There are much higher flows in a few years caused by Shasta Reservoir flood control releases (spills). The major differences between the existing (EBC1 and EBC2) flows and the ELT and LLT flows were caused by different inflow sequences assumed for these future ELT and LLT conditions. Figure C.A-10 shows the simulated monthly Sacramento River flows at Keswick Dam for the six CALSIM cases for the 1994–2003 sequence. The higher flows were different (flood control effects), and the flows in the fall months of some years were sometimes larger for the ELT and LLT cases compared to the EBC1 flows. There were no large differences for the ESO cases compared to the corresponding EBC2 cases.

Table C.A-7 shows the CALSIM-simulated Sacramento River flows at Wilkins Slough (just above the Feather River) for the six cases. The simulated monthly flows are generally higher than the monthly Keswick flows because of the additional runoff from the Sacramento River tributaries, including Battle Creek (350 taf/yr average runoff), Mill Creek (215 taf/yr), Thomes Creek (205 taf/yr), Deer Creek (225 taf/yr), Big Chico Creek (110 taf/yr), Stony Creek (380 taf/yr), and Butte Creek (290 taf/yr). However, flows in the Sacramento River in excess of 25,000 cfs are largely diverted into the Sutter Bypass.

The minimum flow target of 5,000 cfs at Wilkins Slough generally is maintained by CVP operations, but the minimum target flow is reduced in critical years. The Sacramento River at Wilkins Slough higher flows are regulated by the diversions at the three flood bypass weirs between Butte City and Wilkins Slough (Moulton Weir, Colusa Weir, and Tisdale Weir). The maximum monthly Wilkins

Slough flow (channel capacity) is about 25,000 cfs. The average annual flow simulated at Wilkins Slough was nearly the same for the six cases; the average annual flow was between 7,150 taf/yr and 7,300 taf/yr. There were no substantial changes in the monthly distribution of flows at Wilkins Slough.

The Shasta Reservoir operations will have effects on aquatic resources (fish) by changing the reservoir storage levels (drawdown) and affecting the cold-water pool (volume) remaining at the end of each water year. The Shasta Reservoir operations will also affect the Sacramento River flows and the release temperatures at Keswick Dam and downstream in the Sacramento River. The effects of Shasta Reservoir operations on Sacramento River water temperatures for existing runoff and air temperature conditions and with climate change assumptions are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

Table C.A-5. CALSIM-Simulated Monthly Distribution of Shasta Reservoir Storage (taf)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	550	550	672	802	911	1,485	1,559	1,408	942	639	550	550
10%	1,285	1,406	1,452	1,814	2,167	2,804	2,704	2,886	2,503	1,889	1,587	1,490
20%	2,058	2,250	2,287	2,656	2,976	3,366	3,755	3,615	3,202	2,604	2,223	2,187
30%	2,569	2,585	2,696	2,948	3,282	3,550	3,946	3,819	3,410	2,959	2,682	2,654
40%	2,712	2,760	2,985	3,152	3,412	3,756	4,074	4,144	3,686	3,184	2,810	2,813
50%	2,885	2,983	3,234	3,256	3,530	3,896	4,208	4,276	3,898	3,383	3,005	2,969
60%	3,157	3,155	3,276	3,399	3,633	3,980	4,294	4,454	4,048	3,484	3,200	3,152
70%	3,214	3,216	3,309	3,522	3,681	4,033	4,361	4,552	4,233	3,719	3,373	3,334
80%	3,250	3,251	3,328	3,552	3,794	4,118	4,455	4,552	4,355	3,961	3,668	3,400
90%	3,250	3,252	3,347	3,640	3,920	4,221	4,511	4,552	4,480	4,082	3,700	3,400
Max	3,250	3,252	3,368	3,725	4,432	4,384	4,552	4,552	4,500	4,150	3,700	3,400
Avg	2,624	2,645	2,777	3,029	3,299	3,644	3,936	3,961	3,654	3,172	2,838	2,723
B. ESO_ELT												
Min	548	550	552	584	701	1,321	1,444	1,289	724	550	550	550
10%	1,139	1,055	1,230	1,884	2,313	2,631	2,555	2,674	2,340	1,858	1,491	1,319
20%	1,973	2,099	2,165	2,496	2,856	3,259	3,665	3,342	2,846	2,369	2,048	2,071
30%	2,260	2,341	2,461	2,834	3,252	3,451	3,814	3,712	3,373	2,781	2,541	2,416
40%	2,436	2,524	2,762	3,143	3,338	3,704	4,033	4,014	3,506	2,953	2,625	2,559
50%	2,575	2,646	3,064	3,271	3,492	3,841	4,139	4,185	3,693	3,150	2,733	2,684
60%	2,708	2,931	3,235	3,367	3,568	3,960	4,241	4,317	3,863	3,244	2,907	2,748
70%	2,965	3,061	3,266	3,451	3,673	4,007	4,382	4,512	4,163	3,511	3,182	2,955
80%	3,062	3,170	3,310	3,539	3,742	4,118	4,451	4,552	4,252	3,736	3,406	3,046
90%	3,200	3,252	3,338	3,621	3,907	4,225	4,483	4,552	4,432	3,871	3,552	3,225
Max	3,250	3,252	3,369	3,725	4,552	4,381	4,552	4,552	4,500	4,114	3,700	3,400
Avg	2,413	2,481	2,678	2,961	3,245	3,589	3,857	3,853	3,482	2,944	2,632	2,476
C. ESO_LLT												
Min	503	550	550	550	551	986	963	900	550	550	550	550
10%	604	669	845	1,149	1,417	1,900	2,438	2,134	1,631	1,173	897	730
20%	1,412	1,484	1,580	2,133	2,689	2,931	3,106	2,871	2,390	2,003	1,699	1,632
30%	1,898	1,971	2,176	2,505	3,030	3,416	3,542	3,452	3,026	2,527	2,279	2,102
40%	2,107	2,131	2,345	2,841	3,264	3,516	3,849	3,775	3,244	2,766	2,409	2,303
50%	2,261	2,300	2,708	3,078	3,433	3,754	4,084	4,001	3,419	2,881	2,564	2,383
60%	2,353	2,503	2,873	3,252	3,494	3,964	4,224	4,128	3,633	3,006	2,700	2,529
70%	2,603	2,620	3,077	3,367	3,643	4,020	4,305	4,339	3,922	3,245	2,860	2,680
80%	2,703	2,865	3,263	3,531	3,739	4,128	4,410	4,552	4,095	3,438	3,102	2,745
90%	2,900	3,006	3,319	3,615	3,848	4,197	4,479	4,552	4,290	3,696	3,294	2,917
Max	3,250	3,252	3,368	3,723	4,552	4,304	4,552	4,552	4,500	4,108	3,700	3,400
Avg	2,079	2,145	2,414	2,772	3,113	3,470	3,711	3,651	3,214	2,688	2,384	2,181

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	550	550	667	794	831	1,414	1,515	1,385	870	604	550	550
10%	1,379	1,291	1,451	1,869	2,094	2,818	2,699	2,977	2,500	1,984	1,694	1,575
20%	2,107	2,075	2,320	2,662	2,890	3,351	3,725	3,568	3,162	2,618	2,191	2,235
30%	2,391	2,514	2,538	2,913	3,267	3,534	3,888	3,778	3,426	2,879	2,627	2,521
40%	2,598	2,630	2,785	3,013	3,377	3,687	4,058	4,080	3,701	3,200	2,850	2,658
50%	2,794	2,864	3,060	3,252	3,471	3,873	4,173	4,273	3,875	3,371	3,019	2,831
60%	2,943	2,937	3,188	3,358	3,567	3,940	4,292	4,482	4,036	3,462	3,144	2,983
70%	3,110	2,981	3,252	3,402	3,654	4,010	4,396	4,552	4,214	3,695	3,333	3,119
80%	3,214	3,109	3,293	3,541	3,739	4,106	4,456	4,552	4,339	3,936	3,619	3,235
90%	3,250	3,252	3,328	3,616	3,848	4,226	4,503	4,552	4,465	4,079	3,700	3,376
Max	3,250	3,252	3,367	3,678	4,433	4,397	4,552	4,552	4,500	4,150	3,700	3,400
Avg	2,555	2,545	2,710	2,981	3,259	3,613	3,911	3,942	3,631	3,145	2,809	2,628
E. EBC2_ELT												
Min	536	550	550	565	702	1,321	1,451	1,291	676	550	550	550
10%	1,057	1,036	1,064	1,822	2,051	2,604	2,492	2,614	2,321	1,751	1,350	1,217
20%	1,941	1,983	2,165	2,513	2,810	3,226	3,530	3,285	2,877	2,377	2,037	2,013
30%	2,223	2,284	2,425	2,717	3,252	3,439	3,790	3,666	3,363	2,776	2,471	2,374
40%	2,490	2,498	2,615	3,051	3,323	3,718	3,984	4,003	3,580	3,025	2,686	2,556
50%	2,616	2,617	2,948	3,242	3,449	3,766	4,139	4,227	3,779	3,195	2,867	2,704
60%	2,764	2,733	3,081	3,316	3,524	3,960	4,273	4,423	3,973	3,361	3,055	2,833
70%	2,855	2,898	3,249	3,388	3,649	4,018	4,370	4,530	4,172	3,547	3,219	2,990
80%	3,057	3,043	3,275	3,530	3,744	4,115	4,438	4,552	4,280	3,775	3,463	3,051
90%	3,250	3,251	3,317	3,621	3,844	4,212	4,479	4,552	4,432	3,909	3,575	3,306
Max	3,250	3,252	3,349	3,723	4,552	4,381	4,552	4,552	4,500	4,150	3,700	3,400
Avg	2,401	2,408	2,608	2,912	3,210	3,563	3,834	3,848	3,505	2,979	2,661	2,474
F. EBC2_LLT												
Min	537	550	550	550	550	979	650	653	550	550	550	550
10%	618	655	889	1,467	1,756	2,075	2,104	2,034	1,663	1,180	894	803
20%	1,599	1,558	1,693	2,082	2,771	2,985	3,214	2,984	2,586	2,054	1,776	1,754
30%	1,867	1,948	2,118	2,541	2,984	3,416	3,581	3,604	3,129	2,561	2,222	2,018
40%	2,143	2,176	2,423	2,785	3,261	3,490	3,880	3,830	3,406	2,813	2,454	2,331
50%	2,302	2,339	2,610	3,030	3,359	3,754	4,113	4,099	3,642	3,041	2,665	2,436
60%	2,495	2,461	2,783	3,252	3,494	3,959	4,227	4,293	3,817	3,151	2,806	2,601
70%	2,605	2,520	3,045	3,364	3,646	4,007	4,347	4,475	4,085	3,450	3,033	2,695
80%	2,728	2,749	3,252	3,530	3,730	4,107	4,403	4,552	4,173	3,568	3,273	2,848
90%	3,054	3,093	3,304	3,608	3,831	4,180	4,478	4,552	4,403	3,754	3,348	3,035
Max	3,250	3,252	3,349	3,678	4,552	4,365	4,552	4,552	4,500	4,150	3,700	3,400
Avg	2,128	2,141	2,415	2,774	3,129	3,488	3,738	3,720	3,330	2,771	2,438	2,242

Table C.A-6. CALSIM-Simulated Monthly Distribution of Sacramento River at Keswick Dam Flows (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	2,686	3,250	3,250	3,250	3,250	3,250	3,250	3,773	7,283	8,616	7,053	4,026	4,258
10%	4,569	3,634	3,250	3,250	3,250	3,250	3,390	5,453	8,843	10,948	8,638	4,586	4,541
20%	5,071	4,243	3,466	3,250	3,250	3,250	4,500	6,116	9,405	11,744	9,222	5,002	5,016
30%	5,542	4,398	3,946	3,439	3,250	3,250	4,674	6,536	9,690	12,114	9,688	5,215	5,285
40%	5,811	4,693	4,000	3,805	3,878	3,578	5,595	7,171	10,016	12,617	10,110	5,536	5,633
50%	6,101	4,915	4,260	4,355	4,500	4,500	5,881	7,655	10,382	13,031	10,501	5,982	6,424
60%	6,433	5,290	4,541	4,500	5,748	4,500	6,443	8,151	11,013	13,601	10,718	6,398	7,031
70%	7,428	5,589	6,361	7,627	9,363	8,789	7,178	9,000	11,423	14,362	11,129	7,140	7,630
80%	8,603	7,059	10,673	12,895	18,724	12,828	8,284	9,139	11,890	15,000	11,520	9,366	8,858
90%	9,030	8,982	16,051	20,739	27,408	18,579	11,598	10,914	12,553	15,000	12,504	11,338	12,555
Max	9,996	27,986	29,991	52,735	44,007	46,295	30,037	15,837	18,485	16,277	14,207	12,991	6,253
Avg	6,530	5,845	7,267	8,614	10,355	8,728	7,038	7,967	10,742	13,123	10,476	6,899	6,253
B. ESO_ELT													
Min	2,732	2,911	3,250	3,250	3,250	3,250	3,250	3,873	7,424	9,230	3,348	2,356	3,488
10%	4,000	3,503	3,250	3,250	3,250	3,250	3,702	5,354	8,423	11,084	7,998	3,900	4,203
20%	4,568	4,000	3,259	3,250	3,250	3,250	4,500	5,931	9,375	12,102	8,529	4,336	4,452
30%	5,276	4,034	3,493	3,251	3,250	3,250	4,500	6,437	9,853	12,734	9,220	4,775	4,752
40%	5,677	4,388	4,000	3,901	3,715	3,920	5,019	6,732	10,498	13,508	9,639	5,351	5,001
50%	5,883	4,501	4,000	4,184	4,500	4,500	5,394	7,336	10,985	14,495	10,000	5,870	5,801
60%	6,259	4,761	4,241	4,500	5,363	4,738	6,106	7,749	11,444	15,000	10,481	7,594	6,686
70%	6,658	5,308	4,957	8,978	12,340	8,183	6,833	8,379	12,560	15,000	10,827	9,169	7,254
80%	7,024	5,921	8,981	14,353	21,412	12,188	8,048	9,290	13,445	15,000	11,252	10,970	7,907
90%	7,635	7,182	18,198	19,972	29,844	18,666	10,228	10,396	14,760	15,086	12,531	12,898	9,142
Max	9,042	27,138	33,201	58,978	51,790	47,351	30,893	13,219	15,066	16,041	15,000	15,346	12,685
Avg	5,882	5,337	7,255	9,126	11,272	8,697	6,797	7,616	11,274	13,639	10,049	7,430	6,295
C. ESO_LLT													
Min	2,794	2,870	3,059	3,250	3,250	3,250	3,250	3,250	6,217	6,051	2,703	2,803	3,112
10%	4,000	3,489	3,250	3,250	3,250	3,250	3,720	5,232	8,503	10,451	7,563	3,771	4,126
20%	4,554	4,000	3,384	3,250	3,250	3,250	4,500	5,713	10,007	11,257	8,200	4,206	4,565
30%	5,501	4,000	3,667	3,292	3,250	3,422	4,500	6,237	10,861	12,541	8,928	4,721	5,009
40%	6,083	4,242	4,000	3,997	3,565	4,113	4,852	6,866	11,449	13,443	9,634	5,540	5,206
50%	6,605	4,482	4,000	4,482	4,500	4,500	5,657	7,553	12,235	14,092	10,004	7,107	5,669
60%	6,917	4,913	4,195	4,500	4,732	4,784	6,173	7,990	13,033	15,000	10,354	8,964	6,722
70%	7,552	5,136	4,488	8,258	10,115	7,007	7,156	8,987	13,654	15,000	10,647	11,417	7,290
80%	8,051	6,050	6,603	13,647	22,983	12,351	8,490	9,614	14,394	15,000	11,395	12,880	8,258
90%	8,726	7,472	15,302	20,808	30,081	20,167	10,549	11,627	14,977	15,155	12,459	14,741	9,356
Max	13,169	24,163	32,513	60,328	51,105	46,363	30,978	15,000	15,000	16,420	15,000	15,662	12,476
Avg	6,555	5,288	6,587	9,235	11,261	8,834	6,852	7,915	12,008	13,421	9,757	8,248	6,390

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	2,836	3,250	3,250	3,250	3,250	3,250	3,250	3,739	7,297	8,618	7,054	3,365	3,569
10%	4,236	3,483	3,250	3,250	3,250	3,250	3,702	5,340	8,958	10,712	8,740	4,448	4,226
20%	4,892	4,008	3,252	3,250	3,250	3,250	4,500	5,969	9,561	11,779	9,166	5,031	4,510
30%	5,566	4,358	3,524	3,250	3,255	3,301	4,535	6,514	9,761	12,341	9,557	5,586	4,892
40%	5,791	4,668	3,842	3,811	3,919	3,947	5,349	6,854	10,121	12,826	10,101	5,894	5,235
50%	5,971	5,196	4,000	4,333	4,500	4,500	5,678	7,526	10,464	13,319	10,613	6,552	5,717
60%	6,270	5,859	4,239	4,500	4,500	4,500	6,264	8,192	10,966	13,815	10,847	8,125	6,565
70%	6,628	6,927	5,348	7,438	9,287	8,305	7,131	8,962	11,527	14,871	11,098	9,953	7,096
80%	7,426	8,853	8,732	10,515	18,724	11,832	7,685	9,199	12,054	15,000	11,857	12,194	7,736
90%	8,711	9,871	15,046	18,980	27,436	18,400	11,571	10,801	12,853	15,000	12,773	13,110	9,025
Max	9,992	27,546	26,142	52,735	44,007	46,295	30,037	15,837	18,485	16,218	14,304	16,438	12,453
Avg	6,196	6,348	6,694	8,274	10,217	8,560	6,899	7,856	10,838	13,219	10,557	8,070	6,259
E. EBC2_ELT													
Min	2,615	2,911	3,250	3,250	3,250	3,250	3,250	3,577	7,416	9,064	3,724	3,027	3,403
10%	4,000	3,483	3,250	3,250	3,250	3,250	3,702	5,164	8,420	10,796	8,334	3,999	4,151
20%	4,572	4,000	3,270	3,250	3,250	3,250	4,500	5,919	8,914	11,930	8,886	4,480	4,442
30%	5,430	4,253	3,528	3,325	3,250	3,250	4,500	6,323	9,867	12,706	9,343	5,118	4,814
40%	5,786	4,628	3,871	3,982	3,669	3,753	5,034	6,485	10,127	13,356	9,709	5,692	5,197
50%	5,950	5,143	4,000	4,482	4,500	4,500	5,490	7,016	10,496	13,979	10,115	6,857	5,758
60%	6,504	6,005	4,298	4,500	4,798	4,500	5,893	7,638	11,040	14,624	10,377	8,516	6,804
70%	6,759	7,468	5,256	8,759	11,833	7,719	6,866	7,953	11,472	14,971	10,885	10,133	7,371
80%	7,234	8,669	10,503	11,726	21,412	12,188	7,646	8,608	12,694	15,000	11,466	11,615	7,965
90%	8,223	10,203	16,985	19,967	29,826	18,389	10,159	9,640	13,638	15,000	12,131	13,463	9,130
Max	10,094	28,457	33,201	58,978	51,790	47,351	30,893	13,219	15,066	15,177	14,087	15,000	12,732
Avg	6,038	6,399	7,278	8,829	11,015	8,577	6,748	7,321	10,797	13,424	10,108	7,926	6,300
F. EBC2_LLT													
Min	2,693	2,884	3,209	3,250	3,250	3,250	3,250	3,250	7,385	4,655	2,703	2,708	3,316
10%	4,000	3,488	3,250	3,250	3,250	3,250	3,719	5,152	8,411	10,946	7,947	3,931	4,129
20%	4,746	4,000	3,270	3,250	3,250	3,250	4,500	5,452	9,142	12,171	9,316	4,401	4,605
30%	5,645	4,070	3,516	3,251	3,250	3,250	4,500	6,003	9,933	12,809	9,708	4,651	4,939
40%	6,046	4,411	3,830	3,947	3,565	3,753	4,803	6,353	10,506	13,901	10,065	5,448	5,266
50%	6,558	4,920	4,000	4,482	4,500	4,500	5,443	6,832	10,924	14,614	10,472	6,372	5,776
60%	7,209	5,980	4,326	4,500	4,500	4,500	6,119	7,428	11,643	15,000	10,867	8,654	6,620
70%	7,800	7,335	4,796	9,386	9,054	7,710	6,649	7,885	12,368	15,000	11,454	10,764	7,312
80%	8,567	9,100	7,205	11,727	21,836	12,767	7,995	8,717	13,151	15,000	11,791	12,938	8,136
90%	9,552	10,388	16,297	20,731	30,081	20,167	10,223	10,849	14,209	15,000	12,290	14,750	9,392
Max	14,104	23,506	32,513	60,146	51,005	46,363	30,978	12,313	15,000	20,916	16,592	15,399	12,305
Avg	6,752	6,324	6,557	9,215	11,039	8,800	6,733	7,233	11,160	13,689	10,269	8,094	6,385

Table C.A-7. CALSIM-Simulated Monthly Distribution of Sacramento River Flow (cfs) at Wilkins Slough

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	3,151	3,621	4,036	4,567	4,882	5,427	4,862	4,666	5,526	5,565	4,989	3,574	4,034
10%	4,525	4,821	5,197	5,978	6,401	6,016	5,624	5,046	6,194	7,114	5,920	4,636	4,927
20%	5,152	5,162	5,690	7,545	8,386	8,512	6,326	5,672	6,773	7,296	6,500	5,305	5,524
30%	5,240	5,503	6,332	8,291	11,062	9,568	6,670	6,217	7,059	7,473	6,575	5,362	5,873
40%	5,431	5,785	7,794	9,937	13,533	11,678	6,937	6,398	7,198	7,884	6,601	5,449	6,169
50%	5,747	6,356	8,822	12,029	16,606	14,854	7,087	6,563	7,252	8,553	6,658	5,744	6,838
60%	6,195	6,862	12,467	17,750	19,911	16,491	7,691	6,739	7,320	9,394	7,344	6,249	7,762
70%	7,405	7,843	15,450	19,481	20,924	19,051	10,350	7,364	7,550	9,647	7,898	7,244	8,233
80%	8,540	10,039	19,881	21,305	21,548	20,293	16,956	10,137	8,271	10,147	8,263	9,557	8,594
90%	9,491	14,519	21,354	22,354	22,759	21,663	19,193	13,809	9,067	10,416	8,910	11,616	9,940
Max	15,096	21,678	22,810	24,057	24,537	24,249	22,121	20,085	20,653	14,498	10,857	14,554	12,877
Avg	6,600	7,865	11,633	13,912	15,476	14,269	10,100	8,256	7,719	8,774	7,297	6,955	7,159
B. ESO_ELT													
Min	2,912	3,283	3,930	5,029	4,743	5,133	3,285	3,272	3,335	3,284	3,252	2,605	3,360
10%	4,033	4,514	5,030	6,013	6,419	6,560	3,638	3,595	4,464	5,093	3,527	3,586	4,282
20%	4,855	4,895	5,586	7,226	7,566	8,738	4,438	4,267	4,866	5,534	4,010	4,094	4,801
30%	5,152	5,191	5,952	8,092	10,998	9,581	4,798	4,610	5,207	6,349	4,520	4,557	5,181
40%	5,367	5,669	7,597	9,961	12,955	11,416	5,126	4,866	5,363	7,191	5,014	4,948	5,351
50%	5,721	6,242	8,897	11,428	16,510	13,819	5,413	5,191	5,619	7,414	5,034	5,742	6,374
60%	6,037	6,877	12,193	18,051	19,504	16,107	6,201	5,520	6,004	7,929	5,149	6,898	7,242
70%	6,207	7,676	15,521	19,576	20,968	18,871	9,223	6,726	7,038	8,067	5,578	8,873	7,921
80%	6,600	9,325	19,919	21,170	21,457	20,155	15,990	8,677	7,463	8,536	6,631	10,681	8,339
90%	7,299	11,821	21,190	22,023	22,693	21,586	17,990	11,665	8,284	8,991	7,205	12,614	8,994
Max	10,980	21,627	23,027	23,871	24,350	24,094	21,554	18,883	17,683	10,208	10,107	15,000	11,742
Avg	5,764	7,419	11,463	13,788	15,373	14,095	8,608	6,716	6,233	7,134	5,303	7,187	6,565
C. ESO_LLT													
Min	2,788	3,283	3,991	4,874	3,910	5,159	3,312	3,272	3,335	3,263	3,018	3,255	3,497
10%	3,771	4,088	5,093	6,627	6,349	7,239	3,632	3,862	4,319	4,074	3,509	3,510	4,386
20%	5,059	4,731	5,648	7,527	7,520	8,801	4,427	4,304	5,313	5,471	3,869	4,021	4,888
30%	5,189	5,252	6,338	8,344	10,974	9,500	4,810	4,812	5,583	6,235	4,056	4,558	5,245
40%	5,610	5,837	7,781	10,336	12,882	11,132	5,165	5,474	6,246	6,935	4,751	5,433	5,597
50%	6,062	6,444	8,843	12,362	17,143	13,812	5,947	6,359	6,912	7,546	5,056	6,699	6,578
60%	6,568	7,150	12,012	16,614	19,562	16,023	7,447	7,216	7,415	8,007	5,358	8,911	7,459
70%	7,163	8,089	13,994	19,750	20,922	18,646	9,098	7,702	7,764	8,284	5,897	10,891	8,217
80%	7,750	9,360	19,108	21,149	21,544	20,016	14,857	8,163	8,415	8,627	6,753	12,817	8,566
90%	9,298	11,246	21,029	22,131	22,662	21,720	18,076	11,684	9,196	9,178	7,146	14,610	9,177
Max	13,162	21,481	22,911	23,889	24,329	24,063	21,527	18,492	17,650	9,516	10,071	15,257	10,954
Avg	6,409	7,376	11,300	13,890	15,331	14,077	8,642	7,043	6,968	7,041	5,286	8,058	6,705

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	3,226	3,621	3,983	5,081	4,848	5,403	4,723	4,664	5,536	5,585	4,926	3,598	4,005
10%	4,533	4,615	4,827	6,152	6,603	6,426	5,488	5,025	6,184	7,061	5,714	4,375	4,842
20%	5,059	4,915	5,618	7,220	7,928	8,628	6,131	5,524	6,637	7,161	6,421	4,904	5,495
30%	5,255	5,820	6,120	8,312	11,136	9,668	6,410	5,831	7,043	7,623	6,524	5,508	5,811
40%	5,388	6,728	7,549	9,938	13,133	11,724	6,708	6,098	7,215	8,052	6,597	5,860	6,122
50%	5,628	7,467	8,966	11,350	16,728	14,716	7,071	6,499	7,263	8,702	6,706	6,475	6,845
60%	5,911	8,577	12,292	16,728	19,916	16,321	7,694	6,681	7,431	9,479	7,171	7,712	7,803
70%	6,453	10,137	15,073	19,379	20,930	18,671	10,416	7,304	7,695	9,829	7,818	10,318	8,484
80%	7,392	11,549	19,496	21,307	21,549	20,297	17,000	10,185	8,564	10,104	8,375	12,190	8,977
90%	9,053	12,982	21,077	22,031	22,716	21,666	19,222	13,782	9,244	10,548	9,658	13,252	9,850
Max	14,073	21,690	22,809	24,057	24,539	24,249	22,128	20,122	20,588	13,778	11,167	15,304	12,722
Avg	6,233	8,488	11,405	13,816	15,445	14,280	10,028	8,129	7,759	8,776	7,283	8,076	7,208
E. EBC2_ELT													
Min	2,815	3,369	3,950	4,499	4,860	5,379	4,687	4,581	5,378	5,346	3,863	3,372	3,837
10%	4,017	4,195	4,829	6,311	6,600	6,284	5,214	4,833	6,129	7,080	5,550	3,890	4,989
20%	4,832	4,925	5,717	7,499	7,522	8,770	6,077	5,353	6,718	7,348	6,075	4,429	5,404
30%	5,385	6,158	6,168	8,396	11,076	9,672	6,330	5,801	7,038	8,331	6,491	5,056	5,750
40%	5,542	7,038	7,591	9,990	13,272	11,582	6,513	5,980	7,220	8,948	6,579	5,783	6,036
50%	5,824	7,747	8,927	11,414	16,673	13,831	6,986	6,271	7,356	9,590	6,689	6,651	6,888
60%	6,198	8,651	12,252	16,689	19,721	16,255	7,503	6,751	7,701	9,886	6,844	8,718	7,854
70%	6,814	10,027	15,320	19,835	21,069	18,755	10,548	7,104	8,153	10,107	7,209	9,755	8,629
80%	7,271	11,531	20,361	21,451	21,614	20,318	17,205	9,708	8,860	10,534	7,672	12,149	9,068
90%	7,868	12,734	21,172	22,303	22,863	21,750	18,956	12,678	9,651	10,732	8,947	13,412	9,566
Max	14,370	21,750	23,240	24,186	24,662	24,249	22,185	19,722	19,734	12,554	10,988	15,409	12,342
Avg	6,123	8,566	11,544	13,887	15,469	14,192	9,922	7,757	7,826	9,096	6,984	7,990	7,186
F. EBC2_LLT													
Min	2,944	3,377	3,767	4,381	4,325	5,387	4,691	4,580	5,377	4,274	3,633	3,000	3,822
10%	4,146	4,117	5,075	6,217	6,545	6,205	5,231	4,875	6,217	7,050	5,438	3,869	5,026
20%	5,190	5,061	5,752	7,534	7,487	8,654	5,959	5,518	6,921	7,623	6,292	4,314	5,597
30%	5,661	5,752	6,317	8,495	11,096	9,755	6,151	5,871	7,304	8,952	6,609	4,781	5,920
40%	6,278	7,044	7,541	10,542	13,131	11,312	6,570	6,118	7,593	9,526	6,778	5,545	6,217
50%	6,871	7,877	8,924	12,196	17,374	13,490	7,000	6,431	8,153	9,937	7,108	6,246	6,991
60%	7,258	9,009	12,010	16,657	19,787	16,149	7,816	7,150	8,448	10,279	7,530	9,388	8,161
70%	7,900	10,226	14,094	19,976	20,986	18,829	10,554	8,149	8,873	10,513	7,799	10,887	8,660
80%	8,734	11,234	19,077	21,352	21,662	20,485	16,537	9,133	9,408	10,802	8,549	13,480	9,129
90%	9,419	13,517	21,266	22,419	22,884	21,963	19,002	10,638	10,245	11,113	9,346	13,950	9,654
Max	12,216	21,466	23,150	24,197	24,662	24,249	22,171	19,464	19,719	17,207	13,305	15,398	11,540
Avg	6,851	8,504	11,346	14,019	15,466	14,165	9,879	7,697	8,239	9,446	7,289	8,186	7,291

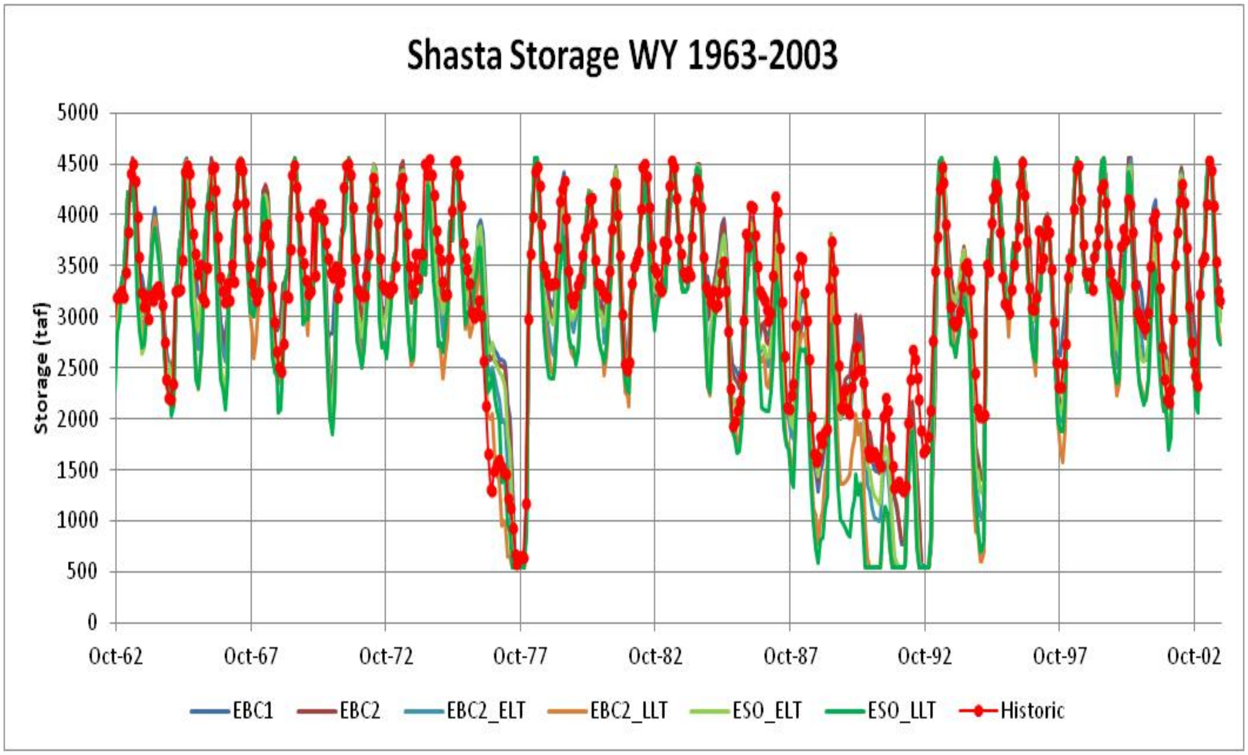


Figure C.A-5. CALSIM-Simulated Monthly Shasta Reservoir Storage for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

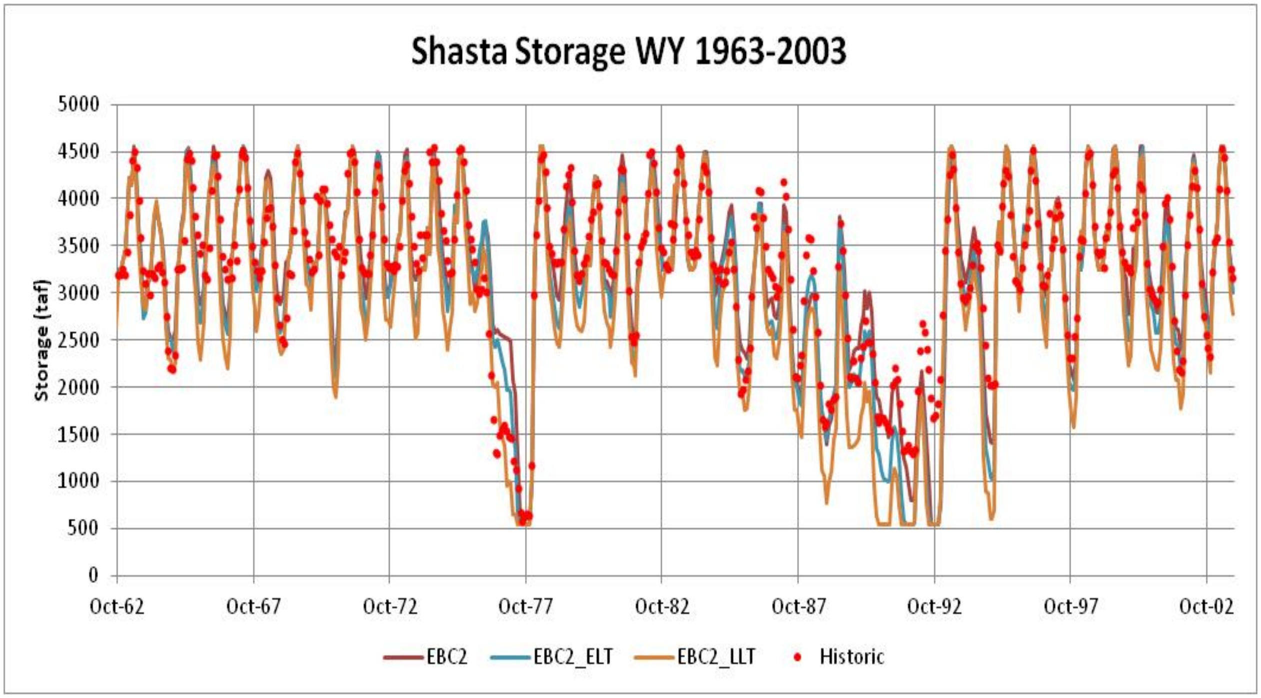


Figure C.A-6. CALSIM-Simulated Monthly Shasta Reservoir Storage for WY 1963–2003 for the and EBC2, EBC2_ELT and EBC2_LLT Showing Effects of Climate Change

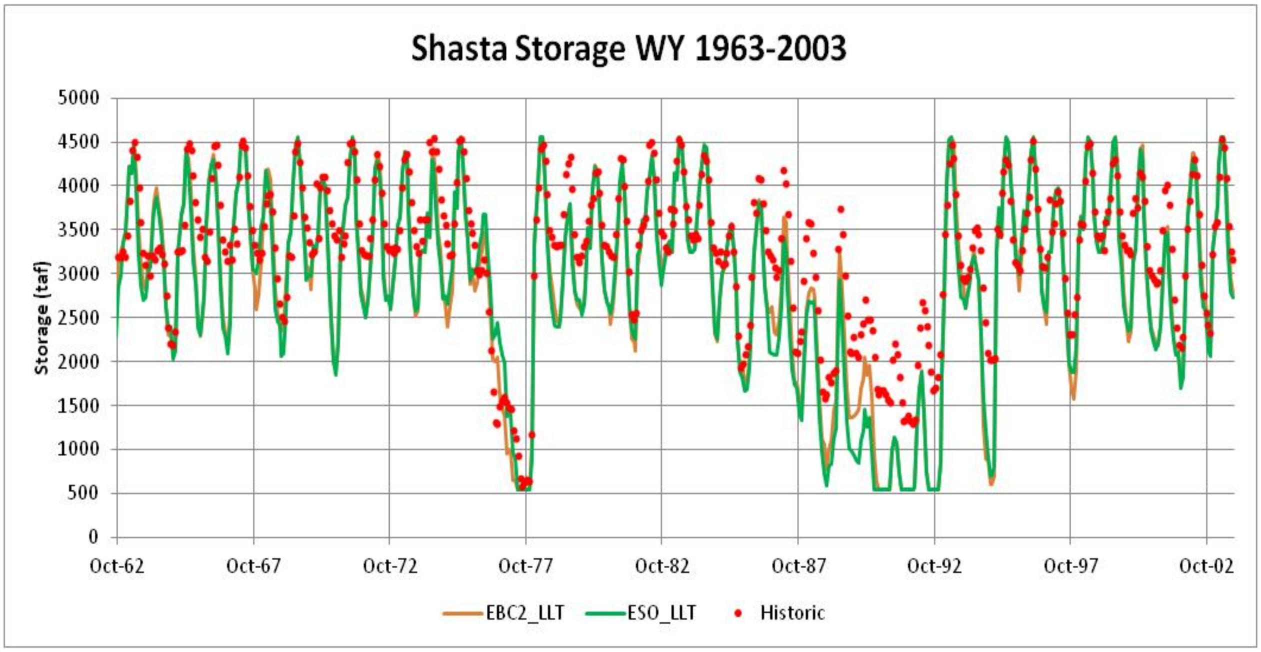


Figure C.A-7. CALSIM-Simulated Monthly Shasta Reservoir Storage for WY 1963–2003 for the and EBC2_LLT and ESO_LLT Showing Effects of BDCP

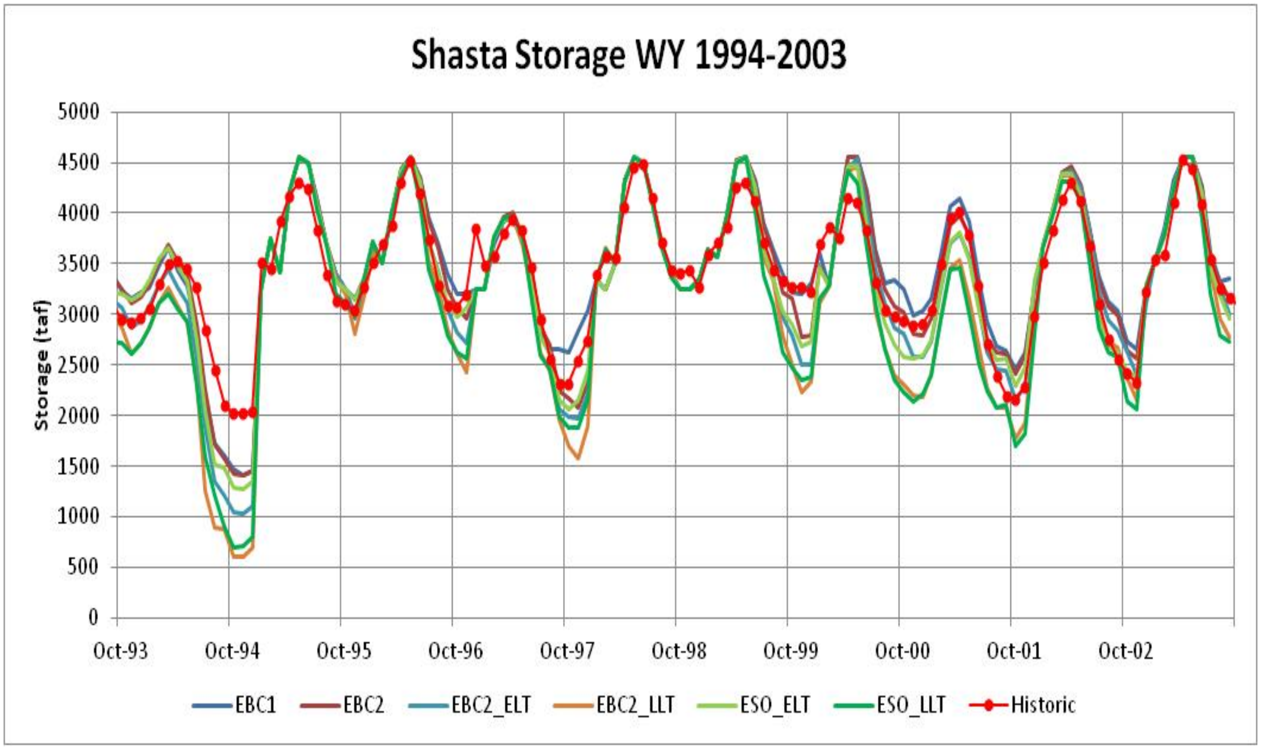


Figure C.A-8. CALSIM-Simulated Monthly Shasta Reservoir Storage for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

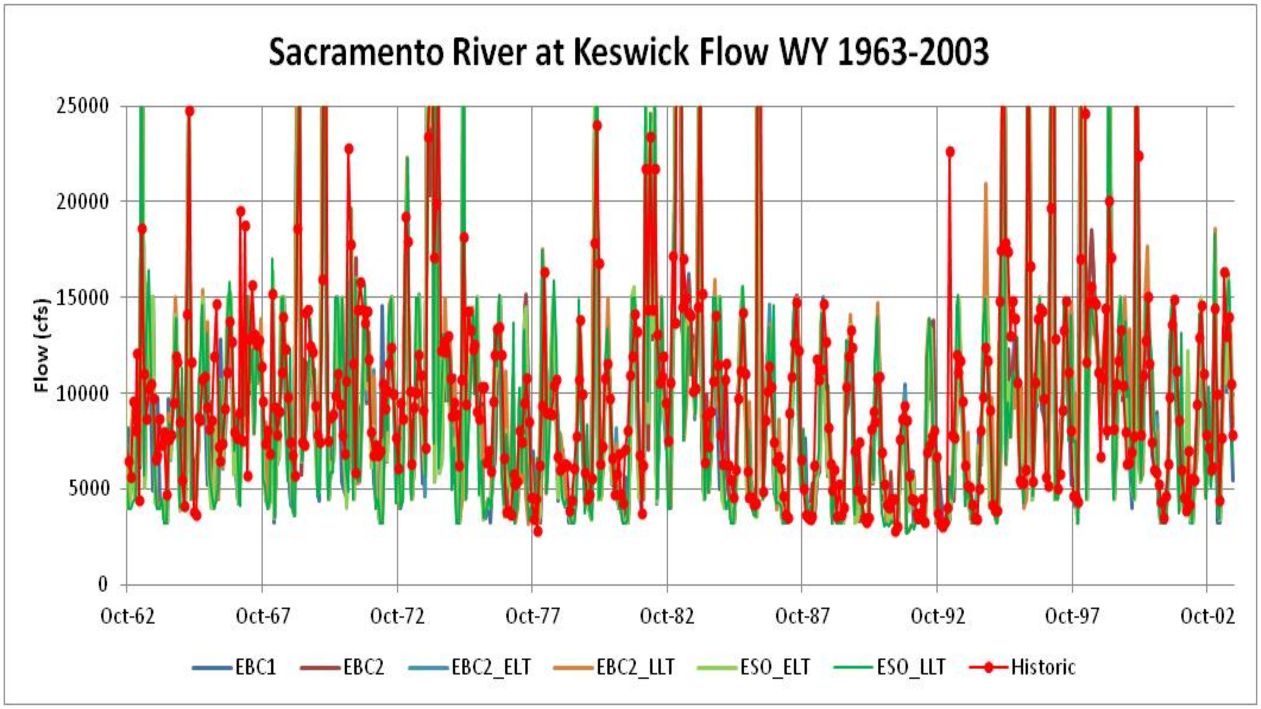


Figure C.A-9. CALSIM-Simulated Monthly Sacramento River Flow at Keswick for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

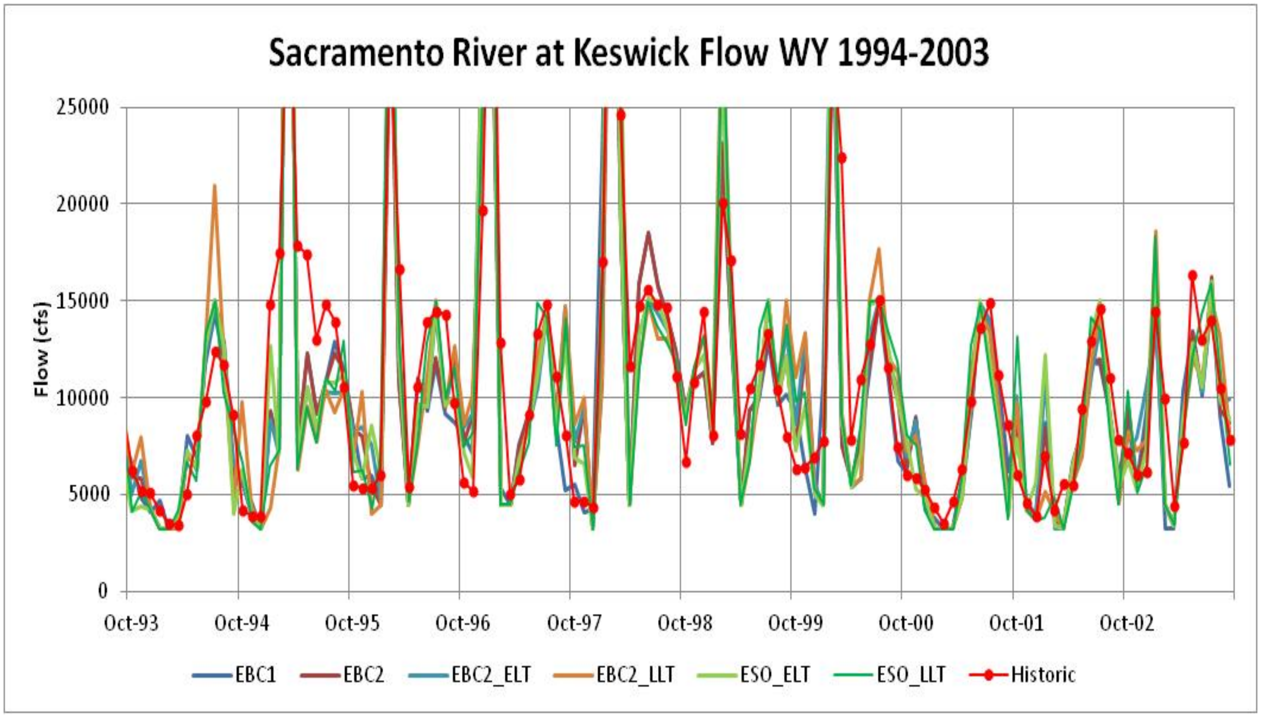


Figure C.A-10. CALSIM-Simulated Monthly Sacramento River Flow at Keswick for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.3.3 Simulated Changes in Oroville Reservoir Operations for the ESO

Table C.A-8 gives the monthly distributions of the CALSIM-simulated Oroville Reservoir storage patterns for the six CALSIM cases. The maximum storage of about 3,500 taf was simulated only in May and June. The maximum flood control storage is about 3,150 taf from October to March. There are some variations caused by runoff conditions (snow vs. rain) but this generally limits the amount of water that can be stored in the winter months of January–March. The Oroville Reservoir maximum flood control storage increases in April, and full storage is allowed in May. The EBC1 monthly median storage volumes for Oroville Reservoir were about 2,000 taf in October and November, increased to about 2,750 taf in January–March, and were about 3,250 taf in April–June, decreasing during the summer to 2,000 taf in September.

The simulated Oroville Reservoir carryover storage for the three EBC2 cases were lower than EBC1 in September and October because some of the increased Delta outflow needed to meet the Fall X2 requirements was released from Oroville. The median September storage for the EBC2 was about 250 taf lower, the median October storage was about 300 taf lower and the median November storage was about 300 taf lower than the corresponding EBC1 storage. The median storage in September–November for the EBC2_ELT case was about 200 taf below the EBC2 case, and the median storage in September–November for the EBC2_LLT case was about 400 taf lower than the EBC2 case. The median storage for the ESO_ELT case was slightly lower than the EBC2_ELT case and median storage for the ESO_LLT case was slightly higher than the EBC2_LLT case. The changes in storage for the Fall X2 was substantial, but the changes for the ESO cases were not very great.

Figure C.A-11 shows the simulated monthly Oroville Reservoir storage for the six CALSIM cases for the 1963–2003 sequence. This historical Oroville storage is shown for comparison. The simulated carryover storage was reduced by 500 taf for the EBC2_ELT and by 1,000 taf for the EBC2_LLT in several years when the EBC1 (and historical) carryover storage was between 1,500 taf and 3,000 taf. When the EBC1 Oroville carryover storage was about 1,000 taf (target minimum storage), the carryover storage for the EBC2 cases and the ESO cases were similar, although minimum storage of about 750 taf was simulated in several years for the ESO_LLT case. The minimum target storage of 1,000 taf was simulated in many more years for the EBC2_LLT and ESO_LLT cases. Figure C.A-12 shows the simulated monthly Oroville Reservoir storage for the six CALSIM cases for the 1994–2003 sequence. Although these 10 years were relatively wet, the additional drawdown in WY 1993 (beginning of graph sequence) was not recovered by runoff in WY 1994 and the additional drawdown in WY 2000 was not recovered in WY 2001. The additional Oroville storage drawdown at the end of the simulation (WY 2003) for the ESO cases was more than 500 taf compared to the EBC2 cases. Although the EBC2 and ESO cases were similar in many years, the simulated changes in runoff under LLT conditions caused a reduction in the carryover storage compared to the EBC2 and EBC2_ELT conditions. The ESO cases (ELT and LLT) were often similar to the EBC2 cases.

Table C.A-9 gives the CALSIM-simulated Feather River flow below the Thermalito release to the river (upstream of Gridley). There is a constant release of 900 cfs into the low-flow section of the Feather River between the Feather River Hatchery and the Thermalito discharge. The minimum flows in the October to March period range from 900 cfs to 1,700 cfs. The minimum flows in April and May are 1,000 cfs. For the EBC2 cases, the median flows in April, May and June are relatively low, reflecting the 2008 USFWS BiOp and 2009 NMFS BiOp limitations on Delta exports during these months. Simulated releases from Oroville Reservoir increase dramatically in July and August, corresponding to the increased Delta E/I ratio of 65% and the peak water supply demands in the summer months. In comparison, the ESO_ELT and ESO_LLT cases show increased Oroville Reservoir releases in April, May, and June and decreased Oroville Reservoir releases in July, August, and September.

Figure C.A-13 shows the simulated Feather River flows at Thermalito (discharge to river) for the six CALSIM cases for the 1963–2003 sequence. Historical flows at Gridley are shown for comparison. The monthly flows are generally between 1,000 cfs (minimum flow requirement) and 10,000 cfs, but several years had higher monthly flows of 25,000 cfs to 50,000 cfs caused by flood control releases from Oroville Reservoir. The major differences between the flows were the magnitude of the flood control releases caused by different inflow sequences assumed for the existing (EBC1 and EBC2) and the ELT and LLT conditions. Figure C.A-14 shows the simulated monthly Feather River flows below Thermalito for the six CALSIM cases for the 1994–2003 sequence. The higher flows (flood control spills) and the monthly flows in the summer and fall months (i.e., controlled releases) of some years were different for each of the cases.

Table C.A-10 gives the CALSIM pre-calculated Yuba River flows that join the Feather River at Marysville. The median monthly flows follow the same seasonal pattern as the Feather River and Sacramento River flows. The median monthly flows for the EBC1 case are about 500 cfs in October, about 750 cfs in November, about 1,000 cfs in December, about 2,500 cfs in January, about 3,000 cfs in February, about 2,500 cfs in March and April, about 2,000 cfs in May, about 1,250 in June, and about 500 cfs in July–September. The total annual flow for the EBC1 and EBC2 cases were about 1,455 taf/yr. The average annual flow for the ELT cases (EBC2 and ESO) were 1,465 taf/yr and the average annual flow for the LLT cases (EBC2 and ESO) were 1,430 taf/yr. It is not obvious from the CALSIM inputs for the Yuba River flows that the Yuba Accord flow requirements have been included. The CALSIM Yuba River flows in June, July, August and September were less than 100 cfs in many years.

Table C.A-11 gives the CALSIM-simulated Feather River flow near the confluence, but not including the Sutter Bypass (or Butte Creek flows) for the six CALSIM cases. The Feather River flow below Thermalito (near Gridley) was increased by the Yuba River and Bear River, and a few smaller tributary streams. The average simulated annual volume of the Feather River at the mouth is about 5,600 taf/yr for the EBC1, about 2,425 taf/yr more than the Feather River below Thermalito. Much of this water is from the Yuba River (average flow at Marysville of about 1,450 taf) and the Bear River (average unimpaired flow of about 320 taf/yr). The assumed effects of climate change reduced the average annual flow (EBC1 and EBC2) by about 25 taf/yr for the EBC2_ELT and by about 75 taf/yr for the EBC2_LLT cases.

The Sutter Bypass joins the Feather River about nine miles upstream from the mouth of the Feather River at Verona. The Sutter Bypass flows into the Sacramento River just across from the Fremont Weir (with a crest elevation of 33.5 feet) that spills water into the Yolo Bypass when the combined Sacramento River, Sutter Bypass, and Feather River flow is greater than about 55,000 cfs. Because the spills into the Yolo Bypass are thought to provide fish habitat benefits, the BDCP would include a gated notch in the Fremont Weir to allow controlled diversions to Yolo Bypass when Sacramento River flows are greater than about 25,000 cfs. Procedures to estimate daily flows at Verona was therefore included in the monthly CALSIM model, to allow a more accurate evaluation of the diversions into Yolo Bypass for the ESO cases. The next section compares daily and monthly flows in the Sacramento River and describes the CALSIM daily estimation procedures.

The Oroville Reservoir operations will have effects on aquatic resources (fish) by changing the reservoir storage levels (drawdown) and affecting the cold-water pool (volume) remaining at the end of each water year. The Oroville Reservoir operations will also affect the Feather River flows and the release temperatures, as well as the discharge temperatures from Thermalito Afterbay and downstream in the Feather River. The effects of Oroville Reservoir operations on Feather River water temperatures for existing runoff and air temperature conditions and with climate change assumptions are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

Table C.A-8. CALSIM-Simulated Monthly Distribution of Oroville Reservoir Storage (taf)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	630	654	807	1,009	1,097	1,212	1,139	1,079	870	634	634	642
10%	1,031	1,065	1,145	1,293	1,480	1,720	1,759	2,024	1,858	1,283	1,065	1,012
20%	1,156	1,220	1,291	1,490	1,892	2,248	2,563	2,666	2,467	1,885	1,378	1,194
30%	1,443	1,426	1,512	1,891	2,203	2,584	2,807	2,847	2,697	2,105	1,614	1,464
40%	1,690	1,792	2,004	2,217	2,588	2,788	3,100	3,179	3,025	2,422	2,010	1,828
50%	2,031	2,081	2,337	2,688	2,788	2,841	3,205	3,371	3,199	2,651	2,232	2,099
60%	2,169	2,291	2,559	2,788	2,788	2,938	3,237	3,520	3,380	2,789	2,399	2,239
70%	2,408	2,583	2,787	2,792	2,853	2,981	3,293	3,538	3,538	2,959	2,563	2,461
80%	2,778	2,876	2,812	2,869	2,946	3,025	3,352	3,538	3,538	3,037	2,862	2,831
90%	3,161	3,046	2,987	2,976	3,052	3,116	3,395	3,538	3,538	3,378	3,278	3,221
Max	3,163	3,163	3,163	3,163	3,211	3,163	3,470	3,538	3,538	3,538	3,538	3,351
Avg	1,980	2,032	2,141	2,305	2,470	2,644	2,918	3,053	2,945	2,460	2,162	2,054
B. ESO_ELT												
Min	627	649	860	1,042	1,051	1,132	1,051	976	747	685	672	668
10%	1,023	1,039	1,146	1,291	1,431	1,692	1,815	1,739	1,571	1,321	1,097	1,020
20%	1,118	1,204	1,230	1,444	1,798	2,015	2,189	2,175	1,954	1,504	1,191	1,150
30%	1,243	1,296	1,389	1,601	1,980	2,406	2,568	2,644	2,332	1,748	1,461	1,301
40%	1,358	1,424	1,573	1,839	2,233	2,624	2,997	2,948	2,551	1,986	1,716	1,459
50%	1,475	1,523	1,818	2,165	2,621	2,788	3,139	3,149	2,769	2,168	1,817	1,595
60%	1,646	1,761	2,093	2,556	2,788	2,868	3,218	3,387	2,999	2,387	1,921	1,719
70%	1,846	1,985	2,236	2,692	2,788	2,944	3,280	3,502	3,111	2,518	2,190	1,908
80%	2,071	2,202	2,447	2,788	2,845	2,994	3,315	3,538	3,388	2,830	2,475	2,145
90%	2,340	2,451	2,788	2,813	2,952	3,059	3,365	3,538	3,538	3,070	2,756	2,469
Max	3,163	3,008	3,107	3,091	3,101	3,163	3,470	3,538	3,538	3,522	3,497	3,351
Avg	1,592	1,662	1,861	2,118	2,359	2,566	2,821	2,907	2,656	2,178	1,874	1,663
C. ESO_LLT												
Min	600	617	652	677	686	986	868	790	731	667	650	645
10%	838	838	1,014	1,257	1,413	1,616	1,607	1,491	1,278	1,080	976	886
20%	1,026	1,044	1,167	1,399	1,636	1,908	2,057	2,051	1,813	1,425	1,107	1,081
30%	1,125	1,181	1,324	1,525	1,889	2,168	2,507	2,521	2,131	1,610	1,275	1,197
40%	1,228	1,270	1,447	1,685	2,117	2,574	2,756	2,729	2,303	1,872	1,558	1,330
50%	1,333	1,396	1,602	1,924	2,564	2,788	3,106	3,014	2,561	2,011	1,648	1,448
60%	1,476	1,515	1,867	2,318	2,773	2,841	3,213	3,291	2,779	2,167	1,777	1,561
70%	1,574	1,712	1,992	2,605	2,788	2,941	3,262	3,355	2,890	2,271	1,971	1,714
80%	1,811	1,903	2,230	2,788	2,796	2,985	3,292	3,538	3,093	2,599	2,259	1,845
90%	1,982	2,133	2,686	2,843	2,924	3,035	3,354	3,538	3,398	2,790	2,459	2,092
Max	2,829	2,950	3,107	3,538	3,207	3,163	3,470	3,538	3,538	3,441	3,357	2,978
Avg	1,404	1,470	1,703	2,027	2,295	2,515	2,746	2,771	2,454	1,986	1,689	1,474

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	710	759	823	951	966	1,210	1,099	1,041	823	766	766	749
10%	945	987	1,151	1,345	1,518	1,767	1,917	1,973	1,735	1,197	1,044	972
20%	1,161	1,187	1,271	1,552	1,833	2,138	2,387	2,469	2,303	1,697	1,299	1,186
30%	1,353	1,311	1,493	1,747	2,016	2,368	2,676	2,844	2,645	2,076	1,643	1,453
40%	1,627	1,624	1,730	1,973	2,375	2,784	3,045	3,122	2,937	2,326	1,898	1,628
50%	1,732	1,818	1,995	2,268	2,651	2,806	3,161	3,281	3,119	2,545	2,150	1,834
60%	1,931	2,048	2,195	2,554	2,788	2,914	3,227	3,489	3,297	2,675	2,290	1,967
70%	2,100	2,185	2,387	2,729	2,788	2,953	3,283	3,538	3,538	2,952	2,547	2,163
80%	2,285	2,409	2,733	2,788	2,844	3,014	3,320	3,538	3,538	3,030	2,820	2,335
90%	2,651	2,744	2,799	2,853	2,961	3,063	3,362	3,538	3,538	3,315	3,213	2,778
Max	3,163	3,119	3,139	3,091	3,078	3,163	3,470	3,538	3,538	3,538	3,538	3,351
Avg	1,773	1,831	1,973	2,175	2,385	2,594	2,867	3,005	2,892	2,406	2,105	1,837
E. EBC2_ELT												
Min	643	665	840	995	1,167	1,182	1,062	987	764	701	689	685
10%	870	925	1,025	1,253	1,424	1,618	1,828	1,808	1,579	1,052	973	930
20%	1,011	1,079	1,221	1,483	1,732	2,011	2,204	2,285	2,060	1,491	1,117	1,063
30%	1,168	1,236	1,436	1,586	1,928	2,336	2,666	2,614	2,350	1,712	1,320	1,177
40%	1,372	1,457	1,624	1,835	2,312	2,642	2,844	2,962	2,753	2,164	1,752	1,454
50%	1,537	1,545	1,767	2,073	2,574	2,788	3,122	3,174	2,971	2,350	1,953	1,639
60%	1,708	1,827	1,961	2,413	2,788	2,831	3,218	3,387	3,195	2,539	2,117	1,749
70%	1,879	1,930	2,199	2,579	2,788	2,944	3,276	3,504	3,390	2,763	2,366	1,965
80%	1,966	2,054	2,435	2,788	2,804	2,994	3,303	3,538	3,535	2,939	2,540	2,047
90%	2,346	2,440	2,788	2,813	2,961	3,059	3,354	3,538	3,538	3,039	2,802	2,284
Max	3,163	3,008	3,025	3,091	3,153	3,163	3,470	3,538	3,538	3,522	3,497	3,351
Avg	1,564	1,636	1,838	2,088	2,349	2,555	2,816	2,913	2,764	2,230	1,894	1,624
F. EBC2_LLT												
Min	495	535	595	787	796	929	811	774	715	652	578	544
10%	786	804	904	1,161	1,407	1,627	1,667	1,497	1,305	942	834	805
20%	873	935	1,104	1,308	1,638	1,912	2,170	2,152	1,911	1,297	953	898
30%	1,050	1,098	1,231	1,512	1,875	2,290	2,411	2,369	2,121	1,496	1,164	1,076
40%	1,177	1,221	1,337	1,694	2,132	2,499	2,745	2,712	2,415	1,833	1,462	1,260
50%	1,321	1,354	1,533	1,912	2,384	2,786	3,013	3,042	2,816	2,190	1,691	1,406
60%	1,425	1,442	1,817	2,150	2,672	2,809	3,213	3,305	2,970	2,346	1,893	1,523
70%	1,543	1,680	1,962	2,516	2,788	2,937	3,245	3,396	3,148	2,498	2,070	1,655
80%	1,766	1,849	2,149	2,787	2,788	2,983	3,292	3,538	3,310	2,680	2,250	1,843
90%	1,902	2,079	2,701	2,788	2,961	3,056	3,354	3,538	3,535	2,894	2,432	1,931
Max	2,943	3,008	3,107	3,091	3,388	3,163	3,470	3,538	3,538	3,468	3,418	3,084
Avg	1,347	1,411	1,657	1,971	2,278	2,495	2,739	2,795	2,582	2,025	1,667	1,408

Table C.A-9. CALSIM-Simulated Monthly Distribution of Feather River Flows (cfs) below Thermalito Afterbay Discharge

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	900	900	900	800	900	800	750	750	856	1,441	750	773	1,176
10%	921	900	1,014	900	900	800	802	1,000	1,258	3,180	1,090	1,000	1,669
20%	1,700	1,200	1,356	1,175	1,200	1,283	1,000	1,000	1,982	6,536	2,061	1,000	1,846
30%	1,994	1,700	1,700	1,200	1,700	1,700	1,000	1,000	2,482	7,647	2,971	1,273	2,199
40%	2,491	1,700	1,700	1,700	1,700	2,771	1,000	1,139	2,985	8,181	4,870	1,595	2,368
50%	3,147	1,709	1,700	1,700	3,640	4,351	1,229	1,517	3,295	8,455	6,001	2,247	2,660
60%	3,621	2,247	3,064	3,091	4,711	5,308	1,774	2,022	3,570	8,700	6,341	2,680	3,330
70%	3,976	2,500	3,814	4,423	8,596	6,835	2,900	3,052	3,906	8,948	6,763	2,925	3,843
80%	4,000	2,500	4,250	7,711	12,078	10,140	3,835	5,812	4,449	9,393	7,097	3,187	4,517
90%	4,000	4,179	10,091	13,829	17,525	14,397	7,778	10,283	6,126	9,879	7,670	3,429	5,347
Max	6,826	14,550	24,329	40,940	23,673	34,035	18,979	20,380	11,675	10,000	8,566	5,110	8,066
Avg	2,940	2,349	3,973	5,277	6,340	6,487	3,073	3,661	3,632	7,674	4,935	2,201	3,174
B. ESO_ELT													
Min	900	900	800	801	900	800	750	750	1,000	1,000	750	773	1,045
10%	1,201	904	930	900	900	1,000	1,000	1,000	1,691	2,764	1,387	1,000	1,517
20%	1,700	1,207	1,353	927	1,200	1,598	1,000	1,000	2,403	4,063	2,548	1,000	1,683
30%	1,753	1,700	1,700	1,215	1,700	1,700	1,000	1,057	2,811	5,765	3,324	1,267	1,938
40%	2,658	1,700	1,700	1,700	1,700	1,700	1,000	1,487	3,653	6,788	3,944	1,939	2,276
50%	4,000	2,046	1,700	1,700	1,700	3,631	1,609	1,899	5,032	7,378	4,278	2,772	2,754
60%	4,000	2,500	1,773	1,700	4,283	5,526	2,282	2,366	5,813	8,879	4,517	4,109	3,500
70%	4,000	2,500	2,775	1,913	7,862	7,843	2,947	2,951	7,004	10,000	5,903	5,385	4,118
80%	4,000	2,500	4,100	4,702	12,181	10,165	3,876	6,356	7,917	10,000	7,334	6,432	4,907
90%	4,000	2,500	4,965	14,178	20,347	14,789	8,389	8,490	8,733	10,000	9,378	8,648	5,818
Max	4,658	16,211	31,663	45,810	28,331	39,929	21,317	18,809	9,789	10,000	10,000	10,000	7,332
Avg	3,020	2,192	3,358	4,886	6,507	6,660	3,233	3,599	5,021	7,110	4,800	3,790	3,267
C. ESO_LLT													
Min	900	900	900	801	800	800	750	700	802	1,000	750	773	909
10%	1,200	930	1,200	900	900	824	1,000	1,000	2,216	2,121	1,372	1,000	1,496
20%	1,468	1,200	1,389	900	1,200	1,700	1,000	1,000	2,883	3,338	2,647	1,000	1,677
30%	1,906	1,700	1,700	1,582	1,700	1,700	1,000	1,411	3,147	5,042	3,218	1,344	1,959
40%	3,052	1,700	1,700	1,700	1,700	2,072	1,023	2,086	3,498	5,893	3,678	1,740	2,242
50%	4,000	1,703	1,700	1,700	2,132	3,020	1,671	2,643	4,665	6,724	4,253	2,955	2,808
60%	4,000	2,500	1,772	1,700	4,229	4,598	2,528	3,183	6,087	8,773	4,554	4,434	3,466
70%	4,000	2,500	2,423	2,152	8,648	8,322	3,248	3,695	7,216	9,832	4,795	5,943	4,147
80%	4,000	2,500	3,165	4,703	14,768	11,238	4,142	5,089	8,415	10,000	6,304	6,872	4,815
90%	4,000	2,500	4,883	14,463	21,959	16,426	8,573	6,829	9,502	10,000	8,908	7,494	5,712
Max	4,000	9,895	33,811	48,316	33,202	42,044	20,642	15,251	10,952	10,000	10,000	9,756	7,418
Avg	3,006	2,022	3,048	4,751	7,126	6,900	3,330	3,475	5,368	6,714	4,547	3,811	3,258

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	900	900	900	800	900	800	750	750	1,000	1,441	1,000	773	930
10%	907	900	931	900	900	800	802	1,000	1,592	2,854	1,358	1,008	1,642
20%	1,700	1,200	1,303	1,200	1,200	1,074	1,000	1,000	2,102	6,311	1,821	1,657	1,839
30%	1,973	1,700	1,700	1,350	1,700	1,700	1,000	1,000	2,689	7,694	3,365	2,396	2,027
40%	2,472	1,700	1,700	1,700	1,700	1,918	1,000	1,143	2,979	8,324	5,171	2,958	2,260
50%	3,161	2,152	1,769	1,700	1,732	3,652	1,131	1,389	3,340	8,473	5,974	3,409	2,504
60%	3,532	2,500	2,793	1,700	3,309	5,185	1,653	2,054	3,727	8,814	6,440	5,078	3,319
70%	3,969	2,500	3,604	1,700	6,114	6,341	2,982	2,853	4,031	9,116	6,740	7,282	3,849
80%	4,000	2,500	4,469	5,220	10,810	9,321	4,150	5,840	4,449	9,679	6,994	8,768	4,646
90%	4,000	2,500	5,943	13,870	16,371	14,190	7,797	10,303	6,146	10,000	7,353	9,706	5,666
Max	5,232	14,550	24,329	40,947	21,724	34,037	18,991	20,399	11,681	10,000	8,599	10,000	7,836
Avg	2,817	2,243	3,462	4,669	5,502	5,953	3,078	3,635	3,725	7,724	4,998	4,835	3,179
E. EBC2_ELT													
Min	900	900	800	801	900	800	750	750	1,000	1,000	750	773	970
10%	1,017	900	900	900	900	815	852	1,000	1,516	4,425	1,189	1,000	1,553
20%	1,369	1,200	1,208	900	1,200	1,098	1,000	1,000	2,119	6,969	3,764	1,257	1,844
30%	1,700	1,700	1,700	1,277	1,700	1,700	1,000	1,000	2,638	7,877	4,852	1,993	2,041
40%	1,915	1,700	1,700	1,700	1,700	1,700	1,000	1,420	2,968	8,472	5,651	2,612	2,284
50%	3,206	1,700	1,700	1,700	1,700	3,192	1,191	1,765	3,364	8,741	6,175	3,381	2,588
60%	3,799	2,500	1,781	1,700	3,647	5,485	1,864	2,439	3,639	9,125	6,529	6,753	3,287
70%	4,000	2,500	3,194	1,700	6,129	7,853	2,827	2,748	3,866	9,566	6,820	7,737	3,891
80%	4,000	2,500	4,011	4,983	11,826	10,763	3,824	5,438	4,077	9,956	7,223	8,540	4,694
90%	4,000	2,500	5,123	14,407	20,124	14,801	8,391	8,245	4,514	10,000	7,596	9,563	5,912
Max	4,930	16,211	31,663	45,818	28,333	39,935	21,317	18,816	8,604	10,000	8,197	10,000	7,686
Avg	2,756	2,148	3,349	4,970	6,166	6,653	3,150	3,420	3,318	8,041	5,396	4,788	3,270
F. EBC2_LLT													
Min	900	900	800	801	800	800	750	750	975	1,000	750	773	1,014
10%	999	946	900	900	900	820	787	1,000	2,337	4,762	1,130	1,000	1,603
20%	1,264	1,200	1,200	900	1,200	1,387	1,000	1,000	3,001	7,426	3,441	1,007	1,782
30%	1,658	1,598	1,700	1,350	1,700	1,700	1,000	1,070	3,267	8,287	5,812	1,362	2,022
40%	1,756	1,700	1,700	1,700	1,700	1,916	1,000	1,669	3,433	8,642	6,314	2,304	2,253
50%	3,390	1,700	1,700	1,700	2,007	2,657	1,364	2,202	3,617	8,959	6,626	3,408	2,494
60%	3,980	2,500	1,700	1,700	3,106	5,068	2,019	2,653	3,852	9,257	6,754	6,219	3,233
70%	4,000	2,500	2,502	2,152	4,539	8,097	2,954	3,015	4,001	9,574	7,036	7,724	3,999
80%	4,000	2,500	3,736	4,226	12,670	11,259	3,587	4,047	4,367	9,800	7,218	8,233	4,832
90%	4,000	2,505	4,618	14,816	20,547	15,985	8,424	6,279	4,845	10,000	7,691	9,042	5,963
Max	4,943	11,480	33,811	48,328	33,204	42,050	20,642	15,271	5,978	10,000	9,425	10,000	7,390
Avg	2,747	2,058	2,837	4,995	6,444	6,902	3,084	3,005	3,628	8,157	5,634	4,601	3,264

Table C.A-10. CALSIM-Estimated Monthly Distribution of Yuba River Flows (cfs) at Marysville

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	357	440	658	921	871	854	420	316	221	90	82	84	347
10%	443	637	752	1,207	1,112	1,108	734	751	289	117	107	134	489
20%	500	661	811	1,246	1,351	1,323	809	953	418	256	251	252	576
30%	503	683	852	1,344	1,457	1,621	1,029	1,029	663	270	253	253	733
40%	507	712	892	1,575	2,138	2,077	1,454	1,130	768	275	260	400	911
50%	515	750	959	2,323	2,964	2,479	2,364	2,036	1,218	466	659	563	1,145
60%	521	771	1,124	3,398	4,309	3,641	2,693	2,350	1,735	634	760	613	1,577
70%	534	828	1,659	4,731	4,930	4,705	3,519	2,936	2,640	841	830	656	1,966
80%	581	941	2,814	5,187	5,498	5,369	4,310	4,157	3,192	1,519	895	732	2,320
90%	662	1,505	4,667	5,833	7,212	7,069	4,554	6,872	4,954	1,974	999	784	2,823
Max	4,578	6,178	14,711	22,413	19,435	14,558	11,934	11,084	9,247	3,051	2,353	1,215	3,824
Avg	589	1,048	2,236	3,628	3,745	3,637	2,582	2,755	2,073	793	588	498	1,453
B. ESO_ELT													
Min	323	436	639	958	902	786	366	254	0	0	0	75	322
10%	451	628	762	1,171	1,143	1,130	601	430	57	0	62	120	463
20%	467	676	808	1,262	1,350	1,323	761	655	125	0	106	213	532
30%	481	726	855	1,356	1,545	1,616	950	805	174	16	154	229	711
40%	490	758	958	1,667	2,369	2,165	1,499	1,023	329	75	195	350	848
50%	501	816	1,075	2,346	3,410	2,566	2,314	1,669	478	96	442	529	1,105
60%	516	853	1,241	3,611	5,041	3,651	2,677	1,963	1,047	158	549	587	1,583
70%	569	914	1,964	5,063	5,442	4,777	3,536	2,543	1,708	341	593	615	1,985
80%	642	1,022	4,228	5,884	6,537	5,873	4,275	4,188	2,514	520	639	656	2,481
90%	749	1,671	5,597	6,772	9,005	7,204	4,943	6,434	3,574	734	728	761	2,855
Max	4,806	6,237	16,253	24,928	22,484	16,920	13,407	11,892	8,530	2,137	851	1,191	4,074
Avg	604	1,139	2,644	4,046	4,344	3,861	2,591	2,549	1,459	295	391	463	1,464
C. ESO_LLT													
Min	296	393	565	939	874	785	323	174	0	0	0	73	315
10%	426	577	728	1,184	1,161	1,142	566	256	0	0	27	109	431
20%	447	609	750	1,295	1,336	1,365	731	454	0	0	44	197	538
30%	464	635	831	1,412	1,615	1,699	858	567	12	0	86	212	680
40%	480	677	960	1,807	2,556	2,261	1,453	763	78	0	150	326	833
50%	499	716	1,169	2,493	3,572	2,755	2,153	1,009	188	0	313	506	1,034
60%	518	769	1,391	3,868	5,316	3,559	2,532	1,492	524	18	389	561	1,565
70%	552	834	1,881	5,614	5,842	5,047	3,421	2,006	901	83	483	588	1,981
80%	585	917	4,159	6,799	6,887	6,209	4,083	3,356	1,480	216	525	619	2,363
90%	713	1,376	6,179	7,629	10,143	8,029	5,236	5,330	2,465	360	596	720	2,836
Max	4,948	5,068	16,363	26,654	23,985	18,240	13,225	11,376	6,739	887	749	1,882	3,888
Avg	593	1,009	2,645	4,485	4,657	4,079	2,588	2,028	912	105	291	447	1,431

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	357	440	658	921	871	854	420	316	221	90	82	84	347
10%	422	650	752	1,207	1,112	1,108	734	751	289	117	107	134	499
20%	500	672	807	1,246	1,351	1,323	809	953	418	256	251	252	576
30%	503	707	847	1,344	1,457	1,621	1,029	1,029	663	270	253	253	733
40%	507	752	889	1,575	2,138	2,077	1,454	1,130	768	275	260	400	911
50%	515	790	959	2,323	2,964	2,479	2,364	2,036	1,218	466	659	563	1,147
60%	521	833	1,124	3,398	4,309	3,641	2,693	2,350	1,735	634	760	613	1,584
70%	534	899	1,659	4,731	4,930	4,705	3,519	2,936	2,640	841	830	656	1,966
80%	571	1,004	2,814	5,187	5,498	5,369	4,310	4,157	3,192	1,519	895	732	2,320
90%	651	1,523	4,667	5,833	7,212	7,069	4,554	6,872	4,954	1,974	999	784	2,823
Max	4,578	6,178	14,711	22,413	19,435	14,558	11,934	11,084	9,247	3,051	2,353	1,215	3,824
Avg	586	1,082	2,235	3,628	3,745	3,637	2,582	2,755	2,073	793	588	498	1,455
E. EBC2_ELT													
Min	323	436	639	958	902	786	366	254	0	0	0	75	322
10%	454	633	762	1,171	1,143	1,130	601	430	57	0	62	120	463
20%	467	680	817	1,267	1,350	1,323	761	655	125	0	106	213	535
30%	482	727	863	1,356	1,545	1,616	950	805	174	16	154	229	711
40%	492	764	958	1,667	2,369	2,165	1,499	1,023	329	75	195	350	848
50%	513	817	1,075	2,346	3,410	2,566	2,314	1,669	478	96	442	529	1,113
60%	522	860	1,241	3,611	5,041	3,651	2,677	1,963	1,047	158	549	587	1,583
70%	573	939	1,964	5,063	5,442	4,777	3,536	2,543	1,708	341	593	615	1,985
80%	642	1,022	4,228	5,884	6,537	5,873	4,275	4,188	2,514	520	639	656	2,481
90%	749	1,671	5,597	6,772	9,005	7,204	4,943	6,434	3,574	734	728	761	2,855
Max	4,806	6,237	16,253	24,928	22,484	16,920	13,407	11,892	8,530	2,137	851	1,191	4,074
Avg	607	1,143	2,645	4,046	4,344	3,861	2,591	2,549	1,459	295	391	463	1,465
F. EBC2_LLT													
Min	296	393	565	939	874	785	323	174	0	0	0	73	315
10%	425	577	728	1,184	1,161	1,142	566	256	0	0	27	109	440
20%	447	610	757	1,295	1,336	1,365	731	454	0	0	44	197	538
30%	463	647	850	1,412	1,615	1,699	858	567	12	0	86	212	680
40%	477	687	960	1,807	2,556	2,261	1,453	763	78	0	150	326	833
50%	497	717	1,169	2,493	3,572	2,755	2,153	1,009	188	0	313	506	1,039
60%	509	772	1,391	3,868	5,316	3,559	2,532	1,492	524	18	389	561	1,566
70%	553	834	1,881	5,614	5,842	5,047	3,421	2,006	901	83	483	588	1,981
80%	616	917	4,159	6,799	6,887	6,209	4,083	3,356	1,480	216	525	619	2,364
90%	744	1,376	6,179	7,629	10,143	8,029	5,236	5,330	2,465	360	596	720	2,836
Max	4,948	5,068	16,363	26,654	23,985	18,240	13,225	11,376	6,739	887	749	1,882	3,888
Avg	598	1,011	2,649	4,485	4,657	4,079	2,588	2,028	912	105	291	447	1,431

Table C.A-11. CALSIM-Simulated Monthly Distribution of Feather River Flows (cfs) at Confluence [Does Not Include Sutter Bypass Flows]

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	900	900	0	1,200	900	750	1,121	750	750	750	750	997	1,429
10%	1,292	1,280	1,213	2,726	1,932	2,325	2,800	2,800	2,806	5,681	2,572	2,502	2,519
20%	1,700	1,700	1,700	3,656	4,013	3,762	3,283	2,802	3,343	7,110	3,329	2,769	3,084
30%	2,573	2,009	2,502	4,457	4,355	5,009	3,815	3,400	3,621	7,878	4,361	3,238	3,395
40%	3,036	2,325	2,826	4,905	5,501	6,364	4,488	4,089	4,014	8,386	6,029	3,759	3,741
50%	3,397	2,576	3,596	6,123	9,041	9,693	5,745	4,552	4,366	8,756	6,950	4,192	4,506
60%	3,905	2,813	4,137	8,661	12,476	12,101	6,712	5,154	4,724	8,962	7,346	4,445	5,626
70%	4,296	3,008	4,847	10,996	16,450	16,724	8,242	8,065	5,626	9,576	7,744	4,648	7,204
80%	4,663	3,598	6,220	18,500	23,958	19,889	13,158	11,558	7,905	9,829	8,070	4,923	7,990
90%	5,120	4,898	16,011	24,942	33,358	30,702	21,318	17,869	12,387	10,362	8,392	5,286	10,250
Max	11,009	22,986	48,410	98,370	77,827	58,603	49,201	34,934	24,621	12,123	9,028	7,623	14,197
Avg	3,446	3,216	6,279	11,938	13,744	13,521	8,796	7,697	6,197	8,322	5,941	3,937	5,601
B. ESO_ELT													
Min	900	900	900	1,200	900	750	994	750	750	750	750	991	1,111
10%	1,551	1,353	1,273	2,288	2,155	2,178	2,820	2,573	2,408	2,582	2,422	2,515	2,107
20%	1,877	1,804	1,700	2,944	2,969	3,234	3,432	2,800	2,815	4,120	3,221	2,591	2,675
30%	2,364	2,116	2,077	4,037	4,376	4,589	3,950	3,403	3,678	5,915	3,931	3,054	3,253
40%	3,136	2,364	2,855	4,543	5,342	5,995	4,726	3,881	5,069	6,423	4,305	3,465	3,659
50%	3,932	2,642	3,454	5,375	7,653	8,694	5,717	4,457	6,322	7,406	5,015	4,219	4,314
60%	4,357	2,867	4,578	8,471	11,928	13,059	6,524	5,154	7,712	9,068	5,508	6,132	5,975
70%	4,498	3,031	5,088	10,600	17,181	16,722	8,368	8,006	8,560	9,487	6,362	7,502	7,787
80%	4,700	3,253	6,696	18,331	27,556	21,173	12,536	11,535	10,158	9,927	7,941	8,453	8,460
90%	4,959	4,691	11,860	25,828	35,418	31,628	20,964	15,606	12,555	10,628	9,970	10,331	10,993
Max	11,353	25,292	61,996	105,975	87,913	69,111	52,696	34,144	21,251	11,561	11,779	12,498	15,403
Avg	3,536	3,158	6,165	11,967	14,556	13,864	8,893	7,382	6,943	7,203	5,495	5,491	5,691
C. ESO_LLT													
Min	1,144	900	-	1,130	900	750	932	750	750	1,180	1,029	976	1,115
10%	1,510	1,308	1,246	2,471	1,949	2,340	2,998	2,377	2,407	1,707	2,311	2,478	2,055
20%	1,757	1,704	1,700	3,082	2,870	3,289	3,366	2,911	2,976	3,237	3,155	2,569	2,426
30%	2,475	1,912	2,256	4,107	4,465	4,605	4,048	3,438	3,391	4,822	3,692	3,005	3,159
40%	3,391	2,238	2,876	4,812	6,376	5,837	4,803	4,004	4,602	5,404	4,591	3,332	3,623
50%	3,838	2,419	3,321	5,713	7,936	8,296	5,361	4,337	6,223	6,547	4,738	4,483	4,077
60%	4,041	2,659	4,220	8,436	11,967	12,432	6,643	5,414	7,583	8,457	5,141	6,291	5,804
70%	4,473	2,901	5,168	10,556	17,142	17,171	8,601	6,880	9,381	9,187	5,415	7,845	7,683
80%	4,660	3,079	6,538	17,913	30,043	23,044	12,576	9,693	10,177	9,739	6,912	8,666	8,401
90%	4,915	4,155	11,648	28,437	38,568	33,525	19,395	12,689	11,585	10,387	9,307	9,857	10,940
Max	11,513	18,048	63,838	109,863	93,134	72,550	51,623	29,968	17,414	11,115	11,638	11,510	15,055
Avg	3,507	2,838	5,811	12,271	15,446	14,294	8,941	6,708	6,685	6,519	5,129	5,490	5,624

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	900	900	0	1,200	900	750	1,082	750	750	750	750	995	1,301
10%	1,307	1,283	1,214	2,404	1,803	2,372	2,800	2,772	3,089	5,300	2,006	2,562	2,456
20%	1,700	1,777	1,701	2,948	2,992	3,215	3,281	2,800	3,368	7,002	3,360	2,901	2,947
30%	2,489	2,267	2,470	3,820	4,193	4,592	3,807	3,358	3,681	8,014	4,718	4,198	3,293
40%	2,855	2,434	3,147	4,491	4,819	6,493	4,621	4,073	4,119	8,563	6,259	4,763	3,642
50%	3,381	2,622	3,589	5,419	7,011	7,704	5,754	4,534	4,532	8,945	6,787	5,104	4,293
60%	3,934	2,798	4,293	8,120	10,554	11,872	6,846	5,120	4,991	9,279	7,279	7,842	5,697
70%	4,203	3,048	4,903	11,117	16,078	15,333	8,299	7,404	5,870	9,751	7,748	9,310	7,377
80%	4,456	3,233	5,966	17,555	23,678	19,915	13,201	11,602	7,928	10,014	7,977	10,850	8,411
90%	4,851	4,514	12,681	21,963	30,951	29,662	21,388	17,879	12,386	10,482	8,455	11,524	10,637
Max	11,104	23,067	48,404	98,431	74,875	58,624	49,219	34,947	24,601	12,198	9,266	12,642	13,971
Avg	3,314	3,161	5,796	11,346	12,922	13,001	8,811	7,665	6,271	8,374	5,977	6,581	5,611
E. EBC2_ELT													
Min	422	900	0	1,062	900	750	986	750	750	750	750	984	923
10%	1,507	1,298	1,212	2,281	1,902	2,173	2,800	2,800	2,723	5,075	2,197	2,518	2,464
20%	1,700	1,722	1,700	2,929	3,067	3,151	3,185	2,969	3,101	6,893	4,303	2,603	2,885
30%	1,922	2,110	2,002	3,948	4,234	4,328	3,784	3,418	3,285	7,951	6,184	3,459	3,179
40%	2,529	2,399	2,954	4,605	5,239	6,010	4,530	3,762	3,714	8,497	6,431	4,493	3,525
50%	3,593	2,573	3,626	5,627	7,323	8,276	5,719	4,408	4,093	8,764	6,834	5,525	4,212
60%	3,934	2,869	4,200	8,506	11,258	12,254	6,516	4,791	4,314	9,101	7,192	8,456	5,767
70%	4,234	3,012	4,958	11,247	17,673	18,076	8,356	6,562	5,036	9,444	7,785	9,553	7,401
80%	4,557	3,239	6,733	17,574	27,593	21,181	12,544	10,249	6,002	9,881	8,033	10,778	8,517
90%	4,729	4,659	13,016	24,469	33,675	31,767	20,974	15,610	8,263	10,297	8,321	11,422	11,337
Max	11,374	25,289	61,994	106,015	83,407	69,116	52,692	34,149	21,247	11,167	9,350	11,835	14,883
Avg	3,266	3,115	6,152	12,049	14,212	13,846	8,805	7,198	5,236	8,164	6,172	6,490	5,698
F. EBC2_LLT													
Min	1,138	900	0	1,132	900	750	929	750	750	1,000	750	956	1,062
10%	1,459	1,243	1,238	2,647	1,932	2,345	2,800	2,429	2,661	4,208	1,751	2,473	2,341
20%	1,678	1,636	1,700	2,988	2,772	3,493	3,284	2,835	3,059	6,930	3,571	2,566	2,688
30%	1,840	1,921	2,057	4,079	4,458	4,580	3,636	3,445	3,464	8,018	6,732	2,652	3,286
40%	2,265	2,256	3,138	4,812	5,880	5,736	4,439	3,751	3,746	8,315	7,016	4,358	3,527
50%	3,649	2,441	3,708	5,895	7,887	8,237	5,285	3,997	4,300	8,799	7,281	5,260	4,049
60%	3,956	2,684	4,334	8,436	10,974	12,680	6,332	4,453	4,650	9,086	7,590	7,965	5,773
70%	4,274	2,922	4,989	10,366	17,143	16,333	8,091	5,981	5,415	9,349	7,768	9,526	7,409
80%	4,461	3,118	5,777	18,356	27,994	22,827	11,930	8,686	6,169	9,727	8,043	10,217	8,467
90%	4,846	4,403	10,944	26,139	35,587	33,527	19,396	12,198	8,067	9,931	8,430	11,429	11,052
Max	11,477	19,626	63,824	109,911	89,751	72,551	51,609	29,973	17,418	10,646	11,057	12,092	14,636
Avg	3,243	2,873	5,599	12,509	14,761	14,300	8,689	6,237	4,951	8,009	6,313	6,289	5,639

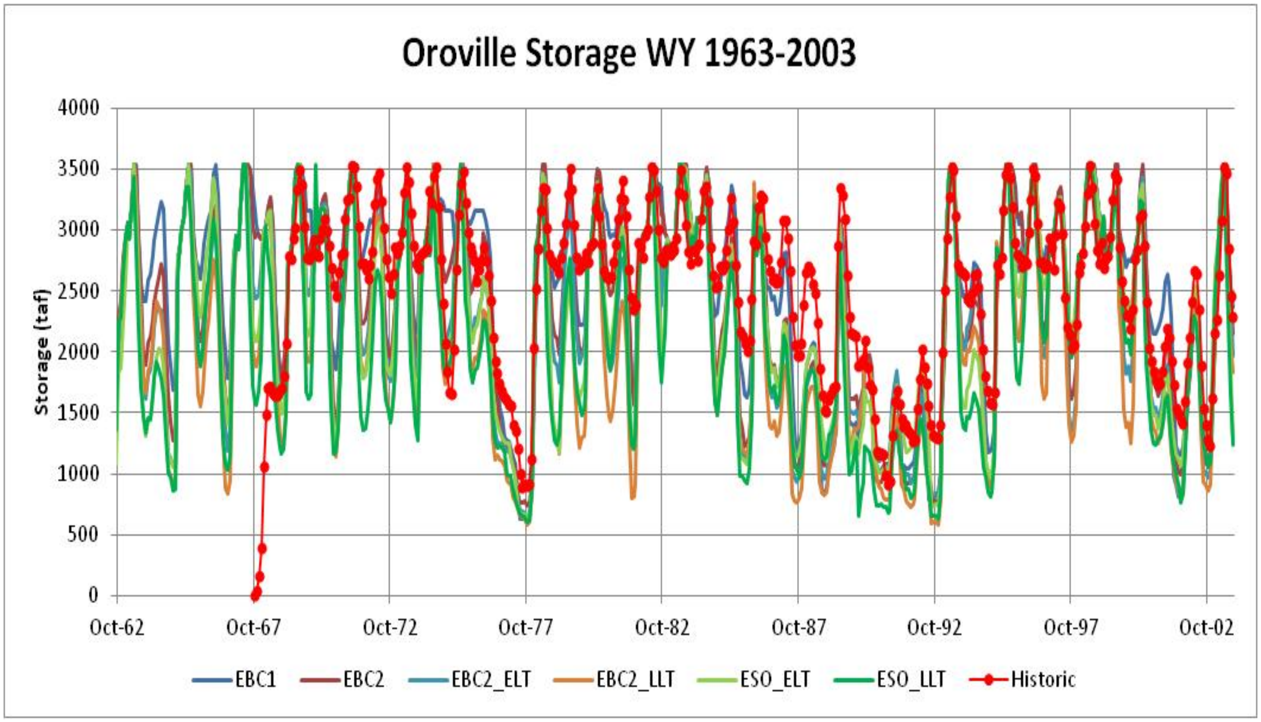


Figure C.A-11. CALSIM-Simulated Monthly Oroville Reservoir Storage for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

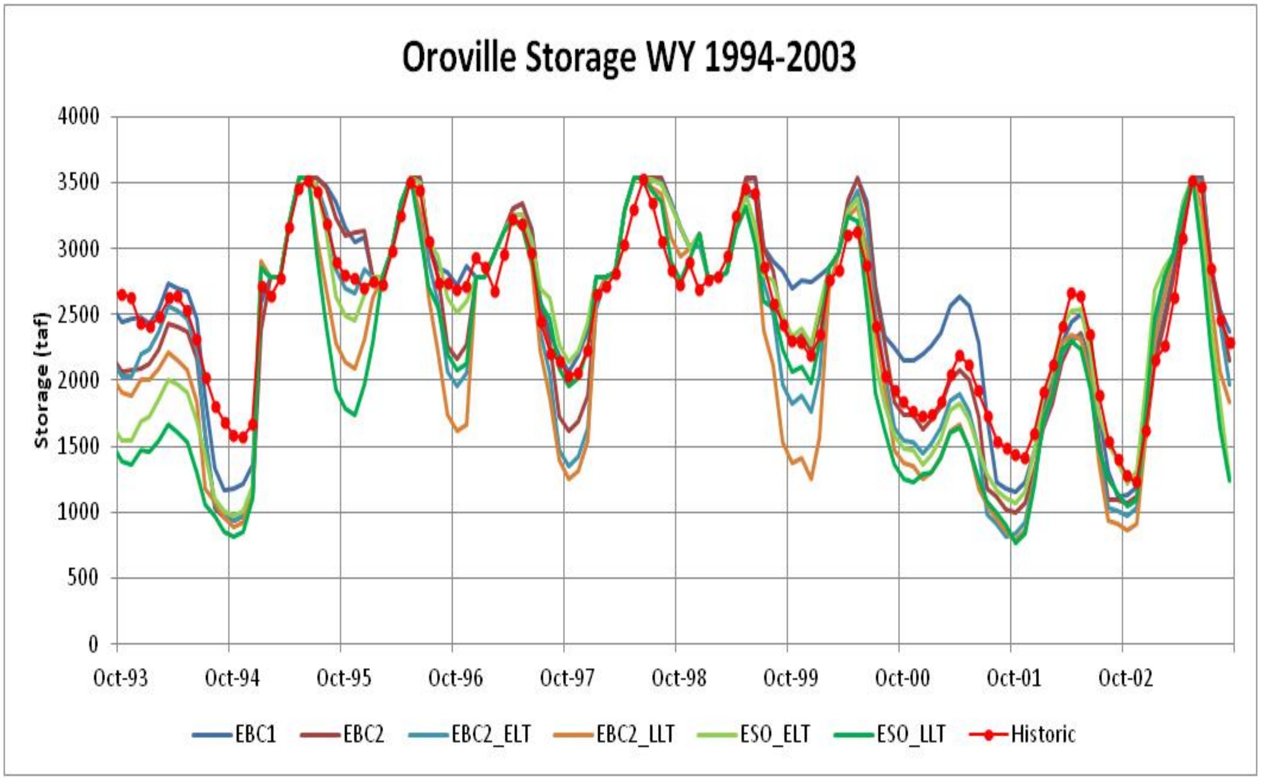


Figure C.A-12. CALSIM-Simulated Monthly Oroville Reservoir Storage for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

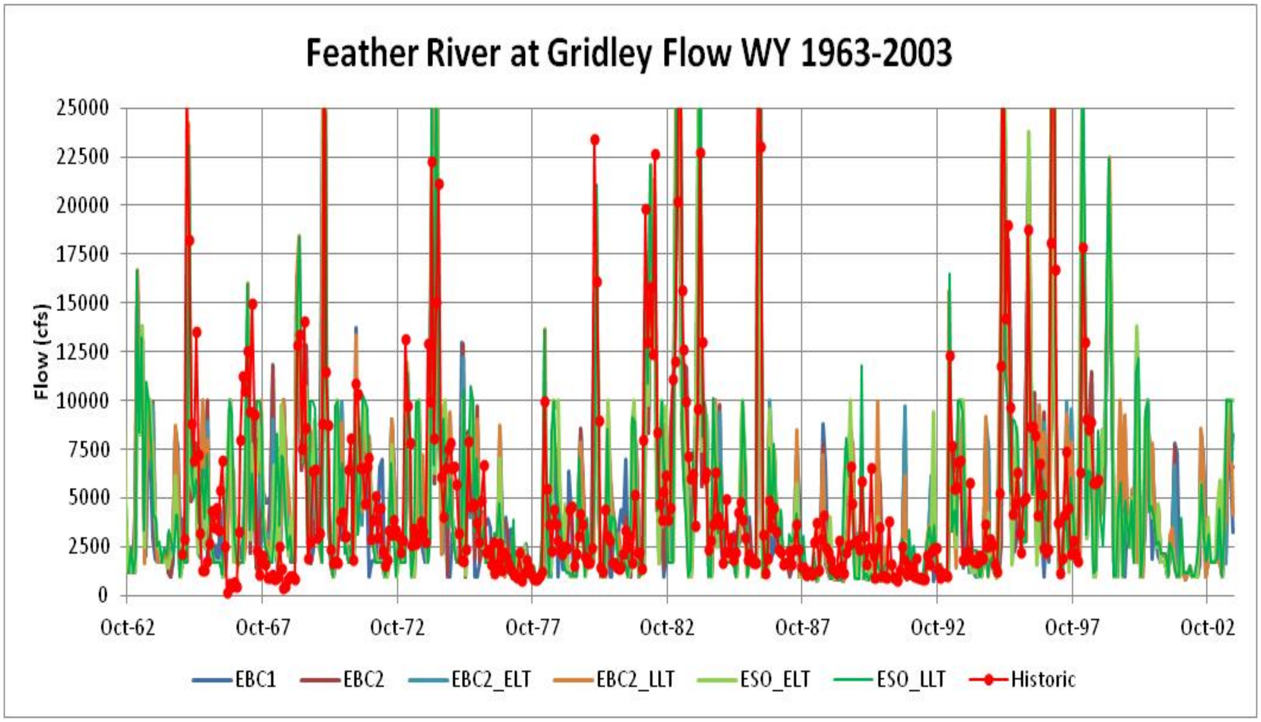


Figure C.A-13. CALSIM-Simulated Monthly Feather River Flow at Gridley for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

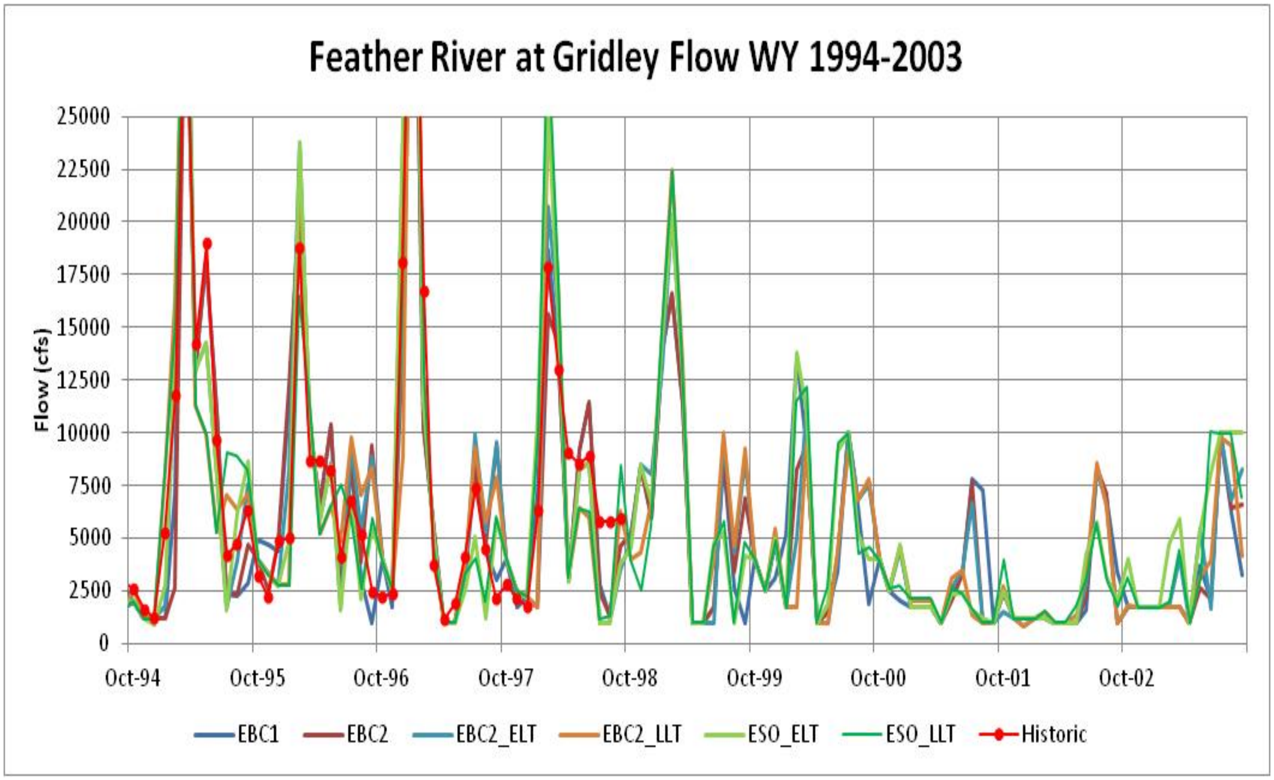


Figure C.A-14. CALSIM-Simulated Monthly Feather River Flow at Gridley for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

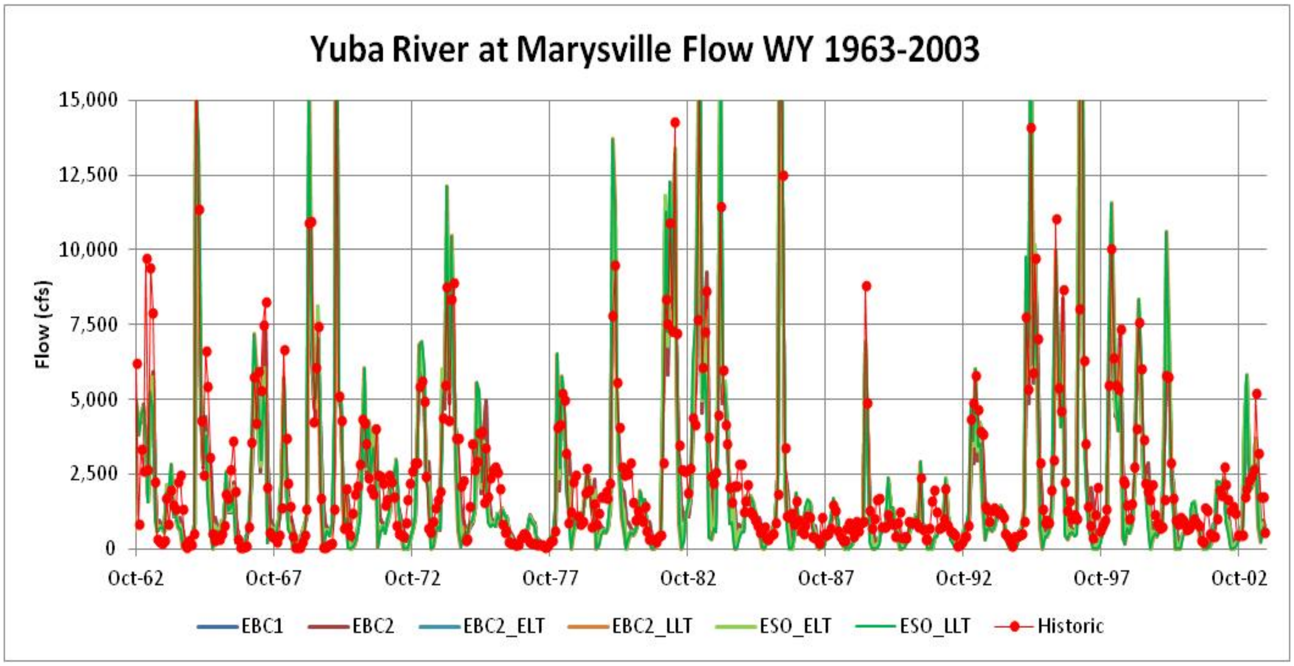


Figure C.A-15. CALSIM-Estimated Monthly Yuba River Flow at Marysville for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

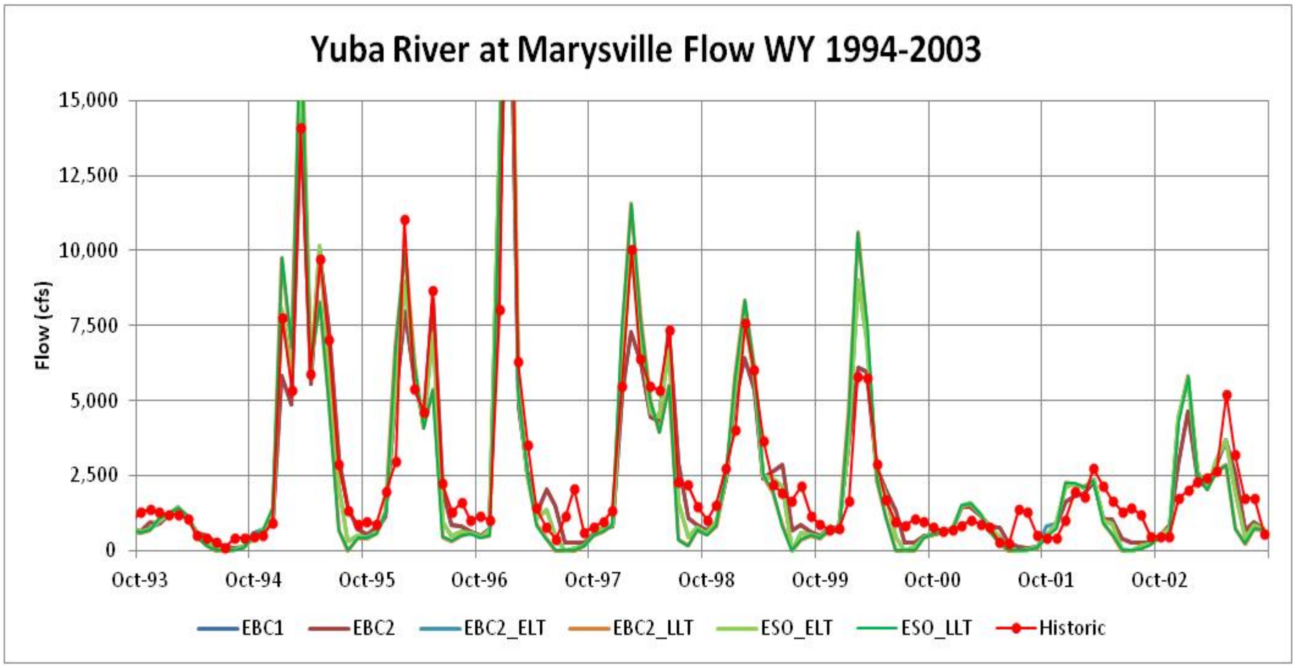


Figure C.A-16. CALSIM-Estimated Monthly Yuba River Flow at Marysville for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

5C.A.3.4 Comparison of Daily and Monthly Sacramento River Flows for the ESO

The CALSIM model uses monthly average reservoir inflows to simulate monthly reservoir operations, water supply diversions, Delta exports and Delta outflow for the long-term sequence of WY 1922 to 2003. This section provides a summary of reservoir operations and river flows in the Sacramento Valley including the flood bypass diversions during WY 1995 to illustrate the daily variations within each month compared to the monthly average flow. Monthly average flow values provide an adequate characterization of Sacramento River flows in months without major storms; the relatively constant monthly flows vary downstream with tributary inflows and major diversions. The Sacramento River flows between Keswick Dam (near the City of Redding) and Freeport (near the City of Sacramento) can vary considerably during a month with major storm flows. Keswick flows are relatively stable within many months because of flood flow storage and regulation in Shasta Reservoir; flood control releases are made only when the flood control storage level is exceeded. Tributary inflows to the Sacramento River cause increases in flow while diversions into Sutter Bypass and Yolo Bypass cause large decreases in Sacramento River flow. Diversions to irrigation canals along the Sacramento River cause reductions in flow during the spring and summer irrigation season.

The methods used in the BDCP flow evaluations are presented for two locations where daily Sacramento River flows are important for estimating the operations of proposed BDCP facilities: (1) the Fremont Weir spills and flows through the proposed gated notch depend on the combined Sacramento River flows at Verona; and (2) the BDCP north Delta intake (pumping) diversions depend on the daily Sacramento River flows at Freeport (entering the Delta). Daily flows at these locations were estimated from the combination of historical daily flows and the monthly CALSIM flows for each EBC or BDCP case (ESO_ELT and ESO_LLT). The basic method assumed that the daily flow patterns would be preserved (flood event) and flows for each day of the month were adjusted by the difference between the CALSIM monthly flow and the historical monthly flow. The historical daily Sacramento River Flows during WY 1995 are used as an example to compare the monthly average and daily flows and introduce the daily flow calculations used in the monthly CALSIM for these two locations.

5C.A.3.4.1 Upstream Reservoir Operations

There are five major storage reservoirs that regulate daily flows on the Sacramento River: Trinity, Shasta, Oroville, New Bullards Bar (on the Yuba River) and Folsom. Each of these reservoirs are multi-purpose, reserving flood control storage (space) in the winter and early spring (November–April) for rainfall runoff, and then filling with runoff for water supply purposes during the late spring snowmelt period (May and June). Trinity Reservoir operations are included because some of the Trinity River flow is diverted to the Sacramento River through the Carr and Spring Creek tunnels and power plants. Because these reservoirs have relatively large storage capacities, the monthly accounting used in CALSIM is generally adequate to determine how much of the monthly inflow can be stored or must be released each month. Actual flood control releases depend on the initial storage at the time of the storm event, and the daily inflow pattern; the U.S. Army Corps of Engineers water control manuals for each reservoir guide the daily operations during major storm events. CALSIM calculates the end of month flood control levels; these are generally fixed monthly values, but are reduced in exceptionally wet months (to mimic the flood control manuals) when additional rainfall would likely have a high runoff fraction.

Figure C.A-17 shows the historical daily operations for Trinity Reservoir during WY 1995. The reservoir storage (taf) is shown with the purple line (right-hand scale), along with the maximum flood control storage levels (red line). The storage was relatively low in October of 1994 (1,250 taf), and increased substantially in January, February and March, reaching the flood control limit in March. The reservoir nearly filled in June, and was reduced to about 1,900 taf at the end of September. The CALSIM EBC1 storage was about 250 taf lower than historical in October, and remained slightly less than historical until July, and was at maximum flood control levels in August and September (slightly higher than historical). The Trinity River flow is highly regulated, with a minimum flow of 300 cfs maintained from October 1 through June 30, and a summer flow of 450 cfs maintained from July1 through September 30. A large pulse flow was released to the Trinity River for flood control purposes in March, shown with the brown line (left-hand scale) in the second half of March. The peak release flow was 4,000 cfs initially with a second pulse flow of 6,000 cfs (maximum allowed flood control releases). A second major river release was made in late April and May for fish habitat benefits, with an initial flow of 4,000 cfs and 4,500 cfs in the second half of the flow pulse. The monthly CALSIM flows are based on the actual daily flow requirements specified in the Trinity River Agreement for improved fish habitat conditions. The diversions to the Sacramento River through the Carr Tunnel began in mid-May and continued through September, to provide hydropower and increase the Sacramento River flows at Keswick.

Figure C.A-18 shows the historical daily operations for Shasta Reservoir during WY 1995. The reservoir storage (taf) is shown with the purple line (right-hand scale), along with the maximum flood control storage levels (red line). The storage was relatively low in October of 1994 (2,000 taf), and increased substantially in January to the flood control limit of 3,250 taf. The flood control limit increases from December 20 to March 20 at a rate dependent on the runoff index (calculated from the daily inflows). The CALSIM model has pre-calculated the end-of month flood control limits from the historical runoff patterns. The reservoir almost filled in June (4,250 taf) and was reduced to about 3,100 taf at the end of September. The CALSIM EBC1 storage was about 500 taf lower than historical in October, filled to flood control limits in January through April, and filled to capacity in May. The CALSIM EBC1 storage followed the flood control seasonal drawdown curve through September. The CALSIM flood control limit was less than 3,500 taf at the end of March (because of high rainfall in March) so that CALSIM releases at Keswick in March were higher than historical releases. The Spring Creek hydropower plant diversions from Clear creek (Whiskeytown Reservoir) to the Sacramento River are shown with a green line, with a maximum flow of about 3,500 cfs. Only the summer flows were diverted from the Trinity River.

The minimum flows at Keswick Reservoir from October through April are 3,250 cfs to 5,500 cfs (depending on reservoir storage) and were about 3,500 cfs in October–December of 1994. A large flood control release was made in late January and early February (40,000 cfs maximum). A second major flood control release was made in March (80,000 cfs maximum) and additional flood control releases of about 30,000 cfs were made in April and May. The Keswick release flows from mid-May through September were very stable at 10,000 cfs to 15,000 cfs (turbine capacity) to provide cold water conditions (<56°F) downstream of Keswick for Chinook salmon egg incubation and rearing conditions. The Sacramento River runoff in WY 1995 was much more than needed to fill Shasta Reservoir, but because it was predominantly rainfall-runoff during January–April (when flood control storage space must be maintained), Shasta Reservoir was not quite filled at the end of May (the EBC1 CALSIM simulation did fill). The monthly CALSIM storage and Keswick flows for EBC1 generally matched the historical monthly storages and flows, but the daily variations caused by the large storm events in January–May cannot be represented in CALSIM.

Figure C.A-19 shows the historical daily operations for Oroville Reservoir during WY 1995. The reservoir storage (taf) is shown with the purple line (right-hand scale), along with the maximum flood control storage levels (red line). The storage was relatively low in October of 1994 (1,750 taf), and increased substantially in January to the flood control limit of 2,750 taf. The flood control limit begins on September 15 and is reduced with cumulative rainfall to a minimum of about 2,750 from October 15 through March 31, and increases to maximum storage of about 3,500 taf by June 15 (earlier in dry years). The CALSIM model has pre-calculated the end-of-month flood control limits from the historical rainfall patterns. Oroville reservoir filled in June (3,500 taf) and was reduced to about 2,900 taf at the end of September. The CALSIM EBC1 storage was about 500 taf lower than historical in October, filled to flood control limits in January through April, and was filled to capacity in May, June and July. The CALSIM storage followed the flood control seasonal drawdown curve through September (3,350 taf). Flood control releases from Oroville were made in February, March, April and May; the peak releases in March were about 80,000 cfs and in May were about 60,000 cfs. Releases in June were more than 10,000 cfs to prevent any spilling of the snowmelt runoff.

Figure C.A-20 shows the historical daily operations for New Bullards Bar Reservoir on the North Fork Yuba River during WY 1995. The reservoir storage (taf) is shown with the purple line (right-hand scale), along with the maximum flood control storage levels (red line). The storage was relatively low in October of 1994 (500 taf), and increased substantially in January to the flood control limit of 800 taf. The flood control limit begins on September 15 and is reduced to about 800 taf from November 1 through March 31. New Bullards Bar reservoir filled in June (950 taf) and was reduced to about 800 taf at the end of September. The CALSIM model does not include New Bullards Bar Reservoir operations; the Yuba inflows at Marysville are pre-calculated from the historical flows and current operating rules. About half of the Yuba River flows (South Fork) are largely unregulated, so the flows at Marysville have a somewhat natural pattern. Flood control releases from New Bullards Bar (delayed) reduced the peak flows at Marysville in January, March, and May. Flows from Oroville Reservoir on the Feather River and from New Bullards Bar Reservoir on the Yuba River join the Sacramento River at Verona. The Sacramento River flows of greater than 55,000 cfs at Verona will spill at the Fremont Weir to the Yolo Bypass and enter the Delta at Rio Vista.

Figure C.A-21 shows the historical daily operations for Folsom Reservoir during WY 1995. The reservoir storage (taf) is shown with the purple line (right-hand scale), along with the maximum flood control storage levels (red line). The storage was relatively low in October of 1994 (200 taf), and increased substantially in January to the flood control limit of 600 taf. The flood control limit begins on September 15 and is reduced to about 600 taf from November 1 through March 31. The flood control limit is reduced by another 100 taf when upstream storage is filled. Folsom Reservoir filled to about 800 taf at the end of April, but additional rainfall in May required the storage to be reduced to 650 taf. Folsom Reservoir was filled to 975 taf in early July, but on July 17 one of the spillway gates failed, and the reservoir drained during the remainder of July, with about 600 taf of storage remaining. The CALSIM EBC1 storage was 650 taf at the beginning of October 1994 and was at flood control limits of about 600 taf through March and filled at the end of May. The CASLIM storage was reduced to 650 taf at the end of September. American River flows were greater than 10,000 cfs in January, March, and May. Flood control releases from January through May reduced the peak flows downstream of Nimbus Dam; the July spillway release was quite unexpected in July. The American River joins the Sacramento River just upstream of Sacramento and is the last major tributary to join the Sacramento River. The Sacramento River enters the Delta at Freeport.

5C.A.3.4.2 Sacramento River Daily Flows between Keswick Dam and Verona

The Sacramento River flow is generally increasing from Keswick Dam to Butte City during high runoff periods because of the inflow from several tributaries. The Sacramento River flow is reduced from Butte City to Colusa by the Moulton Weir and the Colusa Weir diversions, and is reduced from Colusa to Wilkins Slough by the Tisdale Weir diversion. The daily flows along the Sacramento River and at these three weirs during WY 1995 will be used to illustrate the flood control operation of the Sacramento River weirs. Figure C.A-22 shows the Sacramento River flow at several stations between Keswick Dam and Wilkins Slough (upstream of the Fremont Weir). The maximum flow (i.e., channel capacity) at Colusa was about 45,000 cfs and the maximum flow at Wilkins Slough was about 30,000 cfs in 1995. Most of the Sacramento River flow above 30,000 cfs at Colusa was diverted at the three Sacramento weirs into the Butte Sink and Sutter Bypass, which flows into the Feather River just upstream of the confluence with the Sacramento River at Verona.

Figure C.A-23 shows the daily Sacramento River flow at Butte City and Wilkins Slough and the weir diversions for WY 1995. The Tisdale weir had a maximum diversion of about 17,500 cfs when the Sacramento River flow at Colusa was about 45,000 cfs (i.e., channel capacity). The Colusa Weir diversions were the largest, with a maximum of about 50,000 cfs when the Sacramento River flow at Colusa was 45,000 cfs. The maximum Moulton Weir diversion was about 20,000 cfs when the Sacramento River flow at Butte City was about 130,000 cfs. The Sacramento River flow and the measured weir flow can be used to approximate the flow diversions (flow splits) for each weir. The flow over a weir is a function of the water elevation height above the weir crest. But this hydraulic relationship can be estimated as a fraction of the total flow at each weir, once the river elevation (river flow) is greater than the weir crest.

Figure C.A-24 shows the daily Butte City flows and the Moulton Weir flows as well as downstream flows at Colusa and Wilkins Slough. The Moulton Weir is downstream of Butte City and begins to overflow to Butte Sink at a Sacramento River at Butte City flow of 60,000 cfs. The Moulton Weir flow can be estimated as 25% of the Sacramento River flow above 60,000 cfs. Therefore, the Moulton Weir flow is about 10,000 cfs when the Butte City flow is 100,000 cfs, and would be 20,000 cfs when the Sacramento River flow was 140,000. The Sacramento River at Colusa flows are limited to about 45,000 cfs and the Sacramento River at Wilkins Slough flows are limited to about 30,000 cfs. The Colusa and Tisdale weirs begin to divert Sacramento River flow (spills) before the Moulton Weir begins to spill (at 60,000 cfs).

Figure C.A-25 shows the Colusa flow and the Colusa Weir flow compared to the daily combined Colusa flow and Colusa Weir flow, because the Colusa Weir is about 2.5 miles upstream of the Colusa flow station. The Colusa Weir begins to overflow (spill) when the Sacramento River flow (combined) is about 30,000 cfs. The Colusa Weir diverts about 75% of the Sacramento River flow above 30,000 cfs.

Figure C.A-26 shows the daily Sacramento River at Colusa flow and the Tisdale Weir flow. The Tisdale Weir is downstream of Colusa, about 1 mile above Wilkins Slough. The Tisdale Weir begins to overflow (i.e., divert) when the Sacramento River at Colusa flow is about 22,500 cfs. The Tisdale Weir diverts about 75% of the Sacramento River at Colusa flow above 22,500 cfs. The maximum Tisdale Weir flow in WY 1995 was about 17,500 cfs (weir capacity) when the Colusa flow was greater than 45,000 cfs.

Figure C.A-27 shows the relationship between Wilkins Slough flow and the total Sacramento River flow at Butte City. This is the reverse of what was shown with the individual weir diversions. Once

Wilkins Slough flow is greater than 22,500 cfs, some upstream weir diversions are occurring, and the upstream flow at Colusa and Butte City will be more than the Wilkins Slough flow. When the Wilkins Slough flow is 25,000 cfs, the upstream flow at Colusa and Butte City is about 35,000 cfs, with weir diversions of about 10,000 cfs. When the Wilkins Slough flow is 27,500 cfs, the upstream flow at Colusa is about 40,000 cfs and the Butte City flow is about 80,000 cfs. Therefore, the total weir flows into Butte Sink and Sutter Bypass would be more than 52,500 cfs. The Wilkins Slough flow is much less than the upstream Sacramento River flow whenever the Wilkins Slough flow is more than 25,000 cfs.

Figure C.A-28 shows the Yolo Bypass flow (Fremont Weir spill) compared with the upstream Sacramento River weir flows into Butte Sink and Sutter Bypass for WY 1995. This comparison indicates that the periods of Yolo Bypass flooding (Fremont Weir overflow) correspond very closely with the Sacramento River weir diversions to the Sutter Bypass. The total diversion from the Sacramento River weirs to the Sutter Bypass is a maximum of about 75,000 cfs, whereas the Fremont Weir diversion to the Yolo Bypass can be much higher. Therefore, juvenile Chinook on the Sacramento River may be diverted into the Sutter Bypass during the same periods as they may be diverted into the Yolo Bypass. Figure C.A-29 shows the Fremont Weir spill into the Yolo Bypass as a function of the combined Sacramento River flow at Verona and the Fremont Weir flow for WY 1995. The Fremont Weir started to spill when the combined flow was greater than about 55,000 cfs. The Fremont Weir spill was about 85% of the combined flow greater than 55,000 cfs. For example, when the combined flow at Verona is 125,000 cfs, the Freemont Weir flow is about 60,000 cfs, which is 85% of the 70,000 cfs combined flow above 55,000 cfs. Figure C.A-30 shows that the Sacramento River flows at Freeport are the sum of the Verona flow and the American River flow. Only when the Freeport flow is greater than 80,000 cfs does some water spill at the Sacramento Weir (located upstream of the American River mouth) to the Yolo Bypass.

The fraction of total Sacramento and Feather River flow that is diverted into the Yolo Bypass can be estimated from the Sacramento River flow at Verona and the Yolo Bypass flow as:

Flow fraction to Yolo = Yolo Bypass Flow / [Verona Flow + Yolo Bypass Flow]

This flow fraction can also be approximated from the Sacramento River flow at Freeport and the Yolo Bypass flow (both available in DAYFLOW) as:

Flow Fraction to Yolo = Yolo Bypass Flow / [Freeport Flow + Yolo Bypass Flow]

The fraction of fish entering the Yolo Bypass will depend on the source of the fish. Sacramento River fish will be diverted into Sutter Bypass during high flows. The fraction of Sacramento River fish passing Wilkins Slough (Knights Landing screw-trap) will flow along the 2-mile Fremont Weir, so most of these fish would likely pass over the weir when it is spilling (Verona flow greater than 60,000 cfs). The Sacramento fish that were diverted into Sutter Bypass will join the Feather River (and Yuba River) fish about 7 miles upstream of the Feather River mouth. When Verona flow is greater than 60,000 cfs and the Fremont Weir is spilling, the fraction of the Feather plus Sutter Bypass flow that does not flow down the Sacramento River will enter the Yolo Bypass. Although the Fremont Weir is two miles upstream of the Verona gage, the Sutter Bypass, which is about 1-mile wide at the mouth of the Feather River, flows directly across the Sacramento River channel to the Fremont Weir. Because the American River is downstream of Verona, American River fish do not generally enter the Yolo Bypass (unless the Sacramento Weir is spilling).

5C.A.3.4.3 Daily Flows at Fremont Weir and Verona

The existing Fremont Weir and the proposed Fremont Weir notch are both governed by a weir equation, with the weir or notch flow increasing rapidly with the water “head” (water surface elevation minus weir crest elevation). The flow increases rapidly, proportional to the the change in head raised to the power of 2.5, because the water velocity increases proportional to as the change in head raised to the power of 1.5. Doubling the head above the weir crest will increase the flow through the notch by about 5.5 times ($2^{2.5} = 5.5$). So it is important to know how Sacramento River elevation at Verona (and Fremont Weir) will increase with Sacramento River flow at Verona. River elevations are controlled by the downstream flow and the water elevations at the downstream control point (i.e., backwater effects). The Sacramento River at Verona flow includes the Feather (and Yuba) Rivers, Sutter Bypass and Sacramento River flows. But only the flow passing Verona controls the water elevation at Verona (the remainder of the Sacramento and Feather River water will spill over the Fremont Weir).

The Sacramento River at Verona flow corresponds to a Verona water elevation (i.e., rating curve) which also governs the daily water elevation upstream at Fremont Weir (water elevation about 2 feet higher than at Verona) and weir spill (or notch flow). The Fremont Weir crest is at elevations 33.5 feet (USED datum) or 33 feet (North American Vertical Datum of 1988 [NAVD88]). The Verona elevation will not increase very much once the flow is above 55,000 cfs (Verona elevation of about 31 feet) because most of the additional water will spill at the Fremont Weir into the Yolo Bypass (as designed). Figure C.A-31 shows the daily water elevations at Verona and at the downstream end of the Fremont Weir during 2011. Figure C.A-32 shows the daily average Verona flow and the Fremont Weir flow during 2011.

Figure C.A-33 shows the rating curves (estimated from 2011 data) for Verona flow and Fremont Weir spills, based on the Sacramento River at Fremont Weir elevations (USED datum). The Fremont Weir crest elevation is at 33.5 feet, so spills begin when the river elevation is greater than 33.5 feet. The Fremont Weir spills are about 30,000 cfs when the water elevation is 35 feet (1.5 feet weir depth). The Verona flow at a Fremont Weir elevation of 33.5 feet is about 57,500 cfs and is about 65,000 cfs at an elevation of 35 feet. At the highest elevation observed at the Fremont Weir during 2011 of 37 feet, the Verona flow was about 70,000 cfs and the Fremont Weir spill was about 85,000 cfs. Figure C.A-34 shows the rating curves (estimated from 2011 data) for Verona flow and Fremont Weir spills, based on the Sacramento River at Verona elevations (USED datum). Fremont Weir spills begin at a Verona elevation of about 31.5 feet, when the Verona flow is about 57,500 cfs. The Fremont Weir spills are about 85,000 cfs when the water elevation at Verona is 35 feet. The Verona flow at an elevation of 35 feet is about 70,000 cfs. The two rating curves give the same flow-split for flows greater than 57,500 cfs.The Fremont weir was assumed to spill about 80% of the Sacramento River flow greater than 57,500 cfs.

The daily CALSIM modeling assumed a slightly different rating curve and flow-split relationship. Figure C.A-35 shows the assumed Fremont Weir flow relationship with combined Sacramento River flow at Verona. The CALSIM model assumed the Fremont Weir begins to spill at a Sacramento River at Verona flow of about 55,000 cfs. At a combined flow of 100,000 cfs, the Fremont Weir spill is about 40,000 cfs and the flow remaining in the Sacramento River would be about 60,000 cfs. At a combined flow of 225,000 cfs, the Sacramento River flow at Verona would be 75,000 cfs and the Fremont Weir spill would be 150,000 cfs. The Fremont Weir was assumed to spill about 87% of the Sacramento River flow greater than 55,000 cfs.

5C.A.3.4.4 Fremont Weir Notch Daily Flows

The BDCP would include a gated notch at the Fremont Weir that would divert a range of target flows into the Yolo Bypass at lower (less than 55,000 cfs) Sacramento River flows so that some portion of the Yolo Bypass would be inundated more frequently. Based on HEC-RAS modeling results and review of previous studies, it was determined that flows of 3,000 to 6,000 cfs would provide sufficient surface area and water depths for substantial increases in suitable fish habitat. For these flows, the average water depths would generally be 2-3 feet, with velocities of less than 2 ft/sec, and water travel times in the Yolo Bypass would be 3-4 days. The anticipated inundated area would be about 10,000 acres at a flow of 3,000 cfs and 20,000 acres at a flow of 6,000 cfs.

The crest elevation for the gated notch was assumed to be at 18 feet (USED datum), so some gate flow would begin when the Sacramento River at Verona flow was about 15,000 cfs (Figure C.A-32). For a notch with a width of 225 feet, a notch flow of 1,000 cfs would be achieved at a weir depth of about 3 feet (elevation of 21 feet), corresponding to a Verona flow of about 22,500 cfs. A notch flow of 3,000 cfs would be achieved with a depth of 5 feet (elevation of 23 feet), corresponding to a Verona flow of 36,000 cfs. A notch flow of 6,000 cfs would be achieved with a depth of about 7 feet (elevation of 25 feet), corresponding to a Verona flow of about 42,000 cfs.

However, if the notch was opened, the Verona flow would be reduced by the notch flow, reducing the water elevations at Verona and the Fremont Weir, and thereby reducing the notch flow. For example, if the Verona flow was 42,000 cfs at a Fremont Weir elevation of 25 feet and the notch was opened, the Verona flow would be reduced to 36,000 cfs and the elevation would be reduced to about 22.5 feet, reducing the notch flow to 3,000 cfs. The Verona flow and notch flow must reach an equilibrium elevation; a notch flow of 4,000 cfs at an elevation of 23.5 feet would match the reduced flow at Verona of 38,000 cfs. Table C.A-12 provides the elevation-flow tables for the Sacramento River at Verona, the Fremont Weir, and the proposed notch. Without a gate, the notch flow would increase rapidly with Sacramento River flow (elevation). The elevation-flow tables can be rearranged to give a flow-split equation. Figure C.A-36 provides the assumed rating curve for the adjusted Verona flow and Fremont Weir notch flow, as determined by the adjusted Fremont Weir elevations (with a maximum notch flow of 6,000 cfs). The daily CALSIM modeling assumed the gate flow is shut off when the combined Verona and notch flow reached 55,000 cfs allowing the Fremont Weir flow to begin. It is more likely that the notch gate would continue to be open until the Fremont Weir flow was greater than 6,000 cfs.

A preliminary analysis of how often the notch would be operated was made, based on the frequency of Verona flows between about 25,000 cfs (notch flow of 1,000 cfs) and 60,000 cfs (Fremont Weir spills of more than 5,000 cfs) for the months of January–May. Figure C.A-37 shows that flows are above 60,000 cfs (Fremont Weir spills) about 10% of the time in the first part of January, 25% of the time from January 15 to March 15, and about 10% of the time from March 15 through April 30. Verona Flows are greater than 25,000 cfs (notch flow of more than 1,000 cfs) about 50% of the time from January 15 to March 31, and more than 25% of the time in May. So there would be some increased spills to the Yolo Bypass in substantially more days. Table C.A-13 shows the monthly counts of daily historical combined Verona flow and Fremont Weir flows greater than specified values (10,000 cfs to 100,000 cfs) for WY 1941–2010. This table can be used to estimate the benefits for migrating Sacramento River juvenile fish rearing in the Yolo Bypass. The Fremont Weir will spill (at 60,000 cfs) for an average of 25 days each year from December to April. With a notch that diverts Sacramento River water at a flow of 20,000 cfs, the number of days with flows into Yolo Bypass would increase to about 81 during the months of December–April. This would be a substantial increase in the days with inundation of some portion of the Yolo Bypass.

The daily CALSIM modeling was used to simulate these periods of increased Yolo Flows (and corresponding reduced Sacramento flows at Verona and at Freeport. Although the daily CALSIM modeling does not appear to include the Verona flow and notch flow equilibrium, a similar flow-split relationship was assumed. The actual design of the proposed notch may provide a slightly different notch flow relationship; the likely increased Yolo Bypass flows will be similar to those modeled for the BDCP effects analysis.

The daily combined flows at Verona and the Fremont Weir were adjusted by the difference between the CALSIM monthly flows for the BDCP (ESO_ELT and ESO_LLT) and the historical monthly flows. The monthly average Fremont Weir flows (existing weir plus notch) calculated from the daily estimated weir and notch spills are the primary result from CALSIM. Although the monthly average weir flows did not change by very much in most months, the number of days with notch flows (of 1,000 cfs to 6,000 cfs) may be of interest for estimating the fraction of fish using the Yolo Bypass for migration and rearing. The daily estimated CALSIM flows for the Sacramento River at Wilkins Slough and at Verona, and the daily Fremont Weir (and notch) spills to the Yolo Bypass were used in the evaluation of the improved Yolo Bypass rearing conditions for Chinook salmon, and were also used in the Delta Passage Model calculations of migration survival for Sacramento River Chinook salmon.

Table C.A-12. Elevation-Flow Relationships for Sacramento River at Verona and Fremont Weir and Proposed Notch

Verona Elevation (feet USED datum)	Verona Flow (cfs)	Fremont Weir Elevation (feet USED datum)	Fremont Weir Spill (cfs)	Proposed Notch Flow (cfs)
13	12,142	15	0	0
14	13,874	16	0	0
15	15,709	17	0	0
16	17,644	18	0	8
17	19,678	19	0	124
18	21,811	20	0	445
19	24,040	21	0	1,031
20	26,365	22	0	1,933
21	28,786	23	0	3,192
22	31,300	24	0	4,847
23	33,907	25	0	6,932
24	36,607	26	0	9,479
25	39,398	27	0	12,518
26	42,280	28	0	16,076
27	45,252	29	0	20,182
28	48,313	30	0	24,859
29	51,463	31	0	30,133
30	54,702	32	0	36,027
31	58,027	33	0	42,564
32	61,440	34	265	49,765
33	64,939	35	4,134	57,651
34	68,524	36	14,823	66,243
35	72,194	37	34,376	75,561
36	75,950	38	64,435	85,624
37	79,789	39	106,414	96,451
38	83,713	40	161,575	108,061
39	87,720	41	231,070	120,471
40	91,810	42	315,965	133,699
41	95,983	43	417,254	147,762

Verona Flow Estimate Flow = a + b x (Elev)^c	Spill = width x weir C x (depth)$^{2.5}$		
a =0		**Fremont Weir**	**Proposed Notch**
b = 120	crest	33.5	17.5
c = 1.8	width	5,000	225
	exponent	2.5	2.5
	weir C	0.3	0.2

Table C.A-13. Monthly Distribution of Historical Combined Verona and Fremont Weir Daily Flows of Greater than Specified Values (from 10,000 cfs to 100,000 cfs) for WY 1954–2003

	10,000	20,000	30,000	40,000	>50,000	>60,000	>70,000	>80,000	>90,000	>100,000
Oct	16	1	0	0	0	0	0	0	0	0
Nov	19	5	2	1	1	1	1	0	0	0
Dec	27	12	7	5	4	3	3	2	2	1
Jan	27	16	12	9	7	6	6	5	4	4
Feb	26	19	15	11	9	8	7	6	5	4
Mar	29	21	14	10	7	6	5	4	3	3
April	25	13	8	5	3	3	2	2	2	1
May	24	10	6	3	1	1	1	1	0	0
June	19	5	2	1	0	0	0	0	0	0
July	20	2	0	0	0	0	0	0	0	0
Aug	23	2	0	0	0	0	0	0	0	0
Sep	23	3	0	0	0	0	0	0	0	0
Days per year	278	108	66	44	33	26	23	20	17	15
Days from Dec–April	134	81	56	40	31	25	22	19	16	14

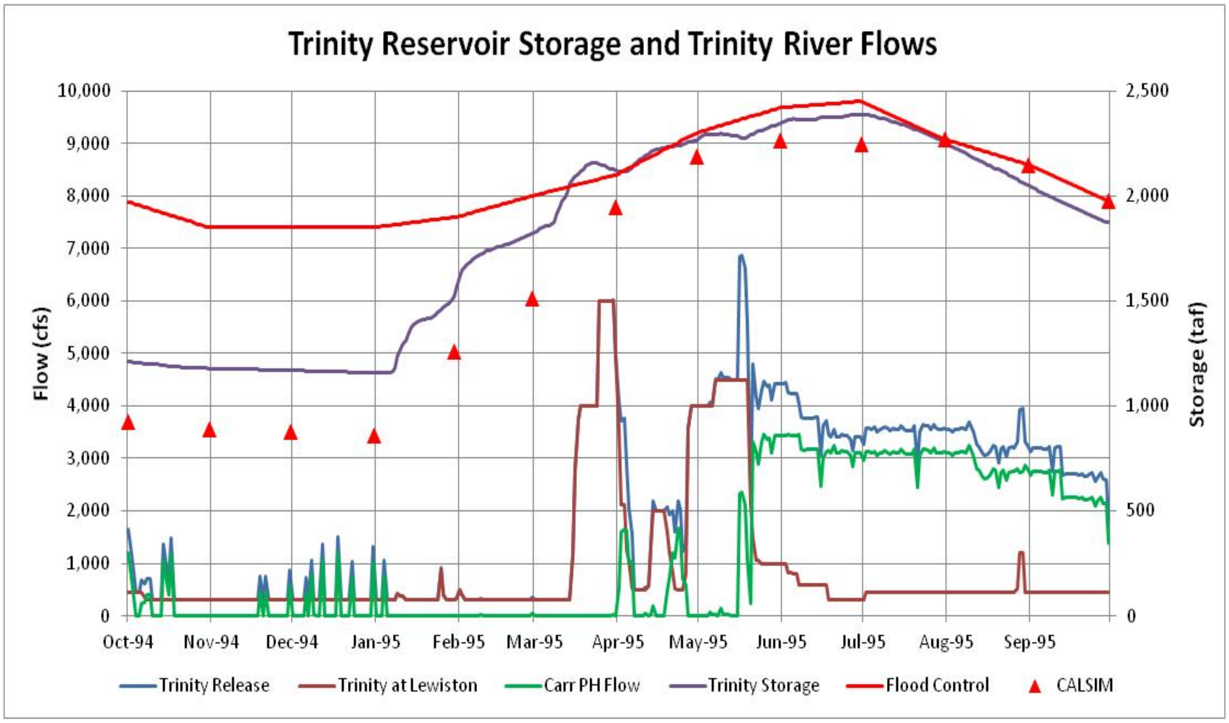


Figure C.A-17. Trinity Reservoir Historical Daily Operations for WY 1995

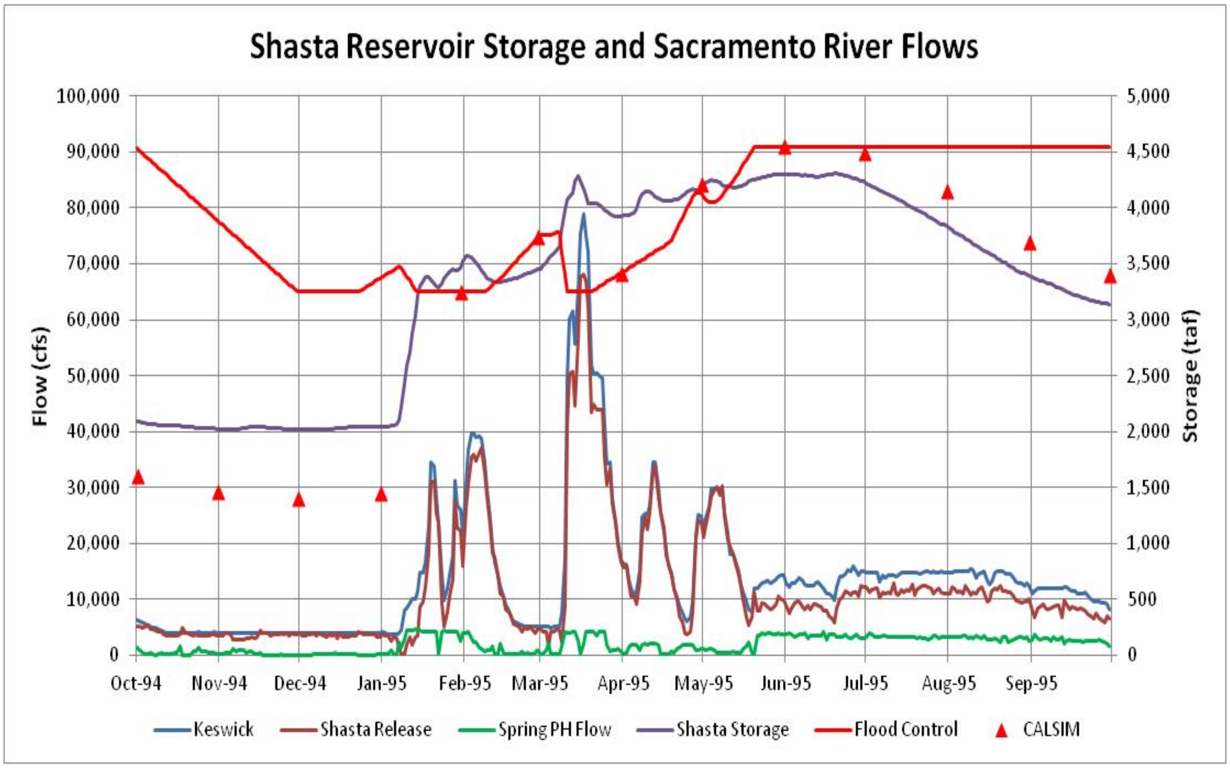


Figure C.A-18. Shasta Reservoir Historical Daily Operations for WY 1995

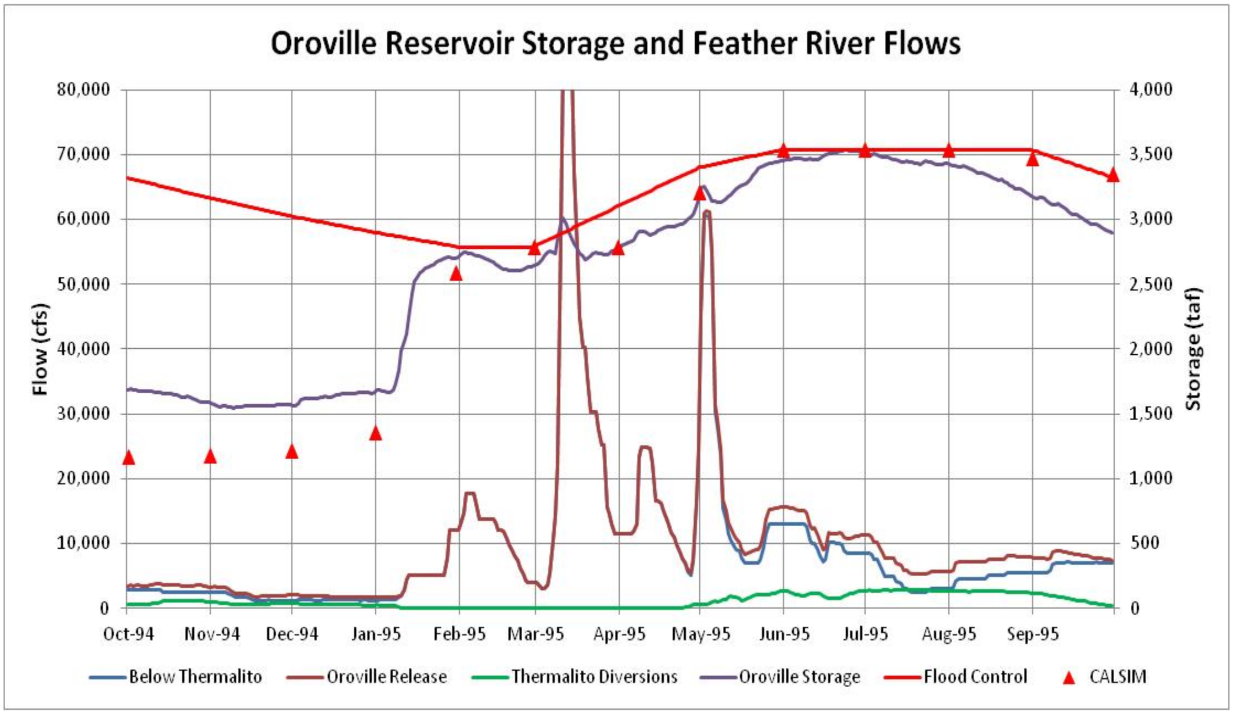


Figure C.A-19. Oroville Reservoir Historical Daily Operations for WY 1995

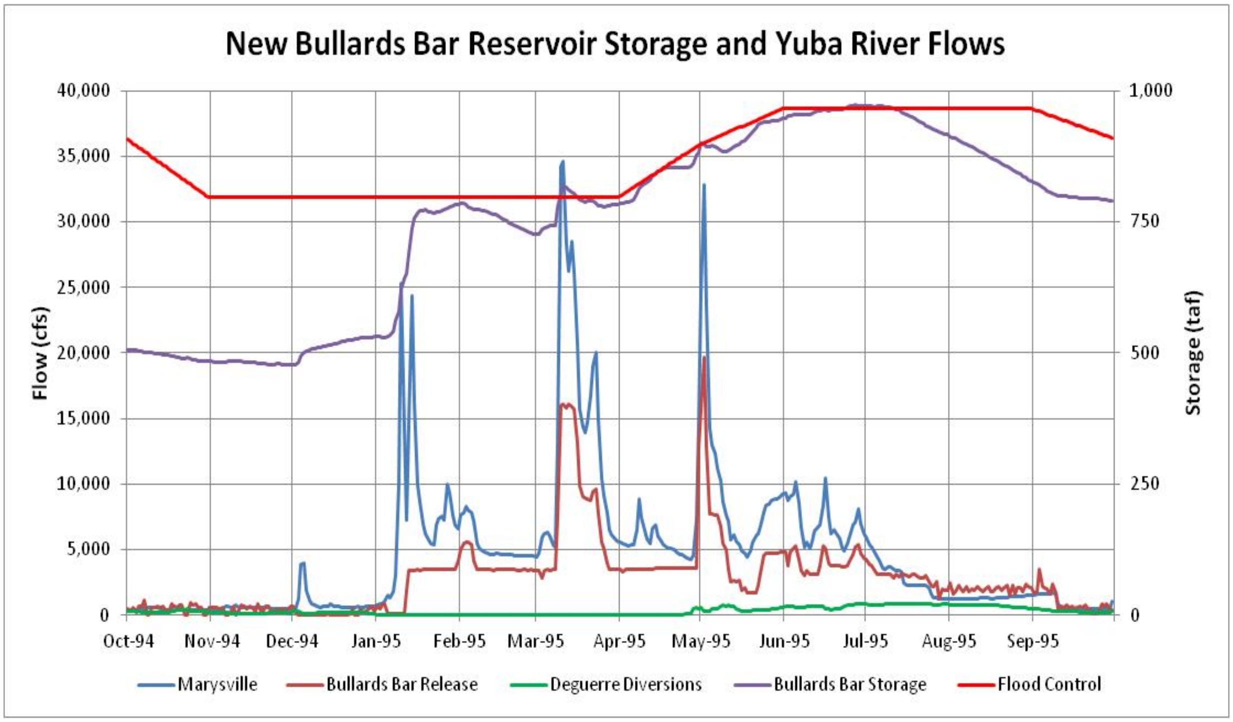


Figure C.A-20. New Bullards Bar Reservoir Historical Daily Operations for WY 1995

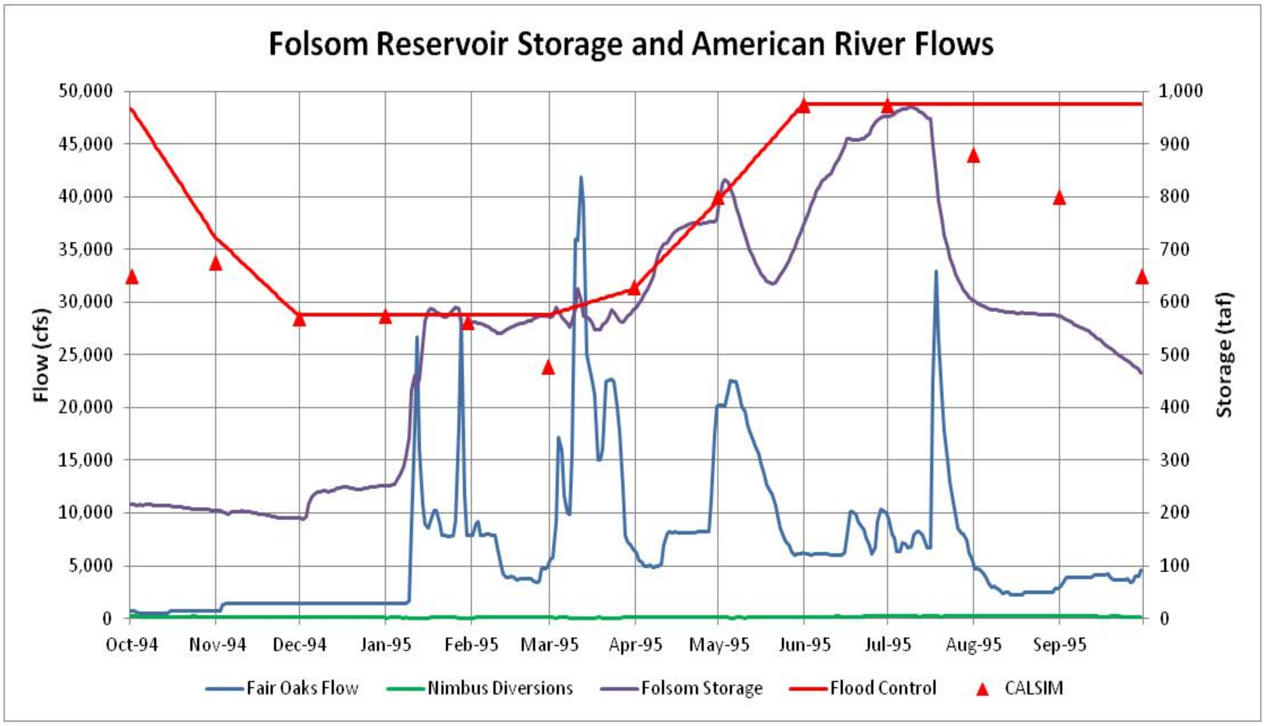


Figure C.A-21. Folsom Reservoir Historical Daily Operations for WY 1995

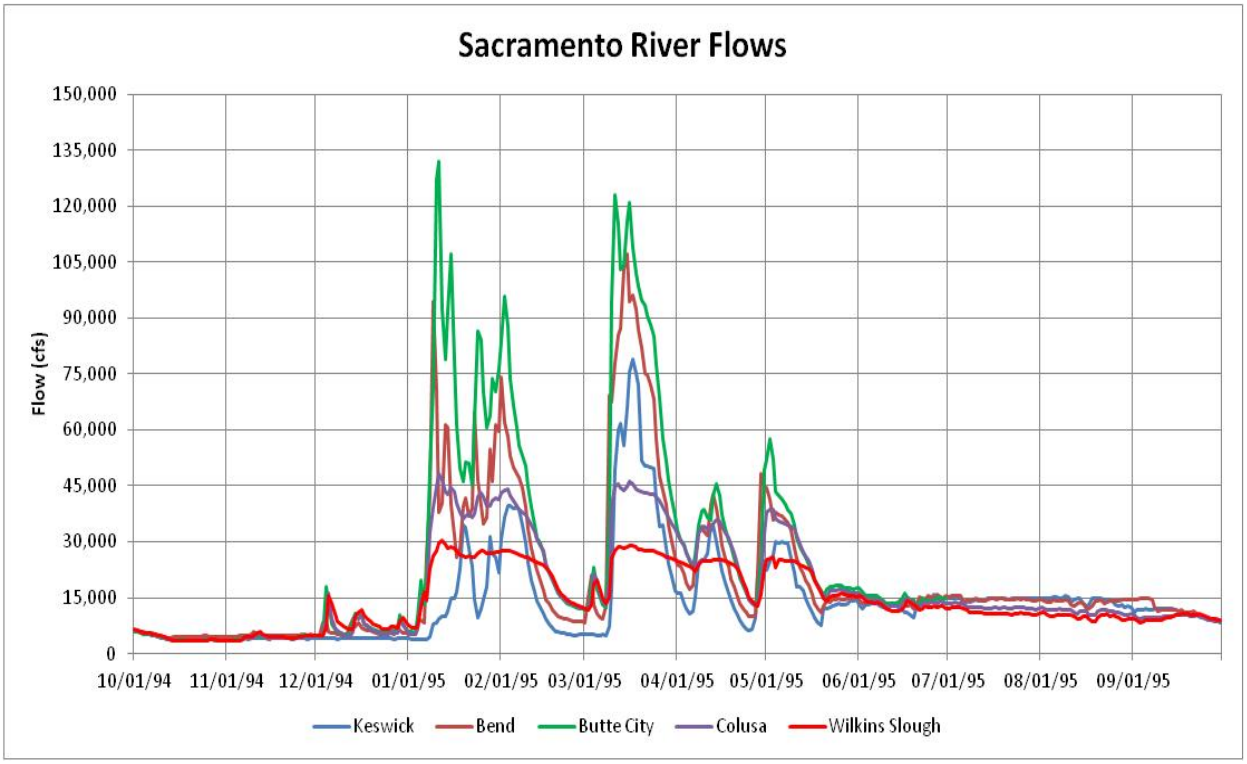


Figure C.A-22. Daily Sacramento River Flows at Keswick, Bend (Red Bluff), Butte City, Colusa, and Wilkins Slough (Grimes) for WY 1995

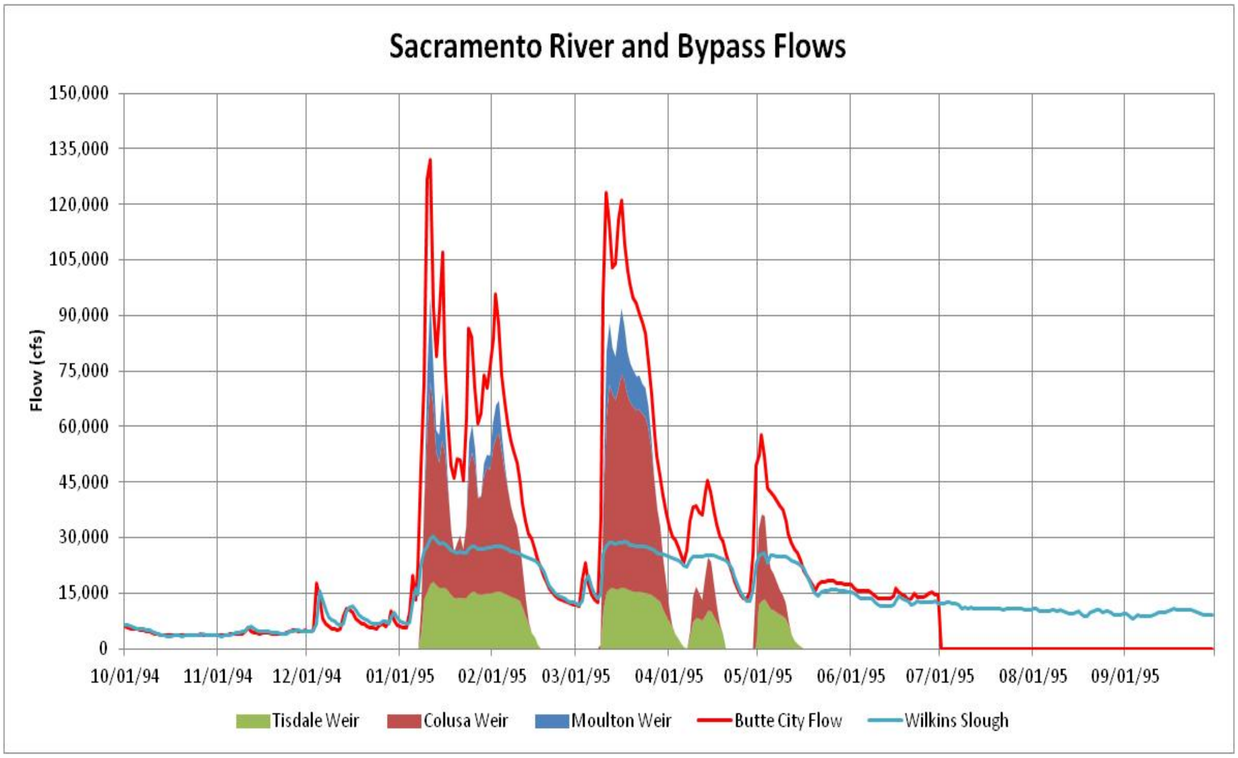


Figure C.A-23. Daily Moulton, Colusa, and Tisdale Weir Diversions from Sacramento River for WY 1995

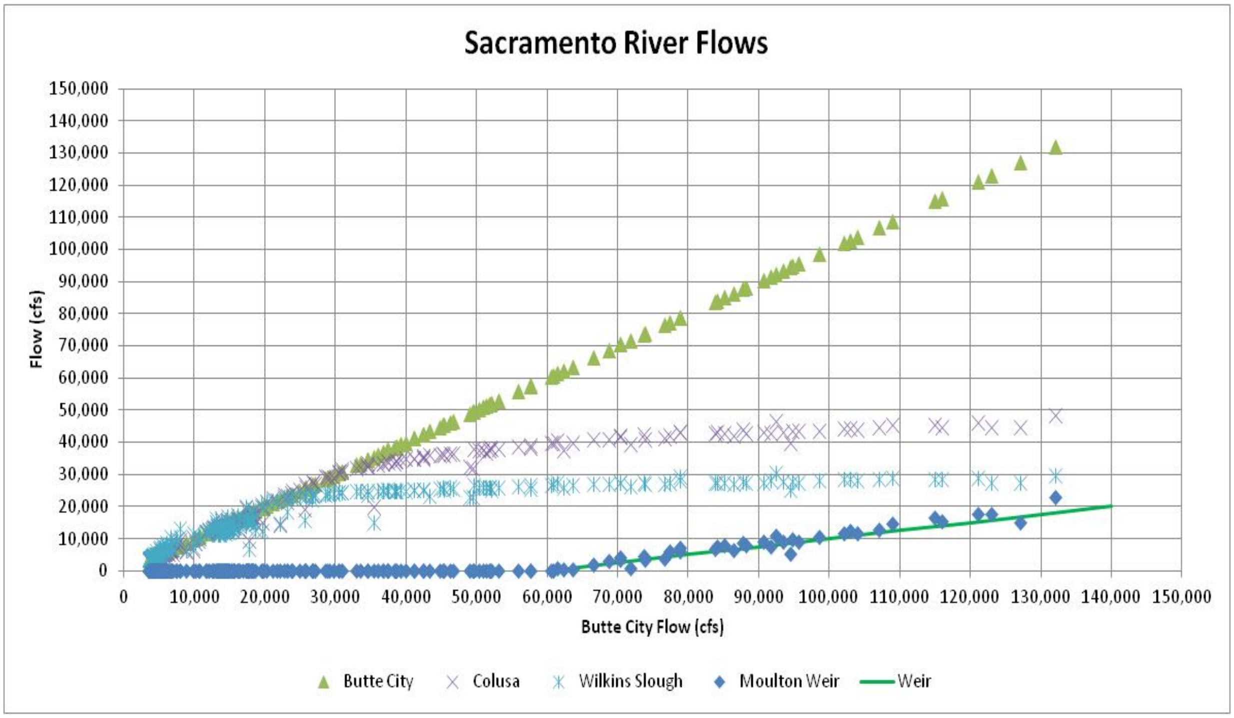


Figure C.A-24. Daily Sacramento River flows at Butte City and Moulton Weir Diversions for WY 1995

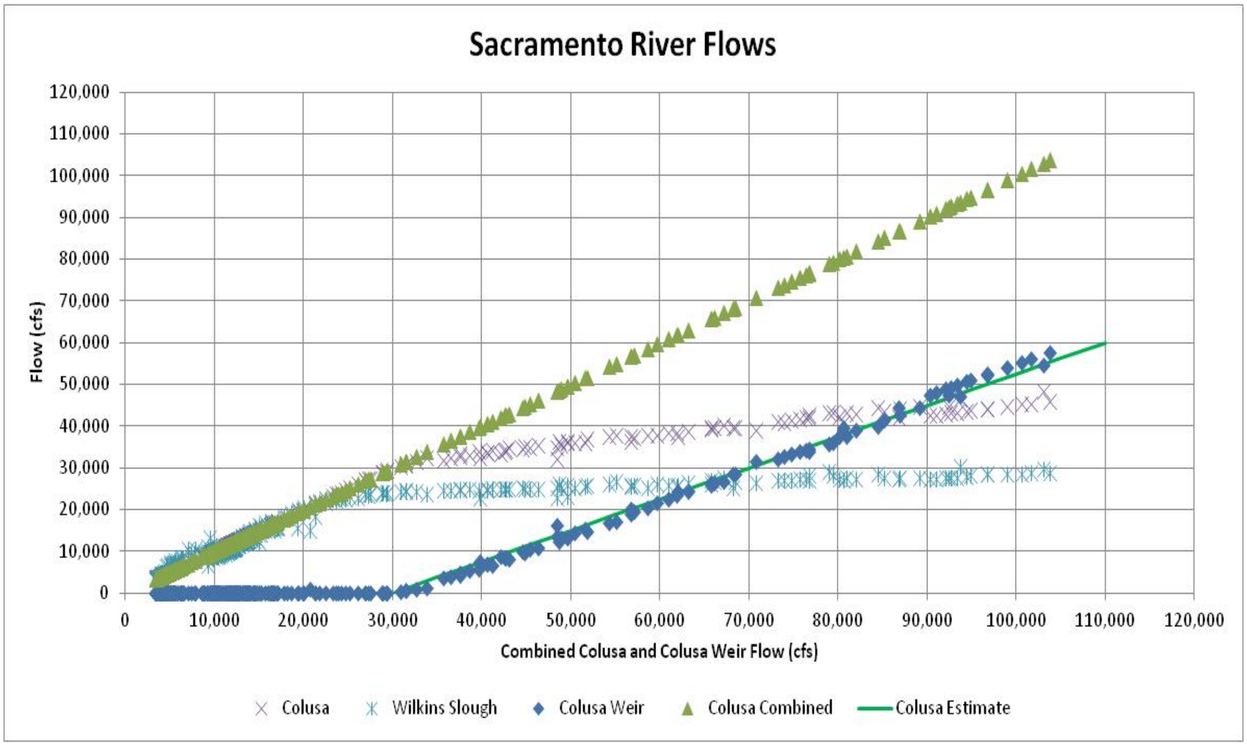


Figure C.A-25. Daily Sacramento River at Colusa Weir flows and Colusa Weir Diversions for WY 1995

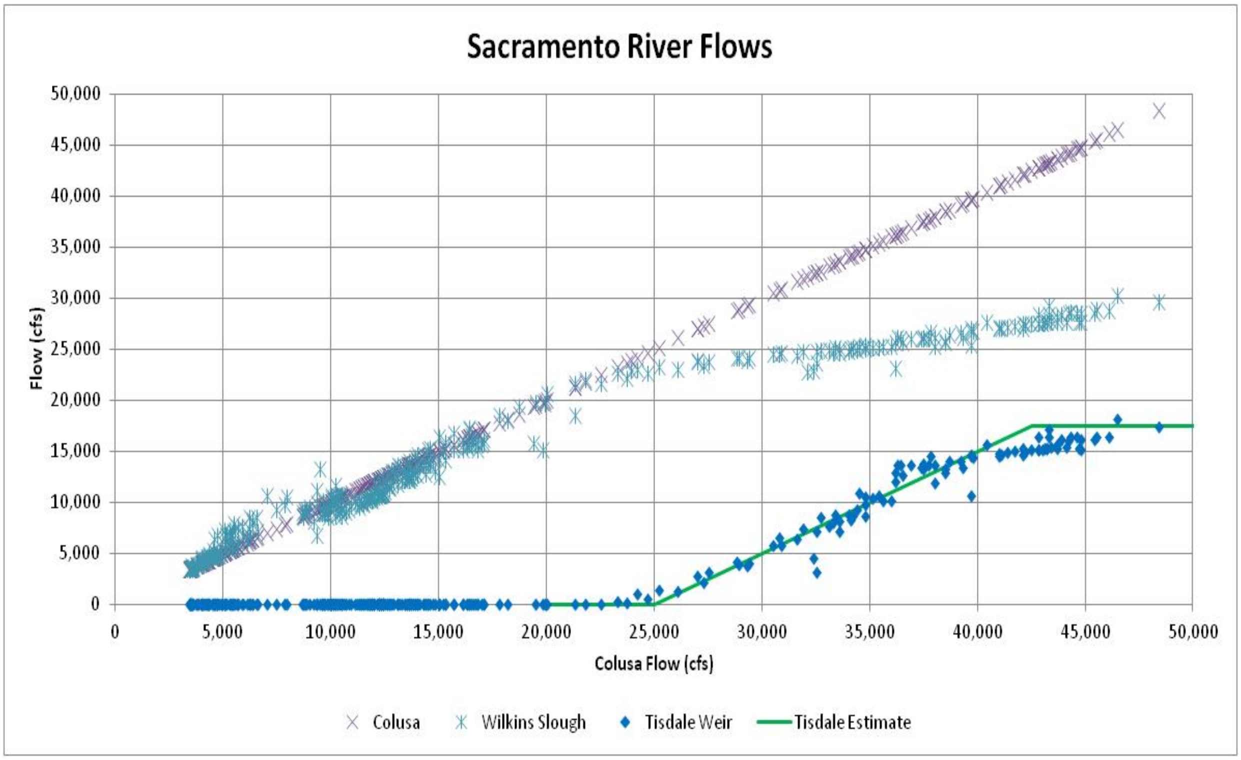


Figure C.A-26. Daily Sacramento River at Colusa and Tisdale Weir Diversions for WY 1995

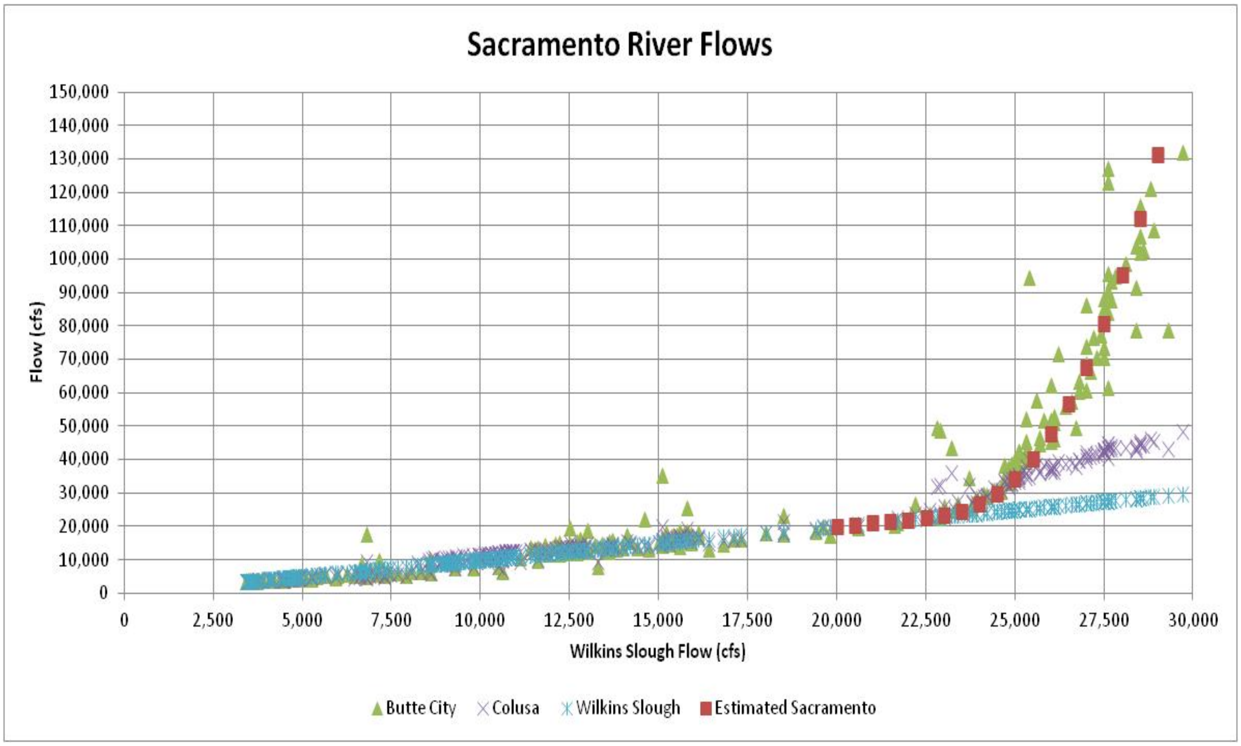


Figure C.A-27. Daily Sacramento River flow at Butte City Estimated from Wilkins Slough Flow for WY 1995

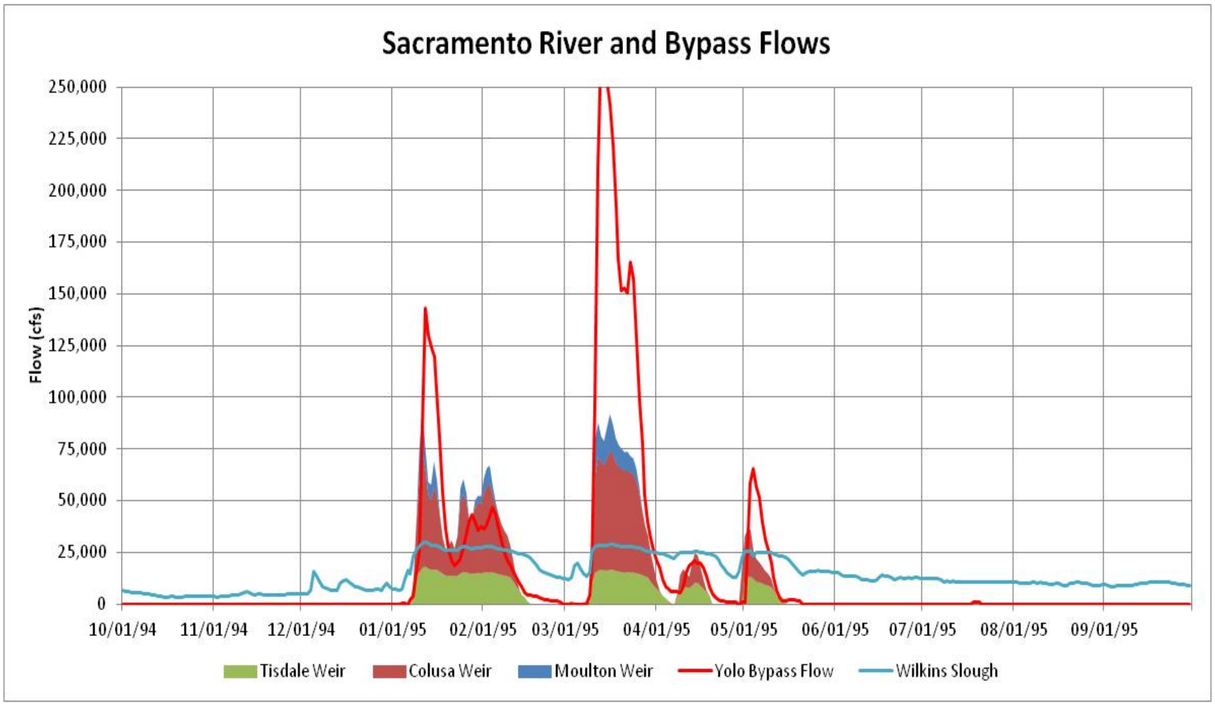


Figure C.A-28. Comparison of Daily Yolo Bypass Flows and Sacramento River Weir Flows for WY 1995

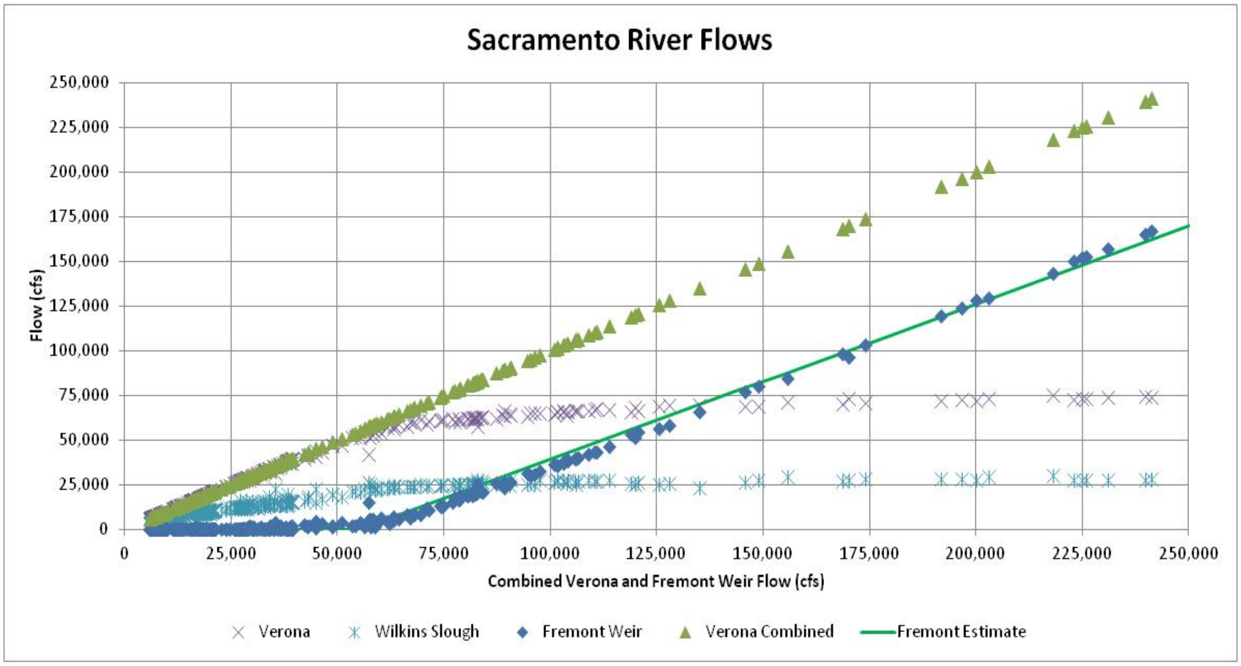


Figure C.A-29. Sacramento River Flow at Wilkins Slough and Verona and Fremont Weir Flows for WY 1995

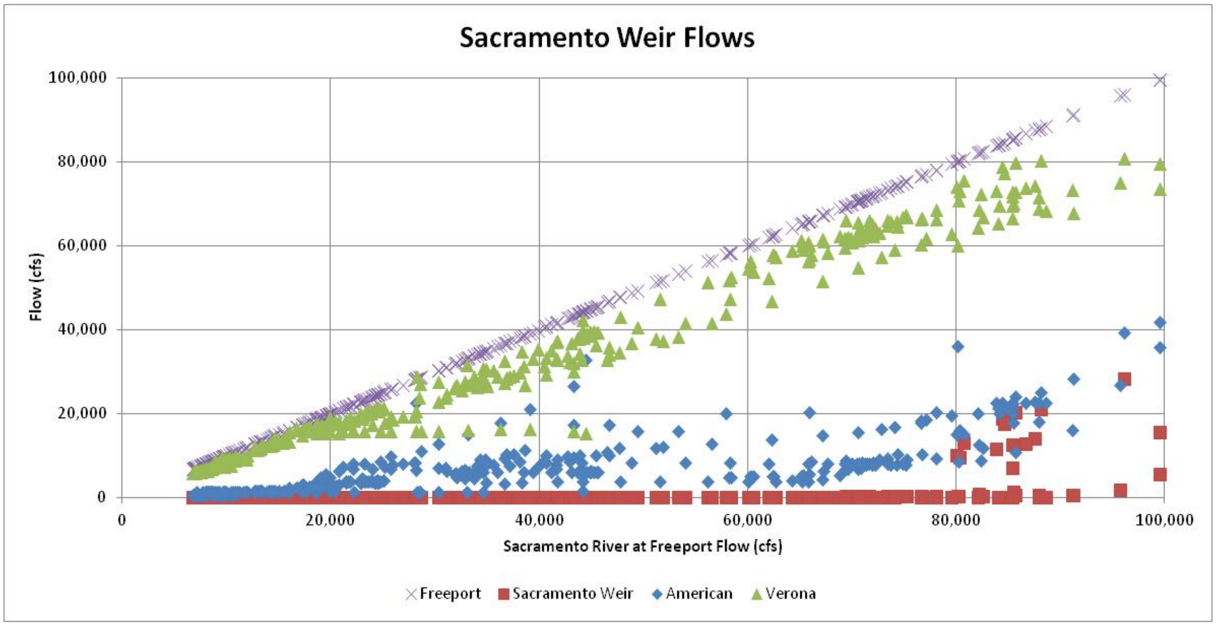


Figure C.A-30. Sacramento River at Freeport and Sacramento Weir Diversions to Yolo Bypass for WY 1995

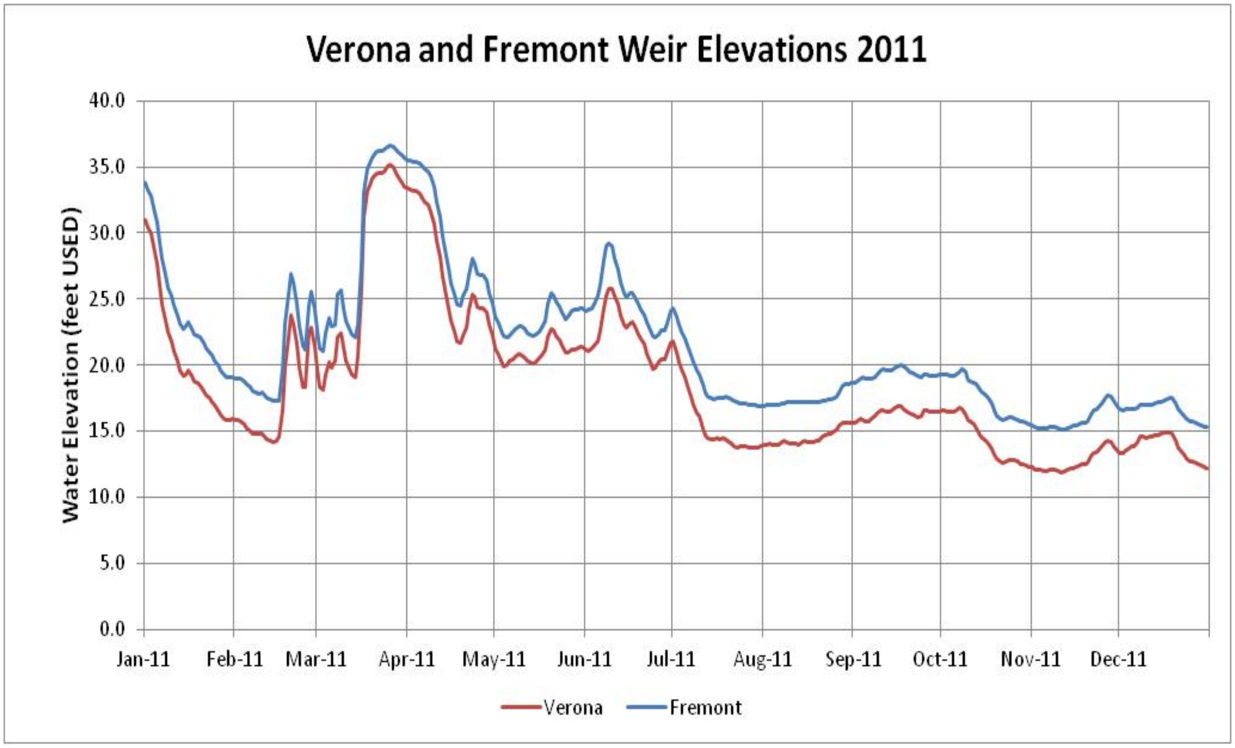


Figure C.A-31. Daily Sacramento River Water Elevations at Verona and Fremont Weir during 2011

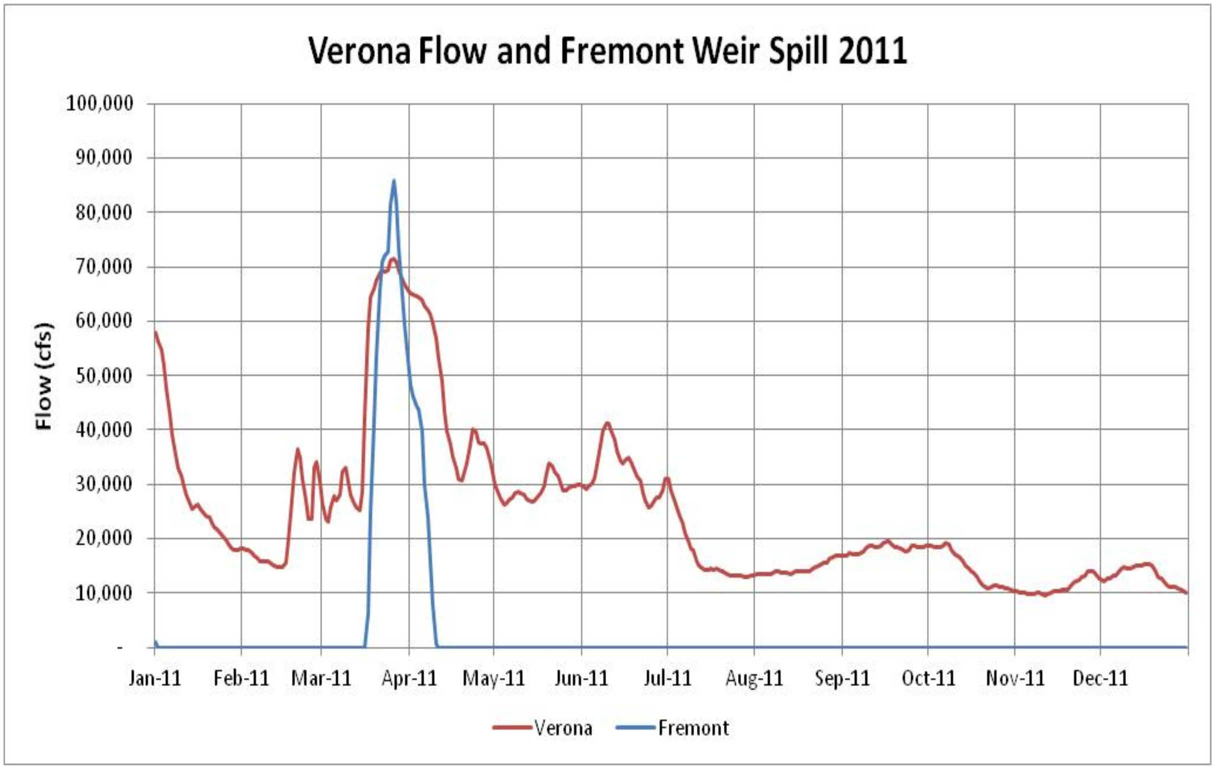


Figure C.A-32. Daily Sacramento River at Verona Flows and Fremont Weir Spills during 2011

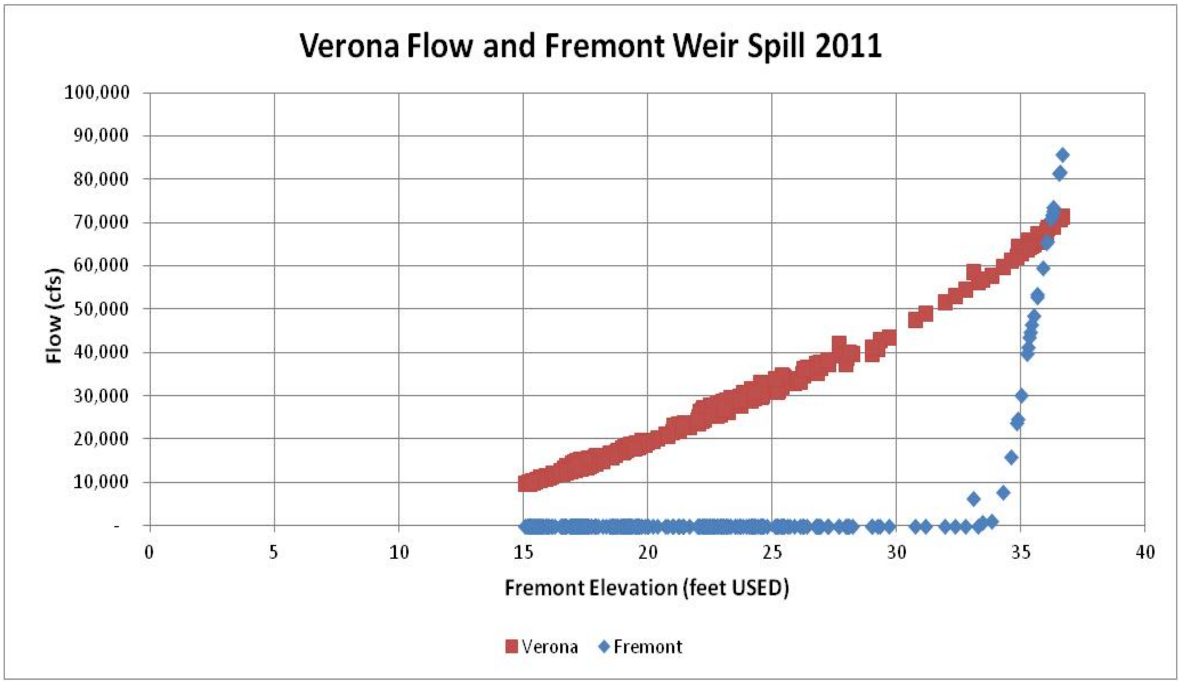


Figure C.A-33. Rating Curve for Fremont Weir Elevations and Verona Flows and Fremont Weir Spills

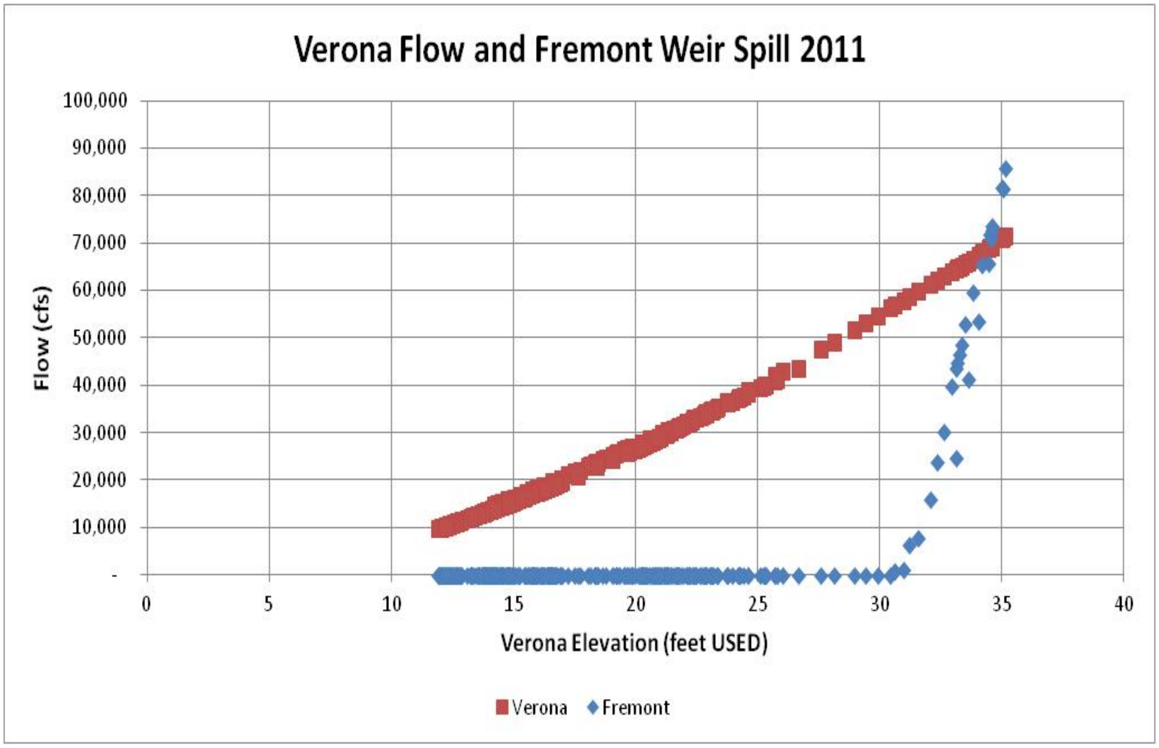


Figure C.A-34. Rating Curve for Verona Elevations and Verona Flows and Fremont Weir Spills

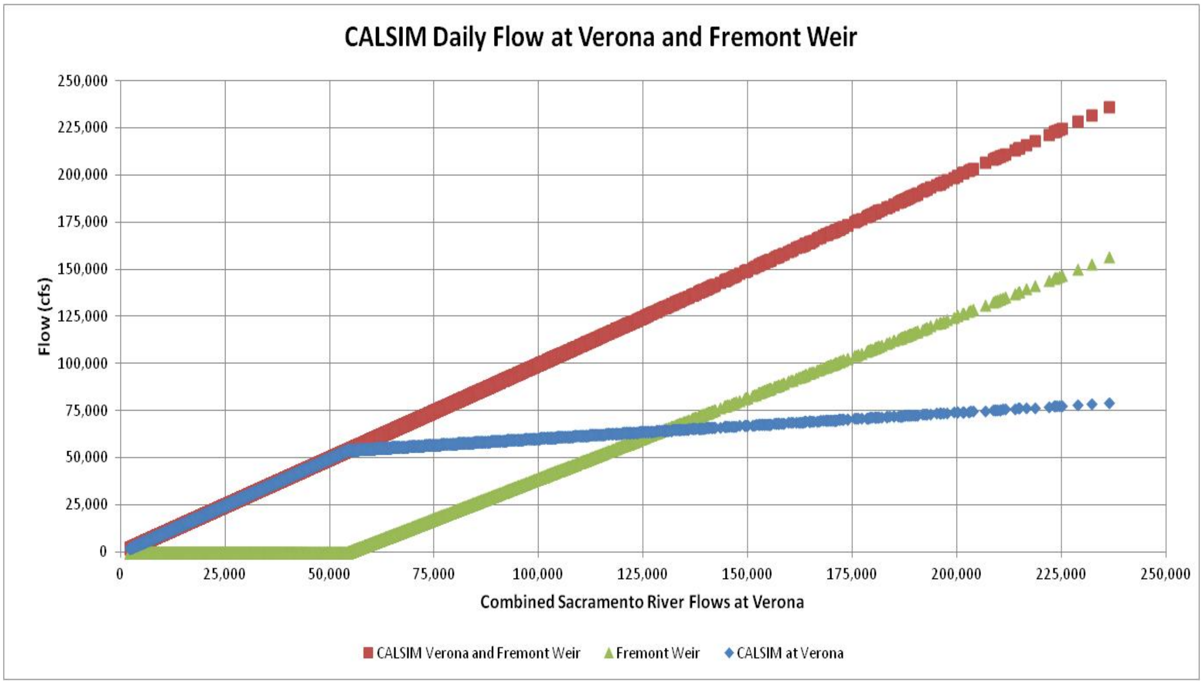


Figure C.A-35. Fremont Weir and Verona Flow Split Assumed in the Daily CALSIM Modeling

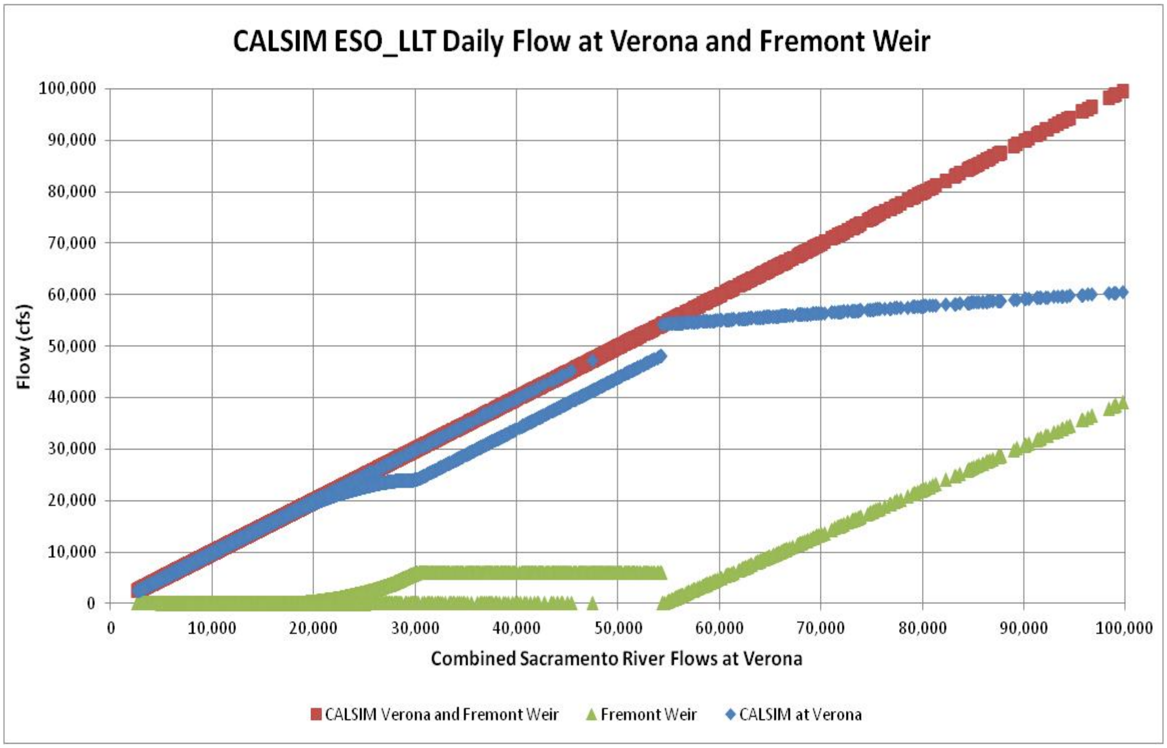


Figure C.A-36. Adjusted Fremont Weir and Verona Flow Split with BDCP Notch Assumed in the Daily CALSIM Modeling

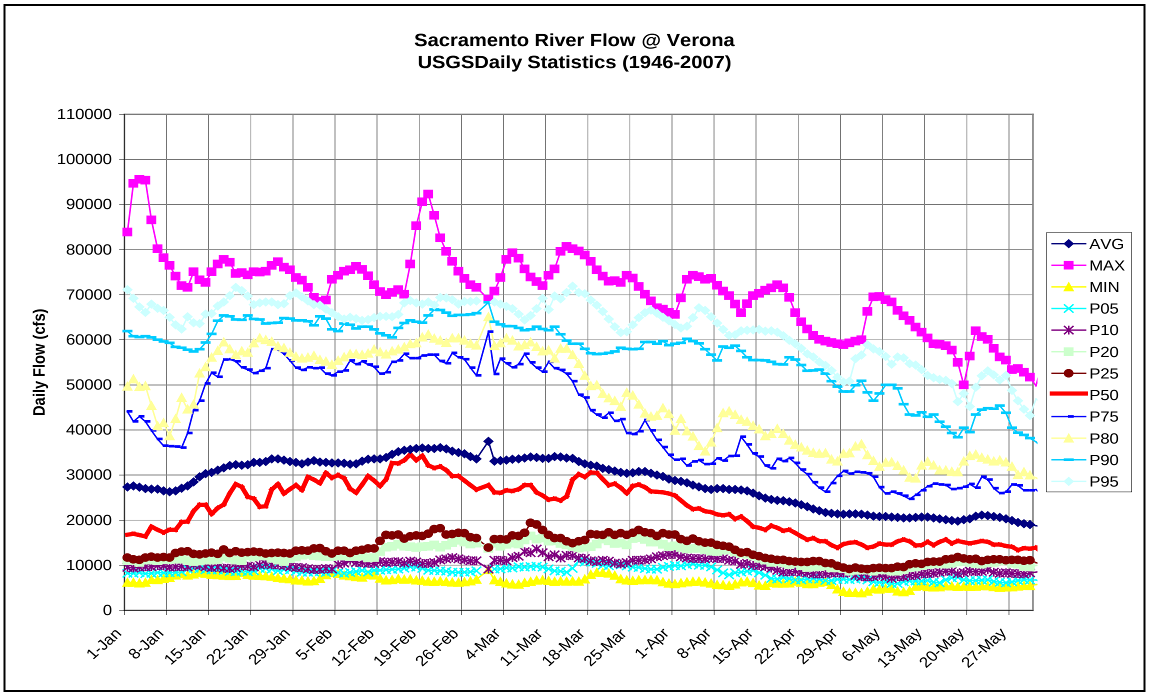


Figure C.A-37. Daily Cumulative Distribution of Sacramento River Flows at Verona for 1946–2007

5C.A.3.5 Monthly Sacramento River Flow at Verona and Fremont Weir Spills into the Yolo Bypass for the ESO

Table C.A-14 gives the CALSIM-simulated monthly Sacramento River flow at Verona for the six CALSIM cases. Verona is located just downstream of the Feather River confluence, the Sutter Bypass outflow, and the Fremont Weir that spills to the Yolo Bypass. The total outflow from the Feather River and the Sacramento River watersheds can be calculated as the sum of the Verona flow and the Fremont Weir spill to the Yolo Bypass. The CALSIM-simulated average annual Sacramento River flow at Verona was about 13,000 taf/yr for the EBC1 and EBC2. The average annual flow at Verona was about 450 taf/yr less for the ESO_ELT and ESO_LLT cases compared to the EBC2_ELT and EBC2_LLT because the proposed notch (gated) in the Fremont Weir would spill additional water from the Sacramento River into the Yolo Bypass, when Verona flows were between 25,000 cfs and 55,000 cfs.

Table C.A-15 gives the CALSIM-simulated monthly average Fremont Weir diversions (weir spill and notch flow) for the six CALSIM cases. The EBC1 and EBC2 results indicate that the existing Fremont Weir generally only spills to the Yolo Bypass during major storms in the months of December–April. Spills in May are rare. The average annual Fremont Weir spill volume was about 1,500 taf/yr for EBC1 and the EBC2 cases.

The ESO_ELT and ESO_LLT cases would increase the probability of Fremont Weir spills by 20% to 30% during December–April because of the combination of climate change (increased monthly runoff) and the notched weir that would allow flows of 1,000 cfs to 6,000 cfs into the Yolo Bypass at a lower Sacramento River flow (25,000 cfs rather than 55,000 cfs under existing conditions). The average Fremont Weir spill volume for the ESO_ELT and ESO_LLT cases was increased by about 400 taf/yr compared to the EBC2. The CALSIM model included a 100 cfs attraction flow for the fish ladder or fish ramp structures to allow upstream migration of adult fish in all months except July and August. The fish ladder and fish ramp might operate year-round if fish are found migrating upstream in all months.

Figure C.A-38 shows the CALSIM-simulated Fremont Weir flow (spill) for the WY 1963–2003 sequence. The historical Fremont Weir spills are shown for comparison (red dots). The periods of high Sacramento River flow are variable from year to year, so the number of months with Fremont Weir spills and the magnitude of the flows are also variable. Because the periods and magnitudes of Fremont Weir spills are controlled by the Sacramento River flow, the simulated flows for each of the cases were quite similar. Figure C.A-39 shows the simulated Fremont Weir flows for the last 10-years of the CALSIM sequence. These years were generally wet, with spills in almost all years. Although the CALSIM model included the effects of the Freemont Weir gate, which would spill at lower flows in the months of December–April, it is difficult to detect the difference in the monthly flows in some years. The daily modeling would show more days with the notch flow for the ESO cases, but the monthly average flows would not change in most months. The Yolo Bypass flows are largely determined by runoff conditions and are not greatly changed by operations or by the proposed notch.

Figure C.A-40 shows the CALSIM results for the flow-split relationship between Verona flow and Fremont Weir flow for the EBC2_LLT (existing Fremont Weir) and the ESO_LLT case (with notch). Because the historical daily flows on the Sacramento River were used in developing the monthly average Fremont Spill estimates, some Fremont Weir spills occur in months with less than 55,000 cfs flow at Verona. The Fremont Weir spill increases rapidly once the monthly average

Verona flow reaches about 55,000 cfs. The ESO_LLT case indicates the increased magnitude of Fremont Weir spills caused by the proposed notch in the Fremont Weir to allow about 2,000 cfs diversion when the Verona flow reaches about 25,000 cfs, and 6,000 cfs when the Verona flow reaches 40,000 cfs. Figure C.A-41 shows the CALSIM results for the Verona flows for the EBC2_LLT (existing Fremont Weir) case compared to the ESO_LLT case (with notch). Months with higher Verona flows could only be caused by changes in upstream reservoir releases under the ESO_LLT conditions. Months with EBC2_LLT Verona flows of 25,000 cfs to 40,000 cfs with about 1,000 cfs to 5,000 cfs less flow at Verona for the ESO_LLT case is the result of the simulated notch flows.

By adding the Fremont Weir spill volume to the Verona flow volume, an average annual simulated flow of 14,500 taf/yr from the Sacramento River watershed upstream of Verona (from 20,000 square miles) was contributing to the Sacramento River and Yolo Bypass flows. The total average simulated water diversions of about 4,500 taf/yr are used for agricultural purposes in the Sacramento Valley upstream of Verona.

Table C.A-14. CALSIM-Simulated Monthly Distribution of Sacramento River Flows (cfs) at Verona

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	4,656	4,421	5,532	6,489	7,299	6,640	7,587	5,700	7,444	8,012	5,451	4,633	5,809
10%	6,827	6,719	7,824	10,401	10,359	10,189	8,860	7,442	8,813	12,350	9,111	7,611	7,637
20%	7,401	7,456	9,469	11,194	12,754	13,582	9,404	8,813	9,575	14,773	10,749	9,093	8,846
30%	8,052	8,183	10,547	12,340	17,463	16,506	10,541	9,423	10,187	15,538	11,675	9,884	9,613
40%	8,764	8,889	12,145	16,008	21,770	19,719	11,170	9,978	10,558	16,166	12,911	10,156	10,165
50%	9,249	9,584	13,606	21,418	27,576	23,606	13,872	10,642	11,126	16,520	13,590	10,708	11,565
60%	9,906	10,145	15,889	26,657	37,154	30,306	16,185	11,951	11,708	17,144	13,807	11,168	15,001
70%	10,749	11,180	20,571	36,479	43,613	38,269	19,703	14,660	12,547	17,739	14,210	11,618	15,894
80%	11,934	13,423	31,537	48,032	51,810	45,783	32,150	23,258	14,790	18,624	15,075	12,714	17,353
90%	13,174	20,186	44,903	54,056	59,434	56,177	45,138	34,208	20,157	19,106	15,397	15,566	20,999
Max	25,416	43,063	62,316	71,150	72,880	69,022	59,675	49,743	49,782	20,104	18,331	21,765	27,856
Avg	9,861	11,565	19,752	27,583	31,979	28,888	19,759	15,840	13,295	16,271	12,813	11,220	13,169
B. ESO_ELT													
Min	4,494	4,510	5,359	7,132	6,997	7,063	7,652	5,642	7,097	6,807	5,124	5,051	5,579
10%	6,166	6,251	7,156	10,031	9,894	9,707	8,660	7,241	8,904	10,078	8,376	7,007	7,061
20%	7,424	6,824	9,705	10,896	12,512	12,731	9,472	8,423	10,100	12,631	9,039	7,538	7,894
30%	8,215	7,703	10,780	11,804	15,907	15,769	10,197	9,133	11,377	13,878	9,810	7,771	8,907
40%	8,599	8,535	11,259	15,282	19,840	18,263	10,940	9,489	12,312	14,685	10,270	8,369	9,602
50%	9,217	9,254	12,839	18,378	24,392	21,330	13,486	10,508	13,583	16,398	11,434	10,192	11,057
60%	9,784	9,999	15,398	22,892	36,487	26,328	15,891	11,802	15,133	17,330	13,053	14,732	14,810
70%	10,132	11,418	18,729	34,956	41,357	33,248	18,954	14,843	16,422	18,611	13,600	18,752	15,873
80%	10,516	12,838	30,027	45,964	52,276	42,136	26,295	21,303	17,454	19,059	14,950	19,948	17,143
90%	11,539	17,474	39,388	53,171	61,381	54,753	41,361	31,021	19,417	19,537	17,172	22,474	20,519
Max	24,676	42,518	65,749	73,850	75,946	70,483	60,216	47,293	44,629	21,462	18,745	24,205	25,342
Avg	9,256	11,032	18,670	26,185	30,862	27,318	18,522	15,176	14,488	15,619	11,919	13,186	12,767
C. ESO_LLT													
Min	4,432	4,496	5,280	7,432	5,952	7,124	7,402	5,531	6,764	5,567	6,032	5,400	5,683
10%	5,742	5,843	7,264	10,682	9,889	9,556	8,793	7,795	9,233	9,017	7,329	6,829	7,394
20%	8,164	6,643	9,694	11,106	12,887	12,638	9,699	8,499	10,527	10,808	9,035	7,454	8,190
30%	9,161	7,354	10,866	12,696	16,083	15,714	10,583	9,980	11,538	12,361	9,805	8,167	8,905
40%	9,447	8,423	11,351	16,117	20,334	17,944	11,588	10,524	12,823	14,523	10,354	9,046	9,588
50%	9,977	9,337	13,489	18,545	24,398	20,956	13,342	11,792	14,679	15,127	10,806	11,668	11,139
60%	10,245	9,920	15,812	22,420	36,529	25,160	16,269	13,299	16,437	16,624	11,446	15,692	14,922
70%	10,847	11,301	17,500	32,405	41,037	32,483	19,282	17,246	17,397	17,837	12,322	19,467	16,057
80%	11,582	12,476	26,796	45,680	53,763	43,886	25,683	19,455	18,614	19,032	14,802	21,866	17,093
90%	12,593	16,204	35,935	53,470	61,020	54,896	40,938	26,326	20,745	19,642	16,150	23,664	20,393
Max	24,760	41,307	65,658	73,806	76,676	70,950	60,064	43,023	40,878	21,532	21,482	26,487	24,275
Avg	9,872	10,711	18,227	26,532	31,200	27,402	18,634	14,865	14,971	14,871	11,549	14,042	12,802

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	4,417	4,425	5,506	8,273	7,159	6,852	7,382	5,782	7,858	7,483	5,803	4,943	5,832
10%	6,816	6,325	7,597	10,076	10,277	9,710	8,742	7,368	8,862	11,811	8,579	7,489	7,751
20%	7,139	7,044	9,842	10,956	12,595	12,556	9,304	8,706	9,846	14,434	10,845	8,919	8,609
30%	7,514	8,205	10,842	12,273	15,343	16,776	10,403	9,008	10,092	15,496	11,766	9,597	9,460
40%	8,137	9,505	11,830	15,989	20,943	19,629	10,940	9,842	10,491	16,263	12,701	10,885	10,171
50%	8,954	10,974	13,152	19,282	26,694	23,103	13,844	10,547	11,473	16,734	13,491	12,196	11,312
60%	9,435	11,972	15,604	24,562	37,191	29,579	16,666	11,745	11,919	17,462	13,948	17,608	15,390
70%	9,898	13,544	19,334	36,540	42,406	36,308	19,853	14,593	12,877	18,060	14,189	18,933	16,469
80%	10,993	14,945	30,164	47,136	51,851	46,359	32,327	23,350	14,778	18,660	14,954	22,724	17,938
90%	12,514	18,149	39,748	54,501	59,421	54,976	45,197	33,963	20,187	19,307	15,942	25,171	21,296
Max	26,602	42,261	62,305	71,167	72,500	69,020	59,683	49,705	49,612	20,272	18,631	27,193	27,454
Avg	9,344	12,145	19,089	27,013	31,446	28,456	19,710	15,679	13,401	16,321	12,820	14,941	13,258
E. EBC2_ELT													
Min	4,581	4,124	5,521	6,315	6,881	6,921	7,452	5,916	7,724	6,710	5,394	4,597	5,593
10%	6,208	6,227	7,158	10,227	10,012	9,664	8,793	7,173	9,080	11,761	7,972	7,007	7,625
20%	7,038	6,913	9,334	11,381	12,256	12,583	9,460	8,425	9,434	13,746	10,939	7,928	8,399
30%	7,451	8,750	10,656	13,343	15,091	17,056	9,802	8,915	10,020	15,552	11,684	8,756	9,367
40%	7,885	9,788	11,802	15,986	21,118	19,184	10,861	9,501	10,422	16,362	12,431	10,504	9,759
50%	8,866	11,087	13,096	19,396	27,496	22,657	13,587	10,204	11,038	17,098	13,605	12,335	11,323
60%	9,875	12,173	15,320	24,432	39,236	30,278	16,241	11,260	11,610	17,743	14,101	17,610	15,212
70%	10,557	13,292	19,829	37,731	42,599	36,643	19,763	13,414	12,326	18,748	14,323	19,911	16,520
80%	11,083	15,383	32,553	47,087	54,116	46,362	30,475	20,405	13,062	19,234	15,134	23,109	18,114
90%	12,098	17,692	42,784	55,093	60,055	55,693	44,960	31,126	16,407	19,715	16,004	24,874	21,202
Max	26,939	42,955	65,747	73,859	75,325	70,483	60,214	47,323	44,705	20,690	18,183	26,976	26,221
Avg	9,181	12,146	19,506	27,430	32,062	28,700	19,488	14,820	12,441	16,464	12,713	14,777	13,218
F. EBC2_LLT													
Min	4,628	4,124	5,777	6,129	6,185	7,034	7,502	5,353	7,331	6,562	5,622	4,459	5,514
10%	5,793	6,150	7,312	10,404	10,270	10,165	8,740	7,862	9,406	11,381	8,928	6,820	7,500
20%	7,439	6,828	8,858	11,194	12,823	12,941	9,435	8,255	10,061	13,821	10,602	7,440	8,567
30%	8,644	7,882	11,024	14,589	15,780	16,053	10,123	9,061	10,644	15,399	12,407	8,340	9,302
40%	9,227	9,371	11,787	16,988	21,191	19,263	10,724	9,879	11,516	17,368	13,417	9,454	9,952
50%	9,718	11,134	13,835	19,598	27,738	22,562	12,949	10,265	12,025	17,991	13,827	11,442	11,329
60%	10,876	12,490	15,466	25,221	37,639	29,434	15,642	11,789	12,505	18,565	14,332	19,209	15,443
70%	11,384	13,459	18,325	35,090	43,187	38,267	19,298	13,946	12,829	18,990	14,977	21,179	16,521
80%	11,645	14,756	27,672	47,897	55,335	48,100	29,941	18,349	13,515	19,457	15,355	24,019	18,029
90%	12,707	16,548	39,831	54,003	60,158	55,722	44,507	26,294	15,374	19,933	16,042	25,191	21,073
Max	24,700	41,148	65,656	74,165	76,211	70,949	60,061	43,096	40,979	23,711	21,286	27,488	24,747
Avg	9,900	11,846	18,852	27,795	32,192	28,877	19,298	13,828	12,576	16,651	13,204	14,755	13,221

1 **Table C.A-15. CALSIM-Simulated Monthly Distribution of Fremont Weir Flows (cfs) into Yolo Bypass**

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year (taf)
A. EBC1													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	2
50%	0	0	0	0	0	0	0	0	0	0	0	0	190
60%	0	0	0	0	1,014	0	0	0	0	0	0	0	719
70%	0	0	0	945	4,562	274	0	0	0	0	0	0	1,552
80%	0	0	163	6,615	10,476	4,328	0	0	0	0	0	0	3,111
90%	0	0	8,900	2,5431	35,828	18,376	1,191	0	0	0	0	0	5,646
Max	1,370	10,695	5,0174	10,5276	116,073	92,002	33,696	7,838	2,137	0	0	0	9,877
Avg	17	263	2,388	7,170	9,269	5,946	1,014	110	26	0	0	0	1,557
B. ESO_ELT													
Min	100	100	100	100	100	100	100	100	100	0	0	100	60
10%	100	100	100	100	100	100	100	100	100	0	0	100	80
20%	100	100	100	101	123	188	100	100	100	0	0	100	180
30%	100	100	100	140	527	427	100	100	100	0	0	100	265
40%	100	100	101	776	1,635	1,044	100	100	100	0	0	100	348
50%	100	100	167	1,456	3,356	1,836	123	100	100	0	0	100	717
60%	100	100	522	2,655	5,148	3,456	351	100	100	0	0	100	1,388
70%	100	100	1,617	5,123	7,367	5,197	1,031	100	100	0	0	100	2,098
80%	100	100	3,647	10,478	13,643	6,622	4,161	100	100	0	0	100	4,067
90%	100	100	9,427	28,133	45,078	18,112	5,904	100	100	0	0	100	7,071
Max	1,126	10,589	71,584	122,120	135,196	101,117	37,070	4,751	238	0	0	100	12,086
Avg	113	366	3,676	9,426	12,422	8,003	2,251	158	102	0	0	100	2,177
C. ESO_LLT													
Min	100	100	100	100	100	100	100	100	100	0	0	100	60
10%	100	100	100	100	100	100	100	100	100	0	0	100	81
20%	100	100	100	103	131	177	100	100	100	0	0	100	176
30%	100	100	100	199	609	454	100	100	100	0	0	100	261
40%	100	100	107	911	1,775	964	101	100	100	0	0	100	333
50%	100	100	182	1,462	3,247	1,735	113	100	100	0	0	100	603
60%	100	100	518	2,795	5,582	3,757	349	100	100	0	0	100	1,320
70%	100	100	1,461	5,420	7,472	5,727	1,095	100	100	0	0	100	2,263
80%	100	100	2,770	11,310	17,192	8,031	4,013	100	100	0	0	100	3,891
90%	100	100	6,879	25,466	43,746	21,552	5,748	100	100	0	0	100	7,368
Max	1,168	6,712	71,021	121,847	139,748	104,032	36,123	1,177	100	0	0	100	12,775
Avg	113	253	3,075	9,568	13,055	8,532	2,206	113	100	0	0	100	2,204

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year (taf)
D. EBC2													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	0
50%	0	0	0	0	0	0	0	0	0	0	0	0	117
60%	0	0	0	0	246	0	0	0	0	0	0	0	593
70%	0	0	0	964	2,553	252	0	0	0	0	0	0	1,460
80%	0	0	0	5,537	9,668	4,084	0	0	0	0	0	0	2,851
90%	0	0	5,703	21,049	34,099	13,589	1,257	0	0	0	0	0	5,606
Max	2,010	8,759	50,102	105,383	113,700	91,992	33,746	7,784	1,999	0	0	0	9,877
Avg	25	225	2,043	6,879	8,856	5,744	1,025	109	24	0	0	0	1,481
E. EBC2_ELT													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	0
50%	0	0	0	0	0	0	0	0	0	0	0	0	187
60%	0	0	0	0	837	0	0	0	0	0	0	0	629
70%	0	0	0	1,250	4,544	405	0	0	0	0	0	0	1,811
80%	0	0	0	7,416	12,129	4,996	0	0	0	0	0	0	3,476
90%	0	0	9,454	23,544	41,843	16,433	1,617	0	0	0	0	0	6,737
Max	2,217	10,548	71,577	122,180	131,325	101,117	37,060	4,675	147	0	0	0	11,760
Avg	27	268	2,800	8,003	10,636	6,488	1,142	58	2	0	0	0	1,747
F. EBC2_LLT													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	1
50%	0	0	0	0	0	0	0	0	0	0	0	0	115
60%	0	0	0	0	821	0	0	0	0	0	0	0	602
70%	0	0	0	849	3,953	621	0	0	0	0	0	0	1,893
80%	0	0	0	9,090	14,222	5,684	0	0	0	0	0	0	3,272
90%	0	0	5,079	23,714	42,108	17,813	1,744	0	0	0	0	0	6,970
Max	1,012	6,381	71,007	124,085	136,849	104,026	36,105	1,108	0	0	0	0	12,320
Avg	12	159	2,151	8,533	11,171	7,037	1,142	14	0	0	0	0	1,793

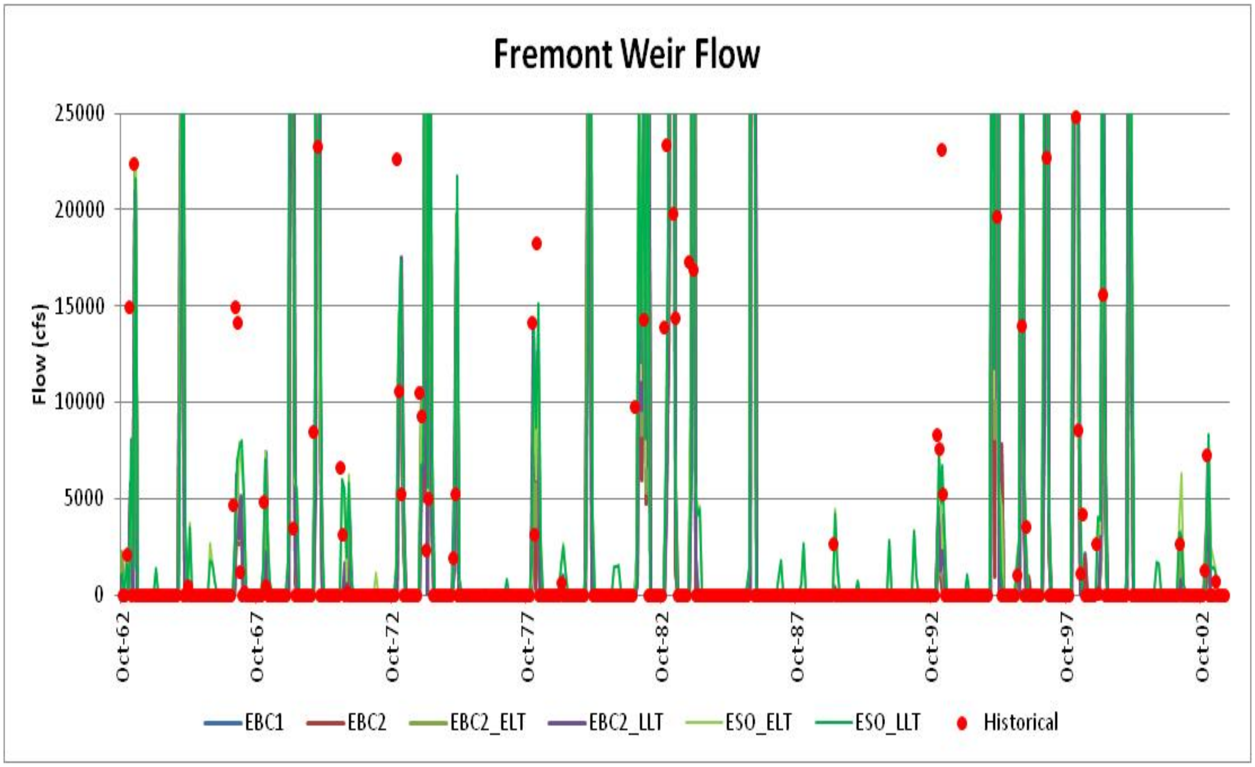


Figure C.A-38. CALSIM-Simulated Monthly Fremont Weir Spill (cfs) for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

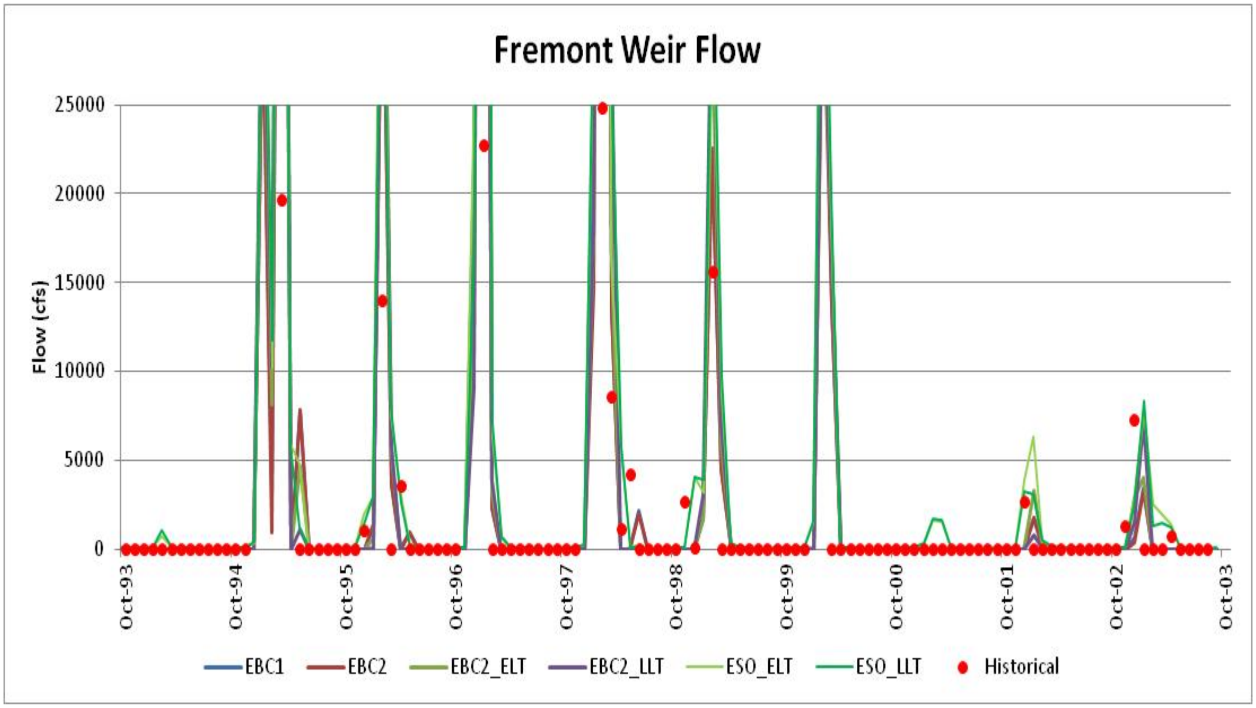


Figure C.A-39. CALSIM-Simulated Monthly Fremont Weir Spill (cfs) for WY 1994–2003 for the EBC2 and ESO_ELT and ESO_LLT Cases

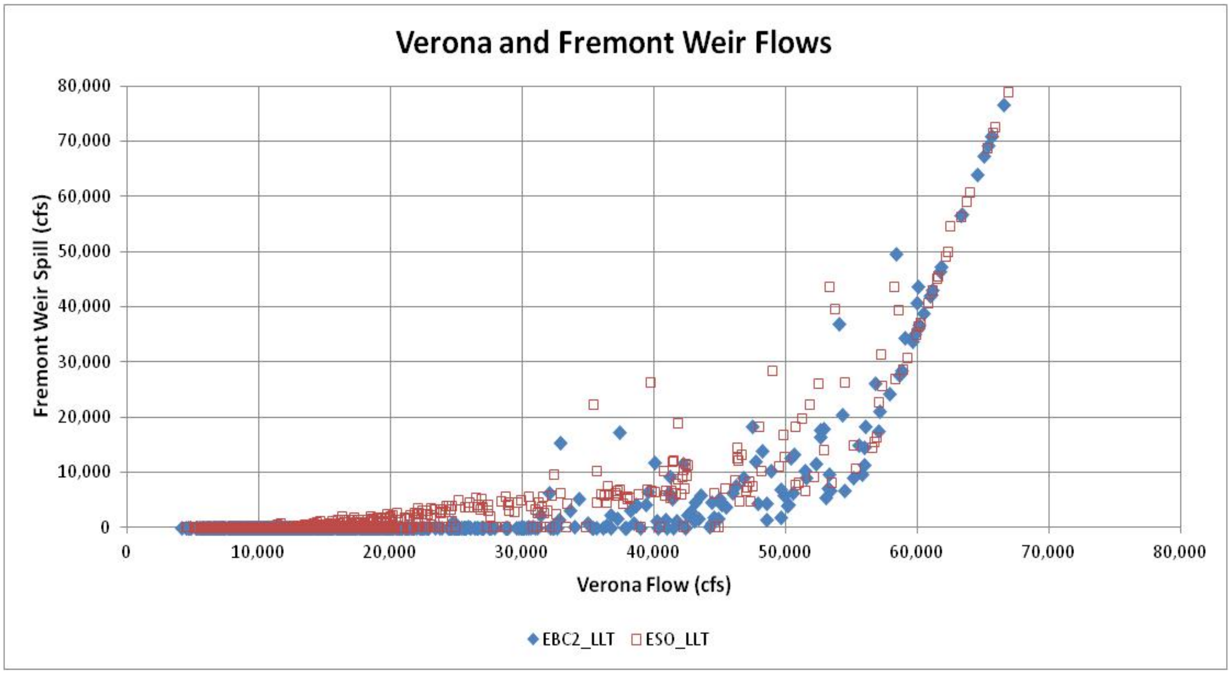


Figure C.A-40. CALSIM-Simulated Relationship between Monthly Fremont Weir Spill (cfs) and Sacramento River Flow (cfs) at Verona for WY 1994–2003 for the EBC2_LLT and ESO_LLT Case

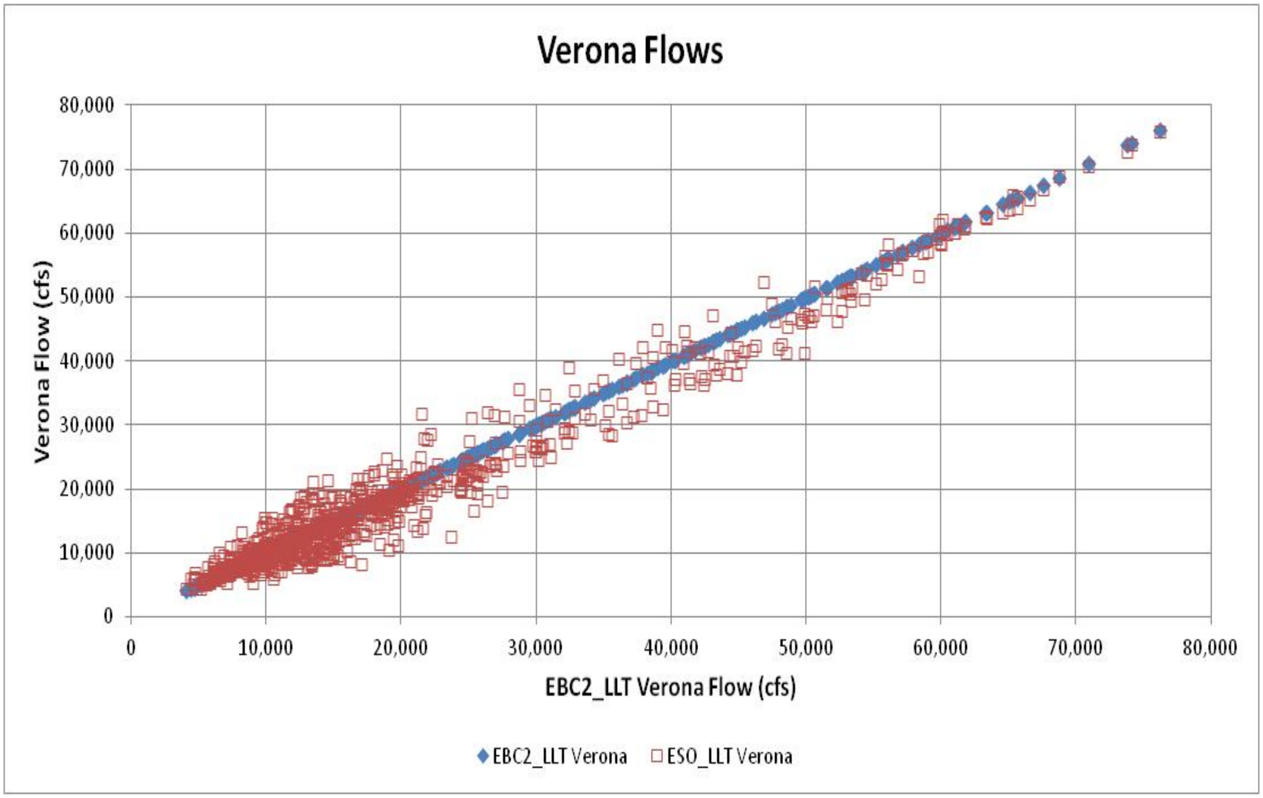


Figure C.A-41. Comparison of CALSIM-Simulated Monthly Sacramento River Flow (cfs) at Verona for 1922–2003 for the EBC2_LLT and ESO_LLT Cases

5C.A.3.6 Simulated Changes in Folsom Reservoir Operations for the ESO

Table C.A-16 shows the monthly distributions of the CALSIM-simulated Folsom Reservoir storage patterns for the six CALSIM cases. The maximum storage of about 975 taf was simulated only in May and June. The maximum flood control storage is about 575 taf from November to February. There are some variations caused by runoff conditions (snow vs. rain) and upstream storage, but this generally limits the amount of water that can be stored in Folsom Reservoir during the winter months of December–March. The Folsom Reservoir maximum flood control storage increases in March and April, and full storage is allowed in May. The EBC1 monthly median storage volumes for Folsom Reservoir were about 500 taf to 600 taf in October through March, increased to 800 taf in April, increased to 975 taf (full) in May and June, and decreased to 750 taf in July, 650 taf in August and 600 taf in September. The simulated Folsom Reservoir monthly median storage levels for the EBC2 cases were similar to the EBC1 case, although the combination of increased CVP municipal water supply diversions and Fall X2 had some effect on lowered carryover storage (median of about 540 taf for EBC2). The median carryover storage level was reduced to about 480 taf for the EBC2_ELT case and to 385 taf for the EBC2_LLT case. These reductions were caused by the shifted runoff conditions. The median carryover storage for the ESO cases were about the same as for EBC2. This suggests that the major factors in the reduced simulated carryover storage were the effects of increased water supply diversions and climate change (shifting in the inflow). The simulated Folsom Reservoir storage does not appear to show much of a direct effect from the ESO cases.

Figure C.A-42 shows the simulated monthly Folsom Reservoir storage for the EBC1 and EBC2 cases and the ESO_ELT and ESO_LLT cases for the 1963–2003 sequence. The historical Folsom storage is shown for comparison. The CALSIM-simulated carryover storage for the ESO_ELT and ESO_LLT cases was reduced by 200 taf to 300 taf in several years when the carryover storage was between 400 taf and 600 taf. Because CALSIM does not have a minimum reservoir carryover target, the increased water supply demands are not balanced by reduced releases, and the reservoir storage is reduced significantly in most years. Actual CVP operations likely would factor in a carryover storage target for coldwater pool and recreation uses. Figure C.A-43 shows the simulated monthly Folsom Reservoir storage for EBC1 and EBC2 cases and the ESO_ELT and ESO_LLT cases for the 1994–2003 sequence. Although these 10 years were relatively wet, the reduced carryover storage levels in WY 1994, 1997 and in WY 1999 and 2000 for the ESO_ELT and ESO_LLT cases appear to be lower than recent years of actual Folsom Reservoir operations.

Table C.A-17 shows the CALSIM-simulated American River flow below Nimbus Dam (Fair Oaks) for the six CALSIM cases. The minimum flows below Nimbus depend on runoff and Folsom storage, but generally maintain flows above 1,500 cfs in all months. For the EBC1, the median monthly American River flows were 1,500 cfs in October and about 2,000 cfs from November–January, with higher flows of 2,500 cfs to 3,500 cfs caused by flood control releases from February to June. The simulated Folsom Reservoir release flows in July often were increased to 5,000 cfs because the Delta E/I ratio was increased to 65% and these flows could be exported for south-of-Delta water supply. Releases in August and September often were limited by the target reservoir drawdown for recreation uses and coldwater pool. The simulated ESO_ELT and ESO_LLT cases generally released more water in January–March and slightly less water in the spring and summer, with more water in the fall months, although the patterns of change are different each year. The average annual release flow for the EBC1 was about 2,475 taf/yr, and the average releases were about 75 taf/y less for EBC2 (increased water supply diversions). The ELT cases were about the same as the EBC2 case, and the

LLT cases were about 50 taf/yr less than the EBC2 and ELT cases. The simulated ESO_ELT and ESO_LLT cases did not change the Folsom Reservoir operations substantially from the EBC2.

Figure C.A-44 shows the simulated American River flows at Nimbus Dam for the six BDCP cases for the 1963–2003 sequence. The monthly flows are generally between 1,000 cfs (minimum flow requirement in most years) and 5,000 cfs, but several years had higher monthly flows of 10,000 cfs to 40,000 cfs caused by flood control releases from Folsom Reservoir. The major differences between the cases were the slightly different flood control releases caused by different inflow sequences assumed for the EBC1 and EBC2 or the ELT or LLT conditions. Figure C.A-45 shows the simulated monthly American River flows at Nimbus Dam for the six cases for the 1994–2003 sequence. The higher flows (flood control spills) and the monthly flows in the summer and fall months (i.e., controlled releases) of some years were different for the ELT and LLT cases compared to the EBC1 and EBC2 (existing hydrology) flows. Because CALSIM uses pre-calculated operations for the several upstream reservoirs, the uncertainty in the Folsom inflows for the ELT and LLT cases is likely greater than for the other reservoirs.

The Folsom Reservoir operations will have effects on aquatic resources (fish) by changing the reservoir storage levels (drawdown) and affecting the cold-water pool (volume) remaining at the end of each water year. The Folsom Reservoir operations will also affect the American River flows and the release temperatures at Nimbus Dam and downstream in the American River. The effects of Folsom Reservoir operations on American River water temperatures for existing runoff and air temperature conditions and with climate change assumptions are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

Table C.A-16. CALSIM-Simulated Monthly Distribution of Folsom Reservoir Storage (taf)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	90	90	152	161	126	185	174	177	157	90	90	90
10%	301	297	285	318	359	465	498	519	499	376	326	310
20%	361	374	359	385	427	563	682	734	640	469	391	381
30%	411	420	404	431	467	601	755	824	743	554	476	452
40%	480	459	476	481	506	622	800	929	874	667	577	532
50%	583	544	516	521	536	634	800	975	975	751	659	613
60%	603	568	546	560	553	645	800	975	975	781	725	650
70%	632	575	571	570	563	659	800	975	975	807	767	650
80%	642	575	575	575	573	667	800	975	975	891	800	650
90%	652	575	575	575	575	672	800	975	975	950	800	650
Max	720	575	575	575	575	675	800	975	975	950	800	650
Avg	505	467	468	479	494	598	727	850	823	684	600	525
B. ESO_ELT												
Min	90	90	95	90	114	164	143	138	108	90	90	90
10%	166	202	242	287	350	469	473	488	432	257	216	182
20%	294	308	309	333	407	530	613	650	536	371	332	328
30%	330	347	350	402	449	591	727	745	618	419	386	361
40%	360	387	415	462	485	625	800	846	726	480	439	408
50%	433	419	475	513	549	636	800	970	803	585	509	456
60%	474	475	508	546	560	649	800	975	896	642	581	530
70%	516	515	536	562	566	660	800	975	974	716	613	565
80%	564	545	575	571	575	667	800	975	975	795	723	596
90%	600	572	575	575	575	670	800	975	975	864	768	644
Max	720	575	575	575	575	675	800	975	975	937	800	650
Avg	416	409	434	461	488	592	712	817	745	563	498	441
C. ESO_LLT												
Min	53	90	90	52	73	90	90	90	90	90	90	90
10%	90	100	188	206	283	383	401	411	331	157	90	90
20%	220	243	257	298	362	509	588	561	412	329	275	236
30%	287	297	302	359	404	561	681	677	557	361	319	313
40%	323	313	341	395	430	617	769	781	640	411	379	349
50%	345	345	382	437	523	632	800	873	691	476	437	389
60%	377	380	430	541	556	649	800	937	753	542	474	447
70%	422	400	500	563	563	659	800	975	839	581	520	464
80%	444	431	549	573	574	667	800	975	886	678	584	503
90%	555	512	575	575	575	670	800	975	975	764	677	558
Max	720	575	575	575	575	675	800	975	975	927	800	650
Avg	345	337	385	428	463	577	693	774	666	475	417	371

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	90	90	146	160	127	142	130	136	114	90	90	90
10%	272	256	252	304	355	456	475	509	459	354	317	289
20%	339	337	345	366	412	521	607	684	612	439	377	366
30%	372	385	394	423	429	590	746	812	725	506	438	396
40%	440	430	433	458	492	623	800	916	834	615	548	493
50%	501	469	479	497	527	637	800	975	964	731	618	539
60%	573	499	506	544	556	652	800	975	975	766	701	587
70%	607	516	548	563	563	661	800	975	975	797	742	617
80%	626	540	574	574	572	667	800	975	975	912	800	642
90%	644	572	575	575	575	672	800	975	975	950	800	650
Max	720	575	575	575	575	675	800	975	975	950	800	650
Avg	474	433	446	465	487	593	717	839	808	665	578	492
E. EBC2_ELT												
Min	90	90	90	90	121	147	126	121	92	90	90	90
10%	176	207	234	283	350	449	461	488	443	274	199	187
20%	315	308	317	338	402	522	613	663	561	389	341	324
30%	343	361	362	386	429	590	731	773	681	435	389	365
40%	375	401	399	444	484	623	800	874	766	528	485	420
50%	434	420	451	489	543	636	800	975	882	618	525	481
60%	470	448	469	533	558	652	800	975	968	700	604	514
70%	509	479	530	560	563	662	800	975	975	751	672	556
80%	554	507	575	571	575	667	800	975	975	837	752	589
90%	621	555	575	575	575	671	800	975	975	909	800	633
Max	720	575	575	575	575	675	800	975	975	950	800	650
Avg	422	400	429	454	485	591	713	823	773	601	523	446
F. EBC2_LLT												
Min	90	90	90	90	90	90	90	90	90	90	90	90
10%	92	115	212	233	330	402	431	463	410	180	90	91
20%	243	259	255	313	360	502	605	585	443	322	285	259
30%	292	299	306	347	417	570	686	706	601	372	332	317
40%	319	330	346	412	474	611	797	835	692	443	396	353
50%	348	351	389	457	518	629	800	917	770	527	428	385
60%	380	376	429	529	555	649	800	970	822	581	491	419
70%	415	399	492	561	562	660	800	975	878	618	547	469
80%	473	424	546	572	570	667	800	975	961	716	620	526
90%	548	494	575	575	575	672	800	975	975	798	718	575
Max	720	575	575	575	575	675	800	975	975	950	800	650
Avg	354	341	388	431	469	580	697	791	712	509	439	379

Table C.A-17. CALSIM-Simulated Monthly Distribution of American River Flows (cfs) at Nimbus Dam

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
A. EBC1													
Min	500	527	520	800	800	299	357	307	359	442	250	355	417
10%	1,210	949	952	1,141	1,225	891	925	925	1,429	1,891	1,256	906	1,119
20%	1,500	1,534	1,499	1,542	1,445	1,143	1,445	1,339	1,750	2,930	1,752	1,207	1,339
30%	1,500	1,714	1,782	1,700	1,565	1,508	1,668	1,445	1,904	3,150	2,263	1,622	1,569
40%	1,500	1,925	2,000	1,700	2,413	1,843	2,057	1,750	2,344	3,623	2,502	2,041	1,830
50%	1,500	2,009	2,000	2,005	3,504	2,524	2,385	2,875	2,850	4,123	2,719	2,570	2,153
60%	1,500	2,398	2,000	3,087	4,750	3,426	3,287	3,591	3,197	4,577	2,920	3,193	2,541
70%	1,500	2,657	2,507	4,684	6,367	4,132	4,121	4,228	4,295	4,982	3,090	3,687	3,123
80%	1,723	3,062	4,444	6,735	9,108	5,544	5,098	5,048	5,136	5,000	3,823	4,177	3,754
90%	2,257	4,282	7,245	10,559	11,669	8,886	6,694	8,326	7,207	5,000	4,280	4,311	4,181
Max	4,421	16,015	19,792	31,370	32,258	16,210	14,475	11,423	14,418	6,499	4,700	5,110	6,186
Avg	1,605	2,706	3,519	4,502	5,218	3,762	3,305	3,587	3,699	3,838	2,707	2,663	2,475
B. ESO_ELT													
Min	500	500	500	800	800	317	343	305	357	362	250	307	384
10%	800	800	800	940	1,029	800	800	818	1,115	1,069	800	800	906
20%	1,076	1,191	1,074	1,439	1,342	995	1,267	1,137	1,750	2,419	1,025	884	1,251
30%	1,433	1,433	1,694	1,700	1,514	1,522	1,715	1,603	2,142	3,056	1,743	1,525	1,475
40%	1,500	1,677	1,894	1,700	2,255	1,865	2,110	1,751	2,566	3,364	1,750	1,533	1,729
50%	1,500	1,925	2,000	1,750	3,208	2,778	2,432	2,437	3,336	4,024	1,750	1,533	2,041
60%	1,500	1,925	2,000	2,739	5,172	3,846	3,188	3,072	3,675	5,000	1,990	1,853	2,504
70%	1,504	1,937	2,031	4,746	7,020	4,544	4,099	3,656	4,118	5,000	2,286	2,413	3,132
80%	2,001	2,191	3,809	7,701	10,272	5,820	4,994	4,389	4,493	5,000	2,652	3,338	3,594
90%	2,351	3,538	8,698	11,923	14,287	9,608	6,912	8,027	5,382	5,000	3,025	4,068	4,263
Max	3,956	17,620	21,955	36,011	36,760	18,874	16,549	12,386	10,897	5,157	4,685	5,000	6,254
Avg	1,589	2,271	3,676	4,825	5,787	3,976	3,306	3,300	3,417	3,670	1,905	2,042	2,392
C. ESO_LLT													
Min	500	500	500	425	63	260	250	294	250	255	259	334	395
10%	800	800	800	800	807	800	800	800	941	939	641	735	966
20%	870	800	800	1,131	1,445	827	1,209	1,289	1,588	2,305	862	805	1,227
30%	1,240	1,133	1,162	1,637	1,560	1,436	1,577	1,551	2,485	2,680	1,482	1,410	1,332
40%	1,500	1,425	1,750	1,700	1,914	1,750	1,805	1,798	2,863	3,203	1,750	1,533	1,636
50%	1,500	1,683	1,848	1,750	3,290	2,910	2,509	2,295	3,272	3,622	1,750	1,533	1,953
60%	1,500	1,817	2,000	2,557	5,186	4,246	3,017	2,561	3,847	4,471	1,753	1,533	2,455
70%	1,681	1,925	2,000	5,645	7,468	4,776	4,263	3,043	4,344	4,998	1,977	2,038	3,143
80%	2,184	1,925	2,501	8,535	11,228	6,070	4,982	3,722	4,935	5,000	2,280	2,847	3,695
90%	2,597	2,831	8,558	13,543	15,920	9,229	6,950	6,542	5,000	5,000	2,509	3,450	4,137
Max	5,000	15,826	23,686	38,305	39,261	20,206	16,572	10,928	7,739	5,337	3,984	4,489	6,167
Avg	1,613	1,965	3,288	5,184	6,155	4,160	3,336	2,886	3,311	3,496	1,685	1,827	2,338

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
D. EBC2													
Min	500	506	500	800	800	317	357	305	357	362	346	327	391
10%	812	800	800	817	1,156	885	1,007	1,001	1,217	1,746	988	889	1,045
20%	1,416	1,416	1,385	1,506	1,445	1,104	1,380	1,199	1,709	2,584	1,456	1,317	1,257
30%	1,500	1,625	1,682	1,700	1,445	1,520	1,649	1,445	1,750	2,943	1,848	1,533	1,469
40%	1,500	1,925	2,000	1,700	1,849	1,757	1,867	1,750	2,313	3,182	2,291	1,974	1,767
50%	1,500	2,033	2,000	1,750	2,953	2,438	2,384	2,781	2,728	3,777	2,466	2,427	2,040
60%	1,500	2,249	2,000	2,696	4,693	3,357	2,956	3,367	3,009	4,597	2,813	2,997	2,426
70%	1,500	3,057	2,000	4,628	6,242	4,159	4,152	4,006	3,940	5,000	3,204	3,941	3,087
80%	1,521	3,514	3,219	6,629	9,060	5,404	4,977	4,819	4,974	5,000	3,621	4,274	3,648
90%	1,704	4,363	7,170	10,397	11,402	8,680	6,537	8,103	6,925	5,000	4,017	4,752	4,140
Max	3,355	17,253	19,679	31,335	32,184	16,578	14,403	11,266	14,137	6,073	4,457	5,000	6,090
Avg	1,483	2,734	3,259	4,363	5,065	3,698	3,249	3,456	3,534	3,642	2,535	2,680	2,389
E. EBC2_ELT													
Min	500	500	500	800	800	317	349	305	357	310	258	336	380
10%	802	808	800	910	917	800	800	802	1,074	1,449	800	800	916
20%	1,079	1,161	1,208	1,352	1,347	920	1,136	1,102	1,531	2,300	1,131	920	1,229
30%	1,392	1,443	1,613	1,675	1,445	1,378	1,522	1,329	1,750	2,764	1,750	1,533	1,479
40%	1,500	1,683	1,942	1,700	2,018	1,866	2,070	1,750	1,910	3,152	1,781	1,578	1,656
50%	1,500	1,925	2,000	1,750	3,095	2,593	2,275	2,239	2,316	3,707	2,083	2,072	2,057
60%	1,500	1,977	2,000	2,850	5,041	3,847	3,211	3,132	2,858	4,090	2,337	2,549	2,439
70%	1,582	2,592	2,000	5,089	6,850	4,309	4,155	3,519	3,618	4,983	2,714	3,386	3,203
80%	1,838	2,926	3,306	7,619	10,320	5,820	4,980	4,388	4,207	5,000	2,973	4,002	3,651
90%	2,488	3,691	8,361	11,923	14,287	9,608	6,912	8,027	5,382	5,000	3,307	4,280	4,321
Max	4,004	17,875	21,955	36,011	36,759	18,882	16,549	12,386	10,897	5,000	4,702	5,000	6,263
Avg	1,559	2,523	3,617	4,865	5,710	3,947	3,271	3,231	3,041	3,509	2,115	2,389	2,393
F. EBC2_LLT													
Min	551	500	500	358	437	317	250	285	250	265	252	325	365
10%	800	800	800	800	902	800	800	800	959	1,349	800	721	909
20%	902	809	800	1,152	1,264	824	1,164	988	1,513	2,331	939	802	1,175
30%	1,181	1,162	1,214	1,488	1,445	1,466	1,513	1,358	1,761	2,923	1,540	1,420	1,403
40%	1,479	1,413	1,620	1,700	2,020	2,092	1,760	1,611	2,347	3,559	1,750	1,533	1,644
50%	1,500	1,593	1,786	1,750	3,198	2,908	2,609	1,759	2,673	4,072	1,839	1,548	1,958
60%	1,509	1,683	2,000	2,559	5,186	3,902	3,070	2,357	3,015	4,657	1,927	1,917	2,379
70%	1,710	1,925	2,000	5,362	6,966	4,749	4,203	2,624	3,266	5,000	2,323	2,588	3,159
80%	1,948	2,541	2,621	8,534	11,151	6,067	4,987	3,495	3,811	5,000	2,586	3,527	3,632
90%	2,799	2,943	8,472	13,543	15,920	9,685	6,898	6,542	5,000	5,000	3,007	4,089	4,254
Max	3,729	15,826	24,195	38,305	39,261	20,206	16,572	10,928	7,739	5,330	4,608	5,000	6,191
Avg	1,592	2,043	3,297	5,194	6,112	4,187	3,334	2,676	2,825	3,670	1,874	2,068	2,337

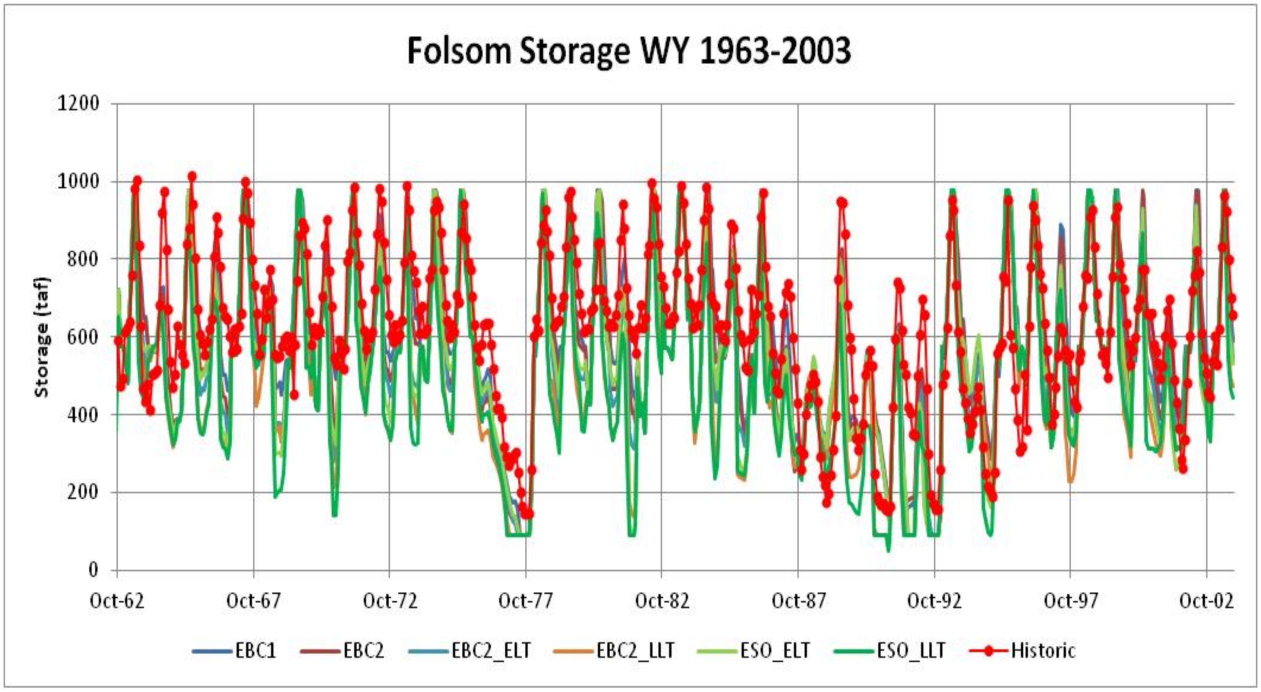


Figure C.A-42. CALSIM-Simulated Monthly Folsom Reservoir Storage for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

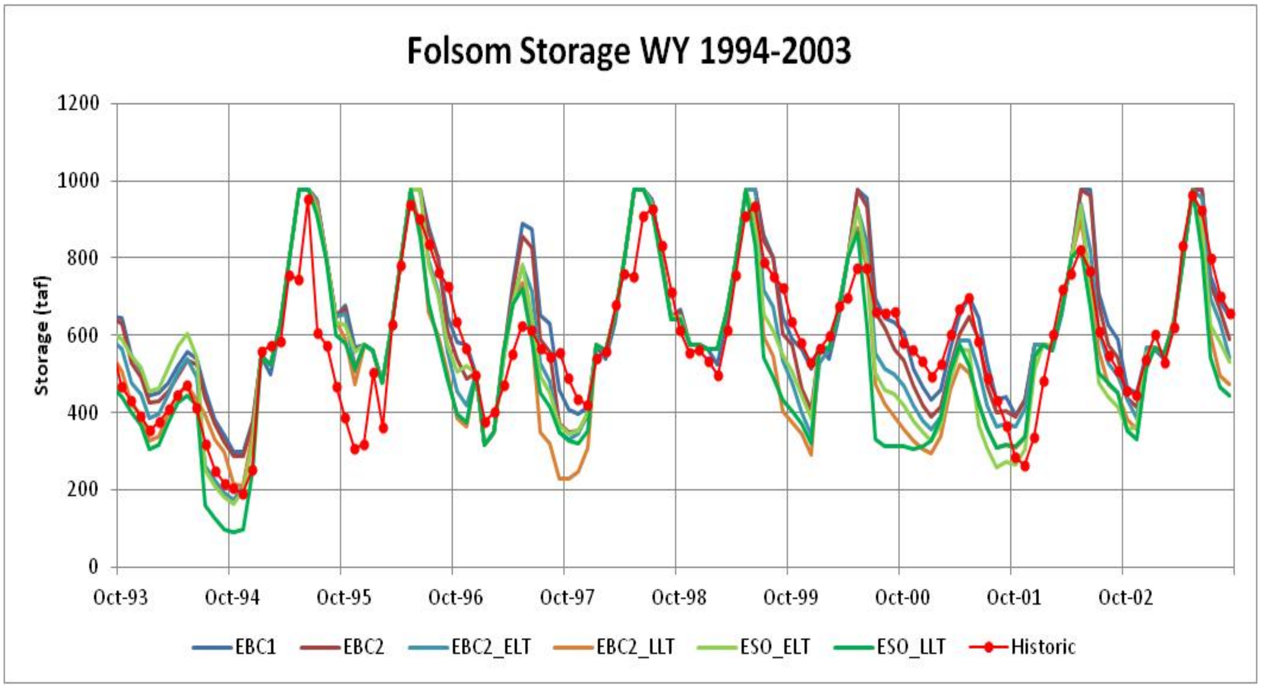


Figure C.A-43. CALSIM-Simulated Monthly Folsom Reservoir Storage for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

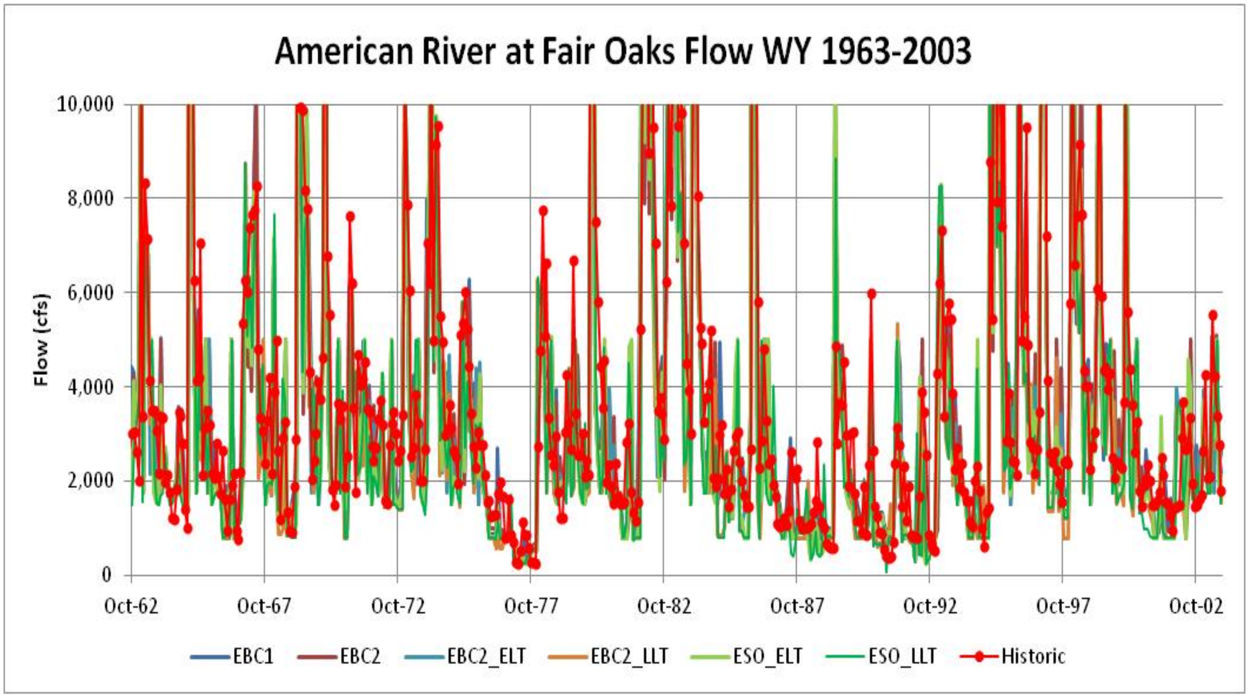


Figure C.A-44. CALSIM-Simulated Monthly American River Flow at Nimbus for 1922–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

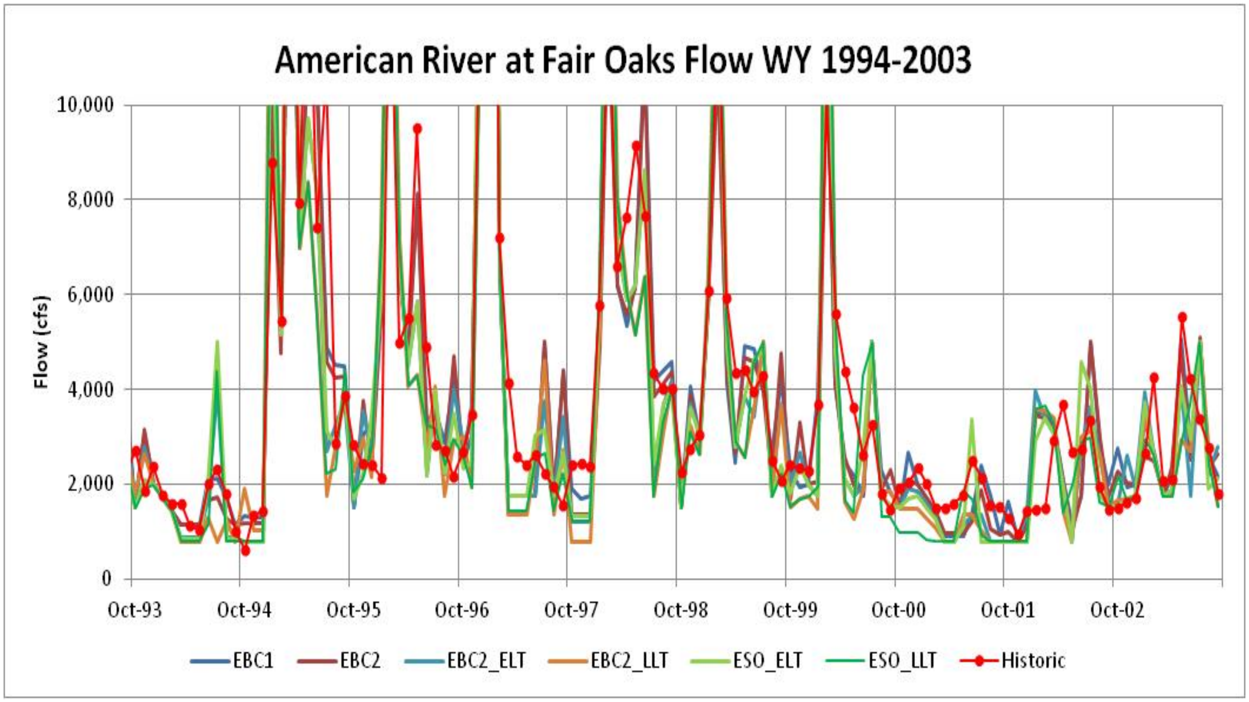


Figure C.A-45. CALSIM-Simulated Monthly American River Flow at Nimbus for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

5C.A.3.7 Simulated Changes in New Melones Reservoir Operations for the ESO

New Melones Reservoir is the only CVP reservoir in the San Joaquin River basin that might be operated differently with the ESO. Operation of Millerton Reservoir (Friant Dam) is being managed under the San Joaquin River Restoration Program. However, the New Melones operations are already fully constrained by the existing contracts and fish flows on the Stanislaus River required by the 2009 NMFS BiOp.

Table C.A-18 shows the CALSIM-simulated New Melones Reservoir storage for the six CALSIM cases. The maximum storage of about 2,400 taf was simulated only in May and June. The maximum flood control storage is about 2,000 taf from October to March. Because the New Melones Reservoir is quite large relative to the average Stanislaus River runoff of about 1,000 taf/yr, the maximum flood control levels limit storage only in a sequence of wet years when the storage level has increased. The New Melones Reservoir maximum flood control storage increases in April to 2,200 taf, and full storage is allowed in May. The EBC1 monthly median storage volumes for New Melones Reservoir were about 1,500 taf from October through January, increased to about 1,600 taf in February through July, and were about 1,500 taf in July–September. The seasonal variation each year is much greater than this monthly median pattern would suggest because New Melones reservoir storage increases with spring runoff and decreases with summer diversions for irrigation. The annual average irrigation diversions was about 600 taf/yr, and the average seasonal storage reduction from May to September was about 200 taf. The monthly median storage levels of New Melones Reservoir were not changed substantially for the ESO_ELT and ESO_LLT cases because, although there was a small reduction in the New Melones inflow for the assumed ELT and LLT conditions, the operations of New Melones for irrigation diversions and minimum monthly fish flows were not changed by the BDCP Delta operations.

Figure C.A-46 shows the simulated monthly New Melones Reservoir storage for the EBC1 and EBC2 cases and the ESO_ELT and ESO_LLT cases for the 1963–2003 sequence. This historical New Melones storage is shown for comparison (filled in 1982). The CALSIM-simulated storage variations for all of these cases were nearly identical to the EBC1 baseline. Figure C.A-47 shows the simulated monthly New Melones Reservoir storage for the six cases for the 1994–2003 sequence. The reduced carryover storage levels in WY 1993 (beginning of graph sequence) were the result of lower runoff during the dry period of 1987–1993. The simulated New Melones Reservoir storage values for the ESO_ELT and ESO_LLT cases were identical to the EBC2. Climate change had only a small effect on New Melones Reservoir operations; BDCP Delta operations had no effects on New Melones Reservoir operations.

Table C.A-19 shows the CALSIM-simulated Stanislaus River flow at the confluence (Ripon) for the six CALSIM cases. The minimum flows below Goodwin Dam depend on runoff and New Melones storage, but generally the river maintains flows above 200 cfs to 300 cfs in all months (based on 10% cumulative flows). The minimum flows in April and May are about 700 cfs because the 2009 NMFS BiOp emphasizes the flows in these months for increased survival of fall-run Chinook salmon. For all of the cases, the median monthly Stanislaus River flows were about 900 cfs in October for adult Chinook attraction flows, and about 300 cfs from November–January for Chinook egg incubation, with higher flows of 500 cfs in February, 650 cfs in March, and about 1,500 cfs in April and May during outmigration of fall-run Chinook juveniles (smolts). The simulated median flows in June were about 600 cfs, and the July–September median flows were about 450 cfs. The simulated

ELT and LLT flows were nearly identical to the existing flows (EBC1 and EBC2), except that there were fewer months with reservoir spills (higher river flows) because the assumed inflows were reduced for the ELT and LLT (climate change) conditions.

Figure C.A-48 shows the simulated Stanislaus River flows for the six cases for the 1963–2003 sequence. River flows are normally between 250 cfs and 2,500 cfs. Higher flows indicate flood control releases (spills) from New Melones Reservoir. The ELT and LLT hydrology sometimes caused increased flood control releases when the assumed inflows were higher than the existing (EBC1and EBC2) inflows when the reservoir was filled to maximum flood control levels. Figure C.A-49 shows the simulated Stanislaus River flows for the six cases for the 1994–2003 sequence. Most of the years had very similar flows, but some years had difference caused by the slightly different assumed inflows. The BDCP Delta operations had no effects on the Stanislaus River flows.

The New Melones Reservoir operations will have effects on aquatic resources (fish) by changing the reservoir storage levels (drawdown) and affecting the cold-water pool (volume) remaining at the end of each water year. The New Melones Reservoir operations will also affect the Stanislaus River flows and the release temperatures at Goodwin Dam and downstream in the Stanislaus River. The effects of New Melones Reservoir operations on Stanislaus River water temperatures for existing runoff and air temperature conditions and with climate change assumptions are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*.

Table C.A-18. CALSIM-Simulated Monthly Distributions of New Melones Reservoir Storage (taf)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	80	80	98	229	242	292	297	203	149	94	80	80
10%	664	688	723	745	754	768	694	662	764	732	672	642
20%	987	973	990	1,006	1,044	1,138	1,103	1,180	1,140	1,102	1,064	1,036
30%	1,185	1,223	1,252	1,314	1,334	1,342	1,281	1,296	1,358	1,315	1,243	1,210
40%	1,324	1,364	1,383	1,457	1,519	1,526	1,486	1,505	1,504	1,441	1,373	1,344
50%	1,448	1,465	1,480	1,555	1,640	1,671	1,631	1,641	1,632	1,596	1,518	1,481
60%	1,514	1,555	1,640	1,692	1,779	1,779	1,746	1,736	1,710	1,638	1,571	1,536
70%	1,630	1,650	1,691	1,777	1,852	1,876	1,849	1,857	1,855	1,794	1,706	1,666
80%	1,758	1,761	1,790	1,849	1,934	1,956	1,876	1,930	1,991	1,955	1,860	1,805
90%	1,872	1,880	1,936	1,954	1,970	1,990	1,971	2,080	2,147	2,069	1,974	1,914
Max	1,970	1,970	1,970	2,116	1,970	2,030	2,220	2,414	2,420	2,300	2,130	2,000
Avg	1,342	1,353	1,387	1,438	1,492	1,516	1,492	1,526	1,547	1,485	1,406	1,364
B. ESO_ELT												
Min	80	80	103	229	282	304	277	185	125	80	80	80
10%	734	741	759	766	817	804	758	797	847	782	726	725
20%	903	895	933	937	1,030	1,079	1,082	1,138	1,099	1,046	985	950
30%	1,123	1,146	1,191	1,224	1,285	1,304	1,254	1,308	1,267	1,211	1,153	1,114
40%	1,288	1,318	1,331	1,388	1,422	1,436	1,419	1,482	1,464	1,398	1,328	1,294
50%	1,370	1,375	1,402	1,509	1,575	1,621	1,568	1,611	1,571	1,493	1,415	1,399
60%	1,458	1,500	1,573	1,643	1,720	1,742	1,687	1,686	1,687	1,618	1,533	1,501
70%	1,594	1,606	1,664	1,738	1,808	1,831	1,765	1,839	1,853	1,769	1,666	1,623
80%	1,663	1,686	1,739	1,765	1,879	1,917	1,904	1,943	1,950	1,875	1,771	1,714
90%	1,784	1,787	1,850	1,945	1,970	2,003	1,981	2,100	2,122	2,026	1,912	1,840
Max	1,970	1,970	1,970	2,363	2,135	2,030	2,220	2,420	2,420	2,300	2,130	2,000
Avg	1,302	1,312	1,350	1,407	1,468	1,497	1,478	1,520	1,532	1,457	1,370	1,325
C. ESO_LLT												
Min	80	80	106	120	178	202	177	87	80	80	80	80
10%	605	613	634	649	697	675	649	736	695	619	560	563
20%	816	825	847	889	950	1,021	1,033	1,052	1,030	950	880	837
30%	1,037	1,074	1,101	1,135	1,194	1,203	1,173	1,279	1,242	1,167	1,085	1,044
40%	1,186	1,181	1,235	1,325	1,362	1,402	1,389	1,401	1,356	1,283	1,231	1,205
50%	1,293	1,300	1,330	1,439	1,538	1,569	1,523	1,565	1,504	1,422	1,349	1,313
60%	1,437	1,433	1,509	1,572	1,643	1,714	1,667	1,617	1,654	1,596	1,507	1,462
70%	1,543	1,541	1,574	1,649	1,728	1,780	1,765	1,820	1,788	1,703	1,608	1,564
80%	1,605	1,603	1,653	1,699	1,857	1,879	1,878	1,919	1,906	1,790	1,682	1,638
90%	1,701	1,701	1,762	1,838	1,969	2,005	1,969	2,070	2,066	1,947	1,824	1,758
Max	1,970	1,970	1,970	2,388	2,164	2,030	2,220	2,420	2,420	2,300	2,130	2,000
Avg	1,223	1,230	1,269	1,334	1,407	1,447	1,435	1,469	1,464	1,377	1,289	1,245

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	107	103	121	270	372	436	407	314	261	208	148	123
10%	746	752	776	836	867	864	799	773	889	841	773	736
20%	1,024	1,003	1,009	1,050	1,091	1,149	1,139	1,213	1,177	1,142	1,100	1,070
30%	1,215	1,225	1,303	1,319	1,336	1,410	1,338	1,337	1,403	1,346	1,279	1,238
40%	1,354	1,381	1,423	1,461	1,516	1,517	1,499	1,535	1,533	1,465	1,401	1,364
50%	1,461	1,468	1,488	1,578	1,633	1,675	1,634	1,645	1,641	1,597	1,528	1,492
60%	1,528	1,550	1,635	1,686	1,767	1,798	1,733	1,743	1,707	1,653	1,582	1,543
70%	1,627	1,646	1,686	1,767	1,840	1,863	1,843	1,854	1,853	1,782	1,699	1,669
80%	1,751	1,757	1,777	1,846	1,923	1,950	1,880	1,921	2,007	1,956	1,861	1,799
90%	1,892	1,921	1,928	1,943	1,970	1,989	1,979	2,073	2,149	2,073	1,980	1,919
Max	1,970	1,970	1,970	2,116	1,970	2,030	2,220	2,413	2,420	2,300	2,130	2,000
Avg	1,370	1,379	1,411	1,460	1,514	1,540	1,516	1,551	1,574	1,514	1,435	1,394
E. EBC2_ELT												
Min	80	80	103	229	282	304	277	186	125	80	80	80
10%	732	739	759	765	817	802	757	794	840	773	719	721
20%	893	887	920	920	1,028	1,074	1,074	1,137	1,094	1,043	976	939
30%	1,129	1,173	1,203	1,233	1,294	1,332	1,292	1,313	1,277	1,214	1,164	1,145
40%	1,302	1,328	1,331	1,395	1,429	1,437	1,428	1,485	1,495	1,445	1,371	1,324
50%	1,371	1,376	1,403	1,538	1,581	1,623	1,583	1,611	1,572	1,495	1,420	1,400
60%	1,461	1,506	1,585	1,653	1,728	1,742	1,688	1,687	1,692	1,629	1,534	1,509
70%	1,598	1,606	1,665	1,738	1,809	1,838	1,768	1,850	1,856	1,773	1,669	1,624
80%	1,662	1,693	1,740	1,765	1,880	1,920	1,908	1,947	1,955	1,889	1,778	1,719
90%	1,784	1,789	1,856	1,953	1,970	2,004	1,982	2,104	2,127	2,027	1,914	1,841
Max	1,970	1,970	1,970	2,363	2,135	2,030	2,220	2,420	2,420	2,300	2,130	2,000
Avg	1,301	1,312	1,350	1,407	1,467	1,497	1,478	1,520	1,532	1,456	1,370	1,325
F. EBC2_LLT												
Min	80	80	106	122	180	204	179	88	80	80	80	80
10%	605	612	632	646	697	671	645	733	678	607	552	560
20%	814	823	839	887	928	1,016	1,028	1,049	1,024	942	877	837
30%	1,059	1,074	1,111	1,170	1,211	1,230	1,196	1,280	1,251	1,177	1,095	1,055
40%	1,196	1,194	1,237	1,327	1,367	1,425	1,392	1,408	1,370	1,294	1,231	1,212
50%	1,301	1,308	1,330	1,475	1,547	1,574	1,527	1,577	1,515	1,436	1,365	1,319
60%	1,450	1,433	1,510	1,575	1,658	1,717	1,669	1,619	1,657	1,598	1,510	1,462
70%	1,544	1,543	1,578	1,662	1,734	1,800	1,766	1,841	1,793	1,703	1,608	1,566
80%	1,605	1,607	1,669	1,711	1,856	1,880	1,877	1,920	1,926	1,806	1,693	1,642
90%	1,701	1,702	1,765	1,842	1,970	2,007	1,969	2,072	2,067	1,949	1,824	1,758
Max	1,970	1,970	1,970	2,388	2,164	2,030	2,220	2,420	2,420	2,300	2,130	2,000
Avg	1,224	1,231	1,270	1,335	1,408	1,448	1,436	1,470	1,465	1,378	1,290	1,246

Table C.A-19. CALSIM-Simulated Monthly Distributions of Stanislaus River Flow (cfs) at Ripon

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	76	136	175	219	138	168	453	454	244	246	0	9	192
10%	322	248	206	260	241	315	791	641	336	339	347	322	318
20%	719	263	243	289	335	468	985	767	377	388	377	373	346
30%	766	270	267	311	415	535	1228	869	411	404	401	403	403
40%	823	302	286	325	459	604	1331	961	475	407	428	423	432
50%	918	325	304	343	497	667	1669	1379	630	422	439	434	500
60%	964	347	318	387	550	1478	1841	1503	1103	468	451	462	587
70%	995	378	341	449	592	1616	1967	1638	1215	528	480	529	644
80%	1073	437	388	489	670	1787	2089	1782	1367	628	556	586	744
90%	1152	481	503	580	1858	2027	2347	1861	1584	785	682	770	1047
Max	1987	3463	5132	8185	6356	6175	2907	2448	4960	4501	2678	3093	2557
Avg	867	410	450	635	827	1167	1562	1271	932	607	560	595	596
B. ESO_ELT													
Min	71	126	136	123	121	168	385	371	246	84	11	9	163
10%	296	248	202	250	230	277	550	530	295	306	341	313	290
20%	710	263	241	275	244	372	839	680	339	337	372	364	318
30%	750	270	262	304	320	439	1,060	788	370	368	396	403	365
40%	818	301	282	321	373	486	1,272	872	437	380	428	423	389
50%	872	323	299	335	400	525	1,524	1,236	617	412	439	434	458
60%	956	341	311	359	456	1,000	1,727	1,481	1,105	464	446	443	524
70%	994	360	336	415	497	1,595	1,922	1,637	1,216	511	465	502	628
80%	1,064	429	385	483	727	1,734	2,042	1,734	1,342	609	553	568	736
90%	1,136	471	507	706	2,457	2,032	2,280	1,829	1,584	805	642	755	1,026
Max	1,926	3,879	6,187	8,129	8,269	6,518	3,186	2,616	5,071	3,844	2,246	2,792	2,523
Avg	840	409	459	638	847	1,134	1,475	1,211	952	588	530	567	582
C. ESO_LLT													
Min	57	101	111	107	103	163	361	371	10	19	9	94	139
10%	285	247	202	221	227	276	527	524	297	308	335	309	275
20%	678	261	234	275	242	337	829	631	332	350	372	362	314
30%	741	267	262	304	278	386	1,005	778	364	370	394	398	364
40%	809	292	282	321	354	467	1,206	821	412	383	422	423	388
50%	834	319	295	337	389	490	1,336	913	614	418	439	434	413
60%	887	337	309	353	426	545	1,614	1,330	1,097	464	445	442	481
70%	977	348	334	383	467	1,504	1,773	1,476	1,217	523	460	484	595
80%	1,051	384	380	450	605	1,619	1,967	1,695	1,371	716	512	555	717
90%	1,128	469	493	545	1,181	1,921	2,103	1,838	1,756	1,186	592	668	914
Max	1,995	2,982	5,410	8,129	8,269	7,461	3,362	2,565	4,873	3,214	1,823	2,315	2,526
Avg	809	386	421	615	721	1,071	1,387	1,125	912	590	492	536	547

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	110	156	165	145	127	168	427	444	226	249	277	209	207
10%	330	248	223	260	236	318	717	596	297	304	349	322	300
20%	735	263	243	289	257	384	1000	735	363	335	378	373	339
30%	768	270	270	308	322	475	1190	877	414	377	401	404	391
40%	827	302	286	325	389	506	1331	930	470	381	428	423	433
50%	934	325	304	343	432	665	1675	1403	633	418	439	435	497
60%	964	348	316	387	474	1478	1841	1503	1105	468	454	462	589
70%	995	378	341	449	569	1616	1967	1638	1222	528	480	529	645
80%	1073	435	388	489	703	1787	2091	1782	1397	628	556	586	744
90%	1152	481	503	580	1763	2027	2347	1861	1584	785	682	770	1036
Max	1975	3414	5077	8129	6297	6143	2873	2450	4999	4537	2706	3081	2547
Avg	869	409	453	624	780	1140	1551	1263	926	610	566	594	590
E. EBC2_ELT													
Min	71	126	136	123	121	168	385	371	246	85	11	9	163
10%	293	248	200	250	229	275	550	529	297	305	349	322	289
20%	710	263	241	276	244	370	836	678	340	339	372	373	317
30%	752	270	263	304	316	438	1081	788	371	371	401	404	364
40%	822	302	285	321	371	486	1273	896	439	381	428	423	395
50%	874	325	301	336	399	520	1536	1282	625	413	439	434	459
60%	957	341	311	362	455	1150	1732	1491	1105	468	450	444	525
70%	995	360	336	420	496	1603	1944	1638	1219	511	466	505	629
80%	1073	434	385	483	703	1738	2045	1734	1348	616	556	569	737
90%	1137	471	507	704	2468	2029	2281	1830	1597	807	646	756	1028
Max	1926	3879	6187	8129	8269	6518	3186	2613	5071	3844	2246	2792	2523
Avg	840	409	459	638	847	1134	1475	1211	952	588	530	567	582
F. EBC2_LLT													
Min	57	102	111	107	103	163	361	371	3	8	9	9	134
10%	282	248	200	220	227	275	522	524	298	303	349	312	275
20%	702	263	232	276	241	337	832	631	338	351	372	365	317
30%	745	269	263	304	276	381	1,018	780	370	371	394	401	365
40%	812	294	285	321	354	468	1,271	829	414	386	428	423	389
50%	836	320	297	338	389	492	1,338	913	644	418	439	434	417
60%	889	337	311	354	426	552	1,636	1,352	1,105	468	450	444	484
70%	980	348	336	384	467	1,506	1,790	1,477	1,219	528	461	486	596
80%	1,058	384	380	450	609	1,620	1,967	1,704	1,374	734	515	559	718
90%	1,129	471	485	545	1,182	1,925	2,104	1,830	1,759	1,189	593	670	921
Max	1,995	2,982	5,410	8,129	8,269	7,461	3,362	2,558	4,873	3,214	1,823	2,315	2,526
Avg	808	386	417	615	723	1,071	1,387	1,125	914	590	491	533	547

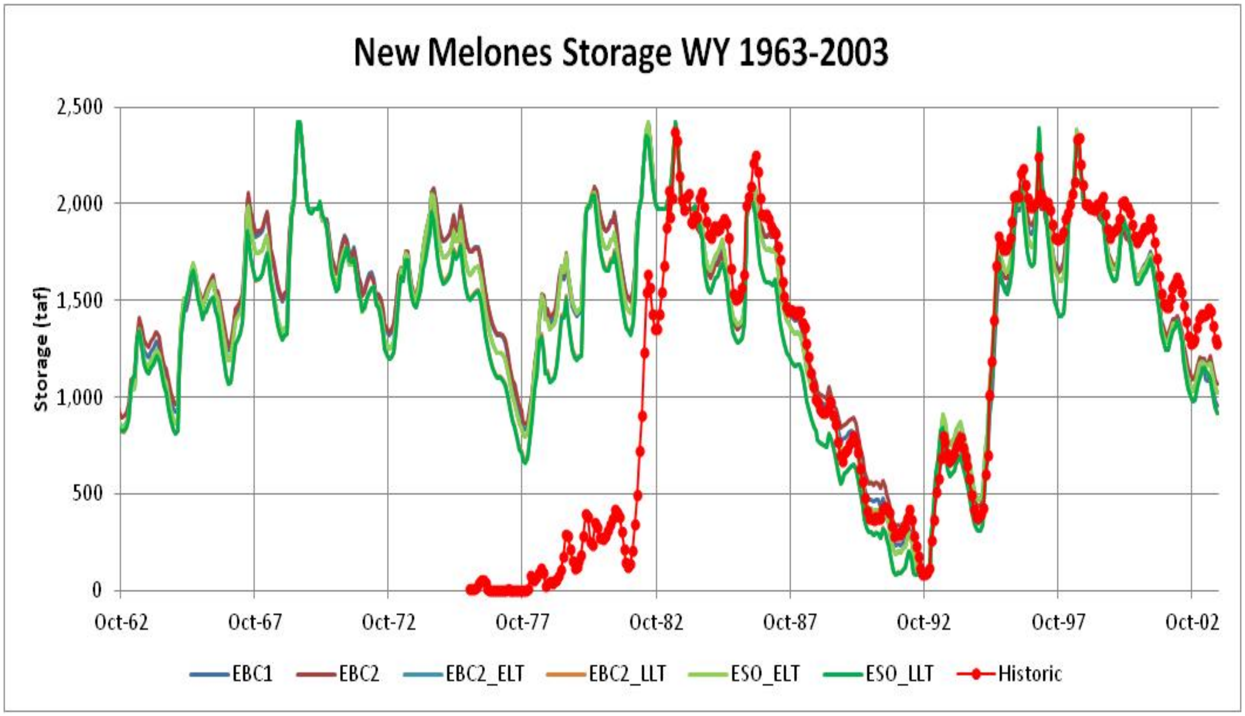


Figure C.A-46. CALSIM-Simulated Monthly New Melones Reservoir Storage for 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

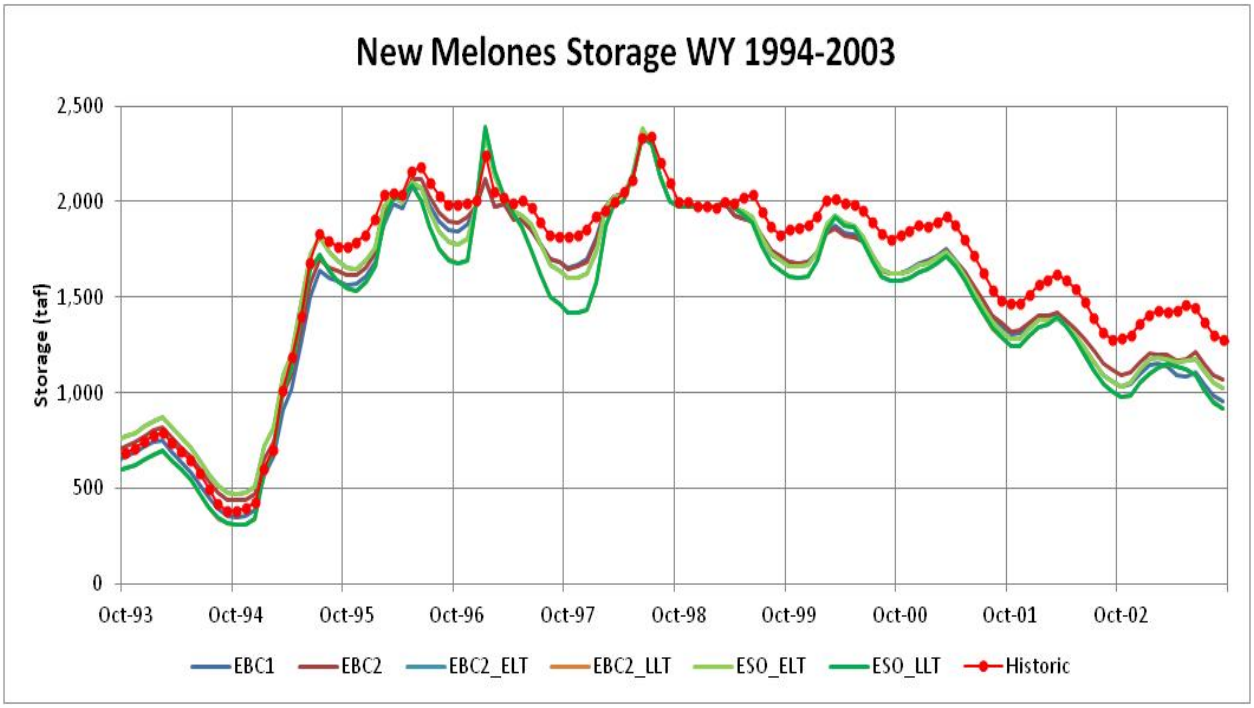


Figure C.A-47. CALSIM-Simulated Monthly New Melones Reservoir Storage for 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

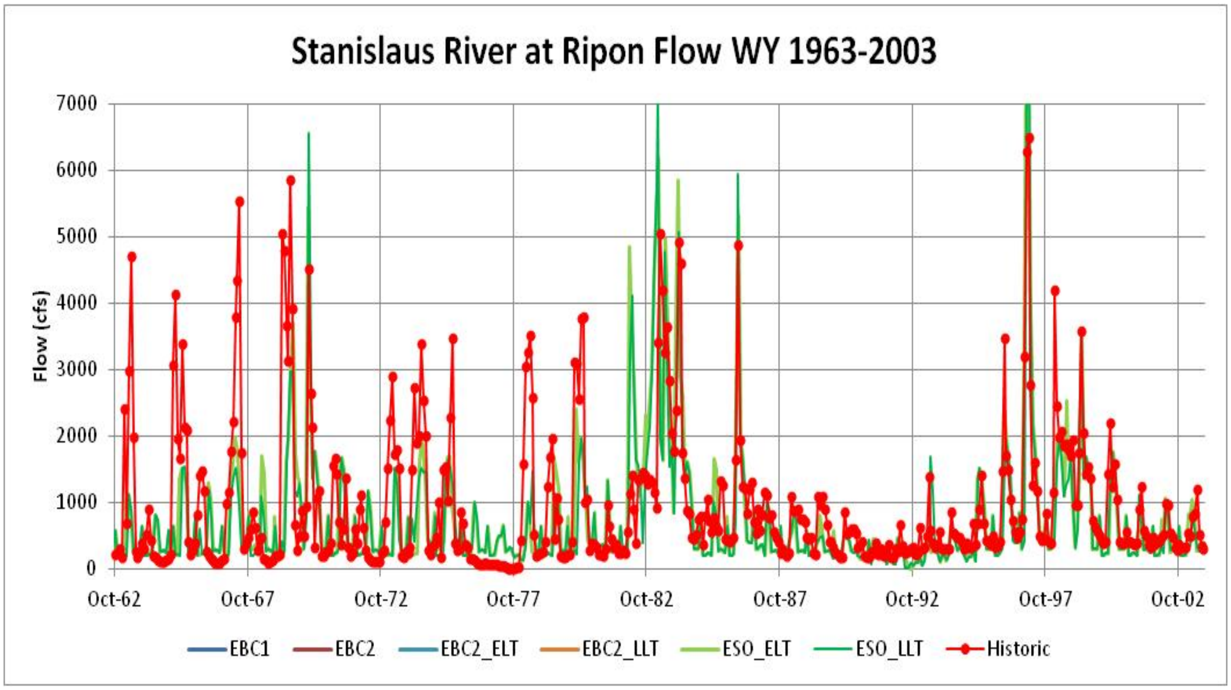


Figure C.A-48. CALSIM-Simulated Monthly Stanislaus River Flow at Ripon for 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

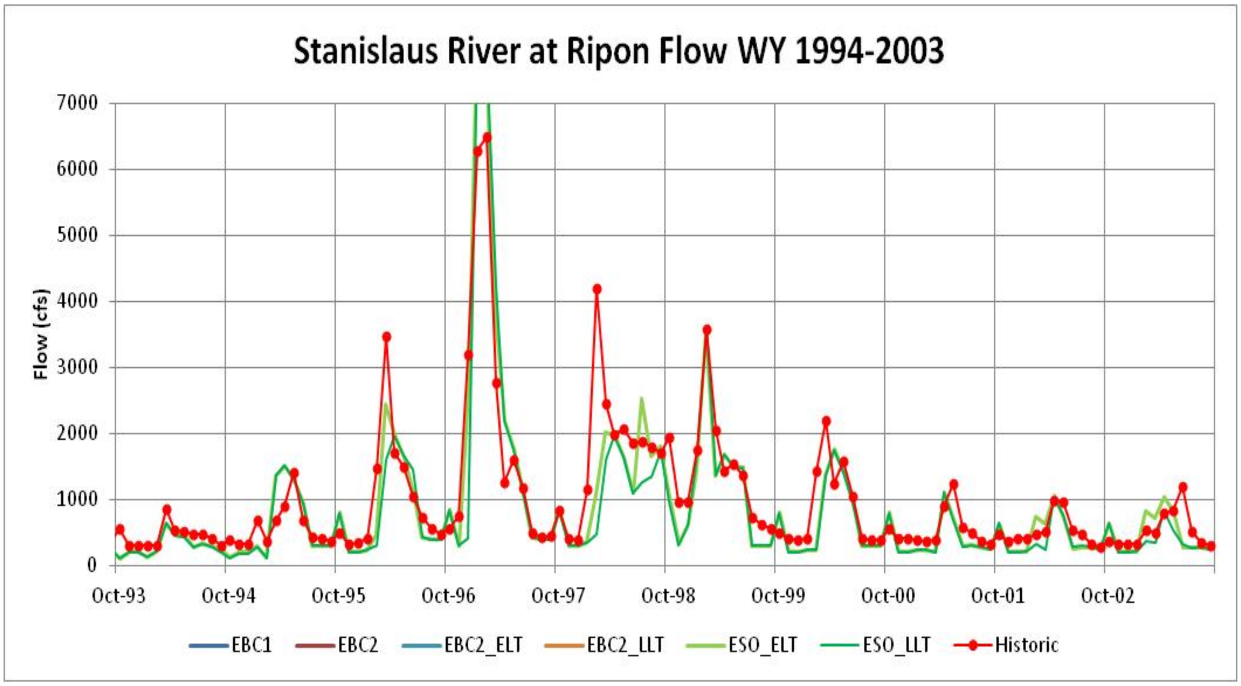


Figure C.A-49. CALSIM-Simulated Monthly Stanislaus River Flow at Ripon for 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT

5C.A.4 CALSIM Delta Flows for the ESO

This section discusses Delta channel flows and the likely effects of the BDCP facilities, restoration activities and operations on Delta channel flows and salinity conditions. The Delta flow evaluations for the ESO (ELT and LLT) rely on the DWR and Reclamation joint planning model (CALSIM II) simulation results for likely future reservoir and Delta operations.

The major effects of the BDCP Delta operations are evaluated from changes in the monthly CALSIM-simulated flows in the Delta, including the inflows, outflows, and exports in the north Delta and south Delta. These monthly Delta inflows and outflows are also used to estimate the major channel flows within the Delta, including the Sacramento diversions into Steamboat Slough and Sutter Slough, the Delta Cross Channel (DCC), Georgiana Slough, and Threemile Slough. The San Joaquin River diversions into Paradise Cut (flood bypass channel) and the diversions into the head of Old River are estimated from the San Joaquin River flow, the assumed head of Old River barrier (or gate) and the south Delta exports. The Old River and Middle River flow (OMR) flowing north (or south if negative) past Bacon Island can be estimated from the monthly San Joaquin River flow and the south Delta exports. The San Joaquin River flow past Jersey Point and Antioch (QWEST) can also be evaluated from the CALSIM results. A comparison of these important monthly Delta flows for the six CALSIM cases is shown and described in this section of CALSIM results for the BDCP effects analysis.

Salinity estimates are calculated in the ANN portion of CALSIM, including the monthly EC at four of the Delta EC compliance locations (Emmaton, Jersey Point, Rock Slough and Los Vaqueros intake). These CALSIM EC values are summarized and compared for the six cases. The X2 locations, which are calculated from the Delta outflow, are summarized and compared. More accurate estimates of changes in Delta salinity (EC) are shown from the DSM2 model results in the following section.

The CALSIM model incorporates the State Water Board D-1641 objectives as well as the several Delta Actions that are included in the 2008 USFWS BiOp and the 2009 NMFS BiOp on the CVP/SWP OCAP. These are the operating rules for the EBC that were used for evaluating the effects of the BDCP. The Delta facilities and operating rules (objectives) will be described, and the CALSIM results for each important Delta location then will be summarized.

5C.A.4.1 Delta Facilities and Operations

The following description of CVP and SWP facilities and existing operational constraints in the Delta is provided to establish current operational conditions needed to evaluate BDCP changes in Delta flows for the effects analysis.

5C.A.4.1.1 Delta Pumping Capacity

The CVP Tracy facility, about 5 miles north of Tracy, consists of six pumps, including one rated at 800 cfs, two rated at 850 cfs, and three rated at 950 cfs. Maximum pumping capacity is about 5,100 cfs. The CVP Tracy facility is located at the end of an earth-lined intake channel about 2.5 miles long. At the head of the intake channel, louver screens that are part of the CVP Tracy Fish Collection Facility intercept fish, which are collected and transported by tanker truck to release sites near Antioch. Other CVP facilities in the Delta include the DCC and the Contra Costa Canal (CCC). The DCC is a gated diversion channel, just over a mile long, connecting the Sacramento River near Walnut Grove with Snodgrass Slough. Flows into the DCC from the Sacramento River are controlled by two 60-foot-wide by 30-foot-high radial gates. When the gates are open, water flows from the

Sacramento River through the DCC to natural channels of the lower Mokelumne and San Joaquin Rivers and toward the interior Delta to supply the CCC and the CVP Tracy facility in the south Delta and improve water quality by reducing saltwater intrusion from Antioch.

The CCC originates at Rock Slough, about 4 miles southeast of Oakley, and supplies the Contra Costa Water District (CCWD). The canal and associated facilities are part of the CVP but are operated and maintained by the CCWD. CCWD now also operates a diversion on Old River just south of the State Route (SR) 4 Bridge that provides the intake for Los Vaqueros Reservoir and connects with the CCC; however, this intake and Los Vaqueros Reservoir are not CVP facilities. CCWD is constructing an alternative intake on Victoria Canal about 1 mile northeast of Old River.

The CVP Jones Pumping Plant (CVP Jones) has an authorized capacity of 4,600 cfs. This is equivalent to 9,125 acre-feet per day (af/day). Table C.A-20 compares the CVP monthly demands to the maximum possible CVP Tracy monthly pumping. The full CVP monthly demands usually exceed the CVP monthly pumping capacity in the May–August period. Water must be stored in San Luis Reservoir during the winter period to supply the typical CVP demands. If the CVP Jones pumps were at maximum permitted capacity (4,600 cfs) for the entire year, they would deliver about 3,330 taf/yr (about 275 taf each month). This is unlikely to occur, however because there are required periods for maintenance of the pump units and the hydrology in the Delta may not allow full pumping every day of the year. The Delta-Mendota Canal (DMC) capacity generally declines to about 4,200 cfs at the O'Neill pumping plant near Los Banos. CVP Jones pumping is limited during the October–June period when diversions from the upper DMC (near CVP Tracy) are low. The DMC–California Aqueduct Intertie facility being constructed will allow full pumping of 4,600 cfs year-round by pumping about 500 cfs from the DMC to the aqueduct during these winter months. Because the demand for CVP water pumped at the CVP Jones pumping plant is more than 3,000 taf/yr, full CVP delivery depends on wheeling capacity at SWP Harvey O. Banks Pumping Plant (SWP Banks) to deliver some of this water each year.

The CVPIA (Anadromous Fish Restoration Program [AFRP]) has introduced additional constraints on the CVP Tracy pumping capacity. A portion of the Section 3406(b)(2) water that is dedicated to anadromous fish restoration purposes (maximum of 800 taf) normally is allocated by USFWS to reduced pumping during the April–June period for fish entrainment protection. Therefore, under current regulations, it is difficult for the CVP Jones pumping plant to supply the full CVP demands. During some wet years, flows from the upper San Joaquin River (Friant Dam) and the Kings River can meet San Joaquin River Exchange Contractor demands at the Mendota Pool and allow CVP Jones pumping plant to supply other CVP contractor demands.

Table C.A-20. CVP Tracy Pumping Plant Demands and Pumping Capacity

Month	Monthly CVP Tracy Demand (taf)	Maximum Volume at 4,600 cfs Tracy Capacity (taf)	Additional Needed from San Luis Reservoir (taf)
October	204	283	–
November	123	274	–
December	107	283	–
January	137	283	–
February	166	255	–
March	192	283	–
April	236	274	–
May	344	283	61
June	502	274	228
July	583	283	300
August	476	283	193
September	262	274	–
Total	3,332	3,330	784

cfs = cubic feet per second.
taf = thousand acre-feet.

SWP Banks has an installed capacity of about 10,668 cfs (two units of 375 cfs, five units of 1,130 cfs, and four units of 1,067 cfs). The SWP water rights for diversions specify a maximum of 10,350 cfs. With full diversion capacity (20,530 af/day) each day of the year, SWP Banks is theoretically capable of pumping 7,493 taf each year. The current permitted Clifton Court Forebay (CCF) diversion capacity of 6,680 cfs would provide a maximum of about 4,836 taf/yr if the full diversion could be maintained every day of the year. Additional permitted diversions of one-third of the San Joaquin River at Vernalis is allowed under the current permit rule for a 90-day period from December 15 to March 15, if the Vernalis flow is above 1,000 cfs. This additional increment of permitted diversions (3,670 cfs) could yield a maximum of 655 taf/yr (for a total of 5,490 taf) if the San Joaquin River flow at Vernalis was higher than about 11,000 cfs for the entire 90-day period (an unlikely hydrologic condition). Diversion and pumping at 10,350 cfs for each day of the year (20,540 af/day), if it were possible, would yield a potential water supply of about 7,480 taf/yr.

The monthly pumping capacity of SWP Banks with these pumping limits is given in Table C.A-21. The seasonal SWP demands are highest in the summer months, requiring a portion of the demands to be supplied from San Luis Reservoir storage. San Luis Reservoir releases often are needed during these months because SWP Banks pumping is limited during April–June by a combination of Vernalis Adaptive Management Program (VAMP) and the 35% export/inflow ratio that is specified in D-1641 from February through June.

Table C.A-21. SWP Harvey O. Banks Pumping Plant Demands and Maximum Pumping Capacity

Month	Monthly SWP Banks Demand (taf)	Maximum Volume at 6,680 cfs Banks Capacity (taf)	Additional Needed from San Luis Reservoir (taf)	Maximum Volume at 10,350 cfs Banks Capacity (taf)
October	295	411	–	635
November	261	397	–	615
December	245	411	–	635
January	173	411	–	635
February	203	371	–	575
March	235	411	–	635
April	302	397	–	615
May	407	411	–	635
June	520	397	123	615
July	541	411	130	635
August	532	411	121	635
September	404	397	7	615
Total	4,118	4,836	381	7,480

taf = thousand acre-feet.

There are aqueduct and reservoir storage losses (i.e., evaporation and seepage) that are simulated by CALSIM to be about 170 taf/yr, so SWP Banks pumping for full SWP Banks (south-of-Delta) delivery must be about 4,300 taf. Only in a few years will there be sufficient Delta inflow each month to satisfy the in-Delta water diversions, meet the required Delta outflow for water quality and fisheries protection, supply the full CVP Jones pumping, and also allow SWP Banks pumping of 4,300 taf.

5C.A.4.1.2 Delta Outflow Requirements

The minimum monthly Delta outflow objectives were developed by the State Water Board to protect the salinity range for agricultural uses and the estuarine aquatic habitat, and are included in D-1641. The monthly outflows from February to June are calculated (on a daily basis) to satisfy the X2 objective. Minimum monthly flows for July range from 4,000 cfs in critical years to 8,000 cfs in wet years. The August outflows range from 3,000 cfs in critical years to 4,000 cfs in below normal years or higher. The September minimum outflow is 3,000 cfs in all year types. The October minimum outflows are 3,000 in critical and 4,000 cfs in all other year types. The November and December minimum outflows are 3,500 cfs in critical and 4,500 cfs in all other year types.

5C.A.4.1.3 Delta Salinity Objectives

There are several Delta locations with specified salinity objectives. Some of these protect aquatic habitat conditions, some protect agricultural diversions within the Delta, and some protect diversions for municipal water supply. SWP and CVP operations are required to protect these salinity objectives. The salinity objectives at Emmaton on the Sacramento River and at Jersey Point on the San Joaquin River often control Delta outflow during the irrigation season from April through August. The compliance values as well as the period of compliance change with WY type.

5C.A.4.1.4 X2 Objectives

The location of the estuarine salinity gradient is regulated during the months of February–June by the X2 (i.e., the position of the 2 parts per thousand [ppt] salinity gradient) objective in the 1995 WQCP (D-1641). The X2 position must remain downstream of Collinsville (kilometer 81 upstream from the Golden Gate Bridge) for the entire 5-month period. This requires a minimum outflow of about 7,100 cfs. The X2 objective specifies the number of days each month when the location of X2 must be downstream of Chipps Island (kilometer 75) or downstream of the Port Chicago EC monitoring station (kilometer 64). The number of days depends on the previous month's runoff index value.

5C.A.4.1.5 Maximum Export/Inflow Ratio

D-1641 includes a maximum E/I ratio objective to limit the fraction of Delta inflows that are exported. This objective was developed to protect fish species and to reduce entrainment losses. Delta exports included in the E/I ratio are considered to be CVP Tracy and SWP Banks. Delta inflows are the measured river inflows (not including rainfall runoff in the Delta). The maximum E/I ratio is 0.35 for February through June and 0.65 for the remainder of the year. If the January eight-river runoff index is less than 1 maf (about 30% of the years), the February E/I ratio is increased to 0.45. CVP and SWP have agreed to share the allowable exports equally if the E/I ratio is limiting exports. For the BDCP cases, the north Delta intake diversions are subtracted from the inflow term and are not incuded in the export term; the E/I ratio was still applied to the south Delta exports, using the reduced inflow term. This only rarely allowed slightly higher total pumping from the Delta.

5C.A.4.1.6 Delta Cross Channel Operations

Reclamation operates the DCC to improve the transfer of water from the Sacramento River to the export facilities at the CVP Jones pumping plant, and to improve water quality in the south Delta by reducing seawater intrusion. The DCC gates are closed when flows in the Sacramento River at Freeport reach about 25,000 cfs to reduce scour on the downstream side of the gates and to reduce potential flooding on the Mokelumne River channels. D-1641 provides for closure of the DCC gates from February 1 through May 20 for fish protection. From November through January, the DCC may be closed for up to an additional 45 days (half of the time). The gates also may be closed for 14 days during the period of May 21 through June 15. Reclamation determines the timing and duration of these DCC closures through consultation with USFWS, California Department of Fish and Wildlife (CDFW), and NMFS. Monitoring for fish presence and movement in the Sacramento River and Delta, the salvage of salmon at the Tracy and Skinner facilities, and hydrologic cues (e.g., storm events) are used to determine the timing of DCC closures. The 2009 NMFS BiOp extended the period of DCC closure for fish protection from December 1 to January 31. The DCC gates are closed anytime from October 1 to November 30 when fish are present, as determined by NMFS and CDFW.

5C.A.4.1.7 Old and Middle River Flow Objectives

The 2008 USFWS BiOp included new restrictions for reverse OMR flows. These reverse OMR flow restrictions are based on real-time monitoring and adaptive management triggers and off-ramps (relaxations). The period of potential reverse OMR restrictions begins in December and extends through June. Action 1 requires a 14-day reduction in exports to provide more than -2,500 cfs OMR flow (positive flow is seaward) to protect the "initial pulse" of migrating adult delta smelt (i.e., OMR must be greater than -2,500 cfs). Action 2 protects adult delta smelt prior to spawning. The potential range of OMR flow is -1,250 cfs (least pumping) to -5,000 cfs (most pumping). Highs flows (>10,000 cfs San Joaquin River at Vernalis) will relax this OMR restriction. Action 3 protects juvenile delta smelt in the south Delta. The range of OMR flow is again -1,250 cfs to -5,000 cfs. This OMR flow restriction extends until June 30 unless the CCF temperature exceeds 25°C (77°F), the assumed lethal temperature for delta smelt. The USFWS smelt committee (adaptive management for delta smelt and longfin smelt) is responsible for adaptive (weekly) changes in OMR flow between -5,000 cfs and -2,000 cfs (the USFWS allowed range for OMR flow).

The 2009 NMFS BiOp included slightly different limits for reverse OMR flows. Action IV.2.3 requires a minimum OMR flow of -5,000 cfs ((i.e., OMR must be greater than -5,000 cfs).) from January 1 through June 15. There are adaptive criteria based on fish salvage that would reduce the OMR limits to -2,500 cfs (allowing 1,000 cfs higher pumping than USFWS limits). The NMFS OMR limits end when Mossdale temperatures are greater than 22°C (72°F) for a week because this temperature is assumed to be lethal for juvenile outmigration; few juveniles are caught in the Mossdale trawl once temperatures are above 70°F.

5C.A.4.1.8 San Joaquin River Flow and Export Restrictions

D-1641 included objectives for the San Joaquin River flow at Vernalis during the X2 period of February–June and during the 30-day period of maximum fall-run Chinook juvenile migration through the Delta (nominally April 15 to May 15). Maximum exports during this juvenile migration period and installation of a temporary rock barrier at the head of Old River also were specified as part of this experimental flow program, referred to as the VAMP, that was implemented by Reclamation (water purchases) in coordination with the AFRP fish flows on the Stanislaus River. The flow targets for this migration period were determined from the expected flow at Vernalis without the VAMP supplementary water, and the export restrictions were linked to the target flows each year. The 12-year VAMP (2000–2011) has now ended.

The 2009 NMFS BiOp extended the period of San Joaquin River flows at Vernalis for fall-run juvenile and steelhead outmigration benefits to be April1–May 31 and specified the target flow as a function of New Melones storage and Stanislaus runoff. Maximum exports during the 2-month migration period also are specified with an export/San Joaquin River flow ratio that depends on the San Joaquin River water-year type. For critical years, the maximum export/San Joaquin River flow ratio is 1.0. The minimum San Joaquin River flow in April and May is about 1,500 cfs, which is necessary to meet the Vernalis EC objective of 1,000 µS/cm. This is about one pump at Banks and one pump at Jones, considered necessary for “health and safety” to supply the municipal water supplies dependent on the DMC and California Aqueduct flows. The export/San Joaquin River flow ratio is 0.5 in dry years, 0.33 in below normal years, and 0.25 in above normal and wet years. A San Joaquin River flow of 6,000 cfs would be required to allow pumping to be greater than 1,500 cfs. These 2009 NMFS BiOp export restrictions are much stronger than the D-1641 VAMP limits, and apply for 2 months.

A separate Action IV.3 requires reduction in the combined export pumping to 6,000 cfs under conditions that many fish are captured in the Sacramento Kodiak trawl or Knights Landing screw-traps or in the CVP/SWP salvage in November and December. If more than the specified fish number are caught or salvaged during January–April, the reverse OMR flow restriction is reduced from 5,000 cfs to 4,000 cfs.

5C.A.4.2 Simulated Sacramento River at Freeport Flows for the ESO

Table C.A-22 shows the CALSIM-simulated Sacramento River flow at Freeport for the six CALSIM cases. The Sacramento River flow at Freeport is usually the major Delta inflow and would be the water available for diversion at the proposed north Delta intakes. The average annual inflow at Freeport was about 15,650 taf/yr for the EBC1 and was reduced slightly to about 15,000 taf/yr for the ESO cases. Because the assumed effects of climate change increased the Sacramento River runoff only slightly (150 taf), and the assumed increases in water supply diversions were moderate (250 taf/yr), this reduction in average Sacramento River at Freeport flow was caused largely by the increased Fremont Weir spills to the Yolo Bypass of about 750 taf/yr as described above.

The median monthly flows at Freeport for the EBC1 were about 11,000 cfs in October and about 12,000 cfs in November. The median flows increased to 16,000 cfs in December, to 25,000 cfs in January, to 33,500 cfs in February, and to 27,000 cfs in March because of storm event runoff. The EBC1 median flow in April was 16,000 cfs and was about 13,000 cfs in May and June, but was increased to about 20,000 cfs in July because this is the first month with an increased E/I ratio. Reservoir releases often were increased in July and August to take advantage of this increased E/I for south-of-Delta exports. The EBC1 median flow was about 16,000 cfs in August and 13,000 cfs in September because the high reservoir releases in July could not be sustained in most years. The EBC2 cases included the Fall X2 requirements in the 2008 USFWS BiOp, which caused the median flows at Freeport to shift somewhat. The EBC2 monthly flow distributions were similar in most months, but were considerably higher (2,000 cfs more) in the highest 50% of the years in November and in September. The higher September and November flows were released from upstream reservoirs to meet the Fall X2 requirements in above normal and wet years (about 50% of the years).

The CALSIM-simulated monthly median flows for the two ESO cases were similar to each other, but were shifted slightly in comparison to the EBC2 cases in a few months. The Freeport median flows in January, February, and March for the ESO cases were about 3,000 cfs less in each month than the EBC1 flows, reflecting the increased spills at the Fremont Weir into the Yolo Bypass. The June median flows were increased for the ESO cases. The Freeport median flows in August and September were reduced by about 2,000 cfs, likely reflecting the new north Delta intakes that allow higher exports in April, May, and June and allow the exports to be distributed more evenly during the peak agricultural demand period of April through September. The Fall X2 outflow requirements are largely satisfied with lower exports but also requires higher releases from upstream reservoirs in above normal and wet year types.

Figure C.A-50 shows the CALSIM-simulated monthly Sacramento River flow at Freeport for WY 1963–2003 for the EBC1 and EBC2 cases and the ESO_ELT and ESO_LLT cases. This historical Freeport flows are shown for comparison. The great majority of the monthly flows are between 10,000 cfs and 25,000 cfs. The Sacramento River channel capacity downstream of Sacramento is about 100,000 cfs, but there are no simulated monthly flows of greater than 80,000 cfs. The Sacramento River inflows for the EBC2 and ESO cases appear to follow the same pattern, although almost every month is slightly different.

Figure C.A-51 shows the CALSIM-simulated monthly Sacramento River flow at Freeport for WY 1994–2003 for the six cases. For this recent 10-year sequence, several of the high monthly flows are different because of the different inflows and reservoir spill sequences. The monthly variations in the summer flows June–September are more extreme than observed in recent years.

Figure C.A-52 shows the monthly range of Sacramento River flows at Freeport for the EBC2_LLT and the ESO_ELT case, shown as the monthly 10% cumulative flow distribution lines. These are the same monthly values shown in Table C.A-22 presented graphically. These graphs highlight the seasonal patterns of Sacramento River inflows, reflecting both the seasonal runoff from December through April and the hydrologic variability between different years. It should be remembered that the months with higher average flows actually are caused by one or more storm events (lasting 10–20 days) added to managed releases from the upstream reservoirs. Monthly average flows are more representative of actual daily flows in the summer and fall when storm events are less frequent.

5C.A.4.3 Simulated Daily Sacramento River Flows at Freeport for the ESO

The CALSIM model simulates the monthly average flows, based on monthly average inflows and monthly operations of the upstream reservoirs, as described previously. This provides a good monthly sequence of Sacramento River inflow to the Delta. However, because the BDCP North Delta diversions would be operated with daily bypass flow rules (similar to the daily E/I rules for south Delta exports) the historical daily flows at Freeport were used to estimate daily flows for each of the EBC and ESO cases. The daily variations of the Sacramento River at Freeport are much less than the daily variations of the combined flows at Verona, because most of the high flows are diverted at the Fremont Weir into the Yolo Bypass. Figure C.A-53 shows the range of historical daily flows within each month (daily minimum, average and maximum) for WY 1956–2003 (DAYFLOW). The average Freeport flows in October ranged from about 5,000 cfs to 20,000 cfs, and the variation (maximum to minimum) within each month was about 50% of the monthly average flow, with greatest variation above the average (a few days with higher flows) . The average flows in November ranged from about 7,500 cfs to 50,000 cfs, and the variation was about equal to the average flow (minimum flows were about 50% of the average and maximum flows were about 150% of the average). The average flows in December ranged from about 7,500 cfs to 75,000 cfs, and the variation was somewhat more than the average flow. Although December flows remained low (less than 20,000 cfs, reservoir releases only) in about half of the years, there were about half of the years with December storm events.

Figure C.A-54 shows the average Freeport flows in January ranged from about 10,000 cfs to 75,000 cfs, and the variation was about 50% to 200% of the monthly average flow, with a maximum (channel capacity) of 100,000 cfs. The average flows in February ranged from about 10,000 cfs to 75,000 cfs, and the variation was about 50% to 200% of the monthly average flow, with a maximum of 100,000 cfs. The average flows in March ranged from about 7,500 cfs to 75,000 cfs, and the variation was about 50% to 200% of the monthly average flow, with a maximum of 100,000 cfs. Figure C.A-55 shows the average Freeport flows in April ranged from about 10,000 cfs to 75,000 cfs, and the variation was about 50% to 150% of the monthly average flow. The average flows in May ranged from about 7,500 cfs to 50,000 cfs, and the variation was about 50% to 150% of the monthly average flow. The average flows in June ranged from about 7,500 cfs to 50,000 cfs, and the variation was about 50% to 150% of the monthly average flow. Figure C.A-56 shows the average Freeport flows in July ranged from about 7,500 cfs to 25,000 cfs, and the variation was about 75% to 125% of the monthly average flow. The average flows in August ranged from about 7,500 cfs to 25,000 cfs, and the variation was about 75% to 125% of the monthly average flow. The average flows in

September ranged from about 10,000 cfs to 25,000 cfs, and the variation was about 75% to 125% of the monthly average flow. This evaluation of daily historical Freeport flows for 1956–2003 indicates that there are considerable daily variations in flows, during all months with major storm runoff.

The historical daily Sacramento River at Freeport flow variations within each month were used in the monthly CALSIM model (calculations) to more accurately estimate the allowable BDCP North Delta diversions. These daily calculations for the BDCP North Delta intakes will be introduced using the WY 1995 example, to be consistent with the WY 1995 conditions that were used to describe daily variations in the major upstream reservoir operations and in Sacramento River flows below Keswick and at Verona.

The allowable North Delta diversions are estimated, based on the ESO Bypass Flow rules which are specified for each month. There is a minimum bypass flow required in each month before any North Delta diversions are allowed, and then some fraction of the Sacramento River flow above the minimum bypass flow can be diverted at the North Delta intakes. In the months of December–June there are three different levels of required bypass flows that depend on the Freeport flow, beginning after the occurrence of the first winter flow pulse. A low-level diversion of 6% of the river flow is allowed as long as Freport flow is greater than 5,000 cfs (maximum of 300 cfs in each intake). The most restrictive monthly bypass rules are Level I; these rules apply until 15 days of bypass flows greater than 20,000 cfs after a post-December 1 flow pulse; level II bypass rules apply until 30 days of bypass flows greater than 20,000 cfs after a post-December 1 flow pulse; Level III bypass rules apply thereafter until July 1. The bypass rules for July–November are fixed minimum monthly bypass flows.

Figure C.A-57 shows an example of the ESO bypass rules for December–April. Aside from low-level pumping, Level I requires a minimum of 10,000 cfs bypass and would allow full North Delta diversions of 9,000 cfs (ESO capacity) at a Freeport flow of about 30,000 cfs. Level II bypass rules for December through April are slightly less restrictive and would allow full diversions of 9,000 cfs at a Freeport flow of about 25,000 cfs. Level III bypass rules for December–April would allow full diversions of 9,000 cfs at a Freeport flow of 22,000 cfs.

DSM2 modeling of tidal velocities at the north Delta intake indicated that these bypass rules would be compatible with a downstream sweeping velocity of 0.4 ft/sec that was assumed protective for reducing juvenile fish impingement on the screens. The minimum downstream velocity in the Sacramento River at Sutter Slough would be greater than 0.5 ft/sec whenever the average daily flow was greater than 20,000 cfs. Diversions at the intakes would be possible during most of the day (not during flood tide) at lower average river flows of 10,000 cfs to 20,000 cfs remaining at Sutter Slough.

Figure C.A-58 shows the Sacramento River at Freeport daily flows for WY 1995. Flows were greater than 50,000 cfs for most of the January through May period. Because the flows were very high from January through June, the North Delta diversions could have been 9,000 cfs for most of this year. Historical exports for 1995 are shown for comparison; exports could have been much higher under the ESO (11,000 cfs) for most of the winter and spring months. Historical exports were limited once San Luis Reservoir was filled in March, and deliveries in these months were reduced from wet condition. Daily calculations in the CALSIM model that approximate these bypass rules are applied to each month of the CALSIM period. The historical Freeport flows are used to approximate the daily flows for each BDCP case (adjusted by the monthly average differences). The monthly average North Delta Diversions are reported in the monthly CALSIM results. The ESO_LLT CALSIM estimates of monthly average north Delta diversions and total exports for 1995 are shown with the red and purple symbols. The north Delta diversions were very low in October, November and December, but were about 9,000 cfs (full capacity) from January through September. The total exports were much less than the 15,000 cfs (CVP and SWP combined capacity) in most months during this wet year; although San Luis Reservoir was not filled until the end of May, higher deliveries were not possible.

Table C.A-22. CALSIM-Simulated Monthly Distribution of Sacramento River Flows (cfs) at Freeport

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
A. EBC1													
Min	5,918	6,947	6,608	7,483	8,473	7,851	7,788	5,447	8,310	8,539	7,150	7,193	6,556
10%	7,694	8,451	9,896	12,533	13,059	11,666	9,806	8,901	10,361	14,669	10,150	8,062	8,671
20%	9,000	9,642	11,585	13,339	14,885	15,383	11,232	10,131	11,721	17,257	13,450	11,043	10,656
30%	9,804	10,841	12,950	15,694	19,946	19,191	12,034	10,982	12,374	19,278	15,229	12,051	11,519
40%	10,626	11,177	15,011	19,442	24,695	22,066	13,316	12,101	12,691	19,645	15,692	12,776	12,284
50%	11,278	12,179	16,439	24,758	33,438	27,155	16,221	13,689	13,373	19,911	16,172	13,212	13,232
60%	11,766	13,576	18,406	30,911	43,446	33,804	20,554	15,293	13,924	20,443	16,605	13,660	17,349
70%	12,858	14,563	24,821	41,045	51,013	43,112	23,516	18,662	15,247	21,374	16,921	14,104	19,046
80%	13,765	15,847	36,152	56,012	60,934	51,777	38,496	27,859	20,410	22,708	17,588	17,116	20,672
90%	15,407	24,427	51,094	63,434	68,256	61,156	50,243	41,972	26,032	23,545	18,025	19,590	24,097
Max	32,562	54,287	76,342	77,922	76,675	81,283	71,967	59,039	60,868	25,689	20,448	26,631	33,866
Avg	11,696	14,834	23,734	31,874	37,057	32,865	23,236	19,303	16,633	19,748	15,358	13,847	15,659
B. ESO_ELT													
Min	5,361	5,879	6,900	8,210	8,960	8,545	7,833	5,503	8,134	8,535	6,298	6,002	6,233
10%	7,539	7,691	9,436	12,368	12,263	11,593	9,923	8,877	10,344	11,243	8,425	7,901	8,235
20%	9,053	8,630	12,682	13,453	14,965	15,274	10,964	10,128	11,689	15,560	10,361	8,626	9,577
30%	10,032	10,050	13,513	14,922	18,127	18,379	11,855	10,785	12,836	17,187	11,815	9,252	10,653
40%	10,863	10,750	13,852	18,067	22,967	20,493	13,013	11,530	15,796	17,952	12,507	9,552	11,977
50%	11,347	12,105	15,312	21,839	30,189	24,078	15,633	12,792	16,942	19,661	13,462	11,334	13,142
60%	11,930	12,775	18,388	25,968	43,730	29,054	19,851	14,754	18,213	21,381	14,335	16,845	17,441
70%	12,145	14,236	22,238	38,298	48,197	39,735	22,838	17,536	19,993	22,165	16,043	22,026	18,844
80%	12,513	15,492	34,749	55,148	60,611	50,513	31,852	25,400	20,781	23,427	17,301	23,632	20,754
90%	13,392	21,982	49,387	65,015	69,720	62,051	46,267	39,230	22,308	24,162	18,416	24,983	24,051
Max	29,534	57,482	80,914	78,073	77,818	80,189	74,449	57,436	53,440	26,084	21,268	28,340	31,199
Avg	11,191	14,085	22,916	30,698	36,484	31,483	22,094	18,388	17,561	18,922	13,690	15,225	15,203
C. ESO_LLT													
Min	4,901	5,688	6,349	8,735	6,298	7,801	8,320	5,327	8,127	8,828	7,780	7,047	6,585
10%	8,158	7,141	9,440	12,471	12,363	11,464	10,699	8,674	10,941	10,389	8,373	7,775	8,394
20%	9,283	8,331	12,426	13,741	15,532	15,490	11,204	10,690	12,151	12,743	10,143	8,752	9,485
30%	10,858	9,812	13,603	15,758	19,264	18,403	12,191	11,809	13,276	14,532	11,385	9,426	10,662
40%	11,385	10,872	14,357	18,894	23,192	20,648	13,213	12,595	15,520	16,650	12,036	10,198	11,720
50%	11,859	11,952	15,874	21,948	30,009	23,697	16,021	13,530	17,586	18,805	12,375	12,310	12,988
60%	12,441	12,633	18,001	24,888	43,168	29,230	20,046	15,076	19,523	20,491	13,500	17,197	17,501
70%	13,113	14,515	20,790	39,247	48,812	39,937	22,611	20,088	21,190	21,769	14,502	22,253	19,059
80%	13,813	14,880	31,652	56,986	63,420	51,636	32,225	23,965	23,239	23,464	16,614	25,457	20,553
90%	14,961	20,481	47,114	65,109	70,478	62,099	45,720	33,673	24,086	24,135	17,696	27,249	23,928
Max	29,533	53,220	81,077	80,443	80,031	79,178	74,335	50,028	47,484	26,683	23,129	29,035	29,744
Avg	11,862	13,483	22,156	31,296	37,070	31,666	22,231	17,669	17,959	18,084	13,157	15,923	15,188

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
D. EBC2													
Min	5,944	5,966	7,044	9,901	8,671	8,017	7,485	5,559	8,380	8,374	7,006	7,380	6,190
10%	7,724	7,865	9,623	12,225	12,630	11,451	9,678	8,420	10,713	14,381	9,284	7,807	8,612
20%	9,066	8,992	12,159	13,579	15,095	14,381	11,168	9,881	11,538	16,709	13,547	10,497	10,334
30%	9,199	10,200	13,690	15,369	18,222	19,428	11,763	10,711	12,277	18,569	14,856	11,769	11,362
40%	9,694	12,721	14,548	19,294	24,023	21,972	13,096	11,835	12,772	19,609	15,497	12,541	12,168
50%	10,918	14,250	15,714	22,536	33,681	25,252	16,326	13,500	13,443	20,092	15,968	13,750	13,037
60%	11,269	15,609	18,052	26,683	43,545	33,598	20,663	14,860	14,155	20,433	16,685	20,575	17,242
70%	11,783	17,634	22,585	38,630	48,893	41,582	23,830	18,205	15,332	21,463	17,000	23,482	19,609
80%	12,758	18,970	33,606	55,337	60,800	52,762	38,919	27,562	20,400	22,816	17,308	27,456	21,523
90%	14,604	22,094	49,626	62,341	67,960	61,307	50,497	41,800	26,090	24,026	18,243	29,485	24,835
Max	33,102	54,738	76,389	78,032	76,794	81,371	72,174	58,744	60,463	24,971	20,024	31,418	33,470
Avg	11,156	15,663	23,087	31,371	36,583	32,474	23,234	19,041	16,583	19,626	15,213	17,577	15,740
E. EBC2_ELT													
Min	5,476	5,979	7,079	7,345	7,808	8,024	7,531	5,626	8,381	8,345	6,755	5,551	6,008
10%	7,486	7,784	9,549	12,362	12,593	11,274	9,848	8,917	10,368	13,400	8,993	7,566	8,439
20%	8,486	8,684	11,790	13,606	14,878	14,272	10,661	10,054	11,651	16,243	13,296	8,836	10,078
30%	9,191	10,626	13,534	15,773	17,828	19,068	11,457	10,529	12,148	17,788	13,893	10,590	10,931
40%	9,378	12,375	14,263	18,961	24,057	21,665	12,958	11,091	12,535	18,783	15,092	11,873	12,055
50%	11,157	14,174	15,595	22,916	34,533	25,294	15,490	12,122	13,096	20,041	15,735	12,930	13,037
60%	11,888	16,115	17,960	26,525	46,303	33,515	20,107	12,933	13,501	21,024	16,458	21,051	17,842
70%	12,533	16,914	23,000	38,682	49,350	42,469	23,188	15,743	13,946	23,334	16,834	22,114	19,648
80%	13,539	18,606	36,051	57,205	63,212	55,737	36,254	24,954	16,249	23,940	17,219	27,231	21,386
90%	14,381	22,028	51,773	65,029	70,368	62,162	50,496	36,500	20,318	24,526	17,574	29,272	24,646
Max	33,307	57,481	80,913	78,060	77,817	80,189	74,448	57,535	53,462	24,898	19,249	29,955	32,075
Avg	11,087	15,445	23,694	31,974	37,612	32,837	23,024	17,964	15,134	19,665	14,757	17,159	15,662
F. EBC2_LLT													
Min	5,957	5,447	6,919	6,399	7,112	7,835	7,894	5,055	8,906	8,345	7,858	5,594	6,507
10%	7,626	7,467	9,040	12,248	12,534	11,736	10,202	8,824	11,081	12,424	9,275	7,701	8,409
20%	9,090	8,515	11,822	13,694	15,979	15,217	11,284	9,818	12,057	16,013	13,147	8,103	10,061
30%	10,560	9,757	13,724	17,458	18,823	18,689	11,529	11,019	12,846	18,338	14,318	9,197	11,161
40%	11,467	12,089	14,374	20,243	24,156	21,425	12,262	11,369	13,436	20,200	15,397	10,717	11,854
50%	12,323	14,220	15,914	22,929	34,780	25,417	15,040	12,033	13,684	21,510	15,956	12,835	12,808
60%	12,929	15,236	18,327	26,612	44,753	32,769	19,970	12,679	14,609	22,623	16,386	22,141	17,763
70%	13,143	16,591	21,769	40,737	51,446	43,836	23,034	15,449	15,670	23,385	16,766	23,658	19,656
80%	13,552	17,941	31,611	56,848	65,667	56,138	37,671	21,900	16,565	24,014	17,279	27,036	21,433
90%	14,521	21,110	48,896	65,972	70,606	64,144	49,479	28,944	18,921	24,512	17,778	29,056	24,230
Max	29,556	53,905	81,058	80,420	80,029	79,179	74,332	50,112	47,550	25,438	19,962	31,347	30,231
Avg	11,857	14,692	22,789	32,496	38,028	33,164	22,892	16,422	15,098	20,020	15,039	16,857	15,601

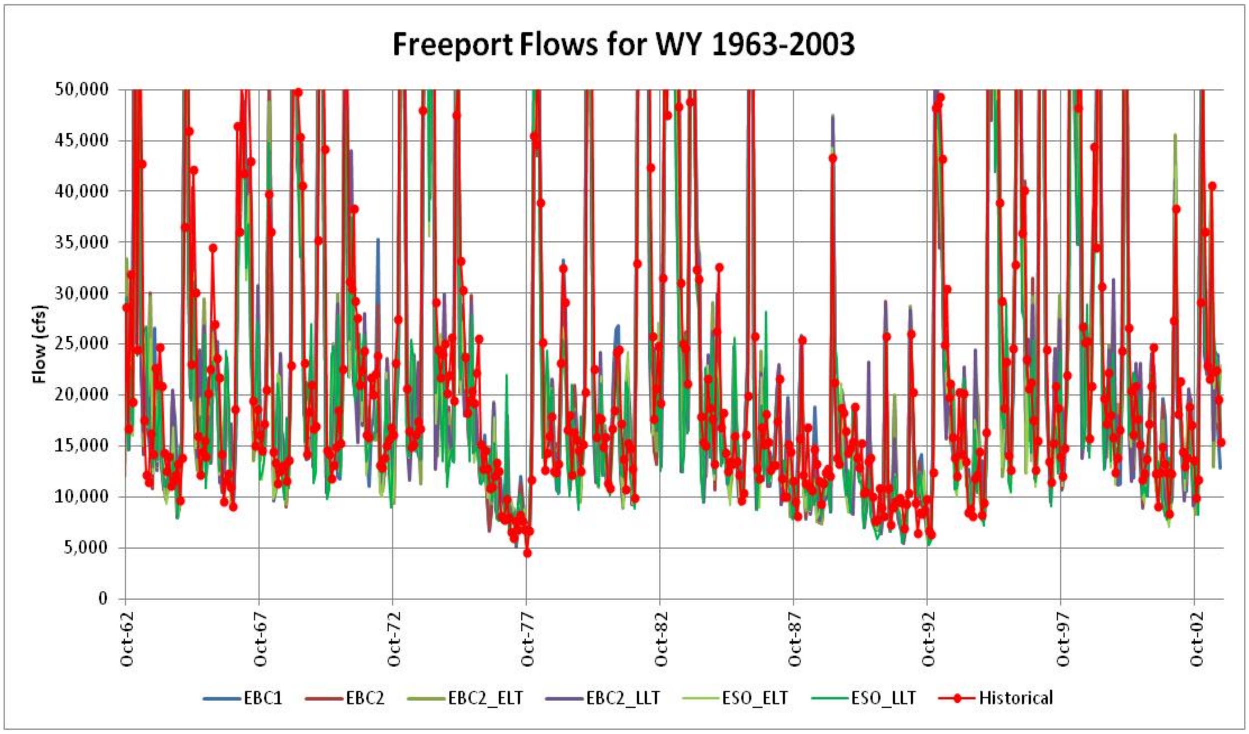


Figure C.A-50. CALSIM-Simulated Monthly Sacramento River Flow at Freeport for WY 1922–2003 for EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

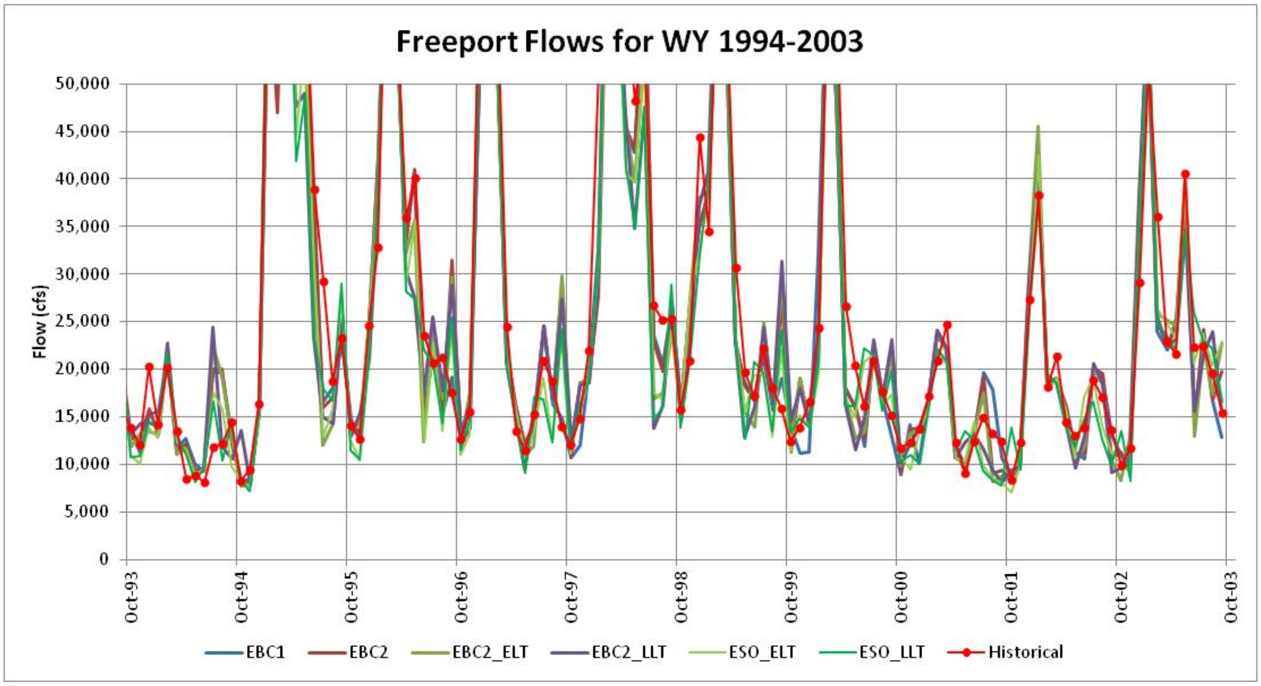
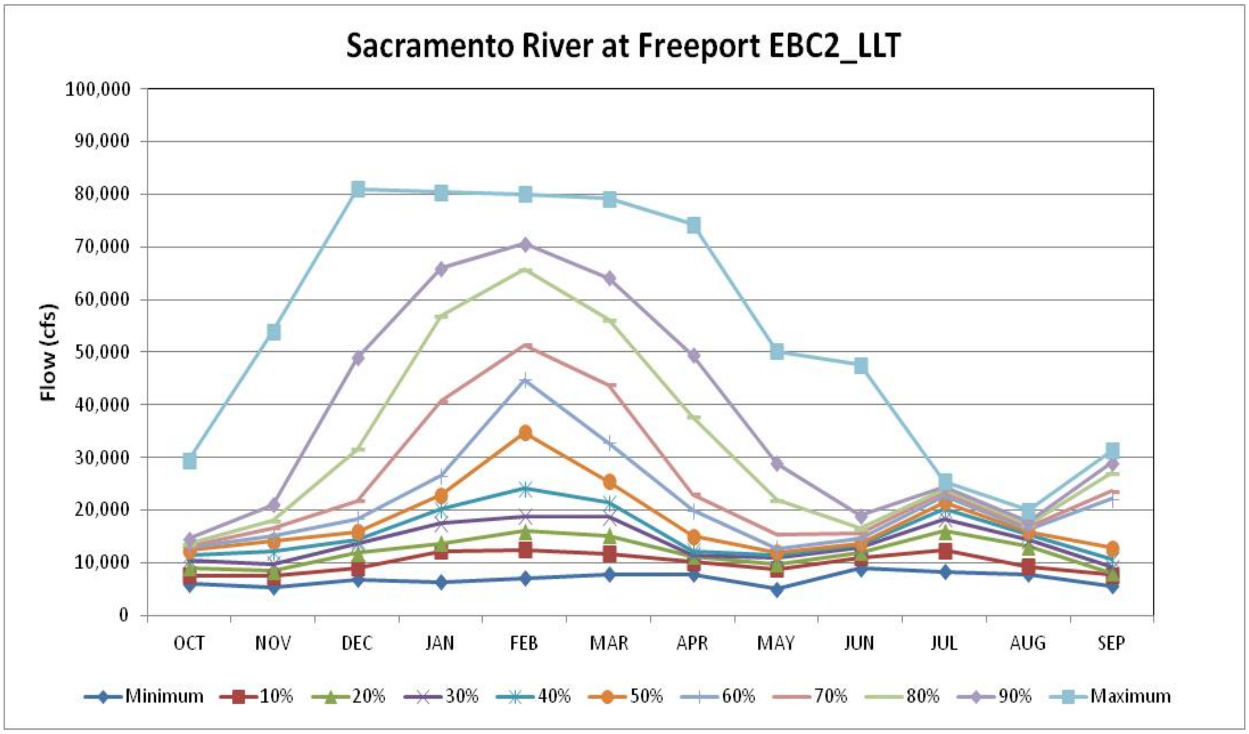


Figure C.A-51. CALSIM-Simulated Monthly Sacramento River Flow at Freeport for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases



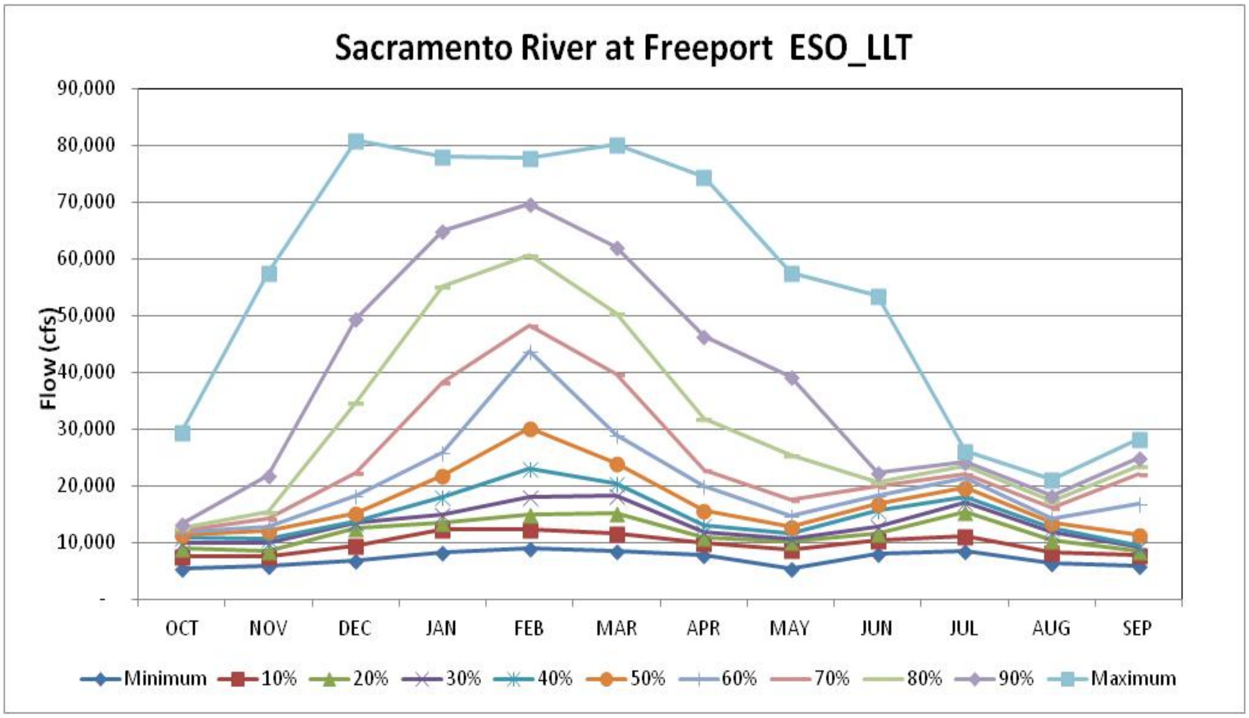
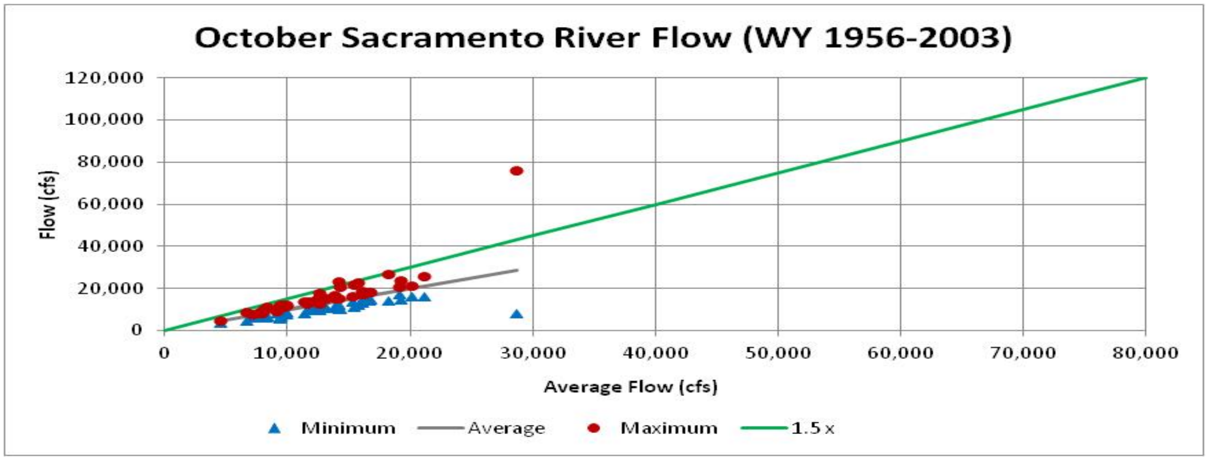
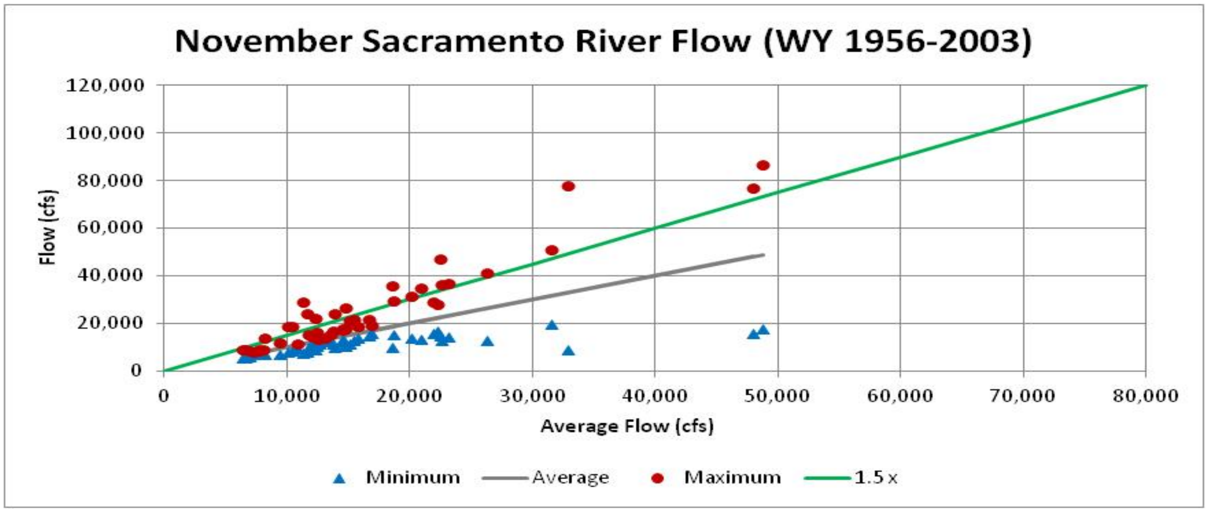


Figure C.A-52. CALSIM-Simulated Monthly Cumulative Distribution of Sacramento River at Freeport Flows for WY 1922–2003 for the EBC2_LLT and ESO_LLT Cases





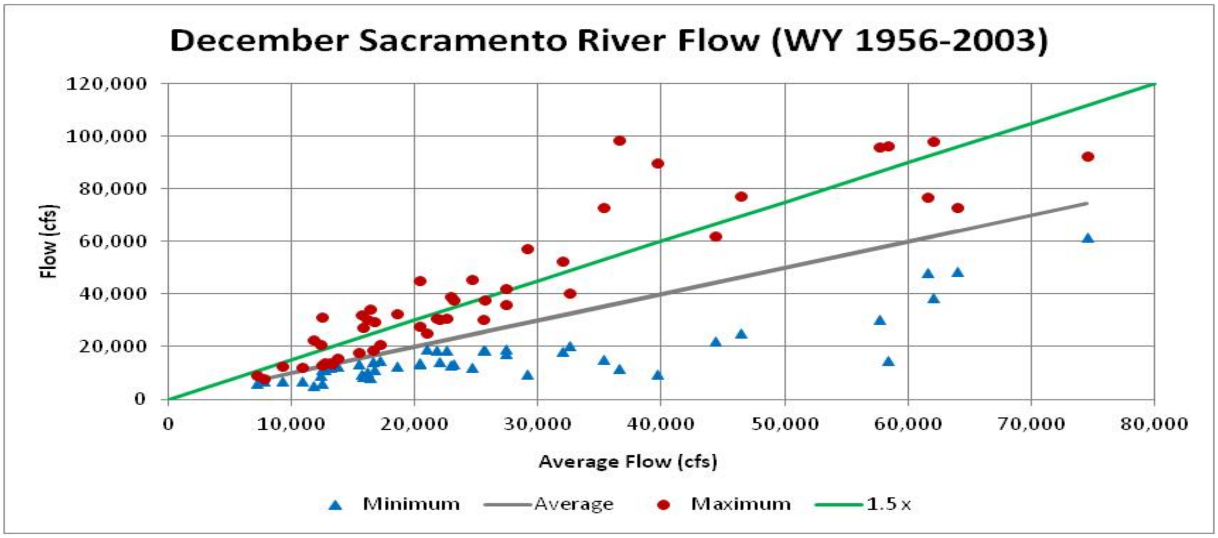
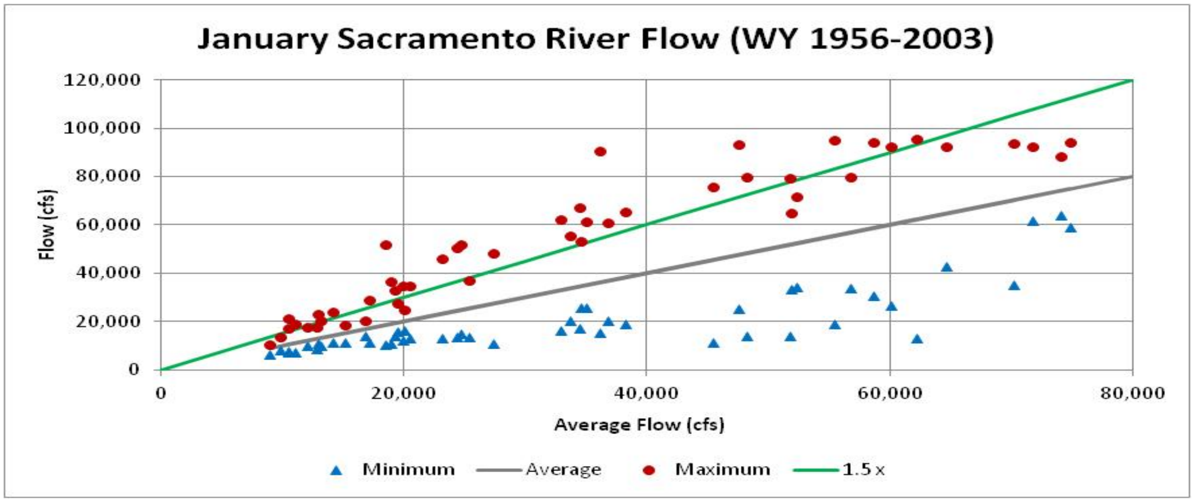
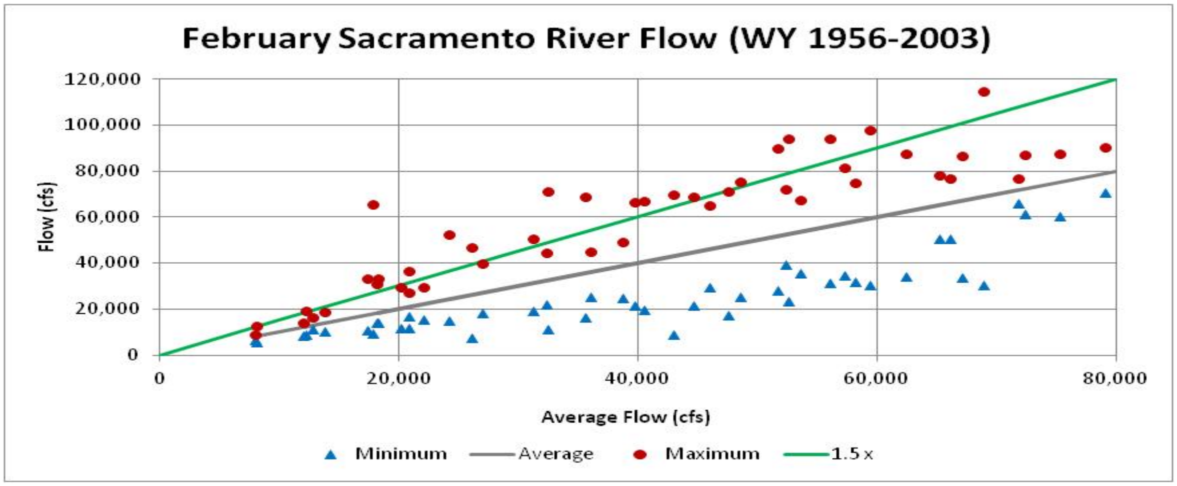


Figure C.A-53. Monthly Range of Sacramento River at Freeport Daily Flows (cfs) for October, November and December





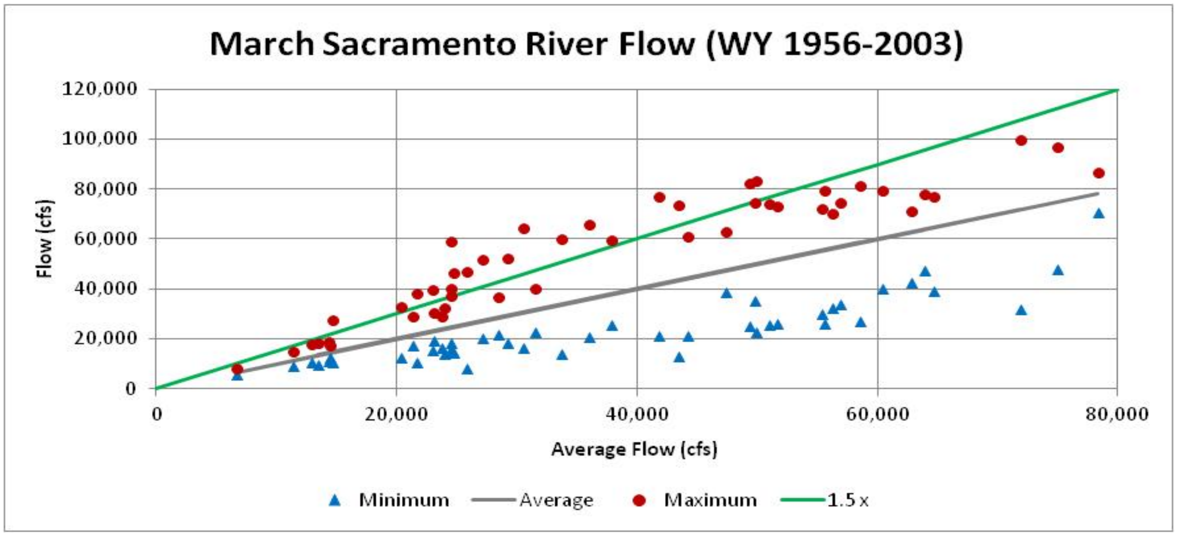
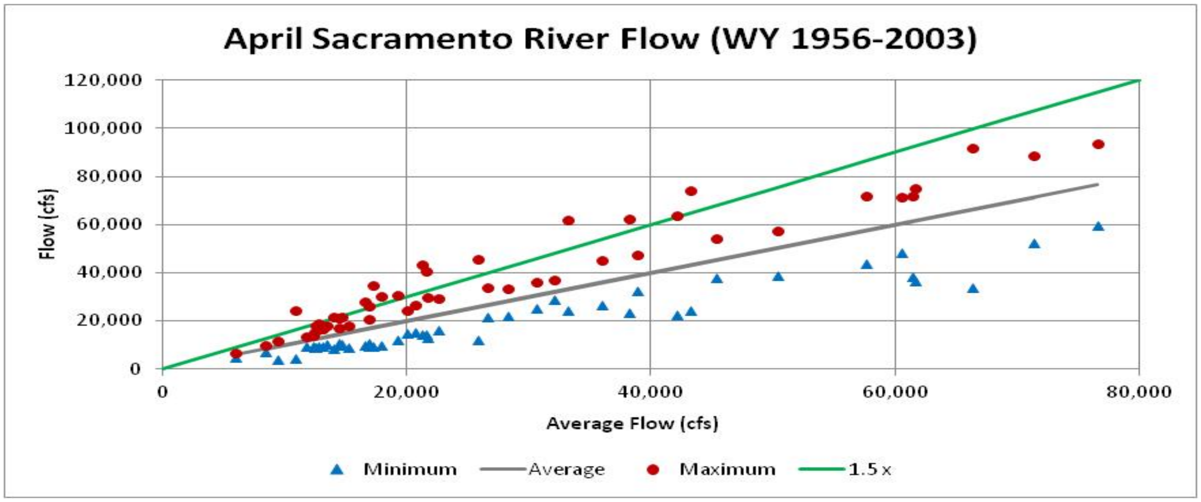
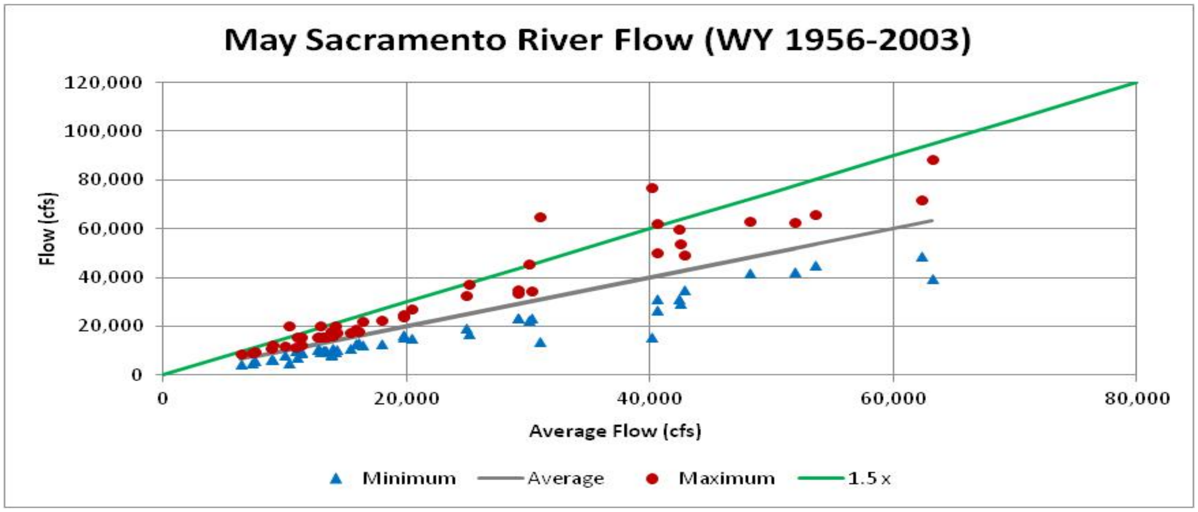


Figure C.A-54. Monthly Range of Sacramento River at Freeport Daily Flows (cfs) for January, February and March





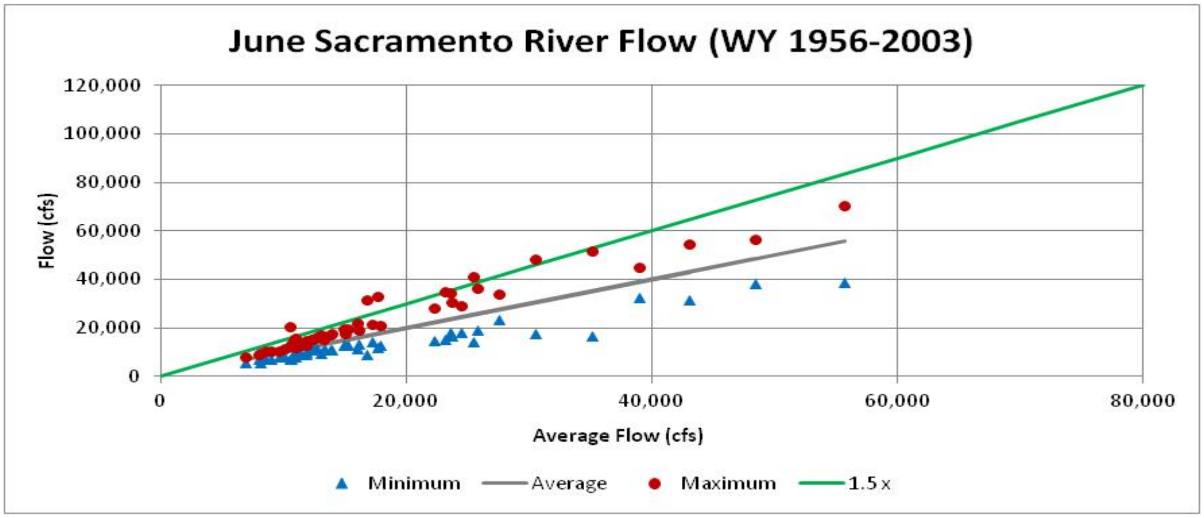
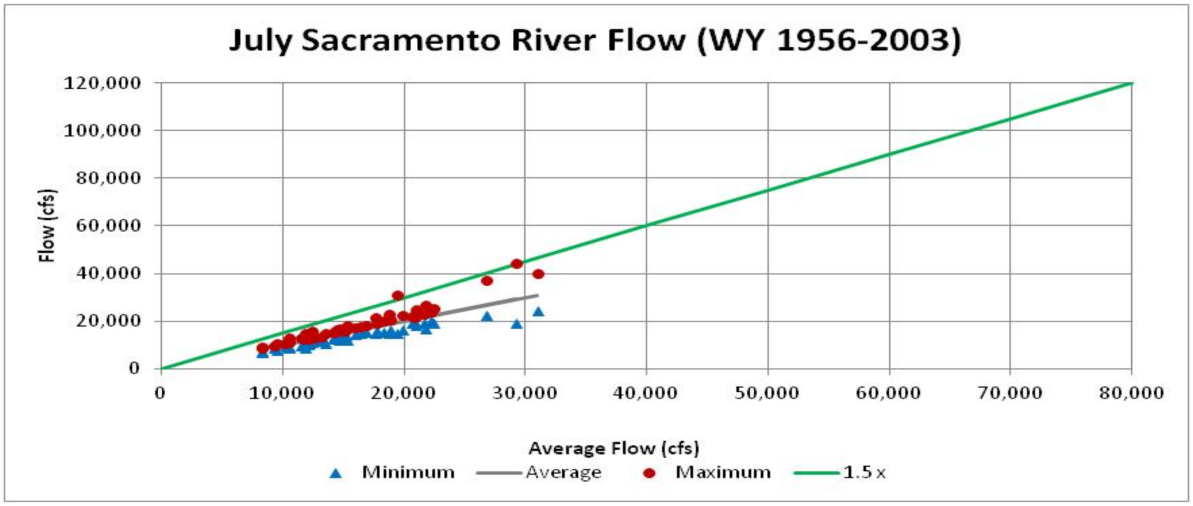
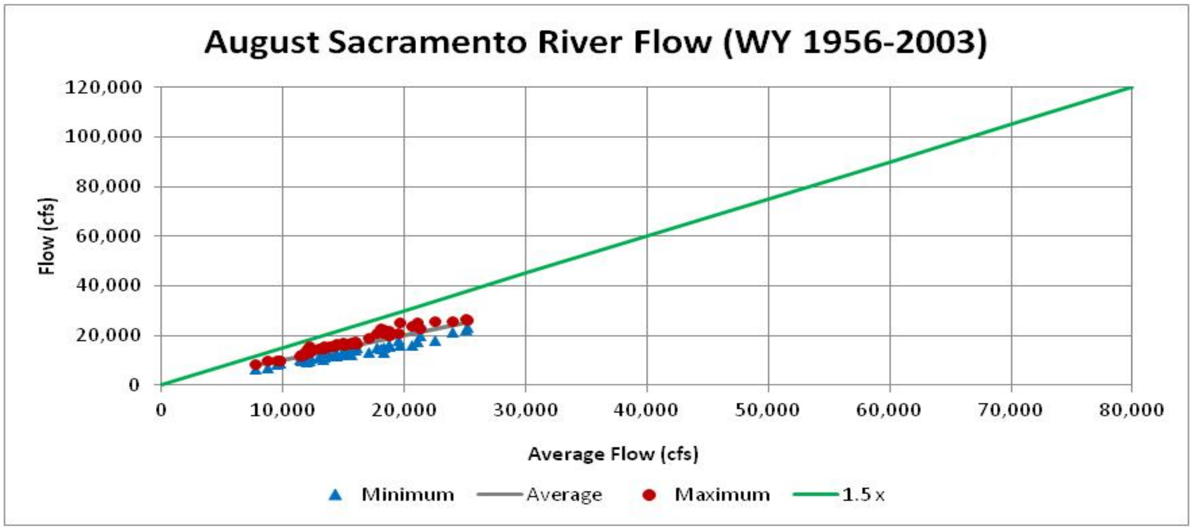


Figure C.A-55. Monthly Range of Sacramento River at Freeport Daily Flows (cfs) for April, May and June





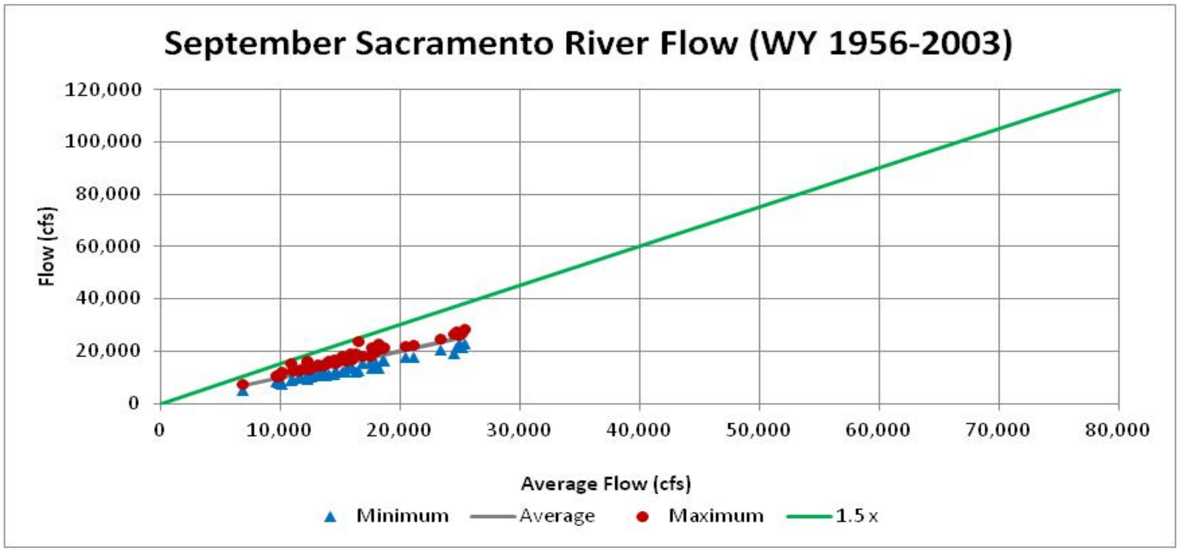


Figure C.A-56. Monthly Range of Sacramento River at Freeport Daily Flows (cfs) for July, August and September

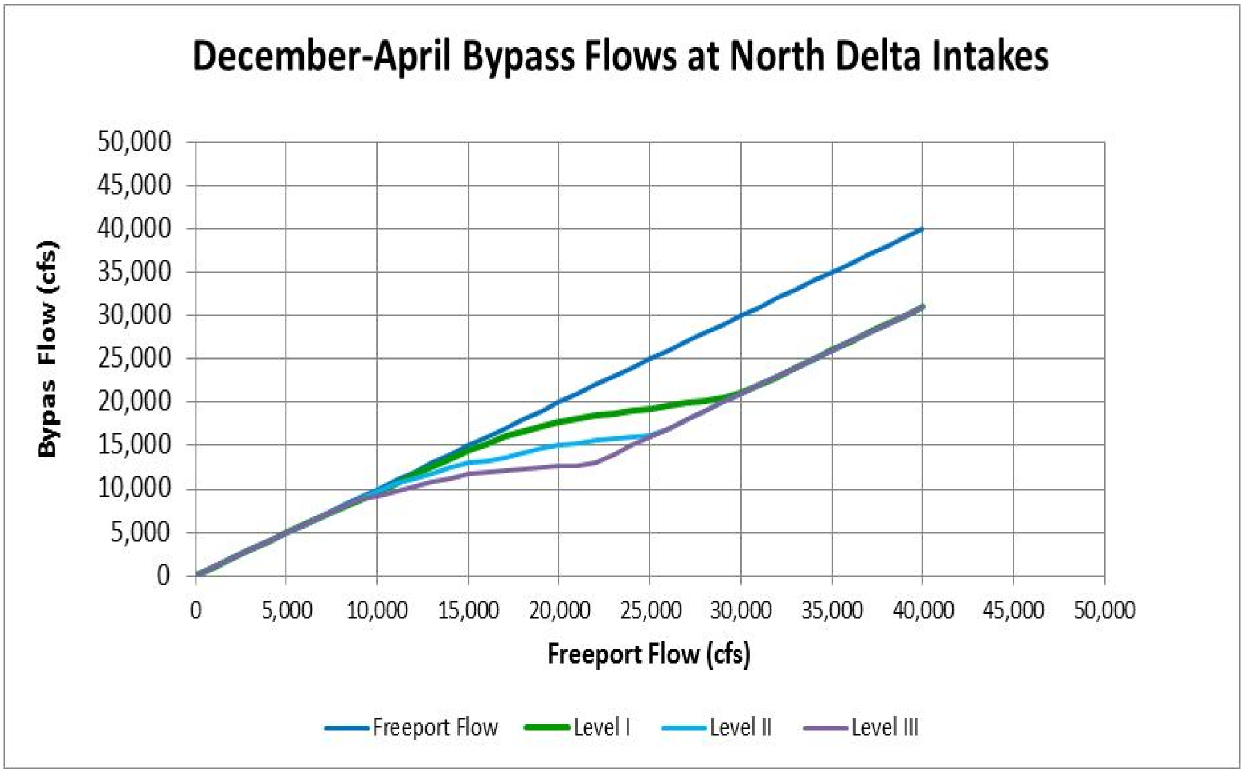


Figure C.A-57. Example of Daily Bypass Flows for BDCP North Delta Intakes (9,000 cfs capacity) for December–April

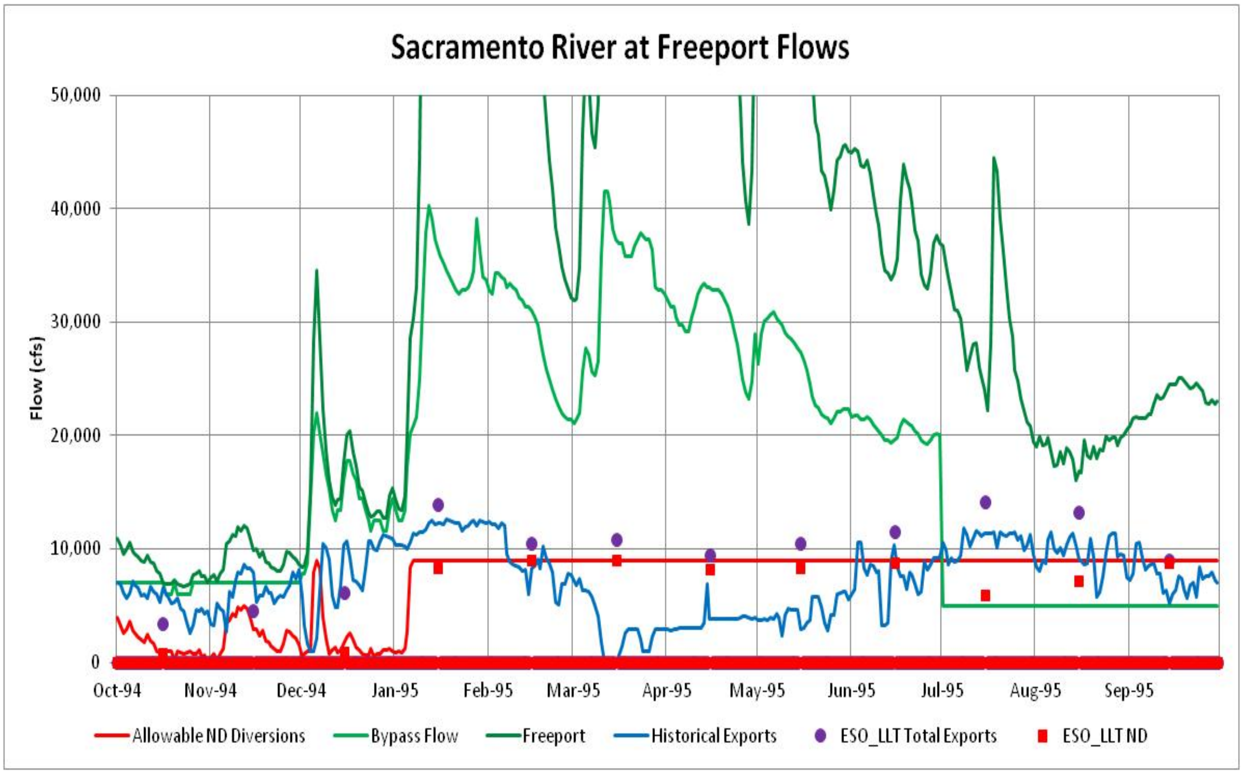


Figure C.A-58. Sacramento River at Freeport Daily Flow and Allowable BDCP North Delta Diversions for ESO (9,000 cfs capacity) with Bypass Flow Requirements in WY 1995

5C.A.4.4 North Delta Intake Diversions

Table C.A-23 shows the CALSIM-simulated Sacramento River diversions into the proposed north Delta intakes, located along the Sacramento River between Freeport and Hood. There are no existing intakes at these locations, so the four EBC cases have no north Delta intake diversions. Although the intakes would have a combined capacity of 9,000 cfs, the simulated average north Delta diversions for the ESO_ELT and ESO_LLT cases are generally less than 5,000 cfs. The north Delta diversions are often limited by the monthly inflow hydrology and the applicable D-1641 objectives that require a minimum Delta outflow. The maximum E/I ratio for the total south Delta pumping was assumed not to apply to the north Delta diversions. However, the proposed BDCP operating rules include monthly minimum bypass flows for the north Delta intakes to reduce the effects of these diversions on migrating Sacramento River fish. DSM2 modeling of tidal velocities at the north Delta intakes indicated that these bypass rules would be compatible with a downstream sweeping velocity of 0.4 ft/sec that was assumed protective for reducing juvenile fish impingement on the screens. The minimum downstream velocity in the Sacramento River at Sutter Slough would be greater than 0.5 ft/sec whenever the average daily flow was greater than 20,000 cfs. Full diversions would therefore be possible with a Freeport flow of 30,000 cfs. The daily bypass rules were applied within CALSIM, as described in the previous section, and the monthly average north Delta diversions for the ESO_ELT and ESO_LLT cases are summarized here.

Table C.A-23 indicates that for the ESO_ELT and ESO_LLT cases, the simulated north Delta diversions would be very similar. Although the Sacramento River inflow is slightly different for each month of the 82-year sequence, the distribution of monthly flows is nearly identical (Table C.A-22). Some north Delta diversions were simulated in almost every month. The CALSIM-simulated north Delta diversions were 9,000 cfs in at least 10% of the years in the months of January through June. For the ESO_ELT case, the median diversions were about 2,500 cfs in October; 2,000 cfs in November; 1,000 cfs in December; 3,000 cfs in January; 6,000 cfs in February; 6,250 cfs in March; 3,500 cfs in April; 2,000 cfs in May; 4,500 cfs in June; 2,000 cfs in July; and 3,000 cfs in August and 2,500 cfs in September. The ESO_LLT monthly median diversions were very similar.

The CALSIM model assumed that there would be some south Delta exports in all months and the monthly pattern of north Delta diversions is not fully explained by the bypass rules; there were many months when the north Delta diversion could have been higher than CALSIM estimated. Figure C.A-59 shows the comparison of CALSIM estimated north Delta diversions and the allowable north Delta diversions for WY 1976–1991. Overall, the average annual north Delta diversions were 2,603 taf/yr for the ESO_ELT case and were 2,435 taf/yr for the ESO_LLT case. The allowable north Delta diversions, estimated for Level I bypass rules (most restrictive for December–June) would have been considerably higher in many months. There will likely be opportunities, under the BDCP adaptive management process to shift total exports between the south Delta and north Delta intakes to maximize protection of fish.

Figure C.A-60 shows the CALSIM-simulated north Delta diversions and total Delta exports for the ESO_LLT case for WY 1963–2003. This allocation of total exports between the north Delta intakes and the existing south Delta intakes follows the D-1641 objectives for required Delta outflow, and follows the initial north Delta bypass flow rules proposed in February 2010. The ESO_LLT CALSIM results for WY 1922–2003 gave average annual total exports of 4,945 taf/yr with average north Delta diversions of 2,435 taf/yr (49% of total exports). The ESO_LLT results for WY 1963–2003 (shown in figure) was an average total exports of 5,141 taf/yr with north Delta diversions of 2,678 taf/yr (52% of total exports). Figure C.A-61 shows the CALSIM-simulated north Delta diversions and total Delta exports for the ESO_LLT case for WY 1994–2003. For this somewhat wetter period, the average annual total exports were 5,558 taf/yr and the average north Delta diversions was 3,081 taf/yr (55% of total exports). The ESO_LLT case would move about 50% of the total exports to the north Delta intakes. The effects analysis (Chapter 5.5) describes the predicted effects on fish from these operations and other components of the BDCP.

Table C.A-23. CALSIM-Simulated Monthly Distribution of North Delta Diversions (cfs) near Hood

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1, EBC2, EBC_ELT, EBC_LLT													
Min	0	0	0	0	0	0	0	0	0	0	0	0	0
10%	0	0	0	0	0	0	0	0	0	0	0	0	0
20%	0	0	0	0	0	0	0	0	0	0	0	0	0
30%	0	0	0	0	0	0	0	0	0	0	0	0	0
40%	0	0	0	0	0	0	0	0	0	0	0	0	0
50%	0	0	0	0	0	0	0	0	0	0	0	0	0
60%	0	0	0	0	0	0	0	0	0	0	0	0	0
70%	0	0	0	0	0	0	0	0	0	0	0	0	0
80%	0	0	0	0	0	0	0	0	0	0	0	0	0
90%	0	0	0	0	0	0	0	0	0	0	0	0	0
Max	0	0	0	0	0	0	0	0	0	0	0	0	0
Avg	0	0	0	0	0	0	0	0	0	0	0	0	0
B. ESO_ELT													
Min	0	0	0	6	474	513	470	218	0	0	0	0	231
10%	0	0	257	680	748	696	636	534	641	235	140	0	654
20%	977	279	701	810	977	1,449	691	608	751	341	450	738	1,041
30%	1,171	1,100	807	912	2,163	3,462	811	678	1,371	783	1,348	1,469	1,540
40%	1,980	1,461	827	1,303	4,714	4,532	1,592	1,197	2,740	1,747	2,161	1,894	1,960
50%	2,470	1,934	935	2,853	6,114	6,270	3,487	1,988	4,453	2,132	2,878	2,531	2,391
60%	2,998	2,232	1,341	4,946	7,119	7,538	4,772	3,034	5,666	2,761	3,161	3,705	3,172
70%	3,343	3,277	1,872	7,476	8,999	8,987	6,979	5,300	6,750	3,270	3,663	4,887	3,672
80%	3,828	4,751	4,923	8,739	9,000	9,000	8,368	8,341	7,626	4,124	4,620	6,127	4,198
90%	4,907	6,533	7,012	9,000	9,000	9,000	9,000	8,999	8,857	6,553	5,261	7,194	4,702
Max	8,321	9,000	8,216	9,000	9,000	9,000	9,000	9,000	9,000	9,000	7,994	9,000	5,362
Avg	2,567	2,633	2,277	4,117	5,320	5,577	4,141	3,554	4,361	2,590	2,785	3,359	2,603
C. ESO_LLT													
Min	0	0	0	0	0	466	499	184	0	0	0	0	178
10%	0	0	183	707	702	699	643	522	658	235	4	0	570
20%	203	37	582	812	1,038	1,423	698	643	775	418	300	191	954
30%	726	997	800	965	2,153	3,468	828	763	1,082	604	581	343	1,137
40%	1,030	1,197	842	1,421	4,499	4,409	1,667	1,040	2,631	1,023	1,368	1,161	1,665
50%	1,675	1,599	919	2,604	6,275	6,489	3,291	1,980	5,089	1,319	2,134	1,986	2,220
60%	2,175	1,917	1,179	5,078	7,894	7,890	4,841	3,199	6,549	1,502	2,916	3,504	3,145
70%	2,703	2,816	1,553	7,873	9,000	8,982	7,008	6,020	7,388	2,189	3,535	4,347	3,520
80%	3,195	3,875	3,814	8,692	9,000	9,000	8,359	8,275	8,247	2,911	4,028	5,831	3,940
90%	4,252	5,744	6,468	9,000	9,000	9,000	9,000	8,810	8,934	3,669	4,645	7,270	4,412
Max	7,685	8,730	8,216	9,000	9,000	9,000	9,000	9,000	9,000	7,143	7,253	9,000	4,946
Avg	1,949	2,219	1,997	4,174	5,393	5,551	4,100	3,589	4,617	1,710	2,277	2,954	2,435

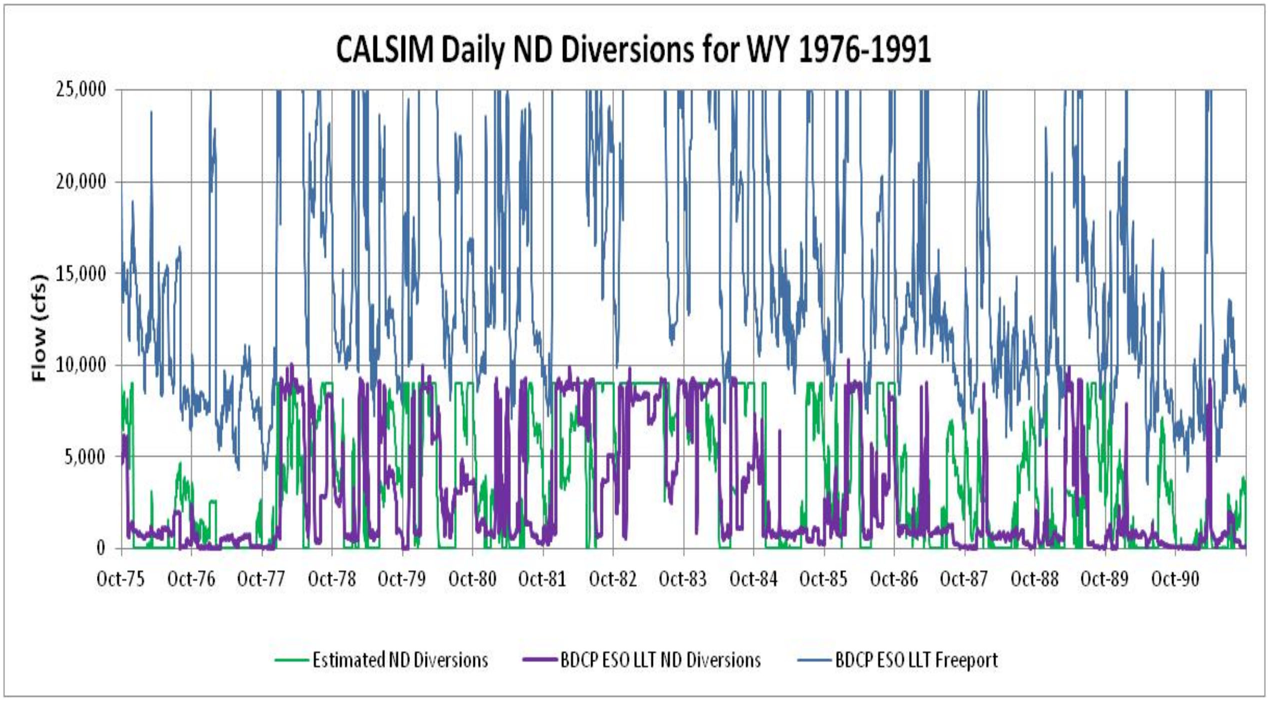


Figure C.A-59. Comparison of CALSIM-Simulated North Delta Diversions and Estimated (Allowable with Level I Bypass Flows) North Delta Diversions for WY 1976–1991

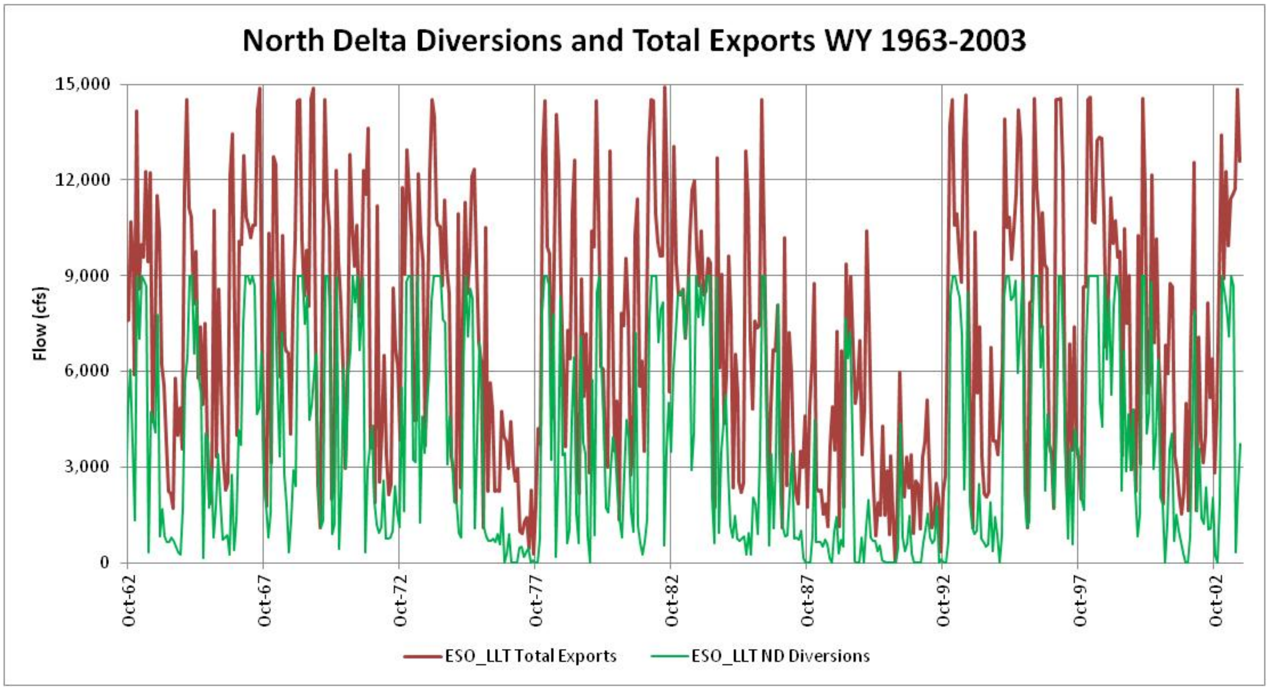


Figure C.A-60. CALSIM-Simulated Total Exports and North Delta Diversions for ESO_LLT for WY 1963–2003

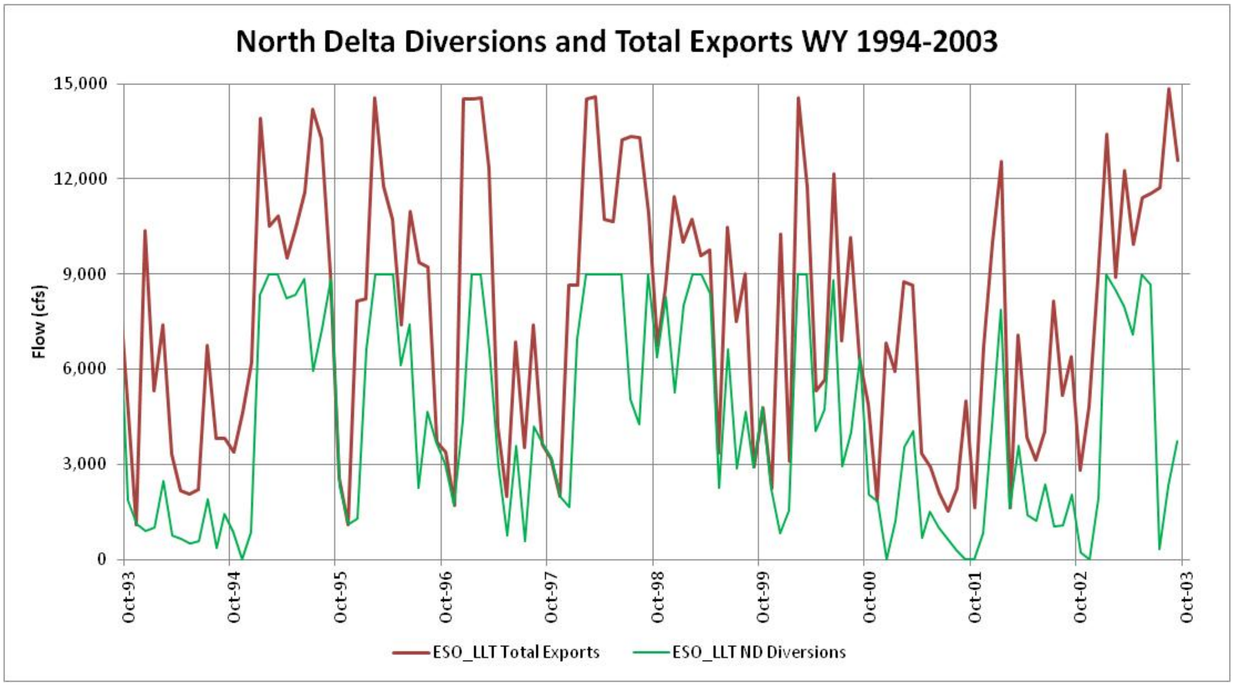


Figure C.A-61. CALSIM-Simulated Total Exports and North Delta Diversions for ESO_LLT for WY 1994–2003

5C.A.4.5 Sutter Slough and Steamboat Slough Flows

Table C.A-24 shows the calculated Sacramento River diversions into Sutter and Steamboat Sloughs. These two channels rejoin the Sacramento River near Rio Vista. These natural channels each divert about 20% of the Sacramento River at Freeport flow. The CALSIM model uses simplified equations (i.e., Diversion = a + b x Sacramento River flow) based on the tidal hydraulic flow results from the DSM2 model to estimate these diversion flows. The flow equations shift slightly if DCC is closed because the tidal elevations in the Sacramento River are slightly increased upstream of the DCC when it is closed. The DSM2 results indicate that the diversions into Sutter Slough, which is upstream of Steamboat Slough, are higher than the diversions into Steamboat Slough. The DSM2 flow splits for a range of Sacramento River at Freeport flows are given in Table C.A-25. The fraction of the Sacramento River flow diverted into these channels is generally much less than the fraction of the Sacramento River flow diverted at the upstream weirs (once the water elevation is above the weir crest; 85% for the Fremont Weir). The DSM2 model results indicate that these diversions are not influenced by south Delta exports.

Table C.A-25 gives the Sutter Slough and Steamboat Slough diversions that reflect the Sacramento River flow and the operation of the DCC gates. The fraction of the Sacramento River flow increases by 8% when the DCC is closed for fish protection or flood control. For the EBC1 case, the median diversion flows reflect the median Sacramento River flows. The median diversion flow was 3,500 cfs in October, 4,500 cfs in November, and 6,500 cfs in December. The median diversion flow was 10,500 cfs in January, 15,500 cfs in February, and 12,500 cfs in March. The median diversion flow was 6,500 cfs in April, 5,500 cfs in May, and 4,500 cfs in June. The median diversion flow was 7,000 cfs in July, 5,500 cfs in August, and 4,000 cfs in September. The monthly median diversion flows into Sutter and Steamboat Sloughs were similar for the three EBC2 cases, except the

September and October diversion flow were higher because the Sacramento River flows were higher in about half the years to provide the Fall X2 outflow requirements.

The calculated monthly median diversion flows into Sutter and Steamboat Sloughs for the ESO_ELT and ESO_LLT cases were about 3,500 cfs in October and November; 6,500 cfs in December; 9,000 cfs in January; 11,000 cfs in February; 8,500 cfs in March; 5,000 cfs in April, May and June; 6,500 cfs in July; about 4,000 cfs in August and September. The median diversion flows for the ESO cases were generally lower than the monthly diversions for the EBC cases because the Sacramento River flow would be reduced by the north Delta diversions and by the Fremont Weir notch flow. The reductions in the Sutter and Steamboat Slough diversions were about 40% of the simulated north Delta intake diversions. The annual average diversions into Sutter and Steamboat Slough were about 6,500 taf/yr (42% of the Sacramento River flow at Freeport) for the EBC1 and EBC2 cases, and were reduced to about 5,500 taf/yr (36% of the Sacramento River flow at Freeport) for the ESO_ELT case (because of north Delta diversions) but were about 6,000 taf/yr (40% of the Sacramento River flow at Freeport) for the ESO_LLT because tidal restoration in the Cache Slough complex would increase the diversions into Sutter and Steamboat Slough slightly.

Table C.A-24. CALSIM-Simulated Monthly Distribution of Steamboat and Sutter Sloughs Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	1,280	1,933	1,832	2,515	2,988	2,677	2,629	1,464	2,286	2,293	1,762	1,801	2,093
10%	2,011	2,557	3,392	5,040	5,289	4,555	3,649	3,146	3,161	4,833	3,001	2,159	3,126
20%	2,571	3,130	4,300	5,470	6,200	6,360	4,363	3,772	3,734	5,908	4,342	3,392	4,004
30%	2,861	3,623	5,023	6,602	8,422	8,270	4,703	4,176	4,021	6,739	5,101	3,805	4,412
40%	3,227	3,877	5,891	8,525	11,644	9,779	5,371	4,725	4,166	6,899	5,294	4,115	4,830
50%	3,493	4,429	6,616	10,787	15,567	12,506	6,821	5,551	4,440	6,998	5,490	4,300	5,316
60%	3,715	4,873	7,772	13,846	20,561	15,733	8,829	6,216	4,668	7,200	5,609	4,503	7,175
70%	4,278	5,493	10,552	17,940	24,517	20,324	10,096	8,029	5,250	7,602	5,806	4,662	8,318
80%	4,883	6,448	16,912	26,390	29,413	25,060	18,101	12,488	7,529	8,106	6,080	5,918	9,096
90%	5,937	11,108	24,360	30,586	33,028	29,302	23,845	19,737	11,753	8,512	6,265	6,943	10,819
Max	15,051	25,875	36,912	37,792	37,192	39,438	34,694	28,168	29,062	11,501	7,258	12,034	15,921
Avg	3,929	5,786	10,456	14,739	17,304	15,169	10,351	8,359	6,139	6,964	5,157	4,607	6,552
B. ESO_ELT													
Min	1,952	2,207	2,698	3,473	3,580	3,366	3,019	1,982	3,059	2,993	2,304	2,206	2,389
10%	2,763	2,745	3,759	5,194	5,041	4,808	4,011	3,511	3,452	3,412	3,007	2,836	3,180
20%	3,068	3,243	5,109	5,719	6,203	5,881	4,471	4,013	4,039	3,913	3,115	2,920	3,558
30%	3,255	3,309	5,447	6,473	6,909	6,559	4,802	4,132	4,371	4,649	3,309	2,953	3,908
40%	3,331	3,367	5,704	7,685	8,716	7,311	5,009	4,528	4,665	5,451	3,539	2,972	4,353
50%	3,356	3,445	6,335	8,947	11,081	8,254	5,405	4,813	4,915	6,545	3,787	3,217	4,766
60%	3,383	4,103	7,923	9,951	17,167	10,023	6,487	5,174	5,085	7,021	4,001	4,394	6,150
70%	3,405	4,550	9,274	15,834	20,031	15,238	7,516	6,008	5,184	7,904	4,749	6,546	6,860
80%	3,449	5,254	14,795	22,532	25,193	20,158	11,043	8,137	5,299	8,695	5,143	7,142	7,585
90%	3,470	8,267	20,624	27,456	30,477	25,902	18,028	14,475	6,225	9,318	6,081	7,530	8,973
Max	11,755	23,778	36,180	34,032	35,366	36,597	33,058	23,541	21,524	12,164	7,477	8,261	12,355
Avg	3,341	4,916	9,590	12,729	15,001	12,327	8,333	6,743	5,260	6,407	4,182	4,595	5,616
C. ESO_LLT													
Min	2,067	2,397	2,699	3,965	2,699	3,224	3,450	2,098	3,374	3,450	3,245	2,961	2,808
10%	3,076	3,028	3,996	5,390	5,307	4,966	4,530	3,608	3,986	3,703	3,364	3,140	3,516
20%	3,483	3,507	5,401	6,067	6,811	6,102	4,759	4,330	4,641	4,404	3,469	3,266	3,850
30%	3,696	3,620	5,803	6,992	7,511	7,147	5,000	4,820	5,020	5,167	3,859	3,318	4,222
40%	3,747	3,669	6,156	8,030	8,911	7,669	5,474	5,050	5,144	6,109	4,018	3,985	4,501
50%	3,808	4,002	7,012	9,432	11,189	8,400	5,754	5,478	5,549	6,738	4,118	4,908	5,006
60%	3,837	4,512	8,079	10,298	17,880	10,556	6,564	5,756	5,654	7,371	4,480	5,385	6,514
70%	4,348	4,876	9,085	15,589	20,380	15,275	7,825	6,267	5,905	8,043	4,816	6,704	7,271
80%	5,110	5,830	13,726	23,846	27,085	21,095	11,461	7,659	6,250	9,262	5,365	8,418	7,774
90%	6,240	7,098	20,473	28,253	30,670	26,402	18,152	12,177	6,942	9,883	6,149	8,749	9,313
Max	12,050	22,056	36,834	35,777	35,863	35,361	33,645	20,225	18,920	12,770	8,886	9,304	12,024
Avg	4,304	5,109	9,651	13,311	15,594	12,737	8,683	6,603	5,646	6,853	4,533	5,424	5,919

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	1,291	1,448	2,033	3,721	3,088	2,760	2,479	1,521	2,317	2,225	1,703	1,882.	1,929
10%	2,077	2,291	3,228	4,906	5,087	4,464	3,560	2,937	3,320	4,722	2,647	2,058	3,088
20%	2,580	2,903	4,388	5,564	6,327	5,942	4,305	3,640	3,652	5,683	4,415	3,171	3,910
30%	2,645	3,574	5,128	6,477	7,862	8,480	4,615	4,076	3,983	6,457	4,946	3,691	4,381
40%	2,852	4,432	5,595	8,483	10,819	9,744	5,282	4,632	4,180	6,892	5,221	4,010	4,755
50%	3,349	5,493	6,428	10,070	15,586	11,402	6,875	5,451	4,472	7,081	5,411	4,515	5,285
60%	3,619	6,092	7,796	12,183	20,556	15,530	9,102	6,149	4,786	7,210	5,704	7,334	7,237
70%	3,778	7,367	10,071	18,093	23,255	19,505	10,665	7,820	5,273	7,647	5,838	8,534	8,523
80%	4,249	8,151	15,631	26,434	29,164	25,125	18,178	12,495	7,429	8,209	5,963	12,438	9,539
90%	5,614	9,755	23,660	30,104	32,894	29,3723	23,942	19,593	11,723	8,710	6,353	13,448	11,183
Max	15,323	26,104	36,936	37,847	37,251	39,4812	34,798	28,023	28,860	9,097	7,081	14,414	15,601
Avg	3,655	6,264	10,124	14,489	17,068	14,976	10,351	8,230	6,116	6,889	5,097	6,705	6,609
E. EBC2_ELT													
Min	1,132	1,488	2,087	2,486	2,699	2,808	2,542	1,589	2,357	2,2523	1,641	1,156	1,914
10%	1,965	2,319	3,237	5,015	5,101	4,434	3,717	3,219	3,2212	4,3467	2,566	1,992	3,103
20%	2,618	2,691	4,331	5,633	6,311	5,955	4,120	3,796	3,733	5,553	4,353	2,524	3,828
30%	2,680	3,801	5,227	6,727	7,734	8,355	4,513	4,029	3,978	6,195	4,606	3,259	4,218
40%	2,825	4,404	5,652	8,365	10,857	9,627	5,268	4,300	4,145	6,611	5,103	3,797	4,776
50%	3,492	5,320	6,361	10,347	16,168	11,488	6,562	4,831	4,390	7,133	5,372	4,228	5,230
60%	3,953	6,508	7,818	12,174	22,065	15,589	8,855	5,270	4,543	7,540	5,683	7,611	7,745
70%	4,293	7,056	10,331	18,241	23,646	20,068	10,413	6,647	4,738	8,506	5,836	8,048	8,631
80%	4,671	8,109	16,910	27,566	30,495	26,748	16,980	11,287	5,742	8,756	5,991	12,415	9,639
90%	5,274	9,872	24,886	31,450	34,120	29,976	24,093	17,066	7,466	9,002	6,139	13,441	11,158
Max	15,532	27,642	39,424	38,050	37,923	39,123	36,146	27,590	25,529	9,153	6,831	13,782	14,916
Avg	3,666	6,237	10,512	14,894	17,701	15,263	10,327	7,760	5,474	6,976	4,966	6,562	6,631
F. EBC2_LLT													
Min	1,359	1,298	2,074	2,093	2,433	2,799	2,809	1,380	2,630	2,292	2,135	1,206	2,178
10%	2,068	2,206	3,064	5,051	5,173	4,769	3,976	3,262	3,582	4,023	2,726	2,087	3,070
20%	2,734	2,673	4,428	5,775	6,926	6,542	4,526	3,769	3,988	5,526	4,350	2,258	3,884
30%	3,419	3,404	5,376	7,721	8,367	8,282	4,655	4,384	4,342	6,499	4,843	2,721	4,385
40%	3,857	4,392	5,660	9,146	11,094	9,683	5,017	4,540	4,568	7,288	5,301	3,360	4,775
50%	4,162	5,414	6,560	10,482	16,416	11,708	6,442	4,869	4,697	7,832	5,534	4,243	5,226
60%	4,422	6,176	8,127	12,370	21,452	15,382	8,921	5,202	5,092	8,297	5,713	8,152	7,801
70%	4,764	7,109	9,842	19,452	24,862	20,958	10,458	6,618	5,576	8,615	5,870	8,784	8,730
80%	4,898	7,890	14,839	27,615	31,979	27,174	17,862	9,882	5,951	8,880	6,086	12,469	9,642
90%	5,909	9,535	23,649	32,177	34,507	31,242	23,827	13,425	6,948	9,098	6,291	13,476	11,156
Max	13,801	26,069	39,794	39,528	39,327	38,909	36,366	24,077	22,766	11,589	7,211	14,634	14,106
Avg	4,140	5,971	10,182	15,313	18,082	15,585	10,389	7,097	5,422	7,232	5,147	6,544	6,676

Table C.A-25. DSM2-Simulated Diversions from the Sacramento River into Sutter Slough and Steamboat Slough for a range of Sacramento River Flows with the Delta Cross Channel Open and Closed

Freeport Flow (cfs)	Sutter Slough Flow		Steamboat Slough Flow		Sutter and Steamboat Slough Percentage of Freeport Flow	
	DCC Open	Closed	DCC Open	Closed	DCC Open	Closed
10,000	1,896	2,435	1,107	1,349	30%	38%
20,000	4,384	5,143	2,753	3,627	36%	44%
30,000	6,872	7,851	4,399	5,905	38%	46%
40,000	9,360	10,559	6,045	8,183	39%	47%
50,000	11,848	13,267	7,691	10,461	39%	47%
60,000	14,336	15,975	9,337	12,739	39%	48%
70,000	16,824	18,683	10,983	15,017	40%	48%
80,000	19,312	21,391	12,629	17,295	40%	48%

5C.A.4.6 Delta Cross Channel and Georgiana Slough Flows

The DCC diversions and the Georgiana Slough diversions are similar to the Sutter Slough and Steamboat Slough diversions. They each divert about 20% of the Sacramento River flow when the DCC is open. However, when the DCC is closed the fraction diverted into Georgiana Slough increases, because of the slightly higher tidal elevations. About 40% of the Sacramento River flow is diverted into DCC and Georgiana Slough when the DCC gates are opened, and about 25% is diverted into Georgiana Slough when the DCC gates are closed. The DSM2 model results indicate that these diversions are not influenced by south Delta exports. For the ESO cases, the Sacramento River flow is reduced by the north Delta diversions, so the resulting DCC and Georgiana Slough diversions are also reduced correspondingly. D-1641 objectives and the 2009 NMFS BiOp require the DCC to be closed generally from November through June. The BDCP would include these DCC closure criteria.

Table C.A-26 shows the CALSIM-calculated Sacramento River diversions into DCC and Georgiana Slough for the six CALSIM cases. The EBC1 median flows were about 5,000 cfs for October–March; about 2,500 cfs in April and May; 5,500 cfs in June; about 7,000 cfs in July and August; and 6,000 cfs in September. The monthly median flows were similar for the EBC2 cases because the Sacramento River flows were similar (some assumed shifting with climate change), and the DCC closure was the same for each of the EBC cases. The ESO cases had reduced monthly median diversion flows because the north Delta intakes reduced the Sacramento River flow, just as described for the Sutter and Steamboat Slough diversions. The annual average diversions into the DCC and Georgiana Slough were about 3,750 taf/yr (24% of the Sacramento River flow at Freeport) for the EBC1 and EBC2 cases, and were reduced to about 3,275 taf/yr (21% of the Sacramento River flow at Freeport) for the two ESO cases.

Figure C.A-62 shows the CALSIM-simulated DCC and Georgiana Slough diversions for the six cases for WY 1963–2003. The minimum monthly combined DCC and Georgiana Slough diversions are about 2,500 cfs in low flow months or when the DCC is closed. The maximum monthly diversions are about 10,000 cfs because the DCC is now closed from November–June. Figure C.A-63 shows the CALSIM-simulated DCC and Georgiana Slough diversions for the six cases for WY 1994–2003. Because about 25% of the Sacramento River water is diverted into the central Delta, additional consideration for screening Georgiana Slough may be warranted. If the non-physical barrier (bubble, light and sound) being investigated by DWR and Reclamation for the 2009 NMFS BiOp does not prove effective, a flat wedge-wire fish screen, similar to what is proposed for the north Delta intakes could be designed and constructed. The likely fish benefits and possible fish impacts could be investigated under the BDCP adaptive management process.

Table C.A-26. CALSIM-Simulated Monthly Distribution of Delta Cross Channel and Georgiana Slough Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	2,885	2,961	2,737	1,820	1,946	1,864	1,851	1,540	4,113	4,217	4,140	4,169	2,453
10%	3,749	3,374	3,123	2,494	2,560	2,365	2,123	1,989	4,614	6,316	5,018	4,379	2,813
20%	4,084	3,467	3,312	2,609	2,803	2,846	2,313	2,156	5,025	6,940	5,969	5,234	3,124
30%	4,326	3,693	3,429	2,911	3,396	3,355	2,404	2,263	5,138	7,650	6,507	5,497	3,255
40%	4,703	3,899	3,621	3,424	4,255	3,758	2,582	2,410	5,298	7,777	6,643	5,740	3,413
50%	4,843	4,012	3,794	4,027	5,302	4,485	2,969	2,630	5,455	7,851	6,782	5,929	3,550
60%	4,993	4,208	3,963	4,843	6,634	5,346	3,505	2,808	5,529	7,978	6,867	6,032	3,924
70%	5,170	4,338	4,284	5,935	7,689	6,571	3,843	3,291	5,717	8,196	7,006	6,177	4,304
80%	5,366	4,557	5,661	8,189	8,995	7,834	5,978	4,481	6,018	8,614	7,201	6,484	4,429
90%	5,522	4,902	7,647	9,308	9,960	8,966	7,510	6,414	7,512	8,909	7,332	7,678	4,829
Max	6,244	8,052	10,996	11,230	11,070	11,669	10,404	8,663	8,902	9,311	8,036	9,329	5,494
Avg	4,719	4,141	4,565	5,081	5,765	5,196	3,910	3,379	5,670	7,744	6,547	5,986	3,785
B. ESO_ELT													
Min	1,868	1,907	2,676	1,915	1,944	1,887	1,795	1,519	4,066	4,177	3,891	3,820	2,299
10%	3,484	2,669	3,074	2,373	2,332	2,270	2,058	1,925	4,321	4,669	4,397	4,274	2,480
20%	3,977	3,059	3,157	2,513	2,641	2,556	2,181	2,059	4,701	5,004	4,474	4,334	2,703
30%	4,181	3,286	3,222	2,713	2,829	2,736	2,269	2,091	4,916	5,403	4,614	4,357	2,805
40%	4,272	3,336	3,342	3,036	3,310	2,936	2,324	2,196	5,107	6,074	4,780	4,372	2,946
50%	4,517	3,540	3,574	3,371	3,939	3,187	2,429	2,272	5,250	6,784	4,958	4,547	3,162
60%	4,659	3,655	3,740	3,638	5,558	3,658	2,717	2,368	5,365	7,186	5,112	5,395	3,501
70%	4,677	3,688	3,881	5,203	6,320	5,045	2,991	2,590	5,440	7,723	5,650	6,943	3,655
80%	4,699	3,734	4,927	6,985	7,693	6,354	3,929	3,156	5,504	8,313	5,933	7,372	3,819
90%	4,726	3,975	6,478	8,295	9,098	7,881	5,787	4,842	5,959	8,874	6,608	7,651	4,053
Max	4,772	7,316	10,615	10,044	10,399	10,726	9,785	7,253	8,504	9,397	7,613	8,177	4,828
Avg	4,235	3,526	4,138	4,377	4,982	4,270	3,208	2,785	5,292	6,679	5,242	5,539	3,275
C. ESO_LLT													
Min	2,126	2,456	2,166	1,991	1,658	1,796	1,855	1,500	4,065	4,171	4,328	4,128	2,301
10%	2,805	2,638	2,985	2,366	2,344	2,254	2,139	1,897	4,453	4,573	4,412	4,254	2,538
20%	3,385	2,999	3,087	2,544	2,739	2,553	2,200	2,087	4,869	4,914	4,486	4,343	2,702
30%	3,780	3,143	3,180	2,787	2,924	2,828	2,263	2,216	5,109	5,534	4,760	4,380	2,798
40%	4,119	3,313	3,291	3,060	3,292	2,965	2,388	2,276	5,188	6,129	4,872	4,849	2,896
50%	4,231	3,402	3,477	3,429	3,891	3,158	2,461	2,389	5,445	6,532	4,943	5,499	3,135
60%	4,564	3,633	3,684	3,657	5,651	3,725	2,675	2,462	5,512	6,987	5,198	5,834	3,457
70%	4,683	3,687	3,845	5,048	6,309	4,966	3,006	2,596	5,671	7,457	5,434	6,763	3,689
80%	4,725	3,829	4,627	7,221	8,073	6,497	3,963	2,963	5,890	8,291	5,821	7,969	3,871
90%	4,751	3,989	6,333	8,380	9,016	7,893	5,723	4,151	6,255	8,918	6,373	8,203	4,157
Max	6,899	6,750	10,637	10,359	10,382	10,250	9,798	6,268	7,285	9,411	8,299	8,594	4,943
Avg	4,145	3,463	4,054	4,449	5,050	4,298	3,232	2,685	5,409	6,626	5,235	5,862	3,288

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	2,883	2,340	2,827	2,142	1,973	1,886	1,811	1,555	4,133	4,469	4,099	4,225	2,379
10%	3,807	3,320	3,130	2,458	2,506	2,340	2,099	1,933	4,666	6,238	4,767	4,298	2,713
20%	4,225	3,429	3,336	2,634	2,837	2,734	2,298	2,120	4,950	6,919	6,021	4,516	3,085
30%	4,459	3,623	3,439	2,877	3,247	3,411	2,381	2,237	5,181	7,468	6,397	4,737	3,252
40%	4,722	3,726	3,741	3,412	4,035	3,749	2,559	2,385	5,310	7,776	6,592	4,848	3,399
50%	4,776	3,902	3,848	3,836	5,307	4,191	2,983	2,604	5,371	7,910	6,726	5,194	3,579
60%	4,890	4,051	3,952	4,399	6,633	5,292	3,577	2,790	5,541	8,001	6,934	5,590	4,059
70%	5,133	4,174	4,177	5,976	7,353	6,352	3,994	3,235	5,806	8,311	7,029	5,825	4,218
80%	5,300	4,589	5,319	8,201	8,929	7,851	5,999	4,482	6,080	8,710	7,118	6,261	4,341
90%	5,469	4,817	7,461	9,180	9,924	8,985	7,536	6,376	7,432	9,065	7,394	8,357	4,805
Max	5,653	8,113	11,002	11,245	11,086	11,681	10,432	8,624	8,848	9,339	7,910	9,140	5,625
Avg	4,709	4,022	4,509	5,014	5,702	5,144	3,910	3,345	5,662	7,774	6,504	5,713	3,743
E. EBC2_ELT													
Min	2,363	2,983	2,834	1,802	1,858	1,887	1,817	1,564	4,133	4,460	4,030	3,688	2,222
10%	3,809	3,313	3,087	2,473	2,496	2,319	2,129	1,996	4,683	5,935	4,681	4,249	2,693
20%	4,246	3,347	3,335	2,637	2,817	2,723	2,236	2,150	4,921	6,784	5,939	4,421	3,011
30%	4,522	3,475	3,406	2,927	3,194	3,359	2,340	2,211	5,093	7,236	6,117	4,652	3,159
40%	4,739	3,668	3,609	3,362	4,023	3,697	2,540	2,283	5,230	7,528	6,467	4,756	3,346
50%	4,762	3,762	3,837	3,888	5,432	4,191	2,883	2,424	5,304	7,896	6,656	4,888	3,456
60%	4,817	3,920	3,967	4,373	6,998	5,279	3,492	2,541	5,471	8,183	6,875	5,449	4,026
70%	5,057	4,026	4,192	5,983	7,417	6,468	3,905	2,906	5,541	8,863	6,983	5,694	4,227
80%	5,321	4,353	5,629	8,457	9,235	8,240	5,648	4,137	5,686	9,039	7,092	7,456	4,412
90%	5,431	4,631	7,746	9,488	10,197	9,097	7,536	5,671	6,514	9,212	7,196	8,317	4,815
Max	6,151	8,477	11,604	11,239	11,206	11,524	10,734	8,464	7,945	9,318	7,684	9,340	5,715
Avg	4,701	3,937	4,585	5,095	5,839	5,192	3,882	3,201	5,457	7,786	6,371	5,672	3,725
F. EBC2_LLT													
Min	3,025	2,878	2,801	1,676	1,766	1,862	1,865	1,488	4,182	4,182	4,351	3,702	2,409
10%	3,743	3,206	3,081	2,457	2,489	2,382	2,173	1,985	4,580	5,470	4,763	4,260	2,673
20%	3,963	3,337	3,283	2,648	2,951	2,850	2,318	2,118	5,106	6,600	5,897	4,381	2,984
30%	4,210	3,400	3,373	3,161	3,331	3,309	2,352	2,280	5,292	7,376	6,241	4,465	3,148
40%	4,428	3,558	3,609	3,537	4,051	3,679	2,448	2,322	5,474	7,879	6,561	4,666	3,308
50%	4,725	3,690	3,778	3,890	5,455	4,213	2,824	2,408	5,547	8,221	6,724	4,796	3,540
60%	4,808	3,722	3,928	4,388	6,784	5,182	3,478	2,496	5,744	8,600	6,848	4,985	3,904
70%	5,049	3,826	4,162	6,256	7,684	6,653	3,883	2,870	5,919	8,863	6,958	5,489	4,298
80%	5,362	4,007	5,039	8,410	9,561	8,293	5,836	3,731	6,284	9,049	7,109	6,526	4,387
90%	5,713	4,478	7,363	9,613	10,228	9,367	7,410	4,666	6,588	9,198	7,252	8,703	4,856
Max	6,243	8,002	11,623	11,553	11,500	11,390	10,719	7,476	8,427	9,307	7,894	9,396	5,543
Avg	4,644	3,785	4,457	5,164	5,895	5,236	3,865	2,996	5,693	7,826	6,453	5,511	3,713

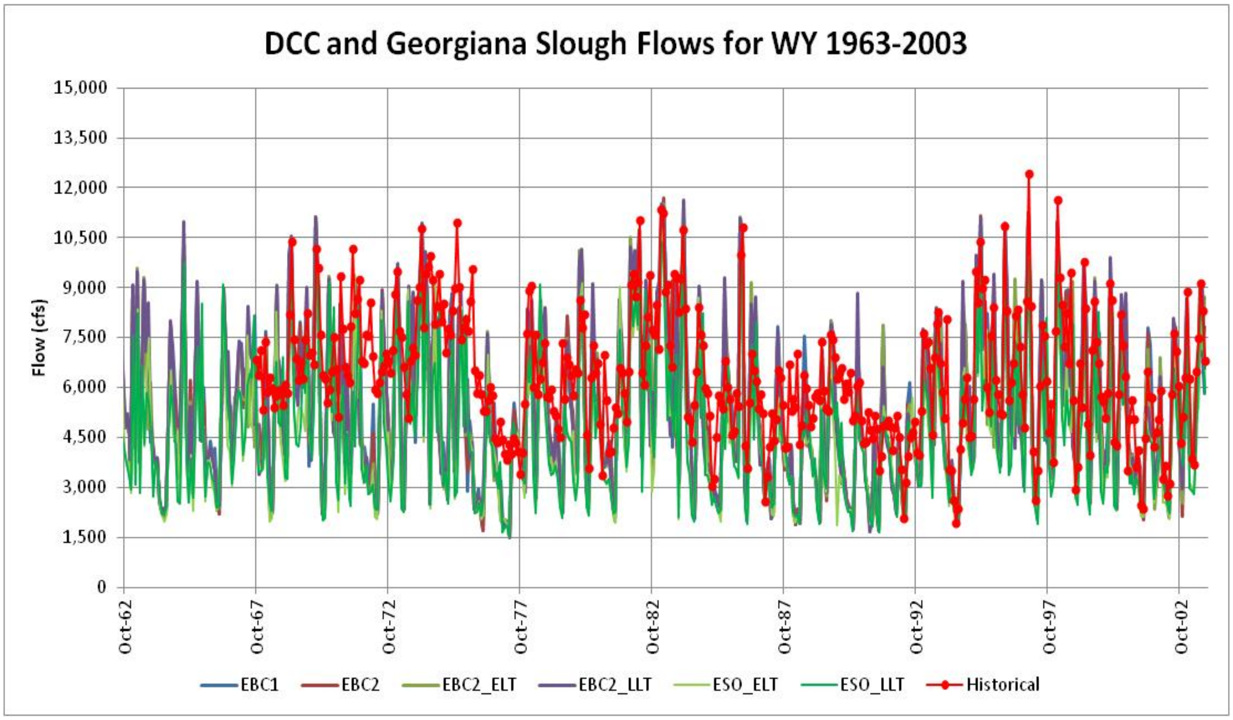


Figure C.A-62. CALSIM-Simulated Monthly Delta Cross Channel and Georgiana Slough Flow for WY 1963–2003 for EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

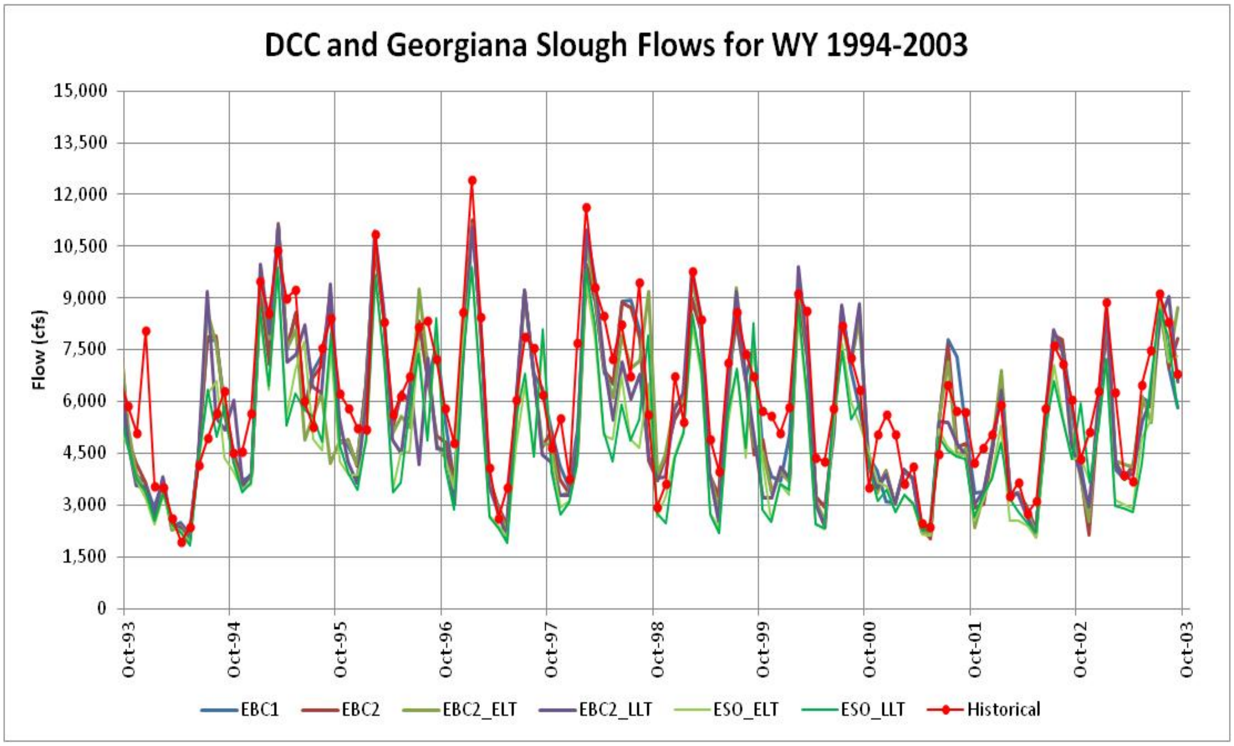


Figure C.A-63. CALSIM-Simulated Monthly Delta Cross Channel and Georgiana Slough Flow for WY 1994–2003 for EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.4.7 Mokelumne River and Cosumnes River Flows to the Delta

Table C.A-27 shows the CALSIM-simulated combined Mokelumne River and Cosumnes River inflow to the Delta for the six CALSIM cases. The Cosumnes River has only a few small reservoirs and the Delta inflows are very similar to unimpaired runoff in the winter months. Agricultural diversions generally deplete the Cosumnes River flows in the summer and fall. The Mokelumne River was developed by East Bay Municipal Utility District (EBMUD) for municipal water supply, and Woodbridge Irrigation District has a major diversion from the river at Woodbridge Dam. The CALSIM monthly inflows from the Mokelumne River near Thornton, just below the Cosumnes River, are very low during the summer months. These flows were nearly identical for all CALSIM cases; some shifting of the runoff to Pardee Reservoir was assumed for climate change conditions (ELT and LLT). The median monthly flows were greater than 500 cfs only in January–May. The annual average inflow for the EBC1 and EBC2 (existing hydrology) cases was 666 taf/yr. The annual average inflow for the ELT cases was 670 taf/yr, and the annual average inflow for the LLT cases was 648 taf/yr.

Figure C.A-64 shows the CALSIM-simulated monthly Mokelumne and Cosumnes River inflow to the Delta for WY 1963–2003 for the EBC1 and EBC2 cases and ESO_ELT and ESO_LLT cases. The historical inflows are shown for comparison. The CALSIM-simulated flows in the summer months were simulated to be 0 cfs in about half of the years. Figure C.A-65 shows the CALSIM-simulated monthly Mokelumne and Cosumnes River inflow to the Delta for WY 1994–2003 for the six cases. There were no effects of the BDCP Delta operations on these river flows.

The Mokelumne River and Cosumnes River inflow enters the Delta upstream of Snodgrass Slough and upstream of the DCC and Georgiana Slough. Mokelumne River juvenile fish migration pathway is down the North and South Forks of the Mokelumne River to the mouth at the San Joaquin River, although some fish are likely diverted into Little Potato Slough and Little Connections Slough, which join the San Joaquin River further upstream. Adult migration may be confused by the mixture of Sacramento River water in the Mokelumne River; the fraction of Mokelumne water at the mouth of the Mokelumne River is generally quite small in the fall months. Nevertheless, the BDCP Delta operations will have very little effect on the Mokelumne River flows. Tidal restoration is anticipated along the Mokelumne River and Snodgrass Slough (upstream of the DCC).

Table C.A-27. CALSIM-Simulated Monthly Distribution of Mokelumne and Cosumnes River Flow (cfs) to Delta

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	35	66	61	56	97	79	92	21	0	0	0	1	36
10%	46	129	167	254	337	483	269	158	8	0	0	6	131
20%	104	196	232	329	494	642	542	309	37	5	1	6	214
30%	130	219	290	388	677	794	647	405	121	5	3	6	265
40%	138	264	317	509	851	904	824	691	304	11	8	11	320
50%	176	288	358	641	1,149	1,048	1,160	1,095	552	157	149	143	492
60%	189	307	425	858	1,559	1,470	1,413	1,376	787	342	322	329	696
70%	193	330	462	1,368	2,225	1,942	1,747	1,669	997	483	454	445	813
80%	206	428	798	2,222	2,827	2,180	1,993	1,969	1,377	630	584	585	1,218
90%	209	839	2,092	3,723	3,968	3,235	3,300	3,878	2,094	789	758	761	1,501
Max	462	5,939	7,077	12,395	11,488	8,990	7,684	6,576	4,239	1,906	1,673	1,653	2,718
Avg	158	474	887	1,460	1,809	1,662	1,503	1,463	779	315	289	291	666
B. ESO_ELT													
Min	32	74	77	100	164	145	79	21	0	0	0	0	61
10%	90	153	177	244	351	456	256	147	8	0	0	5	142
20%	115	197	232	312	474	614	518	275	36	5	1	5	200
30%	127	226	284	395	661	787	584	408	114	5	3	5	254
40%	141	254	327	486	832	874	774	627	266	11	8	10	305
50%	160	272	373	626	1,236	996	1,086	976	446	96	104	97	468
60%	172	298	443	802	1,746	1,414	1,332	1,241	674	217	205	247	720
70%	179	319	512	1,408	2,376	1,745	1,601	1,575	939	307	302	414	866
80%	184	465	879	2,368	3,084	2,217	1,845	2,031	1,165	427	409	485	1,177
90%	214	867	2,747	3,977	4,685	3,467	3,441	3,687	1,798	612	484	661	1,581
Max	537	6,399	9,148	14,197	13,116	9,189	7,729	6,428	3,856	1,495	1,369	996	2,707
Avg	154	497	1,054	1,565	2,014	1,675	1,442	1,392	697	239	200	231	670
C. ESO_LLT													
Min	31	70	74	98	158	142	75	20	0	0	0	0	58
10%	86	137	166	263	341	442	243	139	8	0	0	4	139
20%	108	181	223	302	486	613	503	247	35	5	1	5	201
30%	118	204	261	384	655	759	587	392	111	5	3	5	250
40%	138	228	308	499	867	858	712	587	238	11	8	10	292
50%	151	243	358	629	1,193	995	1,005	864	371	71	77	93	457
60%	163	257	436	849	1,705	1,281	1,245	1,149	551	152	170	239	642
70%	170	295	518	1,387	2,341	1,852	1,493	1,375	739	236	265	339	841
80%	175	389	830	2,670	3,085	2,304	1,798	1,964	1,037	350	290	443	1,132
90%	204	742	2,316	4,363	4,886	3,518	3,300	3,415	1,704	449	406	515	1,513
Max	575	5,365	8,492	14,221	12,824	10,012	7,645	6,407	3,469	1,315	901	954	2,749
Avg	150	429	999	1,660	2,033	1,700	1,384	1,289	616	183	156	213	648

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	35	66	77	104	187	167	92	21	0	0	0	1	68
10%	91	166	185	270	371	491	269	163	8	0	0	6	146
20%	128	213	232	329	494	640	572	311	37	5	1	6	214
30%	133	232	290	388	697	803	647	436	121	5	3	6	265
40%	149	265	317	509	851	909	805	634	304	11	8	11	316
50%	174	288	370	639	1,163	1,038	1,160	1,055	511	143	133	121	488
60%	188	302	432	790	1,494	1,454	1,413	1,296	765	305	284	291	679
70%	193	332	465	1,321	2,210	1,926	1,747	1,725	1,048	451	426	429	879
80%	203	437	757	2,190	2,924	2,155	1,968	1,940	1,339	589	543	544	1,201
90%	212	840	2,075	3,706	4,278	3,511	3,277	3,847	2,060	751	720	723	1,484
Max	490	5,928	7,067	12,394	11,260	8,973	7,657	6,531	4,203	1,866	1,634	1,613	2,700
Avg	163	477	902	1,469	1,832	1,685	1,504	1,446	766	300	274	276	666
E. EBC2_ELT													
Min	32	74	77	100	164	145	79	21	0	0	0	0	61
10%	90	153	177	244	351	456	256	147	8	0	0	5	142
20%	115	197	232	312	474	614	518	275	36	5	1	5	200
30%	127	226	284	395	661	787	584	408	114	5	3	5	254
40%	141	254	327	486	832	874	774	627	266	11	8	10	305
50%	160	272	373	626	1,236	996	1,086	976	446	96	104	97	468
60%	172	298	443	802	1,746	1,414	1,332	1,241	674	217	205	247	720
70%	179	319	512	1,408	2,376	1,745	1,601	1,575	939	307	302	414	866
80%	184	465	879	2,368	3,084	2,217	1,845	2,031	1,165	427	409	485	1,177
90%	214	867	2,747	3,977	4,685	3,467	3,441	3,687	1,798	612	484	661	1,581
Max	537	6,399	9,148	14,197	13,116	9,189	7,729	6,428	3,856	1,495	1,369	996	2,707
Avg	154	497	1,054	1,565	2,014	1,675	1,442	1,392	697	239	200	231	670
F. EBC2_LLT													
Min	31	70	74	98	158	142	75	20	0	0	0	0	58
10%	86	137	166	263	341	442	243	139	8	0	0	4	139
20%	108	181	223	302	486	613	503	247	35	5	1	5	201
30%	118	204	261	384	655	759	587	392	111	5	3	5	250
40%	138	228	308	499	867	858	712	587	238	11	8	10	292
50%	151	243	358	629	1,193	995	1,005	864	371	71	77	93	457
60%	163	257	436	849	1,705	1,281	1,245	1,149	551	152	170	239	642
70%	170	295	518	1,387	2,341	1,852	1,493	1,375	739	236	265	339	841
80%	175	389	830	2,670	3,085	2,304	1,798	1,964	1,037	350	290	443	1,132
90%	204	742	2,316	4,363	4,886	3,518	3,300	3,415	1,704	449	406	515	1,513
Max	575	5,365	8,492	14,221	12,824	10,012	7,645	6,407	3,469	1,315	901	954	2,749
Avg	150	429	999	1,660	2,033	1,700	1,384	1,289	616	183	156	213	648

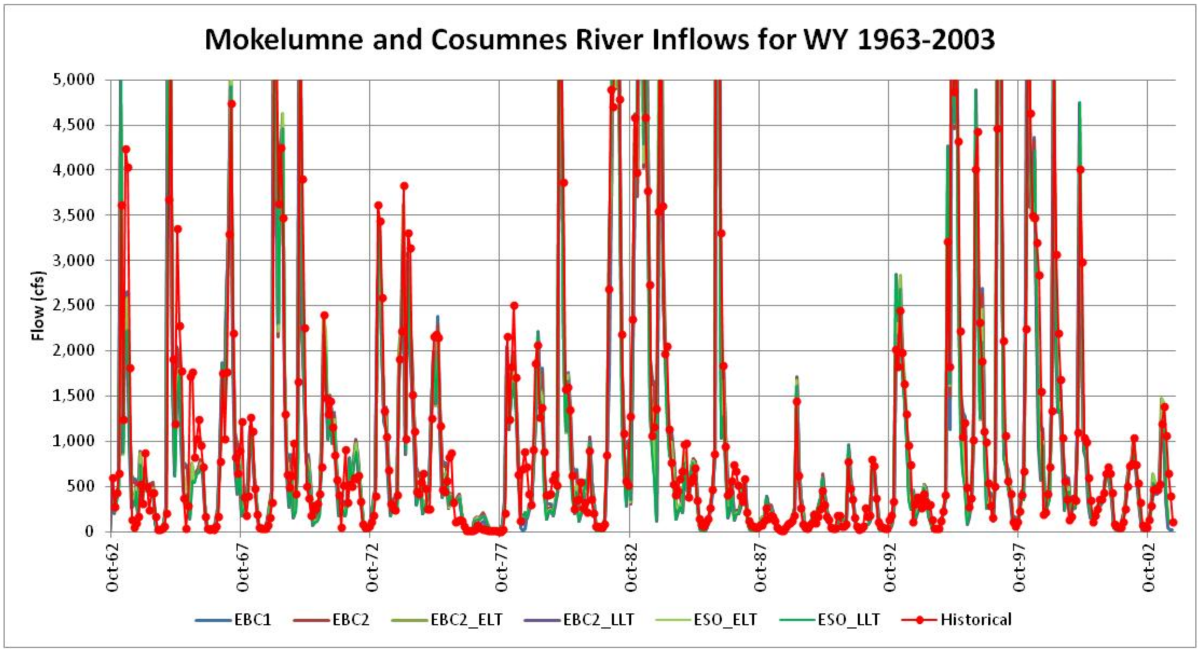


Figure C.A-64. CALSIM-Simulated Monthly Mokelumne and Cosumnes Rivers Inflow to the Delta for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

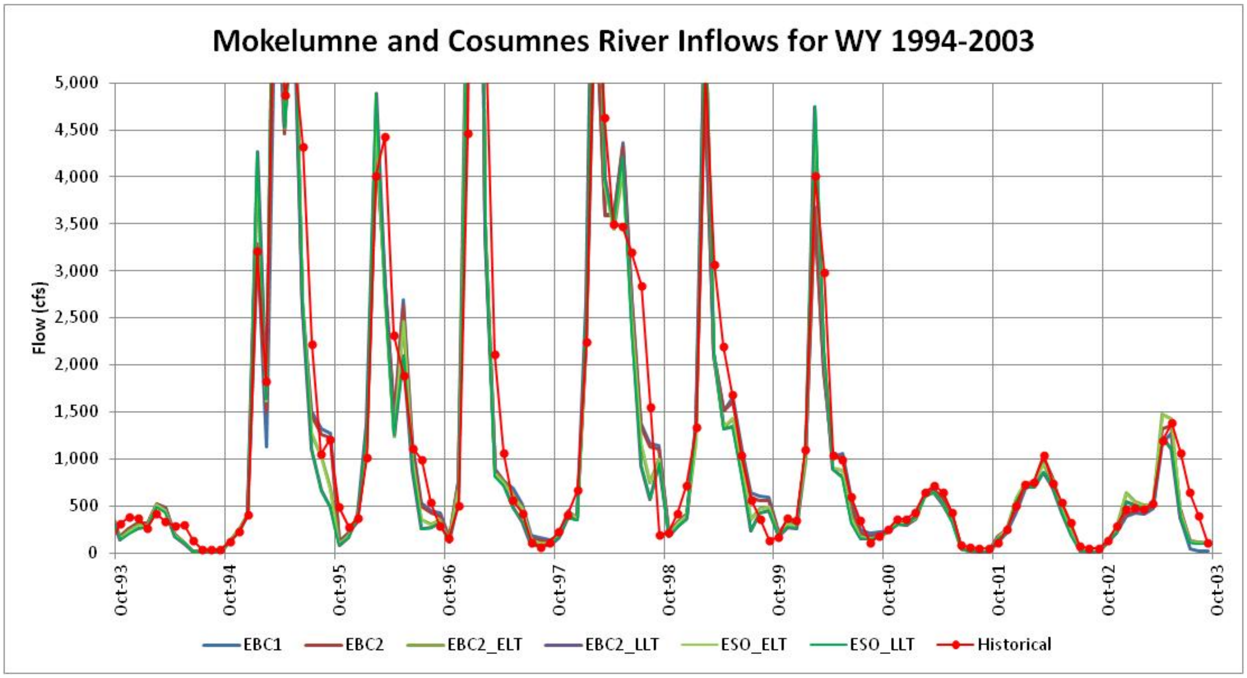


Figure C.A-65. CALSIM-Simulated Monthly Mokelumne and Cosumnes Rivers Inflow to the Delta for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.4.8 Yolo Bypass Flows to the Delta

Table C.A-28 shows the CALSIM-simulated Yolo Bypass Delta inflow for the six CALSIM cases. The Yolo Bypass flow is nearly identical to the Fremont Weir spills with the addition of the Cache Creek and Putah Creek flows entering Yolo Bypass in months with relatively high runoff. The Yolo Bypass inflow carries all Sacramento inflow greater than the 80,000-cfs (monthly average) channel capacity. Although the ESO_ELT and ESO_LLT cases allow some additional flows into the Yolo Bypass at the Fremont Weir (notch), the monthly sequences of Yolo Bypass flows are very similar. A few more months have flows of 3,000 cfs to 6,000 cfs (maximum notch flow). Months with increased Fremont Weir spills of more than 6,000 cfs would have been the result of slightly different Verona flows.

Figure C.A-66 shows the CALSIM-simulated monthly Yolo Bypass flow to the Delta for WY 1922–2003 for the EBC1 and EBC2 cases and ESO_ELT and ESO_LLT cases. The high flow months with spills at the Fremont Weir into the Yolo Bypass are nearly identical for the EBC cases and the ESO_ELT and ESO_LLT cases. Figure C.A-67 shows the CALSIM-simulated monthly Yolo Bypass inflow to the Delta for WY 1994–2003. These Yolo Bypass inflows have almost the same monthly sequence as the Fremont Weir spill and notch flows shown previously. These Yolo Bypass flows are thought to have good benefits for splittail spawning and rearing, as well as improved rearing (growth and survival) for juvenile Chinook. The BDCP effects analysis includes several tools to estimate these fish benefits.

Table C.A-28. CALSIM-Simulated Monthly Distribution of Yolo Bypass Flow (cfs) to Delta

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
A. EBC1													
Min	0	0	0	0	0	0	39	38	52	41	41	22	28
10%	8	0	0	4	1	6	53	50	61	47	53	50	54
20%	17	0	0	50	58	47	73	56	63	47	54	54	128
30%	34	1	5	115	234	115	86	60	64	47	54	56	179
40%	40	5	36	315	700	359	110	62	65	47	54	57	273
50%	47	8	155	552	2,361	940	133	65	66	47	54	57	597
60%	50	9	313	1,888	5,306	1,737	196	67	66	47	54	57	1,210
70%	57	40	955	4,016	7,657	3,425	532	70	66	47	54	57	2,518
80%	59	105	2,852	12,944	17,808	7,921	3,162	75	66	47	54	82	4,497
90%	74	425	13,029	34,322	44,019	23,884	6,581	314	66	47	181	168	7,854
Max	7,102	12,427	55,567	132,155	126,877	118,412	40,899	8,889	3269	47	654	414	13,751
Avg	144	432	3,669	9,989	12,908	8,508	2,428	267	120	47	102	81	2,301
B. ESO_ELT													
Min	100	100	100	100	100	100	150	140	153	41	42	120	101
10%	111	100	100	107	122	149	170	153	162	48	54	152	141
20%	121	100	103	165	239	255	187	159	164	48	55	156	296
30%	138	101	145	467	704	719	211	163	166	48	55	158	451
40%	144	107	240	955	2,721	1,336	229	165	167	48	55	159	597
50%	151	109	516	2,256	5,040	2,882	263	168	167	48	55	159	1,138
60%	154	127	783	4,907	9,328	5,113	496	170	168	48	55	159	1,913
70%	161	150	2,505	8,150	12,003	8,384	2,053	173	168	48	55	159	3,209
80%	163	245	6,358	15,593	21,504	11,041	7,375	178	168	48	55	188	5,465
90%	180	575	11,512	37,213	51,911	23,849	10,346	337	168	48	290	267	9,234
Max	2,502	15,401	82,051	149,183	146,897	132,055	44,759	5,620	1,108	48	628	654	16,248
Avg	190	547	5,147	12,559	16,300	10,686	3,690	310	183	48	104	189	2,972
C. ESO_LLT													
Min	100	100	100	100	100	100	149	126	153	41	42	120	108
10%	105	100	100	106	128	149	170	153	162	48	54	152	142
20%	117	100	106	203	330	228	187	158	164	48	55	156	303
30%	129	102	156	550	703	651	211	162	166	48	55	158	445
40%	141	107	251	1,018	2,360	1,328	234	164	167	48	55	159	581
50%	145	109	483	2,005	4,898	2,818	276	167	167	48	55	159	1,017
60%	154	127	757	4,696	9,109	4,728	620	169	168	48	55	159	1,883
70%	160	150	1,846	8,098	12,242	8,230	2,244	172	168	48	55	159	3,485
80%	163	245	5,841	16,575	26,256	12,367	6,880	177	168	48	55	210	5,319
90%	175	575	11,262	34,729	56,253	27,482	10,302	182	168	48	174	303	9,651
Max	2,540	9,432	82,980	159,716	151,885	138,884	43,789	2,005	954	48	628	906	17,248
Avg	189	412	4,431	12,799	17,034	11,289	3,633	237	181	48	101	201	3,005

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Year
D. EBC2													
Min	0	0	0	0	0	0	42	40	53	41	42	23	27
10%	6	0	0	0	0	7	56	53	62	48	54	52	65
20%	17	0	0	30	58	45	78	59	64	48	55	55	121
30%	29	1	15	110	228	115	88	63	66	48	55	58	173
40%	41	6	60	326	609	279	111	65	67	48	55	59	240
50%	46	9	148	503	1,941	917	135	68	67	48	55	59	605
60%	53	23	342	1,921	4,711	1,571	190	70	68	48	55	59	1,148
70%	59	50	973	4,182	7,177	3,283	635	73	68	48	55	59	2,368
80%	62	145	2,777	10,765	17,696	8,113	3,203	78	68	48	55	64	4,300
90%	63	475	9,981	32,898	44,314	21,993	6,614	276	68	48	165	164	7,645
Max	3,433	12,702	55,535	132,313	124,413	118,511	41,037	8,809	3,047	48	628	525	13,769
Avg	98	414	3,336	9,709	12,490	8,315	2,461	265	118	48	100	84	2,226
E. EBC2_ELT													
Min	0	0	0	0	0	0	42	40	53	41	42	23	27
10%	9	0	0	0	0	7	56	53	62	48	54	52	65
20%	17	0	0	23	58	45	78	59	64	48	55	56	124
30%	29	1	20	62	228	90	88	63	66	48	55	58	170
40%	42	5	74	243	609	249	111	65	67	48	55	59	248
50%	49	9	165	496	2,224	793	135	68	67	48	55	59	668
60%	54	17	365	1,912	5,068	2,055	229	70	68	48	55	59	1,243
70%	60	50	973	4,779	8,395	3,475	635	73	68	48	55	59	2,589
80%	63	145	2,924	12,835	20,635	8,407	3,203	78	68	48	55	85	4,956
90%	75	475	11,359	36,092	50,595	23,666	6,801	238	68	48	174	165	8,559
Max	3,635	15,313	82,043	149,398	142,950	132,056	44,748	5,544	1,017	48	628	554	15,936
Avg	104	457	4,279	11,128	14,511	9,174	2,587	210	83	48	101	89	2,542
F. EBC2_LLT													
Min	0	0	0	0	0	0	42	26	53	41	42	21	27
10%	6	0	0	0	4	7	56	53	62	48	54	52	66
20%	17	0	0	42	65	45	78	58	64	48	55	56	122
30%	32	2	20	79	228	90	95	62	66	48	55	58	165
40%	43	6	60	243	609	229	114	64	67	48	55	59	246
50%	49	9	137	482	2,195	802	139	67	67	48	55	59	570
60%	54	25	328	2,005	4,990	2,026	229	69	68	48	55	59	1,254
70%	60	50	797	4,805	8,687	4,466	635	72	68	48	55	59	2,859
80%	63	145	2,777	14,445	24,550	9,902	3,203	77	68	48	55	134	4,647
90%	74	475	8,414	36,552	52,985	26,415	7,160	82	68	48	174	266	8,930
Max	2,387	10,327	83,492	159,837	148,910	138,877	43,771	1,936	854	135	610	554	16,800
Avg	87	326	3,526	11,835	15,146	9,795	2,596	138	82	49	100	102	2,601

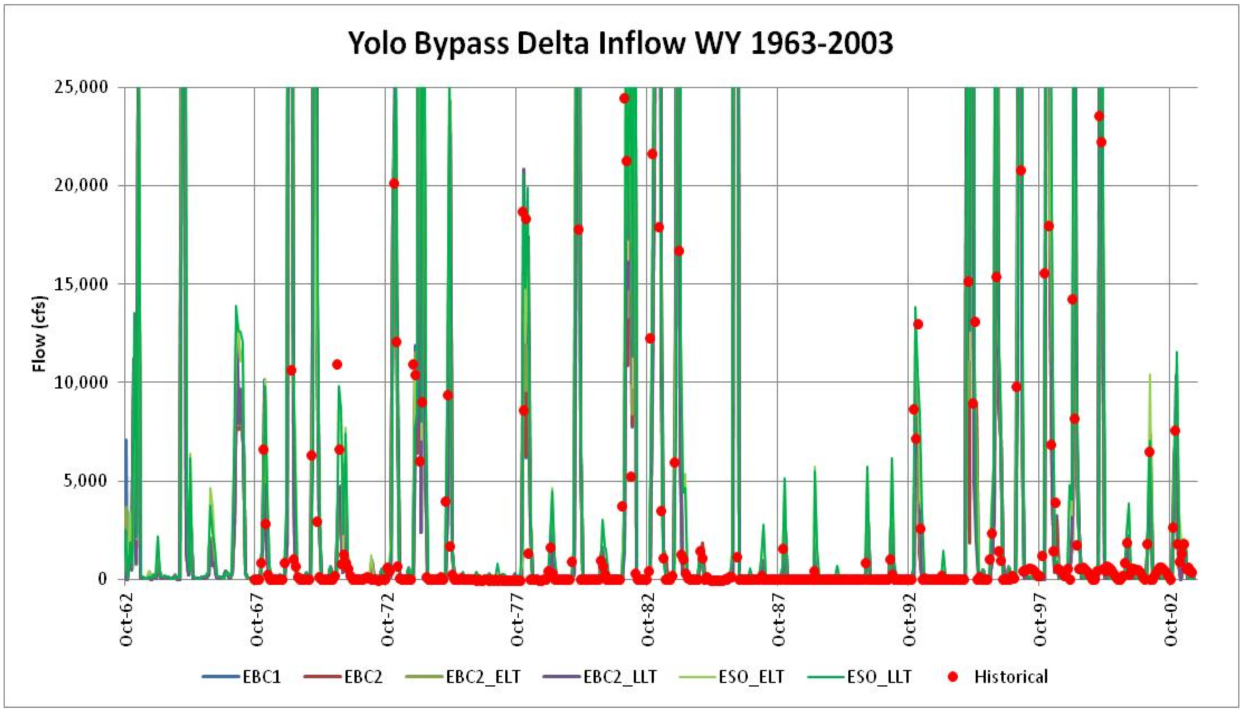


Figure C.A-66. CALSIM-Simulated Monthly Yolo Bypass Inflow to the Delta for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

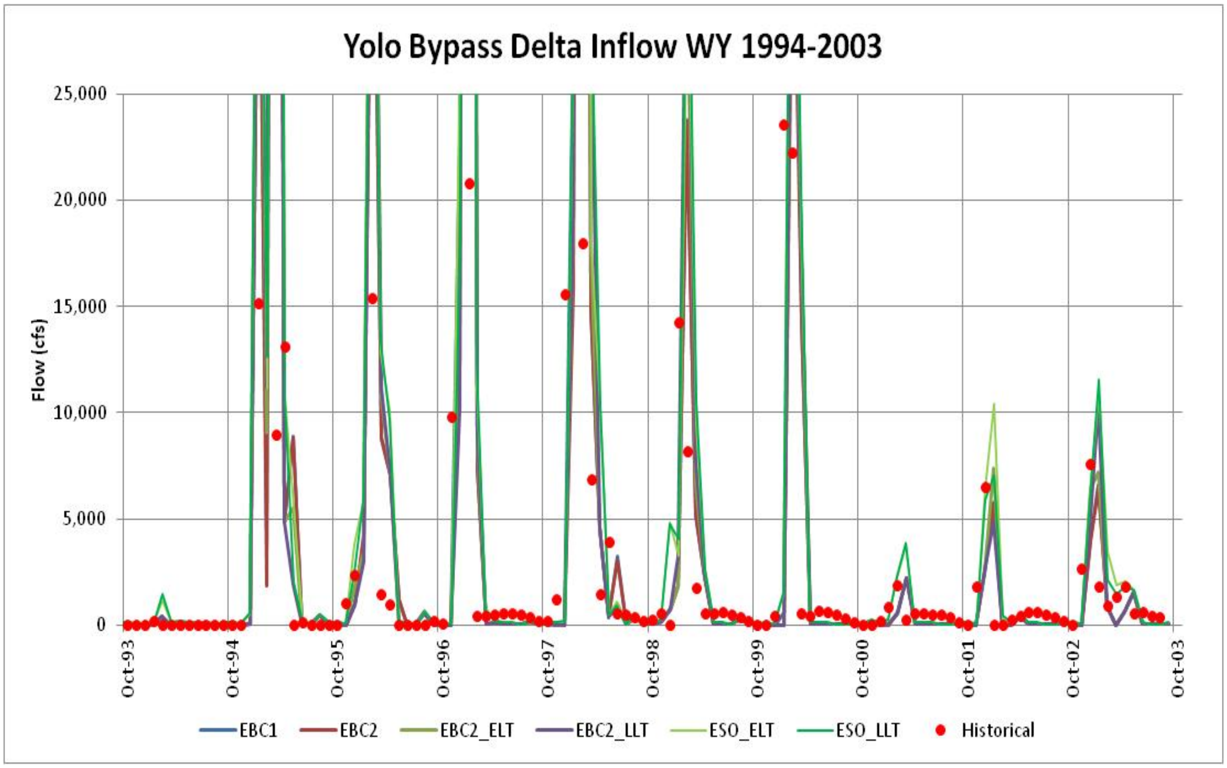


Figure C.A-67. CALSIM-Simulated Monthly Yolo Bypass Inflow to the Delta for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.4.9 Sacramento River at Rio Vista Flows

The Sacramento River flow at Rio Vista includes the Yolo Bypass inflow and most of the Sacramento River flow at Freeport, except the diversions into DCC and Georgiana Slough (to the central Delta) and, for the ESO cases, the simulated diversions at the proposed north Delta intakes. The diversions into Sutter and Steamboat Sloughs rejoin the Sacramento River at Cache Slough, just upstream of Rio Vista. There are D-1641 minimum flows required at Rio Vista for attraction flows for upstream migration of Chinook salmon in the months of September–December. The Rio Vista minimum flows of 3,000 cfs to 4,500 cfs are the same as the minimum Delta outflows specified in D-1641 for these months (depends on water-year type). The Rio Vista flows are therefore very similar to the Delta outflow. The Delta outflow is the sum of the Rio Vista flow and the San Joaquin River net outflow (Calculated in CALSIM and DAYFLOW as QWEST). Because QWEST is sometimes positive and sometimes negative, the Delta outflow can be either greater than or less than the Rio Vista flow. Sacramento River flow at Rio Vista flows will be reduced by the net diversion at Threemile Slough to the San Joaquin River (usually positive towards the San Joaquin River).

Table C.A-29 shows the CALSIM-simulated monthly distribution of Sacramento River flows at Rio Vista for the six CALSIM cases. The minimum flows in September–December were generally satisfied. The EBC1 monthly median flows were about 5,500 cfs in October; 7,500 cfs in November; 12,500 in December; 22,000 in January; 29,000 cfs in February; 23,000 cfs in March; 13,000 cfs in April; 10,000 cfs in May; 6,500 cfs in June; 10,500 cfs in July; 8,500 in August; and 6,500 cfs in September. The median flows at Rio Vista for the three EBC2 cases were similar because the Yolo Bypass and Sacramento River inflows were generally the same. The median monthly Rio Vista flows were reduced in the months when the north Delta intake diversions were simulated for the ESO cases. The reduced Rio Vista flows were generally about 80% of the north Delta intake diversions, and about 20% of the reduced flow is “missing” from the DCC and Georgiana Slough diversions. The annual average Sacramento River at Rio Vista flows were about 14,000 taf/yr for the EBC1 and EBC2 cases, and were reduced to about 12,000 taf/yr for the two ESO cases.

Table C.A-29. CALSIM-Simulated Monthly Distribution of Sacramento River at Rio Vista Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	1,886	3,500	3,502	5,564	6,267	5,655	5,503	3,348	3,078	2,754	2,155	2,915	3,708
10%	3,001	4,434	6,359	10,027	10,247	8,838	7,354	6,231	4,566	7,121	4,307	3,160	5,767
20%	4,025	5,420	7,555	11,049	12,157	12,278	8,593	7,273	5,512	8,938	6,731	5,346	7,179
30%	4,588	6,275	9,181	12,986	16,527	15,820	9,220	7,978	5,929	10,301	7,939	5,956	8,008
40%	5,036	6,814	11,019	16,477	21,293	18,694	10,235	8,800	6,213	10,648	8,257	6,452	8,869
50%	5,561	7,639	12,714	22,123	29,290	23,309	12,956	10,308	6,675	10,792	8,620	6,788	9,880
60%	5,909	8,471	15,982	27,579	43,453	29,789	17,274	11,759	7,116	11,101	9,006	7,028	14,561
70%	7,191	9,775	21,708	42,309	53,726	39,795	19,709	14,689	8,022	11,803	9,233	7,357	17,864
80%	8,600	11,986	34,505	57,830	65,720	50,899	34,809	22,873	11,770	12,820	9,563	9,431	20,767
90%	10,658	21,055	58,431	89,778	103,696	75,988	50,541	35,324	20,345	13,318	10,087	11,399	25,223
Max	34,464	58,499	121,603	200,709	188,081	189,583	102,504	58,232	54,239	20,228	11,851	21,771	42,211
Avg	6,667	10,793	22,749	37,268	44,541	36,084	21,333	15,456	9,847	10,739	8,052	7,348	13,853
B. ESO_ELT													
Min	1,660	2,638	3,850	6,285	6,554	5,937	5,246	3,251	3,035	3,000	2,335	2,184	3,406
10%	3,000	3,536	5,685	9,280	9,120	8,386	6,935	5,826	3,543	3,336	3,000	3,000	4,888
20%	4,000	4,500	8,086	10,240	11,235	10,445	7,712	6,703	4,747	3,965	3,000	3,000	5,592
30%	4,000	4,500	8,692	12,012	13,722	12,425	8,322	6,927	5,242	5,291	3,389	3,000	6,487
40%	4,000	4,500	9,626	14,859	17,535	14,093	8,715	7,576	5,704	6,619	3,668	3,000	7,405
50%	4,000	5,230	11,396	18,534	24,815	17,036	9,436	8,169	6,140	8,564	4,218	3,506	8,321
60%	4,000	6,207	14,468	23,164	38,605	23,001	11,924	8,745	6,453	9,367	4,646	5,485	12,065
70%	4,000	7,164	18,459	37,378	46,751	33,859	14,409	10,343	6,599	10,791	5,777	9,238	15,196
80%	4,000	8,882	33,407	53,049	64,315	46,613	26,083	13,842	6,872	12,249	6,526	10,265	17,980
90%	4,083	14,588	51,264	85,622	106,329	65,871	43,288	25,146	8,323	13,337	8,187	11,018	23,684
Max	23,049	56,684	145,579	209,231	204,829	197,031	102,303	44,088	37,808	20,248	10,604	12,193	37,385
Avg	4,162	8,172	21,538	35,310	42,869	32,241	18,012	11,613	6,839	8,388	4,918	5,921	11,983
C. ESO_LLT													
Min	1,504	2,699	3,500	6,778	4,472	5,477	5,642	3,177	3,112	3,000	3,000	3,000	3,883
10%	3,000	3,570	5,705	9,405	9,153	8,280	7,524	5,557	4,166	3,158	3,000	3,000	5,005
20%	4,000	4,500	8,209	10,657	11,985	10,532	7,848	6,867	5,080	4,240	3,023	3,000	5,758
30%	4,000	4,500	8,817	12,136	14,508	13,250	8,348	7,767	5,696	5,530	3,622	3,034	6,609
40%	4,000	4,714	10,005	15,337	17,536	13,919	9,186	8,168	5,996	7,062	3,957	4,227	7,449
50%	4,000	5,430	12,147	18,522	24,535	17,023	9,594	8,879	6,564	8,181	4,261	5,731	8,510
60%	4,465	6,395	14,034	21,799	39,368	23,516	11,876	9,468	6,837	9,242	4,792	6,547	12,320
70%	5,680	7,333	17,565	35,215	47,962	33,667	14,532	10,354	7,174	10,417	5,353	8,820	15,493
80%	6,940	9,611	28,683	54,345	73,347	49,221	24,954	12,474	7,836	12,341	6,187	11,985	17,610
90%	9,814	12,007	52,522	83,567	108,171	72,493	44,312	20,489	9,007	13,563	7,515	12,395	23,919
Max	23,084	47,021	146,650	219,427	212,170	200,754	101,422	35,919	32,490	20,768	12,260	13,371	37,120
Avg	5,526	7,925	20,431	36,022	44,049	33,031	18,118	10,893	6,864	8,488	4,894	6,715	12,158

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	2,007	2,570	3,862	7,649	6,513	5,829	5,250	3,465	3,147	2,651	2,066	3,000	3,423
10%	3,024	3,955	5,903	9,924	10,205	8,748	7,125	5,881	4,830	6,804	3,737	3,000	5,695
20%	4,000	4,962	8,024	10,926	12,585	11,664	8,411	6,941	5,320	8,562	6,860	4,858	7,011
30%	4,000	6,617	9,347	12,810	15,036	16,139	9,174	7,731	5,929	9,835	7,712	5,703	7,975
40%	4,615	7,826	10,902	16,911	20,838	18,176	10,062	8,667	6,251	10,643	8,115	6,337	8,825
50%	5,268	9,910	12,320	20,033	28,657	22,204	13,022	10,152	6,698	10,880	8,603	7,169	9,882
60%	5,714	10,745	14,961	26,991	42,214	28,753	17,391	11,555	7,382	11,179	8,936	11,900	14,849
70%	6,258	13,348	19,577	40,749	50,509	38,838	20,760	14,379	7,956	12,113	9,185	13,975	18,123
80%	7,050	15,113	32,603	57,266	65,279	51,206	34,885	22,814	11,598	13,133	9,426	22,294	21,526
90%	10,061	18,817	57,707	88,025	103,500	73,374	50,509	35,337	20,272	13,721	10,088	24,150	25,733
Max	31,273	59,175	121,584	200,995	185,324	189,718	102,798	58,077	53,639	14,329	11,306	25,869	41,554
Avg	6,097	11,748	21,806	36,610	43,759	35,567	21,360	15,217	9,795	10,575	7,930	11,386	13,907
E. EBC2_ELT													
Min	1,738	2,673	3,831	5,404	5,764	5,973	5,291	3,522	3,147	2,630	1,985	2,071	3,415
10%	3,000	3,941	5,817	9,977	9,890	8,652	7,268	6,213	4,594	6,059	3,573	3,000	5,658
20%	4,000	4,606	8,223	10,967	12,441	11,511	8,002	7,175	5,370	8,186	6,476	3,769	6,821
30%	4,000	6,822	9,374	12,949	14,776	16,104	8,632	7,669	5,859	9,332	7,052	5,052	7,647
40%	4,218	7,717	10,433	16,333	21,187	17,744	9,949	8,035	6,126	10,076	7,857	5,956	8,706
50%	5,386	9,660	12,305	19,984	30,490	22,134	12,343	9,143	6,457	10,941	8,291	6,732	9,923
60%	6,245	11,948	14,957	26,288	44,581	28,526	16,762	10,099	6,732	11,687	8,877	12,371	15,146
70%	7,051	12,900	20,684	44,316	53,380	38,914	20,608	13,021	7,051	13,009	9,156	13,088	18,706
80%	7,872	15,099	33,978	57,723	73,141	54,069	33,370	21,362	8,813	13,588	9,459	22,067	21,958
90%	8,969	18,836	61,595	92,972	112,189	75,688	50,577	32,872	11,854	13,991	9,698	23,957	27,217
Max	31,651	64,164	152,014	217,257	208,215	202,239	108,480	51,524	45,539	14,302	10,688	24,672	42,242
Avg	6,058	11,671	23,283	38,556	46,674	36,744	21,306	14,232	8,525	10,604	7,610	11,025	14,167
F. EBC2_LLT													
Min	2,054	2,203	3,747	4,584	5,077	5,810	5,606	3,040	3,458	2,630	2,724	2,012	3,763
10%	3,000	3,694	5,397	9,798	9,855	9,118	7,592	6,149	5,228	5,477	3,711	3,000	5,521
20%	4,046	4,500	8,428	11,289	13,038	12,416	8,449	7,162	5,899	8,204	6,458	3,182	6,820
30%	5,282	5,790	9,487	14,561	15,634	15,781	8,874	8,045	6,335	9,620	7,345	4,011	7,813
40%	5,983	7,640	10,484	17,235	20,876	17,885	9,340	8,370	6,673	11,097	8,032	5,126	8,719
50%	6,615	9,360	12,383	20,080	30,201	22,183	12,040	8,895	7,001	11,911	8,420	6,600	9,667
60%	7,110	11,182	15,046	26,404	42,840	28,301	16,992	9,460	7,582	12,637	8,842	12,902	15,346
70%	7,768	12,825	18,736	42,481	55,842	41,531	19,769	12,500	8,345	13,227	9,037	14,195	18,575
80%	8,509	14,404	31,341	60,673	78,156	56,637	32,223	17,879	9,056	13,671	9,462	22,074	21,666
90%	10,453	18,050	55,501	93,523	115,116	79,910	52,612	28,178	10,565	14,010	10,001	23,967	27,183
Max	27,152	56,077	153,587	227,372	216,683	208,184	107,403	43,133	40,250	19,877	14,084	25,868	41,434
Avg	6,858	10,946	21,753	39,721	47,675	37,655	21,211	12,833	8,257	10,921	7,806	10,896	14,179

5C.A.4.10 Threemile Slough Flows

Threemile Slough is a natural channel connecting the Sacramento River near Decker Island, about 5 miles downstream of Rio Vista, to the San Joaquin River near Bradford Island, about 10 miles upstream of Antioch. Because the Sacramento River channel is shorter and deeper than the San Joaquin River channel, flood tide (rising tide) first reaches Threemile Slough on the Sacramento River side and the flood-tide flow is from the Sacramento River to the San Joaquin River. The Threemile Slough tidal flows are quite high (25,000 cfs), but the net flows generally range from about 1,500 cfs to 3,000 cfs from the Sacramento River to the San Joaquin River. Higher San Joaquin River flows will reduce the Threemile Slough flow. The DSM2 model results indicate that the Threemile Slough net flow depends on the Rio Vista flow and the calculated San Joaquin River net outflow (QWEST, estimated as the Delta outflow minus the Rio Vista flow). Threemile Slough flow can be calculated as:

Threemile Slough Flow (cfs) = 1,250 + 0.03 x Rio Vista Flow (cfs) – 0.16 (Outflow – Rio Vista Flow)

The Threemile Slough flow is almost always positive, except when the San Joaquin River flow is quite high (more than 5x the Rio Vista flow). When the DCC is closed and exports are higher than the sum of the San Joaquin River inflow and the Georgiana Slough diversions, a reverse net San Joaquin River flow may result at Antioch (whenever Rio Vista flow is greater than Delta outflow). These periods of reverse San Joaquin River flow will increase the Threemile Slough flow. The large tidal exchange at Threemile Slough flow may have negative effects on larval fish or migrating fish in the Sacramento River. Some of the fish moving from the Sacramento River to the San Joaquin River may not return to the Sacramento, and may have a reduced survival between Threemile Slough and Chipps Island or face a greater percentage entrainment in the south Delta pumping. The BDCP effects analysis included several tools (e.g., DSM2 PTM) that can be used to evaluate the potential effects of Threemile Slough on juvenile migration or larval entrainment.

Table C.A-30 shows the calculated monthly distributions of Threemile Slough flows from the Sacramento River to the San Joaquin River for the six CALSIM cases. The EBC1 monthly median Threemile Slough flows were about 1,500 cfs from October to March, about 750 cfs in April and May, 1,250 in June, and 2,000 cfs in July–September. The Threemile Slough flows were similar for the three EBC2. The Threemile Slough flows were reduced slightly in the ESO cases because the Rio Vista flows were reduced by the north Delta intake diversions. The annual average Threemile Slough flows were about 1,000 taf/yr for the EBC1 and EBC2 cases and were reduced to about 700 taf/yr for the two ESO cases, because the Rio Vista flows were reduced by the north Delta intakes and the San Joaquin River net outflows (QWEST) were increased by the reduced south Delta pumping.

Table C.A-30. Calculated Monthly Distribution of Threemile Slough flow (cfs) from Sacramento River to San Joaquin River (based on CALSIM Rio Vista and Delta Outflow values)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	1,128	-256	-1,157	-5,498	-2,302	-4,224	-1,863	-2,507	-2,011	-939	556	878	-800
10%	1,340	1,355	1,529	924	477	349	-639	-705	626	1,339	1,472	1,340	717
20%	1,375	1,535	1,703	1,250	1,068	1,102	167	162	858	1,767	1,807	1,627	931
30%	1,482	1,615	1,807	1,442	1,223	1,247	360	521	1,084	2,004	1,954	1,745	1,023
40%	1,567	1,758	1,979	1,492	1,395	1,326	484	638	1,170	2,159	2,119	1,814	1,074
50%	1,667	1,852	2,039	1,630	1,481	1,417	611	798	1,223	2,223	2,210	1,889	1,127
60%	1,725	1,983	2,103	1,722	1,588	1,523	843	946	1,282	2,315	2,264	1,917	1,152
70%	1,895	2,045	2,277	1,778	1,659	1,580	909	1,077	1,373	2,372	2,319	1,965	1,227
80%	2,113	2,232	2,392	1,801	1,755	1,736	1,080	1,191	1,386	2,457	2,338	1,992	1,257
90%	2,236	2,337	2,552	1,855	1,844	1,848	1,267	1,344	1,433	2,499	2,374	2,023	1,285
Max	2,858	2,677	2,697	2,770	3,505	2,140	1,346	1,527	1,661	2,584	2,426	2,245	1,348
Avg	1,728	1,830	1,938	1,405	1,298	1,199	487	584	1,079	2,018	2,041	1,793	1,052
B. ESO_ELT													
Min	-118	-1,898	-2,607	-8,247	-3,720	-5,083	-2,560	-3,786	-3,096	-1,388	618	-376	-1,624
10%	493	385	1,386	-84	-930	-572	-895	-1,104	-363	959	1,214	51	199
20%	590	597	1,492	813	170	86	122	125	377	1,180	1,260	112	457
30%	674	697	1,632	931	508	288	331	476	991	1,284	1,304	256	626
40%	746	841	1,772	1,035	857	769	460	551	1,051	1,523	1,343	492	748
50%	794	1,355	1,891	1,177	1,130	1,021	536	795	1,101	1,654	1,449	1,340	855
60%	827	1,385	1,991	1,345	1,315	1,152	898	1,047	1,149	1,847	1,499	1,340	912
70%	858	1,385	2,088	1,465	1,420	1,266	1,125	1,153	1,195	2,031	1,705	1,340	940
80%	945	1,414	2,156	1,596	1,505	1,416	1,172	1,230	1,236	2,264	1,850	1,340	975
90%	1,041	1,633	2,198	1,738	1,595	1,532	1,279	1,330	1,311	2,420	2,157	1,340	1,004
Max	1,393	1,944	2,329	2,274	2,574	1,615	1,430	1,484	1,434	3,794	2,500	2,071	1,152
Avg	779	1,029	1,656	910	705	572	456	434	767	1,664	1,556	822	688
C. ESO_LLT													
Min	-132	-1,504	-2,620	-7,620	-3,807	-5,392	-2,608	-3,962	-2,906	266	1,064	-439	-1,466
10%	335	420	1,046	38	-570	-552	-1,006	-922	-14	1,073	1,180	7	238
20%	410	501	1,448	830	339	126	156	244	627	1,180	1,256	84	465
30%	605	643	1,590	963	717	382	310	472	908	1,273	1,273	203	613
40%	730	832	1,680	1,044	888	896	472	568	1,003	1,423	1,335	407	772
50%	826	1,355	1,801	1,194	1,101	1,073	614	734	1,107	1,549	1,411	912	842
60%	881	1,385	1,925	1,324	1,202	1,188	1,011	1,062	1,142	1,715	1,466	1,227	871
70%	994	1,385	2,079	1,420	1,391	1,242	1,137	1,187	1,168	1,865	1,555	1,340	899
80%	1,062	1,385	2,160	1,546	1,493	1,366	1,186	1,250	1,193	2,074	1,767	1,340	957
90%	1,238	1,654	2,219	1,721	1,591	1,502	1,278	1,321	1,266	2,420	2,038	1,410	983
Max	1,355	1,938	2,332	3,030	2,562	1,617	1,453	1,512	1,393	3,555	2,482	1,916	1,167
Avg	778	1,039	1,633	922	793	597	459	468	834	1,644	1,505	767	692

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	921	-173	-815	-5,117	-2,587	-4,128	-1,763	-2,127	-1,753	-1,668	821	411	-695
10%	1,127	1,035	1,426	924	527	451	-635	-691	631	1,227	1,246	1,340	720
20%	1,264	1,270	1,715	1,212	1,078	1,156	168	173	881	1,681	1,772	1,369	933
30%	1,306	1,385	1,875	1,433	1,222	1,268	358	534	1,105	1,994	1,979	1,617	1,006
40%	1,340	1,469	2,003	1,494	1,374	1,363	479	650	1,156	2,085	2,116	1,705	1,046
50%	1,370	1,563	2,073	1,575	1,490	1,423	608	805	1,229	2,178	2,182	1,872	1,095
60%	1,413	1,659	2,121	1,686	1,612	1,562	838	989	1,270	2,272	2,262	1,947	1,134
70%	1,491	1,855	2,261	1,772	1,676	1,651	910	1,089	1,341	2,355	2,323	2,004	1,187
80%	1,640	2,045	2,409	1,794	1,758	1,760	1,107	1,180	1,395	2,422	2,357	2,317	1,221
90%	1,897	2,292	2,601	1,841	1,831	1,843	1,263	1,334	1,439	2,512	2,398	2,667	1,259
Max	2,790	2,693	2,852	2,784	3,422	2,094	1,346	1,472	1,621	2,590	2,456	2,935	1,341
Avg	1,462	1,615	1,967	1,408	1,293	1,219	495	599	1,085	1,977	2,026	1,868	1,028
E. EBC2_ELT													
Min	750	-391	-1,753	-6,355	-2,667	-4,117	-1,627	-2,331	-1,703	-523	985	542	-694
10%	1,065	1,201	1,389	931	437	513	-693	-756	838	1,391	1,205	1,340	705
20%	1,135	1,355	1,653	1,236	1,057	1,171	171	194	1,002	1,700	1,764	1,343	916
30%	1,215	1,386	1,819	1,376	1,128	1,270	392	530	1,112	1,826	1,877	1,491	998
40%	1,274	1,449	1,966	1,491	1,363	1,353	513	680	1,163	1,931	2,060	1,694	1,034
50%	1,340	1,515	2,075	1,584	1,499	1,423	615	773	1,229	2,053	2,173	1,815	1,078
60%	1,370	1,714	2,147	1,730	1,571	1,537	866	1,015	1,275	2,161	2,228	1,899	1,115
70%	1,370	1,837	2,255	1,780	1,676	1,610	1,047	1,134	1,309	2,235	2,316	2,004	1,183
80%	1,465	1,921	2,384	1,813	1,764	1,689	1,174	1,284	1,362	2,341	2,360	2,313	1,200
90%	1,554	2,223	2,484	1,841	1,855	1,833	1,272	1,359	1,411	2,399	2,400	2,697	1,245
Max	2,803	2,757	2,732	2,928	3,492	2,188	1,350	1,454	1,633	2,547	2,435	2,863	1,311
Avg	1,339	1,625	1,906	1,393	1,265	1,206	525	578	1,119	1,948	2,007	1,829	1,012
F. EBC2_LLT													
Min	553	49	-1,040	-6,395	-2,415	-4,215	-1,717	-2,599	-784	628	920	460	-617
10%	903	1,113	1,306	899	530	433	-781	-616	953	1,276	1,275	1,277	715
20%	990	1,313	1,432	1,181	1,093	1,144	159	309	1,078	1,525	1,600	1,341	893
30%	1,068	1,384	1,656	1,382	1,186	1,233	408	571	1,136	1,693	1,817	1,406	948
40%	1,132	1,394	1,844	1,497	1,323	1,307	584	721	1,172	1,790	2,048	1,596	1,020
50%	1,208	1,571	2,018	1,621	1,450	1,380	727	775	1,200	1,979	2,126	1,713	1,059
60%	1,306	1,625	2,095	1,712	1,552	1,492	943	1,115	1,226	2,067	2,208	1,861	1,091
70%	1,379	1,749	2,245	1,759	1,665	1,601	1,092	1,202	1,266	2,170	2,279	1,968	1,136
80%	1,457	1,849	2,357	1,792	1,780	1,727	1,153	1,293	1,316	2,232	2,325	2,186	1,181
90%	1,530	2,263	2,480	1,825	1,899	1,803	1,277	1,365	1,382	2,427	2,397	2,471	1,207
Max	2,463	2,770	2,713	3,408	3,458	2,444	1,357	1,468	1,565	3,253	2,442	2,815	1,352
Avg	1,229	1,595	1,845	1,377	1,294	1,189	544	629	1,129	1,888	1,972	1,760	994

5C.A.4.11 San Joaquin River at Vernalis Flows

Table C.A-31 shows the CALSIM-simulated San Joaquin River flows at Vernalis for the six CALSIM cases. The only changes in the San Joaquin River flows are caused by the assumed climate change effects on seasonally shifted and slightly reduced San Joaquin River (above Friant Dam) and tributary inflows to the reservoirs. The monthly flows simulated for the 82-year sequence reflect the runoff, upstream reservoir storage and flood control operations (spills), water supply diversions for beneficial uses, and reservoir releases for fish habitat and migration benefits. The D-1641 EC objectives at Vernalis and the 2009 NMFS BiOp Stanislaus River flows sometimes require additional releases from New Melones Reservoir.

The monthly flows reflect the monthly flows required to satisfy the Vernalis monthly EC objective. The EC objective is 700 microSiemens per centimeter (μS/cm) from April through August, which requires a minimum flow of about 1,500 cfs (for the normal monthly San Joaquin River salt load). The EC objective is 1,000 μS/cm from September to March, which requires a minimum flow of about 1,000 cfs (for the normal monthly San Joaquin River salt load). The CALSIM-simulated monthly flows include several years with less than these minimum expected flows. The occasional high salinity conditions are part of the conditions and do not change with the ESO cases. Using the 10% cumulative distribution values as representative of low-flow conditions for the EBC1 and EBC2, the September–January 10% flows are about 1,500 cfs. The February–May 10% flows are about 2,000 cfs, and the June–August 10% flows are about 1,000 cfs. The San Joaquin River at Vernalis monthly median flows for the EBC1 and EBC2 cases are very similar. The median October flows are about 2,500 cfs because the fall-run Chinook salmon attraction flows are simulated (D-1641 objectives and 2009 NMFS BiOp). The median flows are about 2,000 cfs in November–January, about 3,250 cfs in February and March, about 5,000 cfs in April and May, about 2,500 cfs in June, about 1,500 cfs in July–August, and about 2,000 cfs in September.

Table C.A-31 indicates that the CALSIM-simulated monthly flows (distributions) for the six CALSIM cases. The monthly flows for the three EBC2 cases (climate change effects) are nearly identical, as judged by the monthly distribution of flows. The ESO_ELT and ESO_LLT cases are nearly the same as the EBC conditions. The CALSIM-simulated annual average San Joaquin River flow at Vernalis was 3,060 taf/yr for the EBC1 baseline, was 3,024 taf/yr for the EBC2 baseline, was 3,020 taf/yr for the EBC2_ELT, and was 2,879 taf/yr for the EBC2_LLT. The average annual San Joaquin River flow at Vernalis for the ESO cases was the same as the corresponding EBC cases (ELT and LLT). There were no effects of the BDCP Delta operations on the San Joaquin River flows.

Figure C.A-68 shows the CALSIM-simulated monthly San Joaquin River flow at Vernalis for WY 1963–2003 for the six cases. Many years have no monthly flows higher than 3,000 cfs. Most flood control flows (spills) in higher runoff years are between 5,000 cfs and 20,000 cfs, with just a few years having flows of 40,000 cfs or more. The historical average January 1997 Vernalis flow was estimated from the upstream flow records (because San Joaquin River levees failed and flow bypassed the Vernalis gage location) to have been about 50,000 cfs. The January 1997 monthly flow was simulated to be 60,000 cfs for the EBC1 and EBC2 and was the highest flow in the 82-year sequence. The January 1997 flow was simulated to increase to 70,000 cfs for the ELT and LLT cases (climate change effect). Figure C.A-69 shows the CALSIM-simulated monthly San Joaquin River flow at Vernalis for WY 1994–2003 for the six cases. The only differences in these cases were caused by slight differences in the flood control spill amounts in the wet years. The ELT and LLT cases often showed slightly lower spill amounts, although for January 1997 the flows for the ELT and LLT cases were increased substantially.

Table C.A-31. CALSIM-Simulated Monthly Distribution of San Joaquin River Flows (cfs) at Vernalis

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	817	1,226	1,280	1,219	1,795	1,278	1,146	1,113	574	536	346	731	833
10%	1,644	1,637	1,636	1,625	2,154	1,838	2,043	1,941	1,077	956	1,086	1,489	1,156
20%	2,049	1,769	1,795	1,803	2,274	2,110	2,608	2,585	1,420	1,184	1,267	1,687	1,453
30%	2,196	1,876	1,863	2,071	2,354	2,293	3,429	3,293	1,529	1,287	1,367	1,770	1,624
40%	2,314	1,981	1,983	2,200	2,503	2,717	4,194	3,780	1,861	1,439	1,454	1,854	1,833
50%	2,546	2,071	2,064	2,396	3,477	3,225	5,220	4,372	2,367	1,641	1,541	1,961	1,993
60%	2,807	2,243	2,143	2,481	4,405	5,894	5,677	5,175	2,892	1,847	1,775	2,277	2,796
70%	2,975	2,399	2,319	3,273	6,158	7,611	6,570	5,613	3,351	2,124	2,400	2,557	3,372
80%	3,175	2,595	2,845	5,116	9,547	9,119	7,803	7,669	7,050	3,664	2,833	2,804	4,334
90%	3,596	2,902	4,363	9,686	15,593	14,474	12,960	13,526	11,935	7,289	3,181	3,312	5,731
Max	7,297	16,535	24,103	60,130	34,213	48,433	27,278	25,444	27,901	24,293	9,122	7,933	16,027
Avg	2,639	2,448	3,219	4,777	6,388	6,648	6,351	6,148	4,583	3,239	2,072	2,338	3,060
B. ESO_ELT													
Min	845	1,295	1,240	1,078	1,606	1,183	1,089	1,101	626	391	354	863	822
10%	1,459	1,609	1,567	1,575	1,939	1,658	1,948	1,817	1,071	897	1,088	1,454	1,120
20%	1,925	1,741	1,727	1,754	2,027	1,874	2,451	2,351	1,213	1,066	1,188	1,592	1,386
30%	2,102	1,840	1,869	1,998	2,277	2,280	3,160	3,059	1,437	1,194	1,314	1,724	1,500
40%	2,294	1,957	1,938	2,172	2,497	2,556	4,010	3,738	1,788	1,394	1,428	1,821	1,774
50%	2,504	2,057	2,047	2,362	3,436	3,120	5,125	4,371	2,271	1,543	1,498	1,912	1,966
60%	2,729	2,195	2,119	2,584	4,661	5,418	5,642	5,085	2,784	1,789	1,663	2,102	2,758
70%	2,884	2,310	2,324	3,183	6,448	7,803	6,446	5,634	3,085	2,000	1,906	2,455	3,224
80%	3,108	2,683	2,801	5,183	9,252	9,180	8,314	8,047	5,724	2,580	2,523	2,660	4,375
90%	3,516	2,921	4,766	12,197	17,351	15,862	13,531	14,597	9,120	5,778	2,819	3,207	5,974
Max	8,197	17,579	28,904	68,487	37,163	50,536	28,301	30,217	27,769	18,591	7,512	6,750	16,080
Avg	2,565	2,459	3,399	5,054	6,688	6,739	6,288	6,348	3,969	2,661	1,860	2,227	3,024
C. ESO_LLT													
Min	832	1,270	1,214	1,062	1,606	1,183	1,054	1,050	370	305	352	857	791
10%	1,386	1,608	1,567	1,588	1,833	1,658	1,634	1,786	1,040	884	1,066	1,424	1,109
20%	1,878	1,738	1,727	1,781	1,998	1,834	2,430	2,326	1,162	1,019	1,168	1,529	1,332
30%	2,010	1,829	1,869	2,004	2,192	2,139	3,177	2,713	1,304	1,108	1,231	1,645	1,492
40%	2,179	1,929	1,946	2,289	2,469	2,431	3,387	3,310	1,745	1,390	1,410	1,793	1,755
50%	2,439	1,994	2,083	2,398	3,154	2,861	4,882	4,506	2,181	1,512	1,493	1,894	1,886
60%	2,689	2,135	2,138	2,579	4,818	4,228	5,559	5,090	2,542	1,784	1,634	2,079	2,511
70%	2,831	2,248	2,389	3,264	6,061	7,433	6,512	5,334	3,078	1,969	1,803	2,255	3,109
80%	2,933	2,406	2,950	4,962	8,795	8,835	8,638	6,693	3,988	2,462	2,157	2,525	4,021
90%	3,313	2,799	4,421	10,917	15,349	15,922	14,368	13,478	5,718	4,146	2,716	3,125	5,802
Max	10,275	15,172	26,411	70,542	38,520	52,685	28,240	29,868	22,042	12,478	5,888	6,265	15,772
Avg	2,511	2,361	3,225	5,025	6,351	6,763	6,291	6,069	3,207	2,186	1,712	2,145	2,879

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	890	1,222	1,274	1,100	1,606	1,183	1,092	1,076	540	543	664	921	833
10%	1,627	1,609	1,612	1,575	1,973	1,674	1,977	1,850	1,071	924	1,108	1,477	1,120
20%	2,028	1,746	1,766	1,753	2,204	1,888	2,480	2,467	1,252	1,124	1,247	1,660	1,433
30%	2,173	1,853	1,835	2,018	2,280	2,280	3,410	3,153	1,474	1,199	1,332	1,748	1,595
40%	2,293	1,957	1,955	2,150	2,444	2,632	4,187	3,731	1,821	1,392	1,425	1,828	1,795
50%	2,524	2,044	2,035	2,338	3,285	3,076	5,201	4,448	2,330	1,582	1,506	1,936	1,951
60%	2,795	2,216	2,114	2,450	4,284	5,824	5,659	5,158	2,842	1,799	1,780	2,269	2,767
70%	2,976	2,368	2,290	3,219	6,020	7,508	6,545	5,595	3,321	2,149	2,421	2,549	3,325
80%	3,154	2,562	2,816	4,981	9,399	9,029	7,751	7,664	7,128	3,685	2,815	2,779	4,274
90%	3,580	2,873	4,284	9,596	15,380	14,340	12,921	13,455	11,946	7,294	3,160	3,254	5,705
Max	7,227	16,468	23,983	59,985	34,054	48,303	27,210	25,400	27,952	24,338	9,113	7,851	15,977
Avg	2,622	2,416	3,178	4,705	6,250	6,520	6,305	6,106	4,547	3,229	2,056	2,314	3,024
E. EBC2_ELT													
Min	845	1,295	1,240	1,078	1,606	1,183	1,089	1,101	626	393	354	863	822
10%	1,459	1,609	1,567	1,589	1,938	1,658	1,947	1,817	1,070	897	1,087	1,454	1,121
20%	1,926	1,741	1,727	1,753	2,027	1,874	2,451	2,351	1,214	1,064	1,186	1,589	1,382
30%	2,102	1,840	1,868	2,018	2,277	2,280	3,161	3,055	1,441	1,180	1,314	1,722	1,499
40%	2,292	1,957	1,940	2,172	2,496	2,556	4,010	3,731	1,784	1,394	1,424	1,822	1,781
50%	2,504	2,057	2,030	2,388	3,435	3,120	5,125	4,369	2,271	1,532	1,494	1,912	1,948
60%	2,727	2,186	2,114	2,571	4,654	5,418	5,642	5,080	2,786	1,781	1,662	2,096	2,751
70%	2,883	2,295	2,324	3,184	6,457	7,803	6,446	5,633	3,081	2,001	1,901	2,457	3,230
80%	3,107	2,517	2,771	5,067	9,252	9,198	8,263	8,047	5,720	2,585	2,521	2,659	4,376
90%	3,516	2,906	4,682	12,197	17,352	15,857	13,529	14,597	9,120	5,778	2,819	3,206	5,974
Max	8,197	17,579	28,904	68,490	37,163	50,536	28,296	30,214	27,769	18,591	7,512	6,750	16,080
Avg	2,565	2,441	3,366	5,040	6,699	6,739	6,286	6,347	3,969	2,658	1,858	2,226	3,020
F. EBC2_LLT													
Min	832	1,271	1,215	1,062	1,606	1,183	1,055	1,065	370	305	352	857	791
10%	1,386	1,608	1,567	1,588	1,833	1,658	1,634	1,789	1,038	884	1,066	1,423	1,120
20%	1,878	1,737	1,727	1,792	1,998	1,834	2,430	2,326	1,162	1,014	1,167	1,527	1,329
30%	2,010	1,829	1,868	2,017	2,192	2,139	3,177	2,715	1,303	1,108	1,221	1,644	1,488
40%	2,179	1,929	1,957	2,298	2,496	2,431	3,386	3,309	1,743	1,388	1,397	1,791	1,745
50%	2,439	1,994	2,070	2,371	3,296	2,861	4,882	4,511	2,180	1,506	1,492	1,893	1,892
60%	2,689	2,128	2,138	2,637	4,880	4,228	5,560	5,089	2,542	1,779	1,634	2,079	2,526
70%	2,830	2,231	2,392	3,187	6,061	7,433	6,513	5,338	3,077	1,968	1,807	2,252	3,108
80%	2,932	2,406	2,806	4,719	8,794	8,835	8,640	6,693	3,981	2,461	2,155	2,521	3,997
90%	3,313	2,812	4,087	10,918	15,352	15,914	14,360	13,477	5,717	4,146	2,716	3,124	5,804
Max	10,609	15,527	26,411	70,547	38,520	52,685	28,236	29,861	22,042	12,478	5,888	6,265	15,792
Avg	2,515	2,367	3,211	5,018	6,361	6,763	6,291	6,069	3,206	2,184	1,710	2,144	2,879

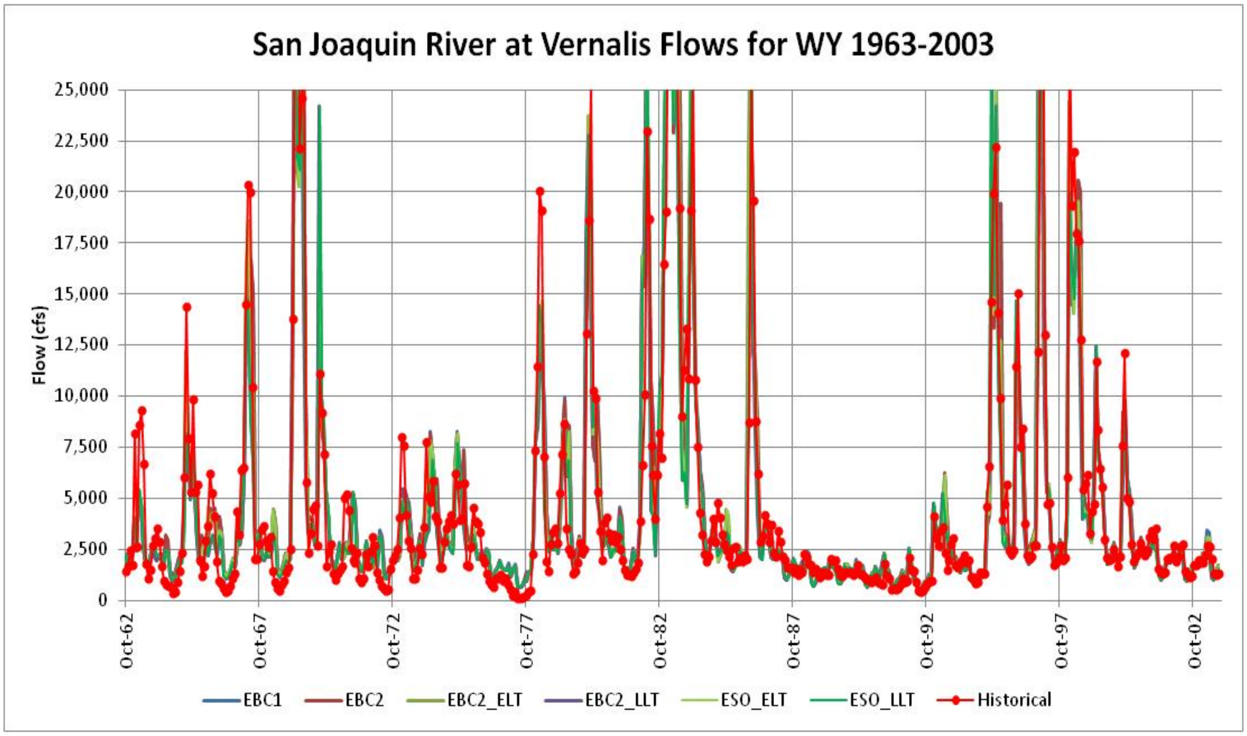


Figure C.A-68. CALSIM-Simulated Monthly San Joaquin River Flow at Vernalis for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

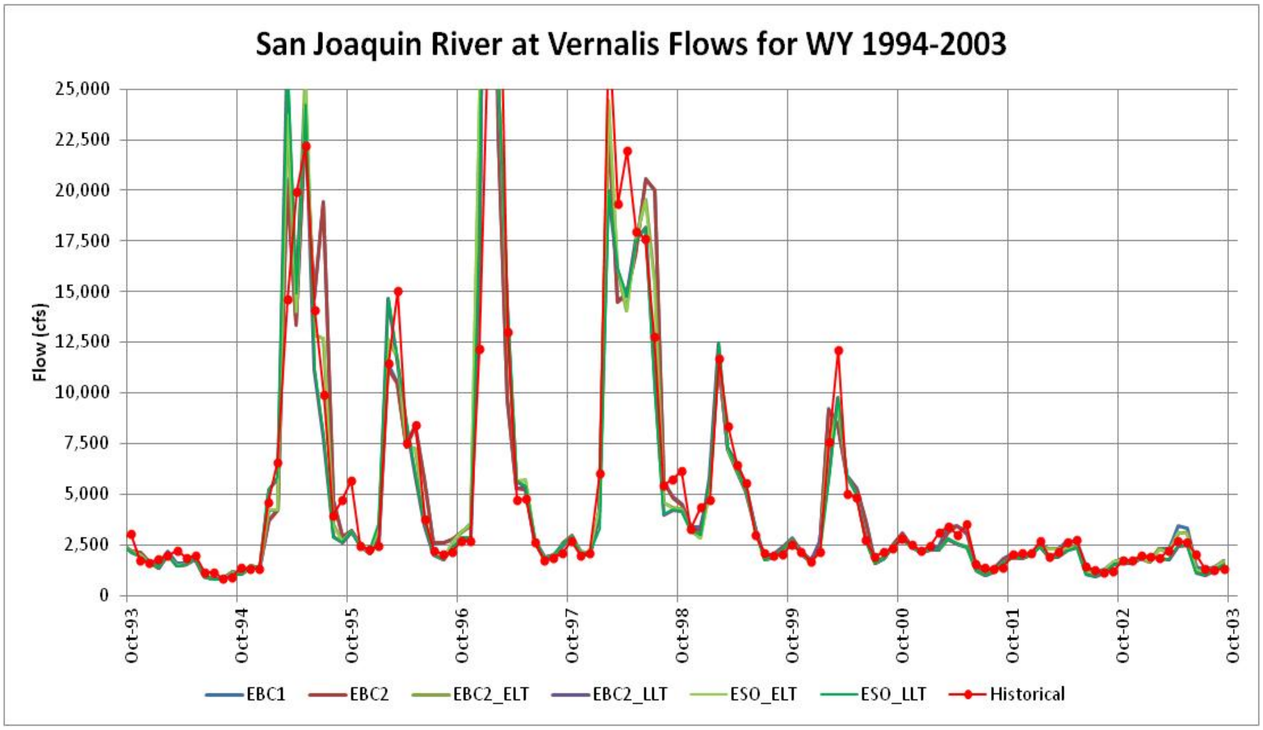


Figure C.A-69. CALSIM-Simulated Monthly San Joaquin River Flow at Vernalis for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.4.12 San Joaquin River Inflow and Diversions to Old River

The San Joaquin River flow diversion into the head (i.e., upstream end) of Old River, located just upstream of Lathrop, was determined from the DSM2 tidal flow model results. A full description of these Delta channel flow splits is given in Appendix D, *DSM2 Delta Tidal Hydraulic and Water Quality Modeling Methods and Results*, in the South Delta Improvements Program (SDIP) Draft EIS/EIR (Jones & Stokes 2005). The head of Old River is near the upstream extent of tidal fluctuations in the San Joaquin River. The average tidal variation at the head of Old River is about 3 feet from high tide to low tide. The natural flow split (without any south Delta pumping) is almost equal, with half of the San Joaquin River flow entering Old River, and half flowing downstream in the San Joaquin River to Stockton. During ebb tide (downstream tidal flow with decreasing tidal elevation), very little flow is diverted into Old River. But during flood tide, the majority of the San Joaquin River flow from upstream and some tidal flow from downstream is diverted into Old River; the flood tide and the San Joaquin River flow “squeeze” most of the water into Old River.

South Delta pumping has an effect on the tidal variation in Old River and generally reduces the tidal elevations, which causes slightly more of the San Joaquin River to enter Old River. The DSM2-simulated tidal flow split, averaged over a tidal day or a tidal month (to account for the spring-tide and neap-tide variations), results in an Old River diversion increase of about 5% of the combined CVP and SWP pumping. About 50 cfs more is diverted into Old River for every 1,000 cfs of pumping. This is a substantial factor only when the San Joaquin River flow is relatively low. For example, when the San Joaquin River flow at Vernalis is 1,500 cfs (typical summer flow), the natural flow split would be 750 cfs into Old River. But if the CVP and SWP combined pumping was 10,000 cfs, an additional 500 cfs would be diverted into Old River, leaving just 250 cfs flow at Stockton. This effect of pumping on the head of Old River flow is reduced somewhat when the temporary rock barriers are installed in Old River near the DMC and in the Grant Line Canal.

Table C.A-32 shows the estimated San Joaquin River diversions into Old River. The CALSIM model calculates the head of Old River flow in order to determine the allowable exports. The allowable exports are the reverse OMR flow limit (2008 USFWS and 2009 NMFS BiOps) plus the Old River flow. The CALSIM-calculated head of Old River flows are slightly more than 50% of the San Joaquin River flows at Vernalis, unless the head of Old River barrier (or tidal gate) is installed. The head of Old River rock barrier was assumed in the EBC cases to be installed each year during October and November to increase the flow at Stockton for improved adult fall-run Chinook attraction. The October median Old River flow was 555 cfs, while the median Vernalis flow was about 2,500 cfs. The November median Old River flow was 334 cfs, while the San Joaquin River flow was 2,071 cfs. The estimated flow through the culverts or through the rock weir was about 20% of the San Joaquin River flow. The median Old River flow for December through May was about half of the San Joaquin River at Vernalis flow. The median Old River flows in June through September were about 40% of the San Joaquin River flow at Vernalis because of the effects of the south Delta rock barriers. The annual average Old River diversion flow was about 1,250 taf/yr, nearly the same for the four cases.

The ESO includes a permanent operable tidal gate at the head of Old River to provide fish protection for juvenile out-migration and adult attraction flows in October. The specified gate operations for the ESO cases included partial closure in the first half of October and complete closure in the second half of October (during the San Joaquin River pulse flow) to provide the greatest pulse flow at Stockton for attracting upstream migrating adult fish. The gate was closed for half of each day from January through June 15, to reduce the Old River diversion to half of what it otherwise would have been in these months. The median monthly flows for the ESO cases were reduced by about 500 cfs in

January, February, and March; reduced by about 1,000 cfs in April and May; and reduced by about 200 cfs in June. The median Old River flows for the ESO cases were increased by about 250 cfs in September and October, and increased by 500 cfs in November (no gate operations). The annual average Old River flow was reduced by 250 taf/yr to about 1,000 taf/yr. Actual tidal gate operations would be adaptively managed to provide maximum fish protection for salmonids and delta smelt. The gate could be closed completely in the spring months when San Joaquin River juvenile Chinook out-migration is highest without causing any higher reverse OMR flows that might impact delta smelt entrainment.

Table C.A-32. CALSIM-Estimated Monthly Distribution of Head of Old River Flows (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	143	-926	145	159	-245	685	623	607	215	199	119	275	356
10%	340	-202	734	777	1,011	931	1,045	997	425	374	429	544	491
20%	437	69	863	848	1,074	1,071	1,311	1,300	569	470	505	614	607
30%	472	188	910	891	1,141	1,157	1,698	1,634	615	513	547	643	663
40%	500	288	948	972	1,181	1,312	2,058	1,864	754	577	583	673	762
50%	555	334	972	1,059	1,417	1,573	2,542	2,142	966	662	620	711	834
60%	608	364	1,022	1,194	1,894	2,270	2,757	2,520	1,186	748	718	823	1,084
70%	651	386	1,090	1,293	2,394	3,357	3,177	2,727	1,378	864	980	923	1,293
80%	701	416	1,233	2,116	3,961	4,026	3,758	3,695	2,928	1,509	1,161	1,010	1,769
90%	747	452	1,656	2,998	5,758	5,840	6,166	6,454	4,975	3,028	1,307	1,190	2,449
Max	1,686	1,736	11,952	33,241	18,231	26,195	12,332	12,067	11,665	10,153	3,796	2,828	7,341
Avg	571	232	1,430	2,117	2,743	3,098	3,043	2,979	1,894	1,331	842	845	1,272
B. ESO_ELT													
Min	233	-387	-12	-486	-733	388	365	367	199	138	123	490	291
10%	415	416	742	366	516	495	601	562	346	350	430	768	410
20%	553	663	823	473	562	553	738	709	393	421	472	832	471
30%	605	713	890	526	620	651	933	905	469	474	525	895	524
40%	662	761	938	571	685	730	1,167	1,091	586	558	573	941	575
50%	724	781	975	633	761	841	1,475	1,266	748	621	602	984	641
60%	791	814	1,032	704	1,111	1,124	1,616	1,462	919	724	671	1,073	782
70%	837	853	1,089	783	1,439	1,774	1,838	1,613	1,020	812	773	1,239	988
80%	903	924	1,225	1,215	2,166	2,304	2,351	2,276	1,902	1,055	1,031	1,336	1,369
90%	977	1,013	1,931	4,358	7,172	6,763	3,781	4,079	3,038	2,395	1,155	1,593	2,431
Max	2,411	6,903	14,821	37,924	19,915	27,537	12,882	14,302	11,604	7,764	3,122	3,262	7,692
Avg	739	848	1,523	1,793	2,311	2,544	1,985	2,064	1,454	1,089	753	1,132	1,098
C. ESO_LLT													
Min	229	-285	428	-443	-845	399	355	353	114	102	122	487	280
10%	393	539	779	370	533	497	513	554	336	344	421	753	401
20%	539	647	853	476	562	552	732	702	377	401	463	803	465
30%	578	714	900	558	615	600	937	809	424	438	490	858	507
40%	628	767	944	582	659	697	998	973	572	557	565	928	558
50%	705	792	984	646	745	773	1,408	1,303	719	608	600	975	619
60%	779	839	1,031	702	929	976	1,589	1,463	841	721	659	1,062	699
70%	821	864	1,081	781	1,296	1,769	1,856	1,530	1,018	799	730	1,145	941
80%	851	930	1,156	945	1,831	2,474	2,430	1,903	1,322	1,006	878	1,272	1,297
90%	964	997	1,710	3,474	5,770	7,262	4,003	3,772	1,900	1,711	1,112	1,555	2,335
Max	4,923	5,539	13,319	39,105	20,580	28,762	12,877	14,138	9,205	5,202	2,441	3,034	7,724
Avg	748	849	1,446	1,790	2,095	2,620	1,994	1,988	1,129	890	691	1,093	1,044

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	161	-933	165	118	-325	638	587	578	193	201	252	342	352
10%	336	-234	707	746	918	844	1,004	941	413	361	438	540	470
20%	432	79	846	824	971	959	1,239	1,231	491	445	497	604	585
30%	466	198	897	870	1,109	1,155	1,678	1,554	583	476	532	636	645
40%	495	293	928	955	1,150	1,280	2,044	1,828	729	557	571	664	741
50%	550	327	949	1,034	1,364	1,526	2,522	2,165	942	637	605	702	816
60%	612	360	1,011	1,169	1,839	2,236	2,738	2,501	1,157	728	720	820	1,069
70%	654	381	1,081	1,273	2,307	3,255	3,155	2,706	1,357	874	989	920	1,277
80%	696	405	1,235	2,064	3,880	3,926	3,722	3,679	2,953	1,518	1,154	1,001	1,742
90%	742	450	1,633	3,100	5,633	5,785	6,153	6,411	4,974	3,030	1,298	1,170	2,426
Max	1,669	1,718	11,871	33,148	18,130	26,113	12,293	12,036	11,681	10,172	3,792	2,799	7,313
Avg	567	230	1,411	2,083	2,674	3,036	3,010	2,947	1,871	1,327	835	836	1,254
E. EBC2_ELT													
Min	150	-854	70	141	-284	638	586	590	229	139	123	322	349
10%	296	-45	716	757	930	845	990	926	413	350	429	531	470
20%	407	210	813	833	979	943	1,225	1,177	473	420	471	579	547
30%	449	287	885	915	1,108	1,070	1,559	1,509	569	469	525	626	614
40%	495	327	935	1,018	1,143	1,253	1,959	1,828	712	558	571	662	731
50%	545	350	964	1,092	1,272	1,429	2,487	2,128	917	616	600	694	801
60%	598	369	1,022	1,189	2,000	2,150	2,729	2,463	1,132	720	670	759	1,054
70%	635	397	1,081	1,297	2,664	3,335	3,108	2,724	1,257	813	770	887	1,252
80%	679	417	1,183	2,118	3,896	4,002	3,963	3,860	2,363	1,057	1,030	958	1,745
90%	748	463	1,910	4,399	7,173	6,760	6,440	6,947	3,790	2,395	1,155	1,153	2,670
Max	1,900	2,072	14,821	37,926	19,915	27,537	12,880	14,301	11,604	7,764	3,122	2,409	7,442
Avg	556	285	1,507	2,264	2,915	3,176	3,004	3,060	1,629	1,088	753	805	1,266
F. EBC2_LLT													
Min	147	-734	428	452	-296	638	569	573	121	102	122	320	336
10%	279	-33	787	720	916	845	840	912	400	344	421	521	470
20%	396	250	853	869	949	929	1,215	1,165	452	399	463	557	540
30%	427	318	900	940	1,031	1,052	1,567	1,348	511	438	486	599	600
40%	468	333	945	1,016	1,148	1,167	1,669	1,629	696	555	559	651	714
50%	530	361	972	1,127	1,257	1,364	2,372	2,196	880	605	599	687	787
60%	589	380	1,022	1,183	1,675	1,815	2,681	2,468	1,033	719	658	753	970
70%	623	411	1,080	1,302	2,467	3,085	3,140	2,584	1,255	799	731	814	1,230
80%	647	455	1,170	1,954	3,435	4,120	4,131	3,222	1,635	1,005	877	910	1,655
90%	737	507	1,687	3,595	5,772	7,262	6,816	6,420	2,362	1,711	1,112	1,124	2,517
Max	2,474	1,954	13,319	39,108	20,580	28,762	12,875	14,135	9,205	5,202	2,441	2,237	7,365
Avg	546	318	1,440	2,268	2,703	3,203	3,011	2,929	1,309	889	691	776	1,209

5C.A.4.13 South Delta Exports and the E/I Ratio

Table C.A-33 shows the CALSIM-simulated combined CVP and SWP south Delta exports for the six CALSIM cases, summarized as the monthly cumulative percentiles for the 1922–2003 sequence. For the four EBC cases, all of the Delta exports are pumped from the south Delta. For the ESO cases, the south Delta pumping was reduced by about half, and about half of the total exports were diverted at the north Delta intakes. More north Delta diversions might be allowed under the adaptive management process, which would further reduce the south Delta fish entrainment risk.

The EBC1 (no Fall X2) annual average south Delta exports were 5,144 taf/yr, with minimum annual exports of 2,538 taf/yr and maximum annual exports of 6,894 taf/yr. The EBC2 (with Fall X2) average annual exports were 4,898 taf/yr, with minimum annual exports of 2,007 taf/yr and maximum annual exports of 6,887 taf/yr. The EBC2_ELT annual average exports were 4,728 taf/yr, and the EBC2_LLT annual average exports were 4,441 taf/yr. The reductions in the simulated south Delta exports for the ELT and the LLT cases were likely the result of climate change and increased water supply demands (reduced Delta inflows) as well as increased Delta outflows assumed to be necessary for X2 and salinity control with sea-level rise effects. The ESO_ELT annual average south Delta exports were 2,662 taf/yr, with a minimum south Delta export of 995 taf/yr and a maximum south Delta export of 4,231 taf/yr. The ESO_LLT annual average south Delta exports were 2,510 taf/yr, with a minimum south Delta export of 1,230 taf/yr and a maximum south Delta export of 4,005 taf/yr. The average reduction in south Delta exports for the ESO cases were about 45%.

The monthly patterns of south Delta exports are very important for evaluating fish entrainment impacts. The CALSIM model accounts for all D-1641 objectives and the 2008 USFWS and 2009 NMFS BiOp actions, as well as the Delta inflows to calculate the south Delta exports. The median exports for the EBC1 were about 9,000 cfs in October–December. The median exports were about 6,500 cfs in January–March and were only about 1,500 cfs in April and May and about 4,500 cfs in June. The median exports were highest at about 11,500 cfs in July and August and were about 10,000 cfs in September. The median south Delta exports for the EBC2 (with Fall X2) were about 6,500 cfs in October and November and about 8,500 cfs in December. The median exports were about 6,500 cfs in January–March, were about 1,500 cfs in April and May, and were about 3,750 cfs in June. The median exports were 11,500 cfs in July and August and were 9,250 cfs in September. The major changes from the EBC1 case to the EBC2 case were a reduction in the September exports of about 500 cfs, a reduction in October and November exports of about 2,750 cfs (when the higher outflows for Fall X2 requirements were simulated), and a reduction in June exports of 500 cfs. The median exports in the other months were similar.

The median south Delta exports for the ESO cases were about 2,500 cfs in October, about 4,250 in November, and about 7,000 cfs in December. The median exports were about 4,250 cfs in January, about 2,500 cfs in February, and about 2,000 cfs in March. The median exports were about 1,500 cfs in April and May and about 2,000 cfs in June. The median exports were 7,000 cfs in July, 5,000 cfs in August, and 4,000 cfs in September for the ESO_ELT case, and the median exports were about 6,000 cfs in July, 5,000 cfs in August, and about 2,000 cfs in September for the ESO_LLT case. The months when the south Delta pumping was reduced the most do not appear to be the months with the greatest risk for entrainment of protected fish species. The CALSIM-simulated diversions to the north Delta intakes may not provide the greatest possible fish protection; the choice of using the north Delta intakes more often when fish entrainment risks are highest can be made under the BDCP adaptive management process.

Table C.A-34 gives the monthly distributions of the CALSIM-simulated total Delta exports for the ESO_ELT and the ESO_LLT cases. The annual average total Delta exports for the ESO_ELT were 5,265 taf/yr, with minimum annual exports of 2,102 taf/yr and maximum annual exports of 8,165 taf/yr. The average annual total Delta exports for the ESO_LLT were 4,945 taf/yr, with minimum annual exports of 1,418 taf/yr and maximum annual exports of 7,810 taf/yr. The south Delta exports would generally decrease with the BDCP, being partially replaced and augmented with north Delta diversions; the total exports would most often increase in the months of January–June, when the existing exports are usually limited by OMR restrictions and the specified export limits in April and May (NMFS BiOp allows 1,500 cfs or 25% of the San Joaquin River inflow).

The total Delta exports were increased about 500 taf/yr for the ESO cases, compared to the EBC2. This volume (500 taf/yr) is the effective annual water supply reduction that is imposed by the 2008 USFWS and 2009 NMFS BiOp limits on reverse OMR and south Delta pumping. The monthly distribution of total exports was shifted from the EBC2 cases to the ESO cases. Total exports for the ESO cases were increased about 500 cfs in December, about 1,000 cfs in January, about 1,500 cfs in February and March, about 3,000 cfs in April, and about 2,500 cfs in May and June. Total pumping was reduced about 1,000 cfs in August, about 2,000 cfs in September, and about 1,000 cfs in October and November. The maximum total exports would be increased from about 12,000 cfs with existing facilities to about 14,000 cfs with the BDCP in the months of December–February and in July and August. However, these higher exports were simulated in only about 10% of the years.

Table C.A-34 also gives the monthly fractions of total Delta exports that were from the south Delta intakes. The south Delta intakes are used for about 55% of the total exports, but the fraction diverted from the south Delta intakes was highly variable; most months had unused north Delta intake capacity and higher than required bypass flows, so more of the south Delta pumping could have been shifted to the north Delta intakes for additional reductions in fish entrainment effects. The potential for shifting more of the south Delta pumping to the north Delta intakes is illustrated with a simple example: assuming that a minimum of 1,000 cfs of south Delta pumping should be maintained for water quality purposes, the north Delta pumping for the ESO_ELT case with the required bypass flow rules could increase from an average of 2,603 taf/yr (40% of the tunnel capacity, 50% of total exports) to about 4,273 taf/yr (65% of tunnel capacity, 84% of total exports). The north Delta pumping for the ESO_LLT case with the required bypass flows could increase from an average of 2,435 taf/yr (40% of the tunnel capacity, 50% of total exports) to about 4,144 taf/yr (65% of tunnel capacity, 81% of total exports). The CALSIM results for the ESO cases reflect the specified north Delta bypass flows and other assumed CALSIM rules used to maintain south Delta pumping in the summer and fall months for water quality (salinity) control. But these rules can likely be adjusted, under the BDCP adaptive management process, to provide additional fish benefits without degrading water quality in the south Delta.

Figure C.A-70 shows the daily patterns of Delta inflow, Delta outflow and the south Delta exports for WY 1995, to illustrate the daily variations in Delta exports compared to the monthly average exports simulated with the CALSIM model. The Delta export pumping was much more uniform that the Delta inflows and Delta outflow in WY 1995. The E/I limits on exports are shown for comparison; because of the relatively high inflows, the E/I limits were not often limiting Delta exports during WY 1995.

Table C.A-33. CALSIM-Simulated Monthly Distribution of South Delta Exports (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	3,267	2,071	3,456	1,006	1,100	1,100	800	1,143	1,347	1,169	900	3,643	2,538
10%	4,824	5,138	6,135	4,451	3,792	2,224	1,500	1,500	1,597	8,966	4,293	4,964	3,439
20%	6,135	6,284	7,095	5,065	4,972	4,506	1,500	1,500	2,764	10,393	8,947	8,199	4,540
30%	7,147	7,417	7,628	5,962	5,966	4,781	1,500	1,500	3,077	11,056	10,999	9,027	4,817
40%	7,716	8,401	8,013	6,366	6,600	5,572	1,639	1,500	3,503	11,280	11,381	9,432	5,110
50%	9,009	9,079	8,607	6,446	6,998	6,629	1,718	1,570	4,441	11,382	11,463	9,895	5,303
60%	9,618	10,144	9,216	6,799	7,715	7,395	1,845	1,676	5,128	11,425	11,554	10,347	5,542
70%	10,392	10,905	9,989	6,884	8,313	8,677	2,076	1,863	5,480	11,502	11,669	11,063	5,839
80%	10,967	10,917	11,242	7,753	9,371	9,145	2,287	2,336	7,351	11,557	11,685	11,137	6,094
90%	11,044	10,934	11,320	8,941	10,800	9,819	3,259	3,440	9,096	11,595	11,725	11,158	6,313
Max	11,067	10,944	11,902	12,720	12,733	11,870	8,861	10,527	11,244	11,733	11,751	11,302	6,894
Avg	8,389	8,488	8,747	6,627	7,105	6,562	2,076	2,188	4,844	10,650	10,084	9,328	5,144
B. ESO_ELT													
Min	0	0	959	0	0	0	0	0	328	303	1,926	0	995
10%	1,199	0	5,100	1,509	1,024	696	968	905	1,127	2,039	3,038	0	2,028
20%	1,820	0	5,827	1,514	1,814	1,472	1,097	1,073	1,476	3,147	3,523	0	2,201
30%	2,182	832	6,286	2,007	2,466	1,575	1,236	1,158	1,661	4,752	3,956	276	2,405
40%	2,552	2,640	6,640	3,039	2,926	1,783	1,419	1,274	1,676	6,296	4,614	810	2,597
50%	2,672	4,378	6,980	4,259	3,638	2,202	1,539	1,415	2,397	7,001	5,092	4,187	2,699
60%	2,715	4,875	7,213	4,558	4,430	2,574	1,641	1,584	3,088	8,154	5,759	4,563	2,771
70%	2,739	5,115	7,822	4,842	4,925	3,830	1,728	1,649	3,346	9,496	6,915	4,719	2,852
80%	2,781	5,828	9,418	5,310	5,180	4,188	2,420	1,794	3,505	11,139	7,833	5,042	3,006
90%	2,846	6,065	9,623	5,864	5,541	4,432	2,781	2,220	3,651	12,224	10,480	5,370	3,296
Max	3,083	6,766	10,851	6,324	6,679	6,792	3,127	3,874	6,020	14,400	12,748	10,332	4,231
Avg	2,303	3,289	7,124	3,608	3,503	2,559	1,668	1,491	2,445	7,135	5,910	2,897	2,662
C. ESO_LLT													
Min	0	0	835	0	0	0	0	0	0	0	1,447	0	1,230
10%	12	0	3,213	1,566	1,131	601	924	748	1,044	1,277	2,880	0	1,916
20%	499	0	5,345	1,566	1,785	1,391	1,104	946	1,411	2,393	3,455	0	2,072
30%	1,014	0	6,106	2,031	2,420	1,575	1,261	1,072	1,616	3,961	3,780	98	2,270
40%	2,097	1,975	6,509	2,849	2,836	1,818	1,437	1,241	1,674	4,838	4,254	338	2,385
50%	2,541	4,328	6,862	4,256	3,618	2,493	1,545	1,366	1,680	6,109	4,864	2,275	2,481
60%	2,632	4,780	7,217	4,595	4,752	2,848	1,627	1,431	2,085	7,547	5,357	3,770	2,567
70%	2,712	5,098	8,320	5,193	5,039	3,713	1,728	1,569	3,095	9,191	5,978	4,633	2,686
80%	2,749	5,689	9,473	5,525	5,404	4,188	2,373	1,649	3,360	10,543	7,850	5,181	2,949
90%	2,790	6,054	9,670	5,907	5,533	4,696	2,749	2,105	3,575	11,735	10,022	5,685	3,199
Max	5,062	7,228	10,354	6,783	8,371	6,194	3,108	3,870	4,231	14,400	13,012	8,868	4,055
Avg	1,883	3,098	6,854	3,665	3,549	2,645	1,621	1,361	2,161	6,513	5,477	2,620	2,510

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	3,211	2,600	3,865	1,100	1,167	1,100	900	1,100	1,277	1,051	900	3,673	2,007
10%	4,544	3,531	6,383	4,370	3,744	2,248	1,500	1,500	1,471	7,830	3,693	4,395	3,424
20%	5,228	4,342	7,220	5,044	4,901	4,470	1,500	1,500	2,426	10,045	8,218	6,304	4,185
30%	5,725	5,129	7,835	5,851	5,723	4,745	1,500	1,500	3,104	10,729	10,721	7,593	4,595
40%	6,075	5,612	8,156	6,319	6,468	5,630	1,633	1,500	3,543	11,280	11,409	8,842	4,744
50%	6,346	6,362	8,770	6,569	6,693	6,634	1,712	1,514	3,831	11,376	11,619	9,262	4,971
60%	6,718	6,780	9,969	6,770	7,609	7,266	1,862	1,630	5,150	11,515	11,746	9,822	5,269
70%	7,317	8,243	10,585	6,881	7,940	8,645	2,021	1,782	5,502	11,574	11,780	10,517	5,623
80%	8,471	10,013	11,622	7,868	9,357	9,295	2,239	2,265	7,204	11,605	11,780	11,224	5,947
90%	9,449	11,280	11,669	9,129	10,514	9,956	3,250	3,421	9,749	11,605	11,780	11,280	6,185
Max	11,280	11,280	12,278	13,100	13,100	12,161	8,851	10,518	11,280	11,780	11,780	11,280	6,887
Avg	6,744	6,777	9,029	6,654	7,055	6,639	2,105	2,219	4,820	10,446	9,885	8,640	4,898
E. EBC2_ELT													
Min	1,544	1,891	2,782	900	1,307	1,100	900	900	1,005	900	900	2,823	1,713
10%	3,982	4,408	5,532	4,242	3,744	2,158	1,482	1,500	1,442	6,668	2,184	4,457	3,186
20%	4,490	4,791	7,169	5,086	4,846	4,315	1,500	1,500	1,680	7,948	7,668	4,818	3,915
30%	5,077	5,135	7,551	6,033	5,647	4,576	1,500	1,500	2,856	9,231	8,346	6,661	4,283
40%	5,455	5,771	7,953	6,409	6,599	5,324	1,650	1,517	3,202	9,994	10,848	8,467	4,397
50%	5,798	6,013	8,402	6,586	6,807	6,490	1,768	1,647	3,723	10,880	11,495	8,952	4,837
60%	6,115	6,769	9,766	6,784	7,651	7,173	1,929	1,769	5,081	11,137	11,630	9,405	5,158
70%	6,371	7,810	10,453	6,933	8,265	8,641	2,164	1,932	5,316	11,328	11,780	10,362	5,470
80%	6,702	9,020	11,545	8,171	9,386	9,396	2,490	2,336	5,904	11,570	11,780	11,098	5,599
90%	8,360	10,853	11,727	9,330	10,454	10,760	3,505	3,666	8,437	11,605	11,780	11,280	5,995
Max	11,280	11,280	12,278	13,100	13,100	12,161	8,851	10,777	11,280	11,621	11,780	11,280	6,977
Avg	5,890	6,753	8,812	6,720	7,148	6,588	2,181	2,307	4,420	9,652	9,433	8,326	4,728
F. EBC2_LLT													
Min	546	1,846	82	1,500	900	959	900	846	760	57	580	2,841	1,520
10%	2,524	3,447	4,120	4,485	3,337	2,149	1,355	1,500	1,480	3,590	3,451	4,333	2,831
20%	3,653	4,479	6,159	4,975	4,369	3,179	1,500	1,500	1,623	5,754	6,529	4,778	3,586
30%	4,160	4,874	7,220	5,697	5,484	4,563	1,597	1,500	2,362	8,258	7,926	5,574	3,825
40%	4,589	5,095	7,903	6,241	6,232	5,233	1,706	1,591	3,007	8,759	9,579	6,377	4,324
50%	4,944	5,660	8,243	6,521	6,655	6,562	1,805	1,686	3,544	9,671	10,931	7,588	4,607
60%	5,413	6,612	9,088	6,756	7,269	7,265	2,069	1,785	4,133	10,396	11,460	8,777	4,841
70%	5,780	7,132	10,518	6,860	8,229	8,209	2,219	1,961	5,105	10,844	11,672	9,392	5,081
80%	6,235	8,458	10,963	7,805	9,253	9,203	2,472	2,356	5,616	11,440	11,780	11,092	5,355
90%	6,644	11,280	11,705	9,581	10,513	10,471	3,606	3,385	6,163	11,605	11,780	11,280	5,735
Max	11,280	11,280	12,278	13,100	13,100	12,161	8,851	10,670	11,280	11,780	11,780	11,366	7,207
Avg	4,938	6,348	8,358	6,562	6,901	6,406	2,235	2,303	3,934	8,751	9,071	7,681	4,441

Table C.A-34. CALSIM-Simulated Monthly Distribution of Total Delta Exports (cfs) and the Percentage of Exports from the South Delta for ESO_ELT and ESO_LLT

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. Total Exports for ESO_ELT													
Min	1,087	1,100	3,788	900	1,751	1,285	830	900	994	1,076	1,926	2,492	2,102
10%	2,605	1,827	5,934	2,370	4,327	3,347	2,015	1,842	1,722	3,392	3,299	4,052	2,891
20%	3,284	2,715	7,319	3,377	5,642	5,107	2,257	2,078	2,300	6,488	4,684	4,394	3,862
30%	3,837	4,051	7,946	5,419	6,025	6,342	3,093	2,388	3,425	8,657	6,653	5,001	4,316
40%	4,270	4,738	8,586	6,407	7,799	7,702	3,679	2,877	5,466	9,680	7,750	5,618	5,115
50%	4,656	5,575	9,672	7,239	8,954	8,583	5,366	3,358	6,776	10,437	8,321	6,126	5,526
60%	5,033	6,376	10,315	7,901	10,364	9,601	6,932	4,343	8,386	11,430	9,332	6,447	5,673
70%	5,724	7,558	10,636	10,447	10,916	10,186	8,146	6,355	9,792	12,079	11,687	6,938	6,106
80%	6,197	9,204	11,403	12,042	11,726	10,587	9,956	9,785	10,975	13,311	12,884	7,504	6,561
90%	7,593	10,794	13,030	13,661	13,232	11,544	10,571	10,649	12,210	14,203	13,674	8,812	7,462
Max	11,262	12,339	14,525	14,528	14,551	14,604	12,026	12,209	14,207	14,898	14,871	13,205	8,165
Avg	4,869	5,922	9,401	7,726	8,824	8,137	5,809	5,045	6,806	9,725	8,695	6,256	5,265
B. Total Exports for ESO_LLT													
Min	1	1,100	1,063	0	1,393	974	828	1,049	994	463	1,490	271	1,418
10%	2,222	1,342	5,170	2,381	3,834	3,356	1,995	1,576	1,726	2,429	3,000	3,227	2,776
20%	2,694	1,878	6,291	3,286	5,580	5,140	2,246	2,057	2,257	4,351	4,009	3,681	3,275
30%	2,841	2,601	7,504	5,092	6,957	5,965	2,962	2,191	3,095	5,224	5,258	4,336	3,904
40%	3,222	4,254	8,377	6,451	7,913	7,484	3,809	2,492	4,809	6,756	6,533	4,872	4,603
50%	3,449	4,793	9,369	7,359	8,828	8,792	5,110	3,357	7,132	8,624	7,448	5,741	5,151
60%	3,843	5,801	10,105	8,456	10,635	9,760	6,491	4,511	8,848	9,405	8,755	6,121	5,576
70%	4,172	6,755	10,341	10,566	11,125	10,480	8,293	7,232	10,274	11,252	9,523	6,655	5,943
80%	4,878	8,871	10,874	12,740	11,778	10,914	9,932	9,455	10,950	12,696	11,819	7,038	6,458
90%	6,302	10,408	12,713	14,399	14,518	12,245	10,589	10,483	12,164	13,953	13,287	8,439	7,095
Max	8,681	13,041	14,525	14,531	14,551	14,596	11,884	12,204	13,231	14,900	14,871	12,601	7,810
Avg	3,831	5,316	8,851	7,840	8,942	8,196	5,721	4,950	6,777	8,223	7,754	5,574	4,945
C. Percentage of Exports from South Delta for ESO_ELT													
Min	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.12	0.15	0.38	0.00	0.16
10%	0.28	0.00	0.49	0.20	0.14	0.09	0.11	0.15	0.25	0.41	0.47	0.00	0.34
20%	0.35	0.00	0.57	0.29	0.19	0.15	0.16	0.16	0.28	0.52	0.55	0.00	0.37
30%	0.40	0.15	0.79	0.38	0.27	0.20	0.21	0.21	0.31	0.62	0.60	0.06	0.42
40%	0.44	0.41	0.85	0.40	0.36	0.22	0.25	0.31	0.34	0.69	0.66	0.15	0.46
50%	0.49	0.55	0.88	0.55	0.39	0.28	0.31	0.38	0.37	0.75	0.72	0.63	0.53
60%	0.57	0.69	0.90	0.65	0.49	0.43	0.45	0.53	0.44	0.82	0.79	0.74	0.63
70%	0.69	0.81	0.92	0.70	0.69	0.51	0.63	0.67	0.53	0.89	0.85	0.79	0.67
80%	0.73	0.95	0.92	0.83	0.80	0.68	0.70	0.72	0.62	0.97	0.90	0.87	0.73
90%	1.00	1.00	0.95	0.86	0.85	0.81	0.75	0.75	0.72	0.98	0.97	1.00	0.80
Max	1.00	1.00	1.00	1.00	0.89	0.88	0.82	0.85	1.00	1.00	1.00	1.00	0.89
Avg	0.55	0.50	0.79	0.54	0.46	0.38	0.40	0.43	0.44	0.72	0.71	0.47	0.55

D. Percentage of Exports from South Delta for ESO_LLT													
Min	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.00	0.23
10%	0.00	0.00	0.54	0.20	0.14	0.10	0.13	0.11	0.18	0.44	0.50	0.00	0.35
20%	0.11	0.00	0.62	0.33	0.19	0.15	0.15	0.15	0.24	0.60	0.55	0.00	0.38
30%	0.31	0.00	0.81	0.38	0.27	0.20	0.16	0.18	0.28	0.66	0.62	0.02	0.42
40%	0.46	0.23	0.85	0.41	0.38	0.23	0.25	0.30	0.31	0.73	0.68	0.09	0.45
50%	0.59	0.54	0.87	0.53	0.40	0.35	0.31	0.42	0.33	0.83	0.78	0.69	0.53
60%	0.68	0.68	0.90	0.66	0.47	0.44	0.43	0.50	0.41	0.85	0.84	0.77	0.62
70%	0.76	0.85	0.91	0.70	0.65	0.50	0.59	0.64	0.47	0.90	0.88	0.91	0.69
80%	0.87	0.99	0.92	0.80	0.73	0.65	0.70	0.67	0.61	0.96	0.92	0.96	0.74
90%	1.00	1.00	0.97	0.84	0.83	0.77	0.75	0.72	0.69	0.98	1.00	1.00	0.79
Max	1.00	1.00	1.00	1.00	1.00	0.87	0.79	0.85	1.00	1.00	1.00	1.00	0.88
Avg	0.53	0.48	0.81	0.54	0.45	0.39	0.39	0.41	0.40	0.75	0.75	0.50	0.56

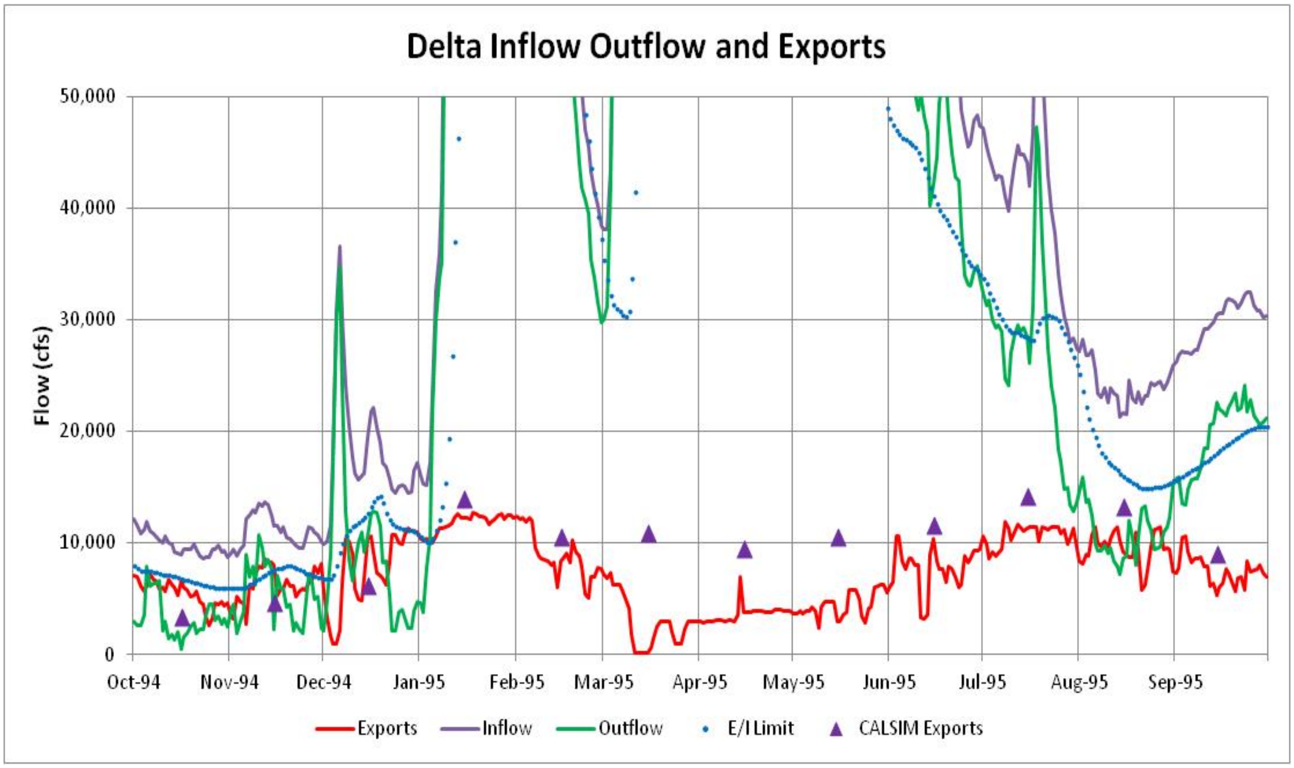


Figure C.A-70. Daily Historical Delta Inflow, Outflow and Exports (with E/I Limits) for WY 1995

The BDCP would modify the D-1641 objectives for maximum E/I ratio. The BDCP assumed the Delta inflow term would be reduced by the ND diversions, because the E/I ratio was generally established by State Water Board to limit the potential effects of entrainment on migrating Sacramento River or estuarine (larval and juvenile) fish. The BDCP would apply the E/I ratio to the south Delta exports, using the total Delta inflow minus the ND diversions. The BDCP calculation of the adjusted E/I limit for the south Delta exports was:

Adjusted E/I = South Delta Export / [Total Inflow – ND diversions]

This may allow the total exports (ND and south Delta) to exceed the existing E/I objectives. However, because the existing D-1641 outflow objectives and salinity objectives and OMR objectives are maintained for each BDCP alternative, the effects of adjusting the E/I ratio (to exclude the ND diversions from the inflow and the export) on total exports are not large. There are only a few months during the 82-year CALSIM simulation with total exports that slightly exceed the existing E/I objectives. The adjusted E/I ratio for the south Delta exports are almost always reduced from the baseline E/I conditions, because the reduction in south Delta pumping is usually greater than the corresponding reduction in the effective inflow.

Table C.A-35A shows the monthly distribution of the E/I ratio for the EBC1 case. The 0.65 limit applies to July–January and the 0.35 limit applies to February–June (an E/I ratio of 0.45 is allowed in February when January runoff is less than 1,000 taf). In most of the years, the E/I ratios were much lower than the maximum allowed E/I ratio. Total exports are sometimes limited by the E/I ratio, but are more commonly limited by the required Delta outflow, or by the OMR limits. The cumulative distributions of the monthly E/I ratios indicate how often the E/I ratio was limiting exports; when the cumulative distribution values are the maximum allowed E/I ratio, the E/I ratio is limiting (controlling) exports.

For the EBC1 case, the 0.65 limit in October was limiting for about 30% of the years (70% cumulative was 0.64) and in November and December for less than 10% of the years (90% cumulative was 0.64 in November and 0.62 in December. The E/I was never limiting in January (maximum was 0.56), was limiting in February for less than 10% of the years (90% cumulative was 0.35), and was limiting in March for less than 10% of the years (90% cumulative was 0.31). The E/I was never limiting in April and May (because the exports are limited by OMR and the NMFS BiOp specified maximum of 1,500 cfs). The E/I was rarely limiting in June (less than 10% of years), was never limiting in July (maximum was 0.56), was never limiting in August (maximum was 0.64) and was limiting September exports in about half of the years (50% cumulative was 0.65).

Table C.A-35B shows that the monthly cumulative distributions of the E/I ratio for the EBC2 (NAA) case were very similar to the EBC1 case in most months. However, the average E/I ratios were reduced considerably in September, October and November because the increased outflow requirements (for Fall X2 following wet and above normal years) reduced the average E/I ratio by about 0.10 in each of these months. The effects of climate change on the E/I ratios were small, as shown by comparing the EBC2 (NAA) E/I ratios to the EBC2-ELT and EBC2-LLT E/I ratios (Table C.A-35C and Table C.A-35F).

Table C.A-35E and Table C.A-35F show that the BDCP (ELT and LLT) would allow the total exports to increase in comparison to the NAA baseline (ELT and LLT) cases, and the Total Export/Total Inflow ratio was slightly greater than the existing E/I objectives in a few months. The E/I ratio was slightly greater than the existing 0.65 objective in November and December in about 10% of the years for the ESO_ELT. The maximum E/I ratio was 0.70 in November and 0.67 in December. The March, April and May E/I ratios were greater than the existing 0.35 objective in less than 10% of the years, with a maximum E/I ratio of 0.38 in March, 0.36 in April and 0.4 in May. The June E/I ratio was greater than the existing 0.35 objective in about 30% of the years, with a maximum E/I ratio of 0.50. Slightly higher exports in June for about 30% of the years were simulated with the modified E/I ratio objective for the BDCP. The results for the ESO_LLT were very similar to the ESO_ELT results; the major effect was in June, with about 30% of the years exceeding the E/I ratio of 0.35, with a maximum E/I of 0.48. The effects of the higher total exports with the north Delta diversions in June were the major difference between the existing E/I ratio and the modified E/I ratio. The most appropriate E/I objective can be further evaluated and selected as part of the adaptive management process; the effects on the BDCP water supply will be relatively small.

The assumed BDCP adjustment in the E/I ratio objective will allow total exports to exceed the existing E/I ratio objectives in only a few months. The North Delta diversions would allow much higher exports during the months of January–June, when the existing exports are limited by OMR limits and by the NMFS limits on exports in April and May (1,500 cfs or 25% of San Joaquin River inflow). The higher total exports will not often exceed the existing E/I ratio objectives, because north Delta pumping is controlled by the assumed bypass flow rules, and the actual E/I ratios in the months of January–June are often much less than the maximum allowable E/I ratio. Using the original D-1641 E/I ratio or the modified E/I ratio for the BDCP will not change the BDCP operations substantially, because the E/I objectives are rarely the controlling factor for south Delta or north Delta exports.

Table C.A-35. CALSIM-Simulated Monthly Cumulative Distributions of Total Exports/Total Inflow Ratio for 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	0.26	0.12	0.05	0.04	0.04	0.02	0.02	0.03	0.09	0.12	0.10	0.23
10%	0.46	0.31	0.12	0.07	0.07	0.07	0.04	0.05	0.13	0.38	0.37	0.45
20%	0.52	0.42	0.19	0.10	0.09	0.10	0.05	0.06	0.15	0.42	0.52	0.48
30%	0.55	0.48	0.26	0.12	0.11	0.12	0.06	0.07	0.20	0.46	0.56	0.52
40%	0.57	0.53	0.42	0.14	0.12	0.13	0.06	0.08	0.21	0.47	0.58	0.63
50%	0.59	0.55	0.49	0.20	0.14	0.17	0.07	0.09	0.22	0.48	0.60	0.65
60%	0.61	0.58	0.53	0.25	0.18	0.20	0.08	0.10	0.24	0.48	0.61	0.65
70%	0.64	0.60	0.56	0.32	0.24	0.23	0.09	0.11	0.27	0.50	0.61	0.65
80%	0.65	0.62	0.58	0.40	0.28	0.28	0.11	0.13	0.29	0.53	0.62	0.65
90%	0.65	0.64	0.62	0.42	0.35	0.31	0.14	0.17	0.32	0.54	0.62	0.65
Max	0.65	0.65	0.65	0.56	0.45	0.35	0.21	0.19	0.35	0.56	0.64	0.65
Avg	0.57	0.51	0.42	0.23	0.18	0.18	0.08	0.09	0.23	0.46	0.55	0.58
B. EBC2												
Min	0.22	0.12	0.05	0.05	0.03	0.02	0.02	0.03	0.10	0.11	0.10	0.15
0.10	0.37	0.22	0.13	0.07	0.07	0.08	0.04	0.05	0.13	0.38	0.35	0.31
0.20	0.40	0.26	0.19	0.10	0.09	0.11	0.05	0.06	0.15	0.41	0.51	0.34
0.30	0.44	0.29	0.30	0.12	0.10	0.13	0.06	0.07	0.20	0.45	0.56	0.35
0.40	0.47	0.32	0.43	0.16	0.12	0.14	0.06	0.08	0.21	0.47	0.58	0.41
0.50	0.50	0.38	0.50	0.20	0.15	0.16	0.07	0.09	0.22	0.47	0.60	0.47
0.60	0.52	0.44	0.54	0.25	0.20	0.20	0.08	0.10	0.23	0.48	0.61	0.50
0.70	0.54	0.48	0.58	0.31	0.24	0.23	0.10	0.11	0.26	0.49	0.61	0.63
0.80	0.56	0.54	0.64	0.38	0.29	0.27	0.11	0.13	0.28	0.51	0.62	0.65
0.90	0.59	0.58	0.65	0.42	0.35	0.32	0.14	0.16	0.31	0.54	0.62	0.65
Max	0.65	0.65	0.65	0.51	0.45	0.35	0.21	0.19	0.35	0.56	0.64	0.65
Avg	0.49	0.39	0.43	0.23	0.19	0.18	0.08	0.10	0.22	0.45	0.54	0.47
C. EBC2 ELT												
Min	0.17	0.11	0.04	0.04	0.03	0.02	0.01	0.03	0.08	0.09	0.11	0.17
0.10	0.29	0.26	0.12	0.07	0.06	0.08	0.04	0.05	0.12	0.30	0.22	0.32
0.20	0.32	0.28	0.18	0.09	0.09	0.11	0.05	0.07	0.14	0.35	0.50	0.34
0.30	0.36	0.30	0.27	0.12	0.10	0.13	0.06	0.08	0.19	0.40	0.52	0.35
0.40	0.41	0.36	0.41	0.15	0.12	0.14	0.07	0.09	0.20	0.44	0.56	0.43
0.50	0.44	0.41	0.46	0.21	0.15	0.17	0.08	0.09	0.22	0.45	0.60	0.46
0.60	0.47	0.45	0.51	0.25	0.19	0.19	0.08	0.11	0.24	0.47	0.61	0.49
0.70	0.52	0.50	0.56	0.30	0.25	0.23	0.10	0.12	0.25	0.47	0.61	0.55
0.80	0.54	0.51	0.65	0.37	0.29	0.25	0.12	0.14	0.30	0.48	0.62	0.65
0.90	0.57	0.56	0.65	0.43	0.35	0.29	0.14	0.16	0.32	0.51	0.62	0.65
Max	0.65	0.64	0.65	0.52	0.44	0.35	0.21	0.20	0.35	0.54	0.64	0.65
Avg	0.44	0.40	0.42	0.23	0.19	0.18	0.09	0.10	0.22	0.42	0.53	0.47

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2 LLT												
Min	0.07	0.13	0.01	0.04	0.04	0.03	0.02	0.03	0.08	0.01	0.07	0.15
0.10	0.22	0.21	0.13	0.07	0.05	0.07	0.04	0.06	0.11	0.23	0.32	0.24
0.20	0.25	0.24	0.19	0.09	0.09	0.09	0.05	0.07	0.13	0.30	0.43	0.30
0.30	0.29	0.29	0.30	0.11	0.10	0.11	0.07	0.08	0.16	0.33	0.49	0.35
0.40	0.32	0.33	0.34	0.14	0.12	0.13	0.07	0.09	0.18	0.39	0.52	0.43
0.50	0.34	0.40	0.39	0.20	0.13	0.15	0.08	0.10	0.20	0.42	0.56	0.46
0.60	0.37	0.44	0.45	0.24	0.19	0.19	0.09	0.11	0.21	0.44	0.59	0.50
0.70	0.41	0.48	0.51	0.30	0.23	0.22	0.10	0.12	0.24	0.46	0.61	0.53
0.80	0.43	0.51	0.63	0.36	0.25	0.25	0.11	0.13	0.27	0.48	0.61	0.61
0.90	0.46	0.58	0.65	0.43	0.35	0.28	0.15	0.15	0.28	0.50	0.62	0.65
Max	0.53	0.65	0.65	0.48	0.42	0.35	0.20	0.19	0.31	0.56	0.64	0.65
Avg	0.34	0.39	0.39	0.22	0.17	0.17	0.09	0.10	0.20	0.38	0.51	0.45
E. ESO_ELT												
Min	0.12	0.07	0.04	0.03	0.03	0.02	0.06	0.08	0.07	0.11	0.24	0.10
0.10	0.24	0.11	0.19	0.10	0.08	0.09	0.11	0.12	0.14	0.28	0.35	0.17
0.20	0.29	0.14	0.25	0.12	0.11	0.13	0.13	0.14	0.17	0.35	0.41	0.23
0.30	0.31	0.22	0.31	0.14	0.13	0.17	0.16	0.16	0.21	0.39	0.49	0.27
0.40	0.32	0.35	0.38	0.16	0.17	0.19	0.18	0.16	0.25	0.42	0.52	0.34
0.50	0.33	0.42	0.43	0.20	0.22	0.22	0.19	0.18	0.28	0.45	0.53	0.46
0.60	0.35	0.48	0.47	0.24	0.26	0.26	0.22	0.20	0.32	0.47	0.56	0.50
0.70	0.36	0.51	0.54	0.28	0.29	0.29	0.23	0.21	0.39	0.50	0.60	0.54
0.80	0.40	0.55	0.62	0.31	0.31	0.32	0.24	0.24	0.43	0.52	0.63	0.57
0.90	0.44	0.63	0.64	0.38	0.35	0.35	0.27	0.28	0.47	0.53	0.65	0.60
Max	0.53	0.70	0.67	0.55	0.41	0.38	0.36	0.40	0.50	0.57	0.68	0.68
Avg	0.34	0.38	0.42	0.22	0.22	0.22	0.19	0.19	0.29	0.43	0.52	0.41
F. ESO_LLT												
Min	0.00	0.06	0.04	0.00	0.04	0.03	0.06	0.07	0.07	0.04	0.16	0.03
0.10	0.16	0.08	0.17	0.10	0.08	0.10	0.10	0.11	0.14	0.19	0.28	0.13
0.20	0.18	0.11	0.23	0.12	0.11	0.13	0.13	0.13	0.16	0.30	0.38	0.18
0.30	0.21	0.15	0.29	0.14	0.14	0.17	0.16	0.14	0.19	0.32	0.41	0.22
0.40	0.22	0.26	0.33	0.16	0.18	0.18	0.17	0.16	0.25	0.35	0.47	0.27
0.50	0.24	0.36	0.38	0.19	0.20	0.22	0.19	0.17	0.30	0.38	0.52	0.32
0.60	0.28	0.47	0.46	0.23	0.23	0.24	0.20	0.20	0.33	0.41	0.54	0.41
0.70	0.32	0.50	0.51	0.28	0.27	0.28	0.22	0.22	0.37	0.48	0.56	0.49
0.80	0.35	0.54	0.58	0.29	0.31	0.31	0.23	0.26	0.42	0.49	0.61	0.54
0.90	0.38	0.62	0.64	0.35	0.34	0.33	0.25	0.31	0.45	0.52	0.63	0.58
Max	0.52	0.68	0.65	0.55	0.39	0.45	0.36	0.35	0.48	0.58	0.66	0.68
Avg	0.26	0.35	0.39	0.21	0.21	0.22	0.19	0.19	0.29	0.38	0.48	0.35

5C.A.4.14 Old and Middle River Flows

The OMR flow restrictions (i.e., minimum flow) are adaptive management rules. The CALSIM modeling assumed that a specified OMR flow restriction would apply for each of the applicable months (December–June) for each water-year type. These assumed restrictions generally were held constant for each of the CALSIM cases. Because south-of-Delta pumping comes from the head of Old River (described above) or from Old and Middle River channels (as reverse flow), the OMR flow restrictions effectively limit south Delta pumping as:

South Delta pumping limit (cfs) = reverse OMR limit (cfs) + head of Old River flow (cfs)

For example if the OMR flow limit is -2,500 cfs and the head of Old River flow is 1,000 cfs, the south Delta pumping limit would be 3,500 cfs. Some flow (about 35% of the monthly net Delta depletion) should be subtracted from the pumping limit to account for CCWD diversions and agricultural diversions in the south Delta.

Table C.A-36 shows the monthly distribution of the assumed minimum OMR flows for each of the six CALSIM cases. A value of -15,000 cfs was used to indicate that there is no OMR restriction for the month. All of the EBC cases would have nearly the same OMR flow limits. Because all of the EBC cases rely exclusively on south Delta exports, the export restrictions caused by these OMR limits would be nearly the same. The December limits would apply to just 2 weeks and the CALSIM model inputs specified a limit of 5,781 cfs in about 30% of the years.

The assumed January limits were -5,000 cfs in about 40% of the years; -4,771 cfs in about 20% of the years; -3,355 cfs in about 20% of the years; and -2,823 cfs in 20% of the years. The assumed February limits were -5,000 cfs in about 60% of the years; -3,500 cfs in about 20% of the years; about -2,750 cfs in 10% of the years; and about -1,500 cfs in 10% of the years. The frequency of assumed restrictions of -5,000 cfs, -3,500 cfs, -2,500 cfs, and -1,250 cfs (the four named flows in the 2008 USFWS BiOp and 2009 NMFS BiOp) was assumed to correspond to water-year type (i.e., arbitrary), but the CALSIM model inputs assumed -5,000 cfs would be the most frequent limit (optimistic for water supply). The -5,000 cfs limit applied to 40% of the January values, 60% of the February values, 50% of the March values, 60% of the April values, 50% of the May values, and 50% of the June values. The assumed April and May OMR values have no effect because the NMFS specified limit of 1,500 cfs (25% of the San Joaquin River inflow if it is greater than 6,000 cfs) is usually the controlling factor.

The magnitude of the export restrictions cannot be simulated accurately with CALSIM because the limits will be adaptively specified by the USFWS smelt working group, based on real-time monitoring of fish and turbidity and temperature conditions. The assumed restrictions provide a representative simulation compared to D-1641 conditions without any OMR restrictions. If the least restrictive OMR flow of -5,000 cfs were allowed for 6 months (January–June), a maximum of 1,800 taf per year could be pumped (assuming the San Joaquin River diversion to Old River satisfied the 35% of the net Delta depletion that is south of the OMR flow stations). But because of the 1,500 cfs limit on exports in April and May (2009 NMFS BiOp), the maximum exports would be 1,400 taf per year. If the OMR restriction was reduced to -2,500 cfs for the 6 months (with 1,500 cfs in April and May), a total of 780 taf could be pumped from the south Delta. This is a very dramatic reduction for the CVP and SWP exports which historically have exported about half (45%) of the total exports during these months. This uncertainty in the potential south Delta exports is a consequence of the adaptive management framework for the 2008 USFWS BiOp and 2009 NMFS BiOp actions regarding OMR flow.

Because CALSIM cannot simulate this range of uncertainty (without giving two answers), the assumed OMR limits were specified for each month of each water-year type. The average CALSIM exports allowed in the January–June period for OMR limits specified in the EBC2_ELT case were 1,477 taf/yr and were 1,432 taf/yr for the EBC2_LLT case. Although the export limits are often just 1,500 cfs for April and May (lower than the OMR limits), the average exports simulated with CALSIM for the EBC2_ELT case in January–June was 1,781 taf/yr, about 300 taf/yr more than the OMR limits because of additional export of the San Joaquin River diversion into Old River. For the EBC2_LLT case, the average CALSIM–simulated exports for January–June were 1,719 taf/yr, about 300 taf/yr more than the OMR limits. The BDCP north Delta intakes are proposed to allow these limits on OMR reverse flows for the protection of estuarine fish (delta smelt and longfin smelt) and limits on south Delta pumping in April and May for the protection of migrating San Joaquin River Chinook and steelhead, while allowing higher total water supply exports during the January–June fish protection period.

The OMR limits for the ESO cases were assumed in CALSIM to be much more restrictive (dependent on water-year type and San Joaquin River inflow). The actual OMR limits would be specified by the USFWS smelt committee based on monitoring, and cannot be simulated with CALSIM. Because these assumed OMR limits apply only to south delta exports, the much more restrictive OMR limits in the October–June period for the ESO cases would not generally restrict total exports, and may not reduce OMR flows compared to the EBC2. The additional OMR restrictions for the ESO cases would shift some fraction of the total exports from the south Delta to the north Delta intakes. As described in the previous section, the split between north Delta intake pumping and south Delta exports can likely be adjusted under the BDCP adaptive management procedures to increase fish protection benefits.

Table C.A-37 shows CALSIM-simulated combined OMR flows for the six CALSIM cases, summarized as the monthly cumulative percentiles for the 1922–2003 CALSIM sequence. Positive flow is north from the export pumping plants near Tracy toward the estuary. Because negative OMR flow is toward the south Delta pumps, the most-negative values indicate higher pumping. The minimum values indicate the maximum diversion of water from the central Delta. For example, the minimum October and November OMR flows for the EBC2 case were -10,000 cfs. The October and November median OMR flows were -8,000 cfs, and the maximum October and November OMR flows were -3,000 cfs and -2,000 cfs. This indicates that reverse OMR flows were high in October and November. The minimum December OMR flow was -9,600 cfs, and the median December OMR flow was -5,871 cfs (the assumed OMR limit in 30% of the years). This suggests that the OMR limits were reducing the December exports to this limit in several of the years. The minimum OMR flow in January–March and June were -5,000 cfs because the assumed OMR limits were restricting pumping to this limit in many of the years in these months. The minimum OMR flows in April and May were higher than the -5,000 cfs limit because the 2009 NMFS BiOp limits on exports of 1,500 cfs or 25% of the San Joaquin River inflow in April and May were reducing the exports more than the OMR limits. The OMR reverse flows in July–September were very high, with minimum flows of -11,000 cfs to -10,000 cfs and median OMR flows of -10,000 cfs to -9,000 cfs.

Table C.A-37 indicates that the ESO_ELT and ESO_LLT cases often would shift pumping from the south Delta to the north Delta intakes, and thereby increase the OMR flows (less reverse flow, more protective of estuarine fish entrainment). The median monthly OMR flows for the ESO_ELT and ESO_LLT cases, compared to the EBC2 caseswere about 1,500 cfs higher in December, about 2,000 cfs higher in January, 2,500 cfs higher in February, 2,000 cfs higher in March, about the same in April and May, and about 1,500 cfs higher in June. As mentioned in the previous section, it may be possible under BDCP adaptive management procedures to reduce the south Delta pumping in these fish protection months whenever there is (1) remaining capacity at the north Delta intakes, (2) no additional fish impacts caused by north Delta diversions and (3) suitable water quality conditions (salinity) in the south Delta channels.

Table C.A-36. CALSIM-Simulated Monthly Cumulative Distribution of Required Minimum (Maximum Reverse) Old and Middle River Flow for 1922–2003[1]

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
10%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
20%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
30%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
40%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
50%	-15,000	-15,000	-15,000	-4,710	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
60%	-15,000	-15,000	-15,000	-4,710	-5,000	-4,516	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
70%	-15,000	-15,000	-5,871	-3,355	-3,527	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
80%	-15,000	-15,000	-5,871	-3,355	-3,500	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
90%	-15,000	-15,000	-5,871	-2,823	-2,750	-1,734	-1,150	-1,150	-1,998	-15,000	-15,000	-15,000
Max	-15,000	-15,000	-5,871	-2,823	-1,531	-1,150	-1,150	-1,150	-1,711	-15,000	-15,000	-15,000
B. ESO_ELT												
Min	-2,564	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-15,000	-15,000	-15,000
10%	-2,491	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-15,000	-15,000	-15,000
20%	-2,430	-5,000	-8,000	-4,710	-4,000	-3,500	-2,000	-1,513	-3,500	-15,000	-15,000	-15,000
30%	-2,399	-5,000	-8,000	-3,850	-3,858	-3,000	-1,386	-1,185	-3,500	-15,000	-15,000	-15,000
40%	-2,377	-5,000	-8,000	-3,500	-3,500	-2,503	-349	-1,150	-3,500	-15,000	-15,000	-15,000
50%	-2,351	-5,000	-5,871	-3,355	-3,500	-1,198	34	-498	-2,376	-15,000	-15,000	-15,000
60%	-2,333	-5,000	-5,387	-2,823	-2,750	-703	232	-90	-2,156	-15,000	-15,000	-15,000
70%	-2,305	-5,000	-5,290	-903	-819	0	337	1	-2,074	-15,000	-15,000	-15,000
80%	-2,279	-5,000	-4,342	-704	0	0	475	264	-685	-15,000	-15,000	-15,000
90%	-2,218	-5,000	-4,129	-7	0	0	2,149	2,308	0	-15,000	-15,000	-15,000
Max	-1,620	-5,000	-3,935	0	0	0	5,660	6,000	2,000	-15,000	-15,000	-15,000
C. ESO_LLT												
Min	-2,564	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-15,000	-15,000	-15,000
10%	-2,495	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-15,000	-15,000	-15,000
20%	-2,447	-5,000	-8,000	-4,710	-4,000	-3,500	-2,000	-1,321	-3,500	-15,000	-15,000	-15,000
30%	-2,416	-5,000	-8,000	-4,000	-4,000	-3,011	-1,451	-1,176	-3,500	-15,000	-15,000	-15,000
40%	-2,383	-5,000	-8,000	-3,500	-3,500	-2,823	-1,150	-1,150	-3,500	-15,000	-15,000	-15,000
50%	-2,359	-5,000	-5,871	-3,355	-3,500	-1,285	-171	-372	-2,359	-15,000	-15,000	-15,000
60%	-2,341	-5,000	-5,387	-2,823	-2,750	-893	232	-90	-2,154	-15,000	-15,000	-15,000
70%	-2,313	-5,000	-5,290	-1,461	-963	-25	348	-7	-2,114	-15,000	-15,000	-15,000
80%	-2,285	-5,000	-4,342	-697	0	0	662	221	-1,243	-15,000	-15,000	-15,000
90%	-2,256	-5,000	-4,129	0	0	0	2,434	1,979	-561	-15,000	-15,000	-15,000
Max	-1,364	-5,000	-3,935	0	0	0	5,648	5,974	2,000	-15,000	-15,000	-15,000

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
10%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
20%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
30%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
40%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
50%	-15,000	-15,000	-15,000	-4,710	-5,000	-5,000	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
60%	-15,000	-15,000	-15,000	-4,710	-5,000	-4,516	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
70%	-15,000	-15,000	-5,871	-3,645	-3,527	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
80%	-15,000	-15,000	-5,871	-3,355	-3,500	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
90%	-15,000	-15,000	-5,871	-2,823	-2,750	-2,024	-1,150	-1,150	-2,069	-15,000	-15,000	-15,000
Max	-15,000	-15,000	-5,871	-2,823	-1,531	-1,150	-1,150	-1,150	-1,801	-15,000	-15,000	-15,000
E. EBC2_ELT												
Min	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
10%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
20%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
30%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
40%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
50%	-15,000	-15,000	-15,000	-4,710	-5,000	-5,000	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
60%	-15,000	-15,000	-15,000	-4,710	-5,000	-3,839	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
70%	-15,000	-15,000	-5,871	-3,645	-3,527	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
80%	-15,000	-15,000	-5,871	-3,355	-3,500	-3,500	-3,500	-1,229	-2,315	-15,000	-15,000	-15,000
90%	-15,000	-15,000	-5,871	-2,823	-2,750	-2,024	-1,150	-1,150	-2,051	-15,000	-15,000	-15,000
Max	-15,000	-15,000	-5,871	-2,823	-1,249	-1,150	-1,150	-1,150	-1,788	-15,000	-15,000	-15,000
F. EBC2_LLT												
Min	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
10%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
20%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
30%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-5,000	-5,000	-15,000	-15,000	-15,000
40%	-15,000	-15,000	-15,000	-5,000	-5,000	-5,000	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
50%	-15,000	-15,000	-15,000	-4,710	-5,000	-5,000	-5,000	-3,500	-3,500	-15,000	-15,000	-15,000
60%	-15,000	-15,000	-15,000	-4,710	-5,000	-3,790	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
70%	-15,000	-15,000	-5,871	-3,355	-3,500	-3,500	-3,500	-3,500	-3,500	-15,000	-15,000	-15,000
80%	-15,000	-15,000	-5,871	-3,355	-3,500	-3,016	-3,500	-1,150	-2,163	-15,000	-15,000	-15,000
90%	-15,000	-15,000	-5,871	-2,823	-2,750	-1,328	-1,150	-1,150	-2,051	-15,000	-15,000	-15,000
Max	-15,000	-15,000	-5,871	-2,823	-1,249	-1,150	-1,150	-1,150	-1,667	-15,000	-15,000	-15,000

[1] A value of -15,000 cfs was used to indicate that there is no OMR restriction for the month.

Table C.A-37. CALSIM-Simulated Monthly Distribution of Old and Middle River Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	-10,083	-10,146	-9,616	-5,000	-5,000	-5,000	-1,399	-1,769	-5,000	-11,487	-11,104	-10,072	-4,702
10%	-9,984	-9,897	-9,357	-5,000	-5,000	-5,000	-1,006	-1,150	-5,000	-11,263	-10,976	-9,914	-4,479
20%	-9,702	-9,810	-8,916	-5,000	-5,000	-5,000	-410	-702	-5,000	-11,166	-10,850	-9,742	-4,344
30%	-9,226	-9,629	-7,836	-5,000	-5,000	-5,000	-208	-495	-5,000	-11,117	-10,762	-9,588	-4,254
40%	-8,610	-8,782	-7,025	-4,898	-4,780	-4,537	182	-184	-4,950	-10,955	-10,588	-9,205	-4,148
50%	-8,044	-8,183	-5,871	-4,710	-4,165	-3,645	675	74	-3,500	-10,680	-10,400	-8,899	-4,014
60%	-6,974	-7,412	-5,871	-3,355	-3,500	-3,500	1,053	516	-3,500	-10,164	-10,278	-8,430	-3,728
70%	-6,480	-6,536	-5,871	-3,355	-2,776	-2,024	1,450	685	-3,500	-9,354	-9,737	-8,115	-3,393
80%	-5,641	-5,725	-5,729	-2,823	-2,268	-1,501	1,707	1,036	-2,223	-8,732	-7,732	-7,143	-3,068
90%	-4,606	-4,615	-4,552	-2,636	-742	-288	2,990	2,088	-1,975	-6,611	-4,516	-4,491	-2,419
Max	-3,179	-1,923	5,341	27,085	12,907	24,802	6,283	5,987	3,088	-11	-1,146	-3,489	2,222
Avg	-7,568	-7,592	-6,513	-3,449	-3,158	-2,758	843	353	-3,780	-9,715	-9,283	-8,236	-3,687
B. ESO_ELT													
Min	-2,526	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-14,049	-11,934	-9,090	-3,647
10%	-2,279	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-11,514	-9,736	-4,389	-2,738
20%	-2,234	-4,624	-7,795	-3,500	-3,932	-3,000	-2,000	-1,311	-3,500	-10,109	-7,479	-4,211	-2,457
30%	-2,205	-4,189	-6,321	-3,355	-3,500	-2,158	-1,150	-1,150	-3,500	-9,057	-6,511	-3,987	-2,280
40%	-2,153	-3,910	-5,484	-3,114	-2,766	-1,288	-306	-884	-2,888	-8,026	-5,088	-3,874	-2,168
50%	-2,070	-3,620	-5,290	-2,823	-2,128	-932	34	-498	-2,220	-6,715	-4,731	-3,682	-1,969
60%	-1,971	-1,129	-5,046	-1,046	-646	-156	232	-90	-2,081	-5,355	-4,235	-69	-1,816
70%	-1,670	437	-4,255	-710	0	0	337	1	-1,360	-4,313	-3,917	536	-1,478
80%	-1,059	809	-3,955	-134	1,385	1,449	475	264	-607	-3,062	-3,459	759	-857
90%	-658	973	-3,226	1,700	4,884	4,398	2,218	2,308	0	-2,105	-3,158	932	-169
Max	1,109	7,262	15,917	41,143	22,272	31,220	11,078	12,180	9,269	2,153	-2,324	1,926	7,159
Avg	-1,700	-2,143	-4,906	-1,042	-323	337	132	101	-1,922	-6,777	-5,602	-2,019	-1,577
C. ESO_LLT													
Min	-2,531	-5,000	-8,000	-5,000	-4,000	-3,500	-2,000	-2,000	-3,500	-13,965	-12,268	-7,940	-3,483
10%	-2,415	-5,000	-8,000	-4,971	-4,000	-3,500	-2,000	-1,791	-3,500	-11,002	-9,256	-4,841	-2,584
20%	-2,343	-4,457	-7,810	-3,500	-3,864	-2,991	-1,844	-1,190	-3,500	-9,770	-7,109	-4,410	-2,259
30%	-2,247	-4,117	-5,977	-3,355	-2,968	-2,304	-1,150	-1,150	-3,500	-8,479	-5,637	-3,918	-2,117
40%	-2,107	-3,817	-5,387	-3,286	-2,691	-1,453	-386	-738	-2,273	-7,415	-4,901	-3,227	-1,958
50%	-1,978	-3,503	-5,145	-2,823	-1,587	-911	-37	-296	-2,138	-5,783	-4,534	-1,903	-1,775
60%	-1,664	-79	-4,323	-1,032	-636	-379	237	-85	-1,867	-4,963	-4,198	233	-1,632
70%	-195	714	-4,129	-702	0	0	376	29	-1,378	-4,232	-3,771	626	-1,306
80%	203	838	-3,936	-210	477	1,265	662	381	-1,093	-2,900	-3,265	798	-878
90%	452	994	-2,222	462	2,766	5,097	2,434	1,979	-520	-1,855	-2,783	890	-261
Max	768	5,503	14,235	38,533	23,131	32,580	11,083	12,577	6,869	-983	-1,979	2,038	6,291
Avg	-1,333	-2,013	-4,764	-1,097	-570	333	181	148	-1,981	-6,373	-5,221	-1,819	-1,493

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	-10,349	-10,493	-10,021	-5,000	-5,000	-5,000	-1,393	-1,754	-5,000	-11,752	-11,299	-10,386	-4,522
10%	-8,167	-9,916	-9,687	-5,000	-5,000	-5,000	-1,008	-1,150	-5,000	-11,363	-11,173	-9,992	-4,245
20%	-7,467	-8,671	-9,164	-5,000	-5,000	-5,000	-532	-681	-5,000	-11,327	-11,080	-9,579	-4,112
30%	-6,488	-7,274	-8,513	-5,000	-5,000	-5,000	-219	-516	-5,000	-11,105	-10,899	-9,250	-3,989
40%	-5,877	-6,125	-7,585	-4,710	-4,947	-4,738	152	-232	-4,666	-10,811	-10,696	-8,787	-3,855
50%	-5,663	-5,634	-6,406	-4,710	-4,143	-3,790	681	122	-3,500	-10,507	-10,389	-8,361	-3,704
60%	-5,489	-5,039	-5,871	-3,355	-3,500	-3,500	1,046	381	-3,500	-10,030	-10,220	-7,898	-3,559
70%	-5,136	-4,600	-5,871	-3,355	-2,776	-2,823	1,445	630	-3,500	-9,410	-9,791	-6,867	-3,271
80%	-4,764	-3,692	-5,871	-2,823	-2,268	-1,506	1,710	988	-2,314	-8,358	-7,568	-5,564	-3,009
90%	-4,134	-3,157	-4,425	-2,823	-1,151	-781	2,947	1,943	-2,033	-6,433	-3,876	-4,070	-2,328
Max	-3,157	-2,222	5,490	24,928	14,644	24,301	4,951	3,952	1,518	-1,478	-1,306	-2,947	1,307
Avg	-6,019	-5,990	-6,768	-3,504	-3,188	-2,855	799	267	-3,761	-9,603	-9,184	-7,691	-3,485
E. EBC2_ELT													
Min	-10,424	-10,543	-9,883	-5,000	-5,000	-5,000	-1,960	-1,711	-5,000	-11,744	-11,328	-10,339	-4,481
10%	-7,064	-9,164	-9,579	-5,000	-5,000	-5,000	-1,150	-1,373	-5,000	-11,256	-11,173	-9,960	-4,116
20%	-6,015	-7,870	-8,944	-5,000	-5,000	-5,000	-827	-1,117	-5,000	-10,962	-11,028	-9,707	-3,943
30%	-5,722	-6,996	-8,428	-5,000	-5,000	-5,000	-511	-711	-5,000	-10,694	-10,863	-9,018	-3,805
40%	-5,494	-6,062	-6,877	-4,710	-4,801	-4,226	-207	-445	-3,774	-10,236	-10,712	-8,412	-3,707
50%	-5,267	-5,222	-5,871	-4,710	-3,631	-3,500	659	207	-3,500	-9,745	-10,399	-8,101	-3,612
60%	-4,867	-5,068	-5,871	-3,355	-3,500	-3,489	956	366	-3,500	-9,238	-9,751	-7,493	-3,385
70%	-4,426	-4,688	-5,871	-3,355	-2,776	-2,823	1,412	620	-3,138	-8,458	-8,012	-6,007	-3,096
80%	-4,024	-4,215	-5,529	-2,823	-2,268	-1,328	1,814	1,244	-2,309	-7,667	-7,427	-4,368	-2,730
90%	-3,437	-4,007	-3,708	-1,955	-235	-759	3,106	2,493	-2,022	-6,071	-2,887	-3,950	-2,302
Max	-1,765	-1,223	8,920	30,312	16,257	25,714	5,298	4,252	1,439	-1,851	-1,436	-2,692	1,381
Avg	-5,248	-5,970	-6,464	-3,373	-3,006	-2,691	715	262	-3,632	-9,110	-8,861	-7,423	-3,321
F. EBC2_LLT													
Min	-8,830	-10,393	-9,883	-5,000	-5,000	-5,000	-1,823	-1,802	-5,000	-11,763	-11,270	-10,442	-4,204
10%	-6,053	-9,876	-9,564	-5,000	-5,000	-5,000	-1,107	-1,325	-5,000	-10,857	-11,161	-10,128	-3,984
20%	-5,600	-7,061	-9,001	-5,000	-5,000	-5,000	-796	-1,150	-5,000	-10,454	-11,028	-9,430	-3,812
30%	-5,268	-6,432	-8,234	-4,794	-5,000	-5,000	-521	-920	-4,442	-10,162	-10,785	-8,480	-3,610
40%	-4,939	-6,103	-6,489	-4,710	-4,170	-3,790	-207	-447	-3,500	-9,931	-10,493	-7,916	-3,456
50%	-4,571	-5,116	-5,871	-4,477	-3,527	-3,500	372	-3	-3,500	-9,401	-9,971	-6,749	-3,284
60%	-4,105	-4,541	-5,871	-3,355	-3,500	-2,823	725	291	-3,500	-8,474	-8,952	-5,693	-3,173
70%	-3,793	-4,342	-5,594	-3,355	-2,750	-1,969	1,373	497	-2,886	-7,737	-7,548	-4,930	-2,823
80%	-3,115	-4,052	-4,118	-2,823	-2,233	-1,150	1,932	953	-2,071	-6,289	-6,581	-4,340	-2,631
90%	-2,306	-2,932	-3,109	-1,903	-652	-514	3,344	2,437	-2,019	-3,901	-3,487	-3,948	-1,967
Max	-837	-1,722	6,559	31,614	15,185	25,900	5,269	5,017	-967	-1,100	-1,187	-2,699	1,086
Avg	-4,427	-5,636	-6,155	-3,228	-2,964	-2,487	659	155	-3,504	-8,473	-8,604	-6,868	-3,122

5C.A.4.15 San Joaquin River at QWEST and Antioch Flows

Table C.A-38 shows the CALSIM-calculated "net" San Joaquin River flow at QWEST. The QWEST net San Joaquin River flow is simply the difference between the Delta outflow and the Sacramento River flow at Rio Vista (the San Joaquin River contribution to Delta outflow). The QWEST flow is generally positive, but it may be reversed during periods with high exports (and reversed OMR flow) during the summer and fall period without OMR restrictions. The QWEST flow is reduced considerably by closing the DCC gates; the DCC gates are assumed to be closed for half of October and November and fully closed from December through June for all of the CALSIM cases. Periods of negative QWEST may have effects on salinity intrusion in the lower San Joaquin River (central Delta), and may have effects on the entrainment risk of estuarine fish in the low salinity zone near the confluence (during period of low Delta outflow).

The median QWEST flows for the EBC2 were near 0 cfs in October, reversed at -250 cfs in November and reversed at -2,500 cfs in December (DCC closed). The median QWEST flows for the EBC2 were about 2,000 cfs in January, about 4,500 cfs in February, about 4,500 cfs in March, about 7,000 cfs in April, About 5,500 cfs in May, and about 1,750 cfs in June (months with OMR restrictions on exports). The median monthly flows for the EBC2 were reversed at about -3,000 cfs in July; about -4,000 cfs in August; and about -2,250 cfs in September. The QWEST flows for the EBC2_ELT and EBC2_LLT were similar to the EBC2 case in most months. The QWEST flows were increased considerably with the ESO cases because the reduction in south Delta exports will increase QWEST flow by the same amount. Figure C.A-71 shows the QWEST flows for the six CALSIM cases for 1963–2003. The historical QWEST is shown for comparison. QWEST has usually been negative in the summer and fall months of most years, and for longer periods during dry years when exports are a larger fraction of the inflows. Figure C.A-72 shows the monthly QWEST for the six CALSIM cases for 1994–2003. The periods of negative QWEST have increased with the more frequent closure of the DCC (since 1995). The median monthly QWEST flows were increased for the ESO cases because the south Delta pumping was generally reduced. There were no major changes in the April and May QWEST flows; the south Delta pumping was not reduced in these months because it was already limited to 1,500 cfs in most years for the EBC2 cases. Although the QWEST values were increased by 1,000 cfs to 3,000 cfs in the months of July–September for the ESO cases, the QWEST flows were negative (reversed) in these months.

Table C.A-38 shows the monthly cumulative distributions fo the San Joaquin River flow at Antioch, estimated by adding the Threemile Slough flow (from the Sacramento River) to the QWEST flow values. The monthly median Antioch flows were about 1,500 cfs to 2,500 cfs more than the QWEST flows, because the Threemile Slough flows are generally between 1,500 cfs and 2,500 cfs. The Antioch flows are almost always greater than the QWEST flows. Periods of negative San Joaquin River flow at Antioch may be a better indicator of salinity intrusion effects in the lower San Joaquin River (central Delta), and may better reflect the effects on entrainment of estuarine fish near the confluence during period of low Delta outflow. The Antioch and QWEST flows could be adjusted under the BDCP adaptive management procedures, by opening the DCC or reducing the south delta exports when fish monitoring indicates that estuarine fish near the confluence may be at risk to south Delta entrainment. 0 cfs in October and November and were reversed at -2,000 cfs only in December. The QWEST flows were about 1,500 cfs in January; 8,500 cfs in February; 6,500 cfs in March; 3,000 cfs in April; 2,500 cfs in May and June; 1,000 cfs in July; 500 cfs in August; and 150 cfs in September. The summer periods of reverse QWEST generally were eliminated by the proposed north Delta intake diversions.

Table C.A-38. CALSIM-Simulated Monthly Distribution of Net San Joaquin River (QWEST) Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	-5,298	-6,080	-6,428	-2,619	-1,870	-1,382	882	-278	-1,013	-5,954	-5,330	-3,800	-1,411
10%	-4,025	-4,270	-5,217	-1,462	-638	-134	1,640	856	445	-5,510	-4,896	-3,308	-774
20%	-3,587	-3,845	-4,815	-1,182	455	920	2,860	2,007	669	-5,287	-4,792	-3,115	-467
30%	-2,686	-3,098	-3,767	-434	1,506	1,731	3,989	2,429	753	-4,510	-4,628	-2,932	-88
40%	-1,770	-2,788	-2,921	830	3,252	2,746	5,535	3,737	1,087	-4,187	-4,438	-2,751	263
50%	-1,404	-2,328	-2,210	2,041	4,843	3,567	6,862	5,648	1,607	-3,555	-4,182	-2,438	607
60%	-921	-1,860	-1,549	3,554	6,850	4,490	8,564	6,656	2,009	-2,996	-3,709	-2,009	1,377
70%	-379	-1,212	-893	6,447	10,122	7,013	10,193	7,735	2,429	-2,291	-2,751	-1,524	2,402
80%	52	-735	1,548	10,964	12,179	11,288	13,258	9,886	4,693	-1,488	-2,047	-395	3,435
90%	93	1,219	7,072	16,469	19,289	17,797	21,124	19,298	8,234	1,169	49	127	5,294
Max	1,188	20,239	34,937	79,644	46,563	69,293	36,954	32,516	28,900	17,761	6,472	4,731	18,570
Avg	-1,667	-1,603	-86	5,921	7,978	7,089	8,874	7,227	3,198	-2,491	-3,210	-1,874	1,744
B. ESO_ELT													
Min	73	-1,853	-4,954	-2,382	-413	-334	465	126	398	-11,850	-5,703	-3,628	-24
10%	2,381	-869	-4,081	-281	620	700	1,546	934	850	-4,607	-3,936	78	536
20%	2,680	-21	-3,632	1,187	1,119	1,388	2,060	1,470	1,334	-3,839	-2,225	110	763
30%	3,165	52	-2,667	1,740	2,127	2,251	2,404	2,203	1,656	-2,405	-1,553	126	961
40%	3,487	87	-1,951	3,175	3,783	3,385	4,733	3,274	2,112	-1,551	-480	139	1,211
50%	3,629	457	-1,142	4,150	5,753	6,396	6,232	5,011	2,298	-766	-218	164	2,328
60%	3,994	4,030	-682	5,333	10,669	9,338	7,145	6,336	2,696	-24	218	5,883	3,306
70%	4,496	4,815	-40	8,516	14,923	11,179	9,435	6,745	3,129	1,108	569	8,484	4,452
80%	4,982	5,637	1,820	12,199	19,494	17,742	12,391	10,176	6,661	1,302	747	9,327	6,714
90%	5,607	6,848	8,933	22,710	29,291	23,582	20,086	18,898	11,778	3,103	912	9,697	8,880
Max	9,598	30,158	49,568	98,428	57,987	76,059	42,986	37,509	32,458	17,607	4,738	11,699	22,816
Avg	3,799	2,923	1,460	8,643	11,363	10,282	8,447	7,436	4,577	-717	-768	3,918	3,671
C. ESO_LLT													
Min	1,244	-1,993	-4,993	-2,375	-449	-287	403	152	27	-10,366	-5,193	-2,790	187
10%	1,918	-645	-4,103	84	304	900	1,707	1,029	1,028	-4,481	-3,284	-77	738
20%	2,409	-26	-3,734	1,563	1,608	1,651	2,145	1,583	1,803	-2,486	-1,839	118	954
30%	2,805	52	-2,252	2,468	2,622	2,321	2,760	2,305	2,043	-1,593	-715	144	1,160
40%	3,287	94	-1,369	3,115	4,534	3,368	4,201	3,232	2,219	-901	-256	894	1,492
50%	3,714	683	-801	3,719	6,008	5,170	5,995	4,660	2,518	-124	10	3,284	2,253
60%	4,053	4,424	-476	4,813	10,724	7,921	7,022	6,034	3,004	843	441	6,786	3,124
70%	5,294	5,381	986	9,139	14,286	11,158	9,349	6,883	3,848	1,250	678	8,742	4,711
80%	6,141	6,125	2,357	12,124	18,275	16,120	12,443	8,817	5,261	1,633	869	9,807	6,275
90%	6,542	6,713	7,403	23,292	27,330	25,099	20,006	16,635	10,023	2,229	1,224	10,190	8,023
Max	9,444	25,885	45,906	96,415	60,108	78,691	42,831	37,885	28,465	7,270	1,906	12,541	21,779
Avg	4,057	2,813	1,389	8,707	11,037	10,275	8,447	7,089	4,165	-579	-453	4,408	3,673

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	-6,180	-5,199	-7,468	-2,448	-1,906	-1,687	878	14	-714	-6,057	-5,488	-5,705	-1,162
10%	-2,189	-3,967	-5,517	-1,405	-693	-494	1,637	851	420	-5,533	-5,071	-4,295	-536
20%	-1,110	-2,411	-4,969	-1,074	401	683	2,941	1,835	623	-4,705	-4,948	-3,500	-113
30%	-519	-1,477	-4,331	-36	1,555	1,713	3,959	2,461	805	-4,405	-4,727	-3,149	170
40%	32.1	-770	-3,355	833	2,853	2,521	5,512	3,568	1,250	-3,878	-4,377	-2,766	483
50%	66.9	-238	-2,627	2,108	4,598	3,540	6,972	5,588	1,723	-3,146	-3,973	-2,300	755
60%	335.7	284	-1,592	3,577	6,632	4,501	8,148	6,635	2,042	-2,762	-3,622	-1,735	1,318
70%	681.3	643	-803	6,025	9,610	6,828	10,182	7,630	2,423	-2,308	-2,941	-441	2,373
80%	1,025	1,373	1,220	11,069	12,477	10,569	13,277	10,302	4,447	-737	-1,861	126	3,681
90%	1,805	3,056	7,393	16,732	19,596	15,716	21,164	19,159	8,057	1,296	923	236	5,532
Max	3,130	19,841	35,058	77,316	48,365	68,720	36,927	30,067	26,951	21,154	4,796	8,055	17,794
Avg	-111	-76.1	-442	5,779	7,862	6,859	8,830	7,084	3,144	-2,267	-3,142	-1,595	1,900
E. EBC2_ELT													
Min	-4,695	-5,327	-6,309	-2,651	-1,911	-1,710	860	148	-866	-5,689	-5,372	-5,305	-872
10%	-650	-3,350	-5,305	-1,530	-592	220	1,623	805	534	-4,727	-5,153	-4,417	-377
20%	-10	-2,388	-4,716	-1,121	379	958	2,252	1,110	760	-4,110	-4,926	-3,349	-10
30%	63	-1,440	-4,217	-44	1,664	1,410	3,422	2,247	1,084	-3,836	-4,762	-2,803	258
40%	78	-583	-3,181	737	2,792	2,305	4,902	3,328	1,273	-3,261	-4,127	-2,359	514
50%	322	-58	-2,222	2,012	4,730	3,422	6,602	5,146	1,526	-2,533	-3,944	-1,696	841
60%	1,086	64	-1,315	3,499	7,339	4,855	7,939	6,250	1,938	-1,858	-3,392	-962	1,510
70%	1,437	258	-369	6,079	11,418	6,674	10,006	7,274	2,274	-1,508	-2,334	-69	2,678
80%	1,923	823	1,534	11,084	13,062	11,345	13,504	9,463	3,241	-508	-1,806	122	4,036
90%	2,488	2,513	7,596	17,405	22,122	17,243	20,518	18,537	6,186	903	1,571	1,042	6,054
Max	4,487	22,144	43,114	88,104	52,396	71,000	38,312	30,323	25,113	13,138	2,298	6,903	17,916
Avg	653	-154	216	6,234	8,579	7,166	8,632	7,033	2,697	-2,078	-3,080	-1,421	2,054
F. EBC2_LLT													
Min	-2,655	-5,440	-6,171	-1,940	-1,621	-1,660	893	-65	-359	-8,470	-5,409	-5,002	-619
10%	-99	-4,002	-5,263	-1,466	-415	325	1,683	1,067	763	-4,731	-5,169	-3,365	-123
20%	204	-1,757	-4,785	-933	670	1,010	2,390	1,238	1,158	-3,919	-4,725	-2,932	120
30%	526	-1,215	-3,802	47	2,109	1,649	3,207	1,833	1,449	-3,083	-4,405	-2,221	599
40%	933	-496	-2,314	751	2,975	2,685	4,345	3,089	1,741	-2,536	-4,026	-1,460	732
50%	1,362	16	-1,377	2,361	4,763	3,359	6,272	4,620	1,969	-1,956	-3,687	-1,235	1,022
60%	1,883	110	-265	4,004	7,594	5,192	7,322	5,854	2,196	-1,237	-3,120	-667	1,596
70%	2,484	543	485	6,290	11,042	7,150	9,859	6,388	2,366	-421	-1,765	-61	2,881
80%	2,782	1,207	1,641	11,699	13,190	10,839	13,494	9,094	2,673	547	-550	115	3,753
90%	3,258	2,512	7,064	17,461	21,369	17,646	20,218	16,434	3,752	1,637	862	925	5,843
Max	5,460	17,876	38,836	90,254	52,773	72,724	38,129	30,692	17,283	5,196	2,771	7,774	17,279
Avg	1,490	-100	312	6,553	8,587	7,442	8,497	6,449	2,581	-1,644	-2,830	-1,015	2,167

Table C.A-39. Estimated Monthly Distribution of San Joaquin River at Antioch Flow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	-2,742	-3,461	-3,751	-716	-26	481	2,228	1,248	648	-3,392	-2,904	-1,675	-62
10%	-1,826	-1,954	-2,769	305	1,074	1,426	2,912	2,193	1,869	-3,005	-2,535	-1,297	509
20%	-1,402	-1,645	-2,375	631	2,077	2,398	4,206	3,194	2,035	-2,819	-2,454	-1,132	811
30%	-787	-1,108	-1,567	1,252	2,892	3,102	4,888	3,577	2,108	-2,116	-2,328	-1,020	1,063
40%	-63	-620	-940	2,568	4,322	3,798	6,211	4,642	2,316	-1,867	-2,179	-853	1,392
50%	228	-270	-197	3,611	6,357	4,908	7,534	6,580	2,828	-1,350	-1,979	-581	1,682
60%	635	9	393	5,769	8,405	6,024	8,708	7,483	3,222	-897	-1,605	-268	2,496
70%	1,117	466	1,051	7,746	11,467	8,286	10,240	8,378	3,632	-330	-821	251	3,217
80%	1,392	1,005	3,442	13,002	14,332	13,113	13,385	9,819	5,490	304	-259	1,160	4,484
90%	1,462	2,371	9,225	16,789	19,295	18,164	19,927	18,247	8,572	2,423	1,406	1,469	5,994
Max	2,316	19,984	34,242	74,147	44,261	65,070	35,366	30,010	26,888	16,822	7,028	5,769	17,771
Avg	61	227	1,852	7,326	9,276	8,287	9,362	7,811	4,277	-473	-1,169	-81	2,796
B. ESO_ELT													
Min	1,467	-85	-2,626	-521	1,168	1,204	1,889	1,505	1,832	-8,056	-3,203	-1,557	1,084
10%	3,349	677	-1,903	1,302	2,009	2,192	2,780	2,277	2,205	-2,187	-1,779	1,418	1,540
20%	3,657	1,369	-1,555	2,511	2,512	2,754	3,276	2,703	2,581	-1,529	-390	1,450	1,716
30%	4,027	1,437	-599	3,233	3,494	3,597	3,549	3,328	2,865	-419	155	1,466	1,891
40%	4,322	1,464	-51	4,297	5,107	4,490	5,596	4,235	3,223	251	1,024	1,479	2,186
50%	4,463	1,824	564	5,254	6,972	7,408	6,827	5,708	3,409	879	1,224	1,504	3,156
60%	4,780	4,770	1,028	6,414	11,753	9,499	7,604	6,905	3,749	1,591	1,558	6,379	4,115
70%	5,165	5,554	1,686	9,883	15,426	11,704	9,528	7,219	4,137	2,339	1,865	8,740	5,066
80%	5,567	6,258	3,561	13,259	19,468	17,405	12,551	10,078	7,038	2,527	2,007	9,437	7,049
90%	6,094	7,221	10,377	21,747	27,684	23,265	19,198	17,854	11,415	4,065	2,135	9,741	8,983
Max	9,480	28,260	47,251	90,181	54,267	70,976	40,425	33,850	29,362	16,219	5,356	11,323	21,192
Avg	4,578	3,952	3,116	9,554	12,068	10,854	8,903	7,871	5,345	946	788	4,740	4,359
C. ESO_LLT													
Min	2,485	-235	-2,662	-513	1,154	1,329	1,840	1,522	1,420	-6,811	-2,716	-874	1,269
10%	3,006	880	-1,924	1,641	1,876	2,390	3,005	2,302	2,322	-2,063	-1,246	1,319	1,749
20%	3,430	1,363	-1,592	3,035	2,962	2,982	3,323	2,825	2,979	-535	-72	1,458	1,913
30%	3,817	1,437	-359	3,895	3,765	3,579	3,886	3,486	3,183	234	836	1,525	2,118
40%	4,156	1,473	394	4,382	5,832	4,537	5,181	4,306	3,359	799	1,221	2,143	2,340
50%	4,567	2,041	849	4,716	6,947	6,184	6,606	5,399	3,581	1,402	1,428	4,196	3,086
60%	4,840	5,281	1,263	5,814	11,375	8,598	7,480	6,613	4,006	2,239	1,798	7,167	3,988
70%	5,861	6,049	2,734	10,193	14,199	11,626	9,459	7,348	4,776	2,460	1,949	8,944	5,342
80%	6,563	6,581	4,020	13,324	18,690	16,723	12,482	9,028	5,896	2,927	2,134	9,886	6,864
90%	6,877	7,061	9,030	23,465	27,099	23,954	18,971	15,768	10,010	3,280	2,404	10,197	8,289
Max	9,312	24,381	44,207	88,796	56,301	73,298	40,269	33,923	25,559	7,536	2,970	12,102	20,313
Avg	4,835	3,852	3,023	9,629	11,830	10,871	8,906	7,557	4,999	1,066	1,052	5,174	4,365

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	-3,563	-2,783	-4,615	-565	-51	181	2,203	1,431	904	-3,471	-3,032	-2,790	179
10%	-524	-1,741	-2,936	391	1,034	1,126	2,929	2,192	1,854	-3,019	-2,683	-1,623	693
20%	496	-558	-2,607	769	1,953	2,254	4,091	3,047	1,979	-2,302	-2,580	-1,315	1,067
30%	988	323	-2,010	1,572	2,809	3,080	4,871	3,585	2,107	-2,017	-2,423	-1,118	1,253
40%	1,396	923	-1,306	2,565	3,905	3,721	6,213	4,483	2,438	-1,745	-2,170	-843	1,524
50%	1,437	1,357	-575	3,506	6,124	4,845	7,501	6,527	2,930	-1,021	-1,836	-98	1,927
60%	1,655	1,807	297	5,108	8,327	5,866	8,632	7,282	3,206	-775	-1,541	218	2,536
70%	1,973	2,155	1,065	7,422	10,886	8,062	10,250	8,302	3,541	-331	-973	1,342	3,262
80%	2,205	2,886	3,173	11,976	14,762	12,017	13,438	10,058	5,311	761	-93	1,475	4,601
90%	2,943	4,042	9,151	16,775	19,325	17,275	19,972	18,122	8,418	2,562	2,148	2,045	6,226
Max	4,050	19,669	34,343	72,199	45,778	64,593	35,351	27,940	25,234	19,486	5,617	8,466	17,099
Avg	1,351	1,539	1,526	7,187	9,154	8,078	9,325	7,683	4,229	-290	-1,115	273	2,928
E. EBC2_ELT													
Min	-2,336	-2,886	-3,699	-728	-55	156	2,193	1,526	768	-3,149	-2,937	-2,442	383
10%	1,008	-1,177	-2,895	255	1,119	1,822	2,888	2,199	1,929	-2,358	-2,768	-1,715	807
20%	1,395	-514	-2,418	706	1,900	2,366	3,399	2,410	2,079	-1,811	-2,594	-1,282	1,180
30%	1,434	209	-1,841	1,611	2,867	2,901	4,482	3,430	2,313	-1,556	-2,419	-786	1,359
40%	1,450	1,064	-1,110	2,382	4,022	3,451	5,820	4,305	2,560	-1,120	-2,029	-397	1,542
50%	1,676	1,371	-294	3,636	6,388	4,829	7,237	5,932	2,759	-540	-1,785	-8	1,929
60%	2,309	1,442	660	5,355	8,517	6,117	8,321	7,021	3,115	24	-1,332	586	2,611
70%	2,669	1,819	1,311	7,605	12,364	8,094	10,020	7,866	3,370	445	-511	1,213	3,457
80%	3,057	2,310	3,756	12,416	15,659	12,700	12,938	9,470	4,196	1,222	-73	1,460	4,843
90%	3,520	3,578	9,533	17,978	22,314	17,775	19,590	17,596	7,174	2,257	2,680	2,197	6,683
Max	5,298	21,753	42,022	81,749	49,728	66,883	36,685	28,026	23,409	12,615	3,286	7,445	17,221
Avg	1,992	1,471	2,122	7,628	9,844	8,372	9,157	7,610	3,816	-130	-1,073	408	3,065
F. EBC2_LLT													
Min	-192	-2,888	-3,582	-107	191	197	2,236	1,352	1,206	-5,217	-2,967	-2,190	626
10%	1,363	-1,597	-2,884	341	1,265	1,848	2,931	2,354	2,112	-2,388	-2,759	-1,201	1,070
20%	1,665	9	-2,441	788	2,212	2,411	3,560	2,564	2,445	-1,760	-2,407	-736	1,228
30%	1,898	509	-1,528	1,810	3,253	3,041	4,227	3,135	2,702	-925	-2,096	-140	1,618
40%	2,250	1,235	-349	2,406	4,144	3,711	5,337	4,181	2,957	-577	-1,802	184	1,737
50%	2,569	1,431	536	3,876	6,536	4,658	6,838	5,415	3,182	-35	-1,554	613	2,008
60%	3,037	1,558	1,326	5,790	8,615	6,552	8,085	6,434	3,325	606	-953	902	2,684
70%	3,516	2,101	1,891	7,623	12,091	8,308	9,989	6,911	3,526	1,313	-81	1,322	3,615
80%	3,761	2,492	3,594	13,197	15,703	12,335	13,048	9,022	3,807	1,950	947	1,476	4,707
90%	4,226	3,611	8,981	18,162	22,521	18,779	19,126	15,714	4,651	2,743	2,118	2,227	6,415
Max	6,013	17,925	38,476	83,858	50,358	68,510	36,499	28,093	16,499	5,825	3,691	8,234	16,662
Avg	2,718	1,495	2,157	7,931	9,881	8,631	9,041	7,078	3,710	243	-858	744	3,160

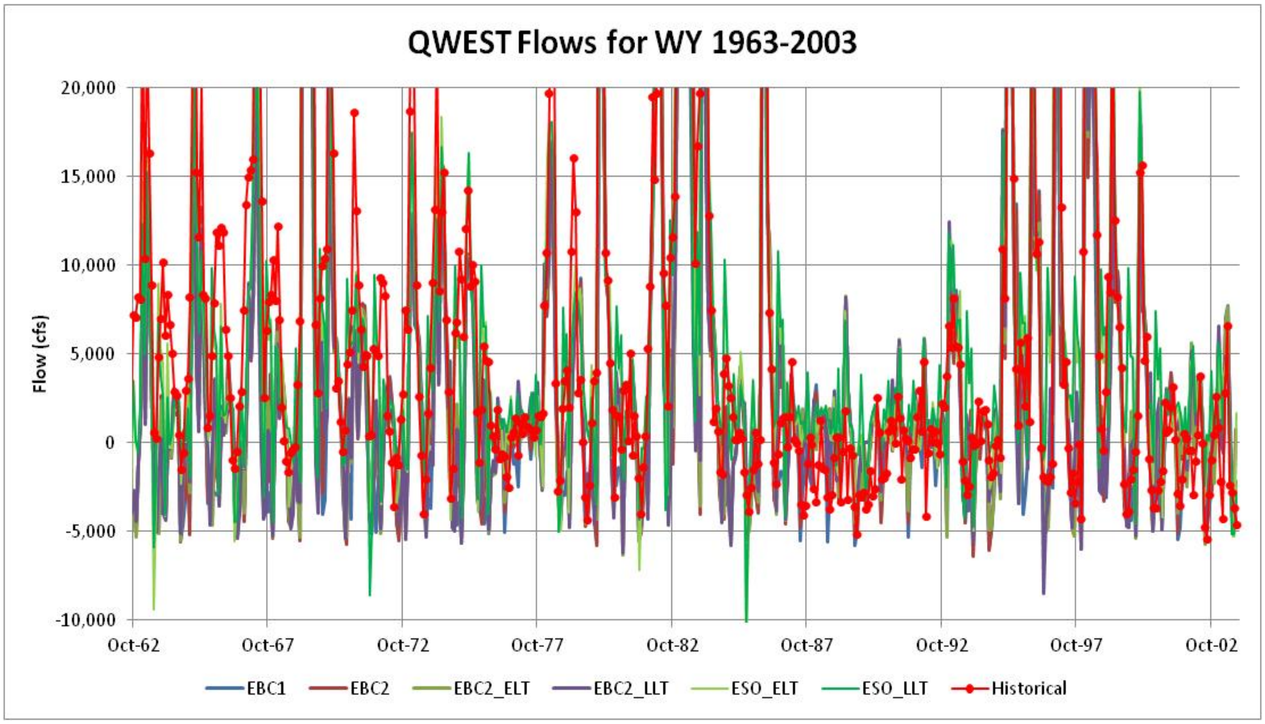


Figure C.A-71. CALSIM-Simulated Monthly QWEST for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

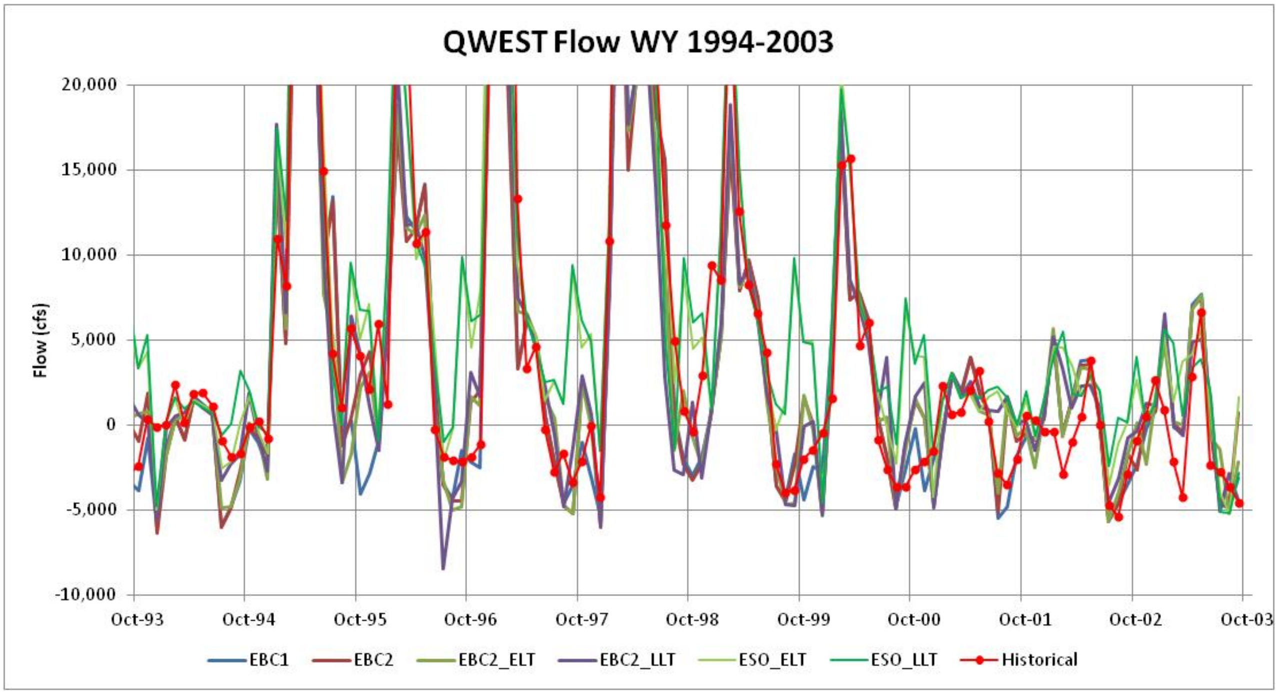


Figure C.A-72. CALSIM-Simulated Monthly QWEST for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.4.16 Delta Outflow and X2

The CALSIM-simulated Delta outflow is the "final outcome" of all of the upstream and Delta operations and is the major link with salinity in the Delta and with the X2 position (salinity gradient). D-1641 has specified Delta outflow in all months; during the February–June period, the required Delta outflow is calculated from the required number of days that X2 must be downstream of three EC measurements locations (Collinsville at 81 kilometers [km], Chipps Island at 75 km, and Port Chicago at 64 km). The CALSIM model uses information from the DSM2 modeling results in a monthly calculation that uses ANN to determine the outflow necessary to satisfy the X2 requirements and EC objectives at Emmaton and Jersey Point. The daily changes in outflow are somewhat averaged because the salinity responds to the recent moving average of outflow within the monthly tidal variations. Monthly outflow and salinity values provide a reasonable summary of the seasonal variations within the Bay-Delta habitat.

The basic relationship between Delta outflow and X2 is summarized in the original equations that estimate X2 from the daily or monthly outflow sequence (Jassby et al. 1995). The monthly average X2 position (km) can be estimated from the previous month's average X2 (km) and the monthly average outflow (cfs) as:

Monthly X2 (km) = 122.2 + 0.3278 x Previous X2 (km) – 17.65 x log [Outflow (cfs)]

The steady-state X2 for a constant outflow can be calculated by rearranging this monthly equation:

Steady-State X2 (km) = 181.8 – 26.26 x log [Outflow (cfs)]

The outflow required to maintain a specified X2 can also be calculated as:

Steady-State Outflow (cfs) = 10 ^ [(181.8 – X2)/26.26]

All of these estimation techniques are somewhat uncertain because the Delta outflow is itself estimated from upstream flows and assumed Delta depletions. Because outflow has an assumed relationship to the X2 position, D-1641 allows the *X2 at Collinsville* objective to be satisfied by an estimated Delta outflow of 7,100 cfs. The *X2 at Chipps Island* objective can be satisfied by an estimated Delta outflow of 11,400 cfs, and the *X2 at Port Chicago* (Roe Island) objective can be satisfied by an estimated Delta outflow of 29,200 cfs. The CALSIM model calculates the required minimum Delta outflow necessary to meet all of the maximum salinity, X2, and minimum outflow requirements. CALSIM provides this monthly estimate of minimum required Delta outflow as an output parameter. Delta outflow requirements often limit the Delta exports, so the simulated Delta outflow for many months is equal to the minimum Delta outflow requirement. Changes in the required Delta outflow (e.g., to satisfy Fall X2 or to compensate for sea-level rise) may have a large effect on the allowable exports.

Table C.A-40 shows the CALSIM calculated minimum Delta outflow requirements for the combination of D-1641 outflow, X2, and salinity objectives. The required Detla outflows are always satisfied in the CALSIM results for each case. For the EBC1 case, the required outflows in October–January and July–September reflect the D-1641 monthly outflow objectives, distributed by water-year types. The February–June required outflows include the X2 outflow equivalents. Many of the required outflows for X2 are about 7,100 cfs, assumed to maintain X2 at Collinsville, and many of the required outflows for X2 are around about 11,400 cfs, assumed to maintain X2 at Chipps Island. For reference, the annual average outflow required for the EBC1 case was about 4,270 taf/yr.

The EBC2 cases include the USFWS Fall X2 requirements in September–November following above normal (X2 near Collinsville) and wet (X2 near Chipps Island) years. The required outflows in September were raised from 3,000 cfs in all years to between 11,000 cfs and 22,000 cfs in about 40% of the years (above-normal and wet years). The required outflows in October were raised from 4,000 cfs to between 6,000 cfs and 11,000 cfs in about 40% of the years. The required outflows in November were raised from 4,500 cfs to between 10,000 cfs and 16,000 cfs in about 40% of the years. This raised the EBC2 annual average required outflow to about 5,000 taf/yr (increase of about 750 taf/yr). The EBC2_ELT and the EBC_LLT cases had higher required minimum outflows, caused apparently by changes in the required Delta outflow to maintain the spring and fall X2 positions as calculated by the CALSIM (ANN). The annual average required outflow for the EBC2_ELT case was 5,250 taf/yr, and the annual average required outflow for the EBC2_LLT case was 5,750 taf/yr.

There may be uncertainty in these higher outflow requirements assumed in CALSIM for Fall X2 and for sea-level rise. The monthly X2 equation suggests that 7,100 cfs will maintain the X2 at Collinsville and 11,400 cfs will maintain the X2 at Chipps Island; but the CALSIM model estimates much higher outflows would be needed in September–November for Fall X2. The CALSIM model also indicates that a very large outflow would be required in September, with much less outflow in October, and then more outflow in November. This variation in the outflow required to maintain X2 at a specified location during these three months does not follow the monthly outflow-X2 equation. In addition, the November outflow was specified in the BiOp to be augmented from the D-1641 outflow (4,500 cfs in most years) only by the excess reservoir inflow (i.e., no storage of water allowed) whereas the CALSIM model appears to require a much greater outflow. The CALSIM estimates of increased outflow requirements for Fall X2 may be higher than necessary; this possible discrepancy between the Fall X2 outflow requirements and the CALSIM estimates of these requirements can be worked out through the BDCP adaptive management procedures.

There may be similar uncertainty in the increased outflow requirements for spring X2 with ELT and LLT sea-level rise. The CALSIM model ANN has estimated the additional outflow requirements with sea-level rise for the ELT and LLT cases; these estimates might be different than what will actually be required. However, since all of the EBC2 and ESO cases include these same estimates of required Delta outflow, the evaluation of BDCP effects (ESO compared to EBC2) for ELT or LLT will not change.

Table C.A-41 shows the CALSIM-simulated monthly cumulative distributions of Delta outflow for the six CALSIM cases. The monthly distributions of outflow reflect the required outflow or X2 outflow equivalents for the months of February–June. Months with substantial runoff (December–May) have a greater fraction of years with Delta outflow that is higher than the required Delta outflow. The minimum October outflow was 3,000 cfs (critical year requirement), and most (60%) of the years had an October outflow of 4,000 cfs. Only a few years had any excess outflow in October (above requirements of 4,000 cfs), although there was one year with 30,000 cfs outflow in October. The 90% cumulative October outflow was 6,761 cfs. The 10% November outflow was 3,500 cfs (critical year requirement), and the 30% cumulative distribution outflow was 4,500 cfs. The other years had slightly more outflow than the D-1641 outflow requirements, but the CALSIM model (ANN) may have estimated that the salinity objectives at Emmaton, Jersey Point, or at Rock Slough required more outflow.

The monthly median outflow for the EBC2 case was about 4,500 cfs in October; about 10,000 cfs in November; about 7,500 cfs in December; about 21,500 cfs in January; about 35,500 cfs in February;

about 27,000 cfs in March; about 19,000 cfs in April; about 15,500 cfs in May; about 7,000 cfs in June; about 8,000 cfs in July; about 4,000 cfs in August; and about 3,500 cfs in September. About half of the months had Delta outflow exceeding the outflow requirements.

Figure C.A-73 shows the monthly CALSIM-simulated Delta outflows for the EBC1 and EBC2 cases and the ESO_ELT and ESO_LLT cases for the 1963–2003 sequence. The historical Delta outflow is shown for reference. There are several months with more than 50,000 cfs outflow in most years, but the graph scale has been reduced to 50,000 cfs to compare the CALSIM cases for relatively low Delta outflow periods. The variations in the Delta outflow are quite large within each year, so it is difficult to determine any differences between cases when looking at the 41-year monthly sequence (second half of CALSIM period). Figure C.A-74 shows the monthly CALSIM-simulated Delta outflows for the six CALSIM cases for the 1994–2003 sequence. For this relatively wet period, the increases in Delta outflow from the EBC1 (blue line) and historical (red line) to the EBC2 and ESO cases (for Fall X2) can be identified. There would be reduction of about 500 taf/yr in the average Delta outflow from the EBC2 cases to the ESO cases; the reduced outflow will be in the months with increased Delta exports that would occur within the D-1641 outflow and E/I limits.

Table C.A-42 shows the CALSIM-simulated monthly distributions for the end-of-month X2 positions (km) corresponding to the monthly average CALSIM outflows for the six CALSIM cases. The median X2 positions for the EBC1 case were highest in the months of August to November, because these months typically have the lowest outflow. Collinsville is located at 81 km, and Emmaton (west end of Decker Island) is located at 92 km. The monthly median X2 position was upstream of Collinsville in July–December. The median X2 for the EBC1 was about 69 km in January, about 58 km in February, about 60 km in March, about 64 km in April, about 67 km in May, and about 77 km in June. The median X2 positions for the EBC2 were very similar to the EBC1 values because the Fall X2 requirements apply to about 40% of the years. Generally the monthly distribution of X2 values for the ESO cases are very similar to the EBC2 cases (for ELT and LLT) because the outflow distribution remains almost the same for the ESO and EBC2 cases. The X2 positions can be influenced by moderate changes in outflow only when the outflow is less than about 10,000 cfs. Because X2 is a logarithmic function of outflow, the X2 position can be moved downstream one kilometer with a 10% increase in outflow. No large changes in the X2 position are expected with the ESO.

Figure C.A-75 shows the CALSIM-simulated X2 positions for the six cases for WY 1963–2003. The historical X2 positions are shown for reference. The seasonal range in X2 position usually extends from the downstream end of Suisun Bay (55 km) to the upstream end of Suisun Bay (80 km) every year. In about half of the years the downstream movement of X2 extends beyond 50 km. The upstream movement of X2 in the fall months usually extends to Emmaton (92 km); the EBC2 cases and the ESO cases will maintain the upstream position at Chipps Island (75 km) following wet years and at Collinsville (81 km) following above normal years. Figure C.A-76 shows the CALSIM-simulated X2 positions for the six cases for WY 1994–2003. The changes in X2 for the Fall X2 requirements can be seen in several of these last 10 years of the CALSIM sequence.

Table C.A-40. CALSIM-Simulated Monthly Distribution of Minimum Required Delta Outflow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	3,000	3,500	3,500	4,500	3,966	4,000	4,000	4,000	4,000	4,000	3,000	3,000	3,149
10%	3,000	3,500	3,500	4,500	4,107	4,363	4,247	4,000	4,000	4,000	3,000	3,000	3,668
20%	4,000	4,500	4,500	4,500	6,250	6,262	5,083	4,839	5,137	5,000	3,500	3,000	3,885
30%	4,000	4,500	4,500	4,500	7,436	7,239	6,220	6,105	5,653	5,000	3,500	3,000	4,001
40%	4,000	4,500	4,500	4,500	7,990	7,684	7,188	6,870	6,248	6,500	4,000	3,000	4,180
50%	4,000	4,500	4,500	4,500	8,482	8,780	7,419	7,100	6,573	6,500	4,000	3,000	4,307
60%	4,000	4,500	4,500	4,500	9,357	9,688	7,795	7,767	7,040	8,000	4,000	3,000	4,435
70%	4,000	4,500	4,500	4,500	11,400	10,548	8,463	9,252	7,100	8,000	4,000	3,000	4,539
80%	4,000	4,500	4,500	4,500	13,634	11,500	9,319	10,476	7,733	8,000	4,000	3,000	4,654
90%	4,000	4,500	4,500	4,500	14,214	13,121	10,639	11,952	9,920	8,000	4,000	3,000	4,842
Max	4,000	4,500	4,500	4,500	15,813	15,629	14,181	16,629	16,017	8,000	4,000	3,000	5,104
Avg	3,854	4,354	4,354	4,500	9,478	8,904	7,547	7,850	6,889	6,500	3,744	3,000	4,269
B. ESO_ELT													
Min	3,000	3,500	3,500	4,302	5,223	6,429	5,504	4,000	4,000	4,000	3,000	3,000	3,190
10%	3,000	3,500	3,500	4,500	6,413	7,321	7,102	4,152	5,497	4,000	3,000	3,000	4,073
20%	4,000	4,500	4,500	4,500	7,449	8,202	7,575	7,027	6,183	5,000	3,500	3,000	4,472
30%	4,000	4,500	4,500	4,500	7,842	9,738	8,110	7,239	6,973	5,000	3,500	3,000	4,619
40%	4,000	4,500	4,500	4,500	8,892	10,931	8,842	8,360	7,100	6,500	4,000	3,000	4,911
50%	4,000	4,500	4,500	4,500	10,773	11,400	9,401	9,002	7,243	6,500	4,000	3,000	5,483
60%	6,438	8,688	4,500	4,500	11,400	12,062	9,840	9,656	7,335	8,000	4,000	11,250	5,848
70%	8,438	11,919	4,500	4,500	14,960	13,355	10,046	11,157	8,188	8,000	4,000	16,500	6,492
80%	8,906	13,750	4,500	4,500	16,737	14,125	10,900	11,899	9,129	8,000	4,000	19,688	7,099
90%	9,359	14,516	4,500	4,500	17,611	17,140	12,724	14,234	10,851	8,000	4,000	20,313	7,522
Max	10,000	15,000	4,500	4,500	28,906	29,200	16,431	17,323	16,308	8,000	4,000	21,563	8,003
Avg	5,843	7,978	4,354	4,498	11,861	12,088	9,554	9,299	7,779	6,482	3,732	9,660	5,591
C. ESO_LLT													
Min	3,000	3,500	3,500	4,396	4,455	7,188	6,567	4,000	4,000	4,000	3,000	3,000	3,275
10%	3,000	3,500	3,500	4,500	7,844	7,723	8,103	7,100	6,679	4,000	3,000	3,000	4,173
20%	4,000	4,500	4,500	4,500	8,206	8,845	8,598	7,239	7,100	5,000	3,500	3,000	4,706
30%	4,000	4,500	4,500	4,500	8,670	10,745	9,673	7,981	7,243	5,000	3,500	3,000	5,052
40%	4,000	4,500	4,500	4,500	10,090	11,400	10,167	9,521	7,694	5,000	3,500	3,000	5,324
50%	4,000	4,500	4,500	4,500	11,325	12,133	10,730	10,742	8,657	6,500	4,000	3,000	5,844
60%	6,750	11,031	4,500	4,500	11,400	14,116	11,153	11,104	9,319	8,000	4,000	13,344	6,502
70%	9,953	11,953	4,500	4,500	19,710	16,886	11,552	11,400	10,093	8,000	4,000	18,859	7,212
80%	10,313	13,525	4,500	4,500	20,382	18,418	12,671	13,829	11,153	8,000	4,000	21,875	7,818
90%	10,625	16,373	4,500	4,500	21,237	19,838	15,094	16,778	13,665	8,000	4,000	22,500	8,358
Max	11,563	16,875	4,500	4,500	25,757	23,645	20,088	21,306	22,142	8,000	4,000	22,813	9,279
Avg	6,305	8,420	4,341	4,499	13,569	13,487	11,144	10,724	9,309	6,378	3,713	10,235	6,127

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	3,000	3,500	3,500	4,500	4,000	4,000	4,000	4,000	4,000	4,000	3,000	3,000	3,161
10%	3,000	3,500	3,500	4,500	5,313	5,520	4,000	4,000	4,000	4,000	3,000	3,000	3,982
20%	4,000	4,500	4,500	4,500	6,474	6,219	5,110	4,944	5,292	5,000	3,500	3,000	4,320
30%	4,000	4,500	4,500	4,500	7,275	7,500	6,108	6,144	5,864	5,000	3,500	3,000	4,494
40%	4,000	4,500	4,500	4,500	7,868	8,444	7,100	6,743	6,375	6,500	4,000	3,000	4,651
50%	4,000	4,500	4,500	4,500	8,241	9,063	7,571	7,172	6,739	6,500	4,000	3,000	4,828
60%	5,938	10,313	4,500	4,500	10,194	9,861	7,947	8,068	7,026	8,000	4,000	11,563	5,109
70%	7,188	12,549	4,500	4,500	12,136	10,625	8,633	9,129	7,100	8,000	4,000	13,750	5,470
80%	7,813	13,849	4,500	4,500	13,703	11,675	9,427	10,167	8,020	8,000	4,000	19,063	5,965
90%	8,125	15,398	4,500	4,500	14,908	13,038	11,048	12,536	9,958	8,000	4,000	20,000	6,371
Max	11,406	16,250	4,500	4,500	16,717	15,065	14,463	16,629	16,017	8,000	4,000	22,031	6,926
Avg	5,423	8,330	4,349	4,500	9,636	9,119	7,669	7,907	6,985	6,500	3,744	9,380	5,020
E. EBC2_ELT													
Min	3,000	3,500	3,500	4,500	4,771	5,469	4,188	4,000	4,000	4,000	3,000	3,000	3,319
10%	3,000	3,500	3,500	4,500	7,407	7,321	7,000	4,375	5,300	4,000	3,000	3,000	4,018
20%	4,000	4,500	4,500	4,500	7,832	8,581	7,431	6,466	5,810	5,000	3,500	3,000	4,438
30%	4,000	4,500	4,500	4,500	8,021	9,294	7,947	7,100	6,422	5,000	3,500	3,000	4,611
40%	4,000	4,500	4,500	4,500	8,482	9,839	8,280	7,464	6,990	6,500	4,000	3,000	4,798
50%	4,000	4,500	4,500	4,500	9,967	10,313	8,638	8,286	7,100	6,500	4,000	3,000	5,168
60%	6,719	9,844	4,500	4,500	10,313	10,418	9,196	9,261	7,243	8,000	4,000	11,094	5,491
70%	9,375	12,273	4,500	4,500	11,145	10,938	9,510	10,323	7,623	8,000	4,000	14,375	5,956
80%	9,531	14,342	4,500	4,500	12,069	11,400	10,156	11,048	8,440	8,000	4,000	19,063	6,367
90%	10,000	14,688	4,500	4,500	13,292	11,917	10,823	12,625	10,019	8,000	4,000	19,375	6,624
Max	13,281	15,000	4,500	4,500	15,638	15,419	15,000	15,347	15,433	8,000	4,000	20,156	7,111
Avg	6,198	8,208	4,352	4,500	9,890	9,980	8,924	8,620	7,368	6,482	3,732	9,348	5,265
F. EBC2_LLT													
Min	3,000	3,500	3,500	3,776	4,000	4,000	4,000	4,000	4,000	4,000	3,000	3,000	3,397
10%	3,000	3,500	3,500	4,500	7,841	7,239	7,100	5,469	6,083	4,000	3,000	3,000	4,077
20%	4,000	4,500	4,500	4,500	8,329	7,932	7,968	7,100	7,100	5,000	3,500	3,000	4,697
30%	4,000	4,500	4,500	4,500	8,580	9,028	8,278	7,377	7,100	5,000	3,500	3,000	5,050
40%	4,000	4,500	4,500	4,500	9,688	9,970	9,000	9,033	7,243	5,000	3,500	3,000	5,238
50%	4,000	4,500	4,500	4,500	11,094	10,684	9,751	9,758	8,044	6,500	4,000	3,000	5,713
60%	7,813	10,625	4,500	4,500	11,400	11,400	10,087	11,276	8,336	8,000	4,000	11,875	6,024
70%	10,469	11,986	4,500	4,500	12,944	12,202	10,258	12,710	9,180	8,000	4,000	18,750	6,593
80%	10,938	13,590	4,500	4,500	17,116	13,755	10,663	13,952	10,685	8,000	4,000	20,781	6,963
90%	11,094	15,156	4,500	4,500	18,793	16,516	11,650	17,323	12,313	8,000	4,000	21,250	7,566
Max	20,938	15,625	4,500	4,500	21,839	19,635	20,650	26,761	20,683	8,000	4,000	21,875	8,013
Avg	6,684	8,138	4,340	4,479	11,863	11,065	9,751	10,825	8,946	6,378	3,713	9,659	5,756

Table C.A-41. CALSIM-Simulated Monthly Distribution of Delta Outflow (cfs)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
A. EBC1													
Min	3,000	3,500	3,500	4,500	7,407	6,219	6,426	4,000	4,000	4,000	3,000	3,000	3,639
10%	3,815	4,500	4,500	8,619	9,530	9,613	9,640	7,100	5,156	4,293	4,000	3,000	5,253
20%	4,000	4,500	5,010	9,879	13,526	12,657	11,153	8,682	6,248	5,000	4,000	3,000	6,471
30%	4,000	4,500	5,232	12,749	16,681	16,684	12,930	10,240	6,713	5,000	4,000	3,078	7,599
40%	4,000	4,778	6,383	17,219	23,683	22,158	15,325	12,419	7,100	6,500	4,000	3,411	8,722
50%	4,000	5,088	8,086	22,361	36,554	26,890	18,921	15,899	7,243	8,000	4,000	3,610	10,486
60%	4,014	5,786	11,294	31,168	51,454	34,199	26,270	19,254	8,081	8,000	4,000	3,872	16,191
70%	4,377	6,269	18,041	47,109	63,643	47,157	29,363	21,788	10,503	8,000	4,452	4,081	19,667
80%	4,625	7,626	35,260	67,477	77,261	62,997	49,728	30,110	14,841	8,751	4,746	7,970	24,098
90%	6,761	16,840	66,009	106,897	123,455	92,083	69,029	54,215	30,492	11,024	5,688	10,154	31,813
Max	30,878	78,878	156,563	280,515	226,138	259,340	139,460	84,439	72,462	37,702	16,427	25,677	60,779
Avg	4,931	9,193	22,714	43,289	52,594	43,172	30,099	22,517	12,765	7,951	4,618	5,334	15,533
B. ESO_ELT													
Min	3,000	3,500	3,500	5,282	7,476	6,854	6,651	4,000	4,000	4,000	3,000	3,000	3,878
10%	5,888	3,500	4,500	9,171	9,340	9,583	8,972	7,101	5,779	4,000	3,500	3,000	5,458
20%	6,492	4,500	4,502	12,333	12,868	11,860	9,696	8,123	6,966	5,000	3,500	3,000	6,390
30%	7,043	4,500	4,521	14,162	16,302	15,711	10,785	9,172	7,133	5,000	3,911	3,000	7,278
40%	7,413	4,500	6,886	16,914	21,043	18,203	14,169	11,868	7,486	6,500	4,000	3,000	8,991
50%	7,652	8,438	9,492	22,942	33,065	23,150	15,875	13,414	8,111	8,000	4,000	3,000	10,157
60%	8,039	9,469	12,763	28,258	50,322	32,335	18,835	14,695	8,921	8,000	4,000	11,250	15,272
70%	8,438	13,633	17,281	43,796	61,912	42,065	23,969	16,918	9,285	8,116	4,000	18,297	19,441
80%	9,038	14,500	34,663	72,701	86,002	66,025	39,200	21,203	11,557	9,376	4,000	19,688	24,685
90%	9,672	16,330	63,579	106,332	137,372	85,369	61,911	41,223	19,133	10,233	4,087	20,313	31,782
Max	26,659	86,986	195,172	307,821	251,077	273,553	145,298	79,212	58,864	21,779	7,513	21,563	60,200
Avg	7,889	11,085	23,042	44,053	54,312	42,524	26,355	18,888	11,138	7,376	3,926	9,708	15,590
C. ESO_LLT													
Min	3,000	3,500	4,500	5,349	4,455	7,239	7,100	4,001	4,000	4,000	3,298	3,000	4,869
10%	5,873	3,500	4,500	10,991	9,923	9,772	9,766	7,123	6,679	5,000	3,595	3,000	6,087
20%	7,179	4,500	4,504	12,809	12,703	13,266	10,288	10,041	7,159	5,000	4,000	3,000	6,898
30%	7,600	4,500	5,624	14,128	18,237	15,095	11,417	10,908	7,600	5,571	4,000	4,002	7,491
40%	8,641	4,500	7,585	16,938	21,307	17,826	13,292	11,850	8,445	6,690	4,000	4,537	8,998
50%	10,117	10,162	10,807	22,789	33,380	22,492	15,716	13,243	9,125	8,000	4,000	6,738	10,270
60%	10,465	11,438	12,945	27,476	48,669	32,545	19,480	14,599	9,748	8,000	4,000	13,344	15,931
70%	10,752	12,905	16,605	42,626	60,788	41,393	23,405	16,868	10,960	8,674	4,230	18,859	19,873
80%	11,220	14,514	30,270	73,944	91,327	67,586	37,925	21,025	11,327	9,547	4,560	21,875	24,846
90%	12,773	16,844	60,010	103,246	134,414	94,765	60,789	32,920	19,706	11,192	5,024	22,500	31,482
Max	26,755	73,050	192,580	316,004	255,260	279,907	144,263	68,727	52,008	14,616	6,860	22,813	58,899
Avg	9,510	10,728	21,867	44,827	55,165	43,308	26,460	17,821	10,751	7,616	4,218	10,995	15,767

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
D. EBC2													
Min	3,000	3,500	3,500	5,749	7,489	6,219	6,141	4,000	4,000	4,000	3,158	3,000	3,832
10%	3,427	4,500	4,500	8,921	9,063	9,320	9,673	7,100	5,313	4,474	4,000	3,000	5,379
20%	4,000	4,500	4,524	10,135	13,351	12,758	10,732	8,516	6,478	5,000	4,000	3,000	6,558
30%	4,000	4,809	4,926	12,765	16,003	16,974	12,574	10,013	6,875	5,168	4,000	3,013	7,515
40%	4,000	5,817	6,055	17,435	22,895	21,291	14,695	11,784	7,100	6,500	4,000	3,178	8,611
50%	4,403	10,313	7,696	21,730	35,578	26,801	18,804	15,655	7,249	8,000	4,000	3,621	10,555
60%	6,094	11,250	11,211	28,909	51,065	33,865	26,521	18,527	8,609	8,000	4,004	11,563	16,780
70%	7,500	13,789	14,983	47,511	59,259	46,311	29,034	21,619	10,669	8,339	4,562	18,438	20,609
80%	7,813	15,313	30,377	67,227	76,708	62,797	49,905	30,014	14,454	9,321	4,768	19,375	25,247
90%	8,438	16,250	65,429	106,860	122,549	86,087	69,025	53,820	29,889	11,201	5,363	20,156	32,140
Max	27,510	79,161	156,667	278,473	220,864	258,901	139,734	84,164	71,767	34,893	14,665	22,592	59,348
Avg	5,914	11,671	21,411	42,487	51,697	42,427	30,085	22,139	12,661	8,014	4,565	9,658	15,743
E. EBC2_ELT													
Min	3,000	3,500	3,500	5,615	7,487	7,239	6,778	4,000	4,000	4,000	3,000	3,000	3,976
10%	3,384	3,612	4,500	8,950	8,915	9,306	9,673	7,258	5,625	4,581	4,000	3,000	5,480
20%	4,000	4,500	4,500	10,176	12,891	12,032	10,139	8,185	6,531	5,000	4,000	3,000	6,536
30%	4,000	4,500	4,727	12,862	15,870	17,468	12,026	9,319	6,939	5,134	4,000	3,000	7,356
40%	4,000	6,044	5,486	17,592	22,702	20,534	15,196	11,075	7,100	7,047	4,000	3,000	8,815
50%	5,425	9,844	8,666	21,342	35,846	25,701	18,708	13,911	7,243	8,000	4,000	3,659	10,639
60%	6,875	10,156	11,062	28,569	53,596	33,360	25,241	16,660	7,743	8,000	4,033	11,094	16,897
70%	9,375	13,732	15,354	49,661	66,028	46,531	28,968	19,798	8,561	9,332	4,259	18,124	20,744
80%	9,688	14,596	33,261	73,247	90,046	68,165	46,063	27,652	10,535	11,102	4,530	19,063	25,305
90%	10,156	15,000	73,195	112,525	137,572	87,794	68,921	48,602	20,916	12,661	5,075	19,375	33,440
Max	27,880	86,453	195,153	305,523	248,113	273,702	146,802	79,224	61,582	22,296	8,687	20,156	60,157
Avg	6,638	11,515	23,546	44,889	55,330	43,911	29,833	21,103	10,945	8,232	4,308	9,473	16,157
F. EBC2_LLT													
Min	3,233	3,500	3,861	4,500	6,657	7,239	7,100	4,000	4,000	4,000	3,000	3,000	4,320
10%	4,759	3,797	4,500	8,788	9,816	9,729	9,920	7,100	6,563	5,000	4,000	3,000	5,918
20%	5,716	4,500	4,788	10,492	12,609	12,686	10,555	9,633	7,100	5,341	4,000	3,000	6,712
30%	6,802	4,500	5,406	14,136	18,250	17,140	11,496	10,183	7,280	6,500	4,000	3,000	7,772
40%	7,309	5,228	7,301	18,238	22,738	19,077	14,880	11,071	8,122	7,694	4,000	3,000	9,095
50%	7,813	10,415	9,156	21,903	37,339	25,784	18,283	12,806	8,336	8,520	4,112	3,430	10,721
60%	8,125	10,938	11,224	28,863	52,213	33,466	24,609	14,355	8,824	10,120	4,610	11,875	16,888
70%	10,625	12,916	16,406	45,305	65,220	49,860	29,321	18,506	10,285	10,846	5,209	18,750	21,041
80%	10,938	14,371	31,145	75,522	92,657	70,864	44,550	25,327	11,153	12,889	5,562	20,781	25,441
90%	11,250	15,469	68,771	106,597	136,295	93,304	68,474	39,949	19,300	13,586	6,209	21,250	33,486
Max	24,664	74,097	192,448	317,787	253,373	281,371	145,542	68,558	53,980	18,471	6,995	21,875	58,712
Avg	8,276	10,844	22,113	46,372	56,338	45,097	29,603	19,121	10,560	8,984	4,754	9,754	16,282

Table C.A-42. CALSIM-Simulated Monthly Distribution of X2 Position (km)

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
A. EBC1												
Min	67.1	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.1	56.2	66.0	63.5
10%	80.3	72.8	53.1	48.2	47.7	48.2	49.6	52.5	58.9	72.8	82.4	81.4
20%	86.0	83.7	64.5	49.6	48.1	49.4	53.6	59.6	66.5	77.0	83.4	85.4
30%	89.3	87.0	73.5	56.0	51.3	53.3	58.6	62.1	71.8	78.5	84.6	88.2
40%	90.3	88.4	81.1	66.1	53.2	57.1	60.4	64.2	75.0	79.9	85.0	88.5
50%	90.7	89.5	85.5	69.2	58.4	59.8	63.7	66.9	76.9	81.3	85.7	89.0
60%	91.1	90.3	87.1	72.9	63.7	63.3	66.7	71.1	79.6	82.2	86.0	89.2
70%	91.3	90.9	88.8	80.1	67.1	65.1	69.1	74.6	81.0	84.6	86.7	89.6
80%	91.7	91.2	89.8	83.0	72.2	73.1	72.6	77.5	81.4	85.4	87.3	89.9
90%	93.0	92.1	90.6	84.8	77.9	75.7	76.6	80.9	83.2	86.4	89.7	91.7
Max	94.7	93.9	92.2	89.7	86.9	83.3	83.2	87.4	90.5	91.2	91.5	92.6
Avg	88.5	86.3	77.9	67.6	60.7	60.7	63.4	67.5	74.6	80.4	85.2	86.4
B. ESO_ELT												
Min	69.3	52.2	47.7	47.6	47.7	47.7	47.7	49.3	51.0	62.3	74.8	74.0
10%	74.0	73.9	53.6	48.8	48.2	48.8	50.6	53.8	63.8	74.9	83.9	74.0
20%	74.0	74.0	62.1	51.6	49.0	50.3	56.6	62.6	70.8	78.3	84.2	74.0
30%	74.0	74.9	70.8	56.1	52.2	55.0	61.3	65.8	74.5	79.0	84.6	74.1
40%	79.6	78.1	78.4	66.1	55.3	58.9	64.6	68.2	76.0	80.0	84.9	81.0
50%	85.6	81.1	81.0	70.1	60.4	62.1	67.0	71.4	77.8	80.8	85.5	89.4
60%	87.2	86.4	82.3	72.6	65.6	66.5	69.8	73.5	80.0	81.9	86.5	90.1
70%	87.9	87.4	85.1	77.9	69.3	68.0	73.2	78.5	80.9	84.4	87.7	90.8
80%	88.4	88.5	88.3	80.5	73.1	73.2	74.6	80.4	82.1	84.8	88.4	91.3
90%	90.0	90.3	89.2	83.3	77.3	77.1	78.7	81.7	83.7	87.0	90.1	92.2
Max	92.6	92.5	92.3	87.3	84.1	82.5	83.1	87.4	90.1	90.5	92.1	93.5
Avg	82.1	80.8	76.0	67.2	61.6	62.4	66.2	70.4	76.1	81.1	86.2	83.1
C. ESO_LLT												
Min	70.9	54.8	48.8	48.7	48.7	48.7	49.1	51.6	55.0	69.9	83.1	74.0
10%	74.0	74.0	57.3	50.4	49.4	49.8	51.9	57.6	66.4	77.6	85.0	74.0
20%	74.0	76.1	65.2	53.3	50.1	51.4	57.5	65.3	73.9	79.6	85.2	74.0
30%	74.1	77.4	74.6	57.7	53.4	55.9	62.9	67.5	76.7	80.6	85.7	74.1
40%	80.6	80.9	80.5	68.6	57.1	60.9	65.8	71.1	78.4	81.1	85.9	81.0
50%	83.1	81.1	82.1	72.2	62.0	64.6	68.6	73.7	80.2	82.8	86.4	88.0
60%	84.5	85.4	84.0	75.1	66.5	67.5	71.1	76.9	80.7	83.8	87.4	89.3
70%	85.9	86.7	85.4	79.9	70.5	69.6	74.5	79.1	82.0	85.7	88.7	90.2
80%	86.9	88.5	88.4	81.4	74.6	73.9	76.4	79.8	83.1	86.8	89.2	91.1
90%	88.5	91.1	90.3	82.8	78.9	78.9	80.1	84.0	85.7	88.8	90.7	92.0
Max	91.5	94.4	92.3	86.7	84.2	84.4	84.3	88.9	92.3	91.4	91.8	92.8
Avg	81.5	81.8	77.8	68.6	63.0	63.8	67.6	72.5	78.4	82.9	87.2	83.0

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
D. EBC2												
Min	67.3	51.7	47.3	47.2	47.2	47.2	47.3	48.5	49.3	57.1	67.3	65.8
10%	73.9	72.9	53.1	48.3	47.7	48.2	49.6	52.6	59.2	73.1	82.6	74.0
20%	74.0	74.0	63.1	49.8	48.3	49.6	53.7	59.5	66.7	77.3	83.8	74.0
30%	74.1	75.8	70.8	55.2	51.4	54.0	58.6	62.1	72.0	78.6	84.5	74.1
40%	81.0	80.9	78.7	64.6	54.0	57.1	60.6	64.9	75.0	79.7	84.9	81.0
50%	90.4	81.1	80.7	70.1	58.6	60.2	64.0	67.1	76.9	81.1	85.6	88.6
60%	91.1	89.5	83.0	72.7	64.0	63.1	67.2	71.4	80.0	81.9	86.0	89.3
70%	91.4	90.8	85.8	79.7	67.3	64.8	69.0	75.5	81.0	84.6	86.7	89.7
80%	91.7	91.4	88.7	82.0	72.8	73.4	73.4	78.0	81.7	85.1	87.4	90.2
90%	92.7	91.8	90.7	84.7	76.9	75.7	77.2	81.0	83.2	86.4	88.9	91.5
Max	94.6	93.4	92.2	87.2	83.2	82.3	82.5	87.2	90.2	90.9	90.8	92.4
Avg	84.1	82.3	76.3	67.4	60.8	61.0	63.6	67.8	74.7	80.4	85.2	82.5
E. EBC2_ELT												
Min	69.5	52.4	47.8	47.6	47.6	47.7	47.9	49.8	51.5	62.1	73.6	70.9
10%	73.9	73.9	53.0	49.3	48.2	49.1	50.2	53.0	62.6	74.4	82.1	74.0
20%	74.0	74.1	61.9	51.1	49.5	50.6	53.5	59.6	69.5	76.8	82.8	74.0
30%	74.1	75.1	71.3	56.3	52.0	53.9	58.3	63.9	74.2	77.3	84.1	74.1
40%	81.0	80.9	80.4	66.5	55.4	58.1	61.7	66.6	76.7	78.1	84.6	81.0
50%	90.2	81.1	81.4	71.0	58.6	60.1	66.2	70.7	77.7	80.4	84.8	88.7
60%	91.0	89.2	83.3	73.6	64.9	65.1	67.5	74.0	80.5	81.6	85.4	89.7
70%	91.4	90.9	84.8	79.6	69.2	66.5	70.0	77.1	81.2	84.3	86.8	90.3
80%	91.8	91.4	89.9	82.2	73.5	73.7	74.4	79.3	81.9	84.8	87.5	90.7
90%	93.0	92.6	90.9	84.1	77.7	76.6	78.4	81.1	83.3	86.1	89.7	91.7
Max	93.9	94.4	93.6	90.4	87.0	82.7	83.1	87.6	90.2	90.8	90.9	92.6
Avg	84.1	82.3	76.6	67.9	61.7	61.9	64.6	68.9	75.9	80.3	85.1	82.7
F. EBC2_LLT												
Min	72.2	55.4	50.0	49.6	49.6	49.5	50.0	53.1	55.7	71.4	81.2	73.9
10%	74.0	74.0	56.7	52.1	50.6	51.2	52.8	57.1	66.1	75.5	83.3	74.0
20%	74.0	75.0	65.1	53.8	51.8	52.8	57.0	63.6	72.7	76.6	83.9	74.0
30%	74.1	76.5	74.3	59.0	54.7	56.3	60.5	66.6	75.4	77.2	84.3	74.1
40%	81.0	80.9	81.2	67.1	58.2	60.4	64.2	70.0	77.6	78.2	84.9	81.0
50%	87.6	81.1	82.7	72.5	60.4	62.9	67.0	72.1	79.1	80.4	85.6	89.2
60%	88.9	88.6	84.2	75.0	66.0	66.3	69.3	75.1	80.6	83.2	86.1	90.2
70%	89.3	89.6	86.7	80.1	69.8	68.0	72.7	78.5	81.5	84.3	86.9	90.8
80%	90.7	90.3	88.5	82.7	74.7	73.9	75.6	79.2	82.2	85.2	87.9	91.8
90%	92.1	92.2	90.4	85.4	80.5	78.4	79.0	82.9	84.6	87.6	89.8	92.4
Max	94.6	94.7	94.0	90.4	87.3	83.8	84.6	88.7	90.9	90.9	92.1	94.3
Avg	83.7	82.7	78.2	69.4	63.5	63.7	66.5	71.4	77.6	80.8	85.8	83.4

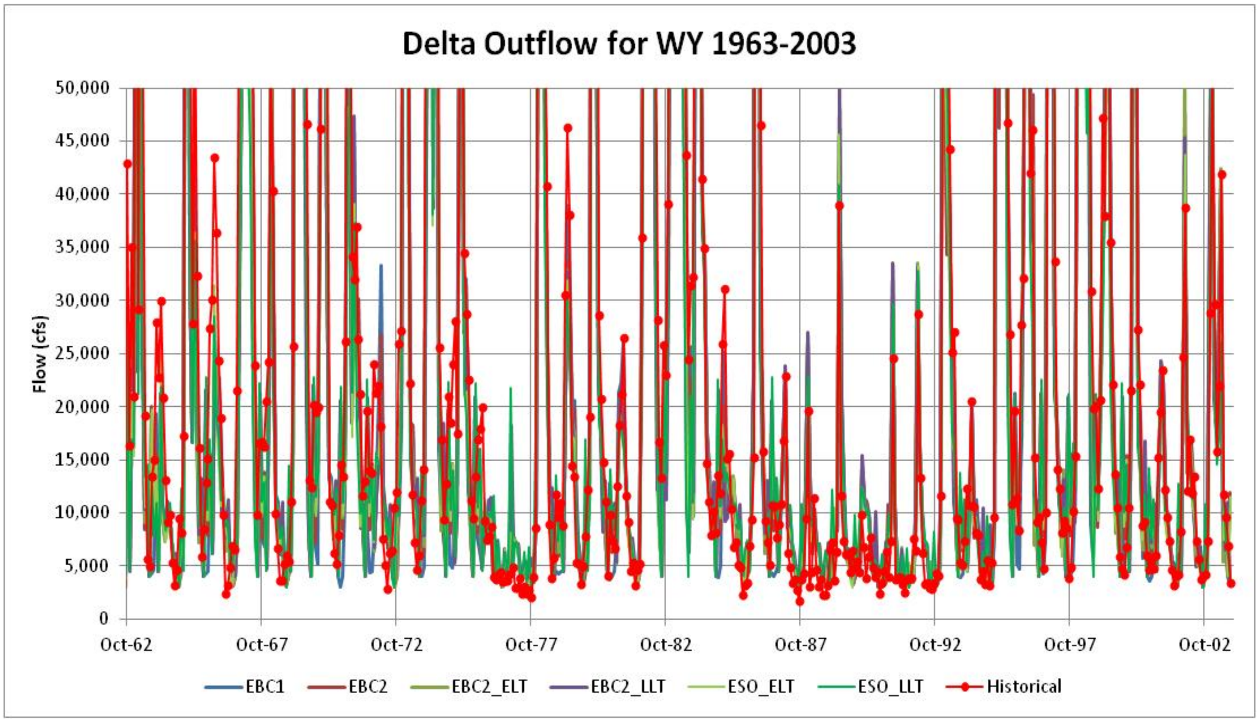


Figure C.A-73. CALSIM-Simulated Monthly Delta Outflow for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

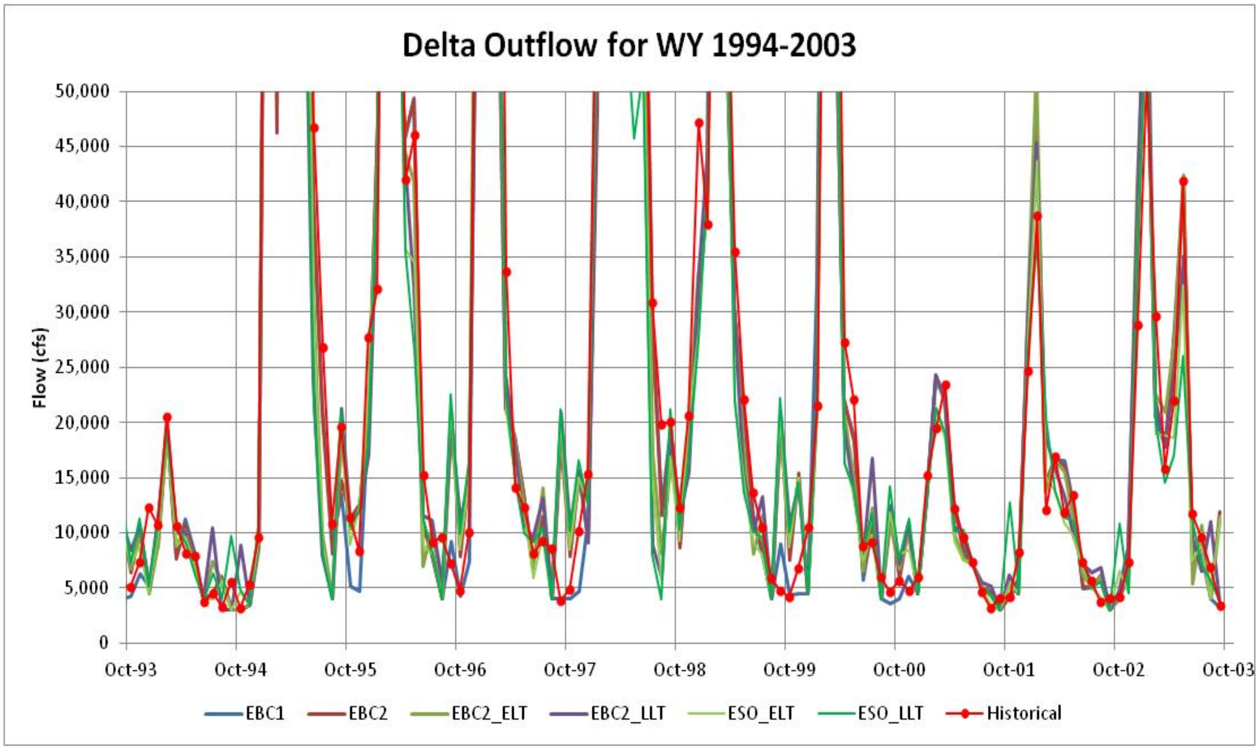


Figure C.A-74. CALSIM-Simulated Monthly Delta Outflow for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

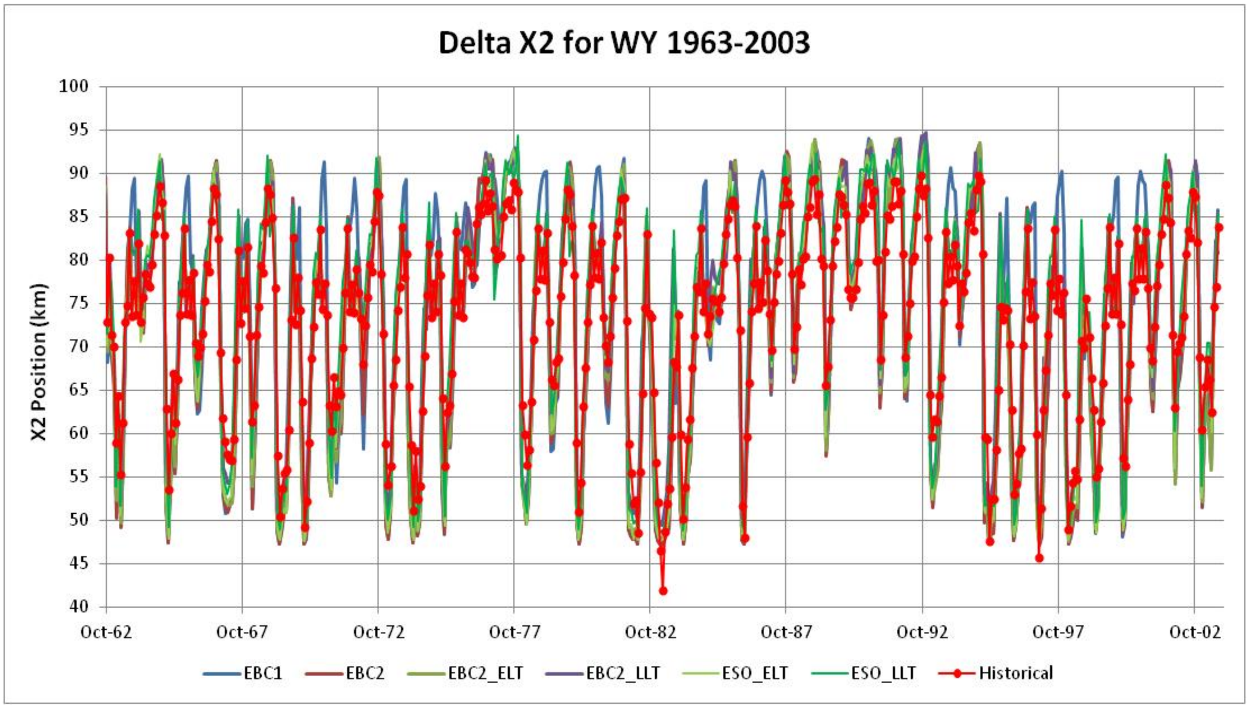


Figure C.A-75. CALSIM-Simulated Monthly X2 Position (km) for WY 1963–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

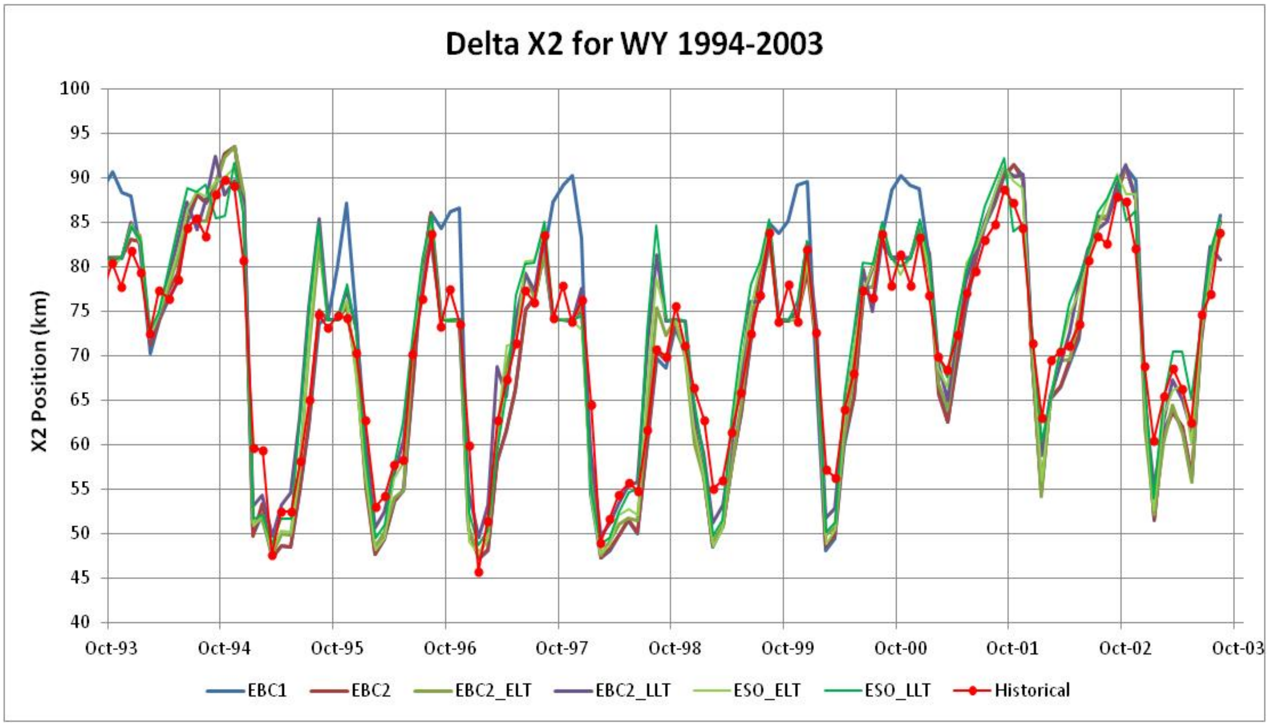


Figure C.A-76. CALSIM-Simulated Monthly X2 Position (km) for WY 1994–2003 for the EBC1 and EBC2 and ESO_ELT and ESO_LLT Cases

5C.A.5 Comparison of Higher Outflow Scenario and Lower Outflow Scenario

As described in Chapter 3, the HOS and LOS are alternative BDCP outcomes related to spring and fall outflow operations. Initial operations will ultimately be determined through the decision tree process (described in detail in Section 3.4). Compared to the ESO, the HOS operations include higher Delta outflow for March, April and May. Compared to the ESO, the LOS operations do not include the Fall X2 requirements; D-1641 outflow requirements were imposed for September, October, and November. These changes in Delta outflows often have a direct effect on total Delta exports and upstream operations.

This section compares the CALSIM results from ESO with the HOS and LOS variations for both the ELT and LLT timeframes, and where necessary, compares results to EBC cases. The CALSIM-simulated differences between the ESO and the HOS or LOS cases are described for Delta outflow, Delta exports, and for selected reservoirs and river locations. The results are summarized with monthly storage and monthly flow distribution tables (i.e., monthly storage and flow probabilities) and graphs. The changes in outflow are identified in specific months for the HOS and LOS cases; the outflow changes are a combination of export changes and upstream reservoir release changes. Flows and reservoir storage patterns at many locations are nearly identical for the EOS, HOS, and LOS. Potential effects on fish as a result of ESO, HOS, and LOS operations are described in Chapter 5 and in Appendices 5.A though 5.H.

Compared to the ESO, the LOS is a reduction in the required Delta outflows in September, October and November following wet and above normal years (about 40% of the years). This results in either reduced reservoir releases or increased Delta exports. A large fraction of the reduced Delta outflow requirements result in higher Delta exports compared to the ESO, although some of the water cannot be exported and therefore contributes to Delta outflow that is sometimes higher than required outflow.

The HOS is intended to achieve higher Delta outflow in March, April, and May in many years compared to ESO, to benefit longfin smelt and other estuarine species. The development of the specific increased outflow goals are described in Chapter 3. Substantial increased March–May outflow was simulated in about 40% of the years; generally in years with moderate Delta outflow of 15,000 cfs to 40,000 cfs. A fourth operational scenario, with D-1641 fall outflow requirements (like LOS) but with the enhanced spring outflow (like HOS) was simulated with CALSIM and is described in comparison to the ESO, LOS, and HOS in the EIR/EIS documents; this scenario is not described here in detail because it included both increased spring outflow and reduced fall outflow in comparison to the ESO.

5C.A.5.1 Comparison of Delta Outflow Changes

The HOS and LOS were compared to the ESO operations for both the ELT and the LLT timeframe. This section will focus on the LLT results, but will provide evidence that the CALSIM changes for the ELT and the LLT timeframes were similar. Table C.A-43 provides an annual average summary of the Delta outflow (taf/yr) and the Delta exports (taf/yr) for the ESO cases along with the HOS and LOS cases. The outflow generally increases and the exports generally decrease for the HOS cases, because the increased outflow in March–May requires reduced storage or reduced exports. The spring outflow for LOS is similar to ESO, but the fall outflow decreased in wet and above normal years.

Consequently, exports generally increased for the LOS cases, because the higher Delta outflow requirements for Fall X2 were eliminated in September–November of about 40% of the years, allowing exports to increase by a similar amount.

The average annual Delta outflow for WY 1922–2003 of 15,590 taf/yr for the ESO (ELT) was increased by 548 taf/yr to an average annual outflow 16,138 taf/yr for the HOS (ELT) case. The average annual outflow for the HOS_ELT was 605 taf/yr greater than the EBC1 average annual outflow of 15,533 taf/yr, was 395 taf/yr greater than the EBC2 average annual outflow of 15,743 taf/yr, and was 19 taf/yr less than EBC2 ELT average annual outflow of 16,157 taf/yr. The average annual Delta outflow for the ESO_ELT was reduced by 351 taf/yr to an average annual outflow of 15,239 taf/yr for the LOS (ELT) case. The average annual outflow for the LOS_ELT was 294 taf/yr less than the EBC1 average annual outflow of 15,533 taf/yr, was 504 taf/yr less than the EBC2 average annual outflow of 15,743 taf/yr, and was 918 taf/yr less than EBC2 ELT average annual outflow of 16,157 taf/yr.

The average annual Delta outflow for WY 1922–2003 was 15,767 taf/yr for the ESO (LLT) and was increased by 510 taf/yr to an average annual outflow 16,277 taf/yr for the HOS (LLT) case. The average annual outflow for the HOS_LLT was 744 taf/yr greater than the EBC1 average annual outflow of 15,533 taf/yr, was 534 taf/yr greater than the EBC2 average annual outflow of 15,743 taf/yr, and was 5 taf/yr less than EBC2 LLT average annual outflow of 16,282 taf/yr. The average annual Delta outflow was reduced by 349 taf/yr to an average annual outflow of 15,418 taf/yr for the LOS (LLT) case. The average annual outflow for the LOS_LLT was 115 taf/yr less than the EBC1 average annual outflow of 15,533 taf/yr, was 325 taf/yr less than the EBC2 average annual outflow of 15,743 taf/yr, and was 864 taf/yr less than EBC2 LLT average annual outflow of 16,282 taf/yr.

The average annual total Delta export volume (from north Delta intakes and south Delta) was about 5,265 taf for the ESO (ELT) and was reduced by 560 taf/yr to an average annual Delta exports of 4,705 taf for the HOS (ELT) case. The average annual exports for the HOS_ELT was 439 taf/yr less than the EBC1 average annual exports of 5,144 taf/yr, was 193 taf/yr less than the EBC2 average annual exports of 4,898 taf/yr, and was 23 taf/yr less than EBC2 ELT average annual exports of 4,728 taf/yr. The average annual Delta exports were increased by 326 taf/yr to an average annual Delta exports of 5,591 taf for the LOS (ELT) case. The average annual Delta exports for the LOS_ELT was 447 taf/yr more than the EBC1 average annual exports, was 693 taf/yr more than the EBC2 average annual exports, and was 863 taf/yr more than EBC2 ELT average annual exports.

The average annual total Delta export volume was about 4,945 taf for the ESO (LLT) and was reduced by 531 taf/yr to average annual Delta exports of 4,414 taf for the HOS (LLT) case. The average annual exports for the HOS_LLT was 730 taf/yr less than the EBC1 average annual exports, was 484 taf/yr less than the EBC2 average annual exports and was 27 taf/yr less than EBC2 LLT average annual exports of 4,441 taf/yr. The average annual Delta exports for the ESO_LLT was increased by 310 taf/yr to 5,255 taf for the LOS (LLT) case. The average annual Delta exports for the LOS_LLT was 111 taf/yr more than the EBC1 average annual exports, was 357 taf/yr more than the EBC2 average annual exports, and was 814 taf/yr more than EBC2 LLT average annual exports.

Table C.A-44 gives the CALSIM-simulated monthly distributions of Delta outflow for the ESO and the changes in the monthly distributions for the HOS and LOS cases for the ELT (2025) and LLT (2060) timeframes. A review of the changes in the outflow indicates that the HOS and LOS outflows were nearly identical to the ESO case in many months, with the primary differences occurring in the spring and fall months. The monthly average outflows for the HOS cases were higher than the ESO cases and higher than the EBC cases in March, April and May. The monthly average outflows for the LOS cases were lower than the ESO cases and lower than the EBC2 cases in September, October, and November; but the average LOS outflows were higher than the ESO cases in December and January (most likely caused by increased flood control releases). The monthly average September–November outflows for the LOS cases were similar to the EBC1 outflows because the EBC1 case also did not include the Fall X2 outflows.

Table C.A-45 gives the annual summary of ESO Delta outflow (taf) for the ELT and LLT timeframes. Because the HOS changes outflow in the months of March–May, the ESO average outflow (cfs) for March–May and the HOS increases for March–May are shown. Because the LOS changes outflow in the months of September–November, the ESO average outflow (cfs) for September–November and the LOS reductions for September–November are shown. The HOS increases in outflow are generally in years with moderate outflow, but can be in any water-year type (because the year-type changes in October). The LOS decreases in outflow are in the wet (1) and above normal (2) water years because these are the years with Fall X2 requirements under the 2008 USFWS BiOp.

The CALSIM-simulated changes in Delta outflow in these specific months required reduced exports for the HOS case and allowed some increased exports for the LOS case. Table C.A-46 gives the CALSIM-simulated monthly distributions of Delta exports for the ESO case and the changes in the monthly distributions for the HOS and LOS cases for the ELT (2025) and LLT (2060) timeframes. A review of the changes in the exports indicates that the HOS and LOS exports were similar to the ESO case in many months, but showed a decrease (for HOS) or increase (for LOS) distributed over the year.

Reductions in Delta outflow for the LOS case were simulated in about 40% of the years because the Fall X2 requirements apply in wet and above normal years; but because the Fall X2 requirements continue in October and November of the next water year, increases in Delta exports of more than 100 taf/yr were simulated in about 70% of the years. Most of the reduced Delta outflow was eventually “transferred” to increased Delta exports outflow, but not all in the September–November period. The top of Figure C.A-77 shows the average September–November outflow for the ESO and the LOS cases for WY 1922–2003 for the LLT timeframe using the purple and light blue lines with the left axis. The average Delta outflow in these three months is about 5,000 cfs (D-1641 objectives), but the Fall X2 requirements simulated in CALSIM for the ESO case increased the average outflow to about 10,000 cfs in above normal years and about 15,000 cfs in wet years. The bottom of Figure C.A-77 shows the reduction in Delta outflow during these months and the corresponding increase in Delta exports and reduction in Sacramento River flows at Freeport during these months; using the blue, red, and green lines with the right axis. The reduction in the average September–November outflow for the LOS case was therefore about 5,000 cfs in above normal years, about 10,000 cfs in wet years, and there were no changes in Delta outflow during these months in about 60% of the years (below normal, dry, and critical years) because neither operation included Fall X2. The changes in exports during these months were less than half of the changes in outflow; the remainder of the water remained in upstream storage, and was released for export in subsequent months.

Compared to the ESO, the annual outflow under the HOS was increased by more than 150 taf in about 50% of the years, was increased by more than 500 taf in about 25% of the years, and was increased by more than 1,500 taf in about 15% of the years. The corresponding reductions in annual Delta exports were greater than 500 taf in about 50% of the years, were greater than 750 taf in about 25% of the years, and were greater than 1,000 taf in about 15% of the years. Overall, most of the increased Delta outflow for the HOS case was achieved with reduced Delta exports (i.e., 531 taf/yr reduced exports with 510 taf/yr increased outflow). Some of the increased outflow was obtained directly from reduced exports, while some of the increased outflow was obtained from increased reservoir releases which subsequently caused reduced exports when reservoir releases were reduced.

Figure C.A-78 shows the CALSIM-simulated average March–May outflow for WY 1922–2003 for the ESO case (purple line) and the HOS case (light blue line) for the LLT timeframe (2060). The average March–May outflow ranged from about 10,000 cfs to more than 100,000 cfs, with an average of 29,196 cfs for the ESO case and an average of 31,854 cfs for the HOS. The changes in the average March–May outflow from the ESO to the HOS case are shown at the bottom of the graph, and the changes in the Delta exports and Sacramento River flows at Freeport during these months are also shown at the bottom of the graph. The HOS case provided increased outflow of more than 1,500 cfs in about 35% of the years. The majority (60%) of the increased outflow was provided by reduced exports in these same months; the remainder of the increased outflow was provided by increased reservoir releases compared to the ESO. There were no changes in the San Joaquin River inflow or reservoir operations. For the years with simulated increased March–May outflow, the increases were generally between 5,000 cfs and 10,000 cfs, which is equivalent to a volume of 900 taf to 1,800 taf for the three-month period. A considerable volume of water is required to increase Delta outflow during a three-month period (e.g., 180 taf for a 1,000 cfs increase for 3 months).

5C.A.5.2 Comparison of Upstream Reservoir Storage

The LOS reduced Delta outflow requirements in September–November of above normal and wet years, and as described above (Figure C.A-77), increased Delta exports by about half of the reduced Delta outflow in those same years. The remainder of the water was retained in upstream reservoirs (reduced reservoir releases). The HOS was developed to preserve the ESO pattern of upstream reservoir carryover storage, so that additional releases in the spring months of March, April and May would not cause any substantial reduction in the end of September storage in Trinity, Shasta, Oroville, or Folsom. Increased March–May releases from Oroville caused reduced end-of-May storage and required reduced summer releases to maintain the EBC carryover storage at the end of September. As described above (Figure C.A-78), about half of the increased outflow was simulated with reduced exports; the remainder of the water was simulated with increased reservoir releases during the March to May period.

Exports from Trinity River (3,300 cfs maximum) were not used to increase Delta outflow in March, April or May, and are generally the same as the ESO scenarios. The monthly operations of Trinity Reservoir are highly regulated by the Trinity River Restoration Agreement. CALSIM has monthly rules for exports from Trinity Reservoir through Carr and Spring Creek tunnels and powerhouses to the Sacramento River. Although there were some differences in the eight CALSIM cases being compared, most of the differences are attributable to the changes in runoff estimated for the ELT and the LLT cases. Figure C.A-79 shows the Trinity Reservoir storage for the eight CALSIM cases; the top graph shows storage variations for WY 1922–1962 and the bottom graph shows storage variations for WY 1963–2003. The Trinity River spring flows depend on the Trinity River runoff at Lewiston, and there were rarely any additional flood control spills to the Trinity River. The exports to the Sacramento River were simulated to be predominantly in July, August and September, with some exports in October, to generate hydroelectric energy and to provide cool summer release flows at Keswick Dam. The average annual exports from the Trinity River to the Sacramento River were about 520 taf/yr for each of the ELT cases, and were about 555 taf/yr for each of the LLT cases. There were no changes in the Trinity River release flows and no changes in the Trinity exports to the Sacramento River between the four ELT cases or between the four LLT cases. Some slight changes can be seen in a few years between the ELT cases and the LLT cases when the estimated runoff changes caused slightly different Trinity Reservoir storage sequences. Tables of the monthly Trinity Reservoir storages and the Trinity River exports are not shown because they were essentially unchanged from the ESO for the HOS and LOS. The Trinity Reservoir storage patterns for the EBC cases were also very similar to the ESO cases.

The HOS did not cause any substantial changes in the Shasta Reservoir storage pattern. Figure C.A-80 shows the Shasta Reservoir storage for the eight CALSIM cases; the top graph shows storage variations for WY 1922–1962 and the bottom graph shows storage variations for WY 1963–2003. Visually, each of the eight cases had very similar maximum storage in May or June and minimum storage in September or October of each year. There were some small differences in a few years between the ELT and the LLT cases caused by shifted inflows. The LOS cases for ELT and LLT allowed slightly higher carryover storage in a few years. Because the Shasta Reservoir inflow (runoff) is very high in many years, Shasta Reservoir was refilled to maximum storage in May or June in about 50% of the years. The simulated increases in spring releases for HOS or the simulated reductions in fall releases for LOS did not have a large effect on the Shasta Reservoir storage pattern. The Shasta Reservoir storage patterns for the EBC cases were very similar to the ESO cases.

Figure C.A-81 shows the CALSIM-simulated cumulative distributions of Shasta Reservoir end-of-May and end-of-September (carryover) storage for the ESO compared to the HOS and LOS cases for the ELT and LLT timeframe for WY 1922–2003. The end-of-May storage was full (4,500 taf) in about 20% of the years for each of the six cases. The end-of-May storage was more than 250 taf lower for the LLT cases in about 30% of the years, because of shifts in the runoff pattern (more flood control spills). There were very few changes in the end-of- May cumulative distribution (i.e., probability) of storage between the ESO and the HOS or LOS cases for either the ELT or the LLT timeframe. The CALSIM-simulated monthly distribution of end-of-September Shasta Reservoir storage were generally lower for the LLT cases, because of the shift in runoff from summer to spring. The storage was slightly higher for the LOS cases, because of reduced releases for Fall X2 in wet and above normal years. There were no changes in carryover storage for the HOS cases.

Table C.A-47 gives the CALSIM-simulated monthly distributions of Keswick Dam release flows for the ESO and the changes in the monthly distributions for the HOS and LOS cases for the LLT (2060) timeframe. A review of the changes in the Keswick flows indicates that the HOS and LOS flows were similar to the ESO case in most months. The Keswick flows for the HOS case showed a small shift from May and June (reduced by 500 cfs to 1,000 cfs) to August and September (increased by 500 cfs to 1,000 cfs). Keswick releases were not increased in the March–May period and did not, therefore, contribute to increased Delta outflow. The Keswick flows for the LOS case showed a reduction in September, with an average flow reduction of 2,500 cfs in about 40% of the years. The October flows were about the same as the ESO, and the November flows were reduced by an average of 1,000 cfs in about 40% of the years. The Keswick flows in December–February were increased in about 25% of the years, likely because of increased flood control releases. The Keswick flow reductions in September–November were about 25% of the outflow reductions for the LOS case.

About half of the water for the HOS-increased March–May Delta outflow was released from Oroville, with releases reduced in the summer months to ensure end of September storage remained similar to ESO. Figure C.A-82 shows the Oroville Reservoir storage for the eight CALSIM cases; the top graph shows storage variations for WY 1922–1962 and the bottom graph shows storage variations for WY 1963–2003. Visually, each of the eight cases had very similar maximum storage in May or June and similar minimum storage in September or October of each year. There were some small differences in a few years between the ELT and the LLT cases caused by shifted inflows. The LOS cases for ELT and LLT allowed slightly higher carryover storage in a few years. Because the Oroville Reservoir inflow (runoff) is high in many years, Oroville Reservoir was refilled to maximum storage in May or June in about 30% of the years. The simulated increases in spring releases for HOS reduced the Oroville storage by about 250 taf in about 10% of the years; the simulated reductions in fall releases for LOS raised the Oroville Reservoir carryover storage by about 250 taf in about 40% of the years. There were variations in the Oroville Reservoir storage patterns between the cases, with the LLT cases generally lower; but the carryover storage for the EBC cases were similar to the carryover storage for the ESO cases.

Figure C.A-83 shows the CALSIM-simulated cumulative distributions of Oroville Reservoir end-of-May and end-of-September (carryover) storage for the ESO compared to the HOS and LOS cases for the ELT and LLT timeframe for WY 1922–2003. The end-of-May Oroville storage was full (3,500 taf) in about 20% of the years for each of the six cases. The end-of-May storage was lower for the LLT cases in most of the years because of shifts in the runoff pattern (more flood control spills). The end-of-May Oroville storage for the HOS cases were much lower (500 taf) than the ESO or LOS cases because of the additional releases from Oroville for increased Delta outflow that were made in about 40% of the years. There were few changes in the end-of-May storage for the LOS cases compared to the ESO. The CALSIM-simulated monthly distributions of September Oroville Reservoir storage were generally similar for the lowest 20% of the years (with storage of less than 1,250 taf). September storage was higher for the HOS and LOS cases compared to the ESO for the ELT and LLT. The Oroville Reservoir operations were adjusted in the summer months to maintain the ESO carryover storages for both the ELT and LLT timeframes.

Table C.A-48 gives the CALSIM-simulated monthly distributions of Feather River below Thermalito flows for the ESO and the changes in the monthly distributions for the HOS and LOS for the LLT (2060) timeframe. A review of the changes in the Feather River flows indicates that the HOS and LOS flows were similar to the ESO case in most months. The Feather River flows for the HOS case showed a large increase in April and May, with a corresponding reduction in June, July and August. The April flows were increased at least 750 cfs in about 50% of the years and were increased more than 5,000 cfs in about 25% of the years. The May flows were increased at least 500 cfs in about 50% of the years and were increased more than 2,500 cfs in about 25% of the years. Feather River flows were increased by an average of 1,250 cfs for the March–May period, and contributed about half of the increased outflow for the HOS case (the remainder of the additional HOS outflow increase was achieved with export reductions). The Feather River flows for the HOS case were reduced in the summer months to maintain the ESO September carryover storage pattern in most years. The Feather River flows for the LOS case were reduced in September by more than 3,000 cfs in about 40% of the years. This was about half of the reduced Delta outflow volume for the September–November period for the LOS case.

Folsom Reservoir operations are relatively constrained because of the relatively low storage volume (975 taf maximum) compared to the runoff; very few adjustments in the ESO operations could be made for either the HOS or the LOS cases. The HOS did not cause any substantial changes in the Folsom Reservoir storage pattern. Figure C.A-84 shows the Folsom Reservoir storage for the eight CALSIM cases; the top graph shows storage variations for WY 1922–1962 and the bottom graph shows storage variations for WY 1963–2003. Visually, each of the eight cases had very similar maximum storage in May or June and minimum storage in September or October of each year. There were some small differences in a few years between the ELT and the LLT cases caused by shifted inflows. The LOS cases for ELT and LLT allowed slightly higher carryover storage in a few years. Folsom Reservoir storage must remain below 600 taf from November through February (flood control) and is allowed to increase storage in March, April and May, to a maximum storage of about 975 taf. If higher releases were made in these months for increased Delta outflow, the storage would be lower at the end of May. Because the Folsom Reservoir inflow (runoff) is high in many years, Folsom Reservoir was refilled to maximum storage in May or June in about 50% of the years. There were no simulated increases in spring releases from Folsom Reservoir for HOS, and simulated reductions in fall releases for LOS raised the Folsom Reservoir carryover storage by about 50 taf in about 50% of the years. Because the Folsom Reservoir operations are constrained by hydrology and limited by maximum storage, the EBC cases had carryover storage that was very similar to the ESO cases.

Figure C.A-85 shows the CALSIM-simulated cumulative distributions of Folsom Reservoir end-of-May and end-of-September (carryover) storage for the ESO compared to the HOS and LOS cases for the ELT and LLT timeframe for WY 1922–2003. The end-of-May storage was full (975 taf) in about 50% of the years for the ELT cases, and was full in about 30% of the years for the LLT cases. The end-of-May storage was lower for the LLT cases in about 60% of the years, because of shifts in the runoff pattern (more flood control spills). There were few changes in the end-of-May storage between the ESO and the HOS or LOS cases for either the ELT or the LLT timeframe. The CALSIM-simulated monthly distribution of end-of-September Folsom Reservoir storage were generally lower for the LLT cases for all years because of the shift in runoff from summer to spring. The September storage was slightly higher for the LOS cases, because of reduced releases for Fall X2 in wet and above normal years. There were no changes in Folsom carryover storage for the HOS compared to the ESO.

Table C.A-49 gives the CALSIM-simulated monthly distributions of American River flows for the ESO case and the changes in the monthly distributions for the HOS and LOS cases for the LLT (2060) timeframe. The American River flows are remarkably constant from February through June, with median flows of 2,250 cfs to 3,250 cfs. There are several upstream reservoirs that provide flow regulation, and Folsom is at flood control capacity in about 50% of the years. The lowest average flows for the February–June period are in May, when the maximum flood control storage increases from 800 taf to 975 taf (more inflow can be stored). A review of the changes in the American River flows indicates that the HOS and LOS flows were very similar to the ESO flows in most months. The American River flows for the HOS case showed a decrease of about 500 cfs in May and June for many of the years compared to the ESO; therefore Folsom Reservoir did not contribute to increased March–May Delta outflow for the HOS. The American River flows for the LOS were reduced in September by about 500 cfs to 1,500 cfs in about 25% of the years. This was about 10% of the reduced Delta outflow volume for the September–November period for the LOS.

Changes in upstream reservoir releases would change the Sacramento River flow at Freeport. Table C.A-50 gives the CALSIM-simulated monthly distributions of Sacramento River at Freeport flows for ESO and the changes in the monthly distributions for the HOS and LOS for the LLT (2060) timeframe. The median monthly Freeport flow was about 23,500 cfs in March, 16,000 cfs in April, and about 13,500 cfs in May. Relatively high flows (twice the median monthly flow) in these months occur in about 20% of the years. The HOS Freeport flows were not increased in March. Compared to the ESO, the Freeport flows in April were increased by about 5,000 cfs in about 30% of the years, with an average increase of 1,845 cfs under the HOS, which accounted for about half of the HOS average outflow increase of 4,000 cfs in April. Compared to the ESO, the Freeport flows in May were increased by about 1,000 cfs in about 25% of the years, with an average increase of 495 cfs under the HOS, which accounted for about 25% of the HOS case average outflow increase of 2,000 cfs in April. The HOS Freeport flows in June and July were reduced to maintain the carryover storage in the upstream reservoirs, as described above.

Figure C.A-86 shows the March Delta outflows for the ESO (LLT) and the HOS, and the increases from the ESO to the HOS. Increases of 2,000 cfs to 10,000 cfs were simulated in some of the years with March outflows of 10,000 cfs to 40,000 cfs. Figure C.A-87 shows the April Delta outflows for the ESO (LLT) and HOS, and the increases for the HOS case. Increases of 10,000 cfs to 20,000 cfs were simulated in some of the years with April outflows of 15,000 cfs to 45,000 cfs. Figure C.A-88 shows the May Delta outflows for the ESO (LLT) and HOS, and the increases for the HOS case. Increases of 2,000 cfs to 20,000 cfs were simulated in some of the years with May outflows of 10,000 cfs to 25,000 cfs. Figure C.A-89 shows the average March–May Delta outflows for the ESO (LLT) and HOS, and the increases for the HOS case. Average March–May increases of 1,500 cfs to 15,000 cfs were simulated in some of the years with average March–May outflows of 15,000 cfs to 35,000 cfs.

Figure C.A-90 provides a summary of the HOS changes in March–May Delta outflow compared to the ESO (LLT). The changes in Delta outflow are shown in comparison with the March–May changes in Freeport flow, and the March–May changes in Delta exports. The outflow increases of less than 5,000 cfs were simulated with reduced exports without any additional Freeport inflow. Outflow increases of 5,000 cfs to 10,000 cfs were simulated with reduced exports of about 5,000 cfs and additional Freeport inflows of between 0 cfs and 5,000 cfs. Outflow increases of more than 10,000 cfs were simulated with about half of the outflow increase from reduced exports and about half of the increase from increased Freeport flow. Operational rules will be needed for the HOS, to reduce the allowable exports and make additional releases from upstream reservoirs, under specified hydrologic conditions. These additional rules would differentiate the ESO from the HOS. The operational rules for the LOS are already established as the D-1641 required Delta outflow for September–November.

Table C.A-43. Comparison of CALSIM-Simulated Average Annual Delta Outflow (taf/yr) and Average Total Delta Exports (taf/yr) for ESO and HOS and LOS Cases

		Baseline EBC1	**Baseline EBC2**	**Reference EBC2 ELT**	**Reference EBC2 LLT**
A. Summary of Annual Delta Outflow for ESO HOS and LOS Cases Compared to Baselines and References					
Case	**Outflow (taf/yr)**	**15,533**	**15,743**	**16,157**	**16,282**
ESO_ELT	15,590	57	(153)	(567)	(692)
HOS_ELT	16,138	605	395	(19)	(144)
LOS_ELT	15,239	(294)	(504)	(918)	(1,043)
ESO_LLT	15,767	234	24	(390)	(515)
HOS_LLT	16,277	744	534	120	(5)
LOS_LLT	15,418	(115)	(325)	(739)	(864)
B. Summary of Annual Total Delta Exports for ESO HOS and LOS Cases Compared to Baselines and References					
Case	**Exports (taf/yr)**	**5,144**	**4,898**	**4,728**	**4,441**
ESO_ELT	5,265	121	367	537	824
HOS_ELT	4,705	(439)	(193)	(23)	264
LOS_ELT	5,591	447	693	863	1,150
ESO_LLT	4,945	(199)	47	217	504
HOS_LLT	4,414	(730)	(484)	(314)	(27)
LOS_LLT	5,255	111	357	527	814

Table C.A-44. CALSIM-Simulated Monthly Distributions of Delta Outflow for ESO and Changes for the HOS and LOS Cases for the ELT and LLT Timeframes for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_ELT Outflow													
Min	3,000	3,500	3,500	5,282	7,476	6,854	6,651	4,000	4,000	4,000	3,000	3,000	3,878
10%	5,888	3,500	4,500	9,171	9,340	9,583	8,972	7,101	5,779	4,000	3,500	3,000	5,458
20%	6,492	4,500	4,502	12,333	12,868	11,860	9,696	8,123	6,966	5,000	3,500	3,000	6,390
30%	7,043	4,500	4,521	14,162	16,302	15,711	10,785	9,172	7,133	5,000	3,911	3,000	7,278
40%	7,413	4,500	6,886	16,914	21,043	18,203	14,169	11,868	7,486	6,500	4,000	3,000	8,991
50%	7,652	8,438	9,492	22,942	33,065	23,150	15,875	13,414	8,111	8,000	4,000	3,000	10,157
60%	8,039	9,469	12,763	28,258	50,322	32,335	18,835	14,695	8,921	8,000	4,000	11,250	15,272
70%	8,438	13,633	17,281	43,796	61,912	42,065	23,969	16,918	9,285	8,116	4,000	18,297	19,441
80%	9,038	14,500	34,663	72,701	86,002	66,025	39,200	21,203	11,557	9,376	4,000	19,688	24,685
90%	9,672	16,330	63,579	106,332	137,372	85,369	61,911	41,223	19,133	10,233	4,087	20,313	31,782
Max	26,659	86,986	195,172	307,821	251,077	273,553	145,298	79,212	58,864	21,779	7,513	21,563	60,200
Avg	7,889	11,085	23,042	44,053	54,312	42,524	26,355	18,888	11,138	7,376	3,926	9,708	15,590
B. HOS_ELT Changes in Outflow													
Min	679	0	0	26	-190	385	178	0	0	0	0	0	2
10%	77	0	0	0	190	711	0	181	-178	0	0	0	173
20%	165	0	2	263	18	1,895	520	-153	-375	0	94	0	301
30%	128	0	90	-5	503	1,731	1,788	536	-13	0	89	0	48
40%	-11	308	-344	22	250	4,515	4,510	1,810	-167	0	0	0	331
50%	-62	217	20	45	-8	5,003	9,229	3,174	-532	-53	0	230	1,100
60%	-115	0	401	1,523	-1,316	1,802	8,850	5,074	-224	0	0	94	783
70%	0	-97	147	988	-109	4,064	8,683	6,585	434	-116	0	47	823
80%	24	-125	614	-377	526	54	3,531	11,354	-711	-846	0	281	2,246
90%	9	111	-2,804	6,555	2,952	1,101	823	8,081	-44	-869	316	313	633
Max	2,113	-1,113	4	14	-8,511	171	220	-489	640	562	-73	0	26
Avg	42	-55	446	146	-160	1,950	4,068	2,868	-192	-250	67	88	548
C. LOS_ELT Changes in Outflow													
Min	0	0	0	4	-9	-20	2	0	0	0	0	0	-9
10%	-292	0	0	287	-19	198	104	14	158	0	0	0	-93
20%	-247	0	0	1,618	-5	-119	81	-268	19	0	14	0	-129
30%	-10	0	158	1,216	207	329	214	423	61	0	-58	0	-209
40%	-73	0	320	498	194	9	259	-101	-73	0	0	0	-195
50%	-153	-3,938	4	960	1,112	875	11	0	-98	0	0	0	-396
60%	-384	-4,969	531	2,169	595	3	-6	-9	7	0	0	-8,250	-713
70%	-579	-9,132	472	2,876	-902	990	-52	-95	33	49	0	-15,297	-473
80%	-993	-9,397	1,134	1,020	16	706	31	145	-662	-165	0	-16,687	-665
90%	-1,374	-360	1,988	-1,242	-560	4,544	6	-38	3	-306	43	-14,704	-918
Max	-86	5	5	-15	-98	7	1	-303	1,796	6	5	-2,550	530
Avg	-388	-2,910	981	1,067	554	483	146	25	16	-5	3	-5,922	-351

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
D. ESO_LLT Delta Outflow													
Min	3,000	3,500	4,500	5,349	4,455	7,239	7,100	4,001	4,000	4,000	3,298	3,000	4,869
10%	5,873	3,500	4,500	10,991	9,923	9,772	9,766	7,123	6,679	5,000	3,595	3,000	6,087
20%	7,179	4,500	4,504	12,809	12,703	13,266	10,288	10,041	7,159	5,000	4,000	3,000	6,898
30%	7,600	4,500	5,624	14,128	18,237	15,095	11,417	10,908	7,600	5,571	4,000	4,002	7,491
40%	8,641	4,500	7,585	16,938	21,307	17,826	13,292	11,850	8,445	6,690	4,000	4,537	8,998
50%	10,117	10,162	10,807	22,789	33,380	22,492	15,716	13,243	9,125	8,000	4,000	6,738	10,270
60%	10,465	11,438	12,945	27,476	48,669	32,545	19,480	14,599	9,748	8,000	4,000	13,344	15,931
70%	10,752	12,905	16,605	42,626	60,788	41,393	23,405	16,868	10,960	8,674	4,230	18,859	19,873
80%	11,220	14,514	30,270	73,944	91,327	67,586	37,925	21,025	11,327	9,547	4,560	21,875	24,846
90%	12,773	16,844	60,010	103,246	134,414	94,765	60,789	32,920	19,706	11,192	5,024	22,500	31,482
Max	26,755	73,050	192,580	316,004	255,260	279,907	144,263	68,727	52,008	14,616	6,860	22,813	58,899
Avg	9,510	10,728	21,867	44,827	55,165	43,308	26,460	17,821	10,751	7,616	4,218	10,995	15,767
E. HOS_LLT Changes in Delta Outflow													
Min	0	0	-1,000	7	3,060	0	0	-1	0	0	-72	0	-556
10%	-310	364	0	-1,152	41	471	141	160	-236	0	122	0	103
20%	-402	0	3	-146	129	6	43	-64	18	0	0	197	57
30%	43	0	-747	-69	74	2,639	542	107	-281	-177	0	112	54
40%	-32	56	37	-998	-204	4,776	4,327	688	-629	-190	0	1,021	413
50%	-78	-220	-730	-686	51	4,103	9,044	1,845	-320	0	0	676	1,155
60%	-28	125	493	179	2,074	1,358	9,590	3,315	-30	0	0	-219	555
70%	-127	0	521	67	2,182	3,844	10,453	4,294	-26	-608	-207	141	351
80%	32	0	464	-3,660	-1,174	1,382	5,613	4,009	89	292	-110	0	1,968
90%	92	0	1,792	9,267	4,101	523	1,311	10,572	-139	-500	251	-156	828
Max	106	-176	-12	4	-8,625	312	71	-205	-369	-998	-706	156	58
Avg	-104	106	86	207	195	2,046	4,010	1,917	-149	-119	9	242	510
F. LOS_LLT Changes in Delta Outflow													
Min	0	0	0	-131	938	0	0	-1	0	0	-65	0	-22
10%	-150	72	0	-116	73	-65	-8	-1	-142	0	67	0	-190
20%	-87	0	1,209	-207	204	-1,207	127	126	81	0	0	0	-220
30%	-18	0	1,812	1,261	-76	484	120	22	-25	-223	0	-1,002	-35
40%	-744	0	758	2,895	69	306	258	59	54	-103	0	-1,537	32
50%	-1,784	-5,662	-277	190	-7	1,840	113	26	165	-26	0	-3,738	-156
60%	-1,536	-6,937	1,110	2,278	325	62	-51	86	85	0	0	-9,869	-1,296
70%	-734	-8,301	206	395	1,031	2,660	20	-68	3	-39	22	-14,761	-459
80%	219	-9,162	3,602	3,715	-1,834	1,882	77	2	135	-143	65	-16,744	-501
90%	397	-1,775	4,190	5,001	7,028	-648	-613	1	3	-188	85	-15,800	-598
Max	-10	5,681	-22	-277	-90	2,573	-1,821	-669	990	-25	-159	-8,041	455
Avg	-481	-3,056	1,329	1,654	740	641	115	-25	66	-78	27	-6,854	-348

Table C.A-45. CALSIM-Simulated Annual Delta Outflow Summary for ESO and Changes for the HOS and LOS Cases for the ELT and LLT Timeframe for WY 1922–2003

Year	Water-Year Type	ESO-ELT Annual Outflow (TAF)	ESO-ELT Mar-May Outflow (cfs)	HOS-ELT Increased Mar-May Outflow (cfs)	ESO-ELT Sep-Nov Outflow (cfs)	LOS-ELT Reduced Sep-Nov Outflow (cfs)		ESO-LLT Annual Outflow (TAF)	ESO-LLT Mar-May Outflow (cfs)	HOS-LLT Increased Mar-May Outflow (cfs)	ESO-LLT Sep-Nov Outflow (cfs)	LOS-LLT Reduced Sep-Nov Outflow (cfs)
1922	2	15,373	36,667	-12	13,906	8,730		15,961	36,701	30	14,999	10,028
1923	3	10,147	15,731	1,814	5,286	62		10,346	16,379	1,404	5,963	-1
1924	5	4,451	6,793	59	4,169	57		5,045	6,946	-12	5,094	225
1925	4	9,703	18,167	8,392	4,987	16		10,194	24,930	6,733	6,301	576
1926	4	7,701	14,183	-70	8,971	67		8,588	15,615	-326	10,164	150
1927	1	19,604	32,726	5,407	9,087	3,747		19,389	35,163	2,371	10,758	4,218
1928	2	12,413	36,306	288	9,392	4,372		11,474	34,898	1,287	5,686	-114
1929	5	5,109	7,987	162	4,203	7		5,568	8,269	151	4,499	47
1930	4	6,873	13,567	87	4,928	-12		7,460	14,980	-104	6,251	-125
1931	5	4,083	6,451	75	4,331	1		4,869	6,501	98	5,225	-582
1932	4	6,792	10,936	1,509	4,149	0		6,912	12,262	1,121	4,733	-22
1933	5	5,365	9,924	11	4,192	1		5,217	10,158	13	5,424	84
1934	5	5,372	9,416	-25	3,400	0		5,741	9,391	-28	5,457	-52
1935	3	9,465	28,588	470	5,037	-1		10,007	29,466	205	5,472	-110
1936	3	13,275	21,796	13,862	5,143	-9		13,506	35,580	13,566	6,325	-25
1937	3	11,294	30,045	-24	10,249	-36		11,203	29,682	446	10,889	3
1938	1	39,820	106,846	264	14,116	9,034		40,401	109,614	62	15,430	10,079
1939	4	5,900	9,405	84	4,788	-273		6,259	10,589	128	7,201	-914
1940	2	20,480	64,925	123	9,098	3,938		21,536	68,345	444	10,651	5,097
1941	1	31,839	67,039	855	14,525	9,497		31,248	64,473	479	15,074	9,992
1942	1	26,766	34,034	10,466	14,479	8,948		25,744	43,862	13,535	16,146	10,940
1943	1	20,053	40,935	-1,021	13,787	8,593		20,306	40,699	-28	14,650	9,404
1944	4	7,340	12,663	32	5,082	85		7,522	12,727	-6	6,209	-451
1945	3	9,473	17,896	9,737	5,338	-5		8,969	23,886	8,267	6,701	-3
1946	3	14,032	15,169	8,430	9,387	4,242		12,938	16,768	3,393	4,910	509
1947	4	6,018	11,395	8	5,013	1		6,410	12,620	-43	5,776	-60
1948	3	7,276	18,200	115	5,003	2		7,478	17,538	138	5,440	451
1949	4	7,139	19,785	34	4,948	-22		7,622	22,184	2,246	6,092	-277
1950	3	7,609	13,736	5,584	19,340	1,299		8,055	24,829	10,052	17,701	32
1951	2	23,904	18,266	12,332	9,404	4,314		23,689	29,568	11,343	11,076	6,127
1952	1	29,198	66,753	37	14,398	7,703		29,231	66,264	420	15,530	9,495
1953	1	16,421	16,555	13,929	14,688	10,126		16,439	28,807	13,456	16,539	11,716
1954	2	13,197	28,624	-3,571	9,175	4,220		13,353	27,688	-1,754	10,781	3,648
1955	4	6,381	8,675	2,146	4,864	-5		6,895	10,689	665	6,982	-181
1956	1	30,815	29,011	14,287	14,792	10,053		31,143	40,506	14,114	15,780	10,119
1957	2	10,166	24,365	-1,329	9,204	4,021		9,784	20,109	-1,333	10,792	5,186
1958	1	31,988	88,211	471	13,818	8,753		32,169	87,738	160	14,908	10,114
1959	3	8,925	10,238	8,266	4,775	39		9,221	12,126	-88	7,428	-219
1960	4	6,204	11,068	2,947	4,840	7		6,934	15,051	2,925	6,280	-784

Year	Water-Year Type	ESO-ELT Annual Outflow (TAF)	ESO-ELT Mar-May Outflow (cfs)	HOS-ELT Increased Mar-May Outflow (cfs)	ESO-ELT Sep-Nov Outflow (cfs)	LOS-ELT Reduced Sep-Nov Outflow (cfs)		ESO-LLT Annual Outflow (TAF)	ESO-LLT Mar-May Outflow (cfs)	HOS-LLT Increased Mar-May Outflow (cfs)	ESO-LLT Sep-Nov Outflow (cfs)	LOS-LLT Reduced Sep-Nov Outflow (cfs)
1961	4	6,174	9,955	275	4,104	-234		6,662	10,731	-356	6,458	-95
1962	3	9,267	15,349	9,112	11,582	43		9,041	24,341	9,021	11,617	3
1963	1	18,481	44,510	2,495	14,531	6,934		18,296	45,530	2,288	10,632	4,310
1964	4	6,424	8,299	1,224	5,338	10		6,381	10,330	508	6,721	-20
1965	1	22,199	22,944	14,638	14,636	6,694		22,223	35,691	12,141	16,719	11,246
1966	3	8,580	12,513	838	5,405	-142		8,877	13,848	712	7,491	-113
1967	1	21,849	52,926	312	14,258	8,468		21,360	51,432	88	15,399	9,976
1968	3	9,829	14,320	7,484	4,709	-288		9,974	20,420	5,960	6,126	1,023
1969	1	32,946	62,523	246	14,688	8,638		33,358	60,721	1,283	16,080	10,302
1970	1	29,476	19,673	9,932	14,531	8,294		29,579	29,285	10,012	16,510	10,609
1971	1	15,583	25,498	2,335	14,781	9,630		15,885	28,198	4,490	15,681	10,636
1972	3	7,284	12,135	2,190	7,161	246		7,413	12,734	673	8,546	157
1973	2	19,059	27,237	7,551	23,262	2,976		19,791	34,709	6,638	21,219	2,110
1974	1	31,271	60,890	4	14,397	9,513		31,508	61,750	-66	15,558	10,000
1975	1	16,257	41,656	1,396	14,803	9,785		16,121	44,017	1,738	16,244	10,417
1976	5	5,569	9,028	652	4,672	-205		6,079	10,399	2	5,396	-1,045
1977	5	3,878	6,113	0	3,761	168		4,928	6,113	0	4,419	-127
1978	2	18,857	46,188	1,294	8,976	2,252		19,908	46,661	384	10,605	3,960
1979	3	9,321	19,972	-565	5,274	0		9,167	18,830	540	8,019	996
1980	2	24,850	32,952	10,228	9,264	4,042		25,135	42,969	9,525	10,924	6,121
1981	4	6,960	11,728	378	12,730	266		7,431	12,314	-302	12,059	-224
1982	1	37,643	89,713	237	24,348	3,556		37,450	88,941	-18	21,890	4,840
1983	1	60,200	147,982	32	38,469	-4		58,899	147,567	90	34,969	811
1984	1	30,768	19,892	9,147	16,074	5,074		29,602	27,144	8,096	16,719	7,314
1985	4	7,611	11,175	74	5,003	453		7,708	11,253	336	5,666	-175
1986	1	29,462	62,632	2,133	14,262	8,842		29,392	64,510	1,899	15,567	10,070
1987	4	6,681	12,156	-1	4,572	-364		7,164	13,944	10	6,272	21
1988	5	5,843	7,960	253	4,127	101		6,644	8,639	236	5,061	-47
1989	4	7,596	24,653	373	4,506	9		8,032	26,566	1,774	6,977	-87
1990	5	4,804	8,373	162	4,032	59		5,471	8,828	299	5,205	156
1991	5	5,212	14,080	54	3,939	25		5,749	14,225	199	4,646	-21
1992	5	6,262	10,674	-3	3,167	0		6,606	11,006	17	5,022	10
1993	2	15,119	28,965	5,600	8,976	4,063		16,074	36,189	3,849	10,729	5,064
1994	5	5,446	8,475	405	3,703	-202		6,168	9,125	548	6,737	955
1995	1	37,748	123,561	-251	13,622	6,675		37,164	120,059	-162	14,568	8,197
1996	1	24,024	47,286	-586	14,896	9,420		23,530	44,314	-531	16,315	10,313
1997	1	36,348	16,029	12,589	14,583	9,435		35,887	26,899	11,227	15,964	10,836
1998	1	37,556	64,168	292	15,387	322		37,989	68,075	403	15,990	2,373
1999	1	20,699	32,996	4,854	14,792	9,697		21,190	35,425	1,927	15,605	10,679
2000	2	17,945	32,173	9,346	9,449	4,219		18,597	41,819	8,467	10,937	5,536
2001	4	6,590	11,763	-12	4,308	81		7,010	12,961	-153	6,678	-246

Year	Water-Year Type	ESO-ELT Annual Outflow (TAF)	ESO-ELT Mar-May Outflow (cfs)	HOS-ELT Increased Mar-May Outflow (cfs)	ESO-ELT Sep-Nov Outflow (cfs)	LOS-ELT Reduced Sep-Nov Outflow (cfs)		ESO-LLT Annual Outflow (TAF)	ESO-LLT Mar-May Outflow (cfs)	HOS-LLT Increased Mar-May Outflow (cfs)	ESO-LLT Sep-Nov Outflow (cfs)	LOS-LLT Reduced Sep-Nov Outflow (cfs)
2002	4	9,089	11,476	4,085	4,686	270		9,561	14,413	2,327	5,495	-555
2003	2	13,670	23,303	5,865				13,033	25,509	6,285		
Min		3,878	6,113	-3,571	3,167	-364		4,869	6,113	-1,754	4,419	-1,045
Avg		15,590	29,256	2,962	9,581	3,091		15,767	31,854	2,658	10,503	3,464
Max		60,200	147,982	14,638	38,469	10,126		58,899	147,567	14,114	34,969	11,716

Table C.A-46. CALSIM-Simulated Monthly Distributions of Delta Exports for ESO and Changes for the HOS and LOS Cases for the LLT Timeframe for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_ELT Delta Exports													
Min	1,087	1,100	3,788	900	1,751	1,285	830	900	994	1,076	1,926	2,492	2,102
10%	2,605	1,827	5,934	2,370	4,327	3,347	2,015	1,842	1,722	3,392	3,299	4,052	2,891
20%	3,284	2,715	7,319	3,377	5,642	5,107	2,257	2,078	2,300	6,488	4,684	4,394	3,862
30%	3,837	4,051	7,946	5,419	6,025	6,342	3,093	2,388	3,425	8,657	6,653	5,001	4,316
40%	4,270	4,738	8,586	6,407	7,799	7,702	3,679	2,877	5,466	9,680	7,750	5,618	5,115
50%	4,656	5,575	9,672	7,239	8,954	8,583	5,366	3,358	6,776	10,437	8,321	6,126	5,526
60%	5,033	6,376	10,315	7,901	10,364	9,601	6,932	4,343	8,386	11,430	9,332	6,447	5,673
70%	5,724	7,558	10,636	10,447	10,916	10,186	8,146	6,355	9,792	12,079	11,687	6,938	6,106
80%	6,197	9,204	11,403	12,042	11,726	10,587	9,956	9,785	10,975	13,311	12,884	7,504	6,561
90%	7,593	10,794	13,030	13,661	13,232	11,544	10,571	10,649	12,210	14,203	13,674	8,812	7,462
Max	11,262	12,339	14,525	14,528	14,551	14,604	12,026	12,209	14,207	14,898	14,871	13,205	8,165
Avg	4,869	5,922	9,401	7,726	8,824	8,137	5,809	5,045	6,806	9,725	8,695	6,256	5,265
B. HOS_ELT Changes in Delta Exports													
Min	628	0	51	200	-708	215	70	0	-270	-30	74	634	-218
10%	343	-307	283	-51	163	-1,847	-515	-351	-657	-1,283	581	129	-71
20%	-18	-408	-51	-132	-16	-3,607	-757	-578	-970	-1,481	326	135	-342
30%	-158	-10	-142	105	143	-4,835	-1,593	-888	-980	-2,067	204	194	-369
40%	-186	-132	-549	46	131	-3,523	-2,179	-1,377	-2,431	-2,207	-130	204	-775
50%	-284	-322	-446	60	-331	-2,639	-3,296	-1,615	-3,151	-1,909	-426	122	-858
60%	-325	35	-70	305	-830	-1,892	-3,531	-1,905	-3,868	-2,254	-853	33	-689
70%	-604	10	-99	-5	-55	-800	-1,196	-2,634	-4,478	-1,111	-2,493	-152	-764
80%	-334	-277	-145	803	-80	-24	-860	-1,893	-4,209	-851	-2,599	-248	-774
90%	-409	309	1,268	746	874	33	-638	-150	-2,648	-856	-1,799	-951	-532
Max	822	2,225	2	3	0	6	-71	13	-828	-55	-1,548	-2,118	-746
Avg	-109	30	-88	133	-77	-1,913	-1,425	-1,225	-2,291	-1,338	-802	-135	-560
C. LOS_ELT Changes in Delta Exports													
Min	2	1,803	111	0	150	0	-2	0	-87	-15	0	602	-69
10%	-3	2,858	361	-42	228	-37	-1	0	63	-598	792	778	191
20%	181	2,811	83	-10	-8	49	1	15	113	70	-92	1,950	239
30%	156	3,035	151	-632	148	-165	-73	0	2	46	-409	2,101	399
40%	993	2,897	257	72	85	87	26	-4	396	95	-311	2,379	195
50%	1,082	3,058	-236	24	-249	103	1	116	540	295	-21	2,318	366
60%	1,098	2,955	-152	396	-763	-92	-72	-50	637	-7	-23	2,508	476
70%	673	2,524	-250	-626	-207	-231	-80	-89	355	226	149	3,137	441
80%	1,292	2,047	-160	-115	-303	-54	-235	1	92	7	128	3,294	353
90%	1,351	995	-534	-116	-290	-384	-271	-81	0	153	362	4,138	253
Max	361	2,202	0	-2	-4	-50	-25	2	-1,111	2	0	1,585	155
Avg	738	2,529	-1	-74	-147	-182	-71	-18	179	46	26	2,433	326

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
D. ESO_LLT Delta Exports													
Min	1	1,100	1,063	0	1,393	974	828	1,049	994	463	1,490	271	1,418
10%	2,222	1,342	5,170	2,381	3,834	3,356	1,995	1,576	1,726	2,429	3,000	3,227	2,776
20%	2,694	1,878	6,291	3,286	5,580	5,140	2,246	2,057	2,257	4,351	4,009	3,681	3,275
30%	2,841	2,601	7,504	5,092	6,957	5,965	2,962	2,191	3,095	5,224	5,258	4,336	3,904
40%	3,222	4,254	8,377	6,451	7,913	7,484	3,809	2,492	4,809	6,756	6,533	4,872	4,603
50%	3,449	4,793	9,369	7,359	8,828	8,792	5,110	3,357	7,132	8,624	7,448	5,741	5,151
60%	3,843	5,801	10,105	8,456	10,635	9,760	6,491	4,511	8,848	9,405	8,755	6,121	5,576
70%	4,172	6,755	10,341	10,566	11,125	10,480	8,293	7,232	10,274	11,252	9,523	6,655	5,943
80%	4,878	8,871	10,874	12,740	11,778	10,914	9,932	9,455	10,950	12,696	11,819	7,038	6,458
90%	6,302	10,408	12,713	14,399	14,518	12,245	10,589	10,483	12,164	13,953	13,287	8,439	7,095
Max	8,681	13,041	14,525	14,531	14,551	14,596	11,884	12,204	13,231	14,900	14,871	12,601	7,810
Avg	3,831	5,316	8,851	7,840	8,942	8,196	5,721	4,950	6,777	8,223	7,754	5,574	4,945
E. HOS_LLT Changes in Delta Exports													
Min	177	-246	-614	6	-580	126	121	-162	-190	476	197	629	41
10%	140	-218	117	-35	-50	-1,856	-539	-311	-694	-413	240	275	-209
20%	86	-29	-26	38	-419	-3,640	-746	-557	-994	-262	217	365	-22
30%	85	-218	-302	-202	-1,035	-4,369	-1,462	-691	-881	96	977	376	-291
40%	-64	-451	-378	-84	-112	-3,727	-2,309	-992	-2,360	-413	599	729	-649
50%	90	3	-454	-252	-97	-3,277	-3,403	-1,834	-3,685	-1,517	739	100	-779
60%	57	-307	-630	0	-126	-2,029	-3,982	-2,344	-3,855	-1,502	-195	174	-806
70%	-118	139	-147	0	-104	-1,084	-1,755	-4,329	-4,052	-2,452	-553	63	-855
80%	-385	-96	-59	33	10	-347	-1,388	-3,270	-3,331	-2,854	-1,873	318	-858
90%	-426	297	1,261	69	0	-81	-630	-116	-2,844	-1,938	-2,262	-384	-472
Max	357	1,522	0	0	0	12	-1,156	24	397	-533	-2,153	-3,151	-585
Avg	-50	29	-66	19	-298	-1,929	-1,635	-1,408	-2,292	-1,076	-281	192	-532
F. LOS_LLT Changes in Delta Exports													
Min	148	-224	-957	2,135	-172	-44	72	-149	0	-402	266	1	-16
10%	205	3,120	78	22	117	444	1	56	-5	-13	-146	287	116
20%	25	3,467	111	168	-30	-26	-7	53	-28	-148	169	1,501	376
30%	169	4,012	361	475	-261	146	-89	122	159	138	269	1,654	185
40%	265	2,824	-44	-83	134	110	0	316	649	-325	-58	2,108	192
50%	491	3,018	-410	84	-54	110	-255	-73	96	-322	244	2,190	449
60%	899	2,868	-571	110	-488	-222	-10	-31	-290	137	-86	2,143	393
70%	1,410	2,494	-143	0	-281	-256	-5	-675	-542	-16	168	2,532	503
80%	1,452	1,435	272	-143	-173	-251	-195	10	-206	229	90	3,145	232
90%	574	1,111	47	-175	-1	-473	-385	-235	-31	65	-235	2,501	314
Max	2,373	803	-3	0	-4	-219	0	0	-730	0	0	2,189	555
Avg	637	2,549	-34	142	-134	-64	-24	-15	-24	33	112	2,000	310

Table C.A-47. CALSIM-Simulated Monthly Distributions of Keswick Dam Releases (cfs) for ESO and Changes for the HOS and LOS Cases for the LLT Timeframe for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_LLT Keswick Flow													
Min	2,794	2,870	3,059	3,250	3,250	3,250	3,250	3,250	6,217	6,051	2,703	2,803	3,112
10%	4,000	3,489	3,250	3,250	3,250	3,250	3,720	5,232	8,503	10,451	7,563	3,771	4,126
20%	4,554	4,000	3,384	3,250	3,250	3,250	4,500	5,713	10,007	11,257	8,200	4,206	4,565
30%	5,501	4,000	3,667	3,292	3,250	3,422	4,500	6,237	10,861	12,541	8,928	4,721	5,009
40%	6,083	4,242	4,000	3,997	3,565	4,113	4,852	6,866	11,449	13,443	9,634	5,540	5,206
50%	6,605	4,482	4,000	4,482	4,500	4,500	5,657	7,553	12,235	14,092	10,004	7,107	5,669
60%	6,917	4,913	4,195	4,500	4,732	4,784	6,173	7,990	13,033	15,000	10,354	8,964	6,722
70%	7,552	5,136	4,488	8,258	10,115	7,007	7,156	8,987	13,654	15,000	10,647	11,417	7,290
80%	8,051	6,050	6,603	13,647	22,983	12,351	8,490	9,614	14,394	15,000	11,395	12,880	8,258
90%	8,726	7,472	15,302	20,808	30,081	20,167	10,549	11,627	14,977	15,155	12,459	14,741	9,356
Max	13,169	24,163	32,513	60,328	51,105	46,363	30,978	15,000	15,000	16,420	15,000	15,662	12,476
Avg	6,555	5,288	6,587	9,235	11,261	8,834	6,852	7,915	12,008	13,421	9,757	8,248	6,390
B. HOS_LLT Changes in Keswick Flow													
Min	-56	-1	150	0	0	0	0	0	10	3,101	0	0	70
10%	0	-62	0	0	0	0	-18	-44	-458	264	252	165	-63
20%	198	0	-79	0	0	0	0	1	-782	190	356	150	17
30%	71	0	-168	-18	0	-172	0	-252	-946	126	661	532	-162
40%	77	-37	-170	-50	144	-555	-48	-483	-856	121	344	721	66
50%	-48	-23	0	-299	0	0	-59	-612	-1,098	-43	420	899	37
60%	10	-99	-195	0	8	-284	-114	-586	-1,481	-58	595	1,264	-120
70%	137	211	-149	-1,362	-858	933	-152	-943	-1,216	0	849	136	72
80%	340	458	152	-2,094	-857	0	-867	-855	-1,146	0	1,002	885	-140
90%	417	1,005	741	0	0	0	-33	-272	-747	-155	1,451	259	12
Max	824	-2,245	0	0	-30	-3	0	-609	0	4,003	0	-13	-139
Avg	206	101	-37	-190	-21	-55	-146	-456	-869	100	758	489	-7
C. LOS_LLT Changes in Keswick Flow													
Min	-59	9	0	0	0	0	0	0	1,232	0	0	0	-2
10%	-82	0	0	0	0	0	27	-11	-26	-101	273	394	18
20%	36	0	86	0	0	0	0	27	-93	278	305	367	187
30%	-240	0	27	200	0	4	0	45	70	323	27	615	-44
40%	-325	-242	0	182	436	-65	116	-23	-3	336	-115	312	214
50%	-271	-432	146	18	0	0	-54	-20	123	262	7	-1,032	178
60%	115	-609	672	1,504	1,826	474	124	83	-106	0	-11	-2,708	62
70%	-49	-595	1,120	1,447	3,362	1,795	-143	75	101	0	210	-4,705	-140
80%	250	-1,191	3,588	1,742	541	130	25	409	345	0	-182	-5,905	-272
90%	429	-1,992	662	3,265	0	17	-26	173	23	395	50	-7,330	-69
Max	1,831	4,720	1,809	0	123	0	0	0	0	76	0	-3,867	-123
Avg	-27	-510	666	814	464	208	43	45	51	105	100	-2,252	-15

Table C.A-48. CALSIM-Simulated Monthly Distributions of Feather River below Thermalito Flow (cfs) for ESO and Changes for the HOS and LOS Cases for the LLT Timeframe for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_LLT Feather River Flow													
Min	900	900	900	801	800	800	750	700	802	1,000	750	773	909
10%	1,200	930	1,200	900	900	824	1,000	1,000	2,216	2,121	1,372	1,000	1,496
20%	1,468	1,200	1,389	900	1,200	1,700	1,000	1,000	2,883	3,338	2,647	1,000	1,677
30%	1,906	1,700	1,700	1,582	1,700	1,700	1,000	1,411	3,147	5,042	3,218	1,344	1,959
40%	3,052	1,700	1,700	1,700	1,700	2,072	1,023	2,086	3,498	5,893	3,678	1,740	2,242
50%	4,000	1,703	1,700	1,700	2,132	3,020	1,671	2,643	4,665	6,724	4,253	2,955	2,808
60%	4,000	2,500	1,772	1,700	4,229	4,598	2,528	3,183	6,087	8,773	4,554	4,434	3,466
70%	4,000	2,500	2,423	2,152	8,648	8,322	3,248	3,695	7,216	9,832	4,795	5,943	4,147
80%	4,000	2,500	3,165	4,703	14,768	11,238	4,142	5,089	8,415	10,000	6,304	6,872	4,815
90%	4,000	2,500	4,883	14,463	21,959	16,426	8,573	6,829	9,502	10,000	8,908	7,494	5,712
Max	4,000	9,895	33,811	48,316	33,202	42,044	20,642	15,251	10,952	10,000	10,000	9,756	7,418
Avg	3,006	2,022	3,048	4,751	7,126	6,900	3,330	3,475	5,368	6,714	4,547	3,811	3,258
B. HOS_LLT Changes in Feather River Flow													
Min	0	0	0	2	100	0	0	50	198	0	-89	-23	197
10%	59	270	-256	0	0	108	0	0	-428	-366	-307	-135	-116
20%	232	41	-182	60	0	0	0	214	-649	-427	-806	65	-5
30%	-168	0	0	-264	0	0	354	401	-546	-1188	-811	421	-37
40%	-601	0	0	0	0	-372	862	387	-619	-707	-427	385	-119
50%	-1050	-3	0	0	133	303	780	558	-1439	-1154	-699	-194	-72
60%	-312	-588	-72	0	75	678	795	945	-2397	-2681	-514	-446	52
70%	0	0	-85	-22	649	-91	4824	2017	-2646	-2560	-381	-755	-123
80%	0	0	380	-124	-1387	759	8716	1836	-1857	-2167	-1538	-369	-40
90%	0	0	-335	218	-932	-435	8427	3000	-1445	-696	-3192	-17	682
Max	0	3303	0	0	0	6	0	1749	5079	0	-3479	-267	470
Avg	-191	-7	-65	355	-154	154	2516	1102	-1238	-1219	-1095	-191	-3
C. LOS_LLT Changes in Feather River Flow													
Min	0	0	0	1	0	0	0	0	-2	0	0	0	95
10%	170	270	-34	0	0	176	0	0	-152	-41	148	0	-41
20%	232	227	-167	0	0	0	0	0	-237	447	194	0	45
30%	190	0	0	-380	0	0	0	2	22	92	210	-344	12
40%	366	0	0	0	0	29	37	-115	-22	-267	152	-740	122
50%	0	-3	0	0	272	596	324	-52	155	-166	-94	-1,799	189
60%	0	0	289	0	1,002	906	125	-326	-340	-204	-11	-3,045	87
70%	0	0	519	1,242	-1,055	0	9	24	-478	96	422	-4,342	-165
80%	0	0	1,282	2,146	155	1,231	31	100	-641	0	542	-4,833	-118
90%	0	0	1,027	3,283	0	648	-122	4	-132	0	-8	-4,611	287
Max	746	5,622	0	0	0	0	0	0	462	0	0	-1,741	-90
Avg	82	124	405	969	159	351	57	-39	-133	28	130	-2,153	2

Table C.A-49. CALSIM-Simulated Monthly Distributions of American River Flow (cfs) for ESO and Changes for the HOS and LOS Cases for the LLT Timeframe for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_LLT American River Flow													
Min	500	500	500	425	63	260	250	294	250	255	259	334	395
10%	800	800	800	800	807	800	800	800	941	939	641	735	966
20%	870	800	800	1,131	1,445	827	1,209	1,289	1,588	2,305	862	805	1,227
30%	1,240	1,133	1,162	1,637	1,560	1,436	1,577	1,551	2,485	2,680	1,482	1,410	1,332
40%	1,500	1,425	1,750	1,700	1,914	1,750	1,805	1,798	2,863	3,203	1,750	1,533	1,636
50%	1,500	1,683	1,848	1,750	3,290	2,910	2,509	2,295	3,272	3,622	1,750	1,533	1,953
60%	1,500	1,817	2,000	2,557	5,186	4,246	3,017	2,561	3,847	4,471	1,753	1,533	2,455
70%	1,681	1,925	2,000	5,645	7,468	4,776	4,263	3,043	4,344	4,998	1,977	2,038	3,143
80%	2,184	1,925	2,501	8,535	11,228	6,070	4,982	3,722	4,935	5,000	2,280	2,847	3,695
90%	2,597	2,831	8,558	13,543	15,920	9,229	6,950	6,542	5,000	5,000	2,509	3,450	4,137
Max	5,000	15,826	23,686	38,305	39,261	20,206	16,572	10,928	7,739	5,337	3,984	4,489	6,167
Avg	1,613	1,965	3,288	5,184	6,155	4,160	3,336	2,886	3,311	3,496	1,685	1,827	2,338
B. HOS_LLT Changes for American River Flow													
Min	0	0	0	-66	323	57	99	12	0	-5	-7	-29	-22
10%	0	0	0	0	15	0	0	0	-4	247	159	32	-39
20%	-70	39	2	34	-78	66	-71	-389	-163	-75	123	73	-61
30%	4	88	67	-150	-80	2	-40	-168	-735	-7	246	-22	39
40%	-3	42	0	0	75	189	-45	-57	-587	-115	0	0	4
50%	0	0	-40	-25	133	-64	-3	-408	-450	5	0	0	18
60%	0	-57	0	211	0	-374	124	-166	-587	-89	281	458	-13
70%	-181	-4	0	-401	-1	-26	-2	-236	-719	2	403	690	35
80%	-455	0	418	49	0	0	0	-56	-637	0	359	819	-30
90%	-360	-136	0	0	7	454	0	0	0	0	457	670	112
Max	-935	0	0	0	0	0	0	0	0	-337	1,016	511	34
Avg	-120	11	88	10	19	-4	-13	-154	-375	-22	240	261	-3
C. LOS_LLT Changes for American River Flow													
Min	0	0	0	-67	374	57	100	12	107	-5	-7	0	-8
10%	0	0	0	0	-7	0	0	3	132	16	159	-13	-59
20%	27	66	64	-55	-3	3	106	36	418	-266	-10	-5	14
30%	-12	-8	8	60	-43	-90	5	-8	158	-7	-45	-56	56
40%	0	33	0	0	687	0	-4	-13	230	-156	0	0	53
50%	0	3	96	33	382	-3	-2	-134	285	-261	0	0	-54
60%	0	71	0	193	-9	22	45	29	70	-335	-3	0	-18
70%	69	0	1	0	-4	53	-46	-51	97	-153	-13	-505	-88
80%	-52	0	756	-602	-278	-4	1	0	-66	0	36	-1,314	-45
90%	-136	-672	121	0	0	150	0	0	0	0	-1	-1,578	-19
Max	0	0	0	0	0	0	0	0	0	315	-205	-671	76
Avg	7	-40	172	60	34	14	15	-14	155	-106	3	-390	-5

Table C.A-50. CALSIM-Simulated Monthly Distributions of Sacramento River at Freeport Flow (cfs) for ESO and Changes for the HOS and LOS Cases for the LLT Timeframe for WY 1922–2003

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
A. ESO_LLT Sacramento River Flow													
Min	4,901	5,688	6,349	8,735	6,298	7,801	8,320	5,327	8,127	8,828	7,780	7,047	6,585
10%	8,158	7,141	9,440	12,471	12,363	11,464	10,699	8,674	10,941	10,389	8,373	7,775	8,394
20%	9,283	8,331	12,426	13,741	15,532	15,490	11,204	10,690	12,151	12,743	10,143	8,752	9,485
30%	10,858	9,812	13,603	15,758	19,264	18,403	12,191	11,809	13,276	14,532	11,385	9,426	10,662
40%	11,385	10,872	14,357	18,894	23,192	20,648	13,213	12,595	15,520	16,650	12,036	10,198	11,720
50%	11,859	11,952	15,874	21,948	30,009	23,697	16,021	13,530	17,586	18,805	12,375	12,310	12,988
60%	12,441	12,633	18,001	24,888	43,168	29,230	20,046	15,076	19,523	20,491	13,500	17,197	17,501
70%	13,113	14,515	20,790	39,247	48,812	39,937	22,611	20,088	21,190	21,769	14,502	22,253	19,059
80%	13,813	14,880	31,652	56,986	63,420	51,636	32,225	23,965	23,239	23,464	16,614	25,457	20,553
90%	14,961	20,481	47,114	65,109	70,478	62,099	45,720	33,673	24,086	24,135	17,696	27,249	23,928
Max	29,533	53,220	81,077	80,443	80,031	79,178	74,335	50,028	47,484	26,683	23,129	29,035	29,744
Avg	11,862	13,483	22,156	31,296	37,070	31,666	22,231	17,669	17,959	18,084	13,157	15,923	15,188
B. HOS_LLT Changes for Sacramento River Flow													
Min	-45	-17	-10	-1,525	1,608	127	-826	210	-154	-442	-79	191	-515
10%	-55	478	-378	-359	-664	49	-468	-10	-971	4	-106	416	-90
20%	-3	95	-1,887	-243	-153	-440	-238	-209	-924	174	42	226	150
30%	-428	-85	-386	-1,094	-321	-354	-255	-250	-1,316	-413	111	-13	-148
40%	-237	309	-361	-760	-316	-221	1,770	-118	-2,659	-1,119	175	434	-412
50%	-381	-54	-214	-843	503	444	5,743	546	-3,740	-1,484	784	1,022	-128
60%	-355	4	79	1,169	212	448	4,740	1,636	-4,306	-2,080	623	1,034	-224
70%	-424	-236	621	31	496	-1,663	4,781	1,106	-4,861	-1,835	266	333	-162
80%	-173	165	-972	-1,977	-553	-49	1,134	-17	-4,019	-2,758	-1,143	-143	-88
90%	449	463	324	2,112	30	7	19	1,182	-894	-1,630	-1,123	191	-408
Max	112	1,319	0	-2	2	-1	2	5	24	2,173	-4,615	33	19
Avg	-176	108	-117	-379	-19	-4	1,845	495	-2,465	-1,204	-264	416	-108
C. LOS_LLT Changes for Sacramento River Flow													
Min	0	39	139	-2,448	595	-45	-40	-371	-3	11	0	204	155
10%	23	346	18	-148	24	306	-17	8	-47	-152	97	262	112
20%	678	203	174	160	387	-352	234	25	502	-137	169	454	273
30%	90	-421	-74	1,528	1,611	262	424	-255	680	377	-114	436	156
40%	-206	-924	505	1,215	-153	201	345	121	248	131	7	76	62
50%	106	-1,324	786	652	-44	728	-298	103	-18	-254	471	-1,518	206
60%	197	-1,318	458	2,043	912	371	247	-210	33	-220	154	-5,943	-652
70%	442	-2,060	964	-290	1,340	1,352	19	-596	-266	142	571	-10,156	-532
80%	370	-508	1,323	616	-450	319	6	-135	-166	66	24	-12,782	-580
90%	238	306	2,013	1,607	270	2	5	302	-89	206	324	-13,455	-545
Max	-7	2,168	0	-4	0	0	1	-22	10	-82	-185	-8,289	-114
Avg	172	-585	911	717	285	374	95	-36	35	-22	145	-4,784	-157

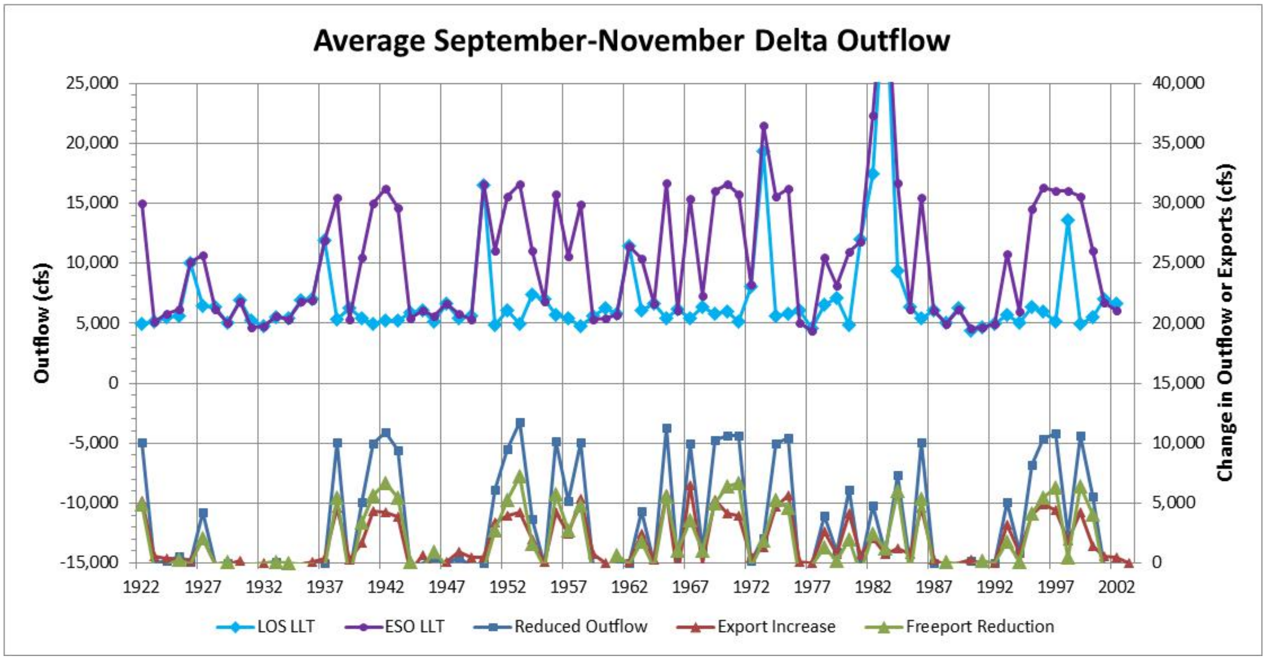


Figure C.A-77. CALSIM-Simulated Average September–November Delta Outflow for ESO and LOS Cases for WY 1922–2003 at the LLT Timeframe (2060)

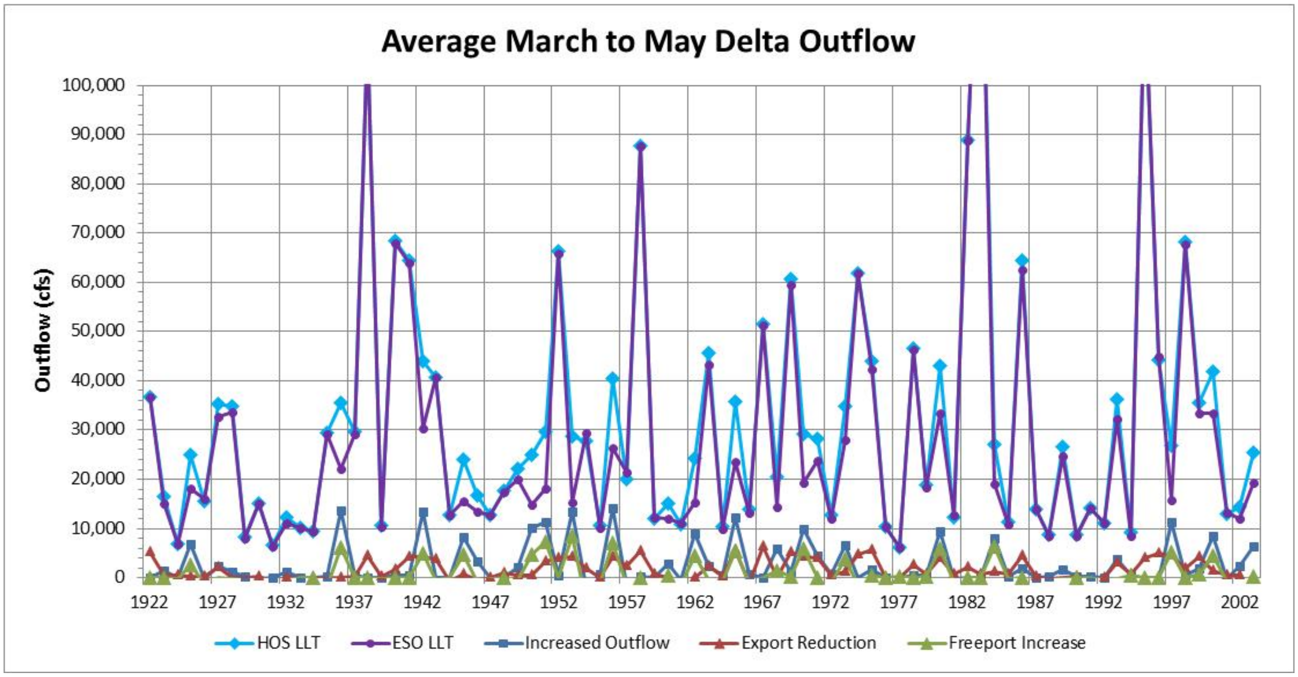
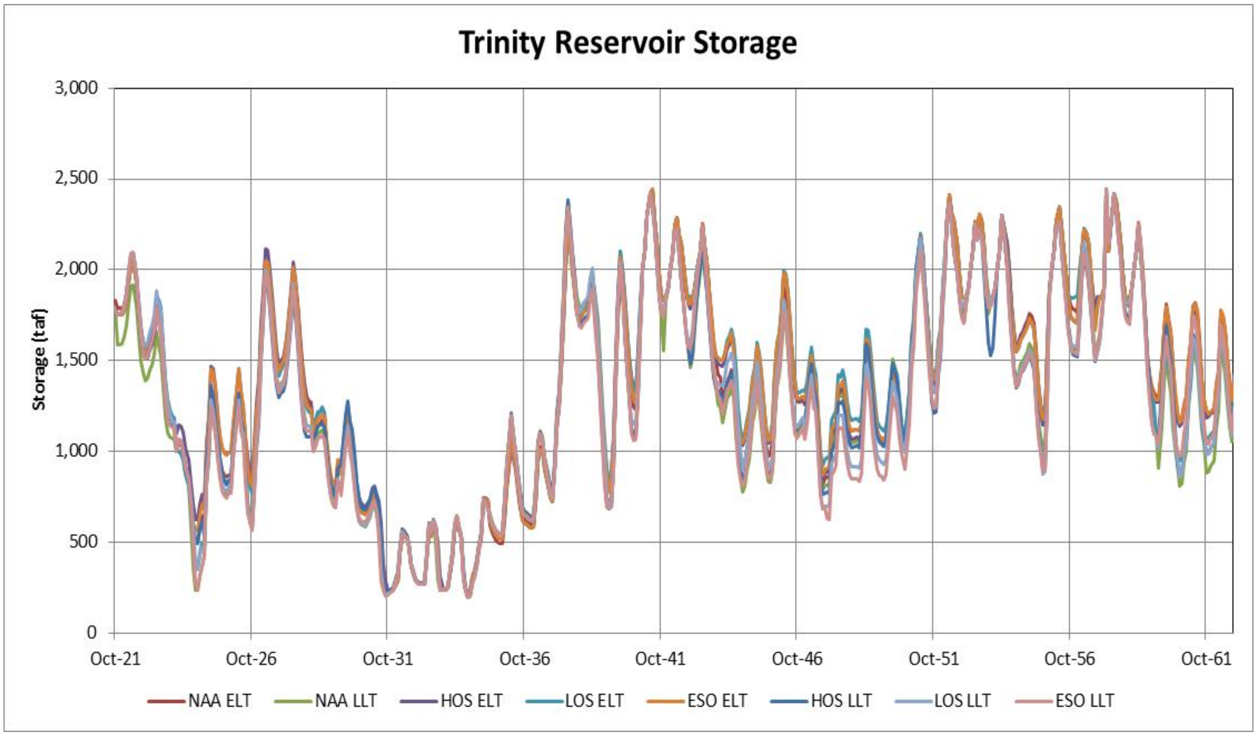


Figure C.A-78. CALSIM-Simulated Average March–May Delta Outflow for ESO and HOS Cases for WY 1922–2003 at the LLT Timeframe (2060)



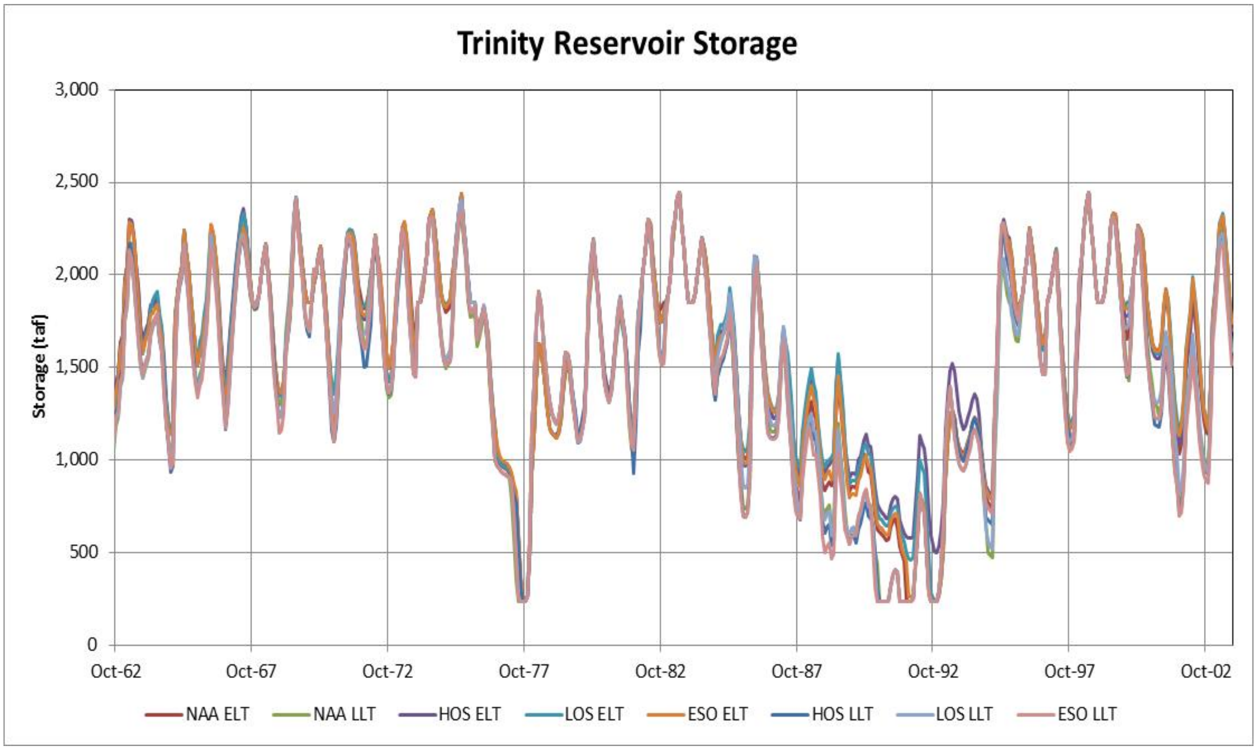
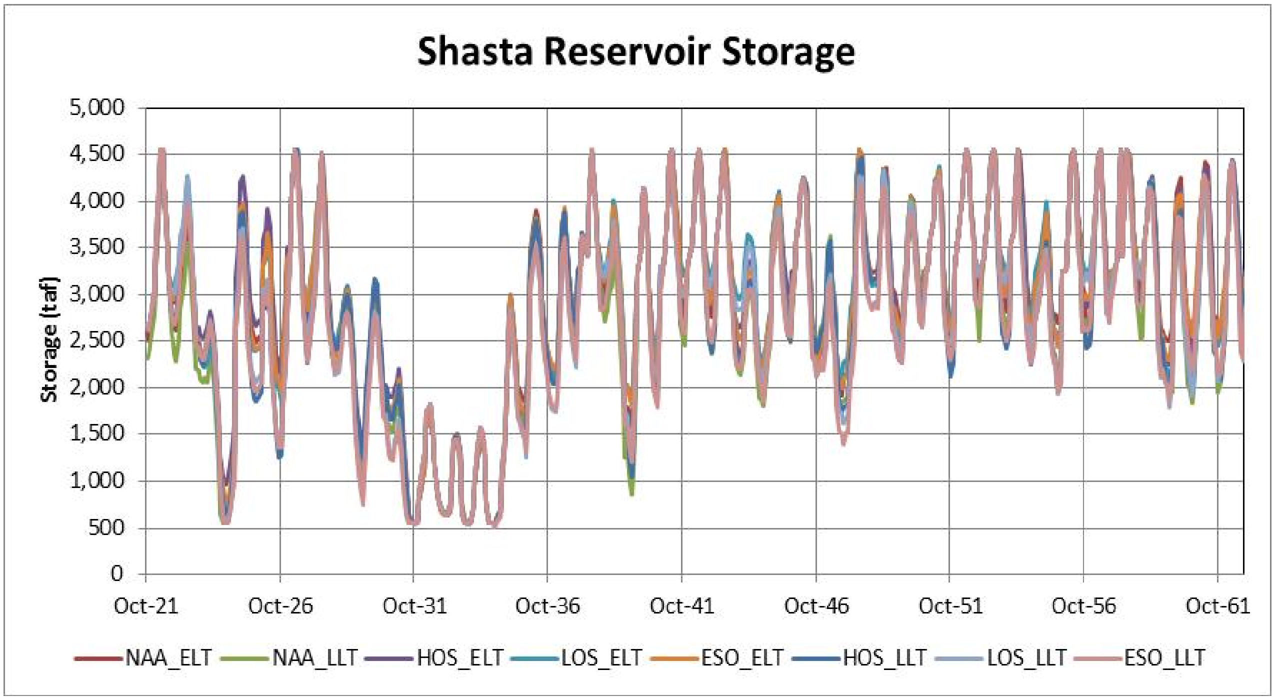


Figure C.A-79. Comparison of the CALSIM-simulated Trinity Reservoir Storage (taf) for the BDCP Cases (A) for WY 1922–1962, and (B) for WY 1963–2003



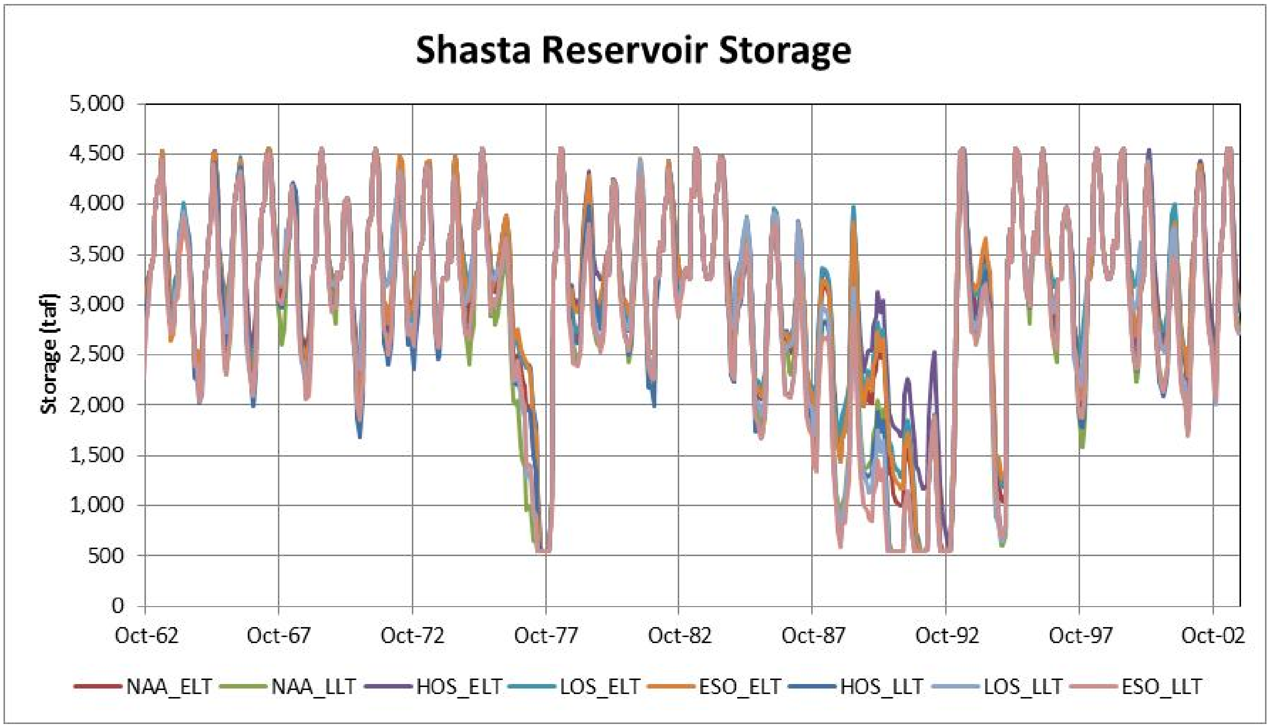
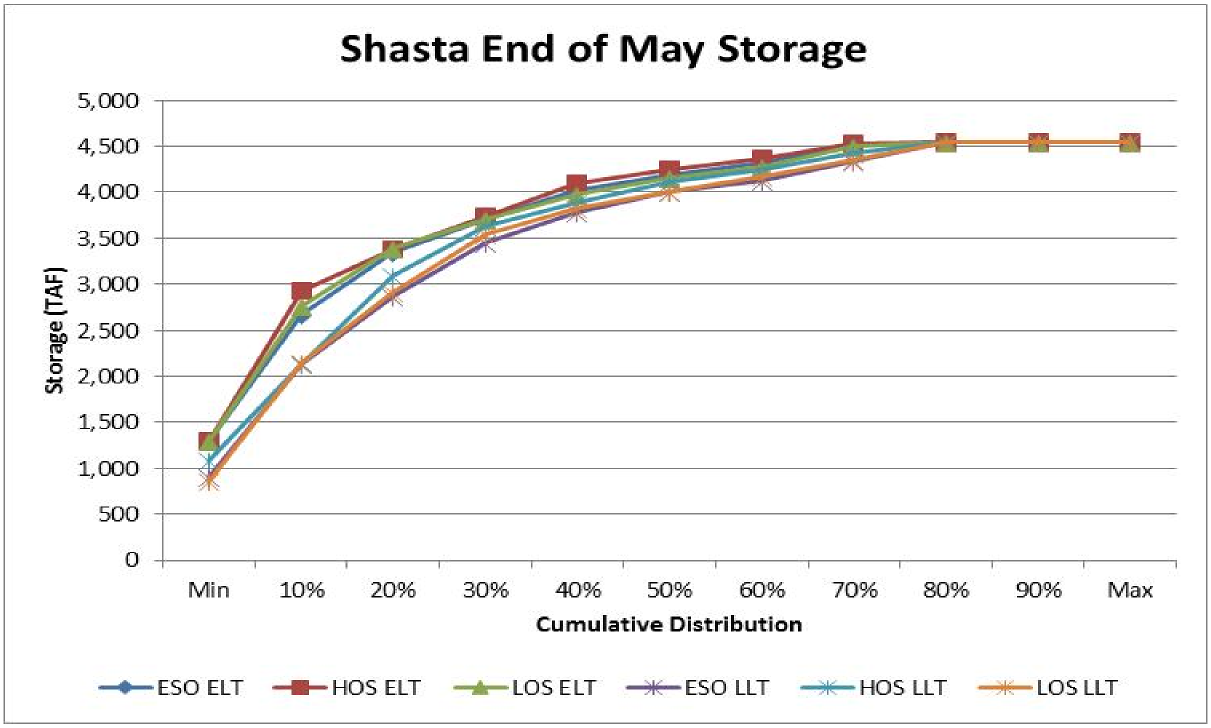


Figure C.A-80. Comparison of the CALSIM-Simulated Shasta Reservoir Storage (taf) for the BDCP Cases (A) for WY 1922–1962, and (B) for WY 1963–2003



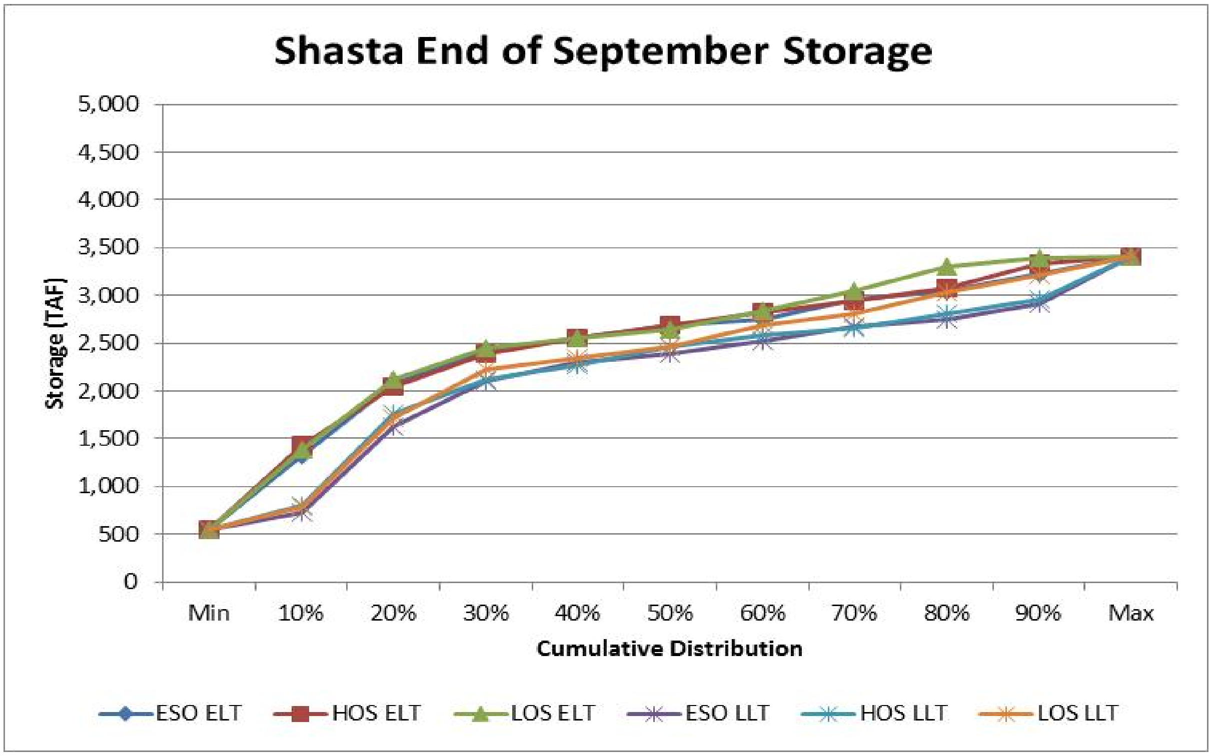


Figure C.A-81. CALSIM-Simulated Cumulative Distribution of End-of-May and End-of-September Shasta Reservoir Storage for the ESO, HOS and LOS cases for WY 1922–2003 for the ELT and LLT Timeframes

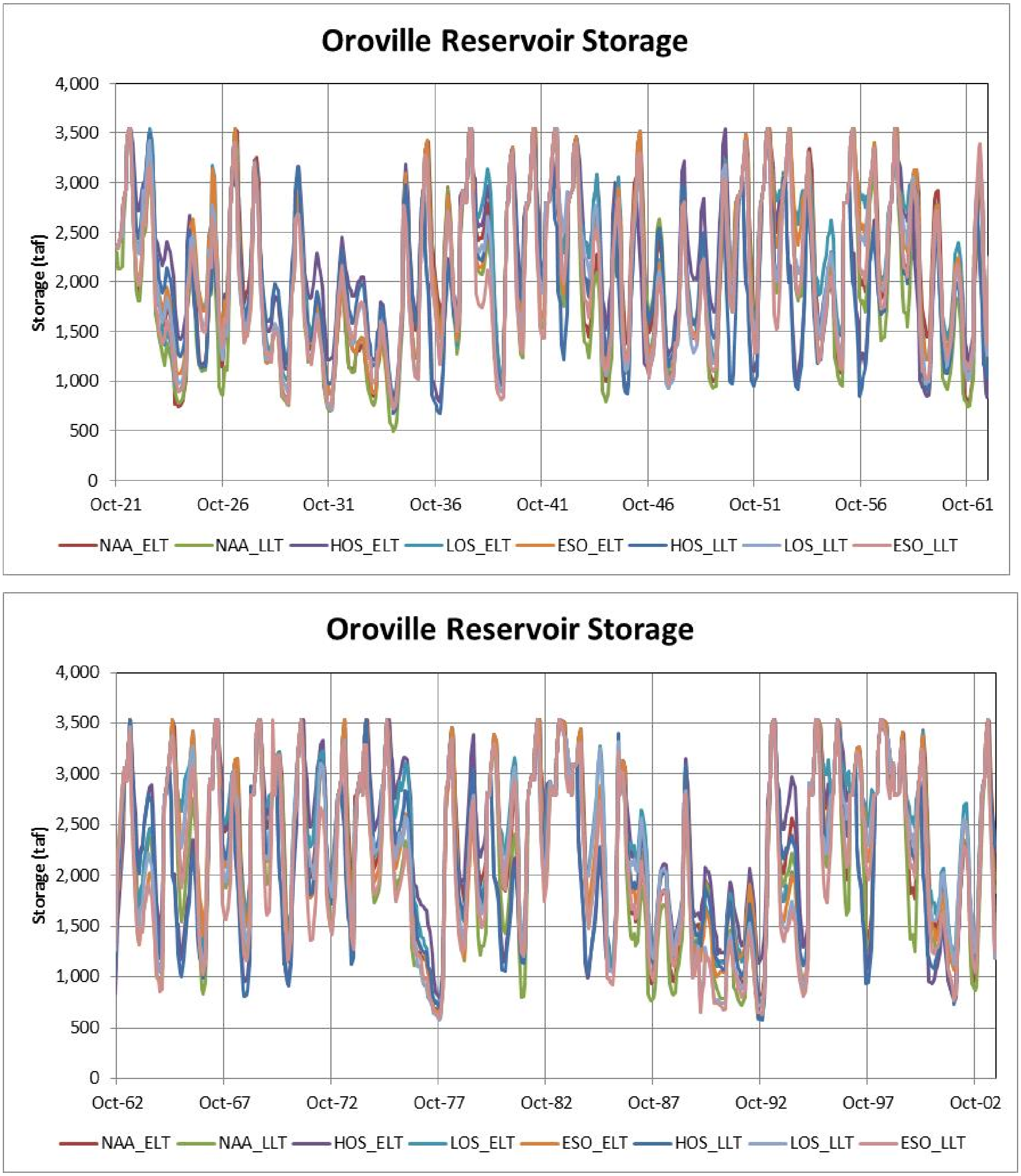
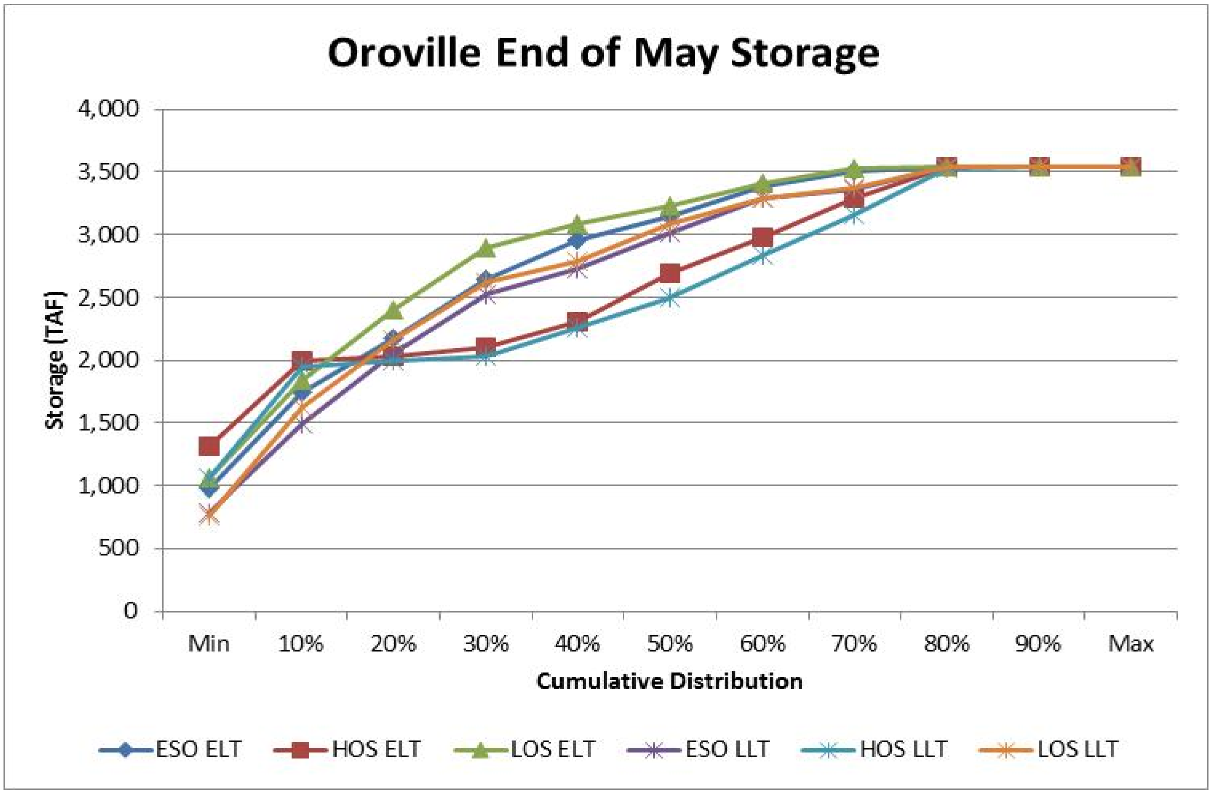


Figure C.A-82. Comparison of the CALSIM-Simulated Oroville Reservoir Storage (taf) for the BDCP Cases (A) for WY 1922–1962, and (B) for WY 1963–2003



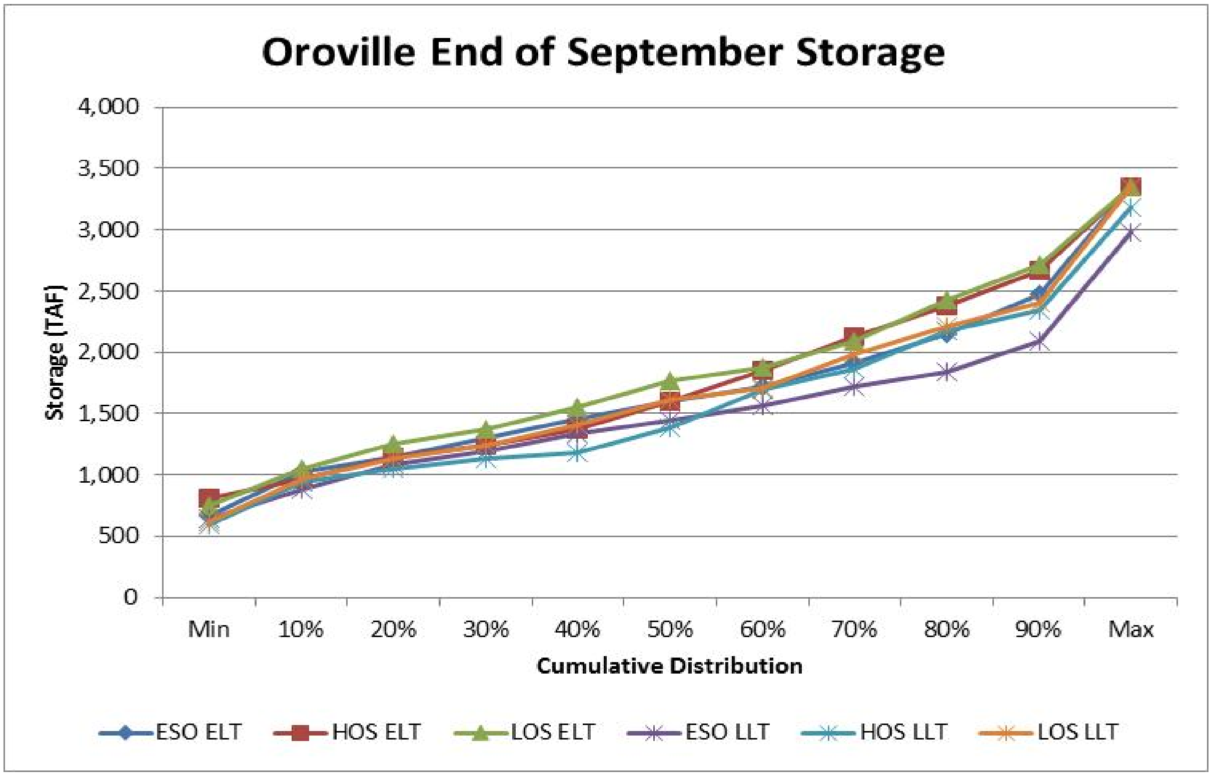
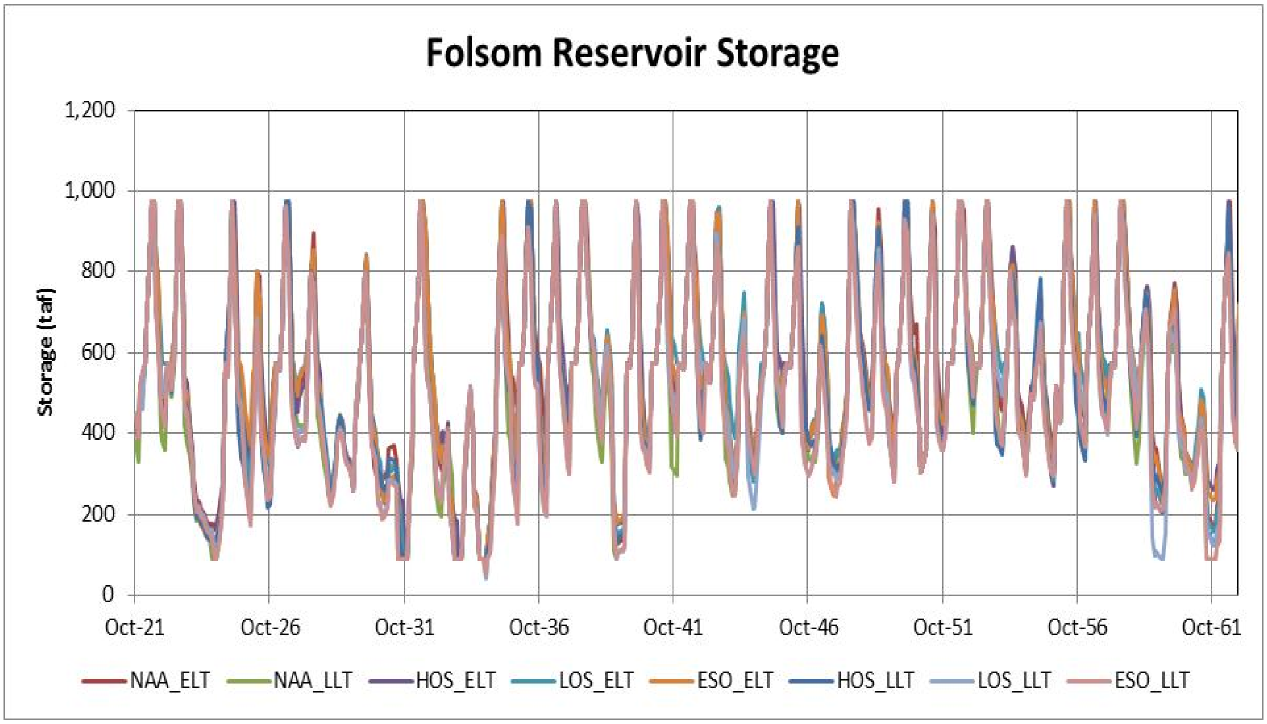


Figure C.A-83. CALSIM-Simulated Cumulative Distribution of End-of-May and End-of-September Oroville Reservoir Storage for the ESO, HOS and LOS Cases for WY 1922–2003 for the ELT and LLT Timeframes



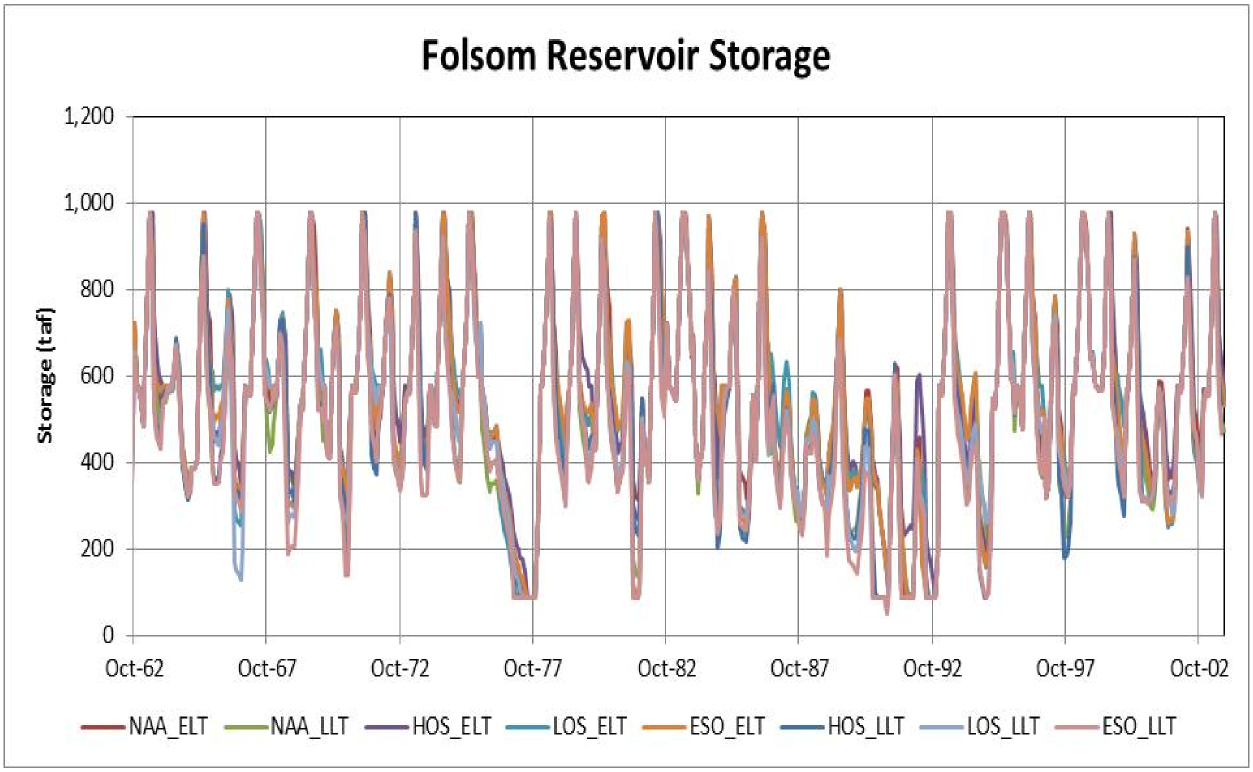
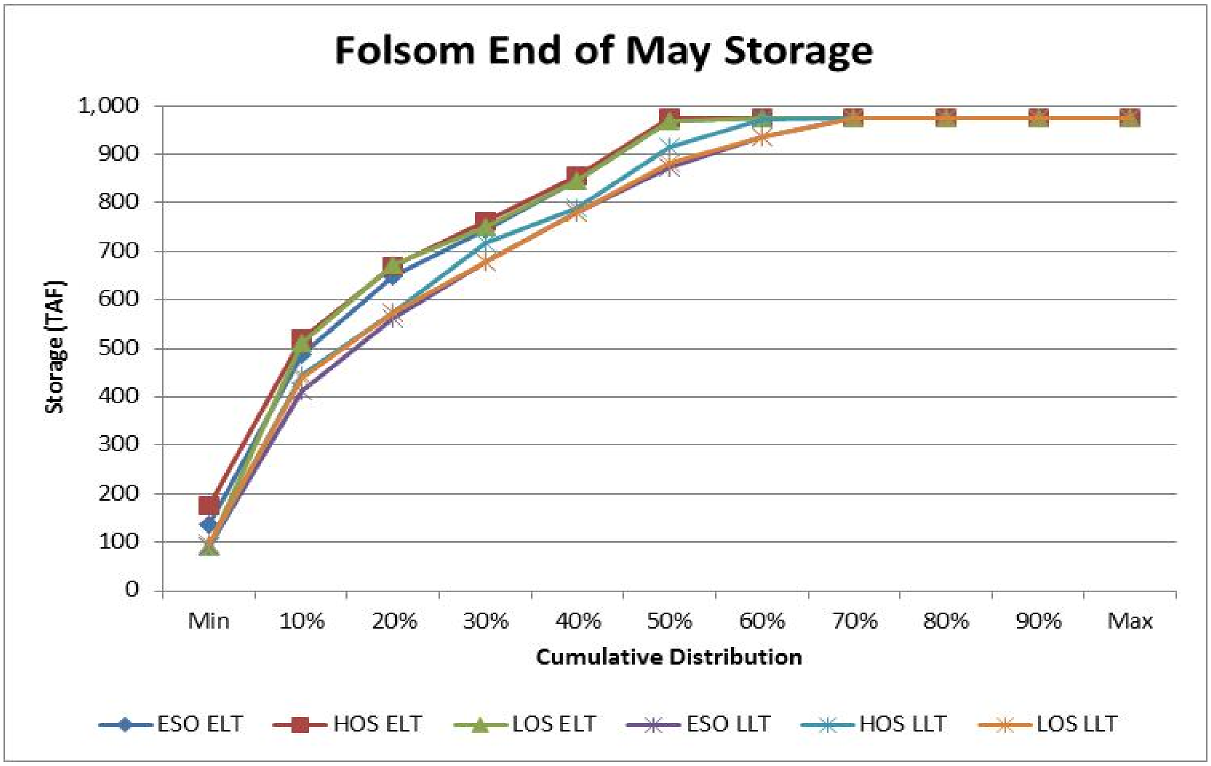


Figure C.A-84. Comparison of the CALSIM-Simulated Folsom Reservoir Storage (taf) for the BDCP Cases (A) for WY 1922–1962, and (B) for WY 1963–2003



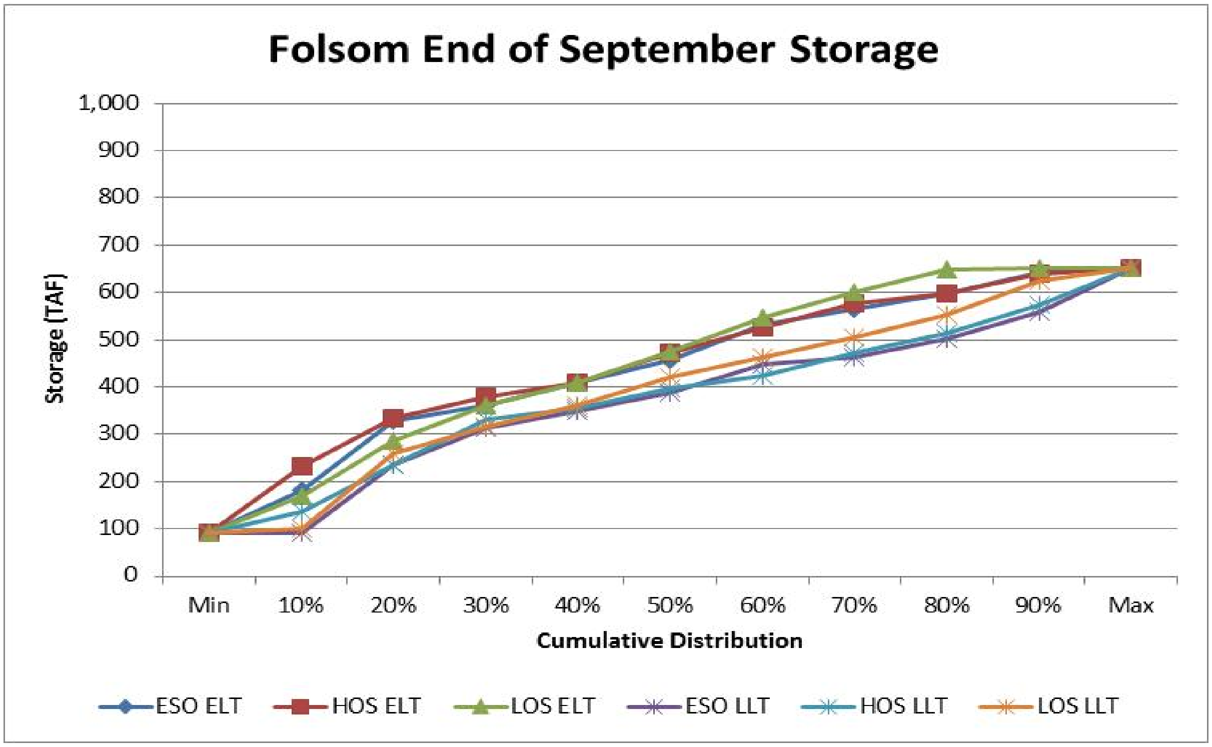


Figure C.A-85. CALSIM-simulated Cumulative Distribution of End-of-May and End-of-September Oroville Reservoir Storage for the ESO, HOS and LOS Cases for WY 1922–2003 for the ELT and LLT Timeframes

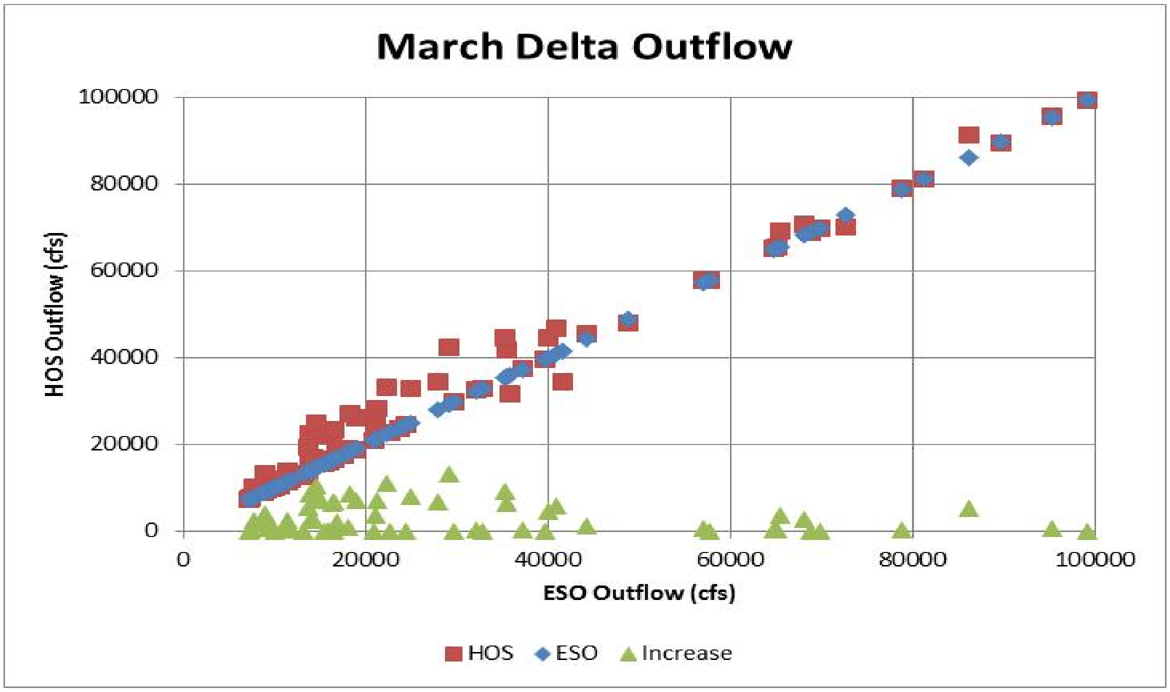


Figure C.A-86. CALSIM-Simulated March Outflow for the ESO_LLT and Increases in Outflow for the HOS_LLT Case

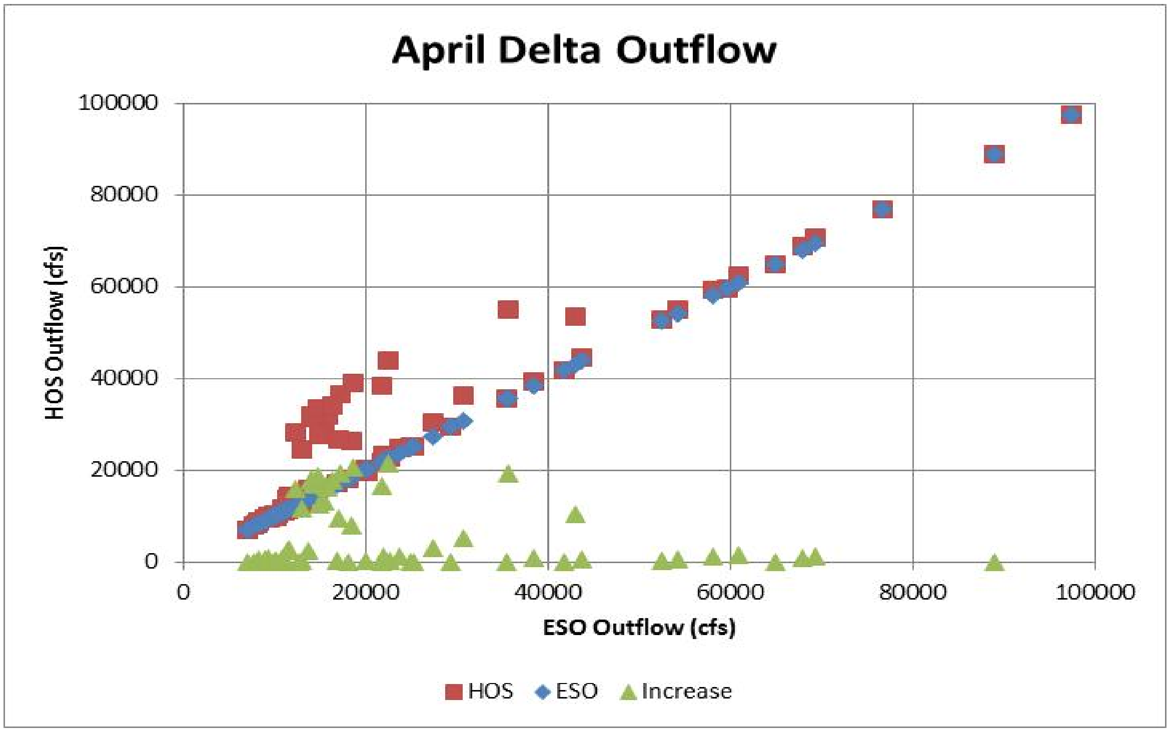


Figure C.A-87. CALSIM-Simulated April Outflow for the ESO_LLT and Increases in Outflow for the HOS_LLT Case

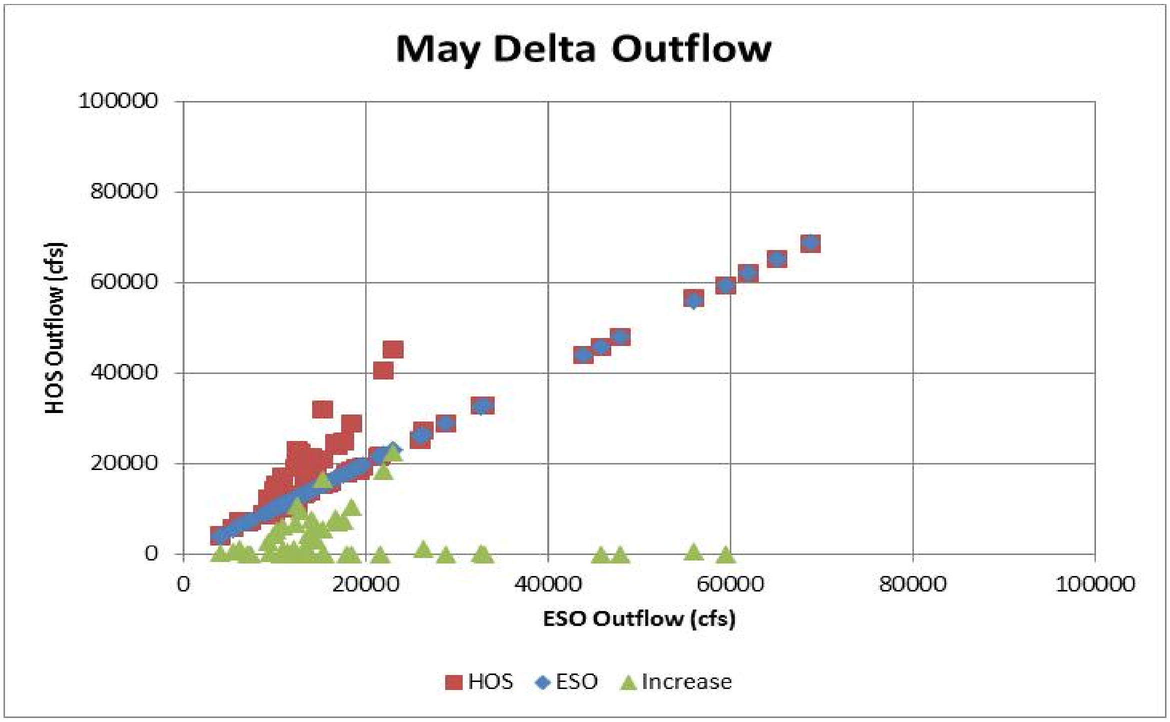


Figure C.A-88. CALSIM-Simulated May Outflow for the ESO_LLT and Increases in Outflow for the HOS_LLT Case

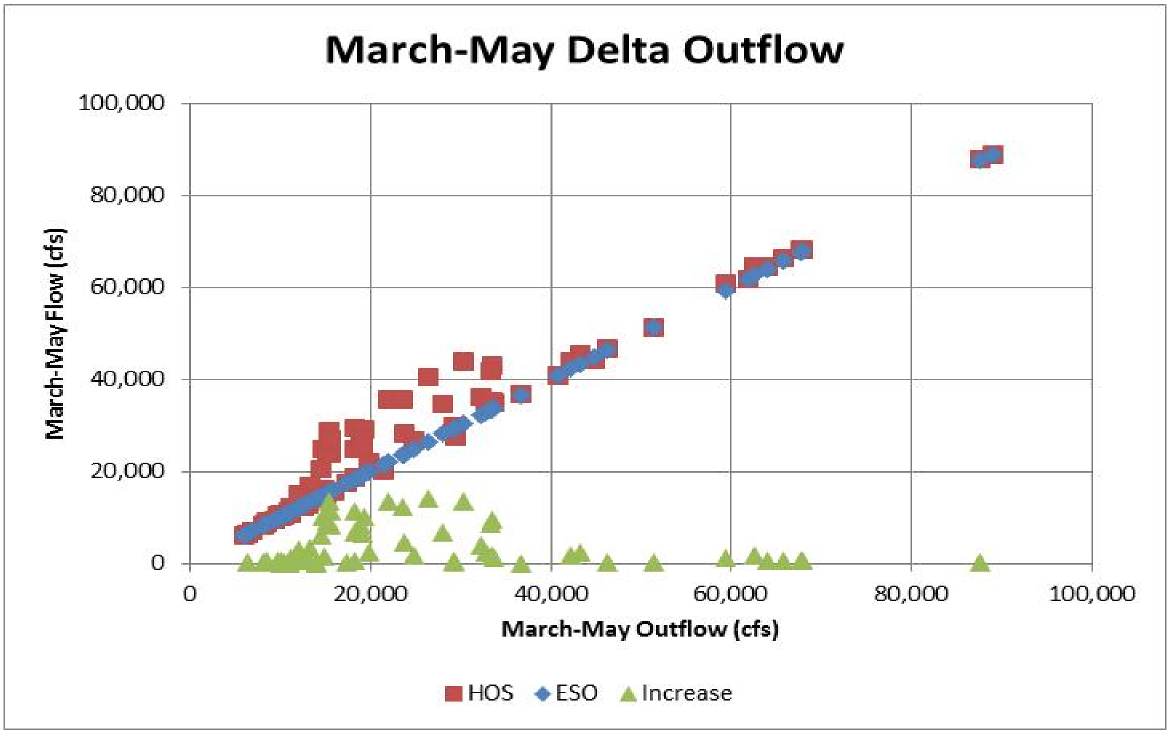


Figure C.A-89. CALSIM-Simulated March–May Outflow for the ESO LT and Increases in Outflow for the HOS_LLT Case

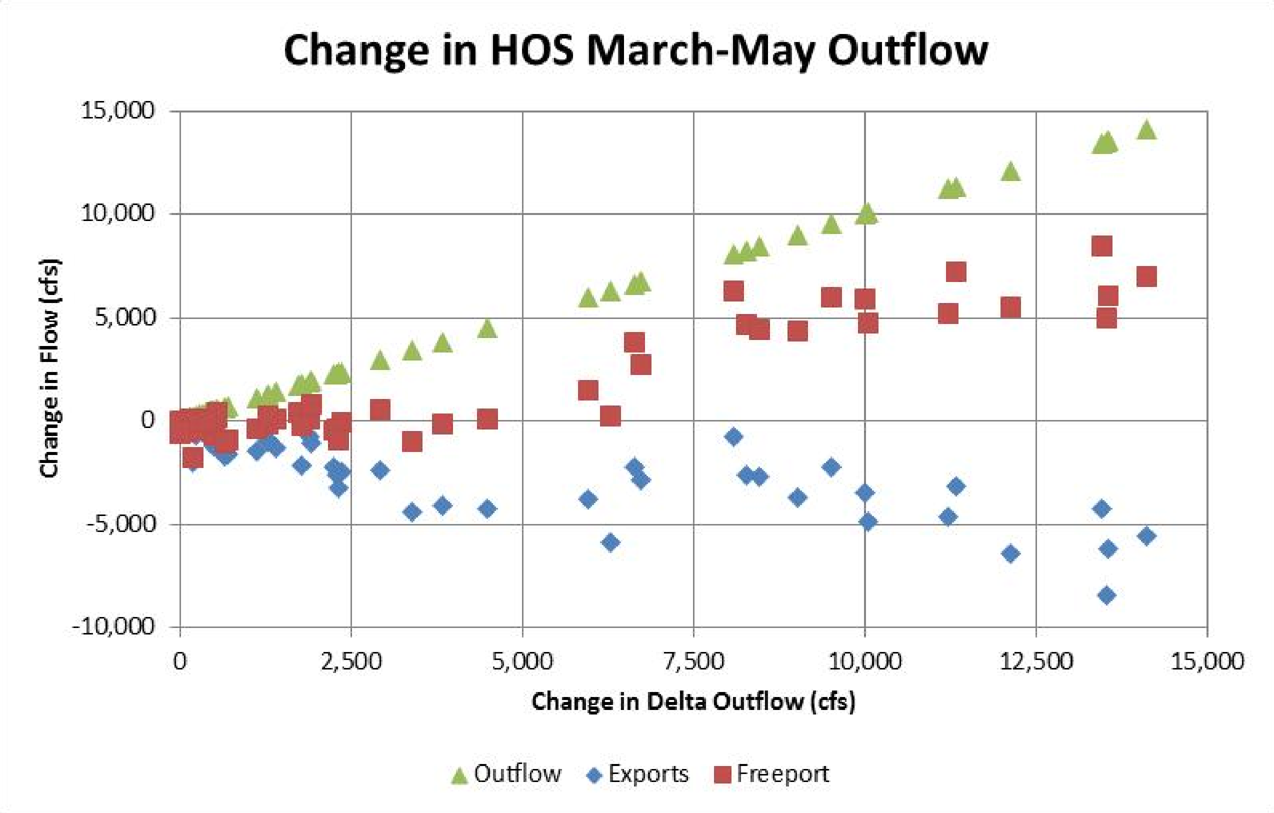


Figure C.A-90. CALSIM-Simulated Average March–May Delta Outflow Increases for HOS_LLT Compared to the ESO_LLT with Corresponding March–May Export Reductions March–May Freeport Flow Increases

5C.A.6 Hydrodynamic and Salinity Modeling—Results

The objective of the DSM2 modeling analysis was to determine the changes in Delta tidal hydrodynamics and salinity caused by the BDCP facilities, tidal restoration and ESO. Six simulations were conducted to also evaluate the likely effects of future sea-level rise on Delta tidal flows and salinity. The EBC2_ELT and ESO_ELT cases assumed 6 inches of sea-level rise, while the EBC2_LLT and ESO_LLT cases assumed 18 inches of sea-level rise. The ESO was simulated only for the ELT and LLT periods (not for current timeframe of EBC2). The DSM2 model inputs and channel geometry files were adjusted for each of the six cases. The new intakes were added to the Sacramento River upstream of Sutter Slough; the additional areas of tidal natural communities and transitional uplands to accommodate sea-level rise were added to appropriate (representative) locations for the ESO_ELT (25,000 acres) and the ESO_LLT (65,000 acres) cases. Some of the existing gates and barriers were modified for the ESO cases. The ESO conditions assume that the Suisun Marsh salinity control radial gates on Montezuma Slough would remain open all year to allow full connection with tidal restoration areas in Suisun Marsh. The south Delta agricultural (water level control) barriers were not installed for the ESO cases to enhance tidal flows in the proposed restoration areas; the head of Old River tidal gate was included in the ESO for San Joaquin River migrating fish protection.

5C.A.6.1 Changes in Model Boundary Conditions

Each of the DSM2 modeling cases for the WY 1976–1991 simulation period had different inflows, exports, and Delta outflows, based on the CALSIM monthly results for each case. Daily inflows were estimated from the combination of historical inflows and the CALSIM monthly results. The model cases combined the effects of four different changes: (1) sea-level rise, (2) expanded tidal habitat (tidal natural communities and transitional uplands) restoration areas, (3) diversions at the north Delta intakes, and (4) changes in inflows and outflow.

Figure C.A-91 shows that the assumed sea-level rise at Martinez was a simple constant shift, and was nearly identical to the assumed sea-level rise at the Golden Gate. The UnTRIM 3-D Bay-Delta model results (MacWilliams and Gross 2010) indicated a very small increase in tidal amplitude (1% for 18 inches of sea-level rise) and a slightly lower mean tide (-0.1 feet) than assumed at the ocean boundary. Figure C.A-91 presents a sample of the Martinez boundary stage applied for the EBC2, EBC2_ELT, and EBC2_LLT simulations. For the ESO conditions, which include the addition of tidal restoration areas throughout the Delta, the net effect on Martinez tide also included tidal muting (reduced amplitude) of about 5% for the full 65,000 acres of additional tidal restoration. The RMA 2-D Bay-Delta model (RMA 2010) indicated that the tidal flows at Martinez would increase slightly (2%), although the tidal amplitude would be reduced by 5%. These effects of sea-level rise and tidal natural communities and transitional uplands expansion on the tidal fluctuations and tidal flows at the Martinez boundary are relatively small.

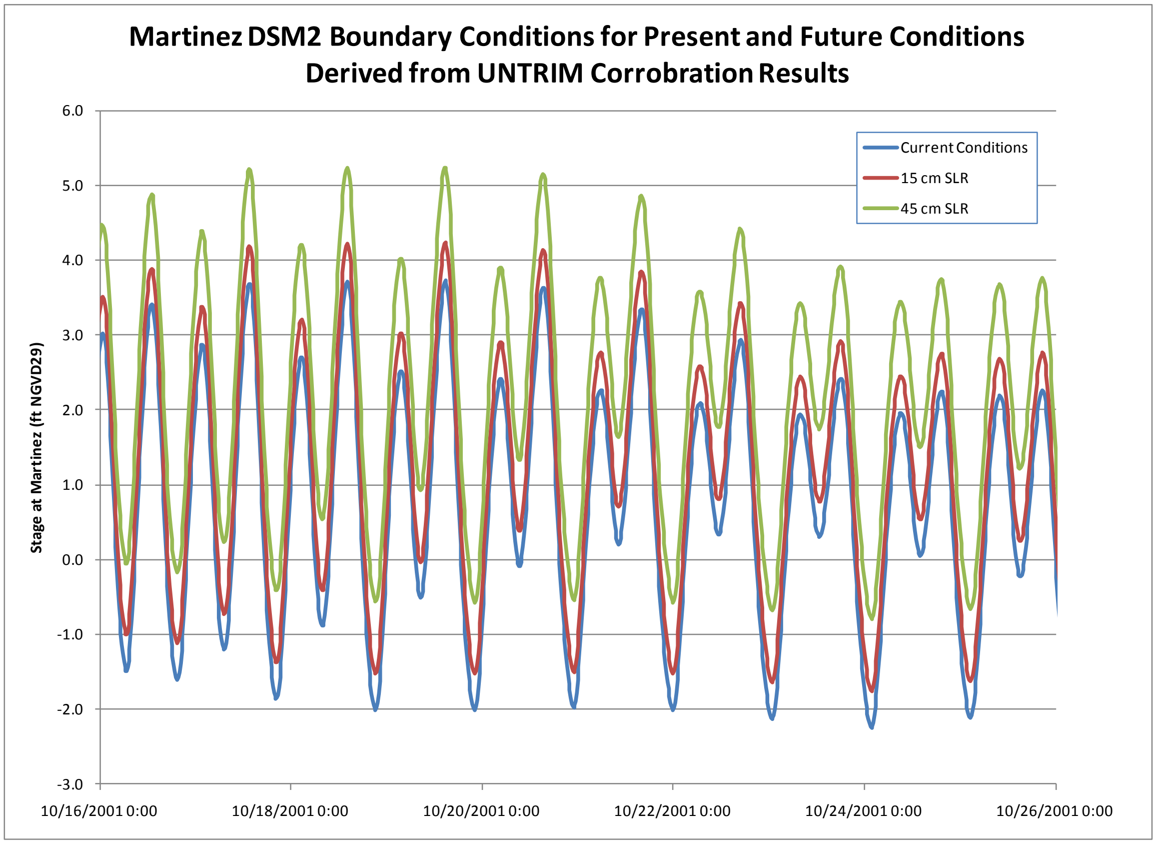


Figure C.A-91. Martinez Boundary Tidal Elevation Variation with Sea-Level Rise (ELT and LLT)

The average flow in the Sacramento River for the simulation period of WY 1976–1991 was about 21,000 cfs for the EBC1 and EBC2 cases, based on the CALSIM results for the same period. The Sacramento River inflows were reduced slightly (1%) for the ELT and LLT cases because of assumed climate change effects on runoff, and were reduced by about 5% because of the additional spills into the Yolo Bypass (Fremont Weir gate) for the ESO cases. The average flow in the Yolo Bypass was about 3,600 cfs for the EBC1 and EBC2 cases and increased by about 15% for the ELT and LLT cases (4,200 cfs) from increased high flows with climate change, and increased an additional 15% with the Fremont Weir notch for the ESO cases (4,800 cfs). The average flow in the San Joaquin River was about 5,100 cfs for the EBC1 and EBC2 cases, and the average flow was within 1% of EBC1 and EBC2 for the ELT and LLT cases. The San Joaquin River inflow did not change with the ESO conditions.

The south Delta exports and diversions into the north Delta intakes were specified from the CALSIM results for the six cases. The Delta diversions and agricultural return flows (drains) were the same for the six cases, although some agricultural diversions and drainage might be reduced with tidal natural communities and transitional uplands restoration (not simulated). The average south Delta exports were about 6,271 cfs for the EBC2_ELT case and about 5810 cfs for the EBC2_LLT case; the south Delta pumping was reduced to 3,542 cfs for the ESO_ELT and 3,228 cfs for the ESO_LLT case. The average north Delta intake diversions were 2,917 cfs for the ESO_ELT case and 2,807 cfs in the ESO_LLT scenario.

Delta outflow was calculated in the DSM2 model, but averaged over a monthly time period the DSM2 outflow would be identical to the CALSIM-simulated outflow for the six cases. Because each of the six cases had a different sequence of Delta outflow, the salinity differences calculated for the six cases will be dominated by the CALSIM-simulated outflow differences; the much smaller effects from sea-level rise and tidal natural communities and transitional uplands restoration will be difficult to evaluate from the DSM2 results themselves.

San Joaquin River EC values (salinity) at Vernalis were calculated by the CALSIM model, and were slightly different for the six cases. The Sacramento River and Yolo Bypass EC was assumed to be a constant of 175 μS/cm for all cases. The Cosumnes River and Mokelumne River EC was assumed to be a constant of 150 μS/cm.

The salinity boundary conditions at Martinez depend on the specified outflow (from CALSIM) and on sea level change; the tidal elevations and EC values were adjusted for each DSM2 case. The 3-D UnTRIM model of the San Francisco Bay and Delta and the 2-D RMA Bay-Delta Model were used to develop adjustments for the Martinez EC boundary conditions (Table C.A-51). The RMA modeling suggested that the tidal natural communities and transitional uplands expansion would have almost no effects on the EC at Martinez. The UnTRIM model suggested that sea-level rise would add about 1,000–1,500 μS/cm to the Martinez EC, for the full range of Martinez EC values. The daily average Martinez EC is about 30,000 μS/cm during low outflow of about 3,000 cfs and is reduced to about 10,000 μS/cm when the outflow is about 25,000 cfs. The EC increment from 18 inches (45 cm) of sea-level rise (LLT conditions) would be 1,500 μS/cm at higher flows of 25,000 cfs and would be about 1,100 μS/cm higher at low outflow of 3,000 cfs. The EC increment from sea-level rise therefore was estimated to be about 5% at the highest EC values and about 15% at the lowest EC values.

Table C.A-51. Adjustments to EBC EC at Martinez for DSM2 Modeling of BDCP Cases

Scenario	Martinez EC (µS/cm)	
	Correlation	**Lag (min)**
NT (14,000 acres)	Y = 1.001 * X + 191.5	8
ELT (25,000 acres)	Y = 0.999 * X + 114.7	10
LLT (65,000 acres)	Y = 0.996 * X + 68.2	13
15 cm sea-level rise	Y = 0.9954* X + 556.3	0
45 cm sea-level rise	Y = 0.98* X + 1778.9	-2
ELT (25,000 acres &15 cm sea-level rise)	Y = 0.999 * X + 357.78	9
LLT (65,000 acres & 45 cm sea-level rise)	Y = 1.002 * X + 1046.3	11

X = EBC Martinez EC.
Y = Scenario Martinez EC.

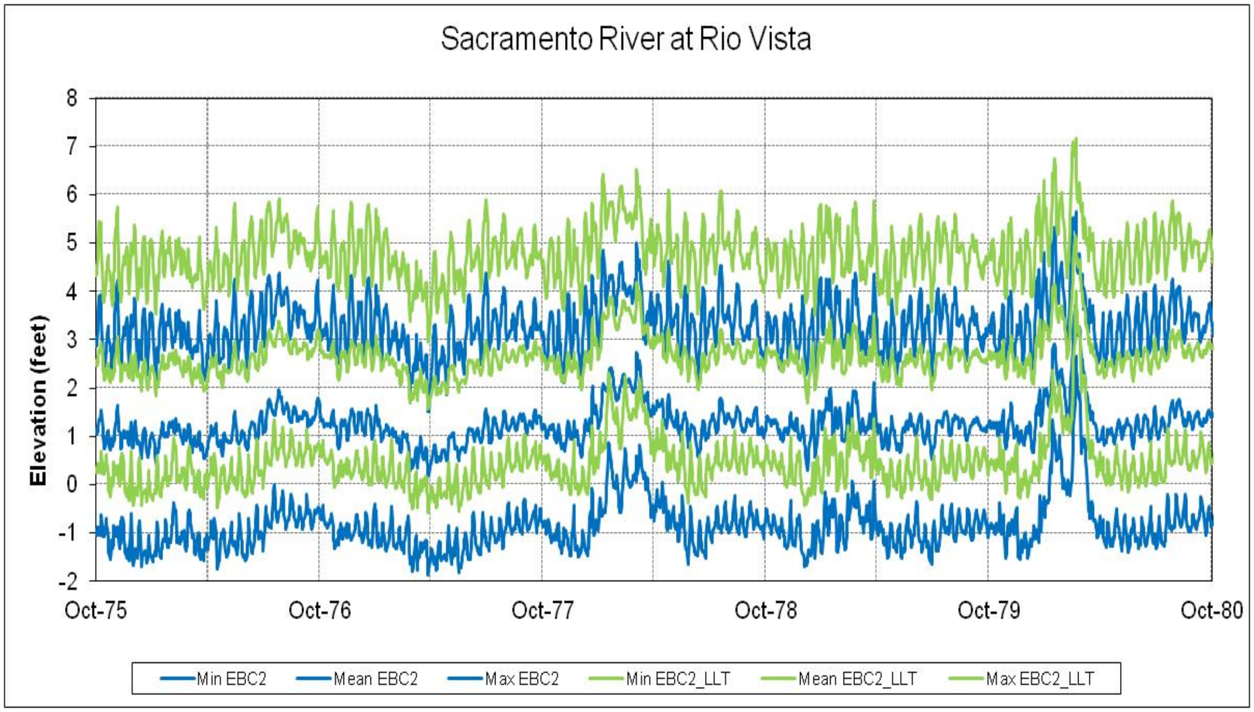
5C.A.6.2 Changes in Delta Tidal Elevations

The BDCP tidal natural communities and transitional uplands restoration in the designated restoration opportunity areas (ROAs) was estimated (from RMA 2D tidal modeling) to increase the mean higher high water (MHHW) water surface area of the Delta and Suisun Bay (upstream of Martinez) from about 90,000 acres to 140,000 acres (+55% increase). The existing mean lower low water (MLLW) water surface area would increase from about 85,000 acres to 115,000 acres (+35% increase). The MHHW volume upstream of Martinez would increase from about 1,500 taf to about 1,900 taf (+25%) and the MLLW volume would increase from 1,000 taf to about 1,150 taf (+15%) with the simulated BDCP tidal natural communities and transitional uplands restoration (based on the RMA model results). The RMA model and the DSM2 model indicated this would cause some tidal muting (reduced tidal amplitude) in most Delta locations. Reduced tidal amplitudes could alter the tidal flows into the major channel diversions and could reduce the net diversion flow as a percentage of the net flow upstream of the diversion.

The tidal elevations will be increased directly by sea-level rise, so the combined effects of sea-level rise and tidal muting from tidal restoration will be dominated by the sea-level rise effects. Delta inflows and Delta outflow have almost no effect on the tidal elevations in Suisun Bay and most of the interior Delta. High river flows will increase the water elevations in the upstream portion of the Sacramento River (above Rio Vista) and in the upstream portion of the San Joaquin River (above Stockton).

Figure C.A-92 shows the DSM2-simulated daily range of tidal elevations (minimum, average, and maximum) in the Sacramento River at Rio Vista for WY 1976–1980 for the EBC2 case (existing conditions) and for EBC2_LLT (1.5 feet sea-level rise). High flows in 1978 and 1980 increased the tidal elevations by about 1–2 feet but had little effect on the daily range of tidal elevations. Figure C.A-92 shows the DSM2-simulated tidal elevations at Rio Vista for the ESO_LLT (1.5 feet sea-level rise with 65,000 acres of tidal restoration). The average tidal range was about 5 feet (from 0 foot to 5 feet) for the EBC2_LLT case; effects of additional tidal restoration upstream in the Cache Slough complex reduced the tidal range to about 3.5 feet (from 1 foot to 4.5 feet). Figure C.A-93 shows the DSM2-simualted daily range of tidal elevations (minimum, average, and maximum) in the Sacramento River at Hood for WY 1976–1980 for the EBC2 case (existing conditions) and for EBC2_LLT (1.5 feet sea-level rise). High flows in 1978 and 1980 increased the tidal elevations by 8–10 feet and reduced the daily range of tidal elevations. Figure C.A-93 shows the DSM2-simulated tidal elevations at Rio Vista for the ESO_LLT (1.5 feet sea-level rise with 65,000 acres of tidal restoration). The average tidal range was about 3 feet (from 2 feet to 5 feet) for the EBC2_LLT case; effects of additional tidal restoration upstream in the Cache Slough complex reduced the tidal range to about 2.5 feet (from 2 feet to 4.5 feet). The ESO simulations show increased minimum elevations caused by the tidal damping that results from the tidal natural communities and transitional uplands restoration. The ESO simulations indicate that the maximum elevations are reduced by the tidal natural communities and transitional uplands restoration. The average tidal muting throughout the Delta was about 0.25 feet for the ELT (25,00 acres) and the average tidal muting was about 0.5 feet for the LLT (65,000 acres) along the Sacramento and San Joaquin River channels upstream of the confluence (near Antioch).

The effects of sea-level rise and tidal natural communities and transitional uplands restoration will cause some changes in the tidal elevations and tidal flows within the Delta channels; tidal elevations will increase directly with sea-level rise, and the daily range of tidal elevations will be somewhat reduced (tidal muting or dampening) by the effects of tidal natural communities and transitional uplands expansion (restoration). Generally, however, the existing tidal fluctuations in the San Francisco Bay and Delta channels will continue much as they are now under the effects of sea-level rise and extensive tidal natural communities and transitional uplands restoration areas in the Bay and Delta.



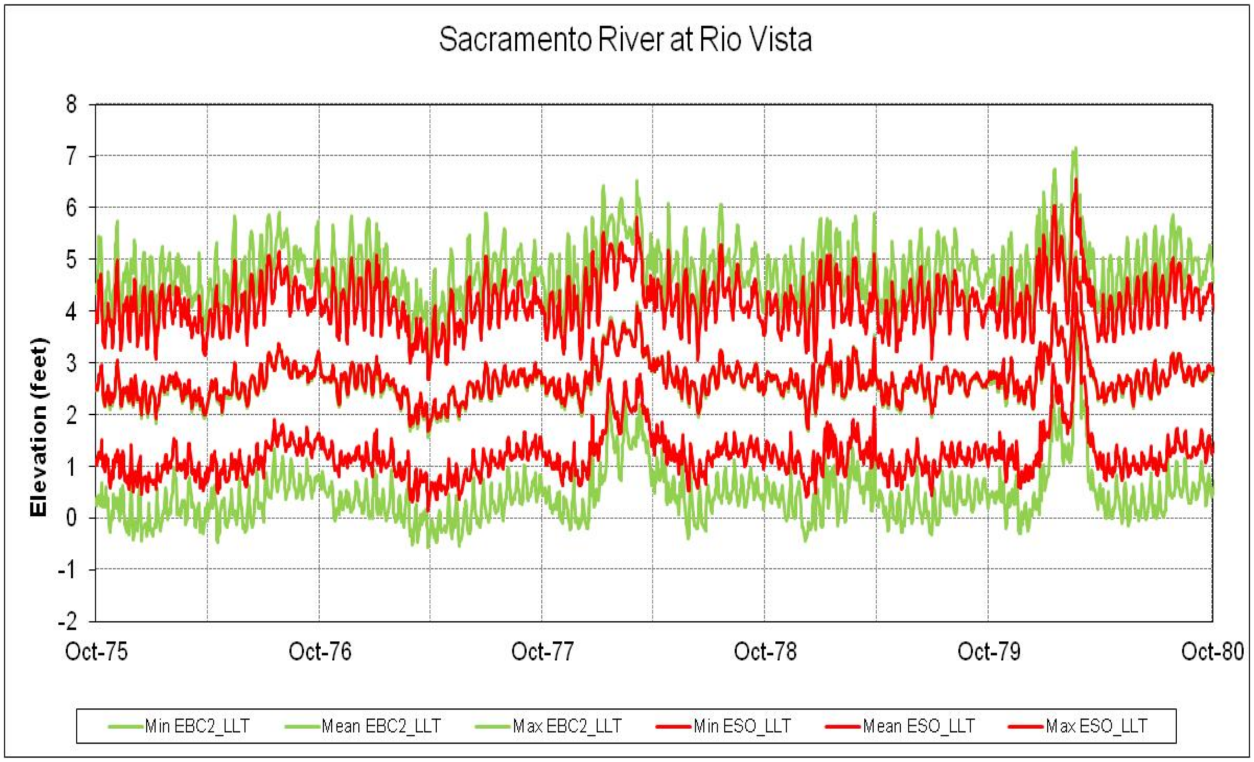
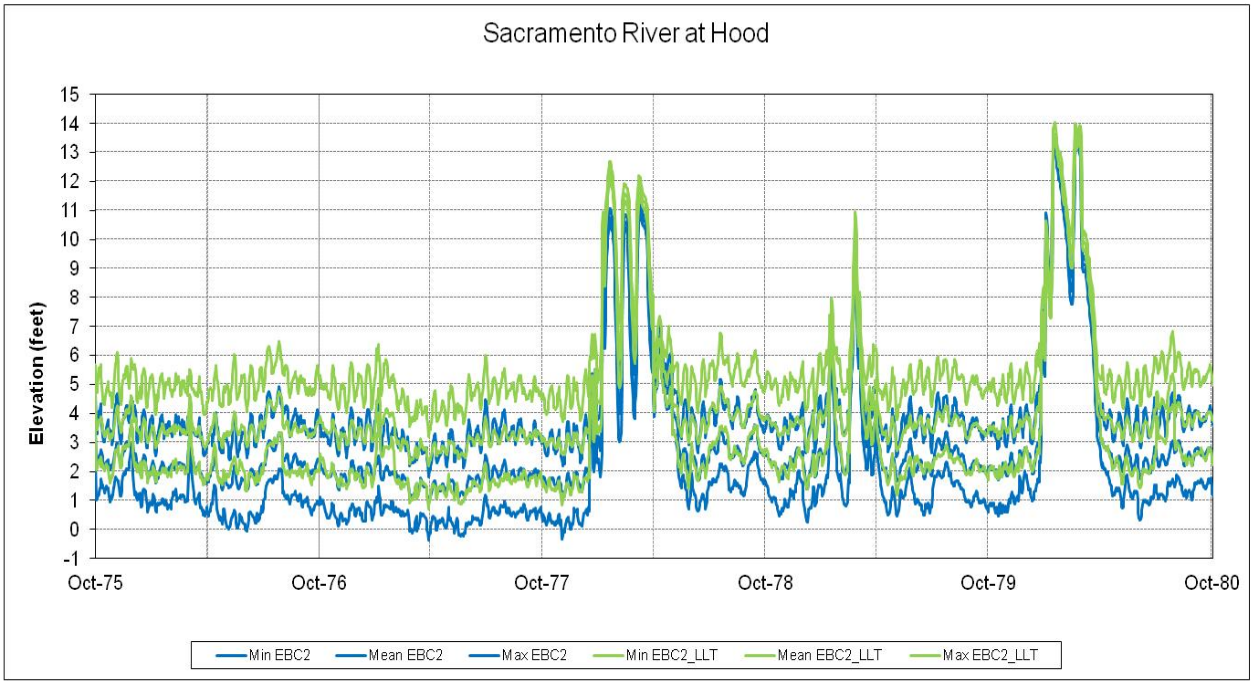


Figure C.A-92. DSM2-Simulated Daily Tidal Elevation Range in the Sacramento River at Rio Vista for WY 1976–1980 for (A) EBC2 and EBC2_LLT Cases and (B) EBC2_LLT and ESO_LLT Cases



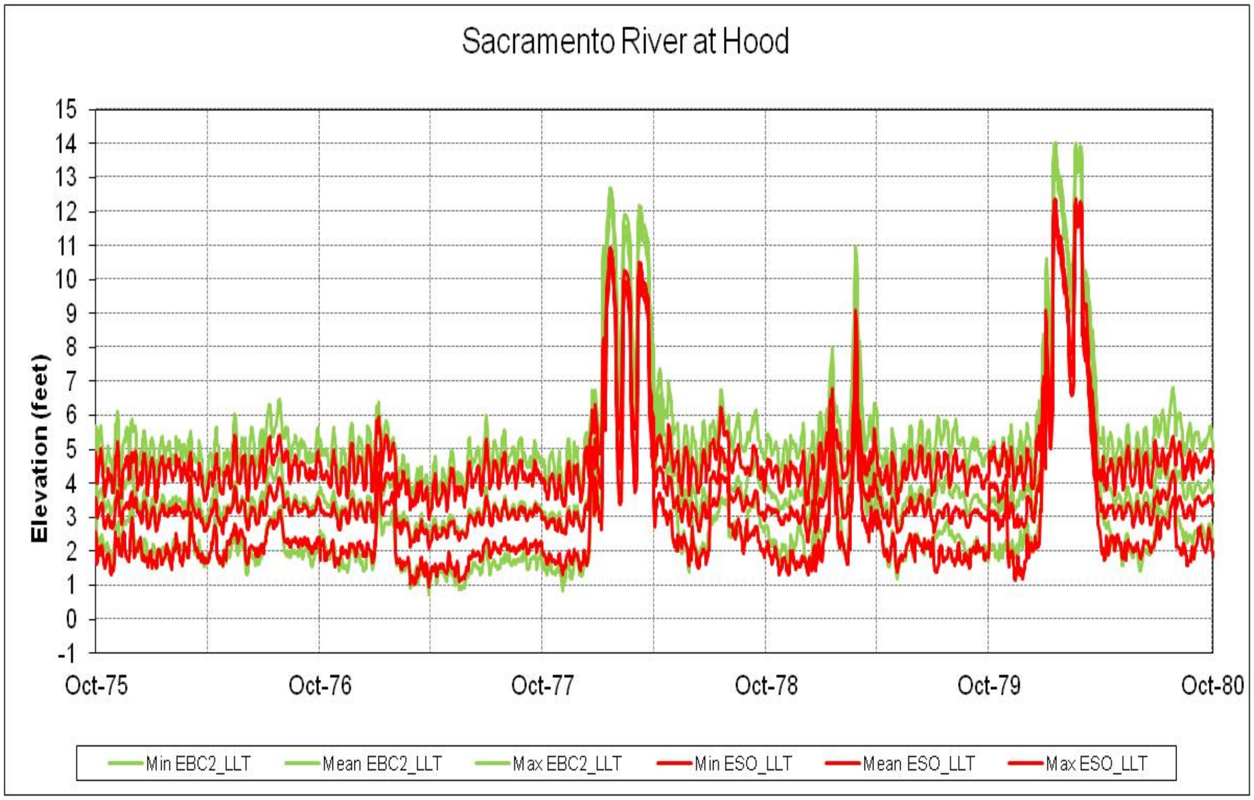


Figure C.A-93. DSM2-Simulated Daily Tidal Elevation Range in the Sacramento River at Hood for WY 1976–1980 for (A) EBC2 and EBC2_LLT Cases and (B) EBC2_LLT and ESO_LLT Cases

5C.A.6.3 Changes in DSM2-Simulated Channel Flow Diversions

The DSM2 daily flow results were used to demonstrate the shifts in the major flow diversion relationships (diversion flow as a fraction of upstream river flow) along the Sacramento River and along the San Joaquin River. For a river channel flow split (e.g., at an island), the diversion flow depends on the water elevation (river flow) and the channel cross-sections. Because there are tidal variations in the water elevations and velocities at the Delta channel junctions, the flow diversions may change. DSM2-simulated changes in these flow diversions ("flow splits") for the ESO cases were caused by the combined effects of sea-level rise and tidal natural communities and transitional uplands expansion (restoration) on the tidal elevations. In this section, EBC2 (existing conditions) daily average flow diversions are compared to the ESO_LLT daily average flow diversions (future sea-level rise and tidal restoration). The DSM2 simulation included the 1976–1991 period, but only daily flows for WYs 1977 and 1978 are shown on the graphs (these years included the full range of daily flows). These flow-diversion relationships are described because the flow diversions and flow pathways through the Delta channels provide the foundation for evaluating effects of the Delta channel flows on fish migrating through the Delta and on the movement of larval and juvenile fish within the Delta.

5C.A.6.3.1 Simulated North Delta Intake Diversions

All of the BDCP intakes would be located upstream of Sutter Slough. Because the magnitude of tidal flows (and velocities) decrease in the upstream direction, the flood tide velocities in the Sacramento River will be greatest at intake 3 near Sutter Slough, and will be less at upstream intakes. The tidal velocities will be lowest and may sometimes move upstream (reversed) at intake 3 when the Sacramento River flow at Freeport is relatively low. Because a moderate downstream sweeping velocity of about 0.5 ft/sec may be protective for reducing impingement of juvenile fish and accumulation of debris on the screens, the operation (pumping) at intake 3 would be somewhat limited (to ebb tides) during periods of low Freeport flow (less than 15,000 cfs). Figure C.A-94 shows the DSM2-simulated relationship between Sacramento River daily flow at Freeport (cfs) and the daily minimum and daily average tidal velocities (ft/sec) for WY 1977–1978. At the maximum daily flow of about 80,000 cfs, the average velocity was almost 5 ft/sec, and the minimum tidal velocity was only about 0.2 ft/sec less than the average. Figure C.A-95 shows the DSM2-simulated relationship between the Sacramento Rier daily flow at Freeport (cfs) and the average tidal elevation for the Sacramento River above Sutter Slough. At this high river flow, the river elevation is about 12 feet (msl) and the high water surface slope greatly reduces the fluctuation in tidal velocities. At Freeport flows of 10,000 cfs to 20,000 cfs, the fluctuation in tidal velocities is greater and the minimum velocity is about 1.0 ft/sec less than the average velocity. For a Freeport flow of 5,000 cfs, the minimum velocity is about 1.5 ft/sec less than the average velocity of 0.5 ft/sec. For Freeport flows of less than 15,000 cfs there will be some periods of reverse (upstream) tidal velocity during each day. The average (net) flow velocity is about 1 ft/sec at a flow of 10,000 cfs, indicating that the cross-section of the Sacramento River upstream of Sutter Slough is about 10,000 ft^2. The cross-section increases with high flow, and is a maximum of about 16,000 ft^2 at a flow of 80,000 cfs (with a velocity of 5 ft/sec).

The daily minimum velocity was greater than 0.5 ft/sec when the Freeport flow was about 20,000 cfs, indicating that some of the intakes could be operated at all times during the day when the net flow below intake 3 was greater than 20,000 cfs. Diversions would be possible during portions of the day when the average Freeport flow was less than 20,000 cfs. The DSM2 model was used to simulate the period of diversion each day with the constraint that the downstream sweeping velocity must remain greater than 0.4 ft/sec. There were very few days when the sweeping velocity constraint would have limited the allowable daily diversion flow, under the ESO north Delta intake "bypass rules". Full ESO diversions (9,000 cfs) could be made when the Freeport flow was greater than 30,000 cfs. This would correspond to the Level I December–April "bypass rules" and would also meet the assumed tidal sweeping velocity criteria.

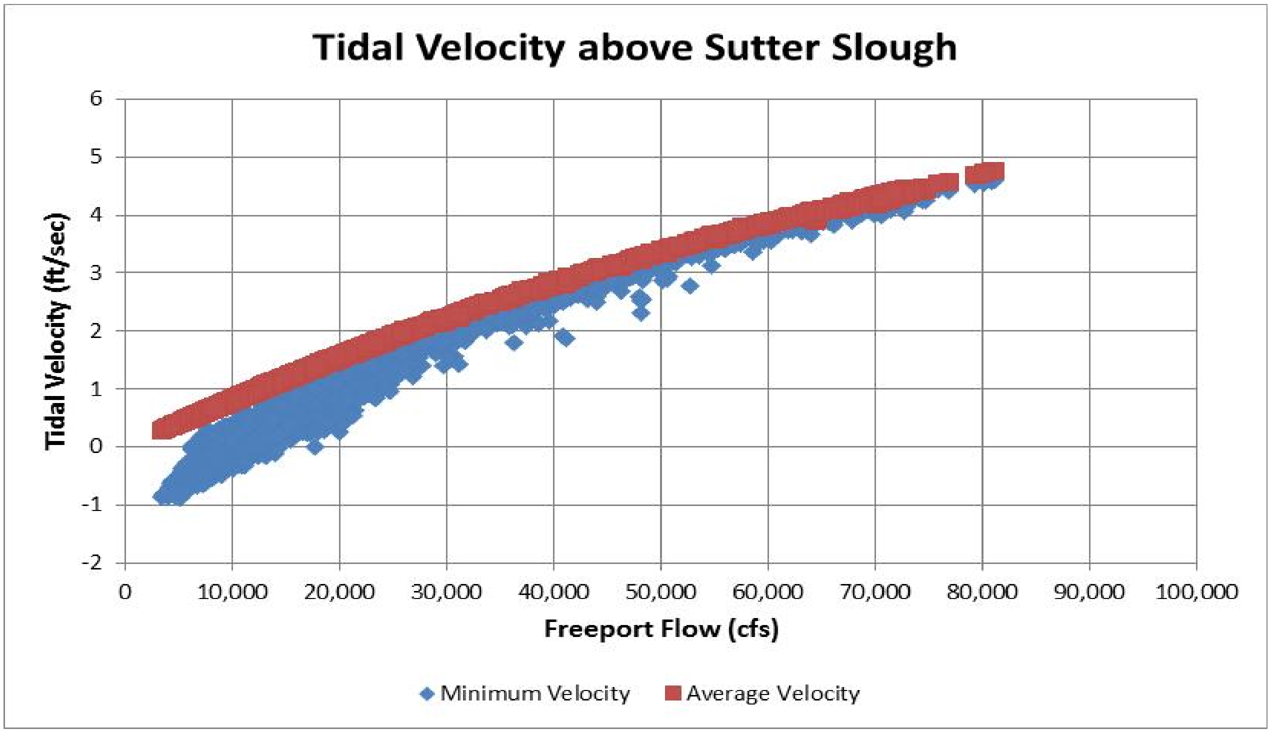


Figure C.A-94. DSM2-Simulated Daily Average and Daily Minimum Tidal Velocities in the Sacramento River above Sutter Slough for WY 1977–1978

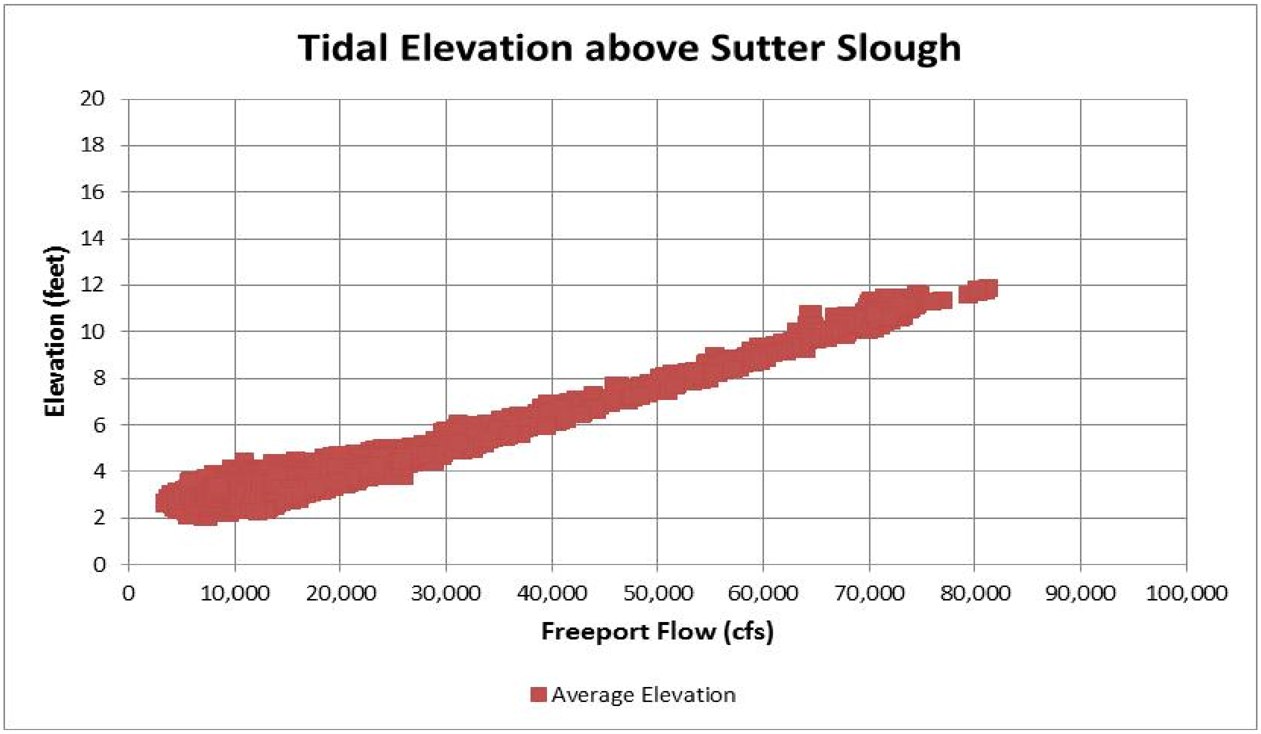


Figure C.A-95. DSM2-Simulated Daily Average Elevation in the Sacramento Rvier above Sutter Slough for WY 1977–1978

5C.A.6.3.2 Changes in Sacramento River Flow Diversions

Figure C.A-96 shows the Sutter Slough diversions as a function of the Sacramento River flow above Sutter Slough. The daily average flows and percent of flow diverted for WY 1977–1978 are shown. For all EBC cases this is the flow at Freeport; for the ESO cases this would be the flow after the north Delta intake diversions. At Sacramento River flows of greater than 25,000 cfs, the DCC is closed, and the Sutter Slough flow (blue diamond) is increased to about 27% of the Sacramento River flow (green diamond). The tidal flow variations at a Sacramento River flow of 25,000 cfs are weak, and at high flows this junction behaves as a river channel split with little variation during a tidal cycle. At a Sacramento River flow of 60,000 cfs, the Sutter Slough diversion flow would be about 16,000 cfs. At flows below 25,000 cfs, there are two cases; with the DCC closed the Sutter Slough diversion is slightly higher than when the DCC gates are open. The percentage of the Sacramento River flow diverted into Sutter Slough declines at river flows of less than 15,000 cfs; the percentage diverted is 22% at a low Sacramento River flow of 5,000 cfs with the DCC gates closed. When the DCC gates are open, the percentage of the river flow diverted increased from 18% at a river flow of 5,000 cfs to about 22% at a river flow of about 20,000 cfs. Closing the DCC gates raises the tidal elevations and increases the diversion to Sutter Slough by about 5% of the Sacramento River flow.

The effects of the BDCP tidal restoration were simulated to slightly increase the Sutter Slough diversion, from about 27% to about 28.5% at river flows of greater than 25,000 cfs (when the DCC gates are closed). The tidal simulation of the percentage diverted increased more at lower flows; the diversion was increased from about 27% to 30% of the river flow at a flow of 15,000 cfs and was increased from about 22% to 37% at a river flow of 5,000 cfs. This was apparently the result of tidal natural communities and transitional uplands expansion in the Cache Slough region that muted the tidal elevations in Sutter Slough and thereby increased the average daily diversion flow from the Sacramento River (Sacramento tidal elevations were higher more of the time).

Figure C.A-97 shows the DSM2-simulated Steamboat Slough diversions as a function of the Sacramento River flow upstream of Sutter Slough (Freeport). The EBC2 Steamboat Slough diversion was about 20% for river flows of greater than 25,000 cfs when the DCC gates were closed. The EBC Steamboat Slough diversion percentage decreased at lower river flow and was about 15% at a low river flow of 5,000 cfs. The diversion flow was reduced by about 5% of the river flow when the DCC gates were open; the Steamboat Slough diversion was about 15% at a river flow of 20,000 cfs and was about 10% at a river flow of 5,000 cfs. The DSM2-simulated changes for the ESO_LLT case were relatively small. The effects of opening the DCC gates were less than for the EBC diversions, so the Steamboat Slough diversion percentage remained 1–2% higher than the EBC at these relatively low river flows of 5,000 cfs to 20,000 cfs.

Figure C.A-98 shows the DSM2-simulated DCC diversion as a function of the Sacramento River flow upstream of the DCC. The EBC2 DCC diversion was about 40% for river flows of 5,000 cfs to 12,500 cfs (highest river flow while open). The highest DCC diversion was therefore about 5,000 cfs. The DSM2-simulated DCC diversions would be reduced for the ESO_LLT to about 30–35% of the river flow above the DCC.

Figure C.A-99 shows the corresponding Georgiana Slough diversion as a function of the Sacramento River flow above the DCC. When the DCC was closed (above a flow of about 12,500 cfs at DCC) the Georgiana Slough diversion was about 30% of the river flow. The Georgiana Slough diversion increased at lower flows when the DCC was closed, to about 40% when the river flow was 7,000 cfs and to 50% when the river flow was 3,000 cfs. When the DCC gates were open, the EBC Georgiana Slough diversion was reduced by about 10% of the river flow, to about 22% at a flow of 12,500 cfs and about 30% at a river flow of 5,000 cfs. The DSM2-simulated Georgiana Slough diversion was reduced slightly with the BDCP at lower river flows. The ESO_LLT diversion percentage was 40% at a river flow of less than 5,000 cfs and about 30% at a river flow of 10,000 cfs. The Georgiana Slough diversion was about the same as the EBC2 for river flows greater than 15,000 cfs (DCC closed).

Figure C.A-100 shows the DSM2-simulated combined Sutter and Steamboat Slough diversions as a function of the Sacramento River flow upstream of Sutter Slough for the EBC2 and ESO_LLT cases. The simulated diversions for the ESO case were slightly increased at higher flows when the DCC gates were closed, and were increased by about 5–10% of the river flow when the river flow was less than 20,000 cfs with the DCC open or closed.

Figure C.A-101 shows the DSM2-simulated combined DCC and Georgiana Slough diversions as a function of the Sacramento River flow above Sutter Slough (Freeport for EBC). At low river flows when the DCC is open, the combined DCC and Georgiana Slough diversion is 50% at a flow of 5,000 cfs and 40% at a flow of 20,000 cfs. The Georgiana Slough diversion was about 30% with a river flow of 5,000 cfs and 20% at a river flow of 15,000 cfs; it decreased to 15% at a river flow of 50,000 cfs. The simulated diversions for the ESO case were reduced at the lower river flows. The diversions with the DCC open were about 30% of the river flow. The Georgiana Slough diversion with the DCC gates closed was reduced from 30% to 20% of the river flow at a flow of 5,000 cfs, but was similar to EBC diversion of about 15% for river flows of 50,000 cfs.

Figure C.A-102 shows the DSM2-simulated average daily diversions in Threemile Slough for EBC2 and ESO_LLT cases. The Threemile Slough flows from the Sacramento River to the San Joaquin River (reverse flow values) were slightly higher at high Rio Vista flow with the BDCP. The tidal flows in

Threemile Slough were reduced because of the general tidal muting within the Delta that was the result of the increase tidal natural communities and transitional uplands (i.e., restoration) simulated for the ESO_LLT, but the net tidal flows were increased for most combinations of Rio Vista flow and San Joaquin River flow.

Flow in Montezuma Slough, on average, is from the Sacramento River into Montezuma Slough and Suisun Marsh. The Montezuma flow is about 1% of Delta outflow. Operation of the Montezuma Slough Salinity Control Gate increases the diversion by a constant daily flow of about 2,000 cfs (when it is operated during October–March of some years). The net diversion flow was not increased by sea-level rise or tidal natural communities and transitional uplands restoration but was reduced with the ESO because the Montezuma Slough Salinity Control Gate was not operated, to allow full tidal exchange into Suisun Marsh restoration areas.

5C.A.6.3.3 Changes in San Joaquin River Diversions

Figure C.A-103 shows the DSM2-simulated changes in the Old River diversion from the San Joaquin River near Mossdale for EBC2 and ESO_LLT cases. The flow diversion is about 50% of the San Joaquin River at Mossdale (or Vernalis) flow. The Old River diversion flow is shown as a function of the San Joaquin River flow at Vernalis. The DSM2 model simulated the Paradise Cut flood bypass diversion upstream of Mossdale for flows greater than 17,500 cfs. The simulated Old River diversion was about 7,500 cfs when the Vernalis flow was 15,000 cfs, and was about 10,000 cfs when the Vernalis flow was 25,000 cfs because about half of the Vernalis flow greater than 17,500 cfs was diverted into Paradise Cut. The Old River diversion for the ESO case was about half of the diversion for EBC2 case for flows of less than 10,000 cfs because the ESO included an operable barrier that was assumed to be closed about half of each day to reduce the Old River diversion to about 25% of the San Joaquin River flow in the months of January–June and in October. Therefore, the ESO case showed reduced Old River diversions in these months. The overall effects of the BDCP on these Sacramento and San Joaquin diversion flows were relatively small compared to the large increase in tidal natural communities and transitional uplands from sea-level rise and restoration efforts. The daily net average flows and average flow splits (pathways) would not be greatly changed by the ESO conditions.

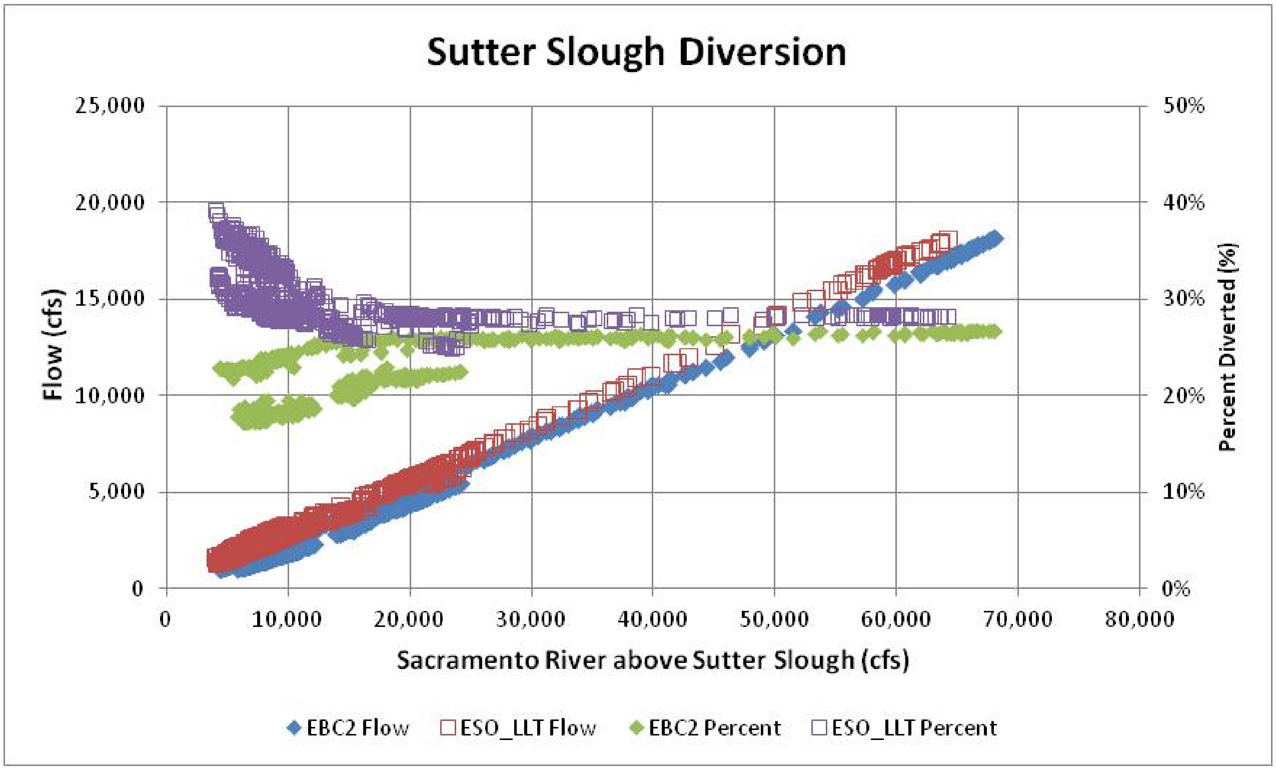


Figure C.A-96. DSM2-Simulated Sutter Slough Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

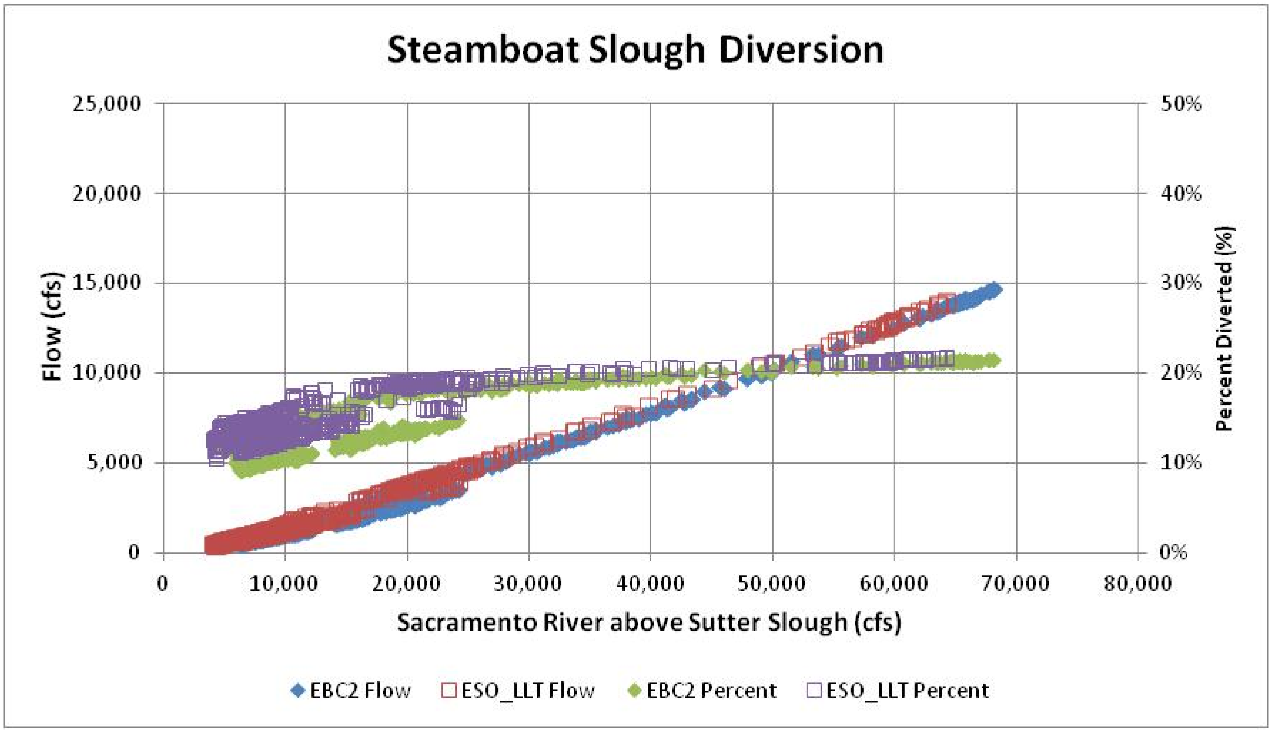


Figure C.A-97. DSM2-Simulated Steamboat Slough Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

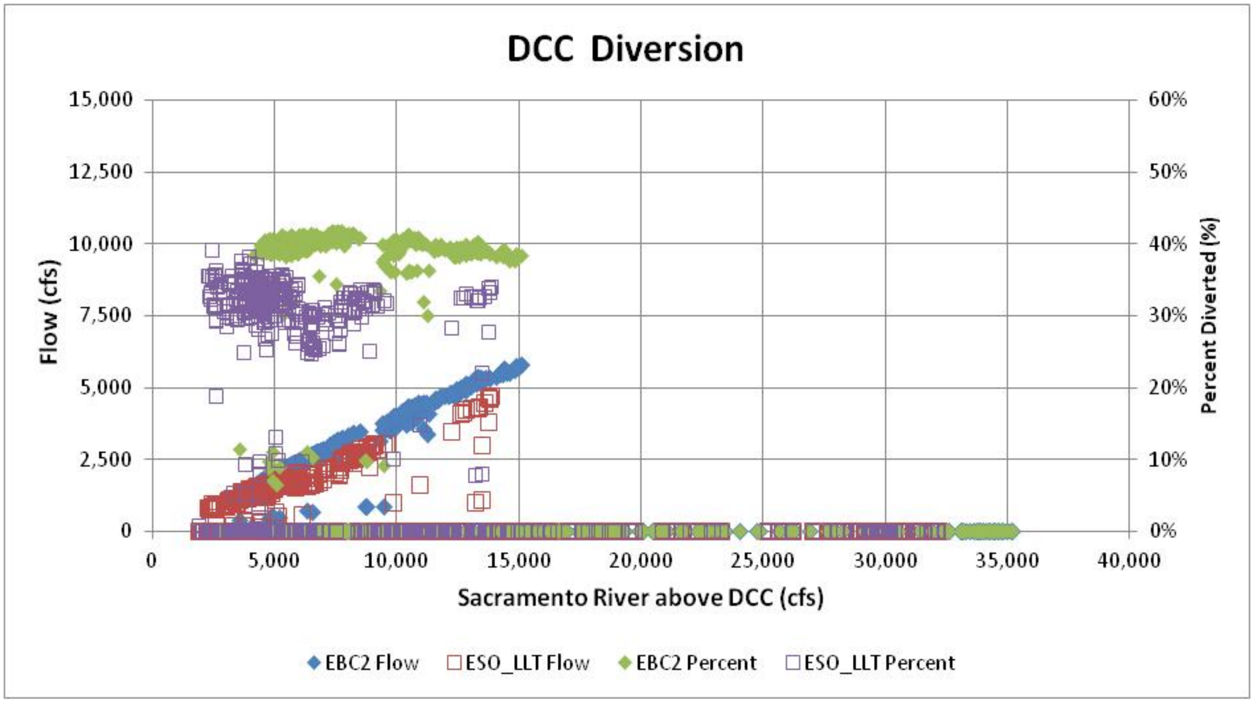


Figure C.A-98. DSM2-Simulated Delta Cross Channel Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

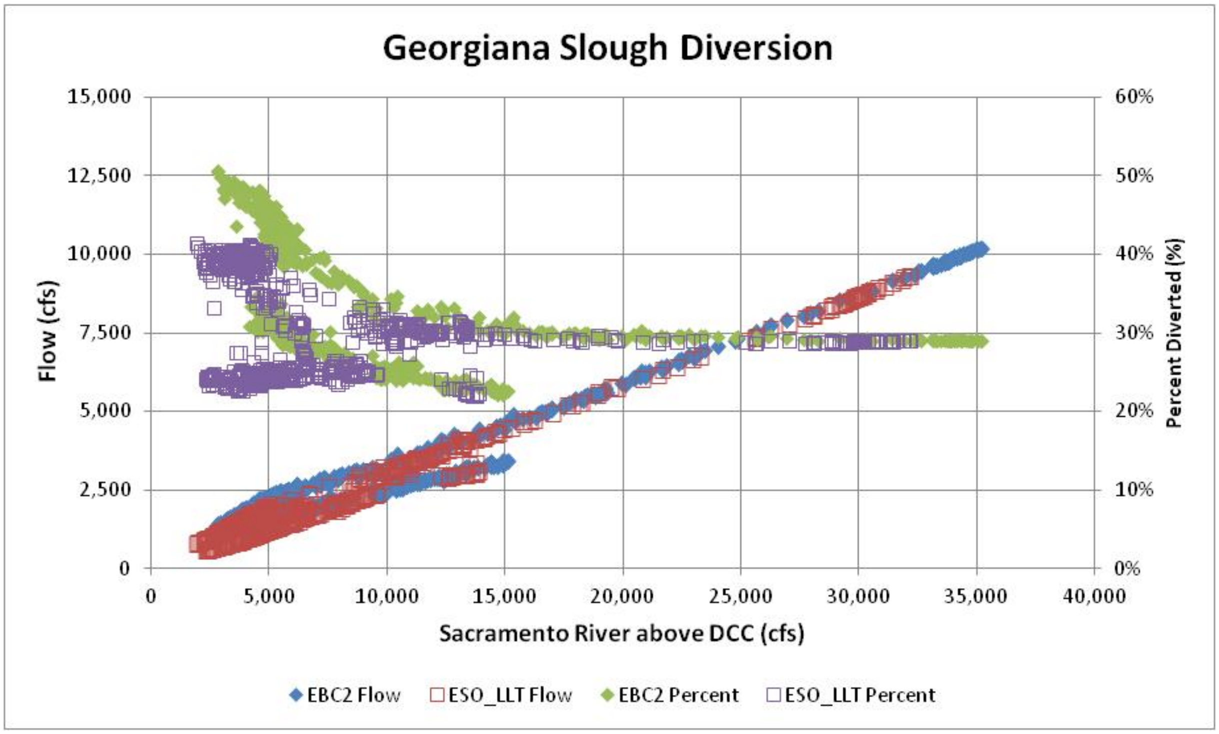


Figure C.A-99. DSM2-Simulated Georgiana Slough Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

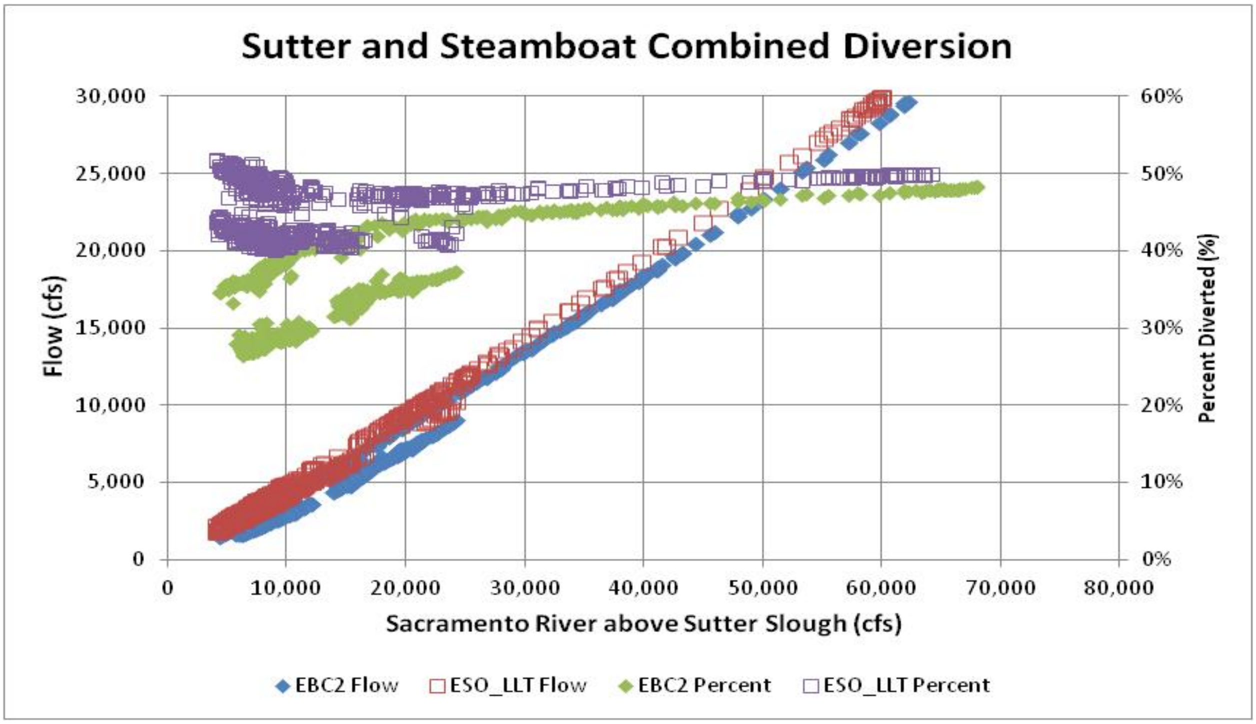


Figure C.A-100. DSM2-Simulated Combined Sutter and Steamboat Slough Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

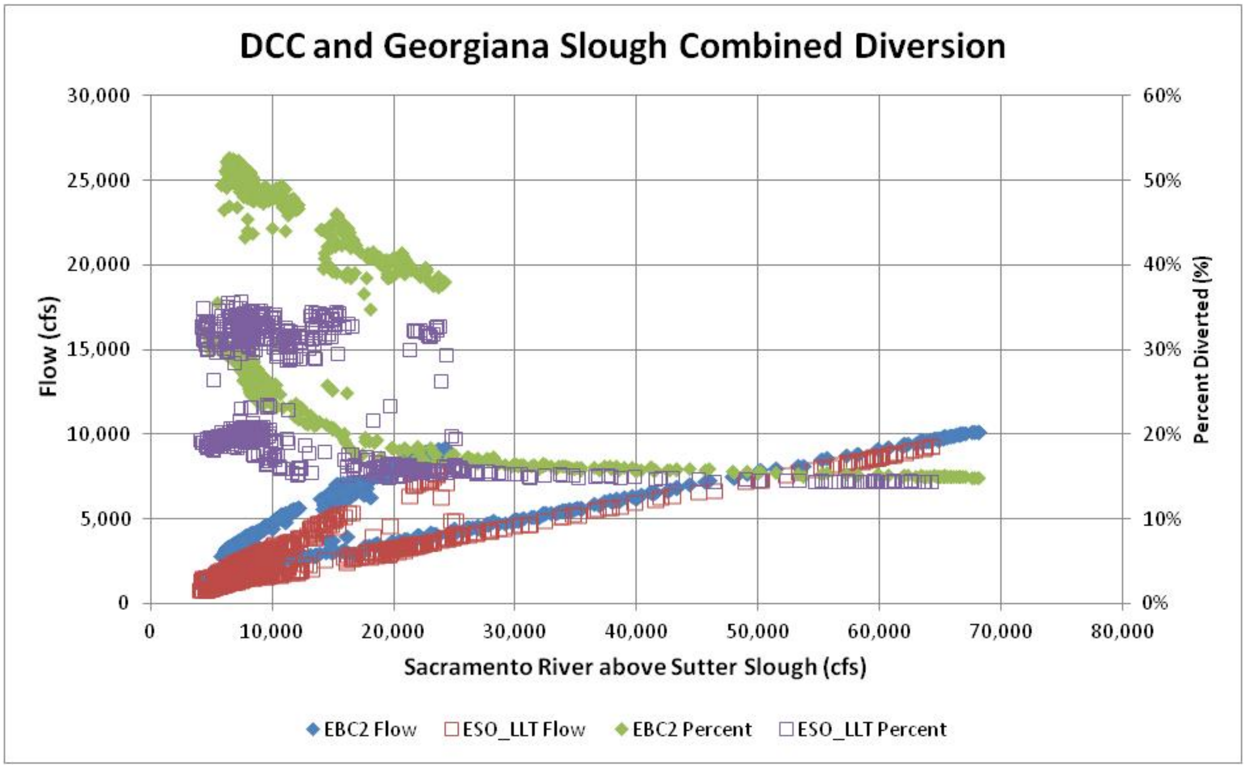


Figure C.A-101. DSM2-Simulated Combined Delta Cross Channel and Georgiana Slough Diversion from the Sacramento River for EBC2 and ESO_LLT Cases for WY 1977 and 1978

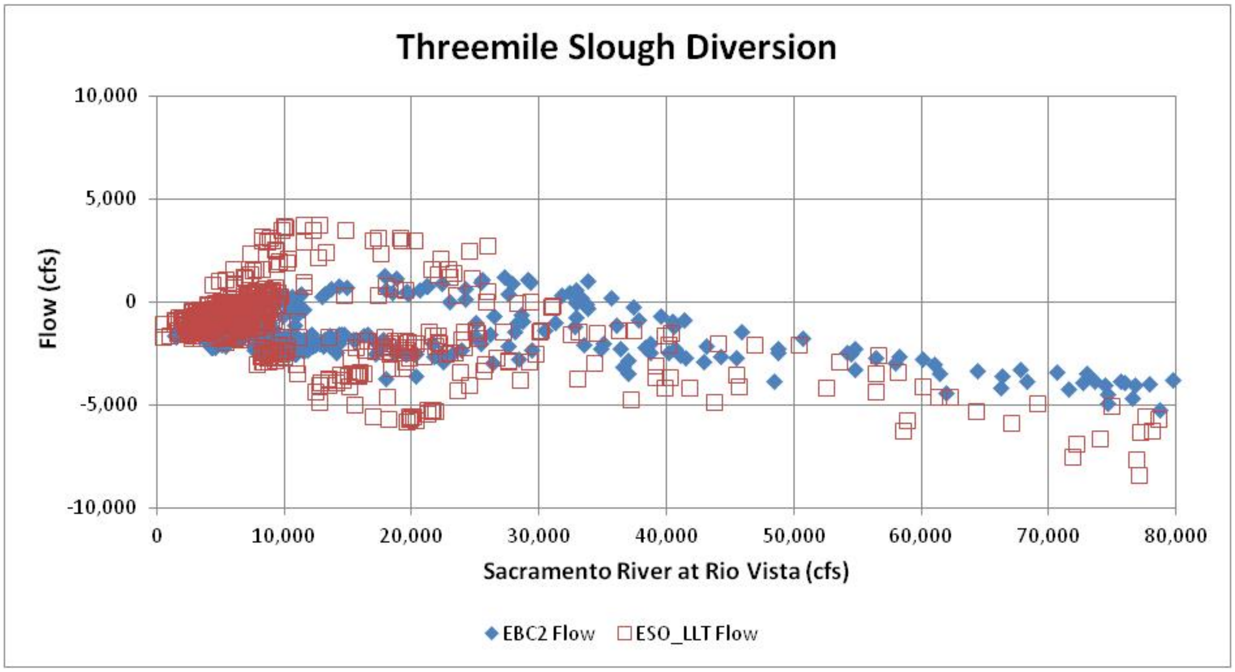


Figure C.A-102. DSM2-Simulated Threemile Slough Diversion (Negative is from Sacramento to San Joaquin River) as a Function of the Sacramento River Flow at Rio Vista for EBC2 and ESO_LLT Cases for WY 1977 and 1978

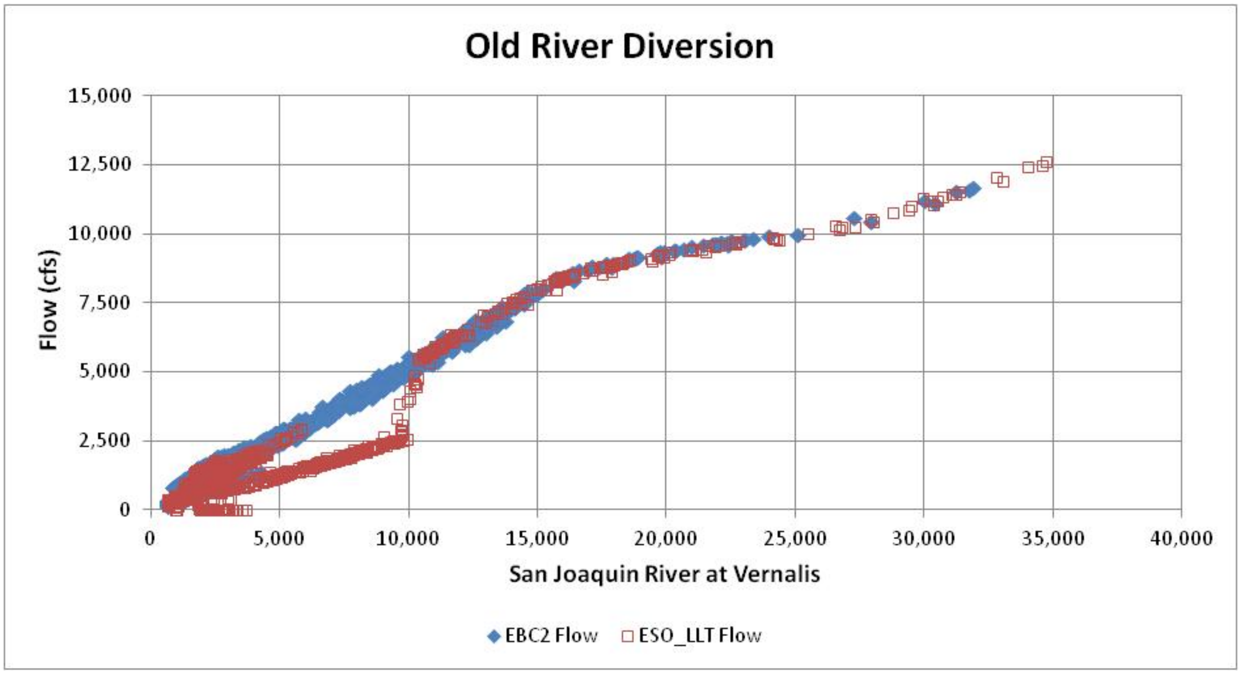


Figure C.A-103. DSM2-Simulated Old River Diversion from the San Joaquin River as a Function of the San Joaquin River Flow at Vernalis for EBC2 and ESO_LLT Cases for WY 1977 and 1978

5C.A.7 DSM2-Simulated Changes in Salinity

The DSM2 modeled salinity in the western Delta and at the south delta exports is largely controlled by the specified outflow, taken from the CALSIM-simulated Delta outflow for each case. The Martinez EC boundary was calculated using the DSM2-preprocessor that uses the historical EC measurements and the adjustments in historical outflow, along with the added effects of sea-level rise and tidal natural communities and transitional uplands restoration to estimate the adjusted Martinez EC values. The upstream salinity in the Delta channels calculated by DSM2 is a direct function of the tidal flows (which are largely unchanged) and the simulated tidal mixing within the existing channels, with or without the additional tidal natural communities and transitional uplands areas. Most of the differences in salinity at upstream Delta locations are caused by the CALSIM-simulated outflow changes, with relatively small adjustments for sea-level rise and tidal natural communities and transitional uplands restoration. The major differences in the DSM2 salinity results are caused by the different assumed Delta outflow sequences. The small effects of sea-level rise and tidal natural communities and transitional uplands restoration cannot easily be identified from the monthly EC results, because the outflow sequences were slightly different for each of the cases, with some relatively large changes in a few months. The changes in salinity that can be expected with sea-level rise and with tidal natural communities and transitional uplands restoration in Suisun Marsh or within the Delta for a specified outflow are more important than the month to month changes caused by different outflows. More information about the likely effects of sea-level rise on Delta salinity that were simulated with the UnTRIM 3-D Bay-Delta model are described in Appendix 5.A.2, *Climate Change Approach and Implications for Aquatic Species*, Section 5A.2.5.2, *Tidal Flows and Salinity.*

Figure C.A-104 shows the DSM2-simulated monthly EC at Chipps Island for the six DSM2 cases. The seasonal salinity at Chipps Island ranged from less than 1,000 µS/cm to about 15,000 µS/cm in most years; the winter EC values remained above 2,000 µS/cm in a few dry years and the fall EC values remained less than 10,000 –S/cm in a few wet years. The salinity at Chipps Island was about 60% of the assumed EC at Martinez (maximum of 25,000 µS/cm during low-outflow periods). The X2 location would be at Chipps Island (75 km) when the EC was about 3,000 µS/cm. The X2 location was generally upstream of Chipps Island (EC was greater than 3,000 µS/cm) in the summer and fall, and downstream of Collinsville in the winter months.

Figure C.A-105 shows the DSM2-simulated monthly EC at Collinsville for the six DSM2 cases. The seasonal salinity at Collinsville ranged from less than 250 µS/cm to about 10,000 µS/cm in most years; the fall EC values were less than 5,000 µS/cm in a few wet years. The salinity at Collinsville was about 40% of the assumed EC at Martinez. The X2 location would be at Collinsville (81 km) when the EC was about 3,000 µS/cm. The X2 location was generally upstream of Collinsville in the summer and fall, and downstream of Collinsville in the winter months.

Figure C.A-106 shows the DSM2-simulated monthly EC at at Emmaton for the six DSM2 cases. The seasonal salinity at Emmaton ranged from less than 250 µS/cm to about 3,500 µS/cm or more in dry years; the fall EC values remained less than 1,500 µS/cm in a few wet years. The salinity at Emmaton was about 10% of the salinity at Martinez, and about 35% of the salinity at Collinsville.

Figure C.A-107 shows the DSM2-simulated monthly EC at Jersey Point for the six DSM2 cases. The seasonal salinity at Jersey Point ranged from less than 250 µS/cm to about 2,500 µS/cm in most years, although the variability between the highest EC values in the fall was greater than at the downstream stations in Suisun Bay. The salinity at Jersey Point was slightly less than the salinity at

Emmaton, and was about 25% of the salinity at Collinsville. The simulated EC variability between years was greater at Emmaton and Jersey Point, because the EC remains low until the outflow is less than about 10,000 cfs. The effects of outflow variations in the range of 3,000 cfs to 10,000 cfs are therefore more noticeable at Enmmaton and Jersey Point.

Because all of the cases except EBC1 assumed that the Fall X2 requirements of the 2008 USFWS BiOp would be satisfied in the fall of 1978, 1980, 1983, 1984, and 1986 (5 of the 16 years simulated), EBC1 (without Fall X2) showed higher EC (lower outflow) in the months of September–November of these years at each station. The effects of assumed changes in salinity-outflow relationships with sea-level rise and tidal natural communities and transitional uplands restoration can be detected in the ESO_ELT and ESO_LLT cases. The assumed outflow in the fall months was quite different than the EBC cases, and the DSM2-simualted EC values were considerably less in several of the years. Nevertheless, the changes in EC at each of these stations were caused by changes in outflow; the assumed changes in the basic relationship between outflow and EC caused by sea-level rise and tidal natural communities and transitional uplands restoration was a secondary effect.

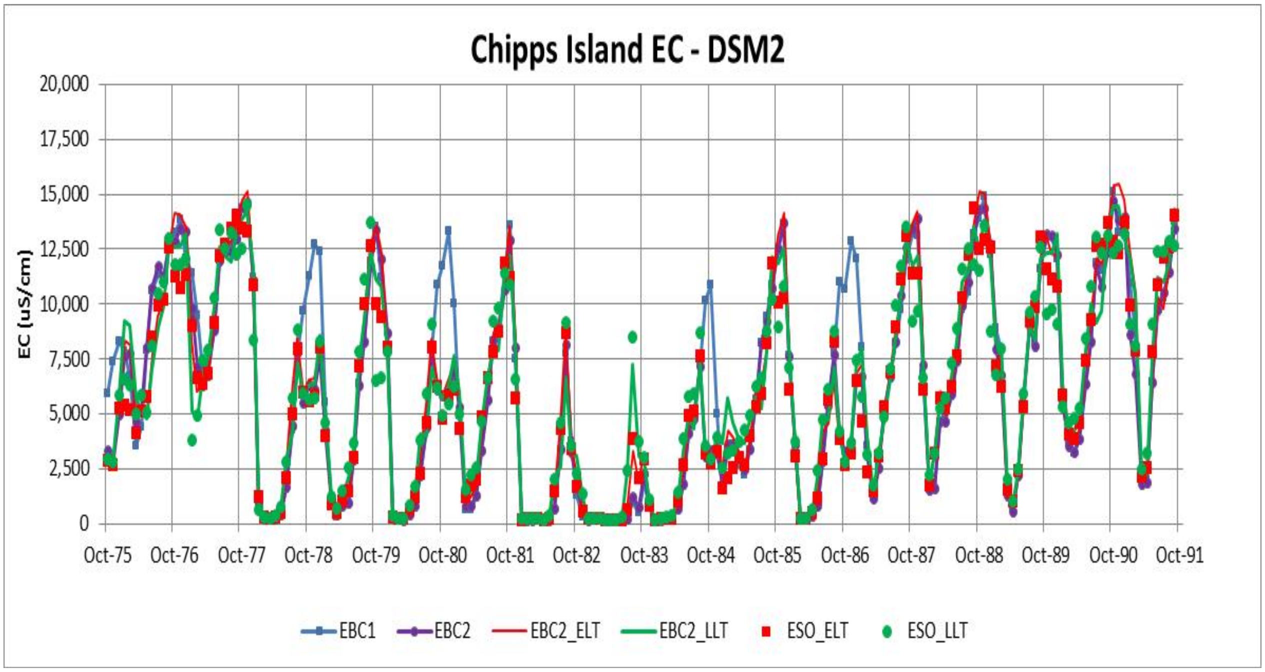


Figure C.A-104. Monthly EC at Chipps Island for WY 1976–1991 for the Six DSM2 Cases

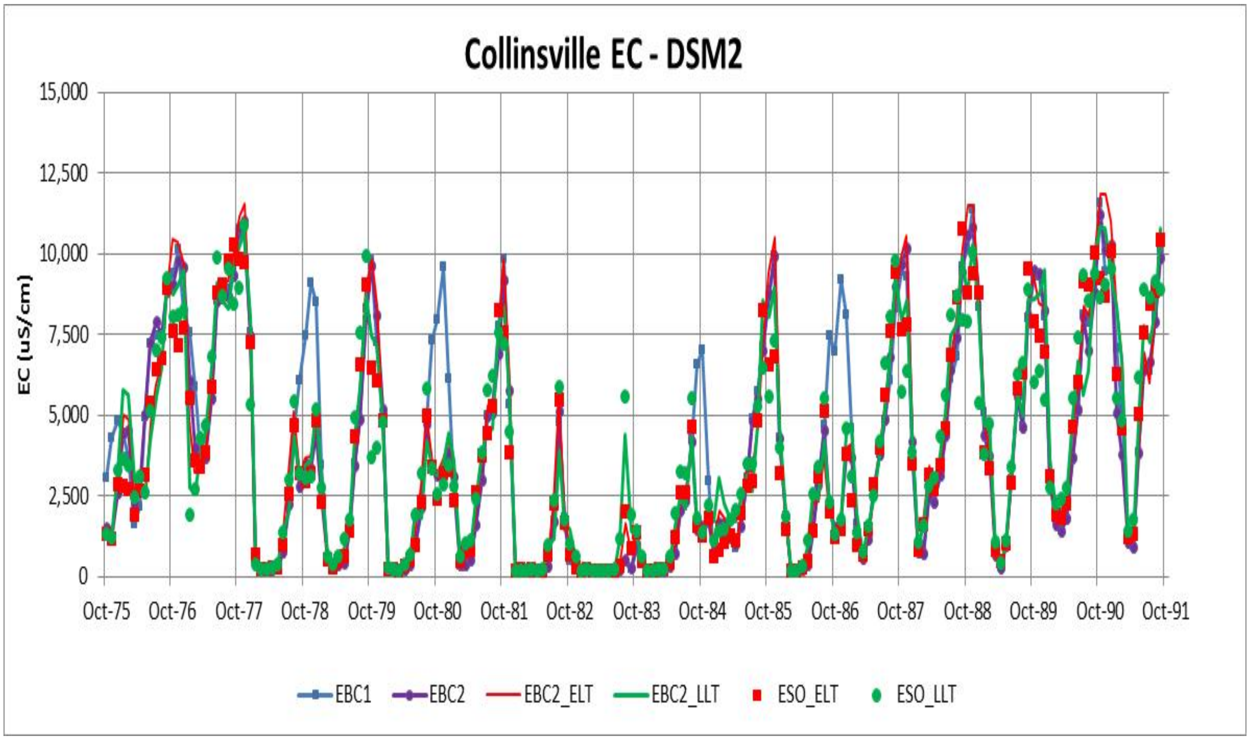


Figure C.A-105. Monthly EC at Collinsville for WY 1876–1991 for the Six DSM2 Cases

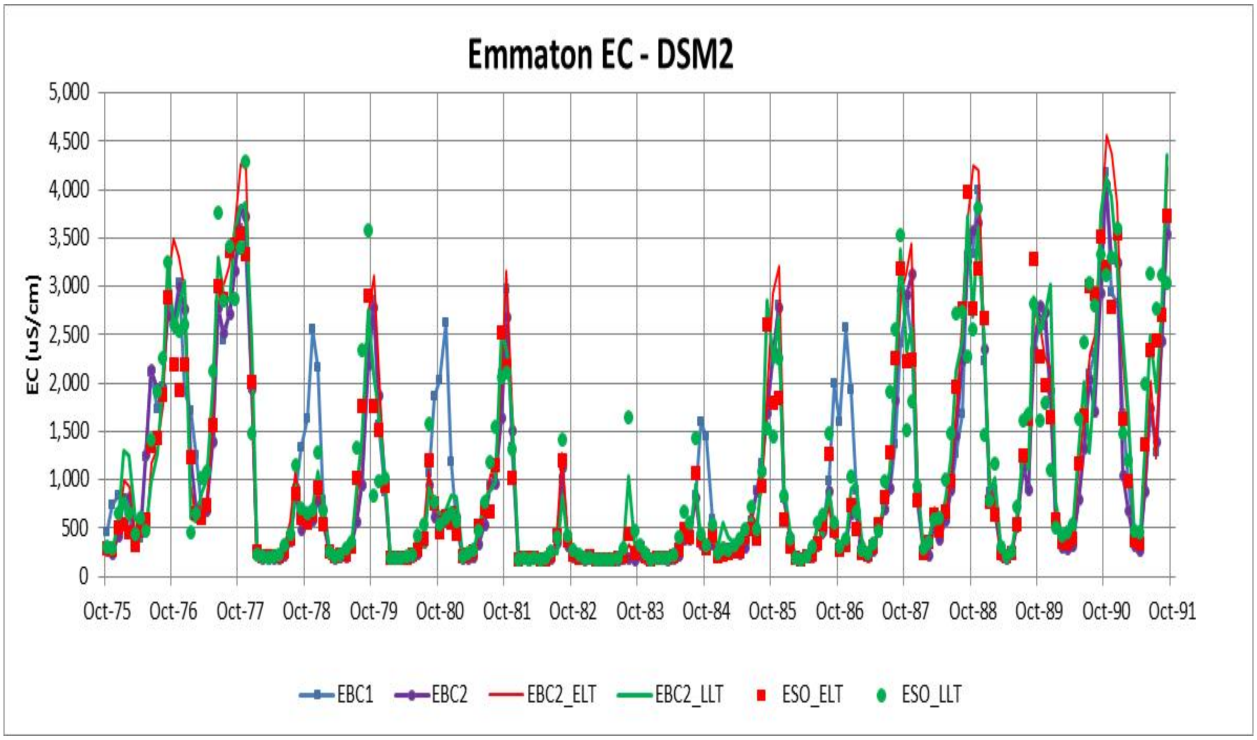


Figure C.A-106. Monthly EC at Emmaton for the Six DSM2 Cases

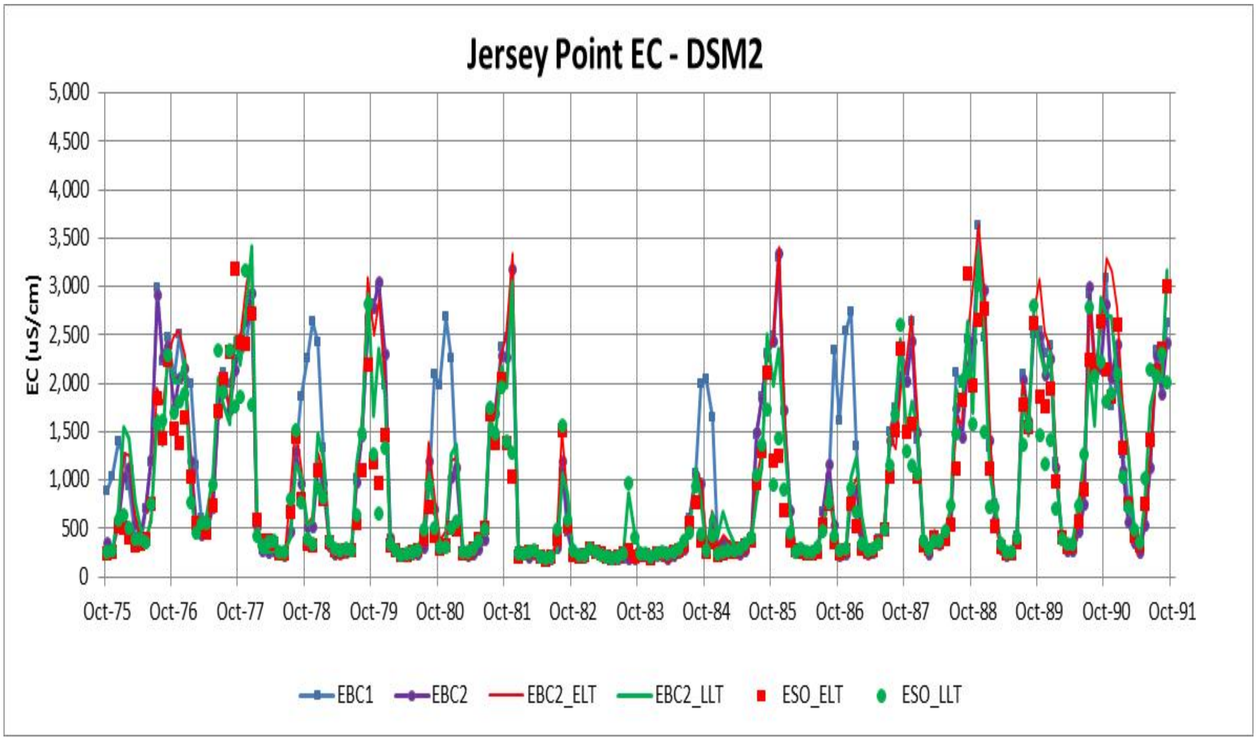


Figure C.A-107. Monthly EC at Jersey Point for the Six DSM2 Cases

The export flow-weighted average EC for SWP, CVP, and CCWD exports was calculated for each of the scenarios. Table C.A-52 provides a summary of the average export flow-weighted EC concentration at SWP, CVP, and CCWD export facilities for the six cases. The export flow-weighted average EC values at Banks (CCF) and Jones pumping plants were reduced slightly from EBC1 to EBC2 because of higher outflows in September and October of wet and above normal years required by the Fall X2 conditions. The flow-weighted average EC values for the combined exports for the ESO cases were reduced by about 100 µS/cm from the EBC2 EC values because about half of the exports were diverted from the north Delta intakes with an EC of 175 µS/cm.

Table C.A-52. Summary of Average Export-Weighted EC (µS/cm) at South Delta Intakes and Combined Exports (ESO cases include North Delta Intakes)

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	ESO_ELT	ESO_LLT
Clifton Court	495	454	460	447	453	457
Jones PP	540	499	512	507	508	499
Combined	519	474	479	463	359	348

The ESO simulations reduced the export flow-weighted EC at Banks pumping plant and Jones pumping plant because about half of the exports were diverted at the north Delta intakes. The combined exports average EC was reduced by 25% for the ESO_ELT and ESO_LLT cases compared to the EBC2_ELT and EBC2_LLT cases. Because the lowest possible export EC value would be 175 µS/cm (assumed Sacramento River EC value), the maximum improvement in export salinity would be to reduce all “excess” salinity from the San Joaquin River, agricultural drainage, and seawater intrusion. The improvement in export salinity was about 40% of the maximum possible improvement (i.e., ELT excess salinity was reduced from 304 µS/cm [479–175] to 184 µS/cm [359–

175] and LLT excess salinity was reduced from 288 µS/cm [463–175] to 173 µS/cm [348–175]). This reduction in the export salinity would be substantial, but these DSM2 results demonstrate the fact that "dual conveyance" operations of the BDCP would allow a considerable portion of the San Joaquin River salt and substantial seawater intrusion to reach the south Delta exports.

5C.A.7.1 DSM2-Simulated Changes in Outflow-Salinity and Outflow-X2 Relationships

The salinity gradient within the San Francisco Bay-Delta estuary depends on the Delta outflow (i.e., estuary freshwater inflow). The salinity changes most dramatically with a change in Delta outflow at the upstream end of the estuary (upstream of Martinez). The relationship between Delta outflow and salinity at the upstream-end of the estuary is generally described with the outflow-X2 equation. X2 is defined as the upstream distance from the Golden Gate Bridge (km) of the 2 ppt bottom salinity and is used as an index of the upstream extent of seawater intrusion into Suisun Bay and the Delta. But the entire salinity gradient is shifted downstream with increasing Delta outflow.

The measured daily average salinity (EC) at a fixed monitoring station (e.g., Martinez, Port Chicago, Chipps Island, Collinsville, Emmaton) shows a decreasing pattern of EC with increased outflow (i.e., negative exponential relationship). The strong relationships between outflow and salinity at each station or between outflow and X2 are the basis for managing Delta outflow to provide salinity control. The relationships between outflow and salinity or between outflow and X2 which are assumed in CALSIM (ANN) or are simulated with DSM2 are very important for determining the required Delta outflow necessary to meet the D-1641 X2 and EC objectives. This section reviews the CALSIM and DSM2 model results for X2 and for EC at the salinity compliance locations (Emmaton and Jersey Point). A comparison of the EBC1 and EBC2 cases with the ESO_LLT and ESO_LLT cases will identify the assumed changes from sea-level rise and from the tidal natural communities and transitional uplands expansion (restoration).

Because the DSM2 model downstream boundary is at Martinez, the effects of sea-level rise and habitat expansion on salinity must be included in the assumed boundary conditions for salinity specified at Martinez for each of the BDCP cases. The effects of sea-level rise were determined from the UNTRIM Bay-Delta model and the effects of tidal natural communities and transitional uplands expansion (restoration) were determined from the RMA Bay-Delta model. Both of these effects were included in the DSM2 model as adjustments to the DSM2 Delta model boundary conditions that were estimated for each of the CALSIM calculated Delta outflow sequences (different from historical outflow) and from the tidal pattern of historical EC measured at Martinez. The DSM2 dispersion coefficients were also increased to account for increased tidal mixing of the Martinez boundary EC, as approximated in the RMA Bay-Delta model. The DSM2 EC results were compared to determine how much of a shift in the outflow-EC or outflow-X2 relationships were simulated between the existing conditions and the LLT conditions (with 1.5 feet of sea-level rise and extensive tidal natural communities and transitional uplands restoration).

The Martinez EC boundary conditions were adjusted for each DSM2 modeling case to match the monthly outflow calculated by the CALSIM model for each BDCP case. These adjustments in the Martinez EC values to match the different CALSIM outflows was generally much greater than the previously simulated EC effects from sea-level rise (using the UnTRIM model) or tidal natural communities and transitional uplands restoration (using the RMA Bay-Delta model). It is difficult to identify the effects of sea-level rise or tidal natural communities and transitional uplands restoration from the direct comparison of the monthly EC simulated for the six BDCP cases because the changes in the monthly simulated EC values for the six BDCP cases were dominated by the different monthly outflow sequences. Therefore, the relationship between Delta outflow and simulated EC were compared to determine how much of a shift in the outflow-EC or outflow-X2 equations resulted from the combination of sea-level rise and tidal natural communities and transitional uplands restoration.

5C.A.7.2 San Francisco Estuary Salinity Gradient

The salinity gradient in the San Joaquin River estuary can be approximated as a logistical (shape) relationship because the salinity at the downstream end (Golden Gate) will remain at ocean salinity (32 practical salinity units [psu], about 47,500 µS/cm) while the salinity at the upstream end (Rio Vista at 100 km) will remain fresh (0.1 psu, about 200 µS/cm). There will be a vertical salinity stratification at higher outflows, with fresh water remaining near the surface, but the depth averaged salinity can be approximated with the patterns shown in Figure C.A-108.

Figure C.A-108 shows the calculated salinity gradient in the estuary between 0 km and 100 km for a range of outflows from 3,000 cfs to about 30,000 cfs. The outflow was selected as increments of 1.55x to show that the calculated X2 position (about 3,000 µS/cm) is moved 5 km downstream for each 55% increase in outflow. The X2 positions is moved downstream 1 km for each 9% increase in outflow, because $(1.09)^5$ is equal to 1.55.

Figure C.A-109 shows the calculated salinity gradient in the estuary between 50 km and 100 km for a range of outflows from 3,000 cfs to about 30,000 cfs. This shows that the Martinez EC (at 55 km) is reduced nearly linearly for each outflow increase of 55%. The calculated Martinez EC was about 24,500 µS/cm with an outflow of 3,000 cfs, and was about 7,500 µS/cm with an outflow of about 28,000 cfs. The EC was reduced by about 17,000 µS/cm for five outflow increases of 55% each, so the EC was reduced by an average of about 3,400 µS/cm for each 55% increase in outflow (corresponding to an X2 shift of 5 km). The EC at upstream locations are generally related to both the Martinez EC and the outflow, because they are located at specific distances along the EC gradient. The logistical equation used to estimate the salinity gradient was originally identified from the USGS monthly Bay-study boat surveys of salinity and other water quality parameters. The approximate logistic equation (Unger 1994) was:

$$\text{EC } (\mu S/cm) \text{ at Distance Z (km)} = 48{,}000 / [1 + 510 \times \exp(-7 \times (1.5 - \text{Distance Z}/X2))]$$

The X2 location must be estimated from the steady-state monthly X2 equation which is:

$$X2 \text{ (km)} = 181.8 - 26.26 \times \text{Log[outflow(cfs)]}$$

The logistic coefficients have been selected so that when the distance Z is X2, and the ratio of Z/X2 is 1.0, the EC will be 2,927 µS/cm. This equation can only capture the basic estuarine gradient, and assumes that Delta outflow has been steady (constant) for long enough to fully establish this equilibrium salinity gradient. This equation applies to daily average salinity only. The actual salinity will move upstream and downstream by several kilometers (5 km at Martinez, 10 km at Chipps Island) during each tidal cycle. This movement of the salinity gradient causes the maximum EC at Martinez to be about 7,500 µS/cm higher than the average EC and the minimum EC to be about 7,500 µS/cm lower when the average Martinez EC is greater than 15,000 µS/cm (at relatively low Delta outflow). As with Martinez, there is a wide range of salinity within each tidal cycle at any given fixed location in the estuary.

5C.A.7.3 DSM2 Outflow-Salinity Relationship at Martinez

The most important outflow-salinity relationship in the DSM2 model is the Martinez Boundary EC which was estimated (with a modified G-model formulation) from the CALSIM outflow values for each of the six BDCP cases. If a higher EC was estimated for the LLT cases (1.5 feet of sea-level rise) with the same Delta outflow, this would represent the assumed effect of sea-level rise on increasing EC at Martinez (because the San Francisco Bay depth was increased). The UnTRIM Bay-Delta model study for 2002 historical conditions estimated that the Martinez EC would increase by about 1,500 µS/cm (0.7 psu) for1.5 feet of sea-level rise for all Delta outflows observed during 2002. The DSM2 Martinez boundary EC values were therefore shifted by about 1,500 µS/cm for the full range of outflow. The DSM2 model results will indicate how this increased EC was tidally mixed upstream into the Delta.

Figure C.A-110 shows the monthly Martinez EC values (DSM2 monthly average EC) plotted against the monthly Delta outflow for the six BDCP cases. The Martinez EC ranged from about 30,000 µS/cm at the lowest Delta outflow of 3,000 cfs to about 1,000 µS/cm at an outflow of about 100,000 cfs. There is considerable scatter in this relationship because when the outflow was high in one month and is reduced in the next, the monthly EC will remain lower than expected for steady outflow. When the outflow was low and is increased, the monthly EC will remain higher than expected for steady outflow. The G-model formulation calculates the effective Delta outflow (i.e., a moving average) and estimates the steady state outflow-EC relationship as a negative exponential equation.

A two or three month moving average outflow is generally close to the effective Delta outflow. Figure C.A-111 shows the monthly Martinez EC values for the six cases as a function of the effective Delta outflow, calculated using a G-model averaging coefficient of 4,000 cfs/month. The DSM2 values for the Martinez EC are quite accurately described by the negative exponential equation (coefficients given in Table C.A-53) once the effective outflow is calculated. The DSM2 EC values are generally above the G-model curve and within 2,500 µS/cm of the G-model curve.

The main purpose for this comparison is to determine if the DSM2 model EC results for the ESO_LLT conditions (with sea-level rise and full tidal natural communities and transitional uplands restoration) showed any large changes in the outflow-salinity relationship when compared to the existing conditions simulations. Figure C.A-112 shows the DSM2 simulated Martinez EC for the two existing conditions EBC1 and EBC2. The monthly average EC follows the negative exponential estimate quite closely.

Figure C.A-113 shows the DSM2 simulated Martinez EC for EBC2_LLT and ESO_LLT. The EBC2_LLT includes the effects of 1.5 feet of sea-level rise, but no tidal restoration. The ESO_LLT included the effects of sea-level rise and full tidal natural communities and transitional uplands restoration. As anticipated from the previous UnTRIM modeling, the DSM2 Martinez EC values were generally about 2,500 µS/cm higher than the existing Martinez EC values at the same effective Delta outflow. For example, the existing conditions Martinez EC values are between 15,000 µS/cm and 17,500 µS/cm for an effective outflow of about 10,000 cfs. The LLT simulations indicate that the EC was increased to between 17,500 µS/cm and 20,000 µS/cm for the same effective outflow of about 10,000 cfs.

5C.A.7.4 DSM2 Simulated EC in Suisun Bay

Figure C.A-114 shows the monthly EC simulated with DSM2 at Martinez, Port Chicago, Chipps Island, and Collinsville for the EBC1 case for WY 1976–1991. The Martinez EC values fluctuated from

250 µS/cm at high outflow to 25,000 µS/cm at low outflow. Each year was similar, but the wet years had lower EC values for more months, and the EC values at Martinez did not approach the freshwater minimum EC of 250 µS/cm in every year. The EC at upstream stations was always lower than the Martinez EC, but the ratio between these EC values was reduced at higher outflows because the X2 location moves downstream past the upstream stations, shifting the relative positions of the upstream stations on the salinity gradient curve (Figure C.A-115). The highest EC values corresponded to the fall months with lowest outflow (about 3,000 cfs minimum outflow).

Figure C.A-116 shows the monthly EC simulated at Martinez, Port Chicago, Chipps Island, and Collinsville for the EBC2 case for WY 1976–1991. The EBC2 case included the Fall X2 requirements, so in about half of the years the EC was reduced in the months of September–November to maintain X2 at Collinsville or Chips Island. The Chipps Island EC of about 3,000 µS/cm indicates a wet year type, while Collinsville EC of about 3,000 µS/cm indicates an above normal year type. The monthly EC pattern for the remainder of the years was very similar to the EBC1 case. Figure C.A-116 shows the monthly EC values for the EBC2_ELT case, which included 0.5 feet of sea-level rise but no tidal natural communities and transitional uplands restoration. Figure C.A-117 shows the monthly EC values for the EBC2_LLT case which included 1.5 feet of sea-level rise but no tidal natural communities and transitional uplands restoration. The EBC2_ELT and EBC2-LLT cases were similar to the EBC2 case, although there were many months with slightly different Delta outflows calculated with CALSIM.

Figure C.A-118 shows the monthly EC values for the ESO_ELT case, which included 0.5 feet of sea-level rise and 25,000 acres of tidal natural communities and transitional uplands restoration. Figure C.A-119 shows the monthly EC values for the ESO_LLT case which included 1.5 feet of sea-level rise and the full tidal natural communities and transitional uplands restoration of 65,000 acres. Careful inspection of these six figures will reveal many small differences caused by the slightly different monthly CALSIM outflows used in the DSM2 modeling of each case. The differences in the fall months of those years without X2 requirements in the EBC1 case are most easily recognized; differences between the five cases with Fall X2 requirements are more difficult to identify. These graphs summarize the DSM2 simulations of the salinity intrusion into the Delta. The major factor controlling Delta salinity is always the effective Delta outflow. The average salinity values at each station for these six cases were very similar, because the basic sequence of Delta outflow was similar and was determined by the required Delta outflow and the Delta inflow variations from wet years to dry years. The largest differences in monthly EC values were seen between the EBC1 case, which did not have any Fall X2 requirements (higher outflow), and the three EBC2 cases and two ESO cases which did have Fall X2 requirements (lower outflow).

5C.A.7.5 DSM2 Simulated Salinity at Chipps Island

The combined effects of sea-level rise and tidal natural communities and transitional uplands restoration on Delta salinity were simulated to be relatively small compared to the salinity variations caused by changes in Delta outflow. The seawater intrusion effects can be identified by comparing the simulated outflow-salinity curve (G-model) at Chipps Island (75 km), which is the middle of three EC stations for regulated X2 (outflow). The outflow is regulated in the February–June period to maintain X2 at or downstream of Collinsville. Therefore, the Chipps Island EC is sometimes expected to be less than 3,000 µS/cm during these months (depending on runoff conditions).

Figure C.A-120 shows the monthly Chipps Island EC values for the six cases as a function of the monthly Delta outflow. There is considerable scatter in this relationship because the monthly outflow may not be the steady-state outflow for the salinity gradient if the outflow has changed substantially. Figure C.A-121 shows the monthly Chipps Island EC values for the six cases as a function of the effective Delta outflow, calculated using a G-model averaging coefficient of 4,000 cfs/month. The DSM2 values for the Chipps Island EC were well described by the negative exponential equation (coefficients given in Table C.A-53) with the effective outflow (calculated from the DSM2 monthly Martinez outflows). The DSM2 EC values were generally above the G-model curve, with a spread of about 2,500 µS/cm at the low-outflow end of the G-model curve. The Chipps Island EC was simulated to be less than 2,500 µS/cm with an outflow greater than 15,000 cfs. An outflow of 11,400 cfs is assumed to maintain X2 at Collinsville in D-1641.

Figure C.A-122 shows the DSM2-simulated Chipps Island EC for the two existing conditions EBC1 and EBC2. The monthly average EC follows the negative exponential estimate quite closely. Figure C.A-123 shows the DSM2-simulated Chipps Island EC for EBC2_LLT and ESO_LLT. The EBC2_LLT includes the effects of 1.5 feet of sea-level rise, but only limited tidal natural communities and transitional uplands restoration. The ESO_LLT includes the effects of sea-level rise and full tidal natural communities and transitional uplands restoration. As anticipated from the Martinez results, the DSM2 Chipps Island EC values were generally about 1,000–2,000 µS/cm higher than the existing Chipps Island EC values at the same effective Delta outflow. For example, the existing conditions Chipps Island EC values were about 4,000 µS/cm for an effective outflow of 10,000 cfs and about 2,000 µS/cm for an effective outflow of 15,000 cfs. Both of the LLT simulations indicate that the EC was increased (from sea-level rise) to between 5,000 µS/cm and 6,000 µS/cm for an effective outflow of 10,000 cfs and to between 2,500 µS/cm and 4,000 µS/cm for an effective outflow of 15,000 cfs.

5C.A.7.6 DSM2 Simulated Salinity at Collinsville

The seawater intrusion effects from sea-level rise and tidal natural communities and transitional uplands restoration can also be identified by comparing the simulated outflow-salinity curve (G-model) at Collinsville, which is the most upstream of the three EC stations for regulated X2 (outflow). The outflow is regulated in the February–June period to maintain X2 at or downstream of Collinsville. Therefore, the Collinsville EC is expected to be less than 3,000 µS/cm during these months.

Figure C.A-124 shows the monthly Collinsville EC values for the six cases as a function of the monthly Delta outflow. There is considerable scatter in this relationship because the monthly outflow may not be the steady-state outflow for the salinity gradient if the outflow has changed substantially. Figure C.A-125 shows the monthly Collinsville EC values for the six cases as a function of the effective Delta outflow, calculated using a G-model averaging coefficient of 4,000 cfs/month. The DSM2 values for the Collinsville EC were well described by the negative exponential equation (coefficients given in Table C.A-53) with the effective outflow (calculated). The DSM2 EC values were generally above the G-model curve but within 2,500 µS/cm of the curve. The Collinsville EC was simulated to be less than 2,500 µS/cm at an outflow of 10,000 cfs. An outflow of 7,100 cfs is assumed to maintain X2 at Collinsville in D-1641.

Figure C.A-126 shows the DSM2 simulated Collinsville EC for the two existing conditions EBC1 and EBC2. The monthly average EC follows the negative exponential estimate quite closely. Figure C.A-127 shows the DSM2 simulated Collinsville EC for EBC2_LLT and ESO_LLT. The EBC2_LLT includes the effects of 1.5 feet of sea-level rise, but only limited tidal natural communities and transitional uplands restoration. The ESO_LLT includes the effects of sea-level rise and full tidal natural communities and transitional uplands restoration. As anticipated from the Martinez results, the DSM2 Collinsville EC values were generally about 1,000–2,000 µS/cm higher than the existing Collinsville EC values at the same effective Delta outflow. For example, the existing conditions Collinsville EC values were between 3,000 µS/cm and 5,000 µS/cm for an effective outflow of about 7,500 cfs. Both of the LLT simulations indicate that the EC was increased (from sea-level rise) to between 4,000 µS/cm and 6,000 µS/cm for the same effective outflow of about 7,500 cfs.

5C.A.7.7 Effects of Increased Salinity on X2

The major effect of increased salinity in Suisun Bay caused by sea-level rise and tidal natural communities and transitional uplands restoration would be that the X2 location would be shifted upstream for a given effective Delta outflow, and that more outflow would be required to maintain the X2 at Chipps Island or Collinsville. Figure C.A-109 indicates that the salinity at Collinsville (81 km) or Chipps Island (75 km) is reduced by about 2,500 µS/cm for each 55% increase in outflow, which also moves X2 downstream about 5 km. The simulated increase in salinity (EC) at Chipps Island and Collinsville between the EBC cases and the LLT cases was generally between 1,000 µS/cm and 2,000 µS/cm for the same effective Delta outflow.

The shift in the outflow-EC relationship at Chipps Island can be identified by comparing the DSM2-simualted relationship for the existing conditions with the LLT cases. The DSM2-simulated salinity at Chipps Island for the existing conditions was about 3,000 µS/cm (assumed equivalent to X2) with an outflow of about 11,500 cfs (Figure C.A-122). The DSM2-simulated salinity at Chipps Island was increased to about 5,000 µS/cm with an outflow of 11,500 cfs for the ESO_LLT case (Figure C.A-123). The simulated Chipps Island EC was about 3,000 µS/cm with an outflow of about 16,000 cfs for the ESO_LLT case. Therefore, maintaining the X2 position at Chipps Island (75 km) would require about 3,500 cfs of additional outflow in the DSM2-simulated EBC2_LLT or ESO_LLT conditions. There was no large differences in the outflow-salinity relationship at Chipps Island for the EBC2_LLT and ESO_LLT cases, based on the DSM2 modeling results; the effects of tidal natural communities and transitional uplands restoration was not as great as the effects from sea-level rise.

The shift in the outflow-EC relationship at Collinsville can be identified by comparing the DSM2-simualted relationship for the existing conditions with the LLT cases. The DSM2-simulated salinity at Collinsville for the existing conditions was about 3,000 µS/cm (assumed equivalent to X2) with an outflow of about 8,500 cfs (Figure C.A-126). The DSM2-simulated salinity at Collinsville was increased to about 5,000 µS/cm with an outflow of 8,500 cfs for the ESO_LLT case (Figure C.A-127). The simulated Collinsville EC was about 3,000 µS/cm with an outflow of about 10,500 cfs for the ESO_LLT case. Therefore, maintaining the X2 position at Collinsville (81 km) would require about 2,000 cfs of additional outflow in the DSM2-simulated EBC2_LLT or ESO_LLT conditions. There was no large differences in the outflow-salinity relationship at Collinsville for the EBC2_LLT and ESO_LLT cases, based on the DSM2 modeling results; the effects of tidal natural communities and transitional uplands restoration was not as great as the effects from sea-level rise.

These simulated shifts in the outflow-X2 relationships are based on preliminary results from three different models (UnTRIM, RMA and DSM2) and are therefore subject to change. The previous UnTRIM and RMA Bay-Delta modeling results and the DSM2 modeling results for the BDCP cases suggest that the combined effects of sea-level rise and tidal natural communities and transitional uplands restoration in the LLT timeframe will cause the salinity gradient to move about 2–4 km upstream for the same effective outflow during periods of relatively low outflow (less than 10,000 cfs). Additional Delta outflow of about 2,000 cfs will likely be required to maintain the X2 position at Collinsville (81 km) and additional Delta outflow of about 3,500 cfs will likely be required to maintain the X2 position at Chipps Island (75 km).

Table C.A-53. Estimated X2 and Salinity (EC) at Delta Locations for Various Effective Delta Outflows

Negative Exponential Estimates derived from 1976–1991 Historical EC and Delta outflow

EC (µS/cm) = minimum (175) + constant x exp [factor x outflow (cfs)]

Delta Outflow	X2	Martinez	Port Chicago	Chipps Island	Collinsville	Antioch	Jersey Point	Emmaton	Rio Vista	Rock Slough
Constant		27,000	32,000	30,000	25,000	20,000	15,000	20,000	10,000	5,000
Factor		-0.00006	-0.00010	-0.00025	-0.00030	-0.00035	-0.00050	-0.00050	-0.00040	-0.00050
2,500	92.6	24,239	25,072	16,208	11,959	8,487	4,498	5,980	3,829	1,683
3,000	90.5	23,552	23,856	14,321	10,314	7,149	3,547	4,713	3,162	1,366
3,500	88.7	22,886	22,700	12,656	8,898	6,025	2,807	3,725	2,616	1,119
4,000	87.2	22,239	21,600	11,186	7,680	5,082	2,230	2,957	2,169	927
4,500	85.9	21,611	20,554	9,890	6,631	4,290	1,781	2,358	1,803	777
5,000	84.7	21,002	19,559	8,745	5,728	3,625	1,431	1,892	1,503	660
5,500	83.6	20,411	18,612	7,735	4,951	3,068	1,159	1,529	1,258	570
6,000	82.6	19,837	17,712	6,844	4,282	2,599	947	1,246	1,057	499
6,500	81.7	19,281	16,855	6,057	3,707	2,206	782	1,025	893	444
7,000	80.8	18,740	16,041	5,363	3,211	1,876	653	854	758	401
7,500	80.0	18,216	15,266	4,751	2,785	1,599	553	720	648	368
8,000	79.3	17,707	14,529	4,210	2,418	1,366	475	616	558	342
8,500	78.6	17,213	13,827	3,733	2,102	1,171	414	535	484	321
9,000	78.0	16,734	13,160	3,312	1,830	1,007	367	472	423	306
9,500	77.3	16,269	12,526	2,940	1,596	869	330	423	374	293
10,000	76.8	15,818	11,922	2,613	1,395	754	301	385	333	284
10,500	76.2	15,380	11,348	2,323	1,221	657	279	355	300	276
11,000	75.7	14,955	10,802	2,068	1,072	576	261	332	273	270
11,500	75.2	14,543	10,282	1,842	944	507	248	314	251	266
12,000	74.7	14,142	9,788	1,644	833	450	237	300	232	262
12,500	74.2	13,754	9,318	1,468	738	402	229	289	217	260

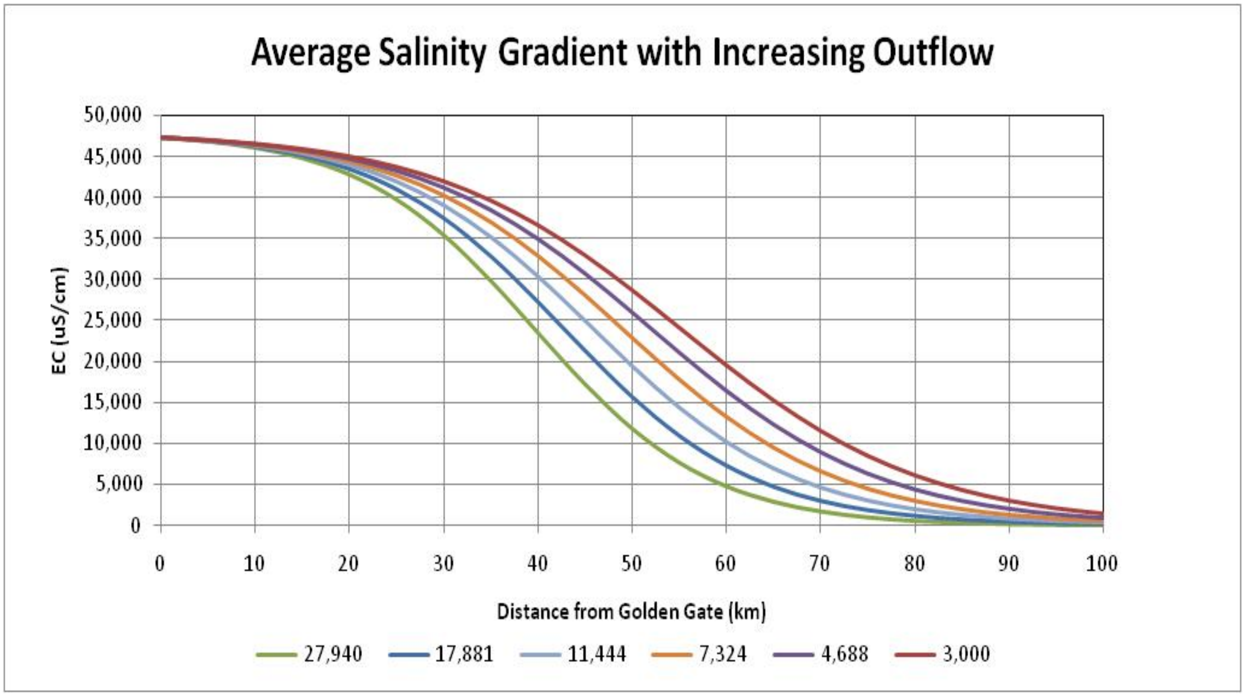


Figure C.A-108. Calculated EC Gradient in the SF Estuary between Golden Gate (0 km) and Rio Vista (100 km) with Increasing Delta Outflow

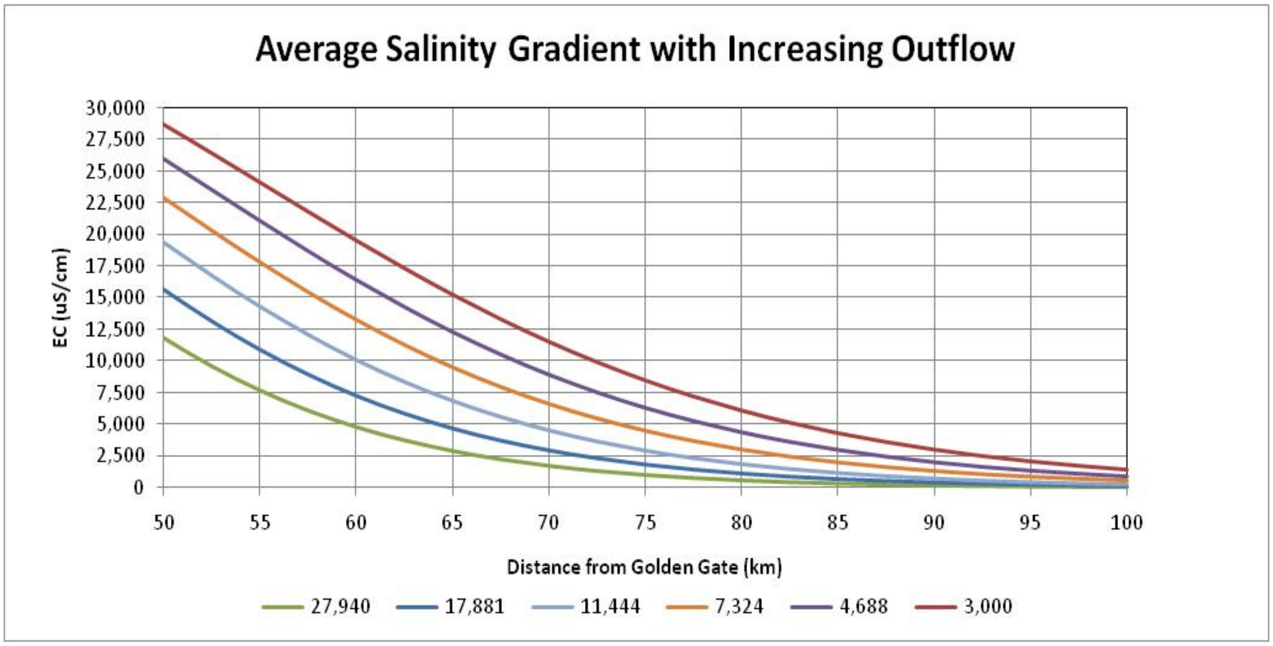


Figure C.A-109. Calculated EC Gradient in Suisun Bay and the Delta between Martinez (55 km) and Rio Vista (100 km) with Increasing Delta Outflow

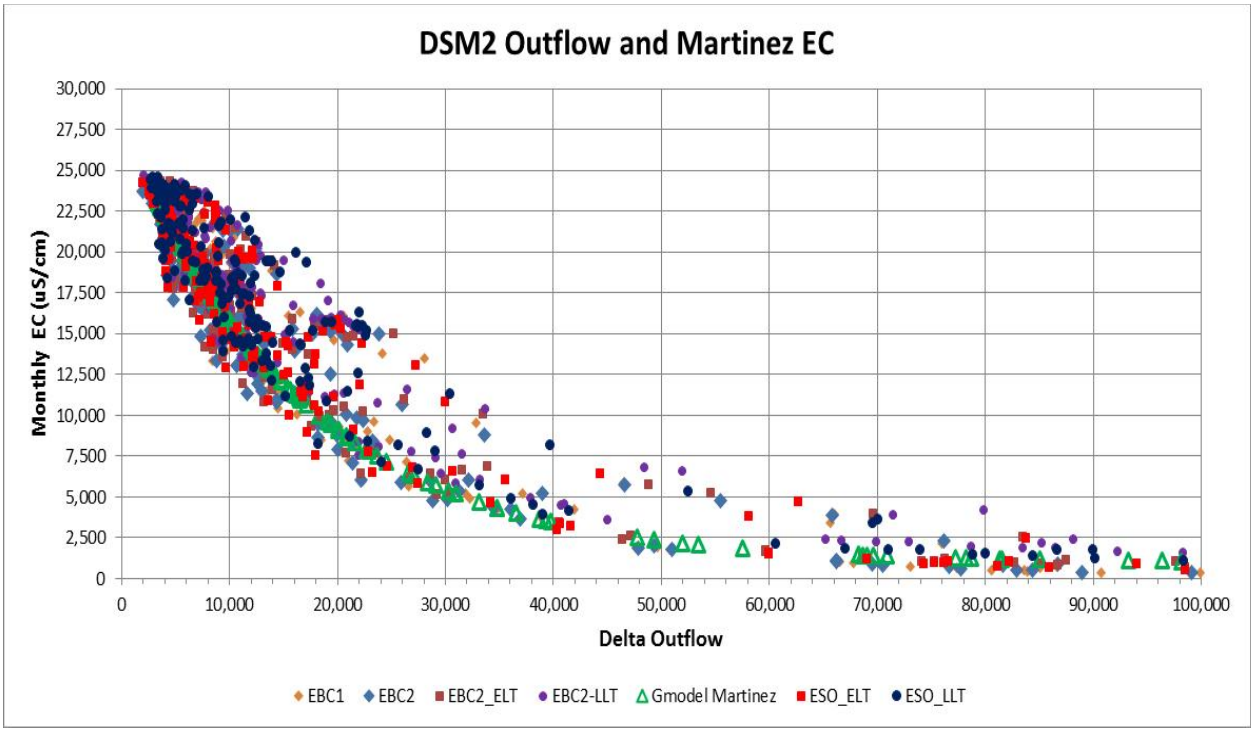


Figure C.A-110. Monthly Average EC at Martinez for the Six BDCP Cases as a Function of Monthly Delta Outflow for WY 1976–1991

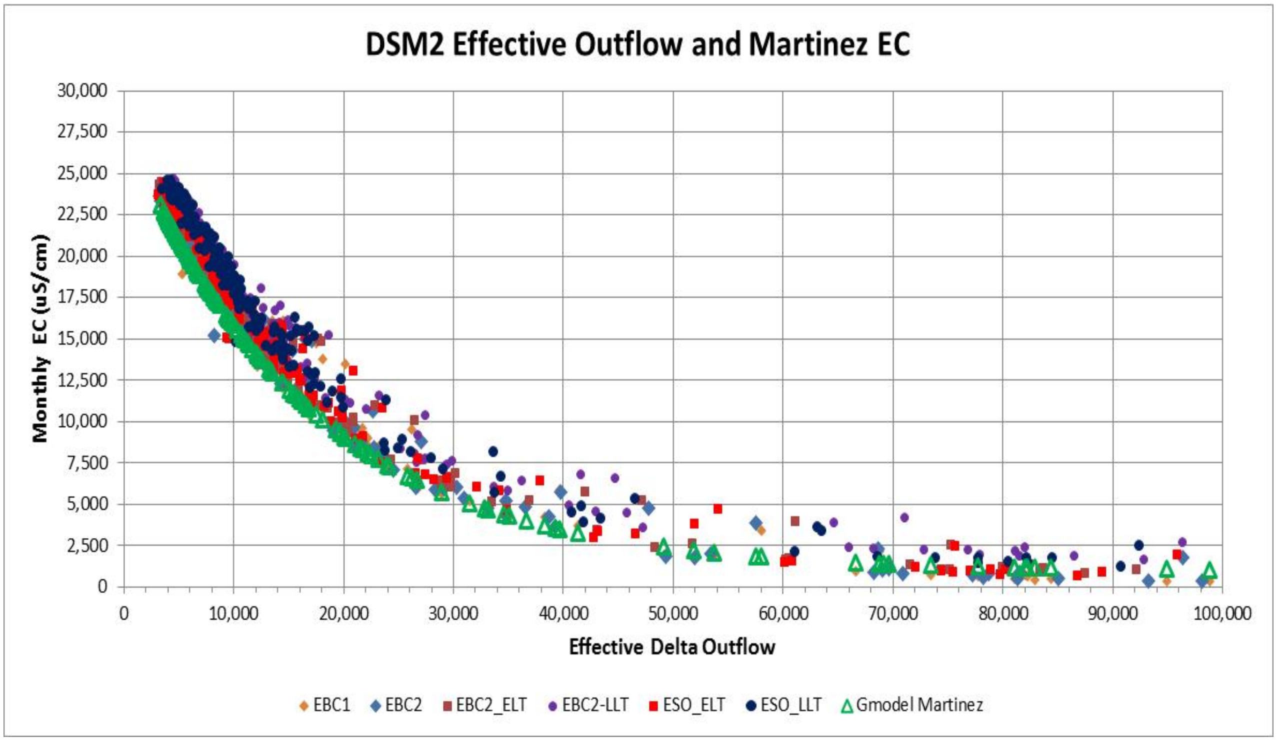


Figure C.A-111. Monthly Average EC at Martinez for the Six BDCP Cases as a Function of Effective Delta Outflow (G-model) for WY 1976–1991

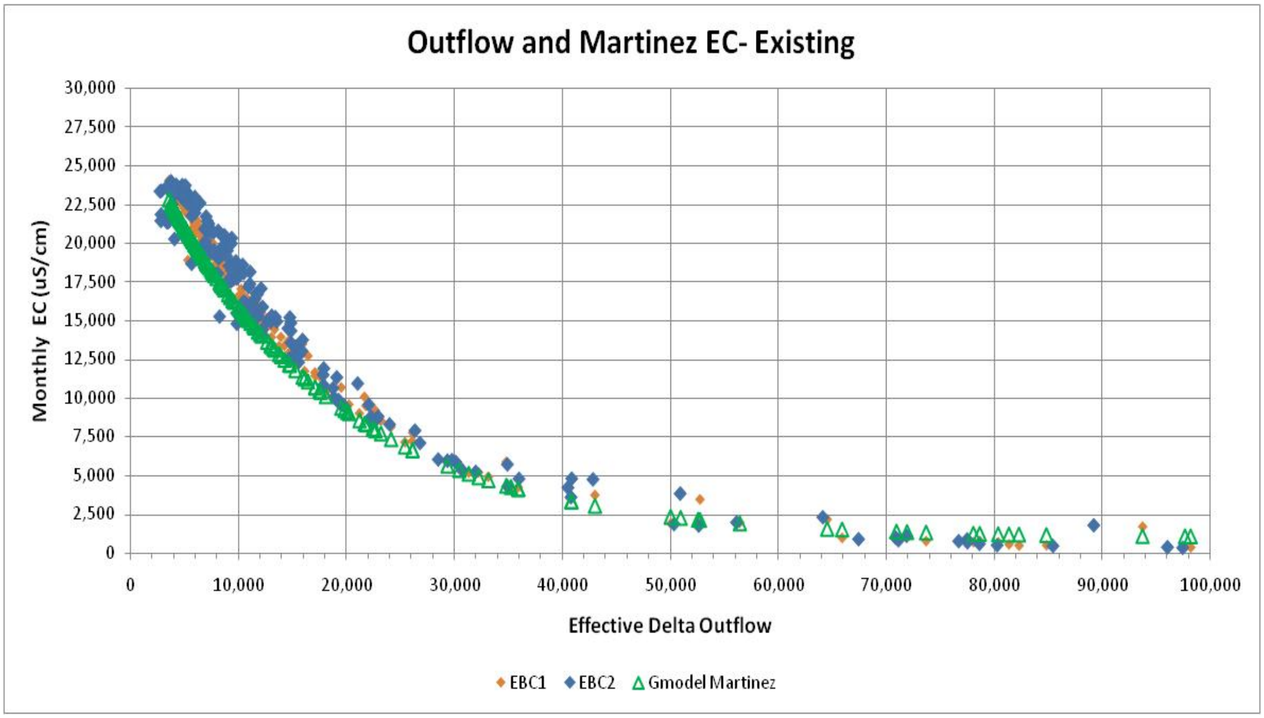


Figure C.A-112. Monthly EC at Martinez for the Existing Conditions Cases (EBC1 and EBC2) as a Function of Effective Delta Outflow for WY 1976–1991

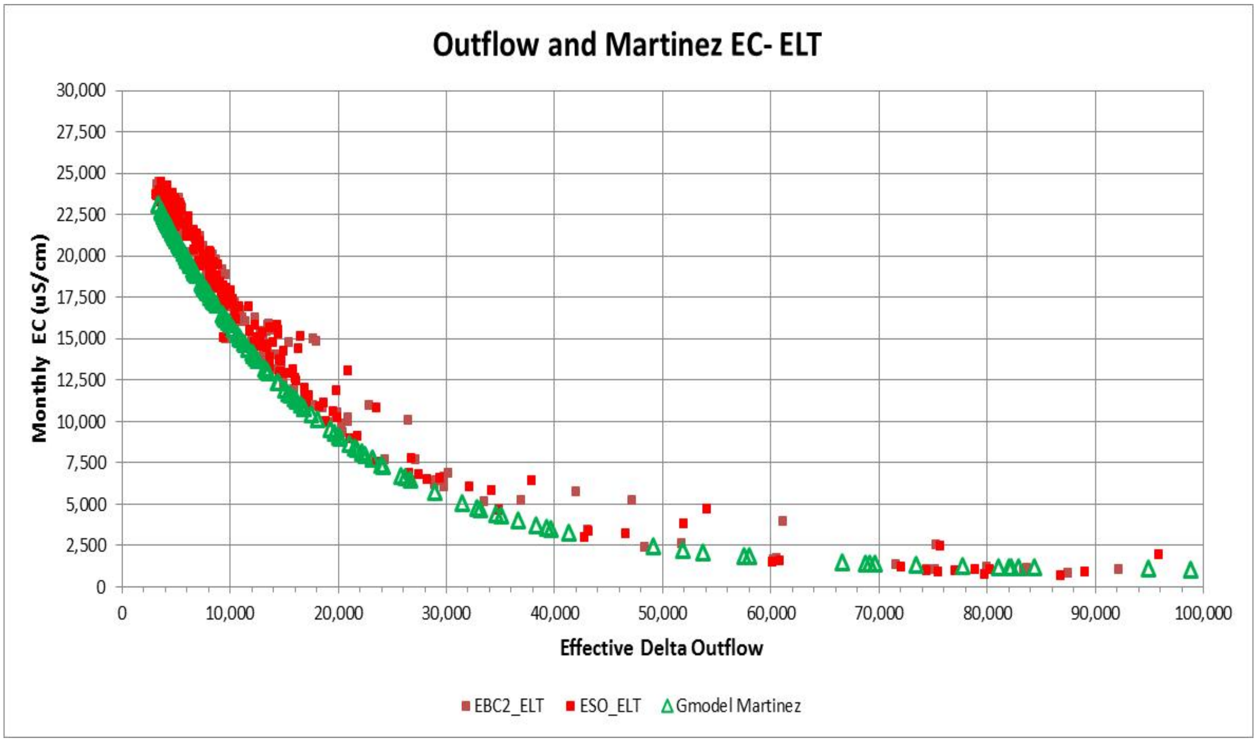


Figure C.A-113. Monthly EC at Martinez for the LLT Cases (EBC2_LLT and ESO_LLT) as a Function of Effective Delta Outflow for WY 1976–1991

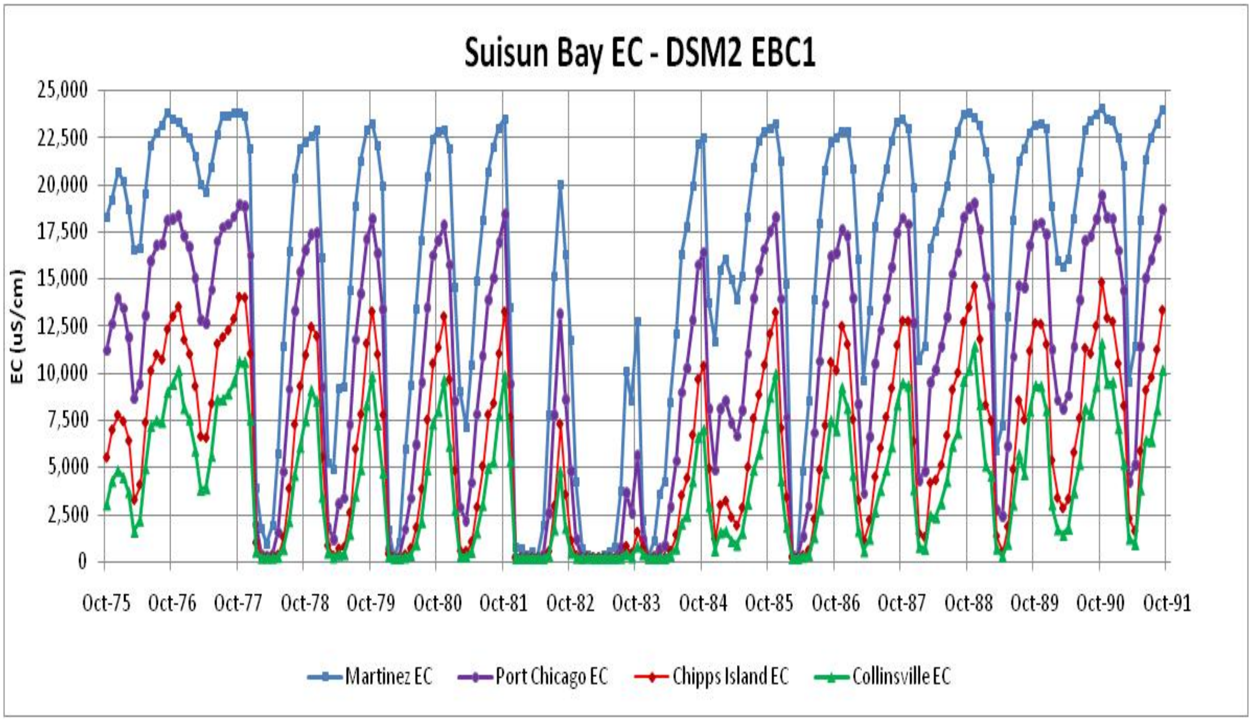


Figure C.A-114. DSM2-Simulated Monthly EC in Suisun Bay for the EBC1 Case for WY 1976–1991

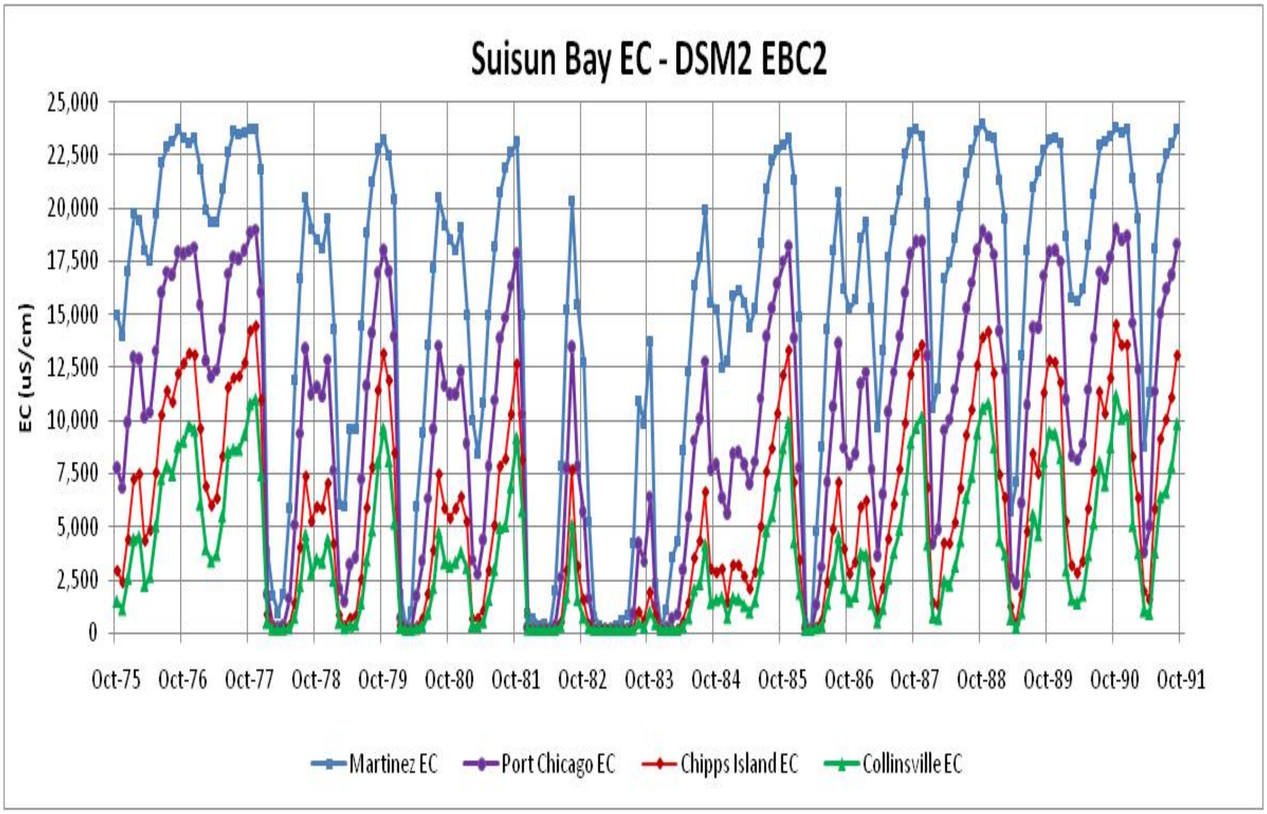


Figure C.A-115. DSM2-Simualted Monthly EC in Suisun Bay for the EBC2 Case for WY 1976–1991

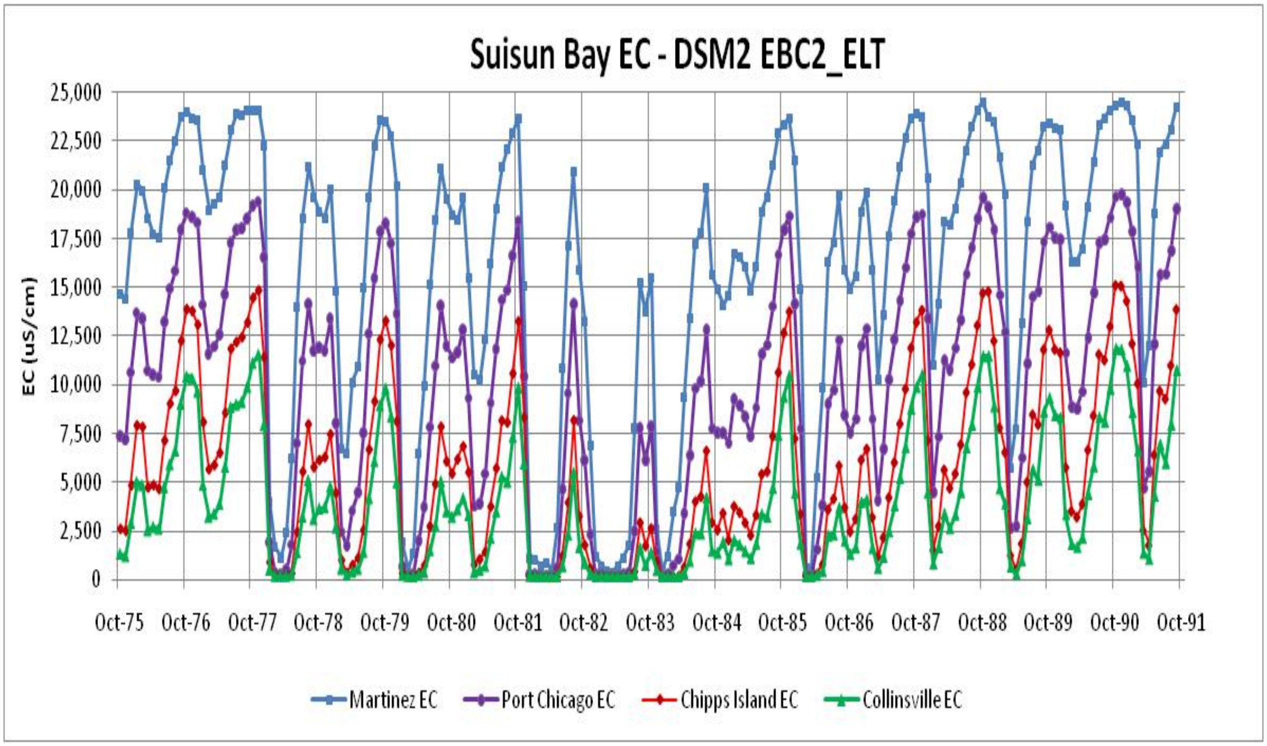


Figure C.A-116. DSM2-Simulated Monthly EC in Suisun Bay for the EBC2_ELT Case for WY 1976–1991

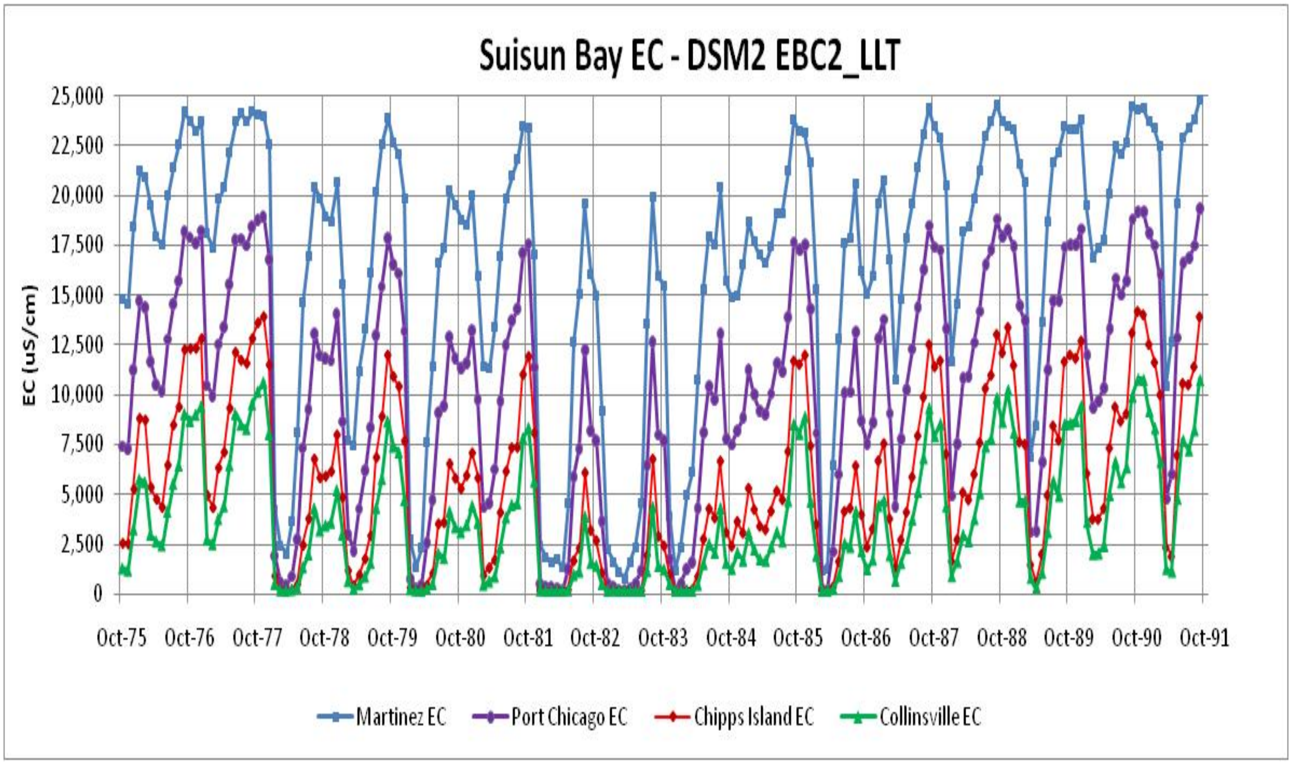


Figure C.A-117. DSM2-Simulated Monthly EC in Suisun Bay for the EBC2_LLT Case for WY 1976–1991

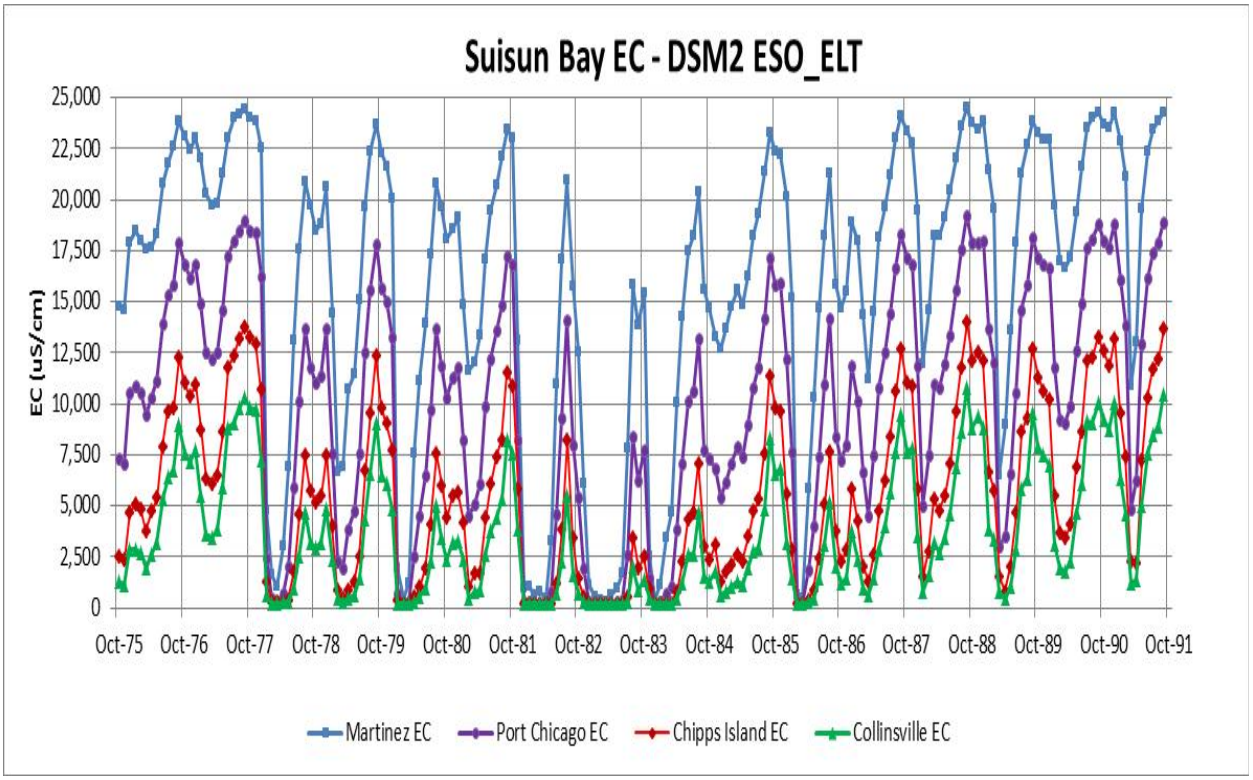


Figure C.A-118. DSM2-Simualted Monthly EC in Suisun Bay for the EBC2_LLT Case for WY 1976–1991

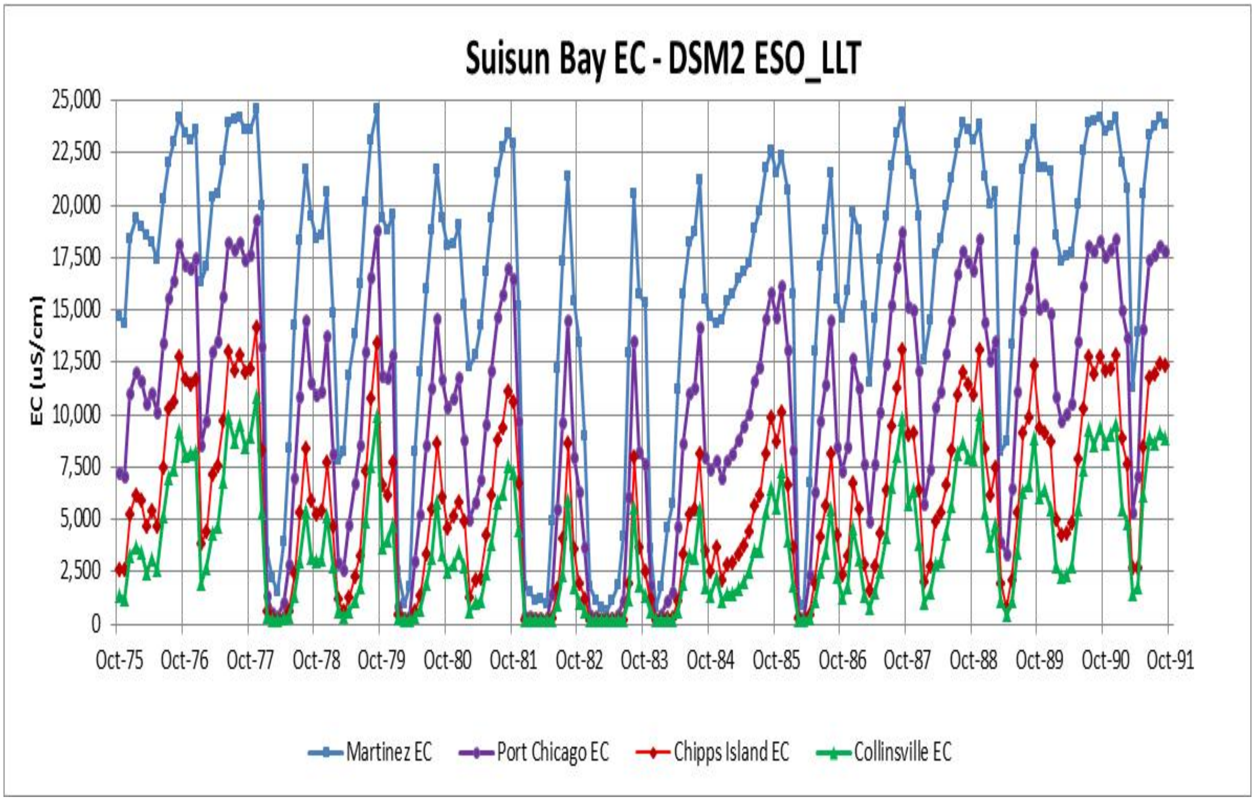


Figure C.A-119. DSM2-Simulated Monthly EC in Suisun Bay for the EBC2_LLT Case for WY 1976–1991

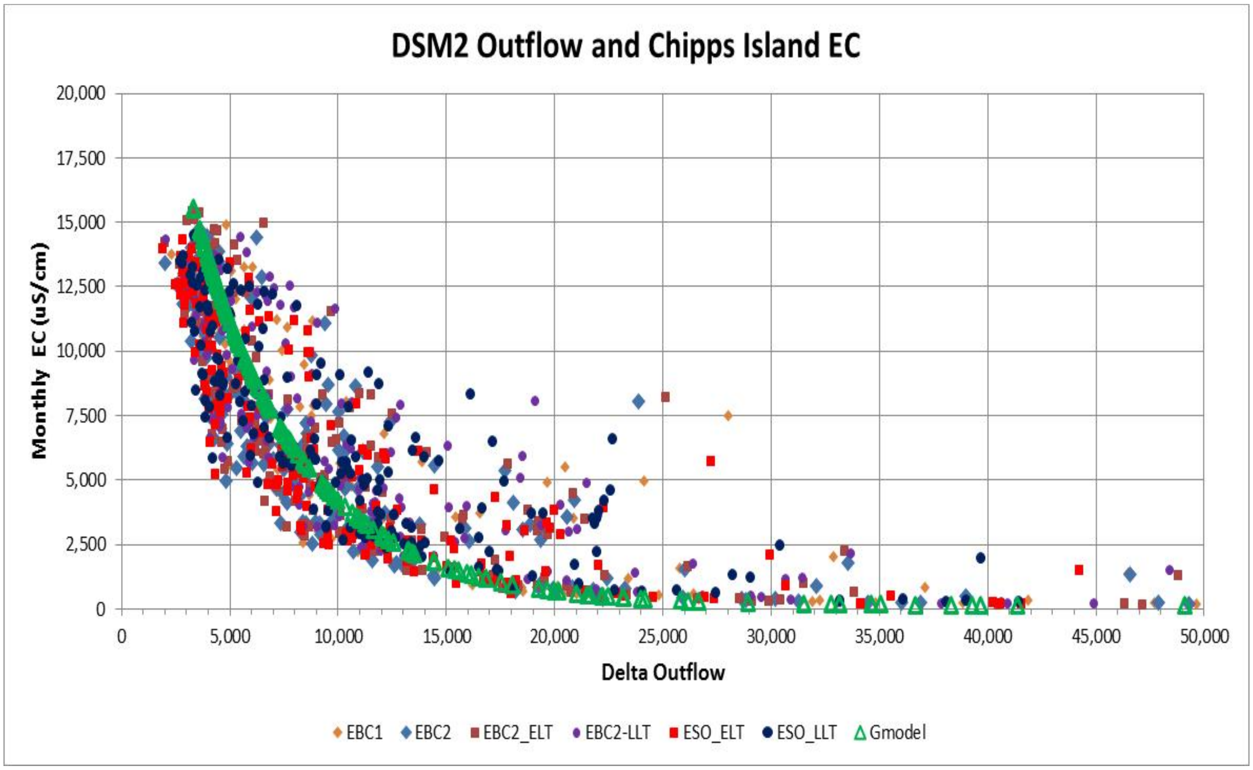


Figure C.A-120. Monthly Average EC at Chipps Island for the Six BDCP Cases as a Function of Monthly Delta Outflow for WY 1976–1991

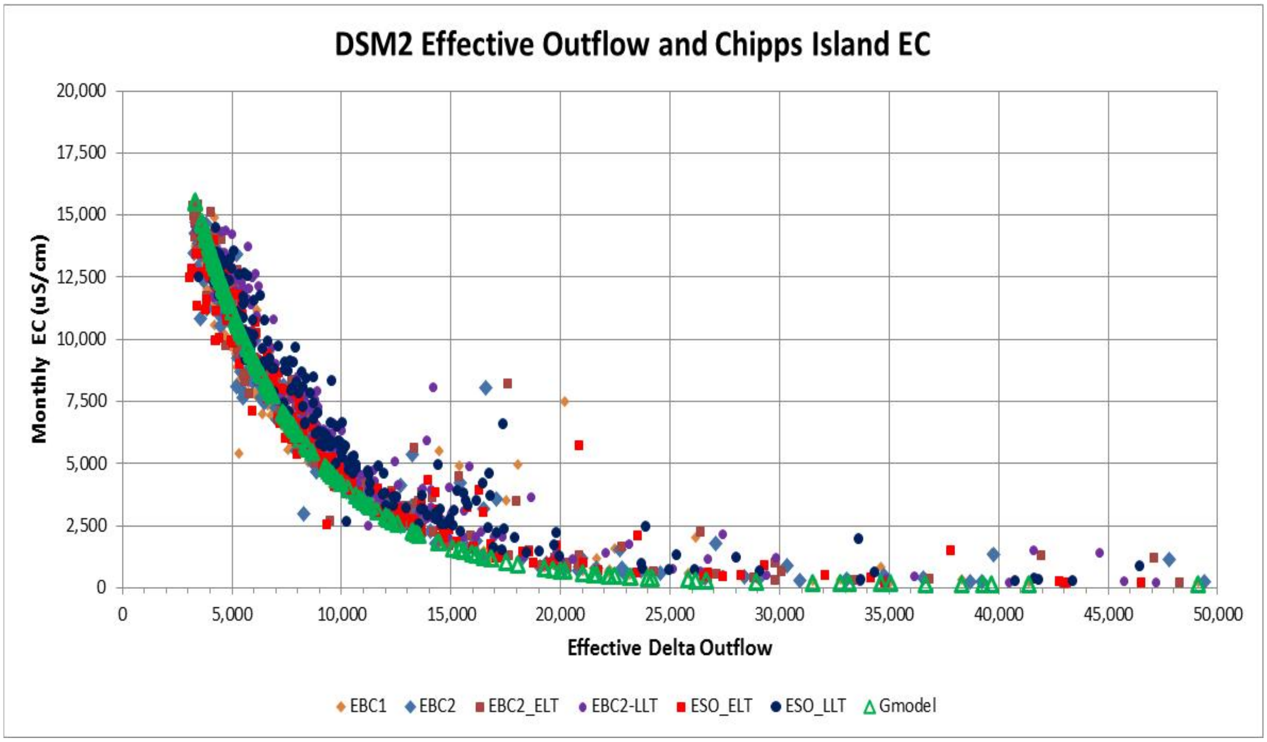


Figure C.A-121. Monthly Average EC at Chipps Island for the Six BDCP Cases as a Function of Effective Delta Outflow (G-model) for WY 1976–1991

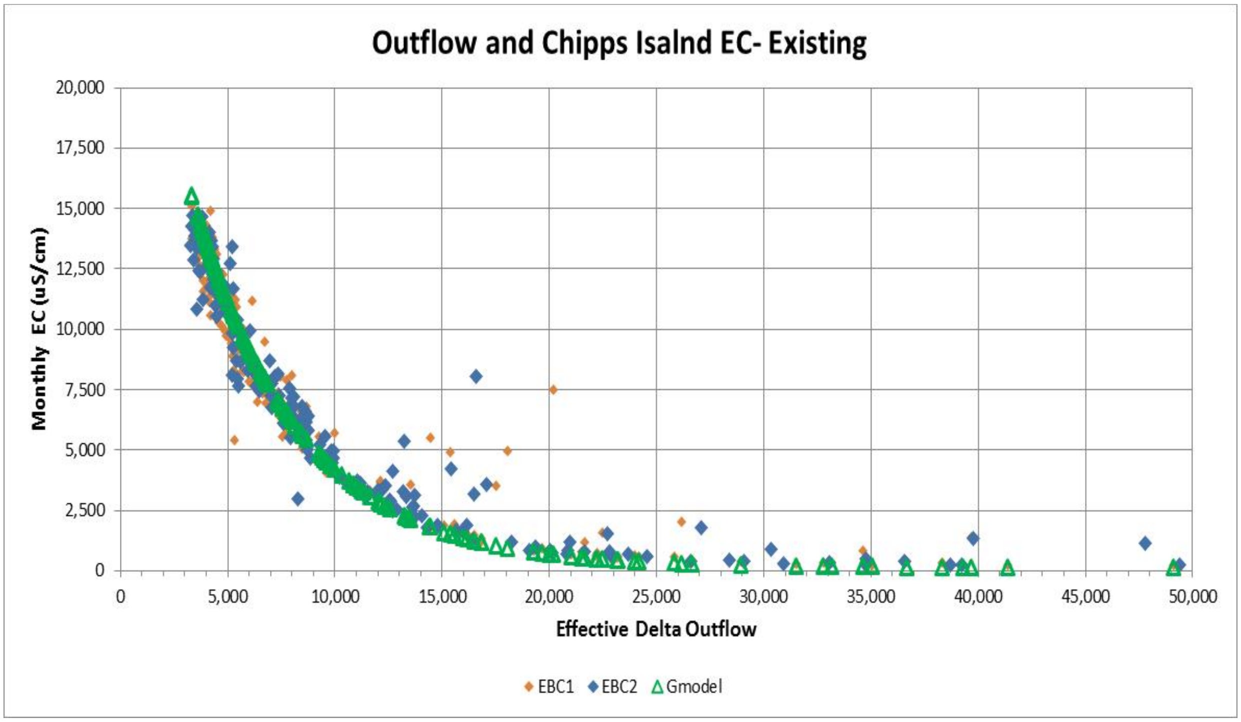


Figure C.A-122. Monthly Average EC at Chipps Island for the Existing Conditions Cases (EBC1 and EBC2) as a Function of Effective Delta Outflow for WY 1976–1991

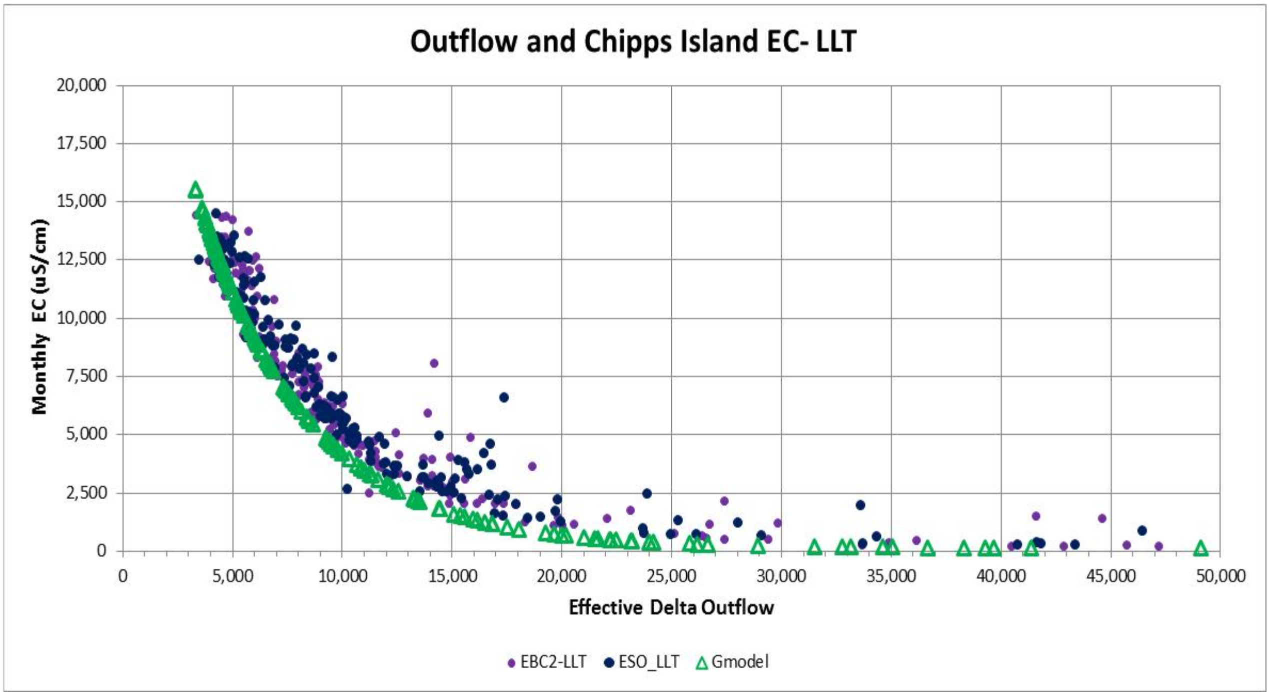


Figure C.A-123. Monthly Average EC at Chipps Island for the LLT Cases (EBC2_LLT and ESO_LLT) as a Function of Effective Delta Outflow for WY 1976–1991

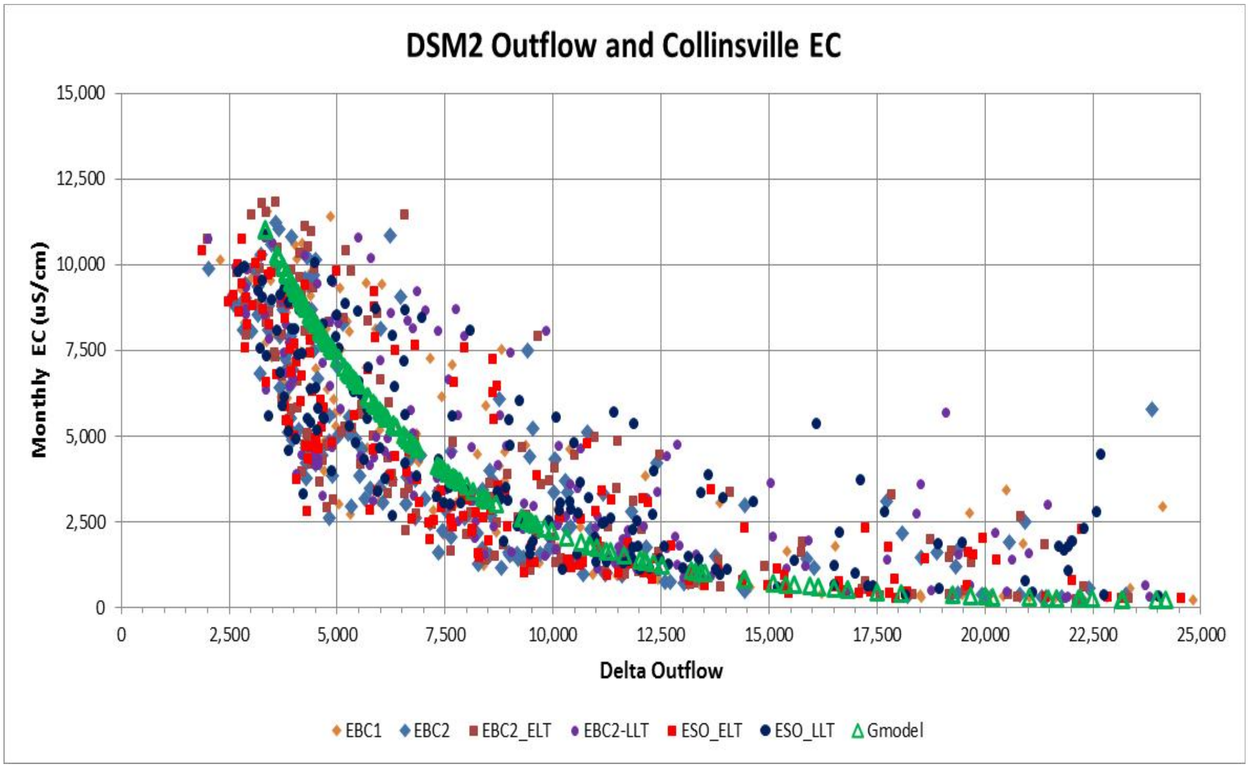


Figure C.A-124. Monthly Average EC at Collinsville for the Six BDCP Cases as a Function of Monthly Delta Outflow for WY 1976–1991

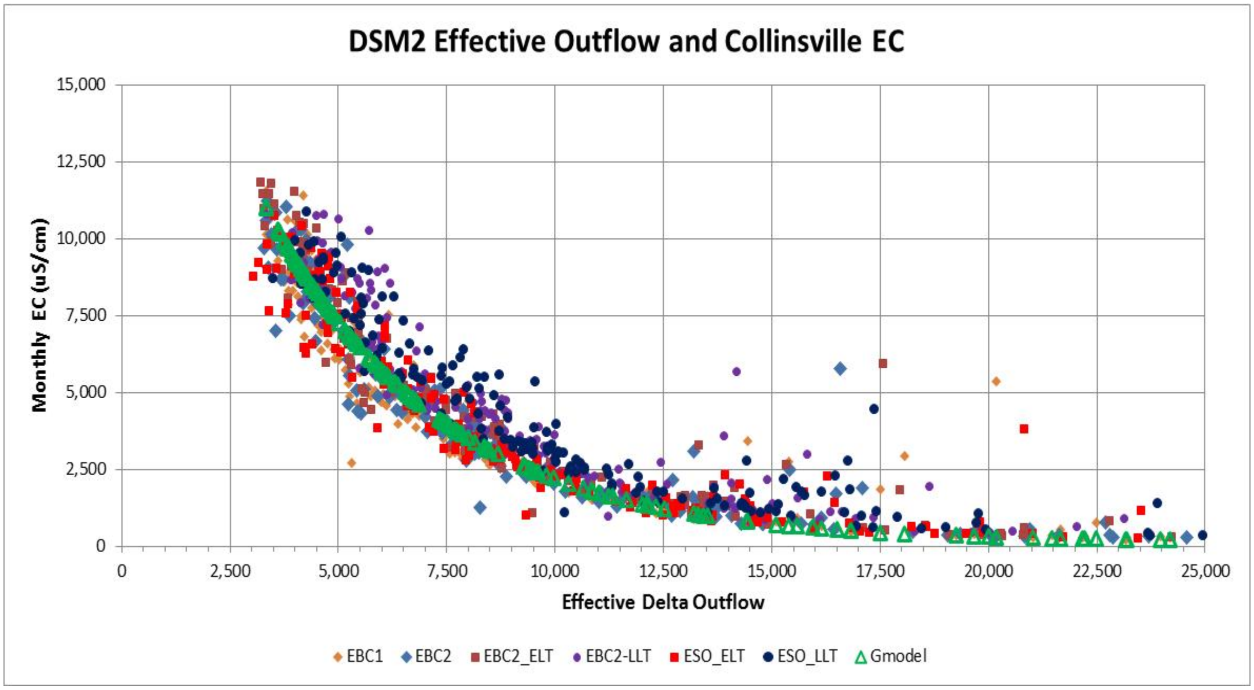


Figure C.A-125. Monthly Average EC at Collinsville for the Six BDCP Cases as a Function of Effective Delta Outflow (G-model) for WY 1976–1991

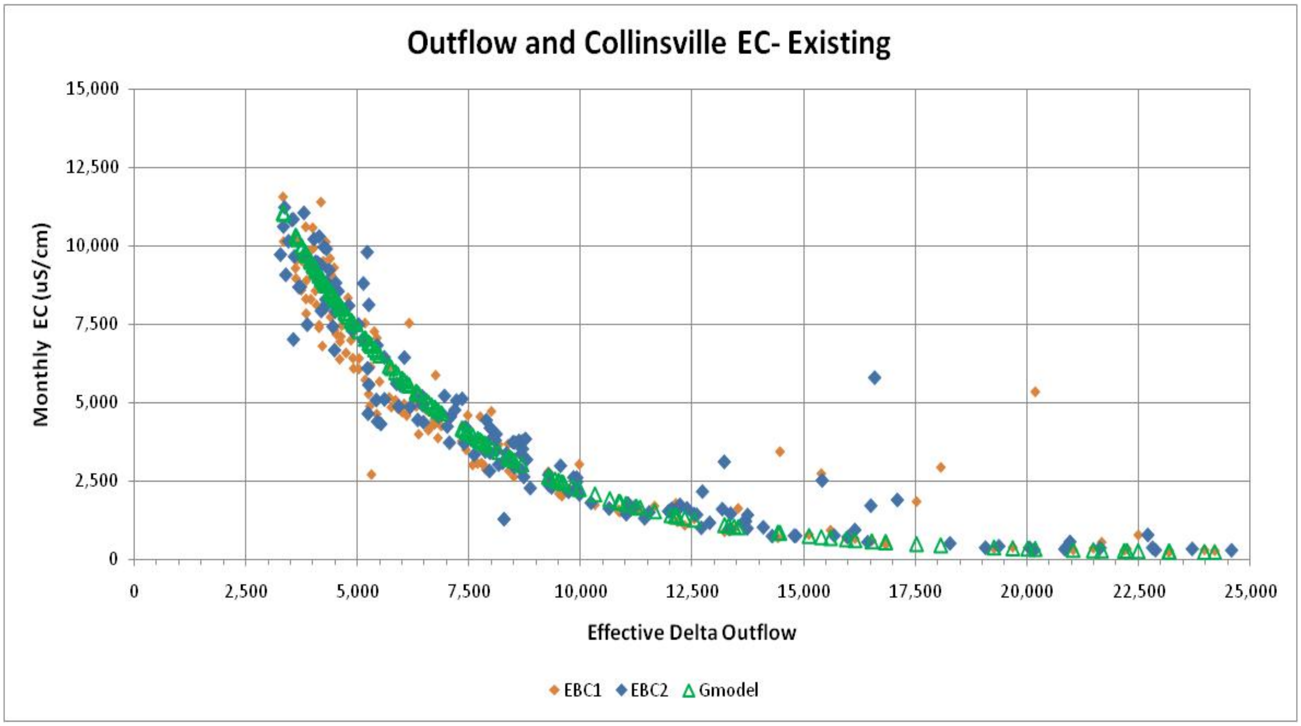


Figure C.A-126. Monthly EC at Collinsville for the Existing Conditions Cases (EBC1 and EBC2) as a Function of Effective Delta Outflow for WY 1976–1991

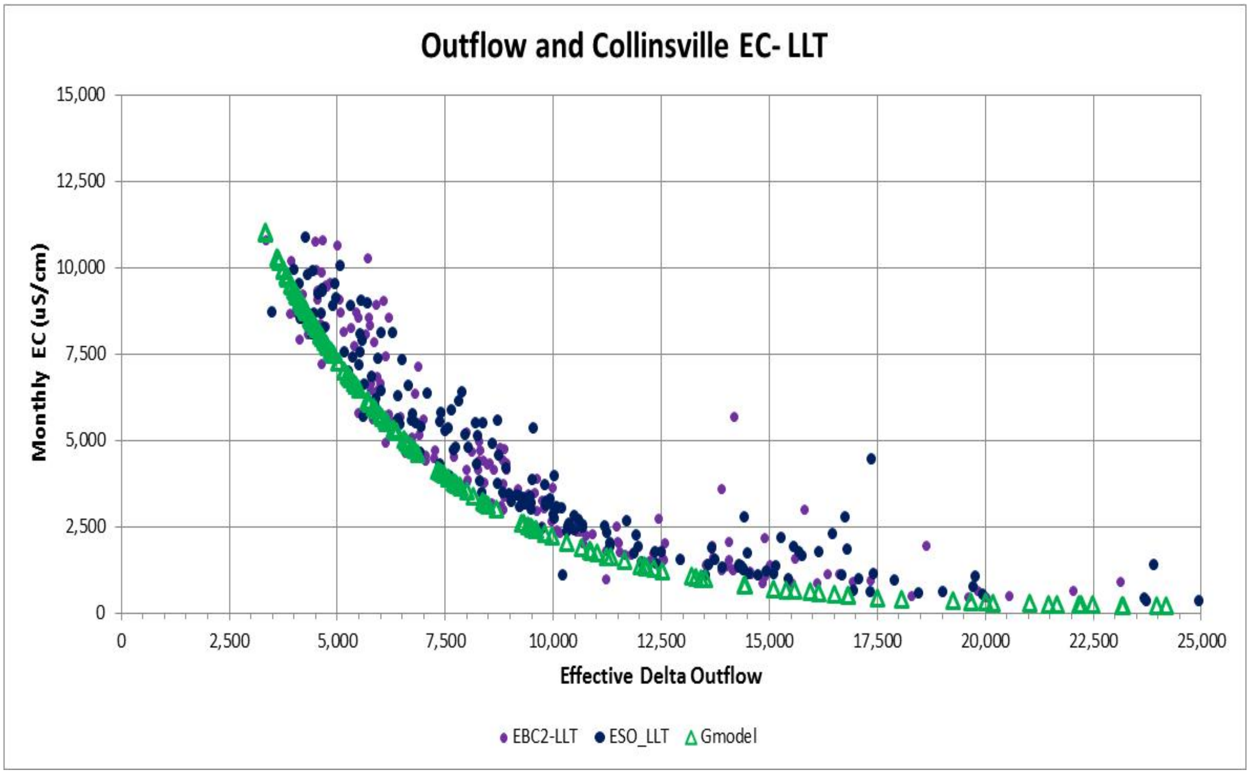


Figure C.A-127. Monthly EC at Collinsville for the LLT Cases (EBC2_LLT and ESO_LLT) as a Function of Effective Delta Outflow for WY 1976–1991

5C.A.8 DSM2 Source Tracking Results

The Delta Inflow source-tracking analysis uses results from DSM2-QUAL to track the six Delta inflows as conservative (no sources or sinks) concentrations. The six Delta inflows are:

1. Sacramento River Inflow (Freeport)
2. Yolo Bypass Inflow (Cache Slough)
3. San Joaquin River Inflow (Vernalis)
4. Cosumnes and Mokelumne and Calaveras Rivers (Eastside)
5. Delta Runoff and Agricultural Drainage (Drains)
6. Martinez Boundary Water (flood tide) Inflow

Each of the six Delta inflows is tracked with a separate “source concentration” variable. Each inflow has a separate constant source concentration of 100. The inflow source concentration will be reduced if the inflow is diluted or diverted within the Delta channels. As the inflow water mixes with other water in the Delta, the inflow source concentration is reduced (diluted). If water is removed in agricultural diversions or exports, the concentration of water from each source also is removed, reducing the downstream source concentrations.

5C.A.8.1 San Joaquin River Inflow

The San Joaquin River inflow provides a good example of this downstream source tracking through the Delta. Figure C.A-128 shows the CALSIM-simulated monthly San Joaquin River flow at Vernalis. The monthly San Joaquin River flows for the six cases were very similar, with some differences simulated by CALSIM for the ELT and the LLT cases. This inflow was tracked at several locations in the Delta to understand how the San Joaquin River inflow was distributed. The first channel diversion for the San Joaquin River inflow is at the head of Old River near Mossdale. About half the San Joaquin River flow is diverted into Old River and about half continues to Brandt Bridge and Stockton.

Figure C.A-129 shows the monthly percentage of the water at Brandt Bridge from the San Joaquin River inflow at Vernalis for the six cases. Usually the San Joaquin River inflow contributes 100% of the water at Brandt Bridge, but there are some summer months of dry years when the agricultural drainage contributes the “missing” 20–40% of the water that is not San Joaquin River inflow.

Figure C.A-130 shows the monthly percentage of the water at Stockton from the San Joaquin River inflow at Vernalis for the six cases. The San Joaquin River inflow often contributes 100% of the water at Stockton, but during the summer months of dry years the San Joaquin River contribution was reduced to less than 50% and the contribution from agricultural drainage, eastside streams, or the Sacramento River increases. As the San Joaquin River flow at Stockton decreases, tidal mixing of Sacramento River water upstream from Turner Cut can contribute a small percentage of the water upstream at Stockton. The ESO cases show more San Joaquin River water at Stockton in the spring monthly because the head of Old River barrier was simulated to reduce the Old River diversions from about 50% of the San Joaquin River flow to about 25% of the flow, allowing more of the San Joaquin River water to reach Stockton.

Figure C.A-131 shows the San Joaquin River inflow contribution downstream of Turner Cut for the six cases. Because Sacramento River water that is diverted at the DCC or Georgiana Slough often moves upstream in the San Joaquin River between the Mokelumne River mouth and Turner Cut, the San Joaquin River inflow contribution was reduced to about 50% in many months. Only when the San Joaquin River flow is much higher than exports in high-flow months does the San Joaquin River inflow contribution to water downstream of Turner Cut remain greater than 90%. The ESO cases show higher San Joaquin River contributions because more of the San Joaquin River water reached Stockton and because the south Delta pumping was reduced by the north Delta intakes, allowing more of the San Joaquin River water to reach Turner Cut and other downstream San Joaquin River locations.

Figure C.A-132 shows the San Joaquin River inflow contribution at Prisoners Point, just upstream of the Mokelumne River mouth. Almost all of the San Joaquin River inflow water has been diverted into Middle River through Columbia Cut or at the mouth of Middle River and does not reach Prisoners Point, unless the San Joaquin River inflow is very high. Figure C.A-133 shows the San Joaquin River inflow contribution at San Andreas Landing, downstream of the Mokelumne mouth. During most months, the Sacramento River water diverted to the Mokelumne River overwhelms the San Joaquin River inflow contribution. The maximum San Joaquin River inflow contribution was about 40% in a few high-inflow months (e.g., 1978, 1986). Figure C.A-134 shows the San Joaquin River inflow contribution at Jersey Point, just downstream of False River. The San Joaquin River inflow contributions are higher than they were at San Andreas Landing because during these high flow months, much of the San Joaquin River inflow diverted into Old River near Mossdale has moved past the CVP and SWP exports and is flowing through Franks Tract and False River to rejoin the San Joaquin River at Jersey Point. The peak San Joaquin River inflow contributions were about 60% in the highest San Joaquin River inflow months.

Figure C.A-135 shows the San Joaquin River inflow contribution at Chipps Island, downstream of the San Joaquin River confluence with the Sacramento River. The San Joaquin River inflow contributions were reduced further by the fraction of the Delta outflow from the Sacramento River and other inflow sources. The maximum San Joaquin River contribution at Chipps Island was about 20–30% in the months with highest San Joaquin River inflows compared to the other inflows. Most of the San Joaquin River inflow was diverted at the CVP and SWP south Delta pumping plants, and only in a few months does San Joaquin River inflow make it to Chipps Island and Suisun Bay. Most of the water at Chipps Island, however, is from the Sacramento and Yolo Bypass inflows. The ESO cases had slightly increased San Joaquin River inflow contributions at Chipps Island because the south Delta pumping would be reduced, allowing more of the San Joaquin River inflow to reach Chipps Island. In the few months when San Joaquin River inflow made it to Chipps Island, the maximum San Joaquin River inflow contributions at Chipps Island for the ESO_ELT and ESO_LLT cases were about 40%. In these months of high San Joaquin River inflow, a greater fraction of the San Joaquin River will make it to Suisun Bay.

The source tracking of the San Joaquin River inflow can be used to determine how much of the monthly San Joaquin River flow makes it to Chipps Island. For this evaluation, the Chipps Island outflow is multiplied by the San Joaquin River contribution (%) to calculate the outflow (cfs) from the San Joaquin River. This San Joaquin River outflow is compared to the San Joaquin River inflow to estimate the fraction of the San Joaquin River inflow that was transported to Chipps Island. The fraction of the monthly San Joaquin River inflow that was exported can be calculated in a similar way. The fraction of the San Joaquin River inflow being pumped at Banks is estimated by multiplying the San Joaquin River contribution (%) times the Banks pumping. Figure C.A-136 shows the San

Joaquin River inflow contributions entering CCF and being exported at the Banks pumping plant. There is a wide range of San Joaquin River contributions at CCF, from less than 10% (during months with low San Joaquin River inflow) to almost 100% (during months with high San Joaquin River inflow or low Banks pumping). Figure C.A-137 shows the San Joaquin River inflow contribution at the Jones pumping plant and the DMC. There is always more of a San Joaquin River contribution at the CVP Jones pumping plant because the San Joaquin River water diverted into Old River and Grant Line Canal will preferentially enter the Jones pumping plant and will enter CCF only if there is additional San Joaquin River water. About half of the San Joaquin River inflow will flow past Stockton and then be diverted into Turner Cut or into Columbia Cut and the mouth of Middle River and then flow upstream in Middle River to the export pumps. This water from Middle River will preferentially enter CCF and the Banks pumping plant.

Only when the San Joaquin River inflow is greater than the combined south Delta export pumping will any San Joaquin River inflow move out of the south Delta channels and flow past Chipps Island to Suisun Bay. Figure C.A-138 shows the San Joaquin River inflow and the DSM2-simulated (i.e., source tracking) fraction of the San Joaquin River at the combined exports for EBC2 case for 1976–1991. The calculated San Joaquin River inflow at the combined exports (i.e., minimum of San Joaquin River flow and exports) is shown for comparison. The DSM2 model source tracking indicates that some of the San Joaquin River flow is not reaching the exports and presumably is being diverted by the agricultural diversions. Figure C.A-139 shows the San Joaquin River inflow and the DSM2-simulated fraction of the San Joaquin River at Chipps Island for the EBC2 case for 1976–1991. The calculated San Joaquin River inflow at Chipps Island (i.e., Delta outflow) is shown for comparison. The simple calculation (i.e., San Joaquin River inflow-exports) slightly overestimates the San Joaquin River inflow reaching Chipps Island. The San Joaquin River inflow can be simply divided between the south Delta exports and Delta outflow, with some portion of the San Joaquin River inflow diverted during the summer period of high agricultural diversions.

5C.A.8.2 Martinez Boundary Water Tracking

The water and salt that enter Suisun Bay at the Martinez Boundary (during flood tide reverse flows) also were tracked by the DSM2 model. Figure C.A-140 shows the monthly Delta outflow and the San Joaquin River inflow contribution at Martinez for the EBC2 case for WY 1976–1991. Outflow is less than 25,000 cfs in most months. Figure C.A-141 shows the DSM2-simulated contribution of water from the Martinez boundary (54 km) at Port Chicago (64 km) for the WY 1976–1991. The average Martinez water contribution is about 80–85% during months with low outflow (5,000 cfs). Comparison of the two figures indicates that an outflow of 50,000 cfs reduced the Martinez contribution to about 20%, an outflow of 100,000 cfs reduced the Martinez contribution to about 10%, and an outflow of 150,000 cfs reduced the Martinez contribution to about 0% at Port Chicago. The Martinez boundary water carries the Martinez salinity with it; the percentage of Martinez water at upstream Delta locations reflects the seawater intrusion effects caused by tidal mixing. During months with low outflow, the Port Chicago EC should be about 80% of the Martinez boundary EC. Figure C.A-142 shows the DSM2-simulated EC at Martinez and Port Chicago. The maximum monthly average Martinez EC was greater than 22,500 µS/cm, and the maximum monthly average Port Chicago EC was above 17,500 µS/cm (80% of the Martinez EC). Figure C.A-142 shows that an outflow of about 75,000 cfs would reduce the Martinez EC and the Port Chicago EC to less than 200 µS/cm (the assumed Sacramento River EC was 175 µS/cm).

Figure C.A-143 shows the DSM2-simulated contribution of water from the Martinez boundary (56 km) at Collinsville (81 km) for the WY 1976–1991. The maximum Martinez water contribution was about 50%, suggesting that the Collinsville EC would be about 50% of the Martinez EC. The maximum Martinez water contribution at Chipps Island (not shown) was about 65%. The simulated Martinez contributions are reduced at higher outflows. Figure C.A-144 shows the DSM2-simulated EC at Chipps Island and Collinsville. The maximum monthly average Chipps Island EC was about 15,000 µS/cm (65% of maximum Martinez EC) and the maximum average Collinsville EC was about 10,000 µS/cm (40% of maximum Martinez EC). The maximum Martinez water contribution at Emmaton was about 15%, and the maximum Martinez water contribution at Jersey Point was about 10% (not shown) during months with low Delta outflow. Figure C.A-145 shows the DSM2-simulated EC at Emmaton and Collinsville. The maximum monthly average Emmaton EC was about 3,500 µS/cm (15% of maximum Martinez EC) and the maximum average Jersey Point EC was about 2,500 µS/cm (10% of maximum Martinez EC). These figures demonstrate that the seawater intrusion estimated from the source tracking and the EC simulations were consistent. The increased salinity during periods of low Delta outflow indicates the upstream movement of salinity and other water quality concentrations or floating particles (e.g., phytoplankton, zooplankton, larval fish) from the Martinez boundary.

Figure C.A-146 and Figure C.A-147show the DSM2-simulated Martinez boundary water contributions at the SWP Banks and CVP Jones pumping plants for WY 1976–1991. The DSM2-simulated Martinez water contribution was generally similar for the SWP and CVP pumping and was greater than 1% in about half of the months. The maximum Martinez water contribution at the Banks pumping plant is generally a little higher than the contribution at the CVP Jones pumping plant because the CVP Jones pumping plant generally has a greater contribution from the San Joaquin River inflow. The maximum Martinez contribution at the SWP Banks pumping plant was about 3%, and the maximum contribution at the CVP Jones pumping plant was about 2%. Because the average Martinez EC was about 23,000 µS/cm in these low-outflow months, the contribution in the combined SWP and CVP exports can be estimated to be about 575 µS/cm (i.e., 0.025 x 23,000 = 575). The modeling results indicate that the Martinez water contribution (seawater intrusion) at the exports was primarily a function of Delta outflow and was not affected by south Delta export pumping. Therefore, because the ESO cases did not increase the Delta outflow, there was no reduction in the simulated EC from Martinez (seawater intrusion contribution) at the south Delta pumping plants. The export EC was reduced by the north Delta intake diversions (Sacramento River EC of 175 µS/cm) but the export EC could have been reduced even more by slightly increased outflow (which would reduce the seawater intrusion contribution).

5C.A.8.3 Agricultural Drainage Tracking

The DSM2 uses an input file (Delta Islands Consumptive Use [DICU]) that is used to simulate the agricultural diversions and seepage and drainage discharges that are located throughout the Delta. The DICU discharges from the islands to the channels are one of the sources tracked. For salinity simulations, the DICU discharges (drains) have assumed monthly EC values, which are highest in the winter. Seepage is assumed to be about 1 inch per acre for the Delta lowlands islands, and agricultural diversions are assumed to be 1.5 x the monthly irrigation ET, so the drainage in the summer is about 50% of the irrigation demand, or about 33% of the agricultural diversions. The salinity of these summer return flows might be as low as the channel EC, but DICU uses fixed monthly values regardless of the channel (diversion) EC. The DICU does not calculate a salt balance for each island.

The DICU discharges include runoff from rainfall, seepage, and irrigation return flow, as well as some leaching water assumed to be applied and drained after a month from some islands in the winter is tracked. Therefore, although agricultural drainage water is tracked in DSM2, it is difficult to estimate the salinity or other constituent concentration (e.g., dissolved organic carbon [DOC], nutrients) of this drainage water. The agricultural diversions are assumed to remove water from the Delta channels, although 33% of this diversion and most of the seepage flow will be returned to the Delta channels as drainage. Nevertheless, the source tracking of agricultural drainage provides a useful general pattern of influence from these internal Delta sources of water (from runoff, seepage, and agricultural diversion return flow).

Figure C.A-148 and Figure C.A-149show the DSM2-simulated agricultural drainage source contributions at the SWP Banks the CVP Jones Pumping Plants for WY 1976–1991 for the six cases. The drainage source contribution was a maximum of about 20–25% in the summer months of most years. The drainage contributions were about the same in the SWP and CVP exports. The lowest drainage contribution in the winter months was about 5%. The highest drainage contribution of about 25% was simulated in months with low export pumping. The drainage contributions were higher in months with reduced export pumping, because the summer drainage flows were constant from year to year, while the channel flows to the exports (i.e., reverse OMR flow, Grant Line Canal) were lower in months with reduced pumping. The ESO cases had higher drainage contributions at the south Delta pumps in months when the north Delta intake diversions allowed the south Delta pumping to be reduced. Therefore, the effects of reduced pumping on water quality at the south Delta pumps are based on these counteracting effects (lower San Joaquin River contributions but higher agricultural drainage contributions).

Figure C.A-150 and Figure C.A-151 show the DSM2-simulated drainage source contributions in the Sacramento River at Emmaton and in the San Joaquin River at Jersey Point for WY 1976–1991 for the six cases. The average simulated drainage contribution at Jersey Point ranged from about 2% in the winter to about 7% in the summer of most years. The average simulated drainage contribution at Emmaton ranged from about 1% in the winter to about 5% in the summer of most years. The ESO cases showed slightly higher drainage contributions at Jersey Point in some of the years, caused by the reduced south Delta export pumping that currently removes a major portion of the south Delta drainage flows.

5C.A.8.4 Yolo Bypass Inflow Tracking

The Yolo Bypass inflow enters the Delta at Cache Slough near Rio Vista. Figure C.A-152 and Figure C.A-153 show the DSM2-simulated Yolo Bypass contribution in the Sacramento River at Emmaton and in the San Joaquin River at Jersey Point for WY 1976–1991 for the six cases. The only way for Yolo Bypass water to reach Jersey Point is to tidally mix through Threemile Slough or to tidally mix upstream from the confluence. Presumably the upstream movement from the confluence is limited because the Yolo Bypass inflow is large only during high outflow months. The Yolo Bypass inflow source tracking results provide a method for estimating the exchange of Sacramento and San Joaquin River water through Threemile Slough. The results indicate that a maximum of about 5–10% of the Yolo Bypass inflow moves through Threemile Slough to the San Joaquin River at Jersey Point. Because the average tidal flow in Threemile Slough is about 30,000 cfs, the flood tide volume is about 15,000 af, representing an equivalent transfer flow of about 7,500 cfs (25% of the maximum tidal flow). This would be 10% of a Yolo Bypass inflow of 75,000 cfs and about 5% of a Yolo Bypass inflow of 150,000 cfs.

5C.A.8.5 Sacramento and Eastside River Tracking

Because the Sacramento River and the Yolo Bypass and the eastside rivers (Cosumnes, Mokelumne, and Calaveras) have low salinity and generally low concentrations of other constituents, the source tracking results for these three major sources were assumed to contribute the remaining water at all Delta locations. Tracking the San Joaquin River inflow, the Martinez boundary water and the agricultural drainage water will identify the contribution of water with increased salinity and increased concentrations of other constituents. The source tracking results therefore provide a general method for estimating likely changes in water quality concentrations at various Delta locations resulting from changes in the Delta inflows and south Delta exports that may be caused by the BDCP operations.

The general method can be described for salinity (EC), although EC is already included in DSM2 modeling. The general water quality analysis requires an assumed EBC concentration. The EC value of 175 μS/cm is used for the Sacramento and Yolo Bypass inflows. The eastside rivers use a value of 150 μS/cm. The increased EC at the exports caused by the San Joaquin River source, the drainage source, and the Martinez source would be calculated as the contribution from these sources times the incremental EC from these sources.

> Increased EC (μS/cm) = San Joaquin River contribution (%)/100 x San Joaquin River EC increment (μS/cm) + Drain contribution (%)/100 x Drain EC increment + Martinez contribution (%)/100 x Martinez EC increment (μS/cm)

The incremental EC (or the incremental concentration) is the measured San Joaquin River EC or drainage EC or Martinez EC minus the assumed EBC Sacramento River EC (or concentration). As can be seen in the figures shown in this section, the changes in the San Joaquin River contributions will depend on the San Joaquin River inflow. The changes in the drainage contributions will depend most strongly on the south Delta pumping, and the changes in the Martinez contributions will depend on the Delta outflow. The general effects of monthly changes in Delta inflows, south Delta export pumping, and Delta outflow on salinity and other water quality concentrations therefore can be generally understood from this analysis of source tracking.

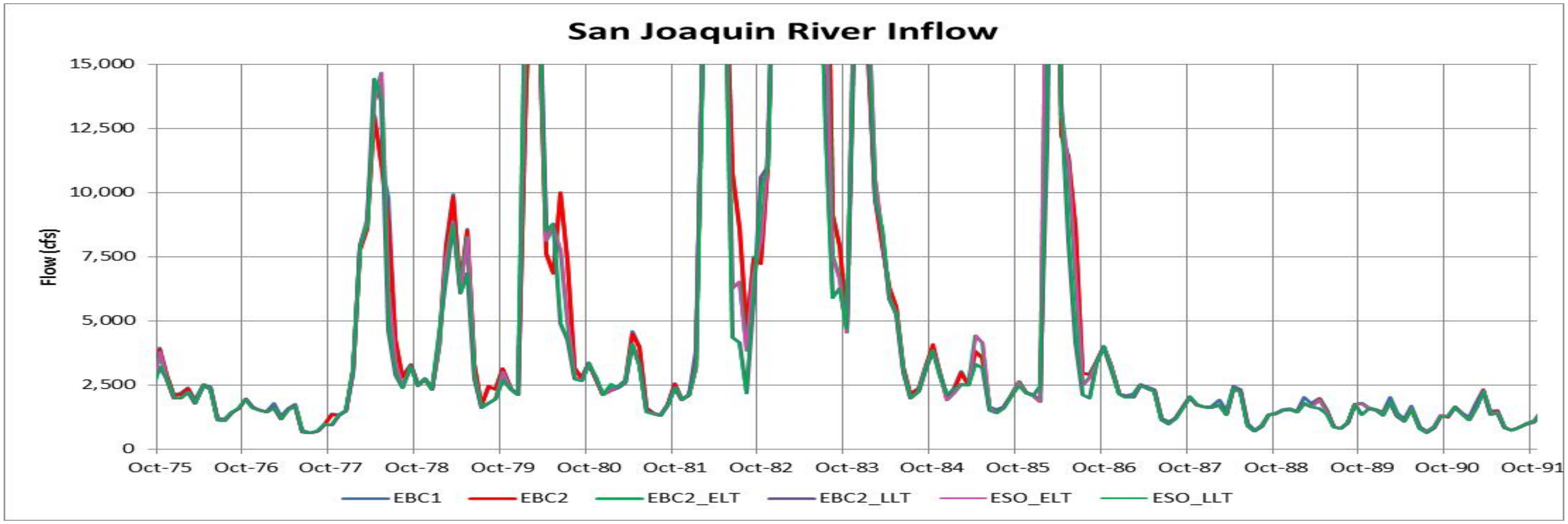


Figure C.A-128. Monthly CALSIM-Simulated San Joaquin River Inflow at Vernalis for WY 1976–1991

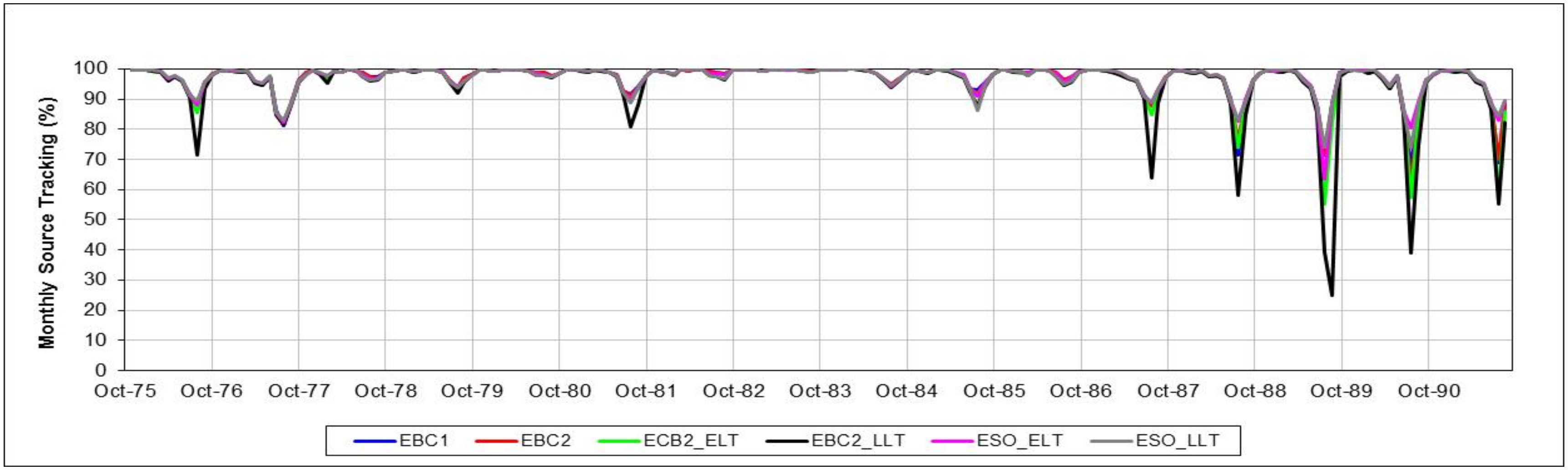


Figure C.A-129. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Brandt Bridge for WY 1976–1991

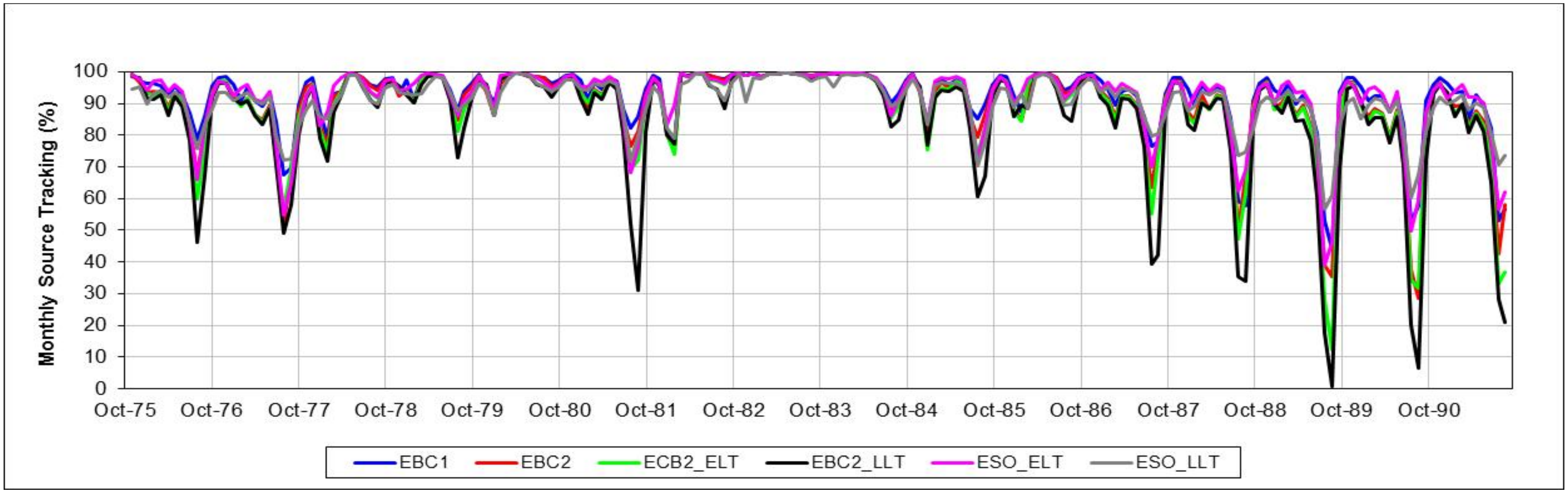


Figure C.A-130. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Stockton for WY 1976–1991

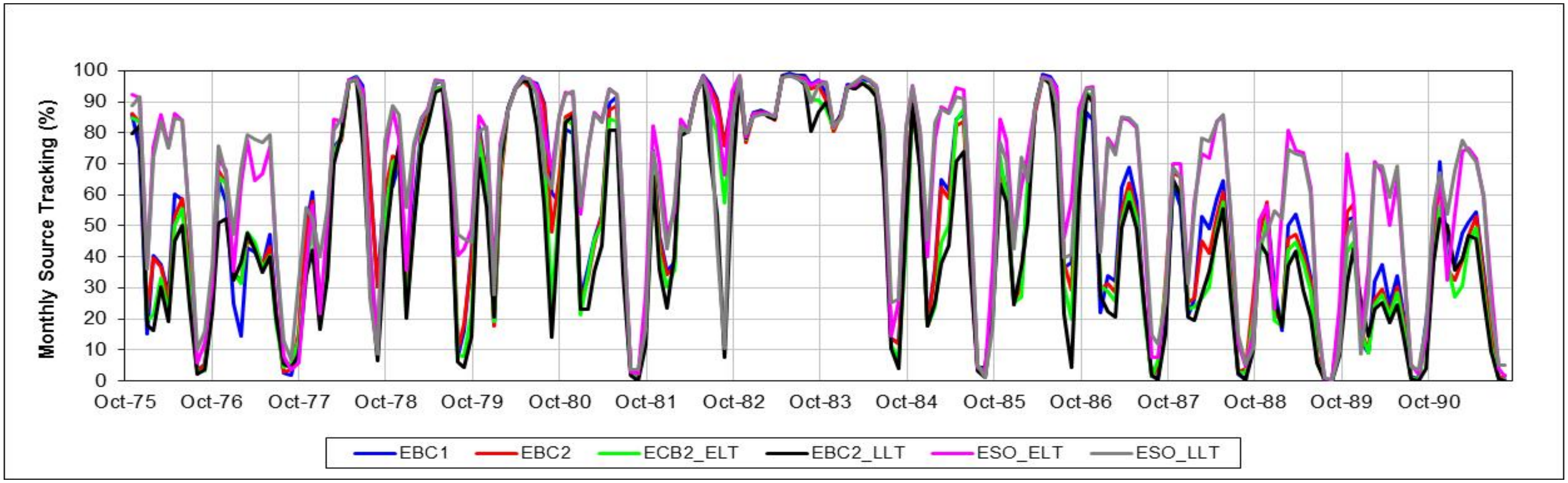


Figure C.A-131. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow Downstream of Turner Cut for WY 1976–1991

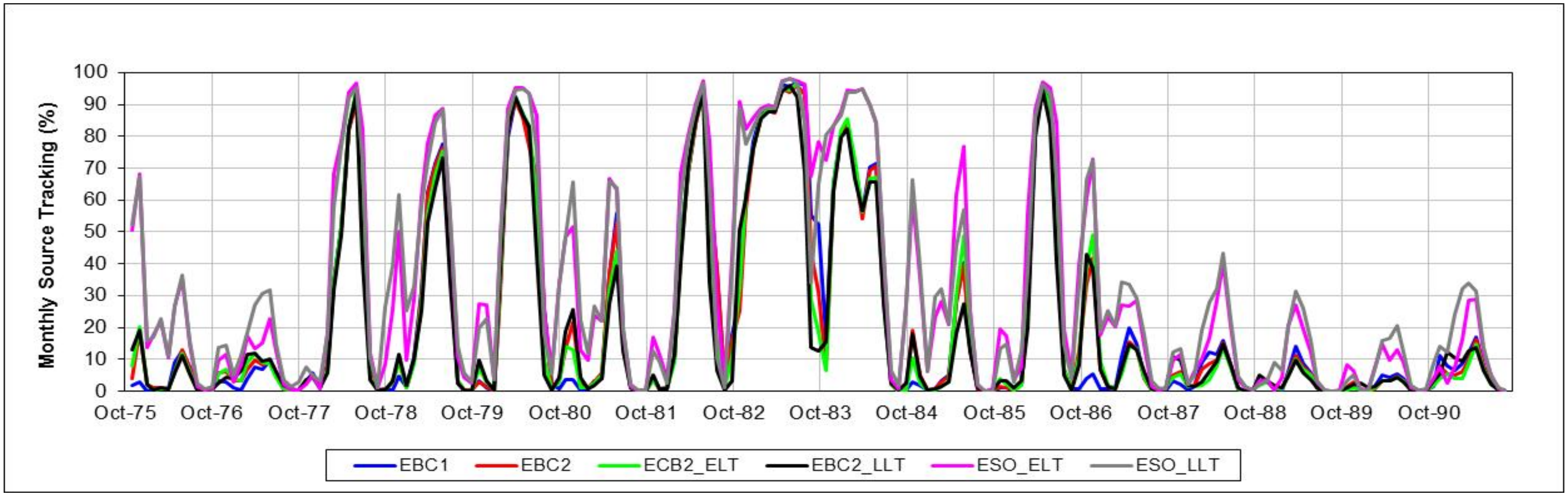


Figure C.A-132. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Prisoners Point for WY 1976–1991

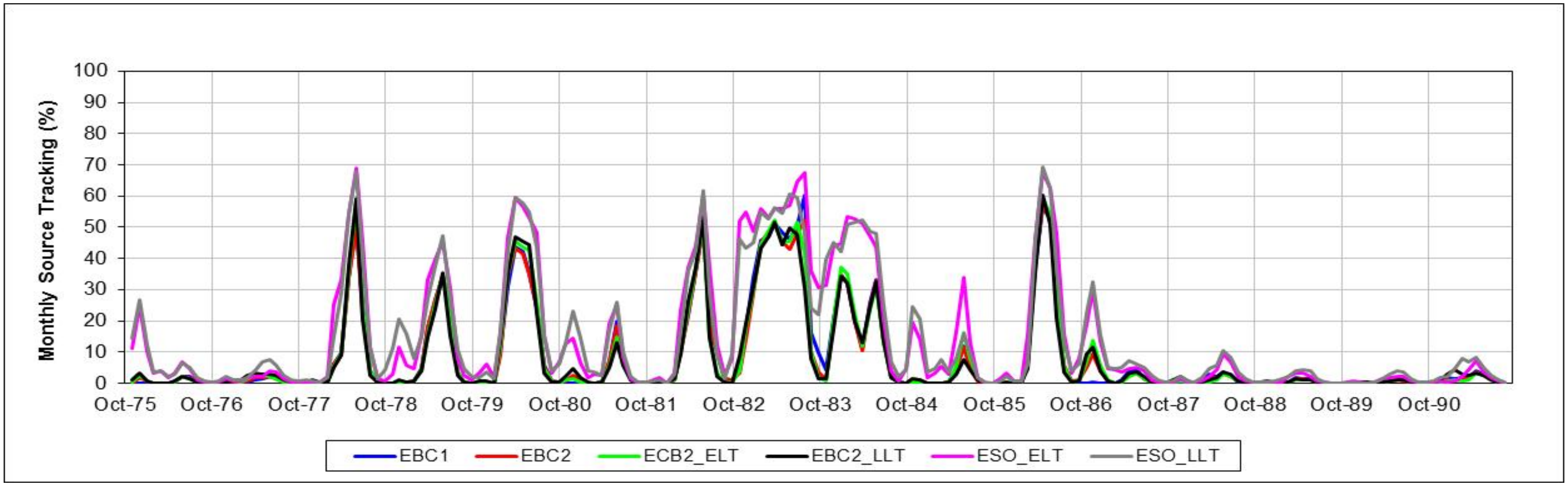


Figure C.A-133. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at San Andreas Landing for WY 1976–1991

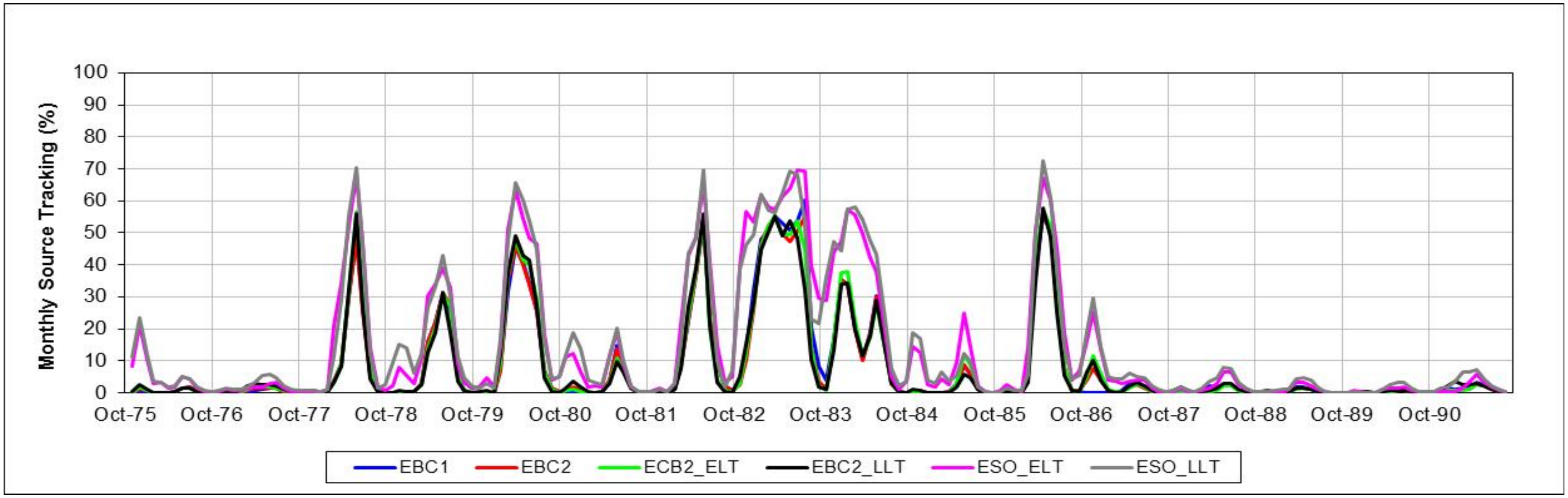


Figure C.A-134. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Jersey Point for WY 1976–1991

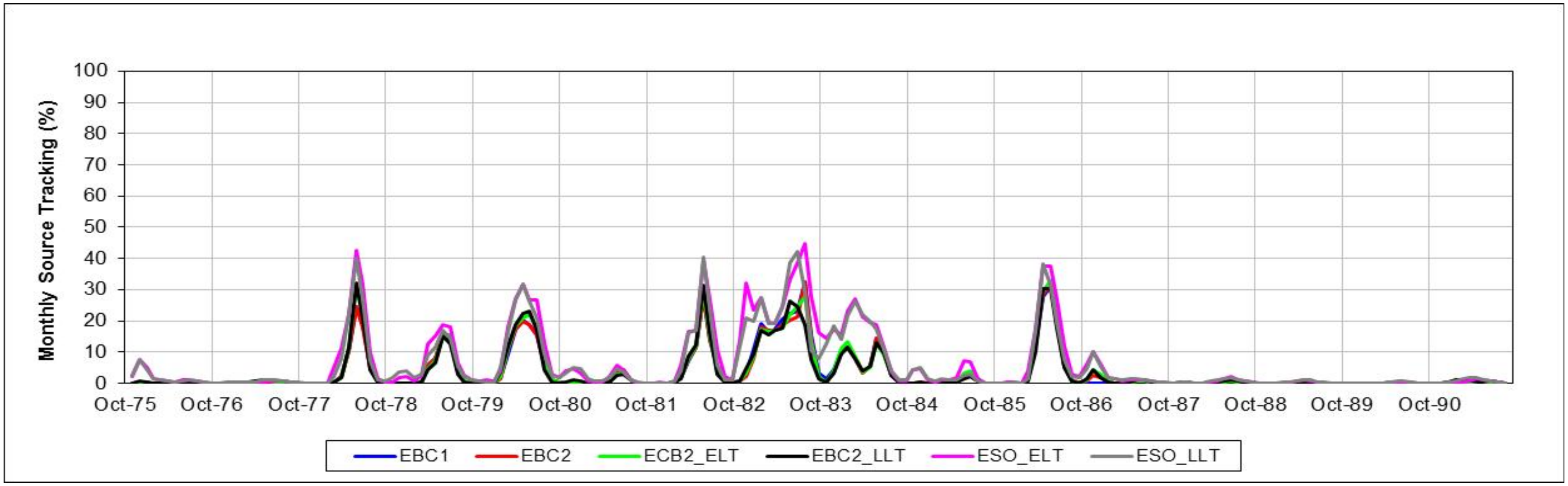


Figure C.A-135. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Chipps Island for WY 1976–1991

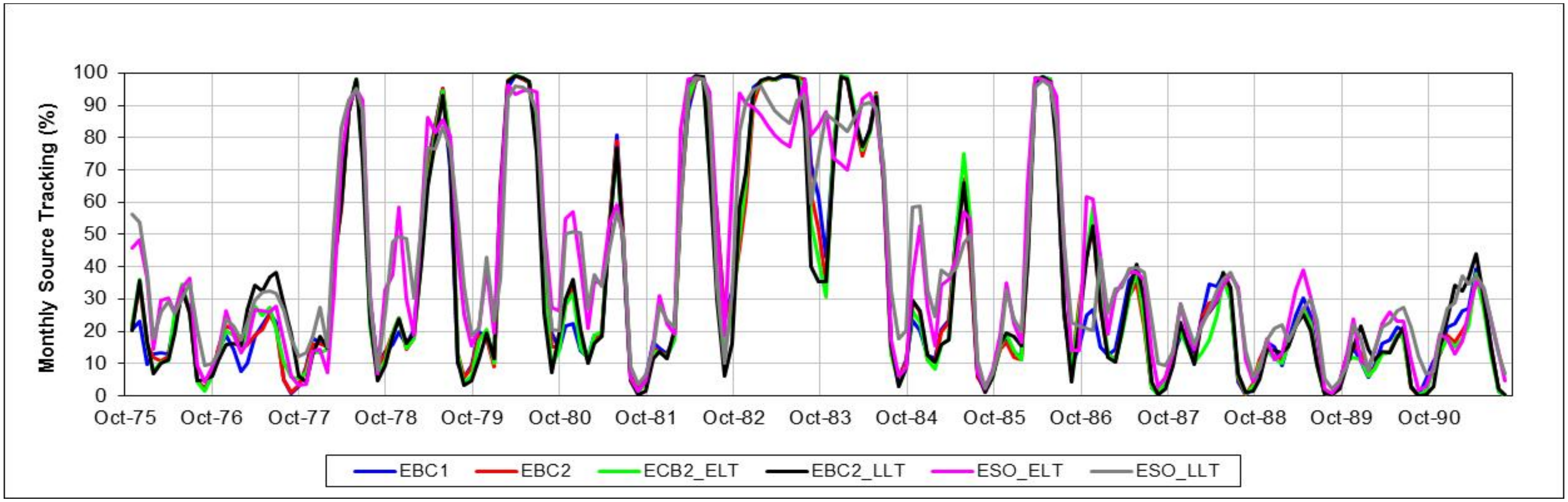


Figure C.A-136. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Clifton Court Forebay for WY 1976–1991

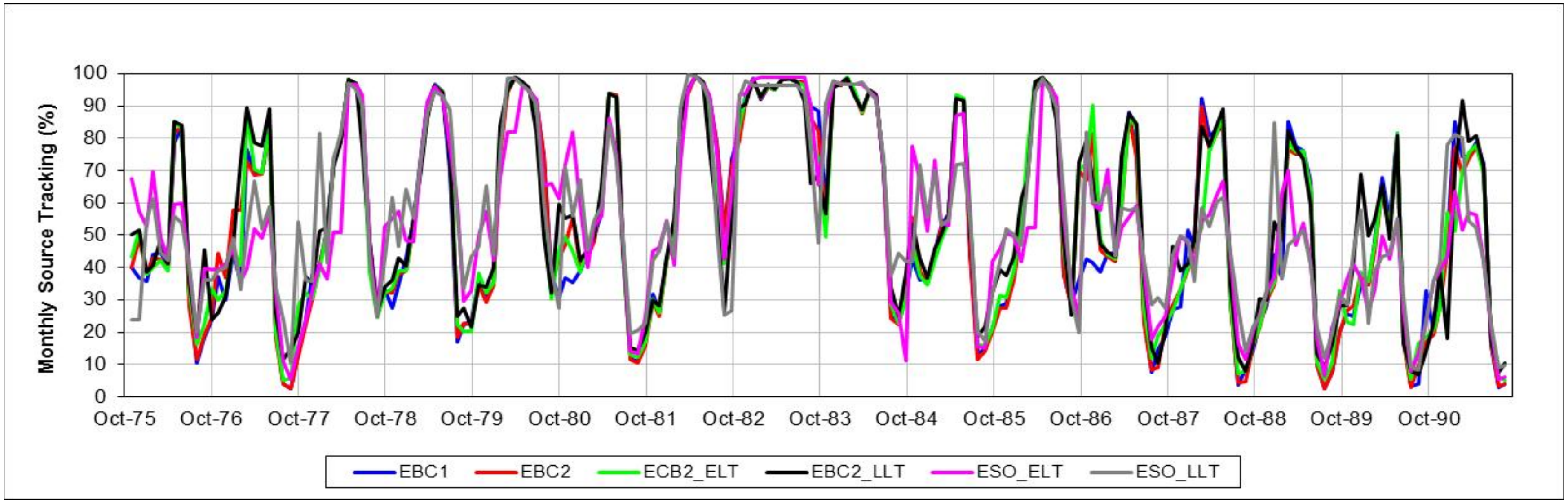


Figure C.A-137. DSM2-Simulated Monthly Source Tracking of San Joaquin River Inflow at Jones Pumping Plant for WY 1976–1991

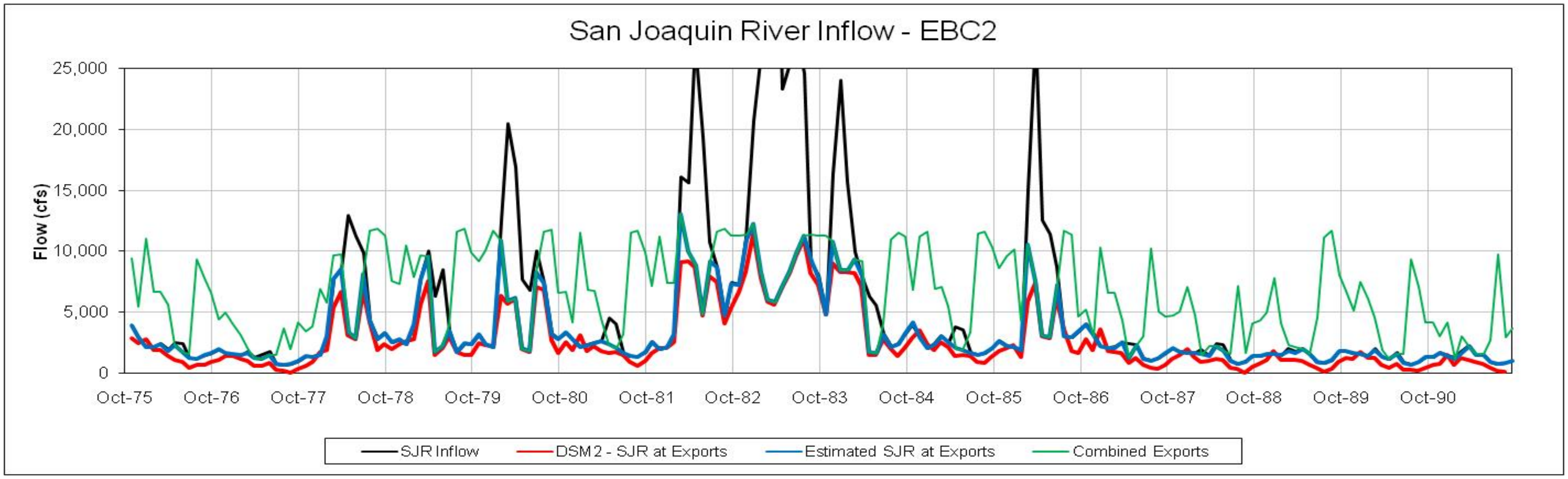


Figure C.A-138. DSM2-Simulated and Estimated Monthly San Joaquin River Inflow at CVP Jones and SWP Banks Pumping Plants for EBC2 Case for WY 1976–1991

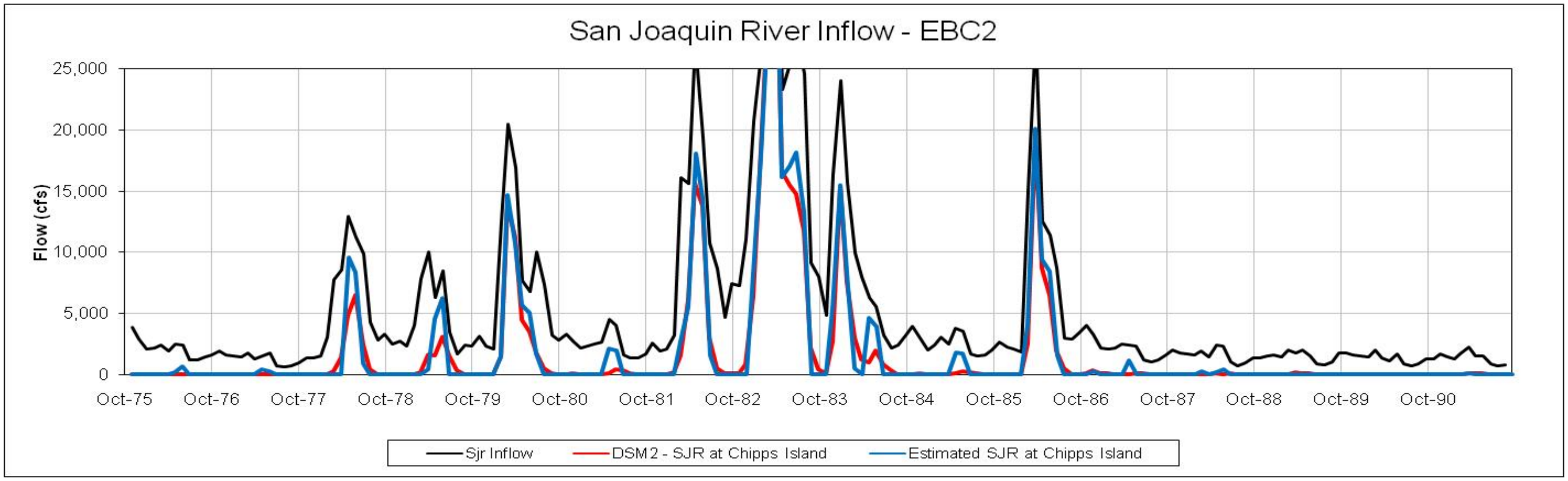


Figure C.A-139. DSM2-Simulated and Estimated Monthly San Joaquin River Inflow at Chipps Island (Delta Outflow) for EBC2 Case for WY 1976–1991

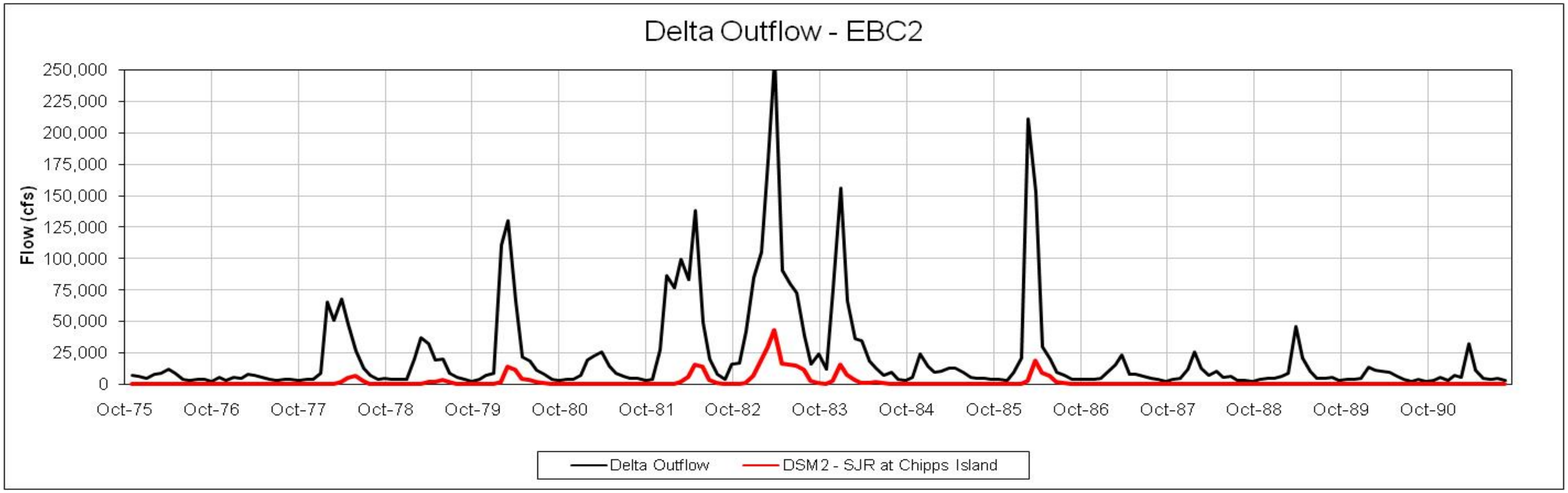


Figure C.A-140. DSM2-Simulated Delta Outflow and the San Joaquin River Flow at Martinez for the EBC2 Case for WY 1976–1991

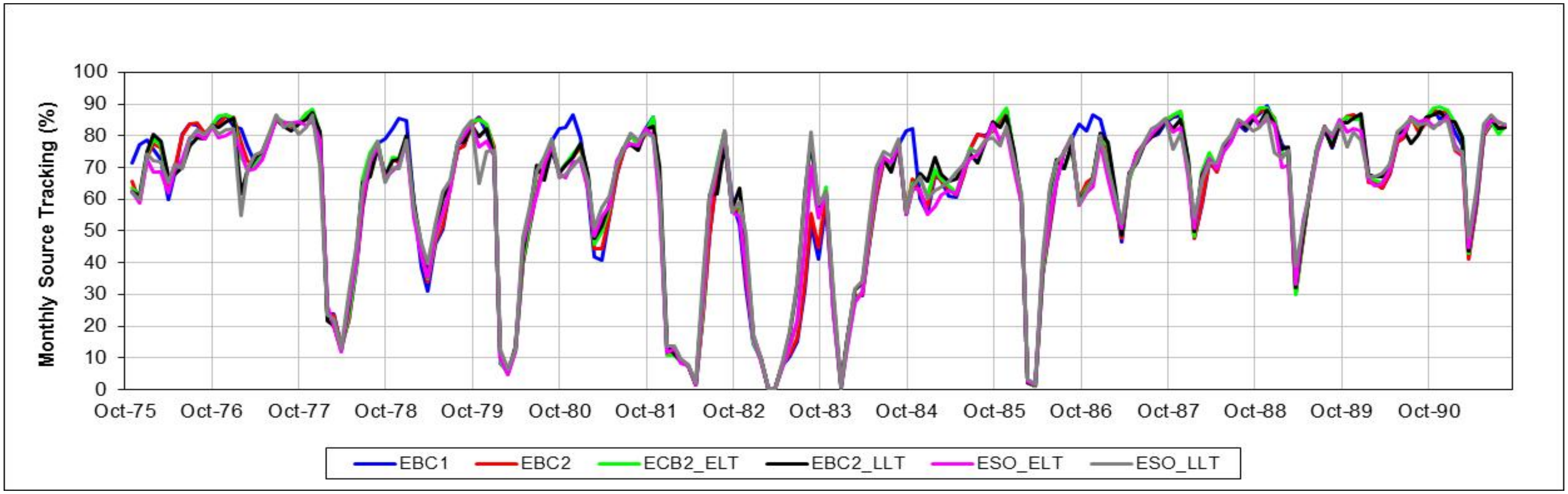


Figure C.A-141. DSM2-Simulated Monthly Source Tracking of Martinez Boundary Water at Port Chicago for WY 1976–1991

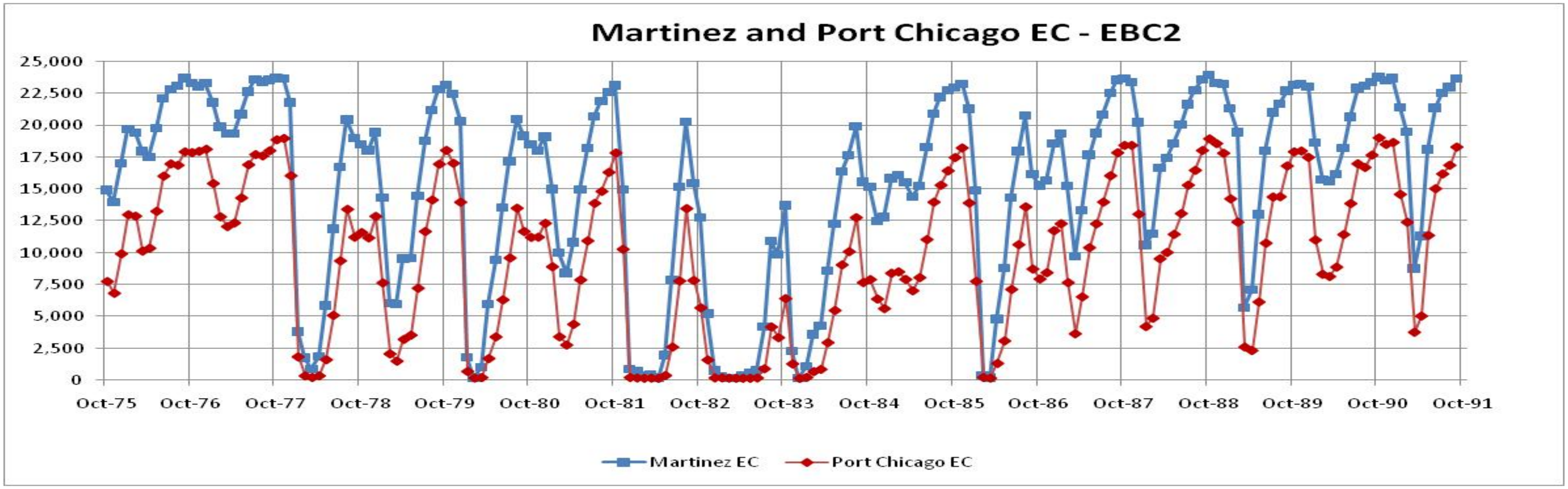


Figure C.A-142. DSM2-Simulated Monthly EC at Martinez (54 km) and Port Chicago (64 km) for WY 1976–1991

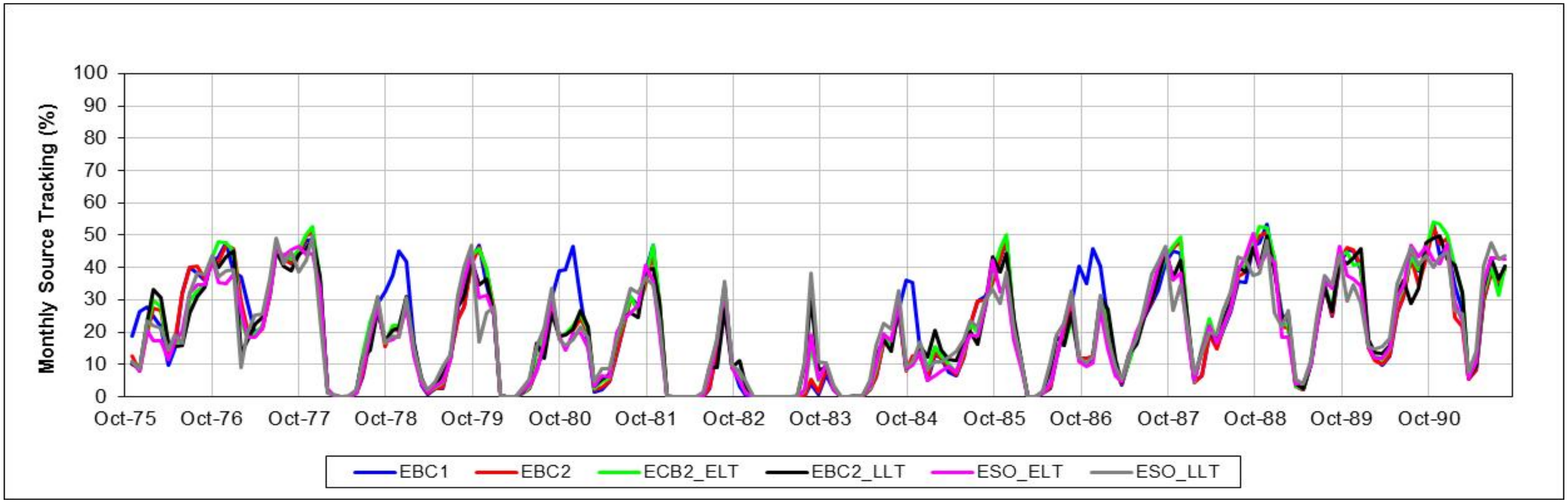


Figure C.A-143. DSM2-Simulated Monthly Source Tracking of Martinez Boundary Water at Collinsville (81 km) for WY 1976–1991

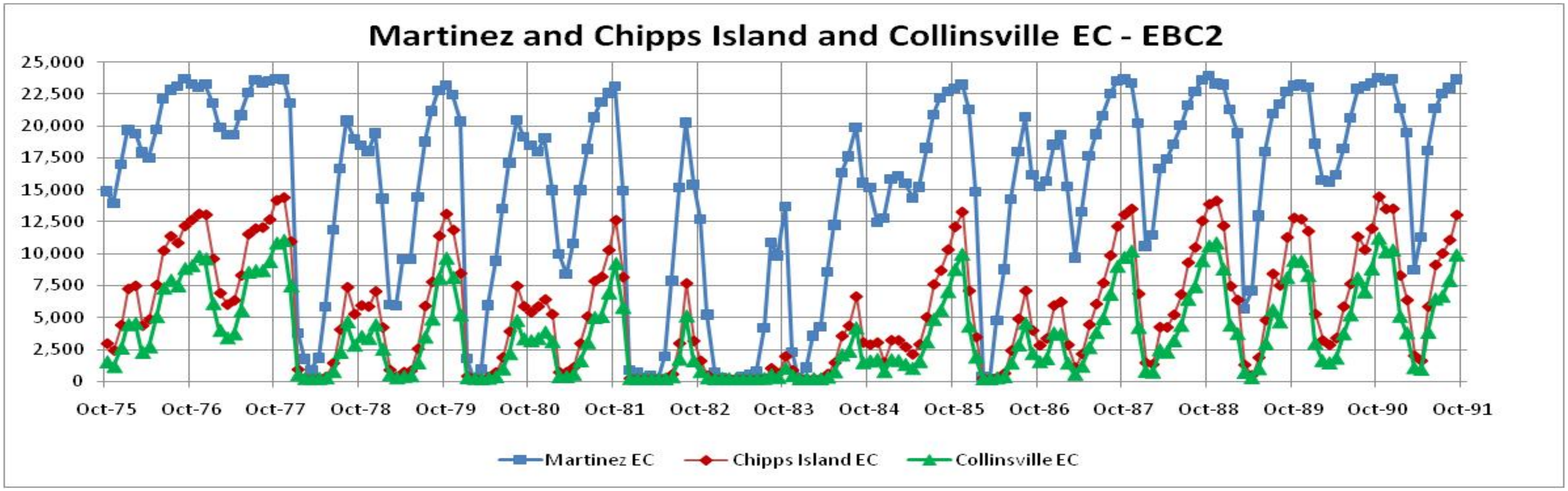


Figure C.A-144. DSM2-Simulated EC at Martinez, Chipps Island and Collinsville for WY 1976–1991

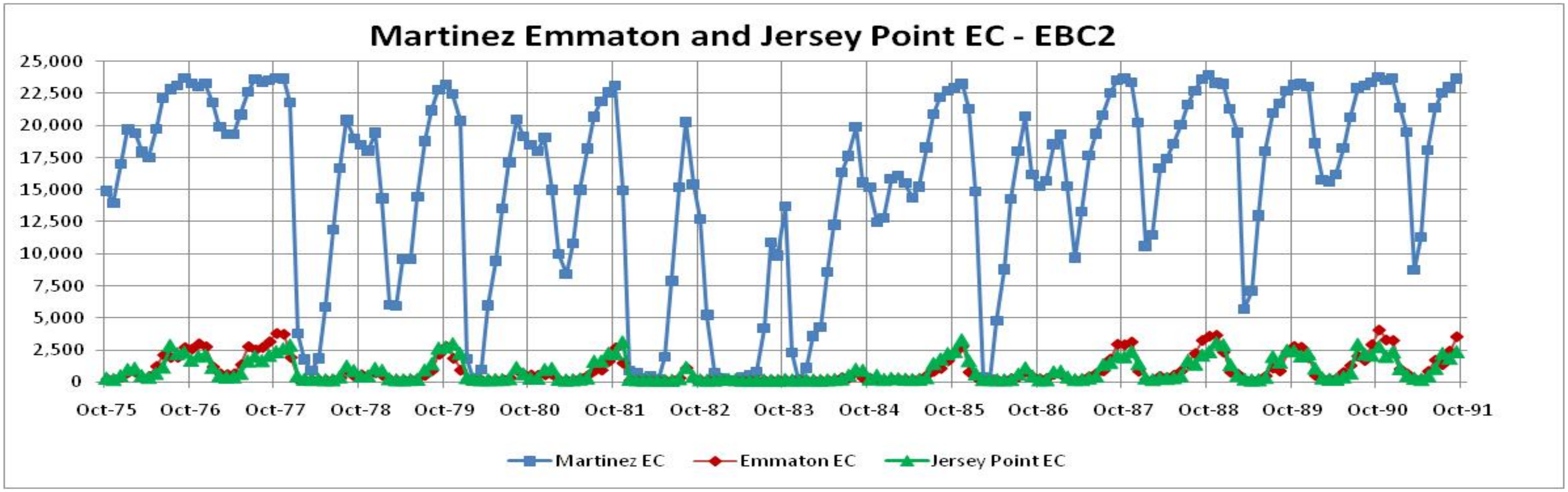


Figure C.A-145. DSM2-Simulated EC at Martinez, Emmaton and Jersey Point for WY 1976–1991

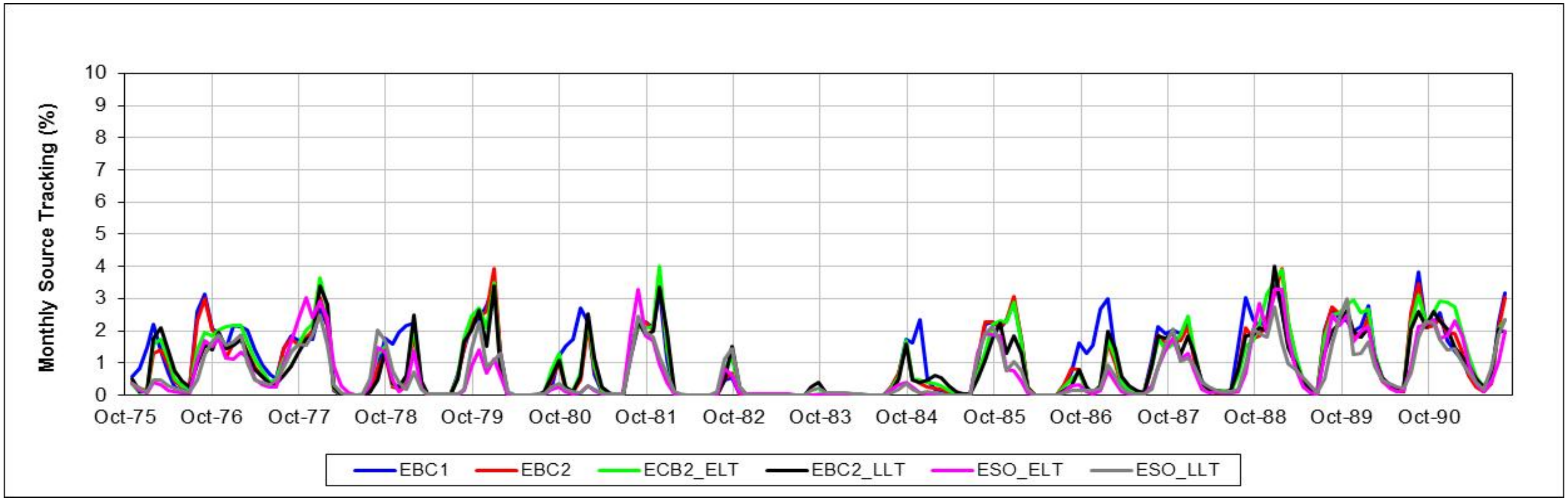


Figure C.A-146. DSM2-Simulated Monthly Source Tracking of Martinez Boundary Water at Clifton Court Forebay for WY 1976–1991

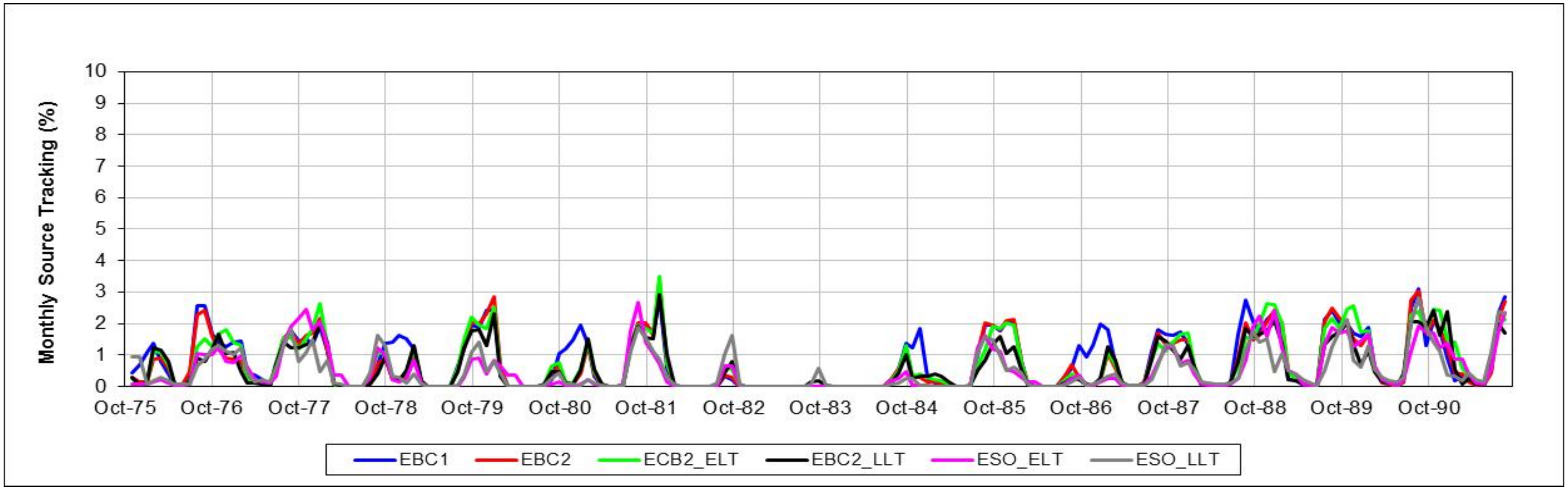


Figure C.A-147. DSM2-Simulated Monthly Source Tracking of Martinez Boundary Water at Jones Pumping Plant for WY 1976–1991

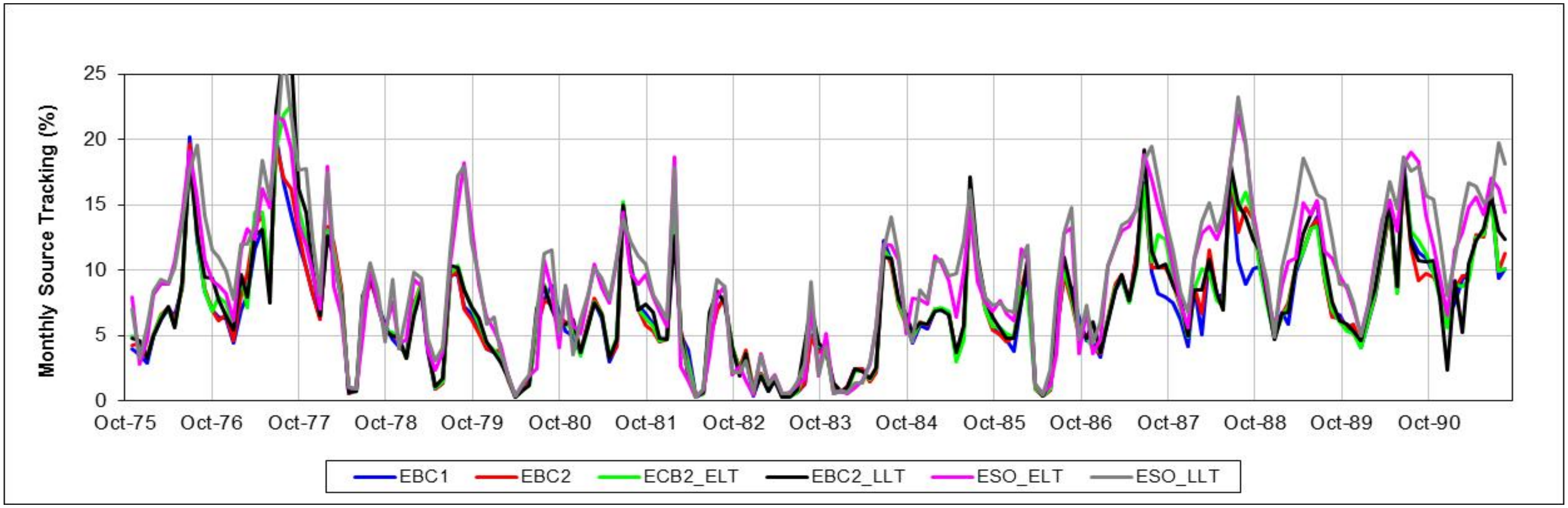


Figure C.A-148. DSM2-Simulated Monthly Source Tracking of Delta Runoff and Agricultural Drainage at Clifton Court Forebay for WY 1976–1991

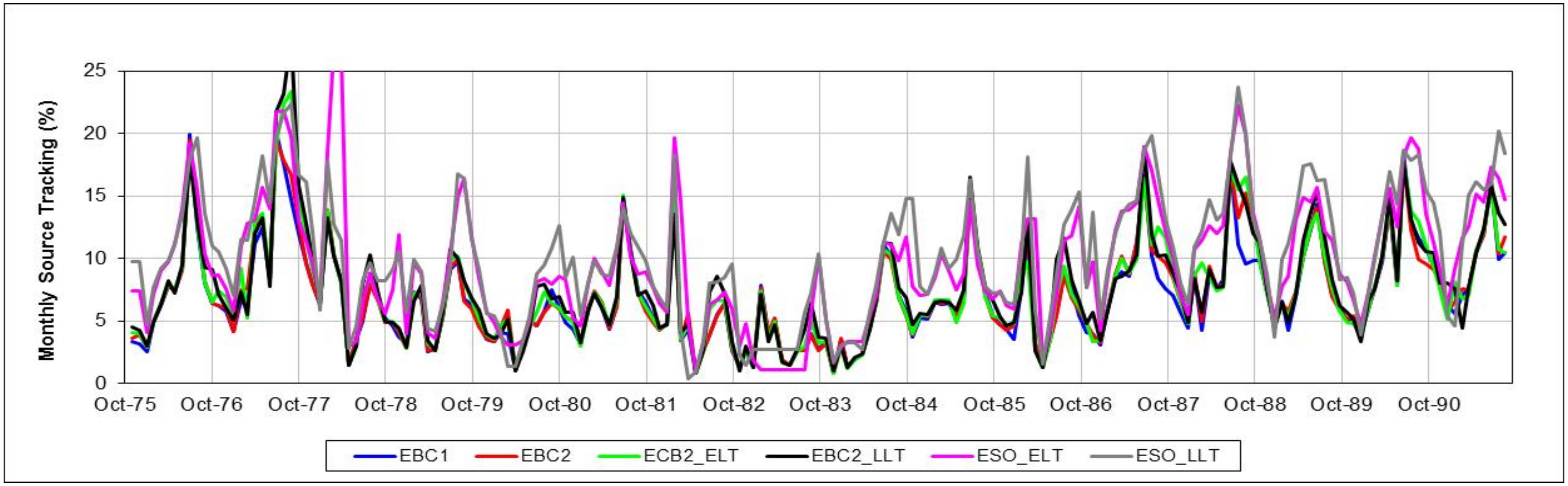


Figure C.A-149. DSM2-Simulated Monthly Source Tracking of Delta Runoff and Agricultural Drainage at Jones Pumping Plant for WY 1976–1991

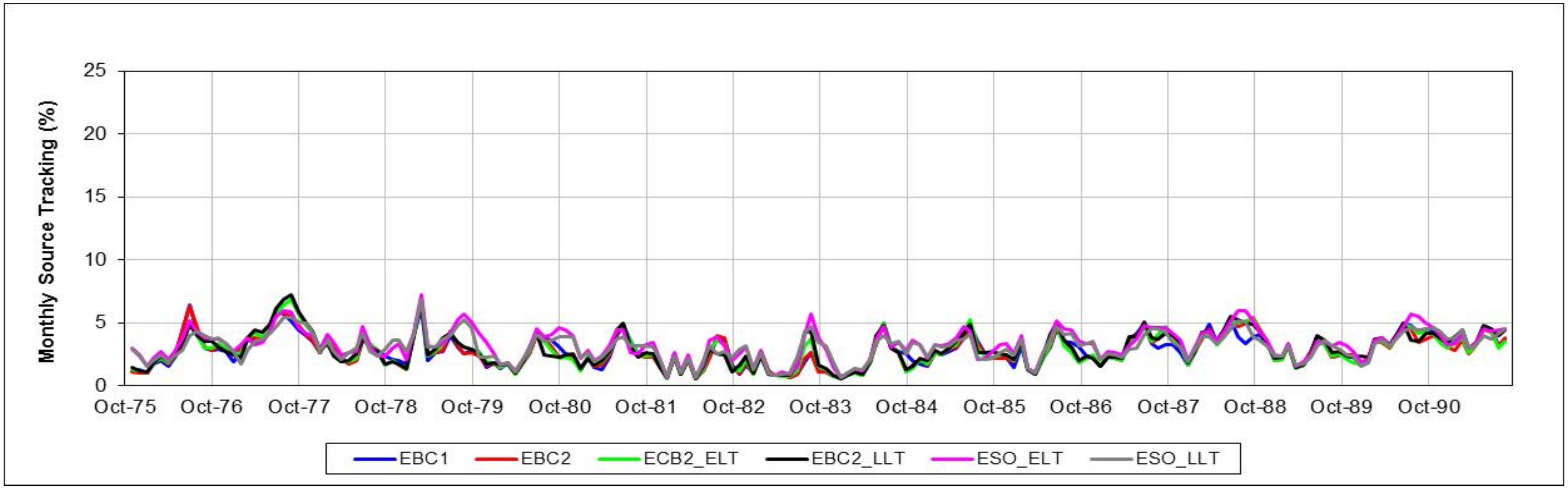


Figure C.A-150. DSM2-Simulated Monthly Source Tracking of Delta Runoff and Agricultural Drainage at Emmaton for WY 1976–1991

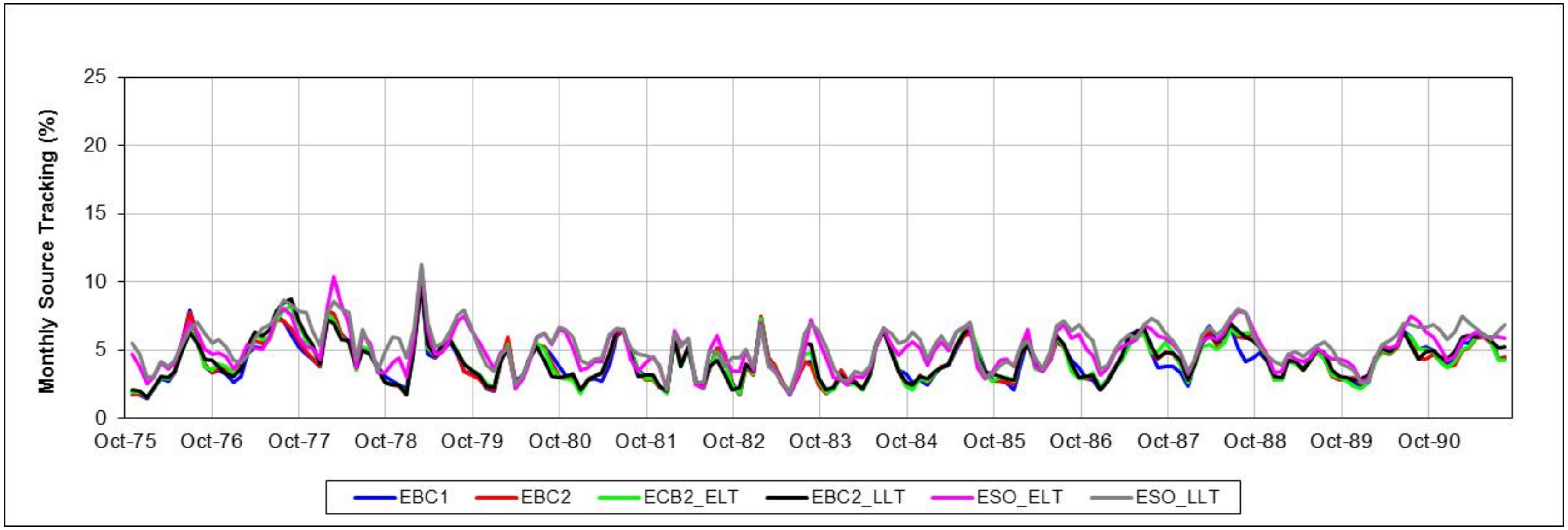


Figure C.A-151. DSM2-Simulated Monthly Source Tracking of Delta Runoff and Agricultural Drainage at Jersey Point for WY 1976–1991

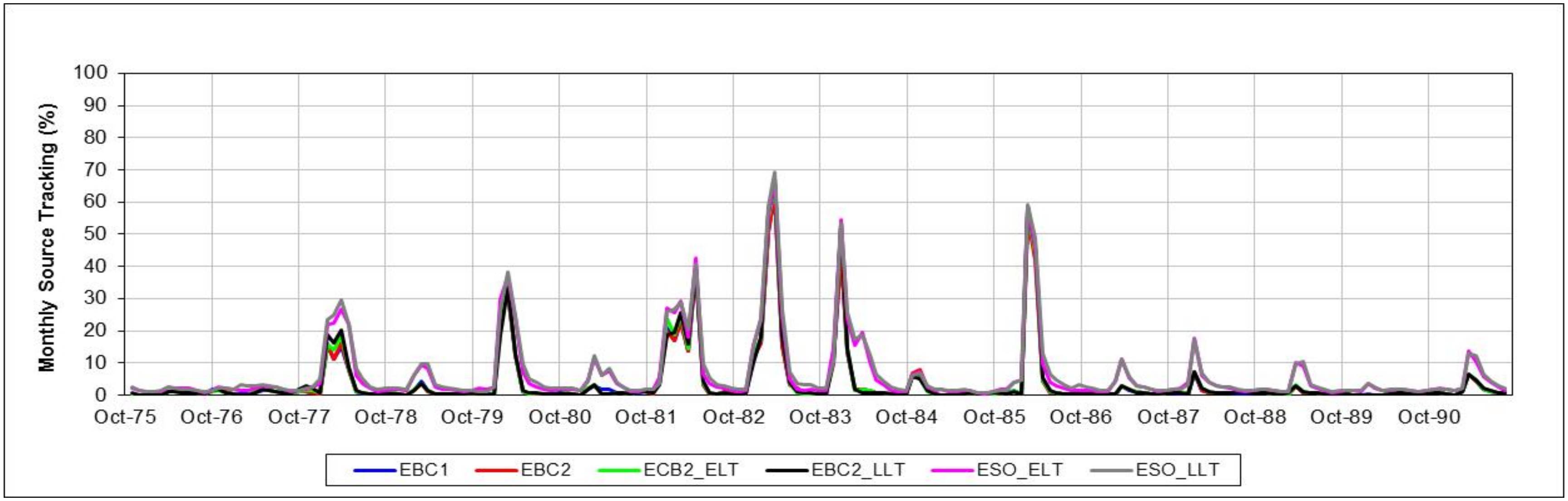


Figure C.A-152. DSM2-Simulated Monthly Source Tracking of Yolo Bypass Inflow at Emmaton for WY 1976–1991

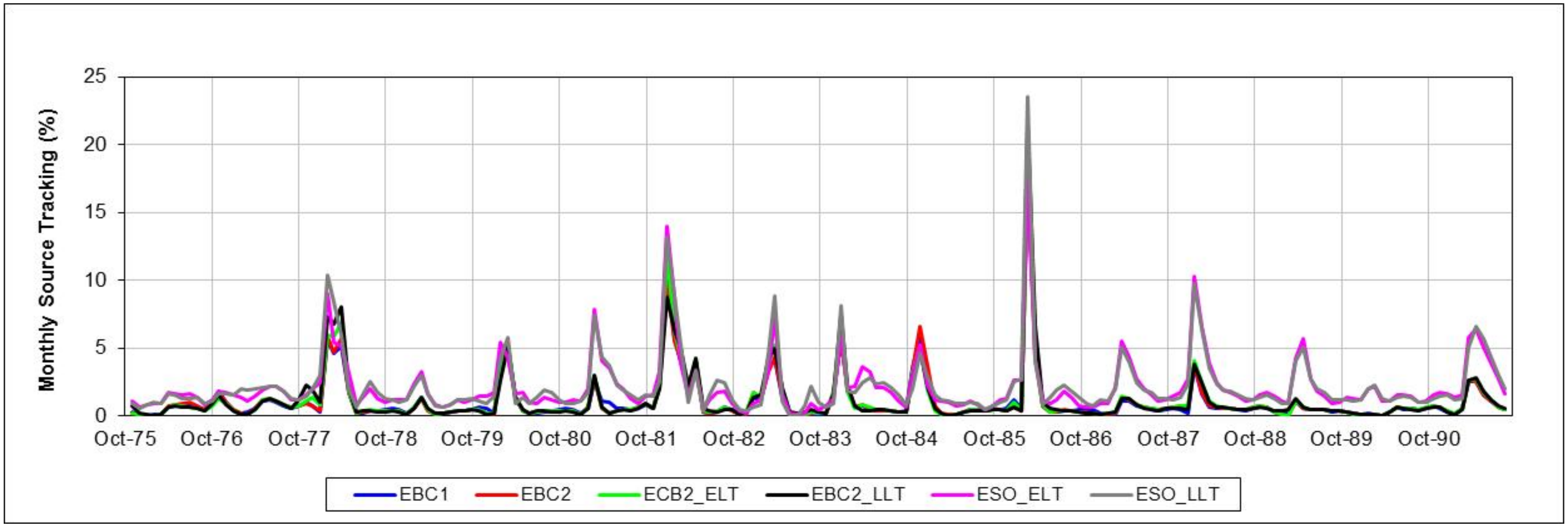


Figure C.A-153. DSM2-Simulated Monthly Source Tracking of Yolo Bypass Inflow at Jersey Point for WY 1976–1991

5C.A.9 DSM2 Particle Tracking—Results

DSM2-PTM simulates the transport of particles based on the simulated tidal flows and assumed vertical and lateral velocity gradients. The average velocity in each 1-D channel segment is used to approximate the 3-D location of individual particles. The PTM module uses geometry files, velocity, flow, and stage output from the HYDRO module to monitor the location of each individual particle using assumed vertical and lateral velocity profiles and specified random movement to simulate mixing. The location of a particle in a channel is determined as the distance from the downstream end of the channel segment (x), the distance from the centerline of the channel (y), and the distance above the channel bottom (z). Particle tracking has been used for visualization of tidal flow transport patterns and evaluation of larval and juvenile fish movement and entrainment.

The longitudinal distance traveled by a particle (each time step) is determined from a combination of the tidal velocity and the assumed lateral and vertical velocity profiles in each channel. The transverse velocity profile simulates the effects of channel shear that occurs along the sides of a channel. The result is varying velocities across the width of the channel. The vertical velocity profile shows that particles located near the bottom of the channel move more slowly than particles located near the surface. The model uses a logarithmic vertical velocity profile. Particles also move because of random mixing. The mixing rates (i.e., distances) are a function of the water depth and the velocity in the channel. High velocities and deeper water result in greater mixing. Particles entering exports or agricultural diversions are considered lost from the system, and their fate is recorded. Once particles pass Martinez (downstream model boundary), they have no opportunity to return to the Delta.

Representative months (24) were selected from the CALSIM simulation period for PTM simulations that included a full range of Sacramento River at Freeport and San Joaquin River at Vernalis inflows as shown in Figure C.A-154. Additional months with higher Freeport flows and proposed north Delta intake diversions have been added to these results for evaluating Delta transport and migration of Sacramento fish in the months of December–June. These additional PTM results are included in the analysis of Delta passage for Chinook fry and parr (See Section 5C.4.3.2.4, *PTM Nonlinear Regression Analysis for Chinook Fry/Parr*). The selected PTM months had evenly distributed E/I ratios between 0.1 and 0.6 as shown in Figure C.A-155. PTM simulations were performed to determine the fate of particles released from 39 Delta locations after 30 days. Figure C.A-156 shows that many of the particle release locations matched the 20-mm delta smelt survey stations. Four thousand particles were inserted at the identified locations on the first day of the selected month. The fates of the inserted particles were tracked for 30 days (or longer). Particles could be tracked at various Delta channels (intermediate fate) or to the individual diversions or to outflow (ultimate fate). Spatial plots of the percentage of particles with a specified fate (e.g., entrainment in south Delta exports) were prepared as shown in Figure C.A-157. Graphs showing the relationship of particle fate over the range of a selected hydrologic variable were also prepared to evaluate the possible movement of larval or juvenile fish released from a given location, as shown in Figure C.A-158.

Location is one of the primary factors controlling the risk of entrainment in agricultural diversions or south Delta exports. For a specified Delta location, the south Delta exports, reverse OMR flow, Delta outflow, or the E/I ratio were often the most useful flow variables for characterizing the entrainment risk or the fraction of particles reaching Chipps Island within a month. The “particle” movement past Chipps Island and the entrainment results for the major Delta regions can be summarized with similar hydrological relationships. This is similar to the presentation of entrainment as a function of the E/I ratio that was described and discussed by Kimmerer and Nobriga (2008). The relationship between particle entrainment and larval and juvenile fish entrainment are described in Appendix 5.B, *Entrainment*.

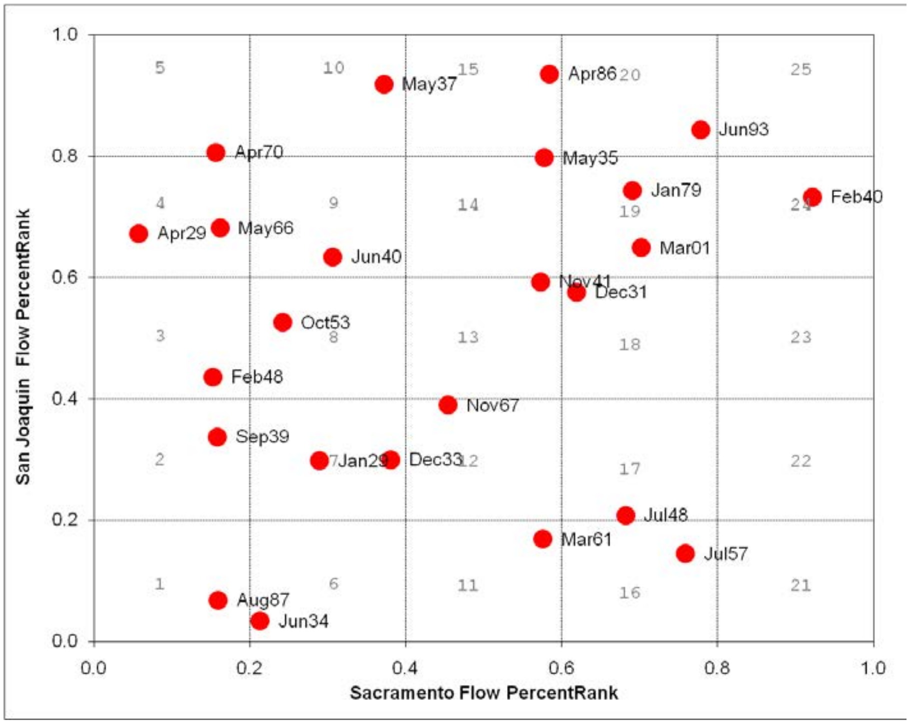
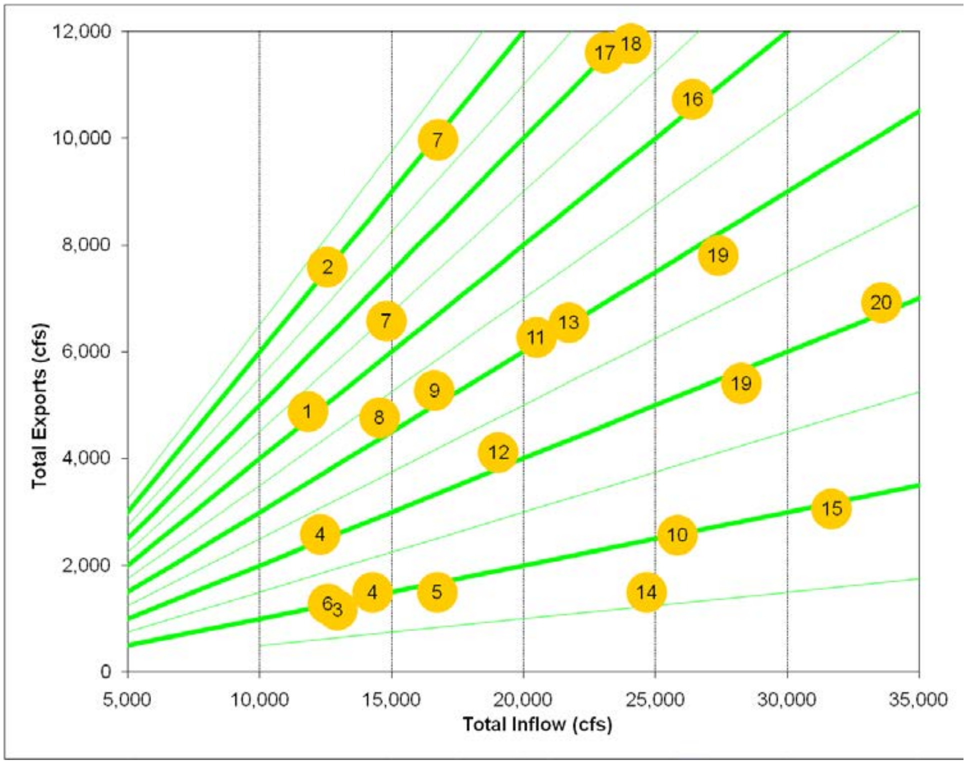


Figure C.A-154. Selected PTM Insertion Periods Plotted on the Sacramento River and San Joaquin River Inflow Hydrology Bins with Month and Year Identified for Each Insertion Period



Note: Green lines indicate constant E/I ratios (5–65%). “Total Exports” do not include North Delta diversions.

Figure C.A-155. Selected PTM Insertion Periods Plotted on the E/I Ratio Plot with the Hydrology Bin for Each Period Identified

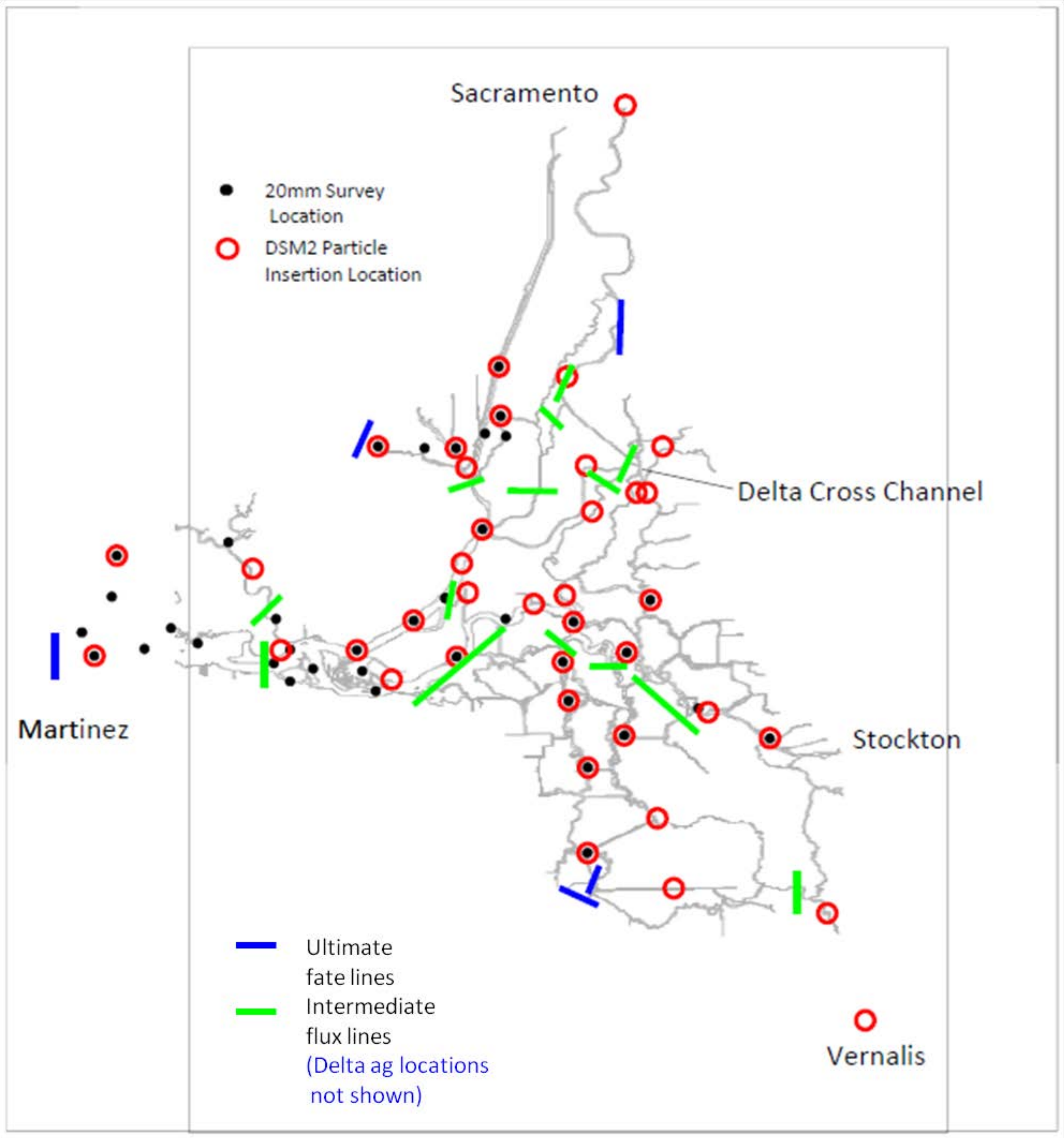


Figure C.A-156. Particle Insertion and Tracking Locations for Residence Time and Fate Computations

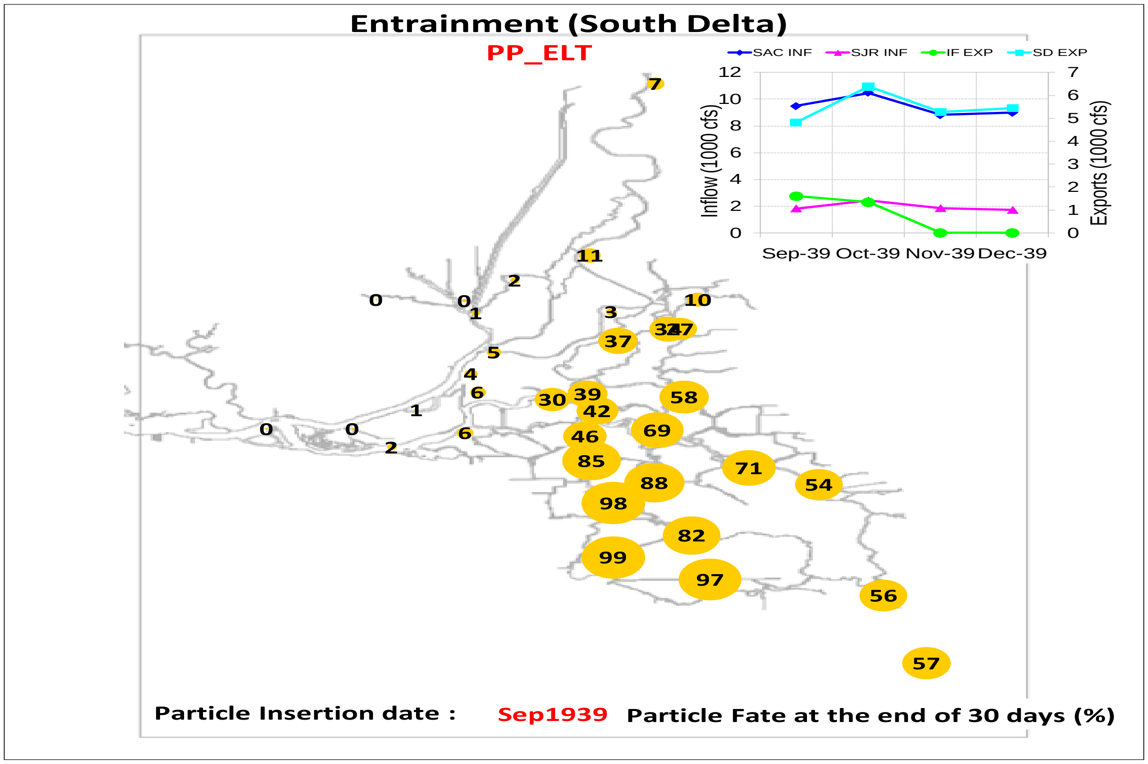


Figure C.A-157. An Example Spatial Plot Showing the Percent Entrainment for Particles Released at Various Locations in the Delta at the End of 30 Days after Insertion

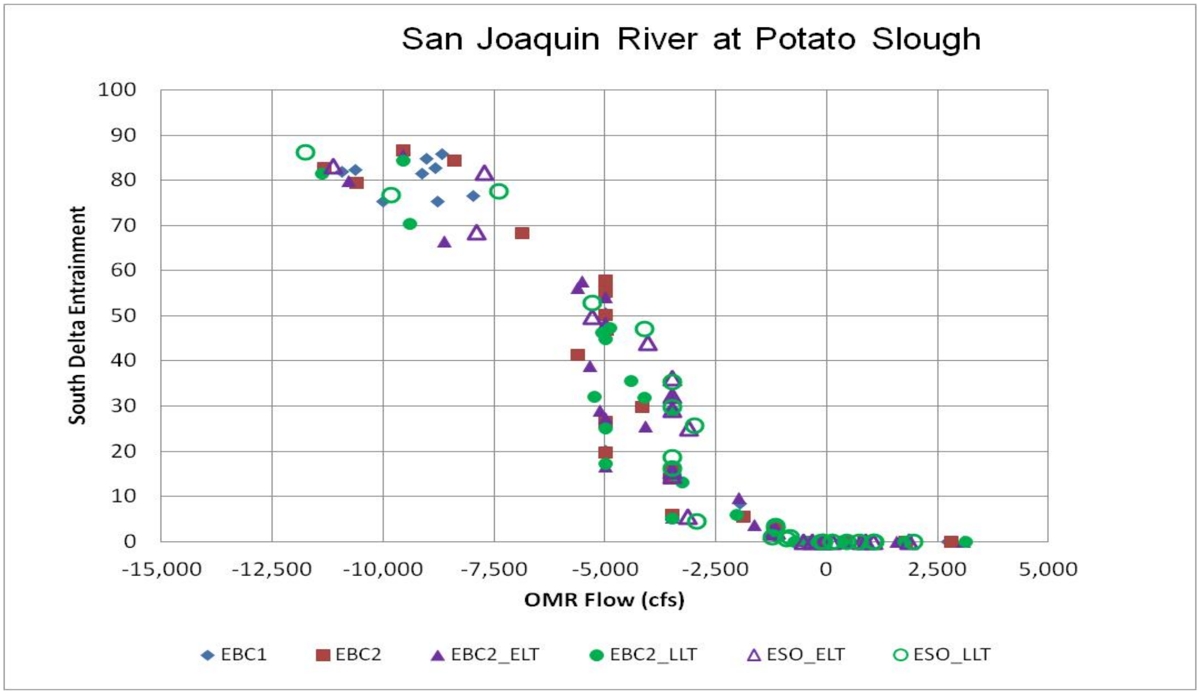


Figure C.A-158. Example Graph Showing the Relationship between the Percent Entrainment and Old and Middle River Flow (cfs) for Particles Inserted in the San Joaquin River at Potato Slough

5C.A.9.1 Identification of Flow-Fate Relationships from PTM Results

The DSM2 PTM results can be interpreted as showing the net tidal movement of water within the Delta channels. The movement of water and particles within the Delta is determined by the combination of river inflows, Delta export pumping (i.e., diversions) and the fluctuating tidal flows in the channels (i.e., tidal velocities). The movement and fate of particles after 30 days of tidal movement is expected to follow some relatively simple relationships with the dominant inflows and outflows (i.e., Delta outflow, Delta exports, or agricultural diversions). Some particles will remain within the Delta channels, but the majority will reach Chipps Island or be entrained in the south Delta exports (or agricultural diversions) within the 30-day tracking period. The relationships between Delta flows and particle fate (flow-fate relationships) for several important locations are described and evaluated in this section. Because Delta channel flows are functions of the inflows and channel flow splits (described in previous section), the movement between a particle release location and an outflow location might be well-described by a channel flow, such as OMR or QWEST, and might be well-described by more than one flow relationship. Ideally, the flow-fate relationships will accurately describe the particle fate for the full range of inflows, outflow, and Delta exports. Several flow ratios, such as Export/Inflow or Export/San Joaquin River, may provide the best descriptive relationship. The relationships describing the entrainment of particles in the south Delta exports are best described by the south Delta exports, OMR, QWEST, or the E/I ratio. The relationships describing the movement of particles past Chipps Island are best described by monthly inflows, outflow, or the E/I ratio. Although the basic hydrodynamic process (i.e., tidal velocities and associated mixing) that move particles within the Delta channels are accurately simulated with DSM2, the flow-fate relationships that best summarize the movement between locations in the Delta have been identified through comparative regression analysis, using the PTM results from a wide range of inflow, outflow and export conditions.

5C.A.9.1.1 Sacramento River at Sutter Slough Particles

Sacramento River water (and particles) is subject to several flow splits as it enters the Delta; some water is diverted into Sutter and Steamboat Sloughs which rejoins the Sacramento River at Rio Vista. Some Sacramento River water is diverted into DCC and Georgiana Slough to the Mokelumne River to the San Joaquin River channel, just downstream of the mouth of Old River and Franks Tract. Some Sacramento River water is diverted downstream of Rio Vista into Threemile Slough to the San Joaquin River upstream of False River. Some of the water (and particles) diverted to the San Joaquin River channel will be tidally transported into Old and Middle River channels and will move south (upstream) toward the south Delta CVP and SWP export pumping intakes. The majority of the Sacramento River water (and particles) will likely flow downstream past Chipps Island into Suisun Bay. The PTM results for 30-day movement of particles released above Sutter Slough were evaluated using comparative regression analysis. The movement of Sacramento River water and particles to Chipps Island and to south Delta exports are shown as example of relatively simple relationships (i.e., algebraic expressions) that describe particle fate as a function of Delta flows. The particle fate relationships can be used as the basis for the evaluation of eggs and larvae or small fish movement in the Delta. Many other biological factors must be considered in addition to the water movement information to provide a biological assessment for a selected species life-stage. But understanding the effects of inflows, outflow, and exports on water movement is the logical beginning for many fish assessment methods.

Particles Reaching Chipps Island

Figure C.A-159 shows the percentage of particles released from Sacramento River above Sutter Slough reaching Chipps Island within 30 days as a function of the Sacramento River Inflow (cfs). The inflow is adjusted by the north Delta intakes for the ESO cases. Sacramento River flow is a logical flow variable that might control the movement to Chipps Island. It may be surprising that there is not a very strong regression between Sacramento River flow and movement to Chipps Island for the range of 10,000 cfs to 25,000 cfs. For flows above 50,000 cfs about 95% of the particles move past Chipps Island. One expected flow relationship would be based on the travel time (e.g., volume/flow) between Sutter Slough and Chipps Island. Higher flows should move the water (and particles) faster; more are expected to move past Chipps Island as the flow increases. Something else must be influencing the water movement to Chipps Island.

Figure C.A-160 shows the percentage of particles released from Sacramento River above Sutter Slough reaching Chipps Island within 30 days as a function of the San Joaquin River Inflow (cfs). This is a good example of a relatively strong regression that is certainly not the primary causal factor. Although the San Joaquin River inflow is a good indicator of total Delta inflow, the San Joaquin River inflow is not directly moving Sacramento River water (and particles) to Chipps Island. High San Joaquin River inflow may be supplying part of the south Delta exports and reducing the reverse OMR flows that would otherwise move more of the Sacramento River water towards the south Delta exports. The percentage of Sacramento River water reaching Chipps Island therefore increases with higher San Joaquin River inflows. Similar correlations with Mokelumne-Cosumnes inflow and with total Delta inflow are found; but these correlations should not be used to “manage the Delta”; increasing the San Joaquin River inflow or the Mokelumne River inflow would not likely increase the fraction of the Sacramento River fish that would reach Chipps Island.

Figure C.A-161 shows the percentage of particles released from Sacramento River above Sutter Slough reaching Chipps Island within 30 days as a function of the Export/Inflow ratio (corrected for ESO cases to be the South Delta exports/ [Inflow minus ND intake]). It might again be surprising that this flow ratio (E/I) does not provide a stronger relationship for describing the movement of Sacramento River water to Chipps Island. Although the maximum percentage is reduced at higher E/I (maximum of 100% at E/I of 0.2; maximum of 25% for E/I of 0.6) there is lots of scatter in the percentage of water (particles) reaching Chipps Island. For example, with an E/I ratio of 0.1, a wide range (25% to 100%) of particle percentages were simulated with the DSM2 PTM module to move past Chipps Island within 30 days.

Figure C.A-162 shows the percentage of particles released from Sacramento River above Sutter Slough reaching Chipps Island within 30 days as a function of the Delta outflow. This was the best relationship that was identified for describing the movement of Sacramento River water to Chipps Island. This relationship indicates that Delta outflow is the primary factor controlling the movement of Sacramento River water. For a Delta outflow of 10,000 cfs, the percentage of particles passing Chipps Island was 30% to 50%; for a Delta outflow of 20,000 cfs, the percentage of particles passing Chipps Island was 70% to 90%; and for a Delta Outflow of more than 25,000 cfs, the percentage of particles passing Chipps Island was greater than 90%. Because Delta exports and agricultural diversions are quite variable from month-to-month, and not a constant fraction of Sacramento River flow or Delta inflow, the correlation with Sacramento River flow or Delta inflow was not as strong as the correlation with Delta outflow.

This relationship with Delta outflow can be compared with the travel time for Sacramento River water between Sutter Slough (near Hood) and Chipps Island. The total volume of water in the Sacramento River channels (including Sutter and Steamboat and Cache Slough) is about 250,000 acre-feet (SDIP 2005 Table 5.2-1). The average residence time for water flowing through a tank is:

Travel Time (days) = Volume (af) /Flow (af/day)

The travel time decreases as the flow is increased, with a 1/flow or "flow-dilution" relationship. A flow of 5,000 cfs corresponds to 10,000 af/day and a travel time of about 24 days. A flow of 10,000 cfs corresponds to 20,000 af/day and a travel time of about 12 days. A flow of 20,000 cfs corresponds to a travel time of about 6 days, and a flow of 30,000 cfs corresponds to a travel time of about 4 days. The travel times for flows of more than 5,000 cfs are less than 30 days. But many of the particles are tidally mixed through the Sacramento River and San Joaquin River channels and remain upstream of Chipps Island for much longer than the average travel time. Without the PTM results, it would be difficult to estimate the linear relationship with outflow shown in Figure C.A-162. This relationship is the result of the combination of outflow determining the average residence time and tidal movement determining the mixing of the particles within the Delta channels and the distribution of particles passing Chipps Island. This outflow relationship might be used to estimate the fraction of small migrating fish that would move (passively) between the Sacramento Trawl and the Chipps Island Trawl in a month. The movement might be faster if the fish are actively swimming (migrating) and might be slower if the fish are rearing (feeding) within the Delta channels. The survival might be a function of the travel time. This relationship suggests that the movement might increase linearly with Delta outflow. Evaluating the likely biological responses and behaviors of the selected fish life-stage will be more challenging than determining the water movement.

Particles Entrained in South Delta Pumping

Some of the Sacramento River water (and particles) diverted to the San Joaquin River channel will be tidally transported (mixed) into Old and Middle River channels and will move south (upstream) toward the south Delta CVP and SWP export pumps. Entrainment of Sacramento River water (and particles) in South Delta Pumping might be expected to be related to south Delta pumping, OMR flows from the central Delta, the E/I ratio, or the diversion flow into DCC and Georgiana Slough. PTM results were reviewed for a variety of hydrological variables to identify the most accurate relationships. Figure C.A-163 shows the percentage of particles released from Sacramento River above Sutter Slough reaching the CVP and SWP south Delta exports within 30 days as a function of the South Delta Exports (cfs). There is clearly a direct relationship with exports; 0% entrainment if exports are less than 2,000 cfs, 0% to 25% if exports are 6,000 cfs and 25% to 50% if exports are 10,000 cfs. Some of the variation in entrainment might be caused by agricultural diversions, which entrain about 0% to 10% of the Sacramento particles, depending on the month and total Delta inflow. But the Sacramento entrainment ranged from 0% to 30% for exports of 6,000 cfs to 8,000 cfs; some other factor must influence the entrainment of Sacramento River water (particles).

Figure C.A-164 shows the percentage of particles released from Sacramento River above Sutter Slough reaching the CVP and SWP south Delta exports within 30 days as a function of the SD Exports/Inflow ratio. The inflow is adjusted for the ESO cases to be the total inflow minus the north Delta intakes (cfs). The relationship with the E/I ratio is similar to the relationship with south Delta exports, but there is considerable scatter for E/I between 0.3 and 0.5. The Sacramento entrainment was 0% for E/I less than 0.15; the entrainment was 0% to 10% for E/I of 0.25; the entrainment was 5% to 35% for E/I of 0.35 and was 30% to 50% for E/I of 0.65 (maximum allowed). Figure C.A-165 shows the percentage of particles released from Sacramento River above Sutter Slough reaching the CVP and SWP south Delta exports within 30 days as a function of the Old and Middle River flow (cfs). The OMR flow might be a better flow parameter because it is the portion of the south Delta exports not supplied by San Joaquin River inflow. There was 0% entrainment of Sacramento River water when OMR flow was greater than -2,500 cfs (i.e., reverse flow of 2,500 cfs toward pumps was not enough to cause entrainment of Sacramento River water in 30 days). Entrainment was 5% to 20% with OMR flow of -5,000 cfs; entrainment was 20% to 50% for OMR flow of -7,500 cfs to -12,500 cfs.

Figure C.A-166 shows the percentage of particles released from Sacramento River above Sutter Slough reaching the CVP and SWP south Delta exports within 30 days as a function of the net San Joaquin River outflow, QWEST. When QWEST is positive there is a net flow from the mouth of the Mokelumne River towards Antioch and Chipps Island. When QWEST is negative, the reverse Old and Middle River flow is greater than the DCC and Georgiana Slough flow from the Sacramento River. The entrainment of Sacramento River water was 0% when QWEST was greater than 5,000 cfs. There was 0% to 10% entrainment of Sacramento River water when QWEST was 2,500 cfs; some months had reverse OMR flows when QWEST was 2,500 cfs. For existing conditions the entrainment was 10% to 20% when QWEST was 0 cfs and was 30% to 50% when QWEST was -5,000 cfs. The effects from the tidal natural communities and transitional uplands restoration apparently caused more scatter for the entrainment simulated for the ESO cases. Managing QWEST (opening the DCC) might be an alternative method for reducing the entrainment of Sacramento River fish, and may be a more sensitive control for reducing the entrainment of longfin smelt or delta smelt that have entered the lower San Joaquin River habitat region. The benefits of closing the DCC (reducing the diversion of Sacramento River water to the central Delta) should be considered relative to the benefits of opening the DCC (reducing the south Delta entrainment of Sacramento and estuarine fish) as part of the BDCP adaptive management procedures.

5C.A.9.1.2 Cache Slough Particles

Sacramento River fish migrating through the Yolo Bypass during high flows and estuarine fish spawning and rearing in the Cache Slough-Liberty Island (flooded) complex were tracked with particles released into Cache Slough at the downstream end of Liberty Island. A considerable amount of tidal wetland restoration is planned as part of BDCP for the Cache Slough ROA.

Particles Reaching Chipps Island

The movement of particles released in Cache Slough at Liberty Island is similar to the movement of particles released in the Sacramento River above Sutter Slough. The percentage of the Cache Slough particles that reach Chipps Island within 30 days was not well-described by the Sacramento River inflow, the Yolo Bypass inflow, the total Delta inflow, nor by the E/I ratio. The percentage of Cache Slough particles reaching Chipps Island was best described by the Delta outflow. Figure C.A-167 shows the percentage of particles released from Cache Slough reaching Chipps Island within 30 days as a function of Delta outflow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was 40–50% for an outflow of 10,000 cfs and was 70–80% for an outflow of 20,000 cfs. There appeared to be a reduced percentage of particles reaching Chipps Island for the ESO cases, perhaps caused by a delay in the movement from the tidal muting (reduced tidal flows) caused by the expanded tidal restoration areas.

Particles Entrained in South Delta Pumping

The movement and entrainment of particles released from Cache Slough in the south Delta exports was most directly related to the south Delta exports, OMR flow, and QWEST. Figure C.A-168 shows the percentage of particles released from Cache Slough reaching the CVP and SWP south Delta exports within 30 days as a function of the south Delta Exports. The maximum scale for the percentage of Cache Slough particles entrained was reduced to 25%. The particles entrained was 0% for exports of less than 4,000 cfs, was 0–5% for exports of 6,000 cfs, was 2.5–7.5% for exports of 8,000 cfs, was 10% to 17.5% for exports of 10,000 cfs, and was at least 15% for exports of 12,000 cfs (not many cases). This is a reasonable relationship with a range of expected entrainment of about 5–10% at exports of more than 6,000 cfs. This relationship might be used to protect juvenile delta smelt or juvenile splittail that have emerged from the Cache Slough complex; maintaining exports of less than 5,000 cfs would reduce entrainment to less than 2.5%.

Figure C.A-169 shows the percentage of particles released from Cache Slough reaching the CVP and SWP south Delta exports within 30 days as a function of OMR flow. The entrainment of particles released from Cache Slough was 0% for OMR greater than -2,500 cfs. The entrainment was 0% to 5% for OMR flow of -5,000 cfs, the entrainment was 5–15% for OMR flow of -7,500 cfs, and was 10–20% for OMR flow of -10,000 cfs. This relationship with OMR is similar to the relationship with south Delta exports; both curves suggest that increasing exports from 5,000 cfs to 10,000 cfs would increase entrainment of Cache Slough particles from 0% to about 15%. Increasing reverse OMR flow from -5,000 cfs to -10,000 cfs would have the same effect, increasing entrainment of Cache Slough particles from 0% to about 15%.

Figure C.A-170 shows the percentage of particles released from Cache Slough reaching the CVP and SWP south Delta exports within 30 days as a function of QWEST flow. The most direct connection between Cache Slough and the exports is through Threemile Slough to the San Joaquin River, just upstream of False River, which connects to Franks Tract and Old River. A positive QWEST indicates that the net flow from Threemile Slough would be downstream past Antioch to Jersey Point. The entrainment of particles released from Cache Slough was 0% for QWEST flow greater than 2,500 cfs. The entrainment was 0–2.5% for QWEST flow of 0 cfs, the entrainment was 7.5–10% for QWEST flow of -2,500 cfs, and was 15–17.5% for QWEST flow of -5,000 cfs. This relationship is similar to the relationships with south Delta exports and OMR flow, but the variation (range) in the estimated entrainment was only 2.5% (rather than 5–10%). The entrainment will increase from 0% to 15% as the QWEST flow is reduced from 0 cfs to -5,000 cfs. This would be the most accurate flow relationship to use for protecting Cache Slough fish from entrainment. The QWEST flow can be controlled by reducing the exports or by opening the DCC to allow more Sacramento River water to be diverted into the Mokelumne River and the San Joaquin River. A QWEST flow of 2,500 cfs would be needed to reduce the Sacramento River fish to less than 10% (Figure C.A-166). Management of these interior Delta flows for fish protection will require adaptive management monitoring and decision-making.

5C.A.9.1.3 Mokelumne and Cosumnes River Particles

Mokelumne and Cosumnes River juvenile fish migrating to the estuary, and Sacramento River juvenile fish diverted into the DCC (when open) and Georgiana Slough were tracked with particles released into the Mokelumne River just downstream of the Cosumnes River confluence. A considerable amount of tidal wetland habitat restoration is planned as part of BDCP for the Cosumnes, Mokelumne and Snodgrass Slough ROA.

Particles Reaching Chipps Island

The movement of particles released in the Mokelumne River that reach Chipps Island within 30 days was not well-described by DCC and Georgiana Slough diversions, Mokelumne-Cosumnes inflow, total Delta inflow, Delta outflow, nor the E/I ratio. The percentage of Mokelumne River particles reaching Chipps Island was best described by OMR and QWEST; this is surprising because these flow variables normally describe the south Delta entrainment. Figure C.A-171 shows the percentage of particles released from Mokelumne River reaching Chipps Island within 30 days as a function of OMR flow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was generally 0% when OMR was less than 0 cfs, but there were some values between 0% and 20% reaching Chipps Island when OMR was -5,000 cfs, and a few values of 80% reaching Chipps Island for OMR of -3,000 cfs. The high percentage of particles reaching Chipps Island with negative OMR flows (toward south Delta pumps) must be the result of another compensating Delta flow condition. When OMR flow was greater than 2,500 cfs, the percentage of particle reaching Chipps Island from the Mokelumne was 80%. Figure C.A-172 shows the percentage of particles released from Mokelumne River reaching Chipps Island within 30 days as a function of QWEST flow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was 0% when QWEST was less than 1,000 cfs, was about 20% when QWEST was 5,000 cfs, and increased rapidly to about 80% when QWEST was 10,000 cfs or more. There appeared to be a reduced percentage of particles reaching Chipps Island for the ESO cases, perhaps caused by a delay in the movement caused by the expanded tidal restoration areas (increased residence time). This would not be a negative effect on juvenile migrating fish if the expanded tidal natural communities and transitional uplands provides good rearing conditions without increasing predation losses.

Particles Entrained in South Delta Pumping

The movement and entrainment of particles released from Mokelumne River in the south Delta exports was best described by south Delta exports, QWEST, and OMR flow. Figure C.A-173 shows the percentage of particles released from Mokelumne River reaching the CVP and SWP south Delta exports (entrained) within 30 days as a function of QWEST flow. The percentage of particles entrained was 0% for QWEST greater than 5,000 cfs, was 0–40% for QWEST of 2,500 cfs, was 0–60% for QWEST of 0 cfs, and was 0% to 80% for QWEST of less than -2,500 cfs. The wide range of entrainment for each QWEST flow indicates that QWEST is not the only factor influencing entrainment of particles (small fish) from the Mokelumne River. Figure C.A-174 shows the percentage of particles released from Mokelumne River reaching the CVP and SWP south Delta exports (entrained) within 30 days as a function of OMR flow. The relationship with OMR flow was somewhat better than QWEST for describing the entrainment of Mokelumne River particles. The entrainment was 0% for OMR flow greater than -2,500 cfs (2,500 cfs toward the pumps). The percentage entrained increased rapidly with higher reverse OMR flow. The entrainment was 0–40% for OMR flow of -5,000 cfs and was 50–80% for OMR flow of -10,000 cfs. There was still a wide range of entrainment percentages for QWEST of -5,000 cfs to -10,000 cfs, suggesting that a combination of OMR and QWEST (or perhaps some other factor) would provide a more definitive relationship. The maximum south Delta entrainment was definitely reduced by increasing QWEST flow, which could be increased by reducing exports or opening the DCC. A 5,000 cfs increase in QWEST would reduce entrainment by 20%. Again, the benefits of opening the DCC for other fish should be considered relative to the protection of Sacramento River migrating fish, especially if fish- screening of the DCC could be implemented.

5C.A.9.1.4 San Joaquin River Particles

San Joaquin River juvenile fish migrating to the estuary enter the tidal Delta channels downstream of Vernalis near Mossdale. Because about half of the San Joaquin River flow is diverted into Old River near Mossdale, the San Joaquin River juvenile fish (including the spring-run Chinook restoration below Friant Dam) are subject to high entrainment at the south Delta exports. The ESO includes an operable barrier at the head of Old River (between Stewart Tract and Upper Roberts Island) to reduce the diversion of water and fish from the San Joaquin River to Old River. There is considerable riparian and floodplain restoration planned for the San Joaquin River and south Delta ROA. The CVP and SWP fish facilities might be improved to provide a higher successful salvage with lower predation losses for these San Joaquin River fish. Alternatively, a fish-screen gate or a non-physical barrier (e.g., combination of light, bubbles and sound) might be installed at the head of Old River to allow water diversion but reduce the diversion of fish into Old River. For existing conditions, the movement of particles (juvenile fish) from the San Joaquin River at Mossdale to the south Delta exports (entrainment) and to Chipps Island within 30 days was evaluated with the PTM results.

Particles Entrained in South Delta Pumping

Figure C.A-175 shows the percentage of particles released at Mossdale reaching the south Delta exports within 30 days as a function of the south Delta exports. There was a strong relationship with south Delta exports, but the variation in entrainment was high for exports of less than 6,000 cfs. For south Delta exports of less than 2,000 cfs the percentage entrained within 30 days was 0–50%; the percentage likely depends on the San Joaquin River flow relative to the south Delta exports. For exports of 2,000 cfs to 4,000 cfs the entrainment ranged from 10% to 50%; for exports of 4,000 cfs to 6,000 cfs the entrainment ranged from 50% to 80%. For exports of 6,000 cfs to 8,000 cfs the entrainment was 65–85%; for exports of 8,000 cfs to 10,000 cfs the entrainment was 80–90%; and for exports greater than 10,000 cfs the entrainment was 90%. However, there were several cases with exports of more than 8,000 cfs with entrainment of 20% to 50%; these cases had reduced Old River diversions (caused by agricultural barriers in the summer or operable gate for ESO cases). Generally more than 50% of the San Joaquin River particles were entrained when exports were greater than 4,000 cfs.

Figure C.A-176 shows the percentage of particles released at Mossdale reaching the south Delta exports within 30 days as a function of the south Delta exports. There was a strong relationship with south Delta exports, but the variation in entrainment was high for exports of less than 6,000 cfs. For south Delta exports of less than 2,000 cfs the percentage entrained within 30 days was 0–50%; the percentage likely depends on the San Joaquin River flow relative to the south Delta exports. For exports of 2,000 cfs to 4,000 cfs the entrainment ranged from 10% to 50%; for exports of 4,000 cfs to 6,000 cfs the entrainment ranged from 50% to 80%. For exports of 6,000 cfs to 8,000 cfs the entrainment was 65–85%; for exports of 8,000 cfs to 10,000 cfs the entrainment was 80–90%; and for exports greater than 10,000 cfs the entrainment was 90%.

Particles Reaching Chipps Island

Figure C.A-177 shows the percentage of particles released from San Joaquin River at Mossdale reaching Chipps Island within 30 days as a function of San Joaquin River flow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was generally 0% when San Joaquin River was less than 5,000 cfs, the percentage reaching Chipps Island was about 30% when the San Joaquin River flow was 5,000 cfs and the percentage reaching Chipps Island was about

80% when the San Joaquin River flow was 15,000 cfs (highest case was 70% reaching Chipps Island for San Joaquin River flow of 14,000 cfs). As expected, particles reached Chipps Island only when San Joaquin River flow was high; the relationship with San Joaquin River flow was apparently linear, once San Joaquin River flow was greater than 5,000 cfs. Figure C.A-178 shows the percentage of particles released from San Joaquin River at Mossdale reaching Chipps Island within 30 days as a function of the OMR flow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was generally 0% when OMR flow was less than 0 cfs, the percentage reaching Chipps Island was about 50% when the OMR flow was 2,500 cfs and the percentage reaching Chipps Island was about 100% when the OMR flow was 5,000 cfs. Particles reached Chipps Island only when OMR flow was positive; this relationship with OMR flow was also apparently linear, once OMR flow was greater than 0 cfs. These PTM results may explain why very few of the San Joaquin River juvenile Chinook make it to the Chipps Island trawl unless the San Joaquin River flows are quite high (greater than 10,000 cfs). Although some make it to the CVP and SWP salvage facilities and are trucked to release locations near Antioch, some improvements in the south Delta configuration (improved salvage efficiency or separated San Joaquin River corridor) appears to be necessary for greater San Joaquin River juvenile Chinook survival.

5C.A.9.1.5 San Joaquin River at Jersey Point

The previous PTM results can be used to evaluate the migration success of juvenile fish entering the Delta channels from the major river inflows. There may be some estuarine fish (i.e., longfin smelt and delta smelt) that spawn and rear in the lower San Joaquin River or Franks Tract habitats. PTM results for particles released in the San Joaquin River at Jersey Point (about 5 miles upstream from Antioch) are presented here to represent the 30-day entrainment and downstream movement for these estuarine fish.

Particles Reaching Chipps Island

The downstream movement of particles (juvenile fish) from Jersey Point to Chipps Island within 30 days was well described by Delta outflow, San Joaquin River inflow, and QWEST flow. Figure C.A-179 shows the percentage of particles released from San Joaquin River at Jersey Point reaching Chipps Island within 30 days as a function of QWEST flow. For the existing conditions, the percentage of particles passing Chipps Island within 30 days was about 20% when QWEST was -5,000 cfs; was 20% to 40% when QWEST was -2,500 cfs; was 30% to 70% when QWEST was 0 cfs; was 60% to 90% when QWEST was 2,500 cfs; and was 90% when QWEST was greater than 5,000 cfs. The range in the percentages of particles from Jersey Point reaching Chipps Island suggests that other Delta flow factors are important; high Delta outflow may increase the percentage and higher exports or reverse OMR flows may reduce the percentage reaching Chipps Island.

Particles Entrained in South Delta Pumping

The entrainment of particles (juvenile fish) released in the San Joaquin River at Jersey Point was well-described by relationships with south Delta exports, OMR flow and QWEST flow. Figure C.A-180 shows the percentage of particles released at Jersey Point reaching the south Delta exports within 30 days as a function of the south Delta exports. There was a strong relationship with south Delta exports and the variation in entrainment was just 10%. The percentage entrained within 30 days was 0% for south Delta exports of less than 4,000 cfs. The percentage of particles released at Jersey Point that were entrained in south Delta exports was 0% to 10% for exports of 6,000 cfs, was 10% to 20% for exports of 8,000 cfs, was 30% to 40% for exports of 10,000 cfs, and was 40% to

50% for exports of 12,000 cfs. The entrainment of Jersey Point particles increased from 0% to 50% as the south Delta exports increased from 4,000 cfs to 12,000 cfs.

Figure C.A-181 shows the percentage of particles released at Jersey Point reaching the south Delta exports within 30 days as a function of the OMR flows. The percentage entrained within 30 days was 0% for OMR flow of greater than -2,500 cfs. The percentage of particles released at Jersey Point that were entrained in south Delta exports was about 10% for OMR flow of -5,000 cfs; was 20% to 40% for OMR flow of -5,000 cfs, was 25% to 45% for OMR flow of -10,000 cfs, and was greater than 50% for OMR flow of -12,500 cfs (highest OMR flow case was -11,000 cfs). The entrainment of Jersey Point particles increased from 0% to 50% as the reverse OMR flow was increased from -2,500 cfs to -12,500 cfs.

Figure C.A-182 shows the percentage of particles released at Jersey Point reaching the south Delta exports within 30 days as a function of the QWEST flows. This flow relationship gave a very precise (small variation) entrainment percentage and was similar to the relationship with QWEST flow for entrainment of Cache Slough particles (see Figure C.A-170). The percentage entrained within 30 days was 0% for QWEST greater than 0 cfs. The percentage of particles released at Jersey Point that were entrained in south Delta exports was about 50% for QWEST low of -5,000 cfs; the relationship was linear and showed very little variation. Apparently a positive QWEST will prevent particles (juvenile fish) from Cache Slough or from Jersey Point from being tidally transported into Franks Tract and Old River and eventually to the south Delta exports. This PTM-simulated relationship suggests that QWEST may provide an important flow index for evaluating the entrainment risk of juvenile fish from Cache Slough or Jersey Point (or perhaps anywhere downstream of these locations). More specific evaluation of the entrainment risks for juvenile fish are presented in Appendix 5.B, *Entrainment*.

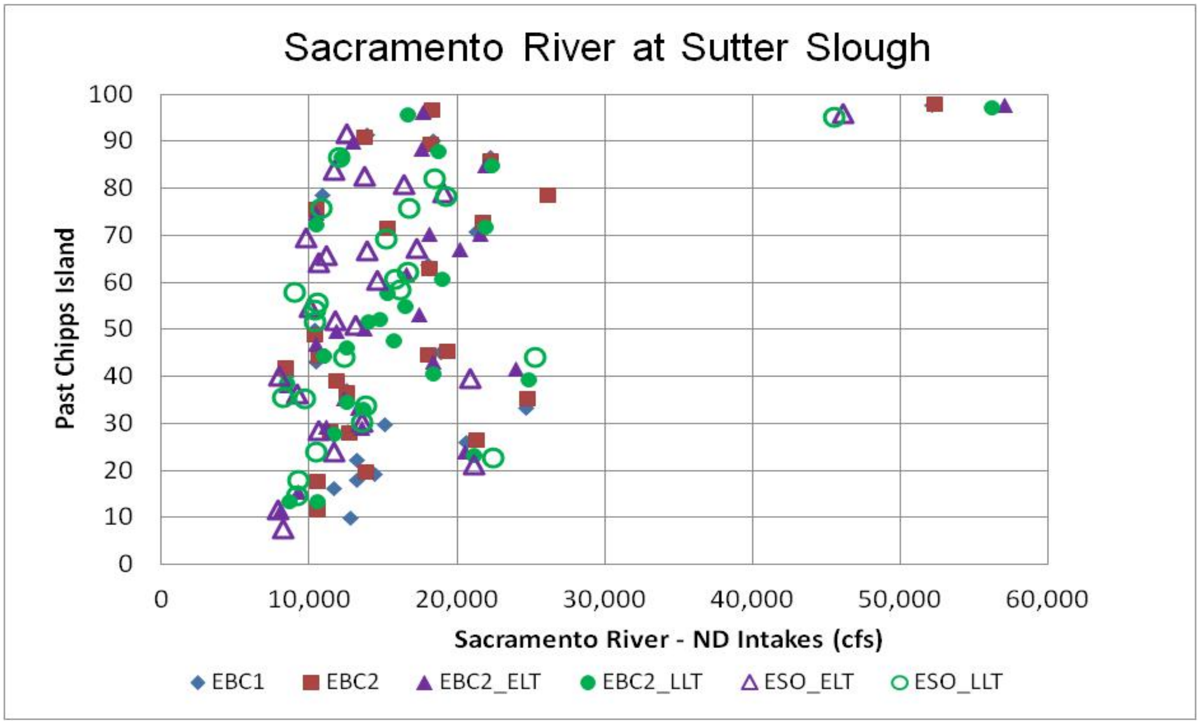


Figure C.A-159. Percentage of Particles from Sacramento River above Sutter Slough Reaching Chipps Island within 30 Days as a Function of the Sacramento River Inflow (cfs)

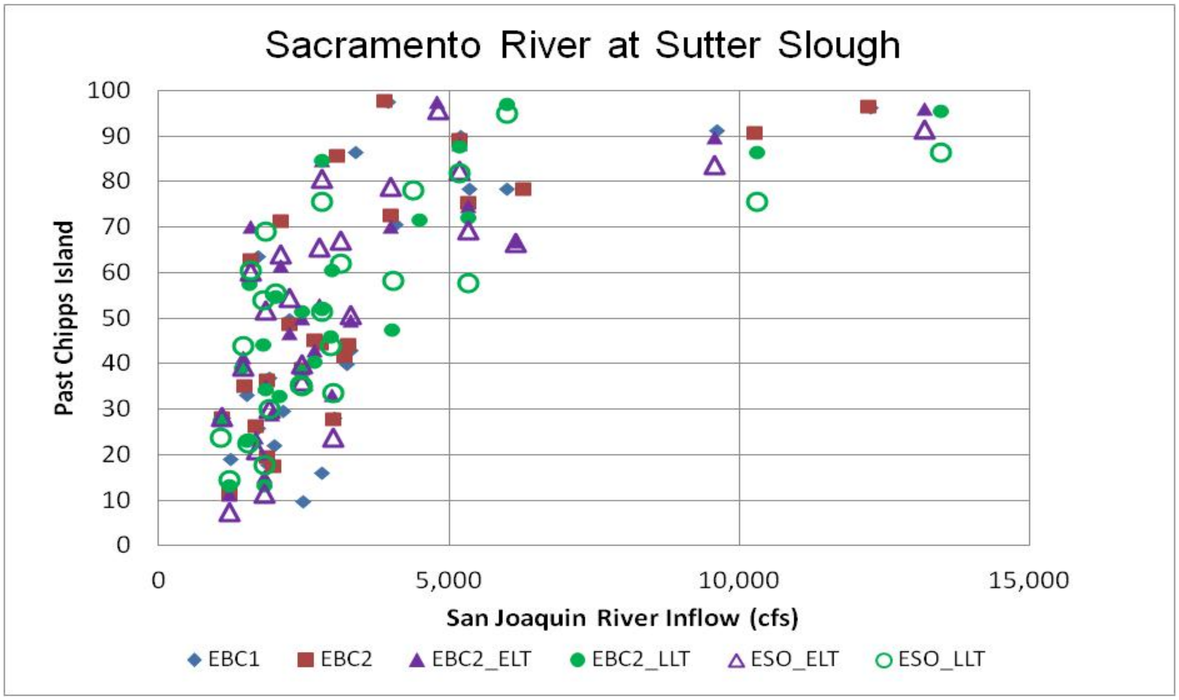


Figure C.A-160. Percentage of Particles from Sacramento River above Sutter Slough Reaching Chipps Island within 30 Days as a Function of the San Joaquin River Inflow (cfs)

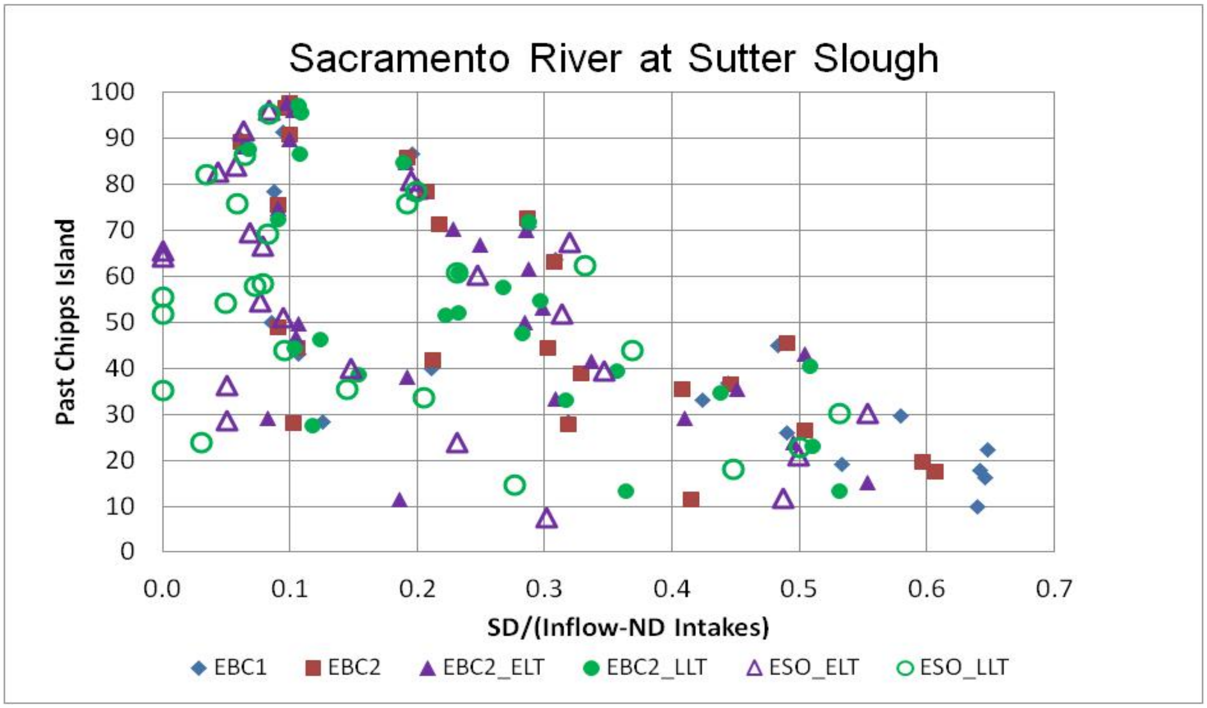


Figure C.A-161. Percentage of Particles from Sacramento River above Sutter Slough Reaching Chipps Island within 30 Days as a Function of the South Delta Export/Inflow Ratio

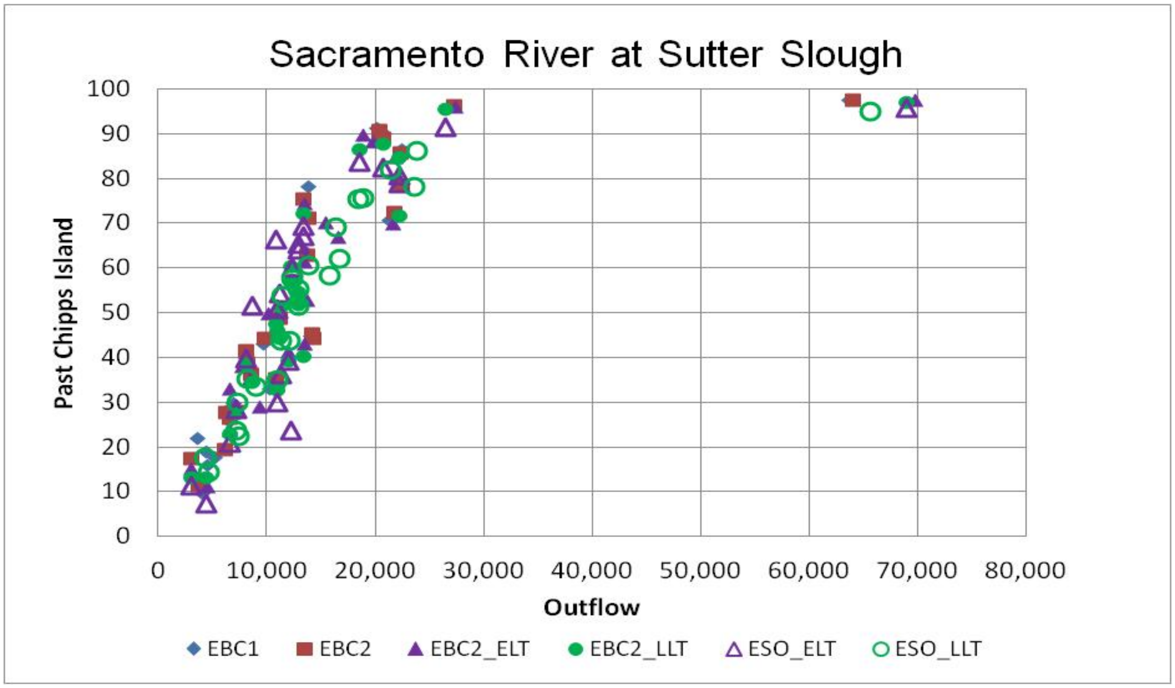


Figure C.A-162. Percentage of Particles from Sacramento River above Sutter Slough Reaching Chipps Island within 30 Days as a Function of the Delta Outflow (cfs)

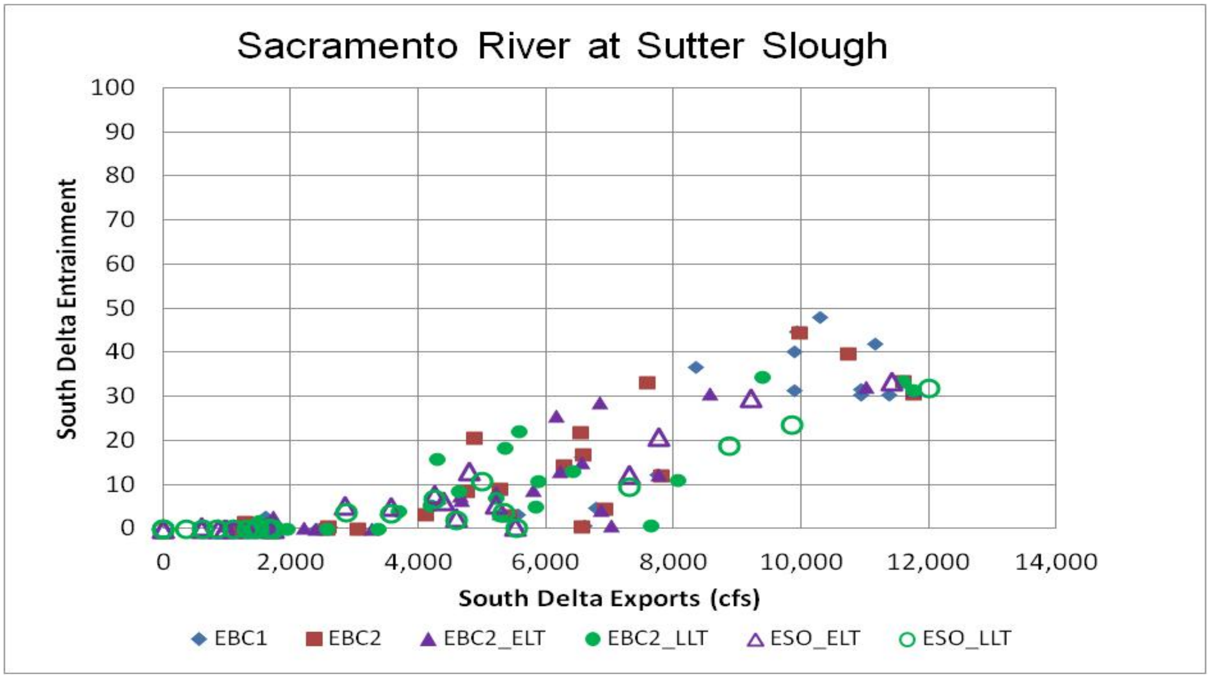


Figure C.A-163. Percentage of Particles from Sacramento River above Sutter Slough Reaching CVP and SWP South Delta Exports within 30 Days as a Function of the South Delta Exports (cfs)

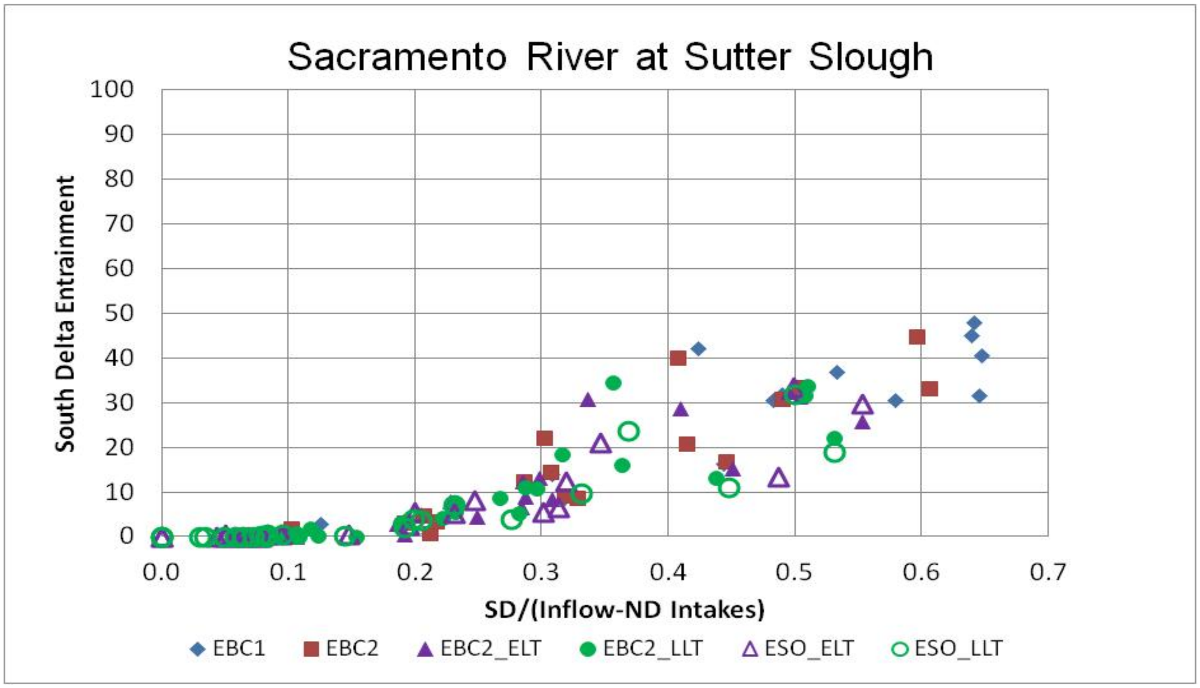


Figure C.A-164. Percentage of Particles from Sacramento River above Sutter Slough Reaching CVP and SWP South Delta Exports within 30 Days as a Function of the Adjusted Export/Inflow Ratio

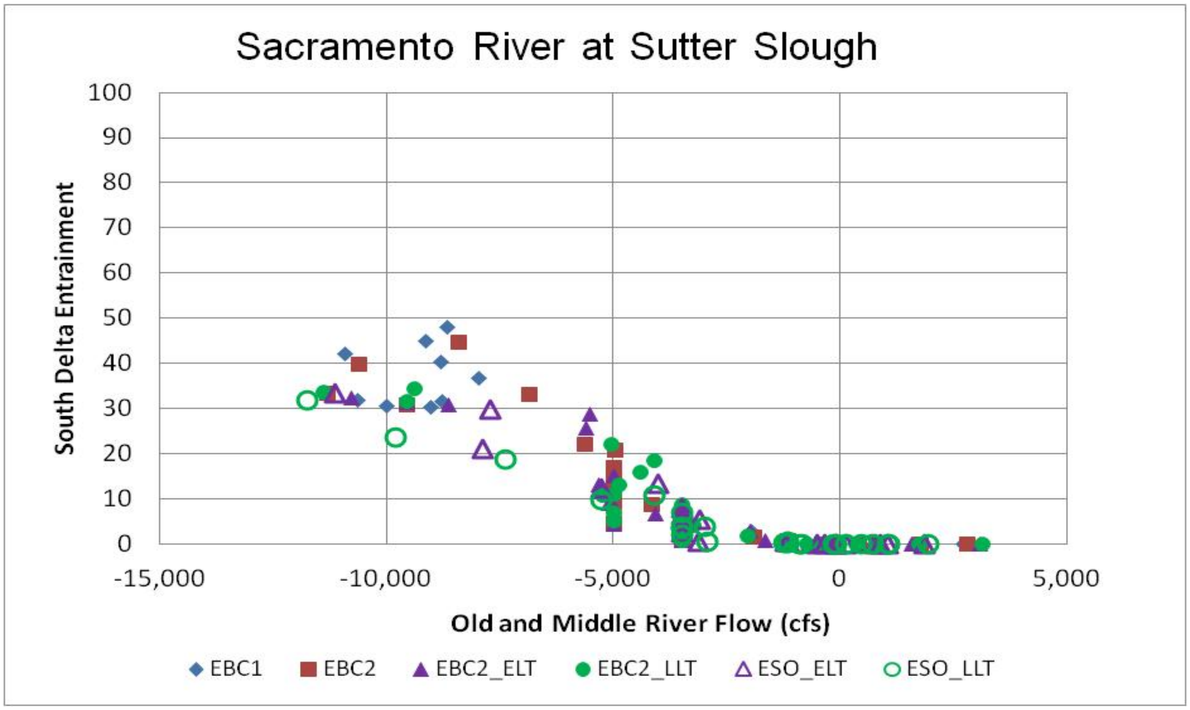


Figure C.A-165. Percentage of Particles from Sacramento River above Sutter Slough Reaching CVP and SWP South Delta Exports within 30 Days as a Function of Old and Middle River Flow (cfs)

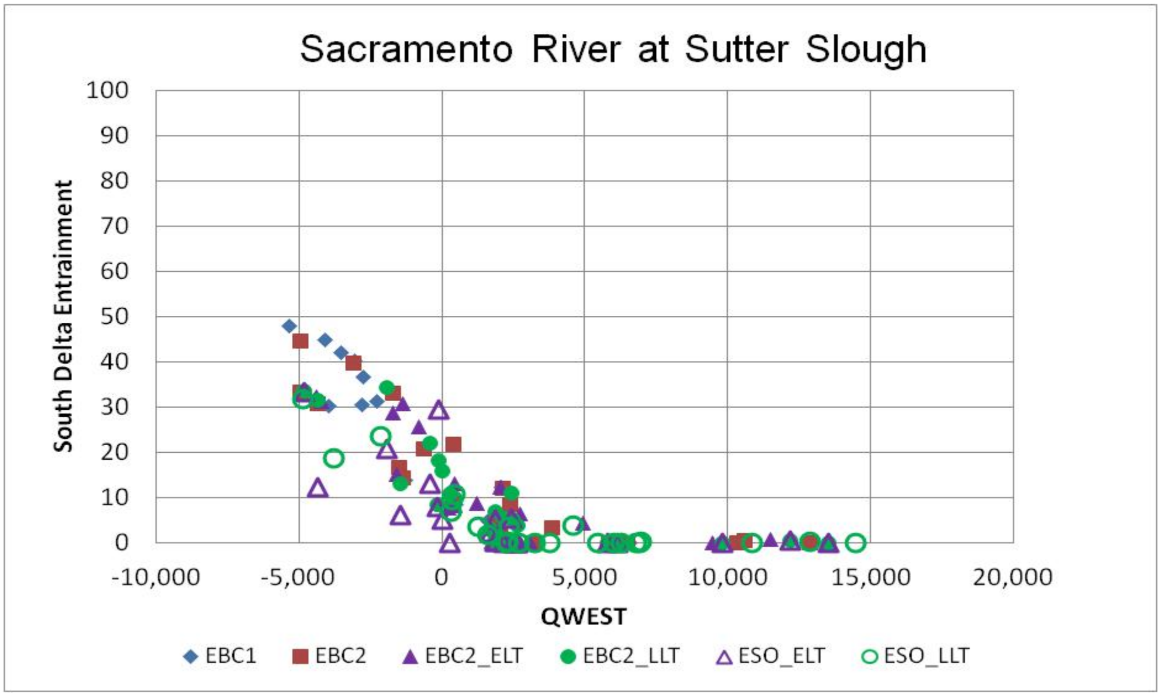


Figure C.A-166. Percentage of Particles from Sacramento River above Sutter Slough Reaching CVP and SWP South Delta Exports within 30 Days as a Function of QWEST Flow (cfs)

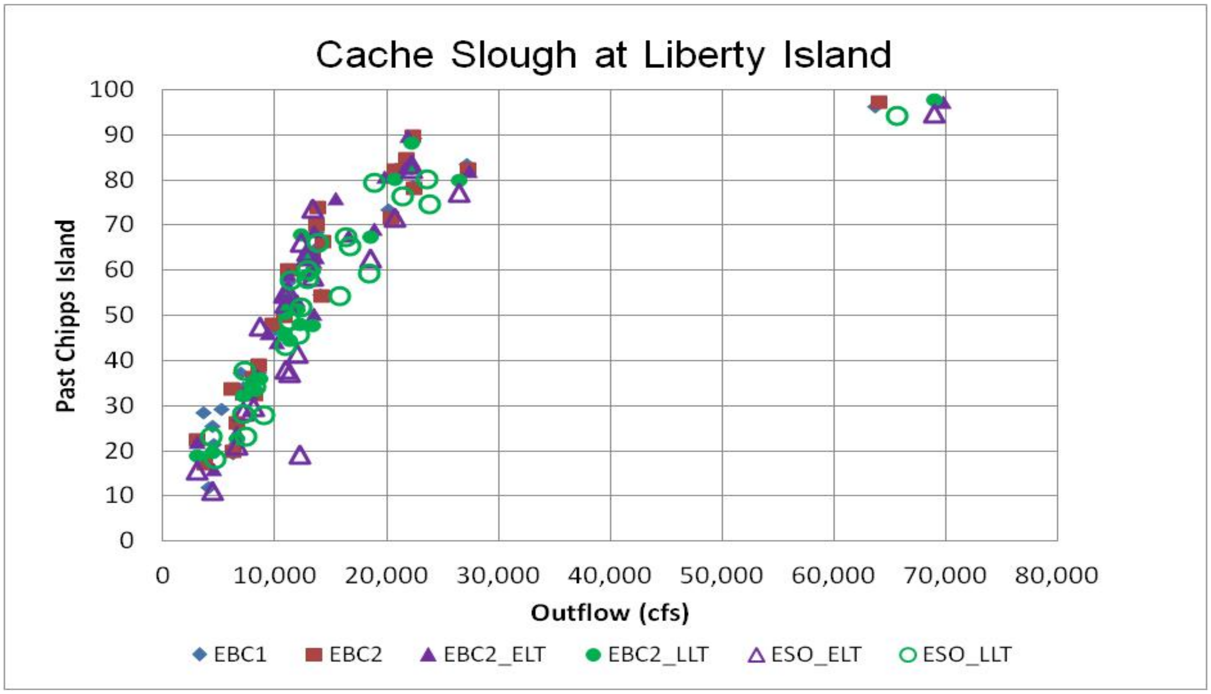


Figure C.A-167. Percentage of Particles from Cache Slough at Liberty Island Reaching Chipps Island within 30 Days as a Function of Delta Outflow (cfs)

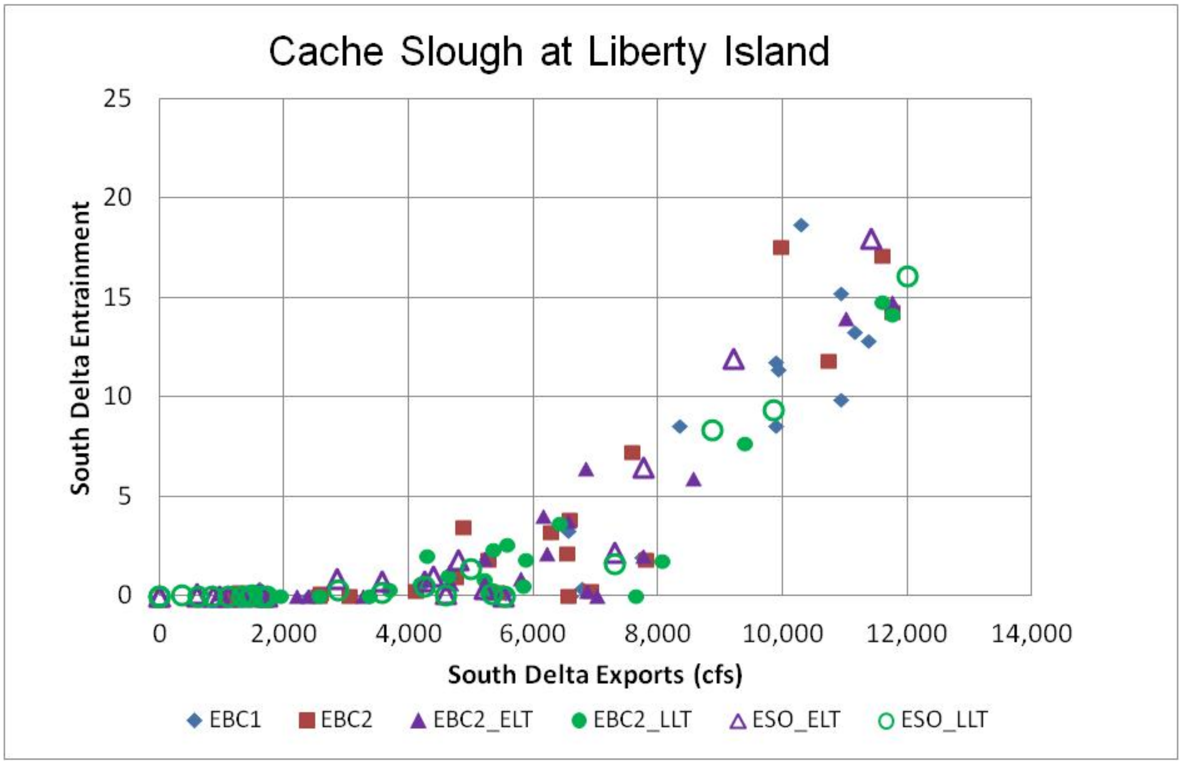


Figure C.A-168. Percentage of Particles from Cache Slough at Liberty Island Reaching CVP and SWP South Delta Exports within 30 Days as a Function of the South Delta Exports (cfs)

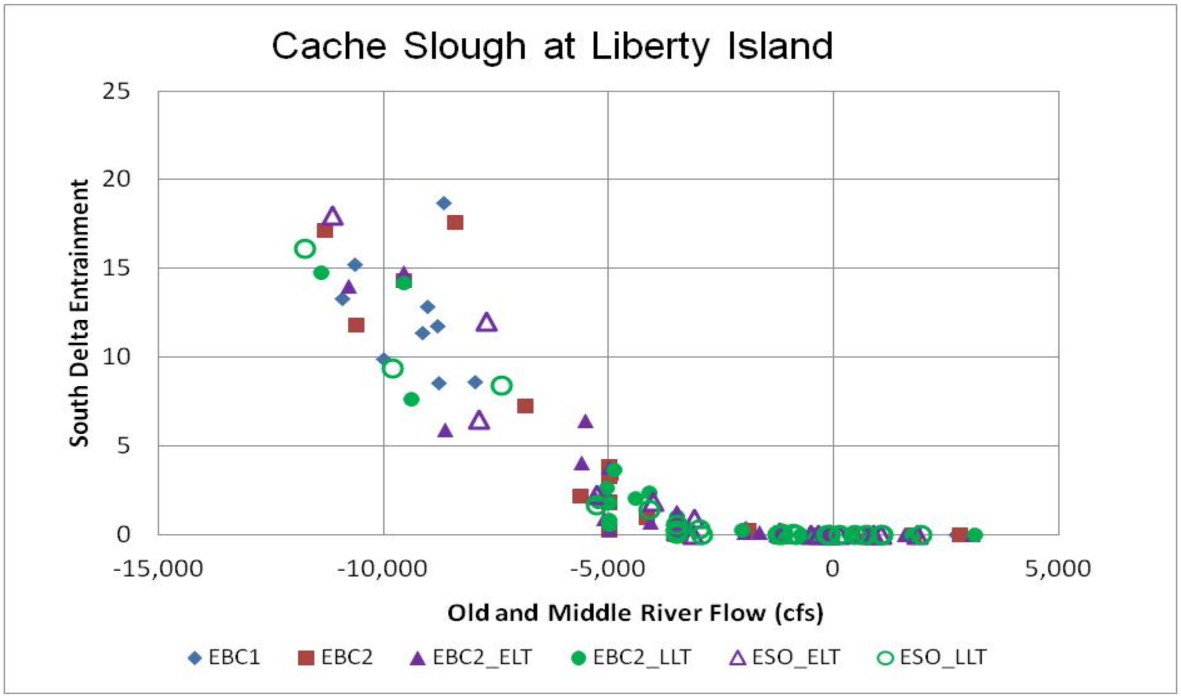


Figure C.A-169. Percentage of Particles from Cache Slough at Liberty Island Reaching CVP and SWP South Delta Exports within 30 Days as a Function of OMR Flow (cfs)

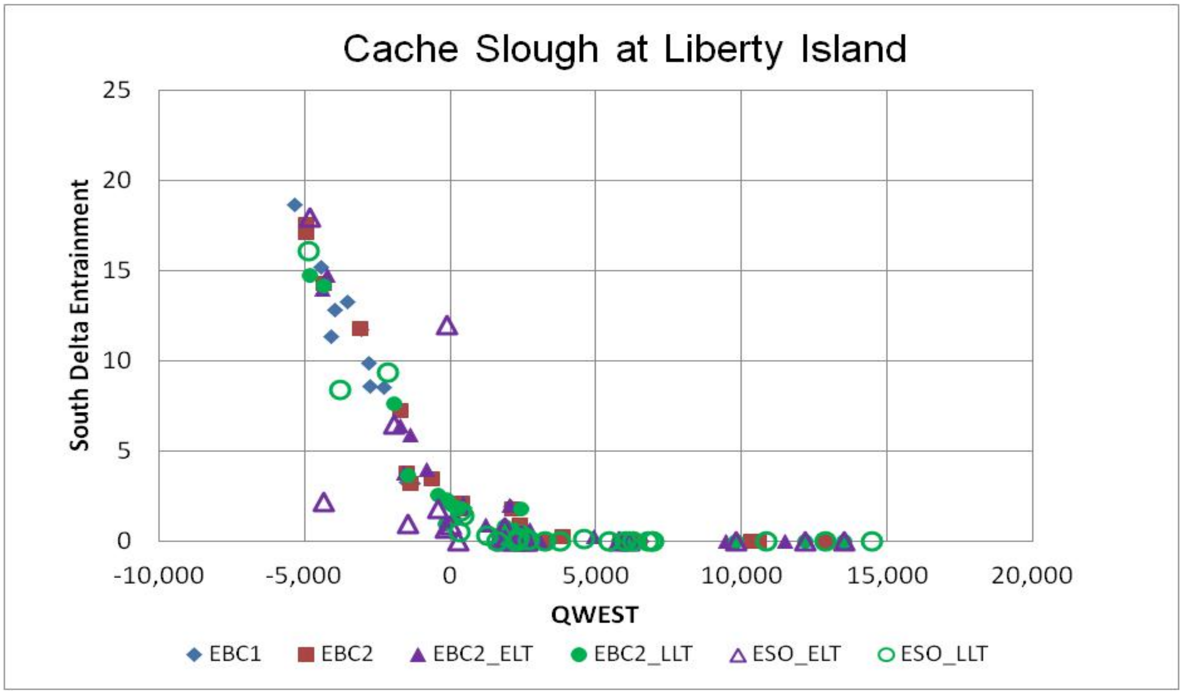


Figure C.A-170. Percentage of Particles from Cache Slough at Liberty Island Reaching CVP and SWP South Delta Exports within 30 Days as a Function of QWEST Flow (cfs)

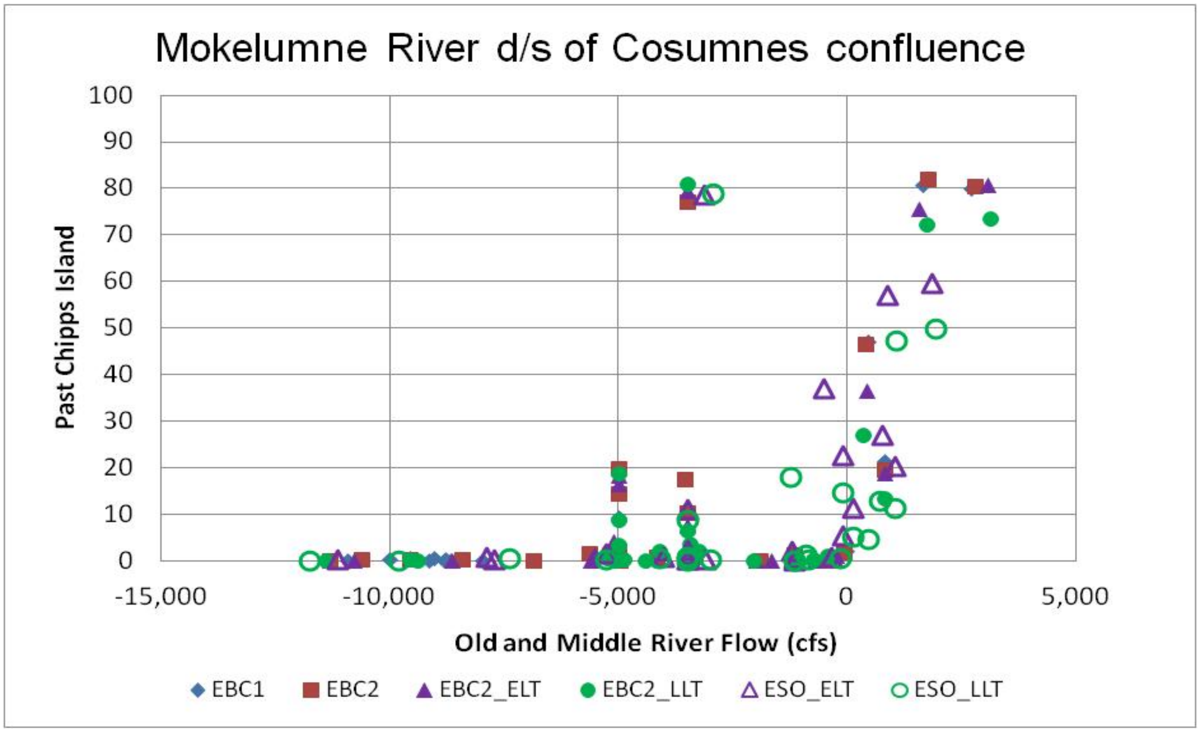


Figure C.A-171. Percentage of Particles from Mokelumne River Reaching Chipps Island within 30 Days as a Function of OMR Flow (cfs)

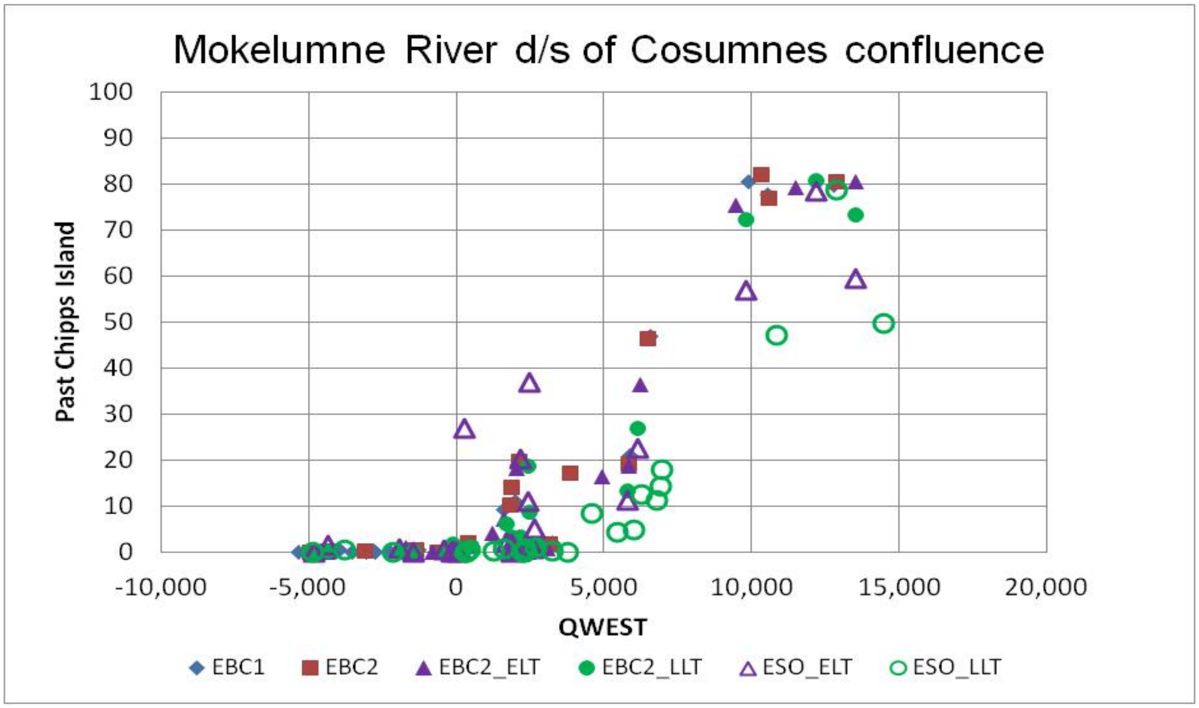


Figure C.A-172. Percentage of Particles from Mokelumne River Reaching Chipps Island within 30 Days as a Function of QWEST Flow (cfs)

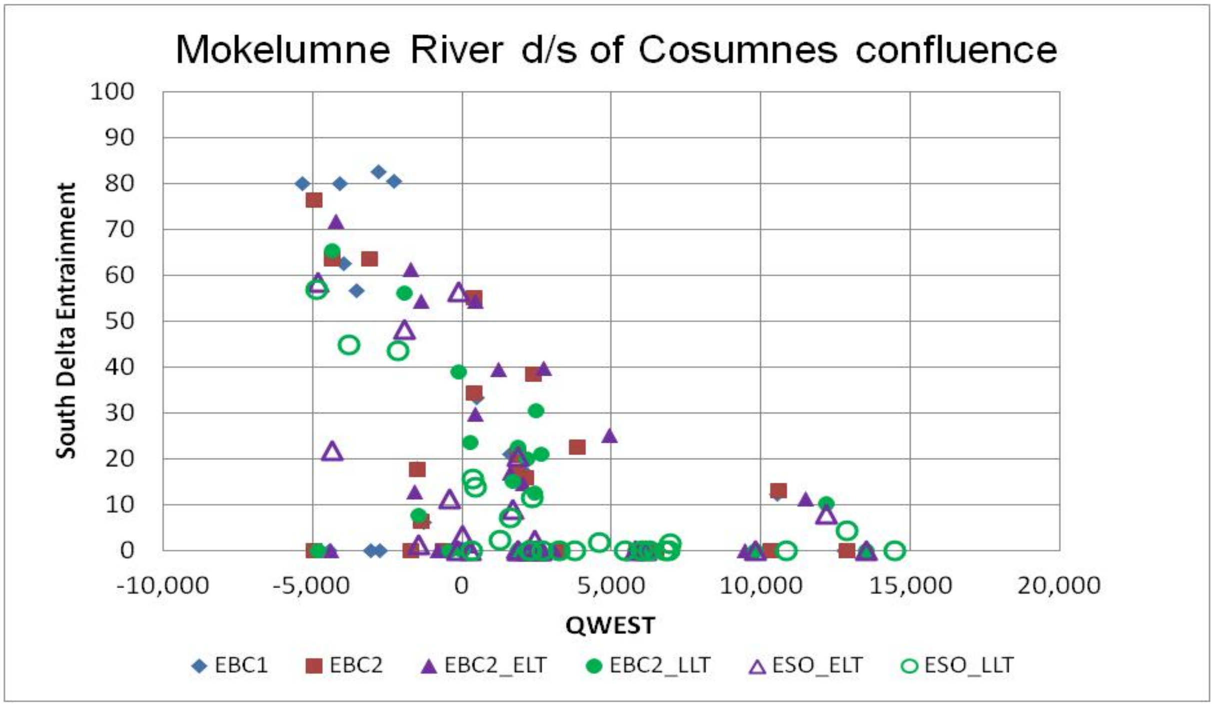


Figure C.A-173. Percentage of Particles from Mokelumne River Reaching CVP and SWP South Delta Exports within 30 Days as a Function of QWEST Flow (cfs)

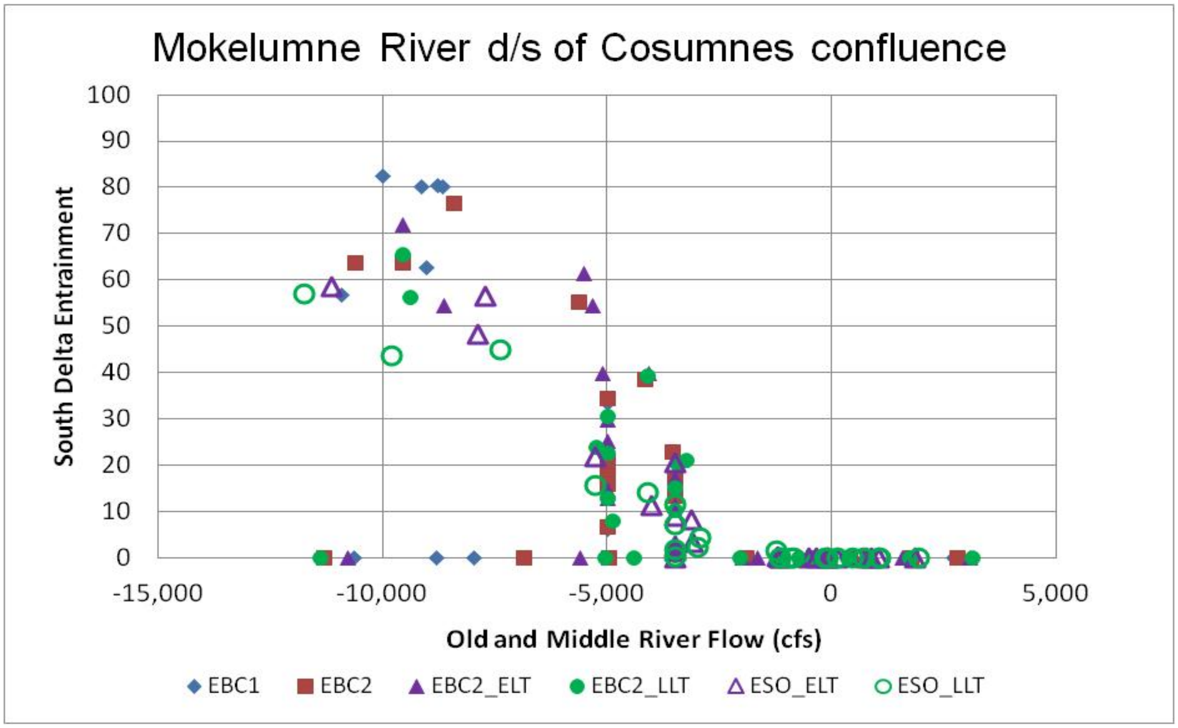


Figure C.A-174. Percentage of Particles from Mokelumne River Reaching CVP and SWP South Delta Exports within 30 Days as a Function of OMR Flow (cfs)

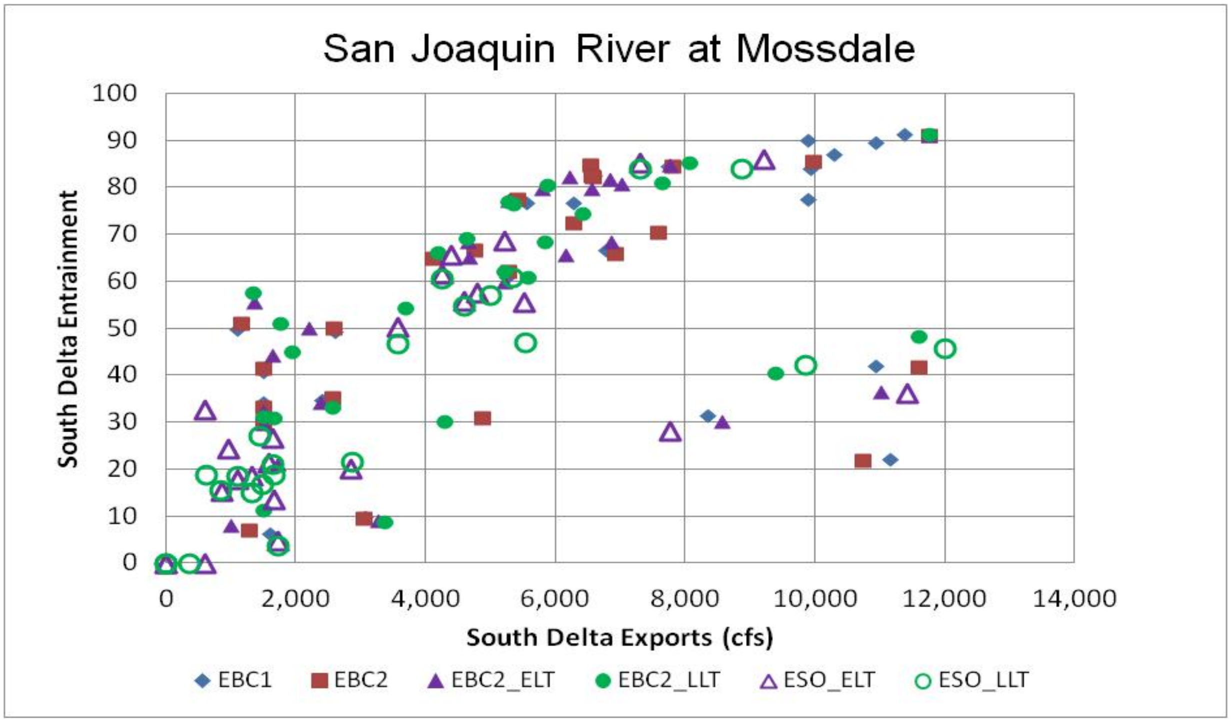


Figure C.A-175. Percentage of Particles from San Joaquin River at Mossdale Reaching CVP and SWP South Delta Exports within 30 Days as a Function of South Delta Exports (cfs)

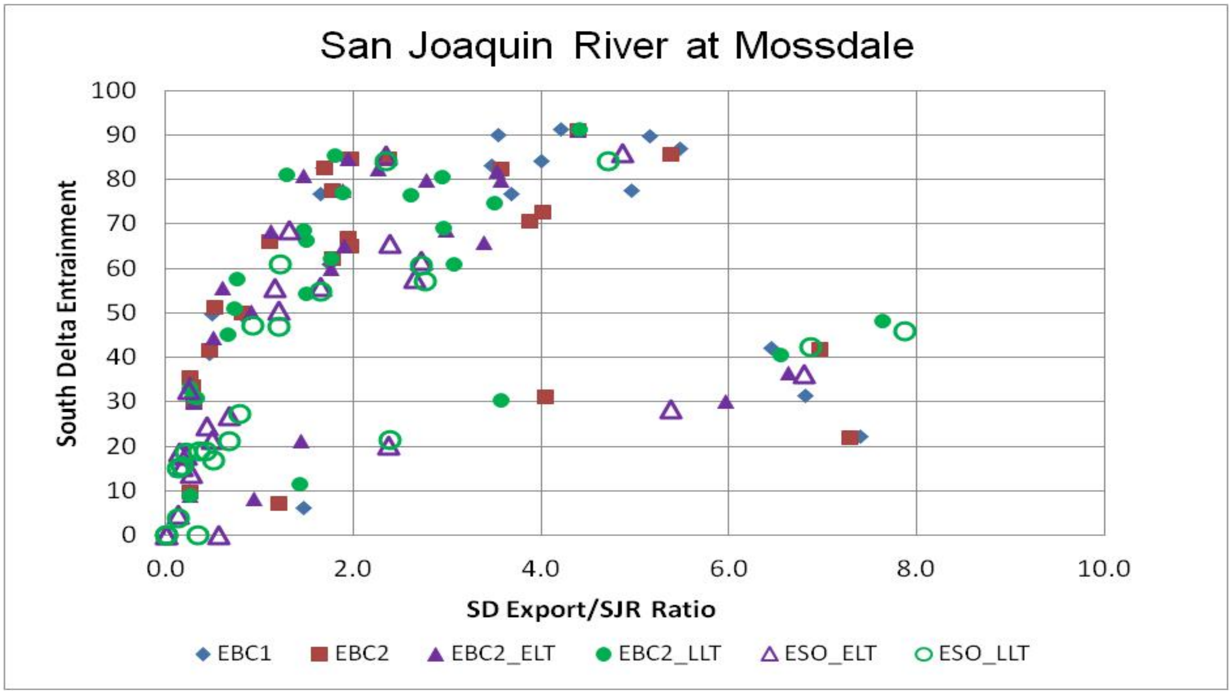


Figure C.A-176. Percentage of Particles from San Joaquin River at Mossdale Reaching CVP and SWP South Delta Exports within 30 Days as a Function of South Delta Exports/San Joaquin River Flow Ratio

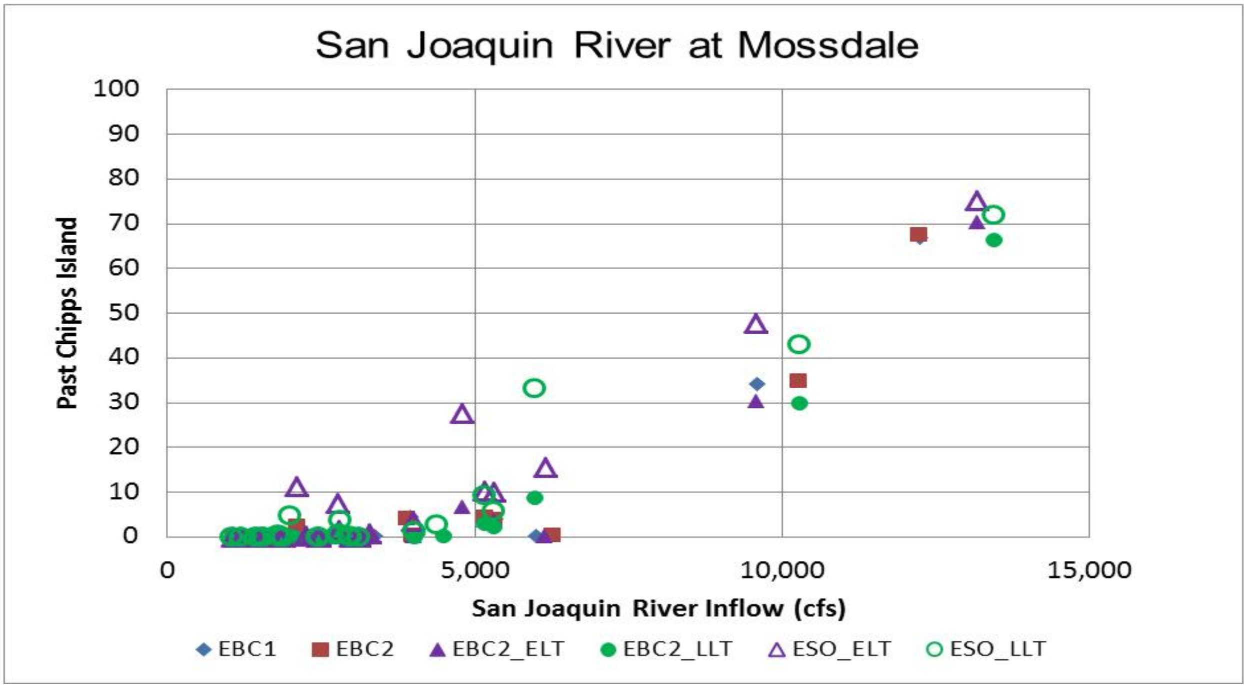


Figure C.A-177. Percentage of Particles from San Joaquin River at Mossdale Reaching Chipps Island within 30 Days as a Function of San Joaquin River Flow (cfs)

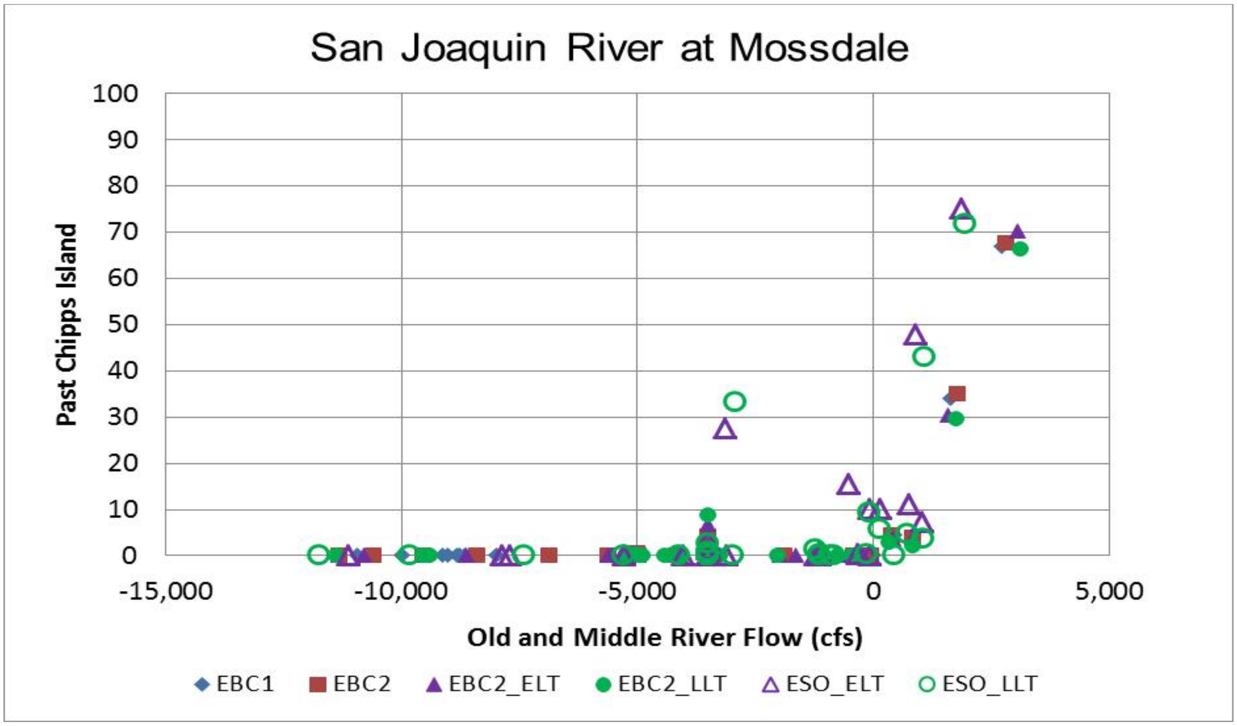


Figure C.A-178. Percentage of Particles from San Joaquin River at Mossdale Reaching Chipps Island within 30 Days as a Function of OMR Flow (cfs)

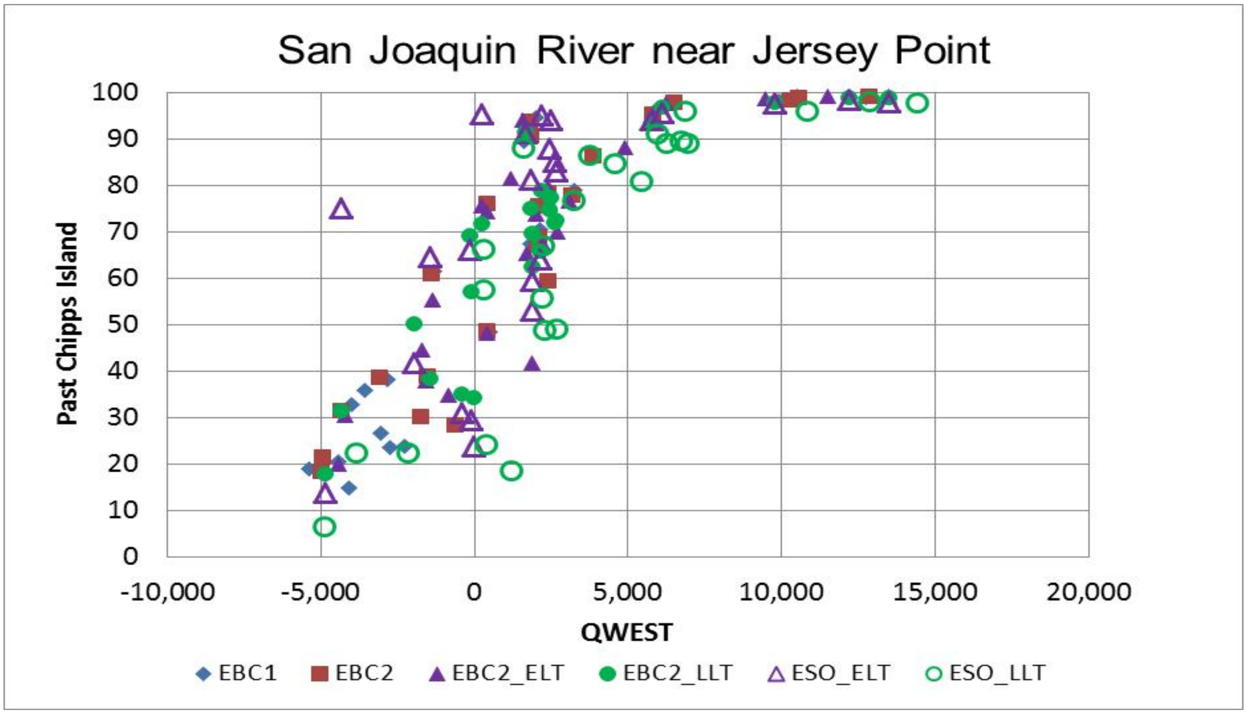


Figure C.A-179. Percentage of Particles from San Joaquin River at Jersey Point Reaching Chipps Island within 30 Days as a Function of QWEST Flow (cfs)

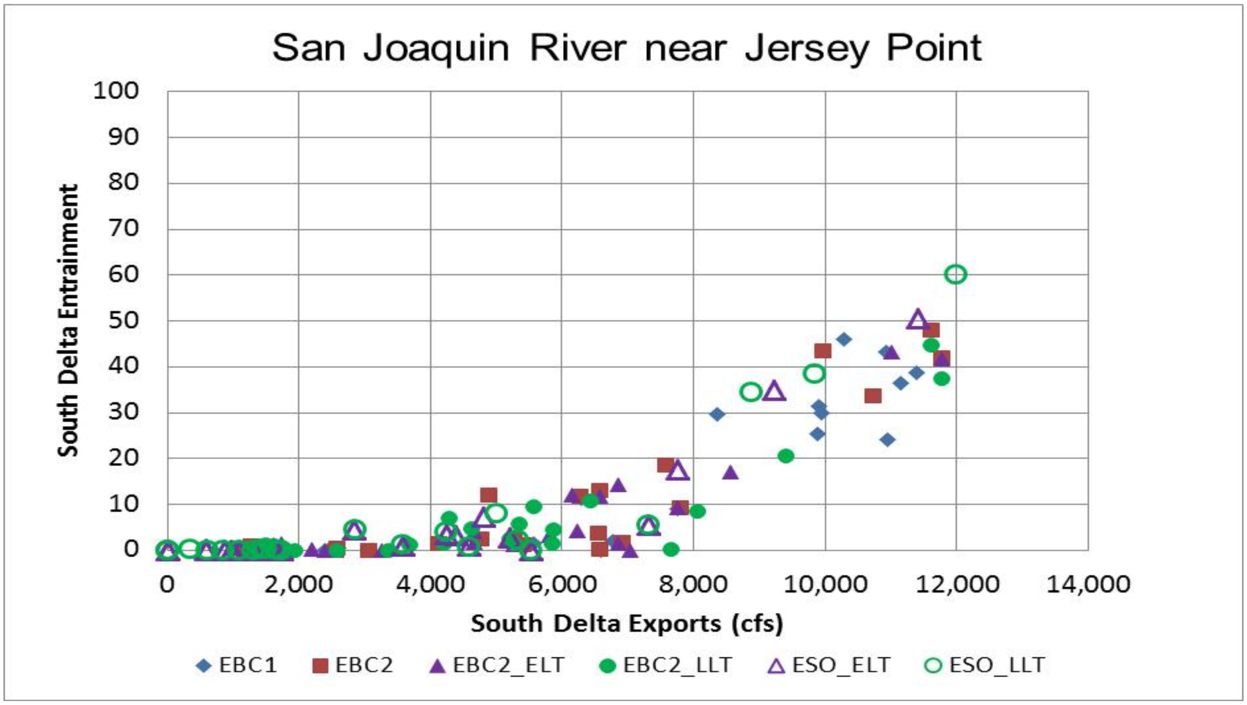


Figure C.A-180. Percentage of Particles from San Joaquin River at Jersey Point Reaching South Delta Exports within 30 Days as a Function of South Delta Exports (cfs)

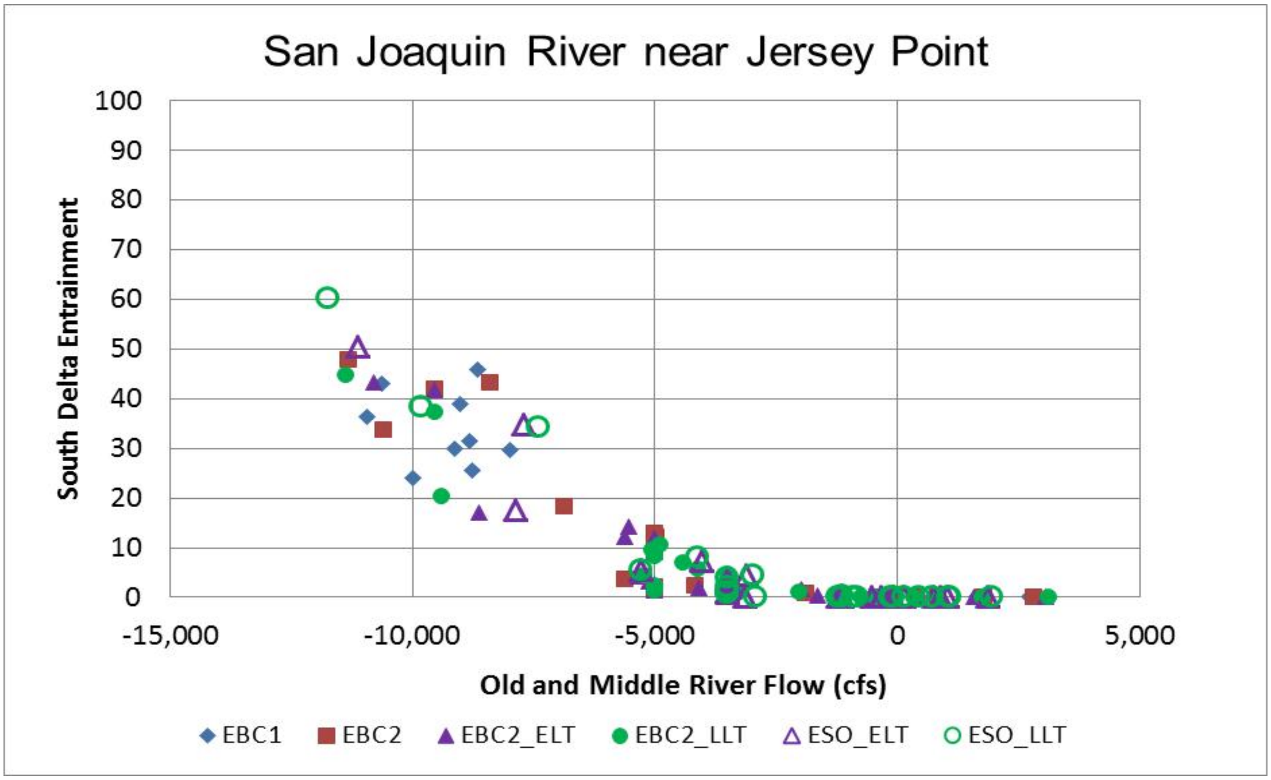


Figure C.A-181. Percentage of Particles from San Joaquin River at Jersey Point Reaching South Delta Exports within 30 Days as a Function of OMR Flow (cfs)

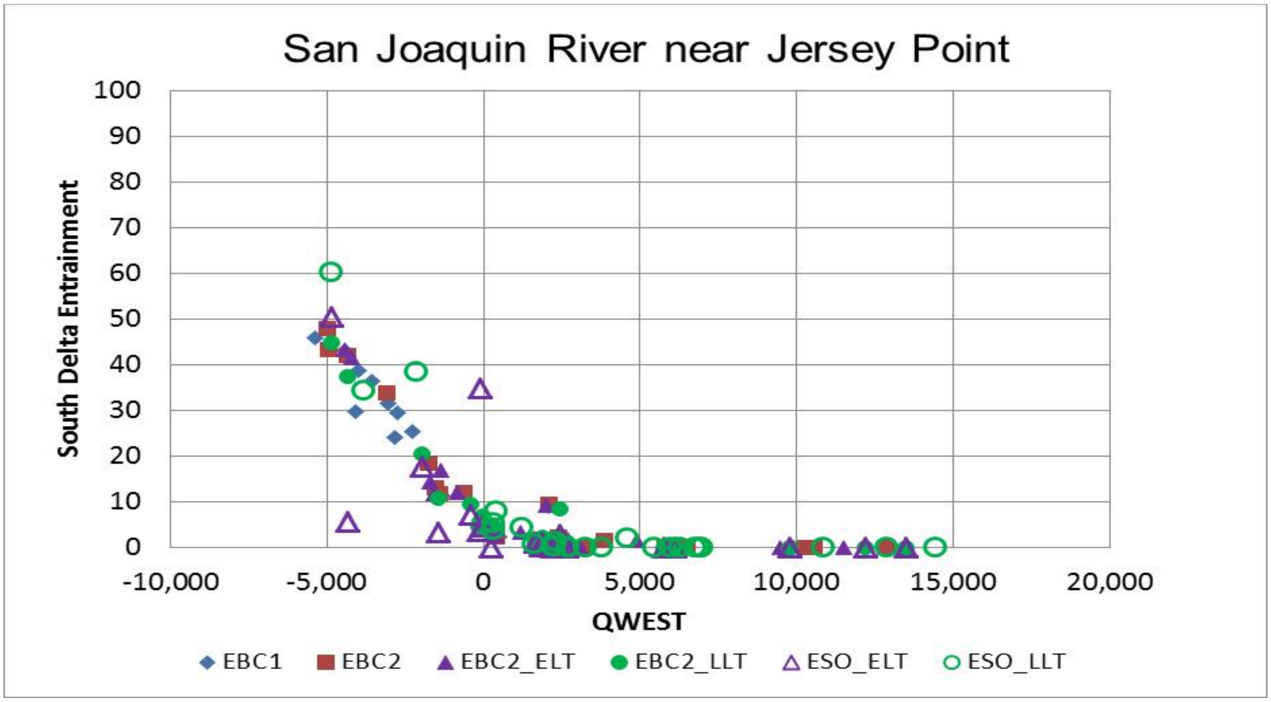


Figure C.A-182. Percentage of Particles from San Joaquin River at Jersey Point Reaching South Delta Exports within 30 Days as a Function of QWEST Flow (cfs)

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Sacramento River Ecological Flows Tool (SacEFT): Record of Design (v.2.00)

Sacramento River Ecological Flows Tool (SacEFT): Record of Design (v.2.00)

Prepared for

The Nature Conservancy
North Central Valley Office
500 Main St.
Chico, CA 95928

Prepared by

ESSA Technologies Ltd.
1765 West 8th Avenue, Suite 300
Vancouver, BC V6J 5C6

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Glossary

ATU	Accumulated Thermal Unit.
ADO.NET	The data-access component of the Microsoft .NET Framework.
Base Class Library (BCL)	An object oriented framework of reusable classes accessible from any .NET language.
BDCP	Bay Delta Conservation Plan.
Binary file	A file containing information that is in machine-readable form that can only be interpreted by a program that understands in advance exactly how it is formatted.
Binary object	A binary large object (BLOB) is a format of binary data stored in a relational database.
Business validation rules	A step or set of steps in a process or procedure or guide (algorithmic or heuristic) used by a customer for doing its business, work, or function, and often embodied in whole or in part in the software of a system.
CalSim II	A state-wide planning model which simulates operations of State Water Project and Central Valley Project facilities, under a Coordinated Operations Agreement, on a monthly time-step.
Cascade delete and update	A process that causes an action to be taken on rows in a database when another row is deleted.
CDWR	California Department of Water Resources.
Class	A template code file that can be used to create objects with a common definition and common properties, operations, and behavior. An object is an instance of a class.
COM components	A set of specification and services that facilitates a developer to create reusable objects and components for running various applications.
Compatibility list	A listing of imported physical model data instances that are allowed to be grouped together, based on having sufficiently similar embedded assumptions. Unless a data instance is part of the same "compatibility family", users cannot add it to a model scenario. This is the mechanism used to encourage use of apples and apples data instances.
Data instance	A SacEFT database concept for tracking imported datasets and their metadata using a unique identifier. Also used to tag information on non-imported (*i.e.*, local) generic rules/parameter values for focal species (*i.e.*, also used as a scenario identifier).
Database engine	The part of the database manager that provides the base functions and configuration files that are needed to use the database.
Desktop centered architecture	The majority of software application code is installed on individual workstations rather than accessed from a centralized server computer.
DOM	Daily Operations Model; a subsystem of CalSim which produces daily location-specific estimates of flow and temperature, while preserving the attributes of the monthly timestep model.
ERP	Ecological Restoration Program.
HEC-5Q	Alternate name for USBR Temperature Model.
IEM	Import/Export Manager – an envisioned SacEFT component for importing external datasets to the SacEFT relational database, using a combination of Excel templates, wrapper code for COM components that may be provided by USACE HEC programmers (for DSS files) and web services.
Metadata	The set of characteristics that describe the underlying assumptions and other major properties of a dataset or model.

NODOS	North of Delta Offstream Storage.
NWIS	USGS National Water Information System.
OOD	Object-Oriented Design. OOD is a design method in which a system is modeled as a collection of cooperating objects and individual objects are treated as instances of a class within a class hierarchy.
PM	Performance Measure.
RBDD	Red Bluff Diversion Dam.
RM	River Mile; a historical (but not rigorously quantitative) system of assigning locations along the Sacramento River Ecol according to early survey work. The benchmark location for RM is located at Chipps Island.
R/Y/G	The Red/Yellow/Green categorical indicator rating system used by EFT. It may sometimes be referred to by the values that define the breakpoints between categories: Hazard Thresholds or Indicator Breakpoints.
SacEFT	Sacramento River Ecological Flows Tool.
SOAP	A lightweight, XML-based protocol for exchanging information in a decentralized, distributed environment. SOAP can be used to query and return information and invoke services across the Internet.
SQL Server 2005 Express	A free, redistributable version of SQL Server 2005 designed for building simple data-driven applications.
SRWQM	Sacramento River Water Quality Model; a subsystem of the CalSim model which predicts water temperature (among other variables).
SSURGO	Soil Survey Geographic.
Structured error handling	An approach for signaling and responding to unexpected problems while a software program is running.
Thick-client architecture	Where application-specific code runs on and processes data on the client, rather than merely rendering data which has been processed by a server.
TNC	The Nature Conservancy.
TUGS	The Unified Gravel-Sand model.
USBR Temperature Model	Occasionally referred to as USBR TMS/HEC-5Q or HEC-5Q; and more recently the USBR Upper Sacramento River Temperature Model.
USFWS	United State Fish and Wildlife Service.
USGS	United States Geological Survey.
USRDOM	Upper Sacramento River Daily Operations Model.
USRWQM	Upper Sacramento River Water Quality Model; a subsystem of the CalSim model which predicts water temperature (among other variables).
Windows event log	The event logs contain the most important information for diagnosing application and operating system failures, determining the health and status of a system and verifying that system and applications are operating properly.
Wrapper	A program or script that sets the stage and makes possible the running of another, more important program.
WUA	Weighted Usable Area.

1. Decision Analysis Tool: Overview

1.1 Background and Goals

With over 50 years of international concern about the effects of flow alteration on ecosystems, the continued advancement of scientifically based tools to quantify the ecological effects of flow regulation and river channel alterations has become a prominent research activity (*e.g.*, Stalnaker 1994; Bunn and Arthington 2002; Annear *et al.* 2004; Veldkamp and Verburg 2004; Arthington *et al.* 2006; Poff *et al.* 1997; Petts 2009; Poff and Zimmerman 2010). Process-based models constitute one powerful and efficient tool for comparing the effects of alternative flow and river channel change scenarios. The Sacramento River Ecological Flows Tool (SacEFT) is a decision support tool emphasizing clear communication of trade-offs for key ecosystem targets associated with alternative conveyance, water operations and climate futures in the Sacramento River eco-region. The vision for SacEFT, one we believe we have achieved, is to create software that makes it easy for non-specialists to expand the ecological considerations and science foundation used to evaluate water management alternatives on the Sacramento River.

Practical integration of multi-species, multi-habitat needs in the evaluation of water operation scenarios is challenging. In SacEFT, we more transparently relate additional attributes of the flow regime to multiple species' life-history needs, thereby contributing to a more effective understanding of water operations on representative sets of focal species and their habitats (Chinook salmon, steelhead, green sturgeon, bank swallows, channel erosion/migration, Fremont cottonwoods, and large woody debris recruitment). Scientifically, SacEFT takes a bottom-up, process-based approach to the relationship between flow and related aquatic habitat variables, and looks at how these variables are tied to key species life-stages and ecosystem functions. Our work and the input of many expert contributors develops a more complete understanding of the flow regime and its relation to natural processes and species' requirements, so as to identify the critical attributes of the flow regime necessary to maintain ecosystem function. The multi-species, multi-indicator paradigm provides a "portfolio" approach for assessing how different flow and habitat restoration combinations suit the different life stages of desired species. In so doing, SacEFT transparently relates additional attributes of the flow regime to multiple species' life-history needs in an overall effort at careful organization of representative functional flow needs. This provides a robust scientific framework to focus the definition of ecological flow guidelines and contribute to the understanding of water operation effects on focal species and their habitats.

The performance indicators and functional relationships built into SacEFT were vetted through two multi-disciplinary workshops and numerous design document reviews. The recommendations of these technical design workshops and subsequent peer reviews provide the basis for the indicators and models described in this document. Collectively, the constituent focal species "submodels" provide twelve (12) performance measures which vary in spatial scale, temporal scale, and levels of reliability. Multi-year roll-ups allow users to quickly zoom in on the much smaller set of performance measures which differ significantly across management scenarios. With the completion of SacEFT v.2, the decision analysis tool provides the ability to:

1. improve the basis for evaluating flow alternatives on the Sacramento River from Keswick to Colusa (*e.g.*, Bay-Delta Conservation Plan flows, North-of-Delta Off-Stream Storage Investigation, Shasta Lake Water Resources Investigation, and other future diversions and water transfers);
2. evaluate a variety of management actions' affects (*e.g.,* gravel augmentation and bank protection alternatives) on ecosystem targets for the five Sacramento River focal species;

3. provide multiple levels of communication of information ranging from simplified formats for managers and decision-makers to in-depth displays of detailed functional relationships and transparent assumptions for review by technical experts;
4. leverage existing systems and data sources (CalSim /USRWQM/USRDOM, historical gauging station records, the Meander Migration Model, and TUGS, a new sediment transport model); and
5. catalyze exploration of new alternatives as data sets become available (*e.g.*, climate change) and help promote the development of needed flexibility in the water management system.

By leveraging many of the same planning models used in existing socioeconomic evaluations in California (e.g., CalSim, USRDOM, USRWQM), SacEFT provides an “eco plug-in” for water operation studies based on use of these physical hydrologic/water balance models. SacEFT advances and enables ecological flow (e-Flow) science by linking these physical models to a representative set of individual ecosystem components inside an overall compressed, cross-disciplinary synthesis tool for evaluating conveyance operation alternatives in the Sacramento River eco-region.

Lastly, SacEFT’s output interface and reports for trade-off analyses make it clear how actions implemented for the benefit of one area or focal species may affect (both positive and negative) another area or focal species. For example, we can show how altering Sacramento River flows to meet export pumping schedules in the Delta affects focal species’ performance measures in the Upper and Middle Sacramento River. One of the biggest challenges in the practical implementation of ecological flow guidelines is the wide range of objectives, focal species and habitat types that need to be considered. Our work to date has brought into focus how these various objectives cannot all be simultaneously met. In nature, conditions often benefit one target or species to the potential detriment of another in any given year. Fortunately, flow characteristics that benefit the various ecological targets investigated are usually required on a periodic basis and not every single year. EFT studies simplify communication of these trade-offs, and catalyze definition of state-dependent management practices that promote the development of needed flexibility in the water management system.

Building a tool that makes accurate future predictions of ecosystem behavior is challenging and usually not possible in complex, open natural systems (Oreskes *et al.* 1994). SacEFT’s main purpose is to characterize and explore important ecological trade-offs and inform managers and decision makers about the relative impacts of various flow management alternatives. The system can also act as a catalyst for exploring deliberate or opportunistic adaptive management experiments (Murray and Marmorek 2003) that assess actual ecological responses on a variety of spatial/temporal scales. This approach (model exploration of management alternatives and adaptive management experiments) will ultimately help water resource managers and stakeholders converge on options that best strike a balance among various of conflicting objectives.

1.1.1 History

Between 2004 and 2008 the Sacramento River Ecological Flows Study team developed a decision analysis tool that incorporates physical models of the Sacramento River with biophysical habitat models for six Sacramento River species (see: www.dfg.ca.gov/ERP/signature_sacriverecoflows.asp). The resultant tool, the Sacramento River Ecological Flows Tool (SacEFT), is a database-centered software system that links flow management actions to focal species outcomes on the mainstem Sacramento River. SacEFT allows: (1) the evaluation of ecosystem responses to alternative scenarios of discharge, water temperature, gravel augmentation, and channel revetment (rock removal) actions, and (2) water operations managers to significantly expand their ecological considerations when evaluating water management projects for the Sacramento River. The SacEFT software leverages considerable previous investment by utilizing data sets from commonly used models, such as CalSim II, USRWQM and

USRDOM, which evaluate statewide water management operations. SacEFT v.2 is now fully operational, and herein we describe its focal species performance indicators and its utility to Sacramento River water management planning processes.

One of the main tasks of the SacEFT project was to create an integrated cross-disciplinary tool to characterize ecological trade-offs that result from the implementation of alternative water management scenarios. We undertook the Sacramento River Ecological Flows Study after noting challenges facing management agencies within existing water management planning efforts for the Central Valley that if addressed could greatly enhance these efforts. First, upon reviewing Sacramento River planning efforts, we noted that ecological considerations included in water management planning were generally narrow in scope and detail (esp. prior to 2008). Ecological considerations were limited to meeting some static minimum in-stream flow targets, meeting basic temperature requirements, or limiting periods of pumping (in the Delta) during times when sensitive species are present. Although these considerations are among the highest management priorities, they are often focused on single species management.

Prior to SacEFT, much of the important information on focal species existed in stacks of separate reports, independent conceptual models, and unconnected modeling tools. SacEFT has synthesized much of this disparate information, linking ecological submodels to existing physical planning models, and providing a major advance in the region's capabilities for rapidly assessing ecological trade-offs. In addition to integrating disparate sources of information, the second challenge we overcame in constructing SacEFT was translating analyses of this information into easily understandable results for managers. Practical synthesis and integration is challenging when considering multiple ecological targets, complex physical models, and multiple audiences (*i.e.*, high level managers as well as technical level staff). In keeping with the design principle of making it easy for non-specialists to understand the model's results, SacEFT creates output that can span the range from high-overview to high-resolution. The output interface makes extensive use of a "traffic light" paradigm that juxtaposes performance measure (PM) results and scenarios to provide an intuitive overview of whether a given year's PMs are healthy (Green), of some concern (Yellow), or of serious concern/poor (Red).

DECEMBER 2005 INITIAL DESIGN WORKSHOP (SACEFT V.1)

On December 5 and 6 2005, ESSA Technologies Ltd., in partnership with The Nature Conservancy and Stillwater Sciences, held a model design workshop to evaluate a preliminary conceptual design of the Sacramento River Ecological Flows Tool (SacEFT). Forty scientists and other technical experts (see Appendix A), each having expertise with one of the focal species or physical submodels on the Sacramento River, were invited to attend the workshop to discuss and *prioritize* aspects of these submodels. Prior to their attendance a backgrounder on the SacEFT tool was provided to workshop participants which described the candidate submodels that would be evaluated at the workshop (ESSA Technologies Ltd. 2005).

Four criteria guided the technical review and prioritization of indicators **for SacEFT v.1**. First, experts assessed whether proposed indicators were directly *relevant* to the Sacramento River – *i.e.*, whether relationships were derived from data on the focal species or physical habitat attribute of interest, or whether indicators were developed using data collected within the study area during recent conditions. Second, scientists evaluated the *clarity* of functional relationships to ensure that they are not contested or confounded by other information. To the extent possible, we wanted to avoid functional relationships predicting species responses to flow that may be confounded by other factors not modeled in SacEFT (*e.g.,* changes in adjacent land uses). Third, participants discussed the level of *rigor* underlying functional relationships. That is, whether the evidence supporting a functional relationship was either: (1) well established, generally accepted, or from peer reviewed empirical studies; (2) strong but not fully conclusive; (3) theoretical support with some evidence; or (4) hypothesized based purely on theory and professional judgment. Finally, recognizing our inability to "include everything", we facilitated a discussion regarding the *feasibility* of integrating the proposed performance measures, ensuring SacEFT reflects both a reasonable level of breadth and depth across the five focal species present in SacEFT v.1.

DECEMBER 2008 REVIEW WORKSHOP (SACEFT V.1 → SACEFT V.2)

Building a software system of this magnitude is an iterative process. Previous steps included preparation of a workshop background document (ESSA Technologies Ltd. 2005), holding a technical design workshop on December 5 and 6 2005 in Davis, CA, and developing and applying SacEFT v.1. Usually, the first iteration of a decision support tool has data and conceptual gaps that are filled by estimates. To improve on the initial version of SacEFT, on October 7 and 8 2008, ESSA Technologies Ltd., in partnership with The Nature Conservancy, held a model review workshop to improve Version 1 of the Sacramento River Ecological Flows Tool. This technical workshop had two goals:

1. Through peer review, ensure credibility in SacEFT's existing focal species' indicators; and
2. Ensure the model's outputs remain clear and directly relevant to water managers.

Over 30 experienced biologists and water managers participated in discussions on how to improve the Sacramento River Ecological Flows Tool (see Appendix A). During the technical review workshop we solicited feedback (both in plenary and subgroups) on the following topics to help define improvements to the initial version of SacEFT:

i) A peer review of critical uncertainties in existing SacEFT functional relationships.

ii) A peer review of SacEFT hazard thresholds. (While SacEFT calculates performance measures in their native units, it uses a tri-state "traffic light" system of R/Y/G zones to rapidly communicate the desirability of flow/temperature/sediment transport outcomes. In the current version of SacEFT, the hazard threshold boundaries between Red/Yellow and Yellow/Green and are based on tercile break points determined by sorting performance measure values from our default water operation scenario based on the 66-year historical time series (1939-2004).)

iii) Discussion of additional/new indicators for SacEFT v.2.

iv) A discussion of how to enhance Excel report model output to show the assumptions associated with each model run.

v) Water manager advice was sought on SacEFT's key synthesis concept of "target and avoidance flow envelopes". This output concept is promising for translating SacEFT's "green" (good) traffic light results emerging from the model into multi-species flow operating rules for dam operators. However, while it may be desirable to satisfy certain ecological objectives every year (*e.g.,* temperature criteria) other objectives may only be satisfied occasionally (*e.g.,* cottonwood recruitment every 5-10 years). Technical discussions were held on how to convert SacEFT target and avoidance flows for multiple focal species into water year specific criteria and constraints to support the vision that this information feed back into other planning tools as new constraints and improved formulations in tools such as CalSim.

Table 1.1 summarizes the priority performance indicators that were identified by workshop participants, and distinguishes indicators developed for SacEFT v.1 that are unchanged in SacEFT v.2 from new indicators or existing indicators that received a significant overhaul in Version 2. The intention was to identify a finite number of priority performance measures per focal species to integrate into SacEFT v.2. *Ideally*, performance measures should be directly relevant to the Sacramento River conditions, very clear and uncontested by technical or non-technical audiences, be supported by a high level of evidence, and manageable to implement. Of course, few performance measures will meet all of these criteria. Four criteria guided the technical review and prioritization of indicators **for SacEFT v.2** (Table 2.3). These revised criteria were based on lessons learned in the subsequent development of design guidelines for DeltaEFT (ESSA Technologies Ltd. 2008b). This updated indicator classification and prioritization system (Table 2.3) is used from this point forwards in this document.

Table 1.1 Summary of the performance measures (PMs), selection criteria ratings (H = High, M = Moderate, L = Low), and priorities following the SacEFT v.2 model design workshop. Note the following PM abbreviations: CS – Chinook salmon or Steelhead trout, GS – green sturgeon, BASW – bank swallow, FC – Fremont cottonwood, and LWD – large woody debris. PMs marked with a red dot in the ver. 2 column are pre-existing indicators that were not significantly modified as a consequence of the December 2008 SacEFT v.1 review workshop. Those marked in green are pre-existing indicators that have been significantly changed; those marked in blue are new indicators created for SacEFT Version 2. Definitions of relevance, clarity, rigor and feasibility are provided later in Table 2.3.

Focal species and performance measure	Relevance	Clarity	Rigor	Feasibility	Priority	Ver. 2	Comments
CS = Chinook/Steelhead							
CS1 - Area of suitable spawning habitat	Direct	H	H	H	H	🟢	5 aggregate reaches, 4 run types, side channel included; gravel augmentation-sediment requires additional data
CS2 - Area of suitable rearing habitat	Direct	H	H	H	H	🟢	3 aggregate reaches, 4 run types
CS3 - Egg-to-fry survival rate	Direct	H	L	H	H	🔴	5 reaches, Bureau of Reclamation model
CS4 - Index of juvenile stranding	Direct	H	H	H	H	🔴	Daily flow; relationships from Gard (United States Fish and Wildlife Service (USFWS)
CS5 - Redd scour	Direct	M	L	H	M	🔴	Max flow during incubation
CS6 - Redd dewatering	Direct	M	M	H	M	🔴	Stage recession during incubation
GS1 – Green Sturgeon Egg-to-larvae survival rate	Direct	M	M	H	H	🟢	Laboratory studies for temperature tolerance
BASW1 – Bank swallow habitat potential	Direct	H	M	M	H	🔵	Only considering length of suitable banks within appropriate soils. Not feasible to assess suitability relative to other variables: bank height and bank slope.
BASW2 – Ramping rates during bank swallow nesting	Direct	M	M	M	H	🔴	Used findings in Linkages report to develop an indicator of bank sloughing due to flows during nesting
FC1 – Successful cottonwood initiation	Direct	H	H	M	H	🔴	Highly relevant issue, box model has been developed, and data are available at 3 locations. Relevant data (stage-discharge and x-sections) are not available for other locations.
FC2 – Cottonwood seedling scour	Direct	M	H	M - L	H	🔵	Highly relevant PM to FC. If seedlings are scoured out in year 2 and 3, actions taken in year 1 (FC1) become moot.
LWD1 – Large Woody Debris recruitment		M	M	L/M	L/M	🔵	Data may not be available; not feasible

1.1.2 Related component in development: DeltaEFT

Early in the project development phase of SacEFT, the project team specifically excluded Delta considerations when bounding the limits of the SacEFT decision analysis tool. We sought to first achieve proof of concept in one location (*e.g.,* the Sacramento River eco-region) prior to expanding efforts to other CALFED Ecological Restoration Program (ERP) eco-regions. We now have a significant foundation of existing work to build upon in light of progress with the Delta Regional Ecosystem Restoration Implementation Plan process, the Bay Delta Conservation Plan (BDCP) process, new Operations Criteria and Plan biological options, Public Policy Institute of California initiatives, State Water Resource Control Board criteria development efforts, and Pelagic Organism Decline research. As of 2010, the timing and information sources were significantly more appropriate to address Delta specific needs in a similar fashion. Incorporation of Delta considerations into the existing EFT framework will provide managers with the ability to better inform Delta management actions for ecological affects, as well as evaluate a management action's affects in the two inseparable ERP eco-regions of the Sacramento River and Delta.

Under the grant ERP-07D-P06 - DFG# E0720044, ESSA Technologies Ltd., in continuing partnership with The Nature Conservancy, is developing the Delta Ecological Flows Tool, which is expected to be completed in the late fall of 2011.

1.1.3 How it will be used

EFT is intended to provide a framework for collaboration and integration that leverages existing tools focused on the human need aspects of water deliveries in northern California (*e.g.*, CalSim II). EFT users are able to download the model from the internet (www.essa.com/tools/EFT/download.html) and immediately work with pre-defined scenarios. In the context of specific water gaming environments, EFT combines outputs generated by existing water planning models with others to illuminate the anticipated ecological tradeoffs. Prior to these gaming sessions, EFT users can verify that the assumptions embedded in its physical submodels (*e.g.*, meander migration, TUGS) are *sufficiently* consistent with those in the primary water planning tools (*e.g.*, CalSim II, USBR Upper Sacramento River Temperature Model). Once a qualified EFT database administrator has imported external datasets and verified submodel compatibility, EFT scenarios can then be configured and run to give immediate feedback on ecological performance and tradeoffs. The efficiency of gaming exercises depends largely on how quickly EFT's external physical submodels can be configured and run, and their results imported into EFT. Once external datasets are imported and configured, and focal species submodels run, gaming and trade-off analysis are instantaneous.

EFT can provide valuable results to two groups of users. Scientists can supply their core data and metadata to EFT for ecological evaluation. Managers and decision makers are able to quickly review "traffic light" (dashboard) summary reports that illuminate the overall balance of performance across ecological indicators. Advanced tools also exist within the EFT relational database to perform further diagnostic and summary level analyses (*e.g.*, identify target and avoidance flows, exceedance plots, *etc.*).

2. Scope and Bounding

2.1 Ecological objectives and performance measures

Complex decisions and associated trade-offs are easier when structured using formal approaches to evaluate management alternatives. SacEFT encourages a PrOACT approach (Hammond *et al.* 1999) to evaluate trade-offs among different ecological objectives and help managers choose amongst water management alternatives. PrOACT is a simplified form of multi-objective decision analysis that provides a framework for decision making in the face of a large number of objectives and uncertainties. PrOACT is a five-step process: (1) define the **Pr**oblem; (2) determine the **O**bjectives; (3) develop **A**lternative actions; (4) assess the **C**onsequences associated with each alternative across the set of objectives; and (5) evaluate **T**radeoffs across alternatives and the range of objectives being considered. This framework is described in more detail in ESSA's (2005) workshop backgrounder. SacEFT is designed with this framework in mind, and can be useful for completing most aspects of PrOACT, particularly steps 4 & 5.

Ecological objectives are statements describing the desired condition or state of the system that decision makers want to achieve. Clear objectives are needed to evaluate alternative management scenarios and help distinguish which among them is the best alternative. The purpose of SacEFT is to evaluate management alternatives on the basis of *fundamental objectives* – what do managers want to achieve? – not *means objectives* – how do decision makers plan to achieve it? With the list of fundamental objectives in mind, we then attribute consequences caused by various alternative actions through predictive performance measures (PMs).

SacEFT v.2's priority objectives and performance indicators – discussed in detail later in this document – are listed in Table 2.1.

Table 2.1 Ecological objectives and performance measures found in EFT Version 2. PMs marked in green have been significantly modified from Version 1; those marked in blue are new PMs.

Focal Species	Ecological Objectives	Performance Measures
Fremont cottonwood (FC)	Maximize areas available for riparian initiation, and rates of initiation success at individual index sites.	FC1 – Successful Fremont cottonwood initiation (incidence of cottonwoods initiated along a given cross section, at end of seed dispersal period)
		FC2 – Cottonwood seedling scour. Following years that have fair to good initiation success, evaluate the risk of seedling scour during the first year following successful initiation.
Bank swallow (BASW)	Maximize availability of suitable nesting habitat	BASW1 – Habitat potential/suitability. BASW2 – Risk of nest inundation and bank sloughing during nesting
Western pond turtle (WPT)	Maximize availability of habitat for foraging, basking, and predator avoidance	LWD1 – Index of old vegetation recruited to the Sacramento River mainstem.
Green sturgeon (GS)	Maximize quality of habitat for egg incubation	GS1 – Egg-to-larvae survival
Chinook salmon, Steelhead trout (CS)	Maximize quality of habitat for adult spawning	CS1 – Area of suitable spawning habitat (ft^2)
	Maximize quality of habitat for egg incubation	CS3 – Egg-to-fry survival (proportion) CS5 – Redd scour (Red/Yellow/Green hazard zones) CS6 – Redd dewatering (proportion)
	Maximize availability and quality of habitat for juvenile rearing	CS2 – Area of suitable rearing habitat (ft^2) CS4 – Juvenile stranding (index)

Relationships between physical datasets (described in section 4.1), submodels and focal species PMs are summarized in Table 2.2.

Table 2.2. Physical datasets that potentially impact focal species and focal habitat performance in SacEFT. Only those species and habitats that are currently expected to be included in SacEFT Version 2 are shown.

Focal Species Performance Measures	Physical datasets and submodels				
	Flow	Stage - Discharge	Temperature	Sediment Transport	Meander Migration
Fremont cottonwood (FC)	●	●			
Bank swallow (BASW)	●				●
Green sturgeon (GS)			●		
Chinook, steelhead (CS)	●		●	●[1]	
Large Woody Debris (LWD) recruitment	●				●

[1] Certain indicators only. The linkage between channel bed conditions and Chinook and steelhead is restricted to weighted useable area for spawning. According to source data from Mark Gard (USFWS), rearing habitat is unaffected by substrate conditions. We relate substrate suitability curves taken from *River-2D* with substrate conditions predicted by the TUGS sediment transport model.

2.1.1 Revised indicator classification and prioritization

Keeping in mind the criteria and priorities stated above, the ecological objectives and performance measures proposed in the backgrounder were reviewed at the December 2005 model design workshop. In SacEFT v.1, these Performance Measures were prioritized based on relevance, clarity, rigor and technical feasibility. Using lessons learned in the subsequent development of design guidelines for DeltaEFT (ESSA Technologies Ltd. 2008b), these categories have been updated so that they are more consistent with the classification scheme used for DeltaEFT (Table 2.3). The updated indicator classification and prioritization system is used from this point forwards in this document.

Table 2.3 Classification and prioritization concepts employed for the evaluation of SacEFT v.2 performance measures. Tables showing the strengths and weaknesses of PMs (Section 4.3) refer to these classification criteria using “I”, “U”, “R” and “F” to label each class.

Label	Explanation	Levels
I **Importance**	The degree to which a linkage (functional relationship) controls the outcome relative to other drivers and linkages affecting that same outcome.	**4 = High:** Expected sustained major population level effect, *e.g.*, the outcome addresses a key limiting factor, or contributes substantially to a species population’s natural productivity, abundance, spatial distribution and/or diversity (both genetic and life history diversity) or has a landscape scale habitat effect, including habitat quality, spatial configuration and/or dynamics. **3 = Medium:** Expected sustained minor population effect or effect on large area or multiple patches of habitat. **2 = Low:** Expected sustained effect limited to small fraction of population, addresses productivity and diversity in a minor way, or limited spatial or temporal habitat effects. **1 = Minimal:** Conceptual model indicates little or no effect.
U **Understanding** (“Clarity”)	The degree to which the performance indicator can be predicted from the defined linkage (functional relationship) and its driver(s).	**4 = High:** Understanding is high and nature of outcome is largely unconstrained by variability in ecosystem dynamics, other confounding external factors. **3 = Medium:** Understanding is high but nature of outcome is moderately dependent on other variable ecosystem processes or uncertain external confounding factors. **2 = Low:** Understanding is moderate or low and/or nature of outcome is greatly dependent on highly variable ecosystem processes or other external confounding factors. Many important aspects are subject of active ongoing research. **1 = Minimal:** Understanding is lacking. Mainly subject of active ongoing

This table continues on the next page.

Label	Explanation	Levels
R **Rigor** ("Predictability")	The degree to which the scientific evidence supporting our understanding of a cause-effect relationship (linkage) is contested or confounded by other information.	**4 = High:** Is generally accepted, peer reviewed empirical evidence, strong predictive power and understanding, evidence not contested or confounded. Data in support of the functional relationship is derived from direct Bay-Delta field observations. **3 = Medium:** Strong evidence but not conclusive, only medium strength predictive power, some evidence for competing hypotheses and/or confounding factors. Data in support of the functional relationship is derived from direct Bay-Delta field observations OR from field observations outside the Bay-Delta estuary. **2 = Low:** Theoretical support with some evidence, semi-quantitative relationships, several alternative hypotheses and/or confounding factors. Data in support of the functional relationship is derived from lab or theoretical studies without field evidence. **1 = Minimal:** Hypothesized based on theory and/or professional judgment, purely qualitative predictions, many alternative hypotheses and/or confounding factors. Support for the functional relationship is largely hypothetical and based on first principles.
F **Feasibility**	The degree to which input data necessary to calculate the proposed performance measure can be delivered in a timely fashion (without external bottlenecks) and the amount of effort (relative to other possible indicators) needed to implement the cause-effect linkage in a computer model.	**4 = High:** Input data currently exists in a format easy to disseminate, can be delivered readily and the effort (time) associated with implementing the cause-effect linkage easily falls within project budget without sacrificing other indicators. **3 = Medium:** Input data currently exists (or can readily be generated by new model runs), and while it might need some additional formatting, can be delivered readily. The effort (time) associated with implementing the cause-effect linkage falls within project budget subject to prioritization decisions elsewhere that remove some other indicators from consideration. **2 = Low:** Input data does not currently exist, but can be generated through additional analyses or external model runs. The time before this external work could be completed is or may be uncertain. The effort (time) associated with implementing the cause-effect linkage could be accommodated within the project budget, but a number of other indicators would need to be eliminated from consideration. **1 = Minimal:** Input data does not currently exist, and it is not clear if it can be generated through additional analyses or external model runs. The time before this external work could be completed is unacceptably long. The effort (time) associated with implementing the cause-effect linkage would take up a disproportionately high amount of the project budget, and the majority of other indicators would need to be eliminated.
P **Priority**	Initial Priority Ranking	

2.2 Spatial extent and temporal horizon

The spatial extent of SacEFT includes the mainstem Sacramento River at RM 301 (Keswick) downstream to RM 143 (Colusa) (Figure 2.1). Specific locations identified in SacEFT are chosen based on three factors:

1. their biological importance (*e.g.*, what is the current or historic range for a focal species?);
2. the areas where we have reliable *biological* relationships (focal species models); and
3. the feasibility of obtaining or producing the *physical* variables required for focal species submodels at these biologically relevant sites (*e.g.*, where have stage-discharge relations and channel cross-section profiles been developed?).

The overlap between these three considerations determines the spatial extent of performance measures throughout SacEFT's 158 mile study area.

The temporal horizon of SacEFT varies by submodel, ranging from specific events occurring at daily resolution (*e.g.*, changes in flow and stage) to performance measures that obtain their meaning when viewed over annual and longer time scales. In practice, we anticipate that the temporal horizon for a given SacEFT model run will be limited by the "weakest" (*i.e.*, shortest) dataset or submodel responsible for supplying inputs to other models. Depending on the purpose of a simulation, the *maximum* temporal horizon of a given SacEFT model run is expected to be in the neighborhood of 60 years.

2.3 Spatial and temporal resolution

Three **spatial** elements are used in SacEFT to describe specific locations:

- **points**;
- **cross-sections**; and
- **segments.**

A concrete example of a variable linked to a point would be a stream gauge. An example of a variable or relation associated with a cross-section is a stage-discharge relationship. The length of newly eroded bank at a particular river bend is well represented using the concept of a segment (*e.g.*, RM *X* to *Y*).

At the December 2005 model design workshop, considerable discussion occurred over the fact that the spatial localization and identification of certain variables changes over time. For example, a river center line determines river mile demarcations, and the center line of a river changes over time. On the Sacramento River, river miles (abbreviated "RM") have acquired a "cultural" significance, with many scientists/managers referring to river mile demarcations that are based on surveys performed decades ago (1950s). Today, these river miles are no longer technically accurate, but they are still commonly used and can be useful for clarifying which discharge or temperature gauge is closest to a biologically significant point or segment.

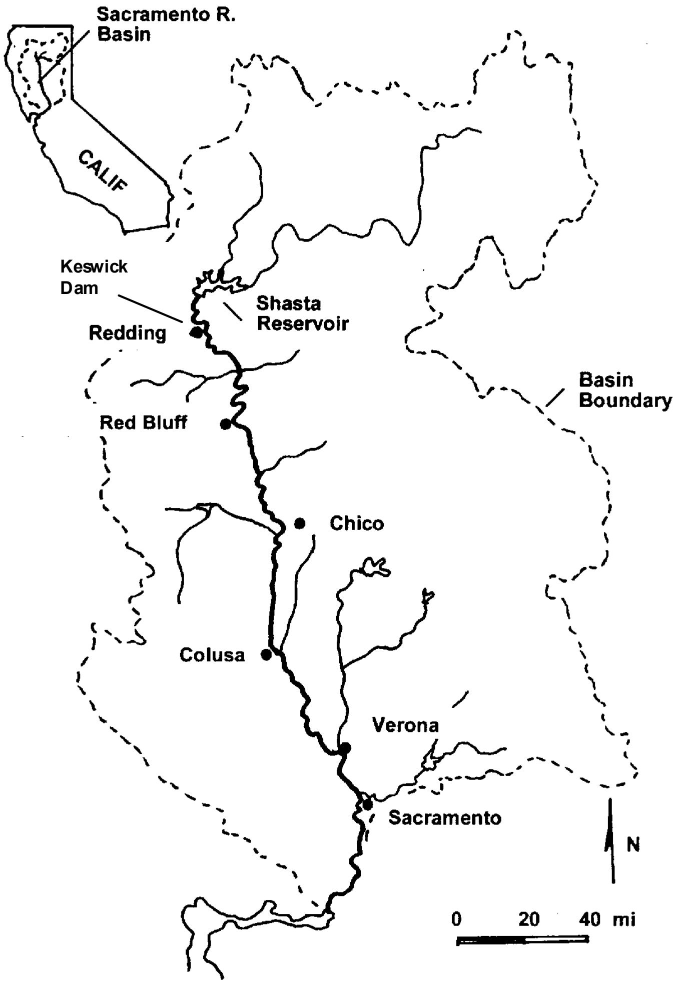


Figure 2.1. Map of the Sacramento River watershed and study area over which the SacEFT Version 2 can be applied – from Keswick Dam (RM 301) to Colusa (RM 143) (source of map: CALFED Bay-Delta Program 2000).

The underlying design of the SacEFT relational database supports spatial definition of points, cross sections and segments. However, focusing on the data needs of focal species and recognizing the relative predictive errors between physical and focal species submodels, SacEFT treats locations as being fixed over the course of a multi-decadal simulation. Conceptually, this introduces what we call a “zonal notion” of points and segments. For example, bank swallow colonies may exist between RM 202 and 183, and we may have a calibrated Meander Migration Model to provide information on the length of newly eroded bank in suitable soils in this region. Let’s assume the river miles just mentioned were based on a 2004 river centerline survey. If the Meander Migration Model is run forward for 50 years (assuming some flow regime for that period), then the precise spatial location of the river miles on the landscape will shift. However, for purposes of determining the suitability of banks swallow nesting habitat, the locations of the individual bends of interest will still be in *approximately* the same zones. A dynamic bend at RM 191—while now technically at (say) RM 186.84—is still in *the same overall zone of interest to bank swallows*. The overall amount of suitable nest habitat for bank swallows is of interest, not its precise location. On this basis, SacEFT foregoes the costly overhead of precisely tracking fine spatial details such as these when this does not interfere with generating and interpreting focal species performance measures.

While SacEFT treats locations as fixed throughout model simulations for purposes of generating and summarizing focal species performance measures, certain inherently dynamic processes like center line change (from the Meander Migration Model output) are still being handled in a spatially explicit fashion. External simulations of centerline change using the Meander Migration Model are summarized and loaded into SacEFT according to the appropriate fixed zonal notion.

The **temporal** horizon of SacEFT varies by submodel, ranging from specific events at the daily scale, to longer duration events (*e.g.*, egg maturation) that may require months, to annual-scale events like channel migration. As well, there are some time periods within a year that are of greater interest for a focal species due to the life-history timing of specific biological processes. Differences in spatial and temporal resolution have implications on the way information is aggregated across the study area and presented to users for evaluation of alternative management actions. Table 2.4 summarizes both the spatial and temporal resolution of performance measures in SacEFT.

Table 2.7 summarizes the life-history timing that is relevant to the various focal species performance measures. In the case of Chinook and steelhead spawning time, closely follows the timing and spread used by Bartholow and Heasley (2006) for the SALMOD model; a distribution which is in turn based on Vogel and Marine (1991). When timing information was provided as a 3-part proportional distribution, the leading and trailing shoulders were each assigned one quarter of the spawning proportion, and the middle third of the distribution was assigned one half of the spawning proportion, divided over the number of days in the period.

Table 2.4. Summary of the spatial location and extent of physical datasets, linked models and performance measures for the ***non-salmonid*** focal species. Performance measures (PMs) for the species are summarized in Table 2.1. Vertical bars denote PMs that are simulated for river segments; dots denote those that are simulated (measured in the case of gauges) at points along the river. Q = river discharge. T = water temperature. Annotation details are listed in Table 2.6.

		Physical Driving Variables						**Linked Models**				**Biological Models**							
		Historical[1]		**NODOS**[2]		**BDCP Analysis**[6]		**TUGS**[3]		**Meander Migration**		**Fremont Cottonwood**	**Bank Swallow**			**Large Woody Debris**		**Green Sturgeon**	
RM	**Name**	***Q***	***T***	***Q***	***T***	***Q***	***T***						**1**		**2**				**RM**
301	Keswick	●	●	●	●	●	●		▮										301
298	ACID Dam		●						▮										298
293	ACID Intake			●					▮						●				292
289	Clear Creek		●	●	●	●	●		▮										289
281	Stillwater Creek			●	●														281
280	Cow Creek		●	●	●	●	●	▮											280
278	Bear Creek			●	●			▮											278
277	Ball's Ferry		●		●	●	●	▮											277
275	Anderson Creek		●		●			▮											275
273	Cottonwood Creek		●	●	●	●	●	▮											273
272	Battle Creek		●	●	●			▮	▮										272
267	Jelly's Ferry		●		●	●	●		▮										267
260	Bend Bridge A	●	●	●	●				▮									●	260
258	Bend Bridge B								▮										258
252									▮										252
243	Red Bluff	●			●	●	●												243
243	Red Bluff DD				●	●	●		▮										243
230	Mill Creek			●	●				▮										230
218	Vina	●		●	●				▮	▮			▮			▮			218
208										▮		●	▮			▮			208
207	GCID Pump									▮		●	▮			▮			207
201										▮	▮		▮	▮		▮	▮		201
199	Hamilton City	●		●	●	●	●				▮	●		▮			▮	●	199
197											▮			▮	●		▮		197
196												●		▮			▮		196
192											▮	●		▮			▮		192
190	Stony Creek										▮			▮			▮		190
185										▮	▮	●	▮	▮		▮	▮		185
183										▮		●	▮			▮			183
182										▮			▮			▮			182
172										▮		●	▮			▮			172
170										▮			▮			▮			170
168	Butte City	●		●	●										●				168
165												●							165
164												●							164
159	Moulton Weir			●	●							●							159
143	Colusa	●		●	●														143

Table 2.5. Summary of the spatial location and extent of physical datasets, linked models and performance measures for the ***salmonid*** focal species. Performance measures (PMs) for the species are summarized in Table 2.1. Vertical bars denote PMs that are simulated for river segments; dots denote those that are simulated (measured in the case of gauges) at points along the river. Q = river discharge. T = water temperature. Annotation details are listed in Table 2.6.

		Physical Driving Variables						**Linked Models**				**Biological Models**																			
												Chinook & Steelhead Spawning & Egg Stage PMs[4]										**Chinook Steelhead Juvenile Rearing Stage PMs**									
		Historical[1]		**NODOS**[2]		**BDCP Analysis**[5]		**TUGS**[3]		**Meander Migration**		*Spring*		*Fall*		*Late Fall*		*Winter*		*Steelhead*		*Spring*		*Fall*		*Late Fall*		*Winter*		*Steelhead*	
RM	**Name**	***Q***	***T***	***Q***	***T***	***Q***	***T***																								
301	Keswick	●	●	●	●	●	●		▮					▮		▮		▮		▮				▮		▮		▮		▮	
298	ACID Dam		●						▮				▮	▮	▮	▮	▮	▮	▮	▮	▮		▮	▮	▮	▮	▮	▮	▮	▮	▮
293	ACID Intake			●					▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮
289	Clear Creek		●	●	●	●	●		▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮
281	Stillwater Creek			●	●								▮		▮		▮		▮		▮		▮		▮		▮		▮		▮
280	Cow Creek		●	●	●	●	●	▮				▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮	▮
278	Bear Creek			●	●			▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮	
277	Ball's Ferry		●		●	●	●	▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮	
275	Anderson Creek		●		●			▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮	
273	Cottonwood Creek		●	●	●	●	●	▮				▮		▮		▮		▮		▮		▮		▮		▮		▮		▮	
272	Battle Creek		●	●	●			▮	▮			▮		▮	▮	▮		▮		▮		▮	▮	▮	▮	▮	▮	▮	▮	▮	
267	Jelly's Ferry		●		●	●	●		▮						▮								▮		▮		▮		▮		
260	Bend Bridge A	●	●	●	●				▮						▮								▮		▮		▮		▮		
258	Bend Bridge B								▮						▮								▮		▮		▮		▮		
252									▮						▮								▮		▮		▮		▮		
243	Red Bluff	●			●	●	●																								
243	Red Bluff DD				●	●	●		▮						▮								▮		▮		▮		▮		
230	Mill Creek			●	●				▮						▮								▮		▮		▮		▮		
218	Vina	●		●	●				▮	▮					▮								▮		▮		▮		▮		
207	GCID Pump									▮																					
201										▮	▮																				
199	Hamilton City	●		●	●	●	●				▮																				
197											▮																				
192											▮																				
190	Stony Creek										▮																				
185										▮	▮																				
183										▮																					
182										▮																					
172										▮																					
170										▮																					
168	Butte City	●		●	●																										
165																															
164																															
159	Moulton Weir			●	●																										
143	Colusa	●		●	●																										

Table 2.6. Annotations for Table 2.4 and Table 2.5.

[1] The common time span of Historic discharge (Q) data is 1-Oct-1938 to 30-Sep-2004. The common time span of Historic temperature (T) data is 1-Jan-1970 to 31-Dec-2001.

[2] The common time span of the NODOS scenario analyses performed in April 2011 include discharge (Q) and temperature (T) data between 1-Oct-1921 to 30-Sep-2003.

[3] TUGS simulations (Cui 2007) shown in red actually comprise 5 distinct reaches between RM 301 and RM 289. TUGS results are not available downstream from Cow Creek but are necessary for linkage to Chinook and Steelhead spawning Weighted Usable Area (WUA) (CS1). TUGS relationships for these downstream segments (pink) are mapped from the nearest upstream location, as described in Section 4.2.3.

[4] Chinook and Steelhead *spawning* WUA relationships shown in pale blue are mapped from the closest downstream segment, as described in Section 4.2.3. Spring Chinook habitat preferences are assumed to follow those of fall Chinook. Chinook *rearing* WUA relationships shown in pale blue are mapped from the closest upstream section, as described in Section 4.2.4.

[5] The BDCP analysis performed in June of 2010 included a subset of PMs: Chinook, Steelhead and green sturgeon in the region from Keswick to Hamilton City only.

Table 2.7. Summary of the life-history timing information relevant to the SacEFT focal species. Only those performance measures requiring information on life history timing are included here. Abbreviations of performance measures (PMs) are described in Table 2.1. Time intervals marked with heavy color denote periods of greater importance to focal species. In the case of the spawning PMs (CS-1), heavily shaded regions denote for each salmonid run-type/species the period between the 25th and 75th percentile, when half the spawning takes place. In the case of the other salmonid PMs, the heavily shaded regions denote the period between the 25th and 75th percentile of the population are present. Specific timing of CS-2, 3, 4, 5, 6 depends on ambient water temperature and varies with discharge scenario and year. Juvenile residency is defined by a fixed 90 day period following emergence for Chinook and a 365 day period for steelhead. This table is based on SALMOD (Bartholow and Heasley 2006, ultimately Vogel and Marine 1991). Salmonid timing values shown here are typical and may shift by as much as five days earlier or later, depending on year and reach. Timing values for green sturgeon, cottonwood and bank swallow are based on workshop discussions, and all values are under user control.

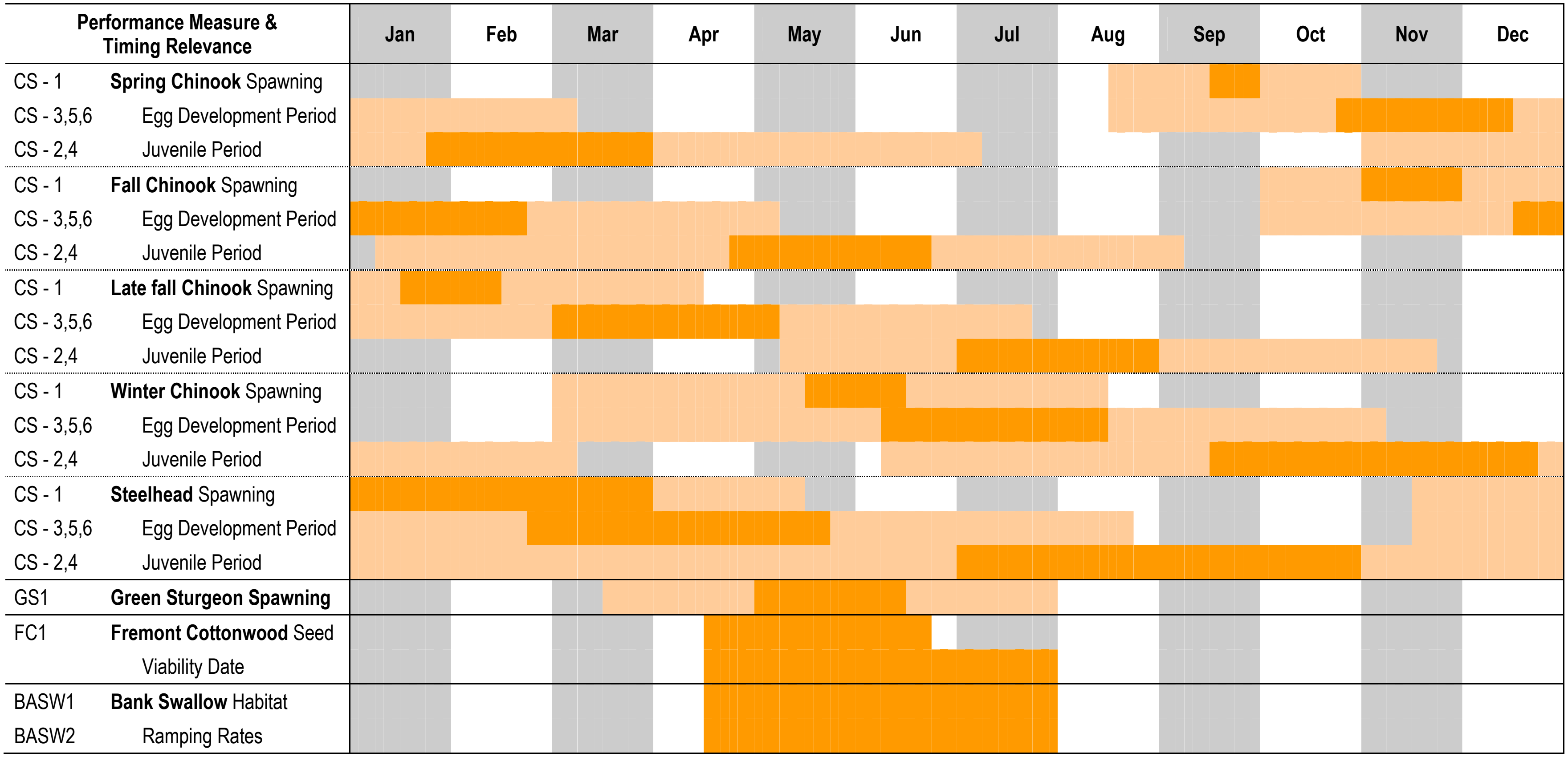


Table 2.8. Summary of the spatial and temporal resolution of performance measures. Abbreviations of performance measure are described in Table 2.1. Physical submodels are abbreviated as: FLOW – Historical flow records and CalSim-USRWQM/USRDOM, STAGE – stage-discharge relations, TEMP – historical water temperatures and USBR Upper Sacramento River Temperature Model (HEC-5Q), TUGS – The Unified Gravel-Sand model, MEANDER – Meander Migration Model. Units describing spatial resolution are after Pasternack *et al.* (2004).

		Temporal resolution				
Spatial resolution		**Event-based**	**Daily**	**Seasonal**	**Annual**	**Decadal**
Hydraulic unit	Point or cross-section: micro habitat, 0.1 to 1 channel width	FC2 BASW2	FLOW STAGE TEMP	FC1		
Geomorphic unit	Segment: meso-habitat, 10 channel widths (100s feet - miles)				TUGS BASW1 LWD1	MEANDER
Reach unit	Segment: 100 to 1,000 channel widths (10 - 60 miles)		CS1-6 GS1		MEANDER BASW1 BASW2	

2.4 Management actions

The primary emphasis of SacEFT is to provide ecological trade-off information for alternative **flow operation alternatives** in water planning forums. Changes in flow will affect all focal species performance measures, either directly by influencing availability or suitability of physical habitats, or indirectly as mediated by outcomes from the physical submodels. Two classes of **channel actions** can be examined using SacEFT: (*i*) gravel augmentation, and (*ii*) channel revetment states (*e.g.*, rip-rap (rock) removal). Gravel augmentation and sediment transport will affect substrate conditions for spawning for Chinook salmon and steelhead. The revetment scenarios affect the amounts of new bank created annually, and thus can affect bank swallow nesting success.

3. SacEFT Solution

3.1 Design principles

A main design aim for SacEFT is to allow exploration of trade-offs amongst key ecological components in a way that is clear to non-specialists. The main technical product is an integrated database, model engine, and user interface for presenting these ecological trade-offs for a defined set of management scenarios. Over time, this database, as well as the information management and reporting that it supports, will provide a foundation upon which additional scenarios can be configured and additional submodels added as new relationships are developed. Table 3.1 outlines some of the principles that underlie the design of SacEFT.

Table 3.1. SacEFT design principles. Various technical terms are defined in the glossary.

Prioritize, avoid being a jack of all trades, master of nothing	**Focus initially on a tight set of key ecosystem attributes.** Considering the scale of the mainstem Sacramento River, the many habitat units it encompasses, and the many species that it supports, it is necessary to focus on the most critical priority ecosystem attributes first. This allows the team to demonstrate how SacEFT can be used to identify and visualize key ecological trade-offs instead of spending all resources cataloguing the entire ecosystem and attempting to integrate everything. The 'integrate everything' approach usually results in having very little to show at the end in terms of actual scientific/management results because all resources will have been spent in data inventory activities.
Do not reinvent existing functionality	**Capitalize on existing tools and models.** To the extent possible, integrate existing quantitative models (including water operation planning tools such as the CalSim, USRWQM and USRDOM), followed by existing qualitative models or other decision support tools. Selectively analyze existing data to build new models (*e.g.*, regression relationships) for focal species, habitats, or habitat forming processes where appropriate and feasible. This principle also includes not spending effort coding custom graphical output controls. Instead, SacEFT leverages MS Excel, a widely held application with powerful graphing and analysis capabilities, when summarizing tabular and graphical outputs.
Generic, flexible relational data model	**Develop a custom relational database as the "glue" holding all submodel data together.** Linking together existing models with new ones to evaluate trade-offs for different scenarios requires a substantial level of planning. Given the large number of sites, variables and scenarios to be evaluated for a system as large as the mainstem Sacramento River, we need an infrastructure to organize and manage the large volume of data and to enable subsequent automation of trade-off analyses. This not only involves fundamental bookkeeping of the required information, but also supports core needs such as having a common way of defining locations and time-steps, linking output for submodels that are in common with a given point-of-interest, archiving metadata and running scenarios to give key output in a useable format. To achieve these and other needs, and to significantly reduce the likelihood of errors, a relational database is essential. The SacEFT database is the backbone of the software and it supports an information management engine used to automate ecological trade-off analysis to the greatest degree possible. Metadata on imported datasets are essential in the interpretation of model output.
Flexible, object-oriented design (OOD)	**Use a flexible model architecture and object-oriented design.** SacEFT incorporates software development strategies that maximize adaptability and ease of revision. The system architecture follows a tiered design that separates the database (first tier) from submodel logic (middle tier) and any user interface (third tier) components (*e.g.*, user reports). It also uses object-oriented design (OOD) within each of these components, which maximizes the reliability and flexibility of software development. However, SacEFT also relies on output from other models which may not have such flexible structures.
User friendly	**SacEFT should be designed for users of low to moderate computer literacy.** This includes the kinds of users who are comfortable building spreadsheets with formulas. The tool does not require power user skills, such as coding, or database design. For example, output reports are generated in Excel, a widely held application familiar to most users of computer models. Further, reporting in Excel typically reduces development costs associated with the alternative of tedious programming/customizing of third party reporting products.

Number of users	The solution provides a desktop software application connected to a remote centralized database. Multiple users can interact with this central database simultaneously. In the future, individual users may obtain copies of the master database for their own analyses.
Database	SQL Server 2005 leveraging ADO.NET Version 2.0.
Client software	Windows®-based rich client application developed in Visual Studio .NET 2005 (.NET Framework v.2.0).
Use error handling and logging	Invisible to users, SacEFT application code uses structured error handling (Try…Catch) and by default log all moderate and severe errors to the Windows Event Log. This simple practice has been shown from experience to greatly simplify debugging and maintenance.
Role of Internet	SacEFT uses a thick-client, desktop centered architecture built around an internet accessible central database. Deployment needs and system help access web resources.
Avoid COM components and 3rd party controls	Use .NET Framework components in user interface to simplify deployment and maintenance. Consider COM components only if functionality cannot be reproduced by a .NET Framework component. The exception in SacEFT is MS Excel.
Installation, accessibility	Deployment needs are currently supported via: www.essa.com/tools/EFT/download.html The deployment model uses standard MSI and .EXE install packages generated by two Visual Studio 2005 setup and deployment projects.

3.1.1 Integration with external systems and data sources

A critical feature of SacEFT identified early in project planning was the need to leverage existing systems and data sources. Millions of dollars have already been spent developing and applying models like CalSim II, USRWQM and USRDOM. As most of these are road tested, commonly used and generally accepted tools, SacEFT does not reinvent their functionality. The Upper Sacramento River Daily Operations Model (USRDOM) was developed to simulate reservoir operations and hydrologic stream routing in the upper Sacramento River from Keswick Dam to Knights Landing on a daily timescale. The simulated daily flows from USRDOM can be used as inputs to SacEFT. The Upper Sacramento Water Quality Model (USRWQM) was developed to simulate daily temperature conditions in the Sacramento River based on the daily flow conditions. The geographical extent of the model is similar to the USRDOM. The simulated daily water temperatures from USRWQM are used as inputs to SacEFT.

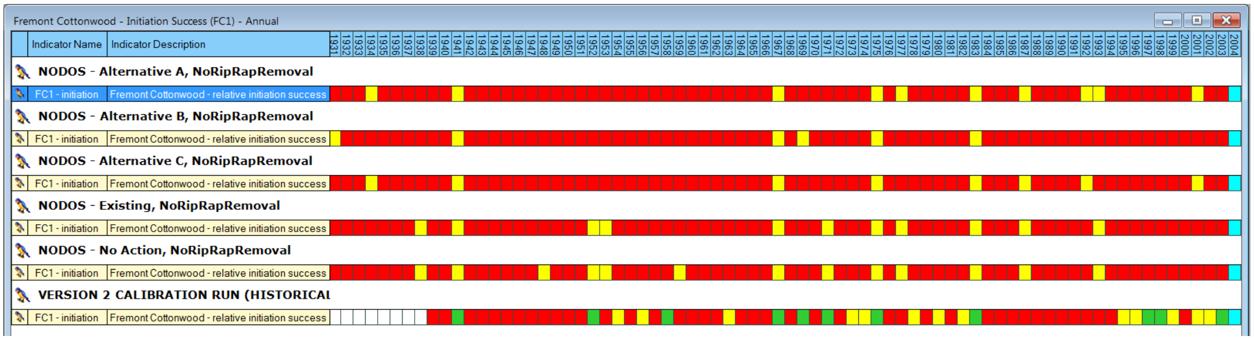
Rather than attempt to replicate this functionality, SacEFT instead makes it easy to link with and import external datasets and enter critical summary metadata. Thus, SacEFT's database contains a mix of imported datasets derived from external models while other components—usually its focal species algorithms—are embedded within SacEFT software itself. Importing of external datasets is performed manually though one-time data preparation and import. As much as possible, we attempt to make use of pre-defined Excel templates to streamline this process. Future versions of SacEFT may provide automated import routines for external data sources (*e.g.*, DSS output files).

In addition to analyzing alternative (CalSim/USRDOM) flow and water temperature (USRWQM) regimes, SacEFT enables comparisons of gravel augmentation and rock removal restoration actions. SacEFT requires annual estimates of the gravel grain size-distribution at each of 5 river segments in order to calculate the weighted useable area available for spawning (ST1/CH1). This habitat estimate is then used as one of the inputs to calculate subsequent performance measures for egg maturation, survival, and juvenile rearing. In the absence of gravel data, no calculations are possible for these linked components. SacEFT was designed to leverage grain-size specific sediment transport results from The Unified Gravel & Sand (TUGS) model (Cui 2007). TUGS simulates changes in grain size of the river by accounting for how its sediment flux interacts with sediment in both the surface and subsurface of the channel bed. Results of a default historical sediment scenario analysis are described in Stillwater Sciences (2007).

Likewise, SacEFT studies can also evaluate alternative bank erosion modeling, e.g., for (a) the existing channel armoring and (b) selected rip-rap (rock) removal scenarios. Bank erosion modeling is informed by the Meander Migration model developed by Eric Larsen and associates at UC Davis (see Larsen 2007). Channel armoring conditions have a direct bearing on riparian model performance measures (bank swallows and LWD recruitment). Conversely, these assumptions do not influence SacEFT's aquatic performance measure results. SacEFT results including the label "NoRipRapRemoval" refer to the existing 2004 channel and existing 2004 revetment (no change to bank protection) while scenarios with the label "RipRapRemoval" refer to selected removal of rock at specific locations (Larsen 2007).

3.1.2 Indicator thresholds and rating system

The SacEFT output interface makes extensive use of a "traffic light" paradigm that juxtaposes performance measure (PM) results and scenarios to provide an intuitive overview of whether a given year's PMs are experiencing favorable conditions (Green), are performing only fairly (Yellow), or are experiencing unfavorable conditions (Red). For all twelve (12) performance measures, annual cumulative weighted performance measure values are calculated for our default historical water operation scenario based on the 66-year historical time series of observed flows and water temperatures from 1938 to 2003. These "annual roll-up" values for each performance measure (e.g., average over days and locations with applicable biological distributions) are then assigned a "Good" (Green), "Fair" (Yellow) or "Poor" (🟥) performance measure rating (*e.g.*, Figure 3.1). The *default* threshold boundaries between Yellow/🟩 and Red/Yellow are based on tercile break points determined by sorting the annual weighted performance measure values from the default historical water operation scenario.



Fremont Cottonwood - Initiation Success (FC1) - Annual

Indicator Name | Indicator Description

NODOS - Alternative A, NoRipRapRemoval
FC1 - initiation | Fremont Cottonwood - relative initiation success

NODOS - Alternative B, NoRipRapRemoval
FC1 - initiation | Fremont Cottonwood - relative initiation success

NODOS - Alternative C, NoRipRapRemoval
FC1 - initiation | Fremont Cottonwood - relative initiation success

NODOS - Existing, NoRipRapRemoval
FC1 - initiation | Fremont Cottonwood - relative initiation success

NODOS - No Action, NoRipRapRemoval
FC1 - initiation | Fremont Cottonwood - relative initiation success

VERSION 2 CALIBRATION RUN (HISTORICAL
FC1 - initiation | Fremont Cottonwood - relative initiation success

Figure 3.1: Typical SacEFT output showing annual roll-up results for the Fremont cottonwood initiation (FC1) performance measure. Analogous plots are available for all of the tools' focal species and performance measures.

These annual performance measure ratings are based on thresholds[1] defined by sorting cumulative annual results produced by SacEFT for historic observed flows and water temperatures between calendar years 1938 and 2003 (*e.g.*, Figure 3.2). The "units" of these plots vary with the performance measure. *In this way, historic observed flows/temperatures provide the de facto "calibration scenario" for SacEFT's twelve (12) focal species performance measures.*

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[1] Indicator thresholds in SacEFT are fully configurable via settings found in the SacEFT relational database.

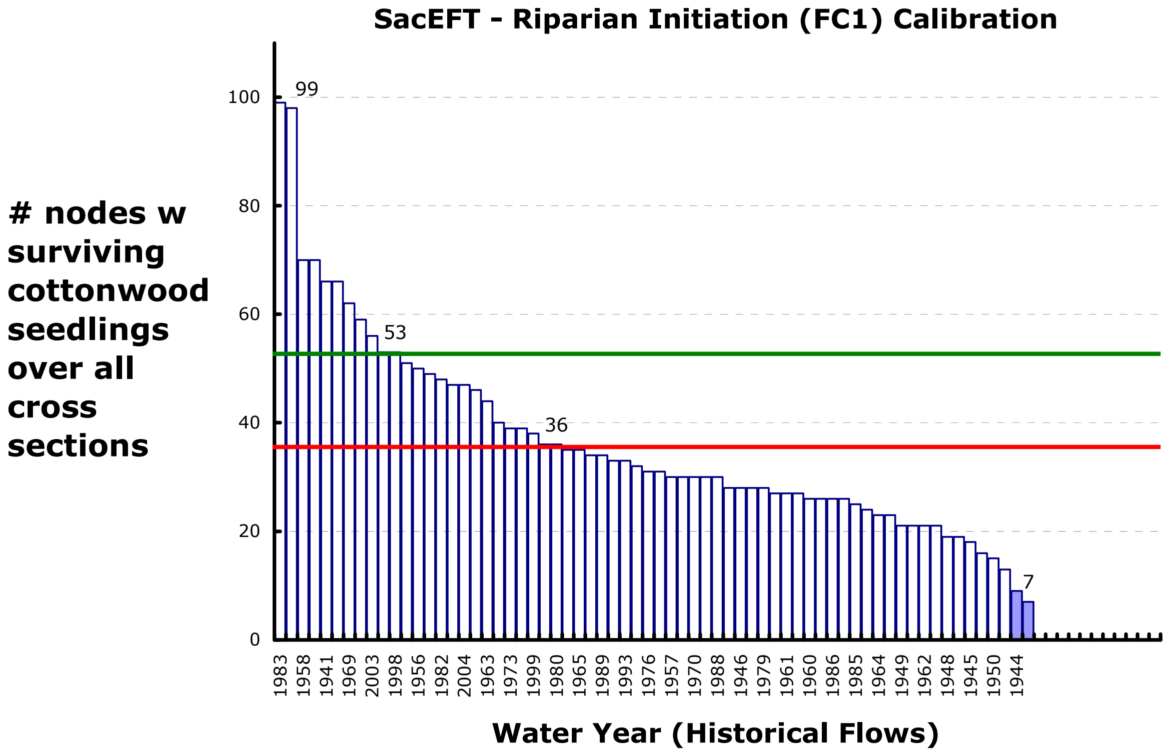
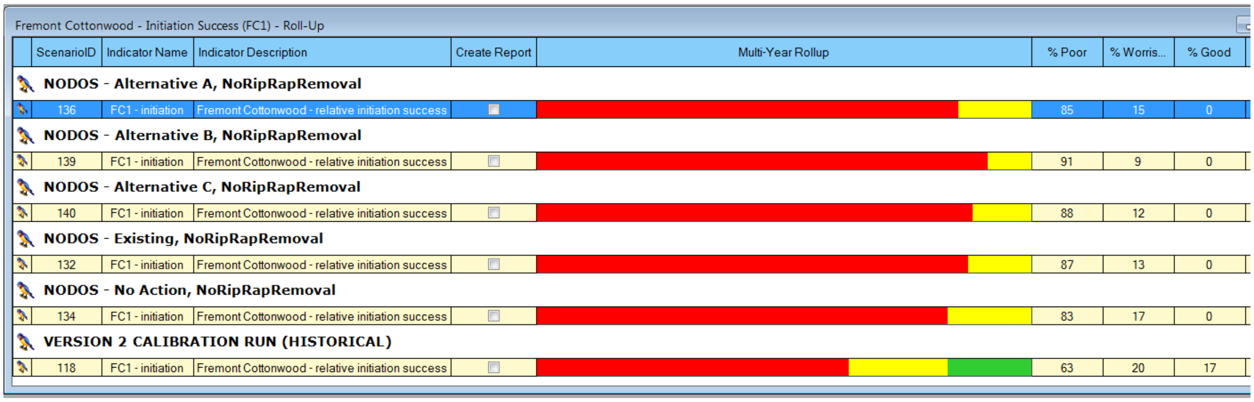


Figure 3.2: Annual roll-up results for the SacEFT Fremont cottonwood initiation (FC1) performance measure run using historic observed flows (1938–2003). This calibration also takes into consideration comparisons with aerial photographs of historically strong Cottonwood recruitment at study sites vs. model results.

Our concept of indicator threshold calibration in SacEFT focuses on historical data (rather than a future no action alternative or an existing condition based on present or future constraints). From an ecological standpoint, aquatic and riparian species are adapted to a historical range and frequency of variations in their habitats. Taken to the extreme, historical conditions would ideally include pre-settlement (natural) flows/water temperatures that represented 'typical' conditions experienced over evolutionarily significant windows of time. The closest flow/temperature time series that we have available to this evolutionarily representative condition is the range of variation in historical observed flows/temperatures (approx. 66 years). It is recognized that during 1938–2003 the Sacramento River experienced a number of waves of human and structural development and operational changes to the hydrosystem. Nevertheless, these flows and temperatures, derived from measurements, actually occurred in recent history and encompass repeat episodes of multiple water year types. Calibrating SacEFT indicator thresholds to a future no action or 'existing' scenario that includes a fixed set of hydrosystem features, constraints, operating regulations and assumed human demands would create a "self-fulfilling prophecy" inconsistent with SacEFT's underlying natural flow regime science foundation.

The highest level synthesis concept in SacEFT is that of a "multi-year roll-up". This is the percentage of years in the simulation having favorable (Green), fair (Yellow), and poor (Red) conditions (*e.g.*, Figure 3.3).



Fremont Cottonwood - Initiation Success (FC1) - Roll-Up

ScenarioID	Indicator Name	Indicator Description	Create Report	Multi-Year Rollup	% Poor	% Worris...	% Good
NODOS - Alternative A, NoRipRapRemoval							
136	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨	85	15	0
NODOS - Alternative B, NoRipRapRemoval							
139	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨	91	9	0
NODOS - Alternative C, NoRipRapRemoval							
140	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨	88	12	0
NODOS - Existing, NoRipRapRemoval							
132	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨	87	13	0
NODOS - No Action, NoRipRapRemoval							
134	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨	83	17	0
VERSION 2 CALIBRATION RUN (HISTORICAL)							
118	FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	63	20	17

Figure 3.3: Typical SacEFT output showing multi-year roll-up results for the Fremont cottonwood initiation (FC1) performance measure. Analogous plots are available for all of the tools' focal species and performance measures.

The preferred method for calibrating the indicator thresholds is to identify historical years for each performance measure that were known (in nature) to have experienced 'good' or 'poor' performance. Unfortunately, our repeat survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*2011; Matt Brown, USFWS, *pers. comm.* 2011) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT v.1 review workshop revealed there are no known synoptic studies of this kind for many of the indicators in SacEFT. Because of this gap and the hesitancy of experts to reveal their opinions, we instead defaulted to the distribution of sorted weighted annual results and selected tercile break-points (the lower-, middle- and upper thirds of the sorted distribution) to categorize results into "Good" (Green), "Fair" (Yellow) or "Poor" (Red) categories. **While this method provides a fully internally consistent method of comparing scenario results (*i.e.*, will always provide an accurate picture of which water management scenarios are "better" than another), it does not *necessarily* provide a concrete inference about the biological significance** of being a "Poor" (Red) or "Good" (Green) category. For example, it is possible that a year that ranks as "Good" (Green) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) *may* be biologically insignificant (*i.e.*, *not* biologically 'unacceptable'). In the focal species/habitat performance indicator calibration summary tables in section 4.3 we flag cases where there are major gradients in performance indicator thresholds.

The challenge of identifying "acceptable" and "unacceptable" changes in habitat conditions or focal species performance measures confronts all biological effects analysis methods. SacEFT makes these inherent value judgments explicit in the model's summary outputs. Future analyses using SacEFT look forward to ecological effects analysis experts themselves providing clearer guidance on the (readily configurable) thresholds in the SacEFT modeling system.

3.2 Application overview

SacEFT uses a thick-client architecture driven by a desktop relational database. The goal is to combine external model datasets and focal species rules/hypotheses in a single client database that facilitates generation of focal species performance measures (via the SacEFT Analysis Engine) over time and space to evaluate ecological trade-offs associated with alternative flow, water temperature, gravel augmentation and channel revetment scenarios.

Snapshots of external data are imported into the SacEFT database where they are stored in an integrated system of related tables that standardize the spatial definition of variables and capture key metadata. Likewise, focal species rules/parameter values/hypotheses are stored in their own system of related tables.

At the time of data import or focal species rule specification, available metadata is specified according to a pre-defined standard. In addition to standard metadata, each imported data instance is allowed to have one or more binary objects (files) associated with it. This allows further flexibility for associating metadata with each dataset. Binary fields can be used for single files (*e.g.*, source reports in Word or PDF), digital images, or even WinZip archives containing a set of model input or configuration parameters.

To carry out ecological trade-off analyses, end users install the client SacEFT software and database on their desktop computers. At the time of writing, the software is available from:

http://www.essa.com/tools/EFT/download.html.

3.2.1 Technology platform

SacEFT uses the Microsoft .NET Framework (Version 2.0) as its software development platform. .NET is a Microsoft technology that allows cross-language development and provides a very large standard library of components and functionality. The .NET Framework includes a Base Class Library (BCL) of types and classes available to all languages which encapsulate a large number of common functions such as file reading and writing, graphic rendering, database interaction, XML document manipulation, and so forth. The BCL is much larger than other libraries, and provides a very large breadth of functionality in one package. The .NET platform also greatly simplifies deployment. For these and other reasons, the majority of future Microsoft-based development will have a .NET foundation, ensuring SacEFT will be supportable well into the future.

The specific .NET Framework 2.0[1] technologies that are used in SacEFT Version 2 include:

- **Windows Forms**: the portion of the .NET Framework that provides managed wrappers for the user interface controls contained in the existing Win32 API.
- **VB.NET 2005**: a fully object-oriented computer language backed by the .NET Framework some view as an evolution of Microsoft's Visual Basic (VB6) though with significant changes that ultimately render it a new language.
- **ADO.NET**: the primary relational data access model for Microsoft .NET-based applications. It is used to access data sources for which there is a specific .NET Provider, or via a .NET Bridge Provider.

The database platform chosen is Microsoft SQL Server 2005. The master EFT database is hosted on a central server, and remote connections from the EFTReader software (www.essa.com/tools/EFT/download.html) are supported. SQL Server 2005 provides high-value database functionality including: stored procedures, triggers, transact-SQL (which supports conditional logic, such as if/then and case blocks), integrated XML and an integrated security model.

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[1] The EFT development team plans to upgrade the application to the .NET Framework 3.x later in 2011.

3.3 System architecture

SacEFT’s component architecture is illustrated in Figure 3.4 and described in the sections that follow.

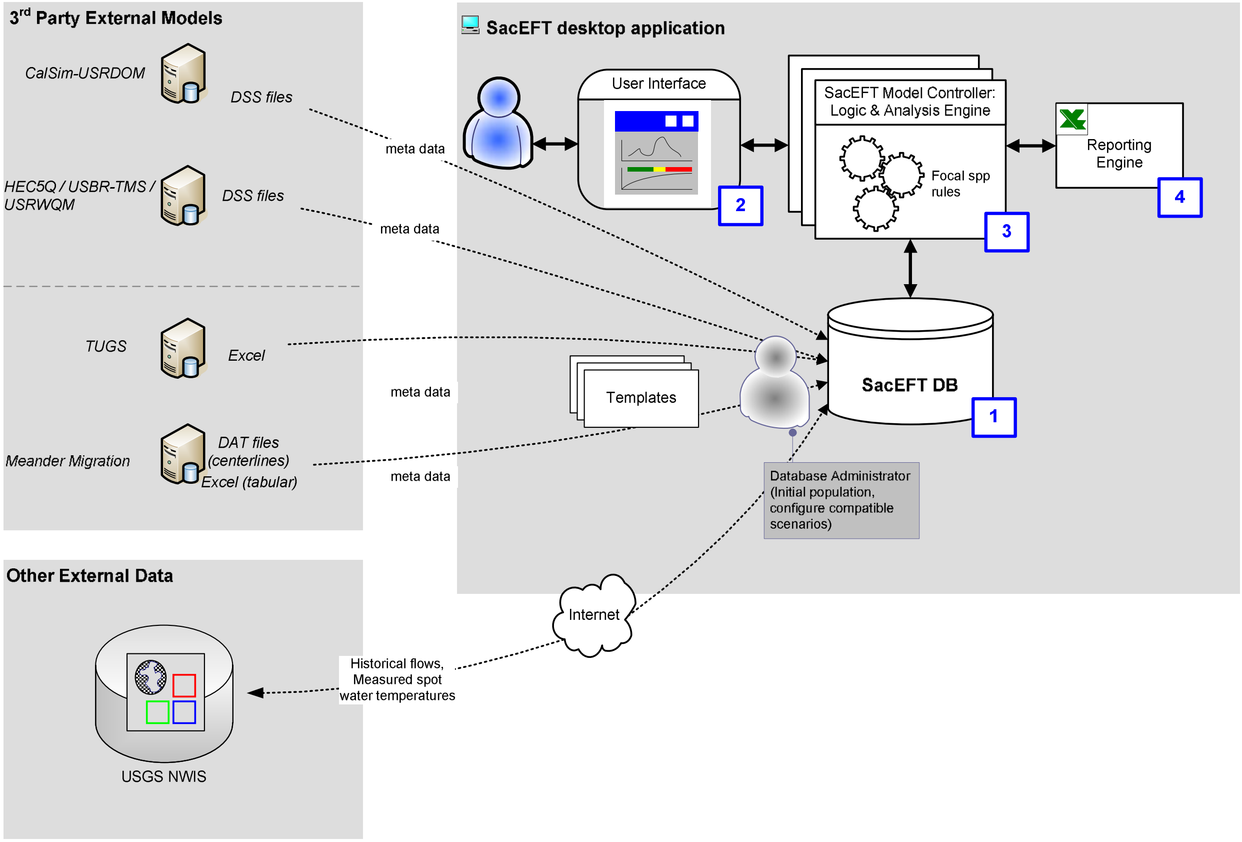


Figure 3.4. SacEFT component architecture.

3.3.1 External physical submodels

The physical input variables required by SacEFT’s focal species submodels are derived from several external models or systems (see Figure 3.4, “3rd Party External Models”). These models vary in terms of sophistication, physical location, data formats and documentation. Many of them depend on the same kinds of input data. For example, the temperature simulation component of the US Bureau of Reclamation’s Water Quality Model (USRWQM) depends on many of the same hydro system operation assumptions that are central configuration properties of CalSim II, as does a sediment transport model (TUGS) and a Meander Migration Model (because these assumptions affect Sacramento River flow). The datasets of results from these models must be accessed and imported to the SacEFT database. In so doing, **SacEFT addresses two issues at the time of data import**:

1. Identifying output variables (daily average flows, daily average water temperatures, sediment transport variables, river bend erosion variables) within a common spatial identification system.
2. Tagging imported data instances with key metadata that allows non-specialist users to: (a) determine whether that given instance should be combined with a dataset that was imported from another related model; and (b) understand a model run’s assumptions and limitations.

Spatial harmonization is simply managed through the common concept of river miles. This includes making assumptions about the river segment that a particular node link in CalSim-USRWQM represents, *even though it is recognized* that as a node link it has no *precise* spatial meaning. We nevertheless must make explicit all the assumptions required to link different models together. The linkage process requires maturity surrounding the relative errors between physical and focal species submodels as well as a realization that even though a high level of detail may be possible, it is not always useful. As stated earlier, SacEFT is not an attempt to make precise predictions of ecosystem behavior or outcomes. The main purpose is to characterize and explore important ecological trade-offs and inform managers and decision makers about the *relative* impacts of various flow management alternatives.

Details of external physical models are described in more detail in Section 4.

3.3.2 Database

SacEFT is built around a single master relational database (Blue box labeled "1" in the upper right portion of Figure 3.4). The SacEFT Graphical User Interface (Box "2" in Figure 3.4), Model Controller & Analysis Engine (Box "3" in Figure 3.4) and Excel Reporting Service (Box "4" in Figure 3.4) connect to and interact with this database.

The SacEFT database contains seven important classes of related tables (Table 3.2). The SacEFT v.2 relational database schema is illustrated in Figure 3.5.

Table 3.2. The seven major classes of SacEFT database table, and their general role.

Table Family	**Role**
(1) Spatial_	▪ Tables under the Spatial namespace are responsible for holding all information related to the spatial definition of locations. This information is managed as points, cross-sections and segments.
(2) Data_Instances	▪ The key generic concept for tracking imported datasets and their metadata ▪ Also used to (optionally) tag information on non-imported (*i.e.*, local) generic rules/parameter values for focal species.
(3) Data_MetaData	▪ Data.Metadata provide a standard set of fields to capture metadata for all submodels. This information, along with optional model reviews, would be inspected by users when building compatibility lists for structuring unified, "apples and apples" SacEFT model runs.
(4) Data_Review	▪ Further comments, opinions regarding Data_Instances and model results can be provided by data reviews, which characterize applicability, relevance and rigor, and allow for general comments.
(5) ModelRun._	▪ Tables under the ModelRun namespace unify the concept of a model scenario, identifying all the associated data instances (imported data sets to be used, and focal species submodel rules) that are to be used within a single model run.
(6) DataImport.<Model>	▪ The DataImport namespace is used to structure how data imported from external physical models are stored. Typically, the variables of interest are arrayed by a DataInstanceID, a LocationID and a date (at the appropriate temporal resolution). ▪ These tables store the physical data itself – the streamflow, water temperatures, model results, *etc.*
(7) FS_ and FSOut_	▪ This family of tables hold the lookup data, rules and parameter values for focal species and their associated model results generated internally by SacEFT code.

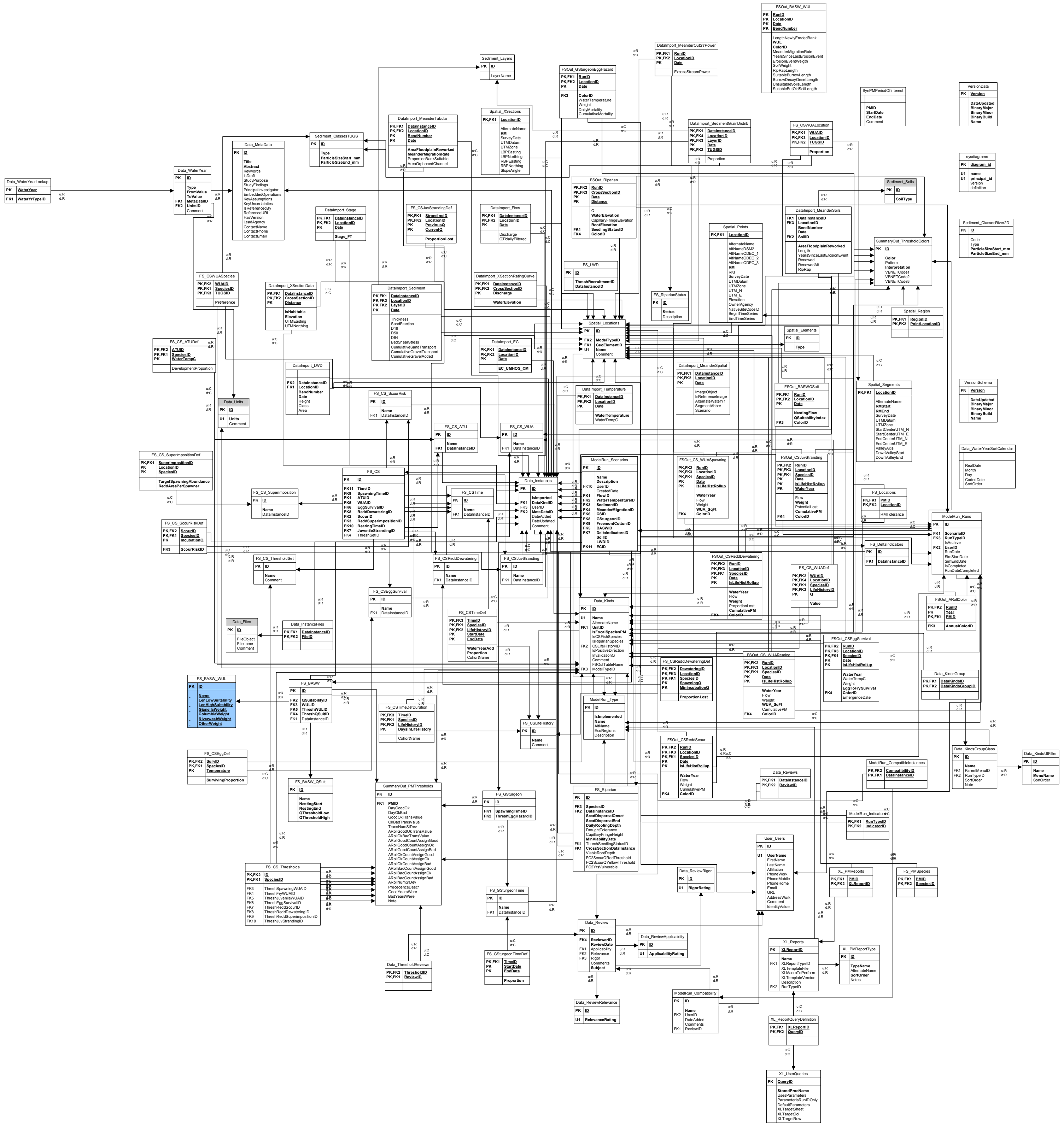


Figure 3.5. SacEFT v.2 relational database entity relationship diagram. DeltaEFT database components are also included in the same master database. PK = part of the primary key. FK = foreign key. U = unique index (values cannot repeat in the table). C = cascading referential action (delete and updates). Not shown are dozens of stored procedures, functions and views that leverage these user tables. (Note: This diagram has not been layout- or print-optimized).

DATABASE CONFIGURATION

As discussed above, a critical feature of SacEFT is the need to leverage existing systems and data sources. This requires import of components of these datasets from these external models, into the SacEFT database. Presently in v.2.00, a database administrator who understands the SacEFT database schema is required to populate the SacEFT database.

DATAMASTER

Data-driven applications require a considerable amount of interaction with their underlying data store(s). Code is required to move data from the physical database tables to: a) the presentation layer (user interface), and b) in-memory datasets, arrays and variables used by indicator algorithms. Different commands are needed to retrieve, add, delete and update.

This functionality is the responsibility of SacEFT's DataMaster project, an ADO.NET wrapper for encapsulating all connection and command-based operations vs. SacEFT's SQL Server 2005 database. The DataMaster also interacts with a wide range of calculation specific SQL functions and stored procedures stored in the SacEFT database.

3.3.3 Model controller and analysis engine

FOCAL SPECIES SUBMODELS (PERFORMANCE INDICATOR ALGORITHMS)

This is the component of the system that is of the most interest to biologists. Unlike external physical submodels, the SacEFT code base is largely comprised of *in-situ* focal species rules and algorithms for the tool's various indicators. This includes, in several cases, porting lookup tables and even code from other studies or external models where this is efficient. These classes house all of the logic necessary to take physical inputs, and translate them into various focal species performance measures.

COMPATIBILITY LISTS AND SCENARIOS

Before a model run, the database administrator must have ensured physical datasets and focal species rules are internally consistent and compatible. This includes review of metadata and user reviews (optional) for the candidate data instances.

ANALYSIS ENGINE

The final job of the ModelController occurs at run-time, once a compatible scenario is established and run. During a SacEFT model run, the ModelController organizes calls to physical and focal species components in the required sequence, ensures that variables are packaged correctly for transfer between submodels. In essence, the ModelController is the thing that ensures performance measures are calculated in an orderly, sensible manner and the appropriate outputs written to the SacEFT database.

When combined with ADO.NET data transfer responsibilities in the DataMaster, the ModelController and focal species components make up the bulk of code in SacEFT.

3.3.4 Excel reporting

As identified earlier, SacEFT uses MS Excel for reporting detailed outputs in tabular and graphical format. MS Excel is a well-established software tool widely used at one time or another by the majority of scientists and planners in the field of water operation planning. SacEFT's Excel Reporting engine involves designing Excel templates, and using them in a "just in time" fashion as the target of a specific set of stored procedure calls. For example, an Excel template may have a "flow" and "temperature" worksheet, and two embedded line graphs that expect this data in a specific location and format. Excel macros (VBA code) are optionally used to further extend the features of these reports.

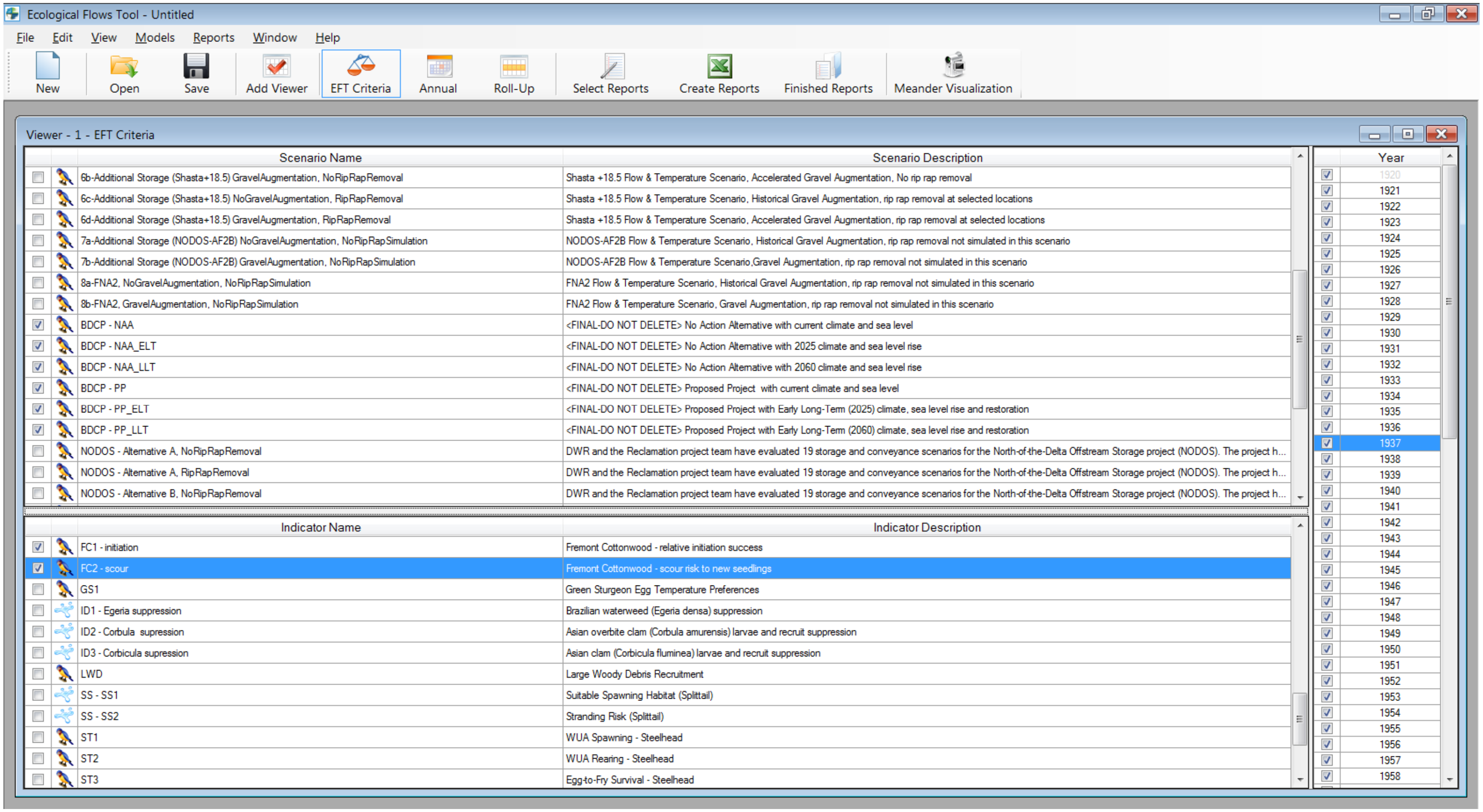
The unique and intuitive manner in which this reporting feature is integrated into the SacEFT User Interface is highly extensible and customizable.

3.3.5 User interface

Figure 3.6, Figure 3.7 and Figure 3.8 illustrate three of the main screens or views provided by SacEFT v.2.00. This user interface was developed using Windows Forms with Visual Studio 2005 and the Visual Basic 2005 programming language.

SacEFT v.2.00 emphasizes display of output rather than dialogue-intensive database editing features. In our experience, it is more important to demonstrate results and iterate on how this is best presented before investing resources in a user interface for editing and configuring all aspects of the underlying database. Typically, database editing capability and the associated myriad of dialogue forms required eats up considerable time without fundamentally enabling users to access modeling results or appreciate the merits of the system.

Readers are referred to the EFTReader on-line User Guide for operational details on the SacEFT user interface, see: www.essa.com/tools/EFT/Help/index.html.



	Scenario Name	Scenario Description
☐	6b-Additional Storage (Shasta+18.5) GravelAugmentation, NoRipRapRemoval	Shasta +18.5 Flow & Temperature Scenario, Accelerated Gravel Augmentation, No rip rap removal
☐	6c-Additional Storage (Shasta+18.5) NoGravelAugmentation, RipRapRemoval	Shasta +18.5 Flow & Temperature Scenario, Historical Gravel Augmentation, rip rap removal at selected locations
☐	6d-Additional Storage (Shasta+18.5) GravelAugmentation, RipRapRemoval	Shasta +18.5 Flow & Temperature Scenario, Accelerated Gravel Augmentation, rip rap removal at selected locations
☐	7a-Additional Storage (NODOS-AF2B) NoGravelAugmentation, NoRipRapSimulation	NODOS-AF2B Flow & Temperature Scenario, Historical Gravel Augmentation, rip rap removal not simulated in this scenario
☐	7b-Additional Storage (NODOS-AF2B) GravelAugmentation, NoRipRapSimulation	NODOS-AF2B Flow & Temperature Scenario,Gravel Augmentation, rip rap removal not simulated in this scenario
☐	8a-FNA2, NoGravelAugmentation, NoRipRapSimulation	FNA2 Flow & Temperature Scenario, Historical Gravel Augmentation, rip rap removal not simulated in this scenario
☐	8b-FNA2, GravelAugmentation, NoRipRapSimulation	FNA2 Flow & Temperature Scenario, Gravel Augmentation, rip rap removal not simulated in this scenario
☑	BDCP - NAA	<FINAL-DO NOT DELETE> No Action Alternative with current climate and sea level
☑	BDCP - NAA_ELT	<FINAL-DO NOT DELETE> No Action Alternative with 2025 climate and sea level rise
☑	BDCP - NAA_LLT	<FINAL-DO NOT DELETE> No Action Alternative with 2060 climate and sea level rise
☑	BDCP - PP	<FINAL-DO NOT DELETE> Proposed Project with current climate and sea level
☑	BDCP - PP_ELT	<FINAL-DO NOT DELETE> Proposed Project with Early Long-Term (2025) climate, sea level rise and restoration
☑	BDCP - PP_LLT	<FINAL-DO NOT DELETE> Proposed Project with Early Long-Term (2060) climate, sea level rise and restoration
☐	NODOS - Alternative A, NoRipRapRemoval	DWR and the Reclamation project team have evaluated 19 storage and conveyance scenarios for the North-of-the-Delta Offstream Storage project (NODOS). The project h...
☐	NODOS - Alternative A, RipRapRemoval	DWR and the Reclamation project team have evaluated 19 storage and conveyance scenarios for the North-of-the-Delta Offstream Storage project (NODOS). The project h...
☐	NODOS - Alternative B, NoRipRapRemoval	DWR and the Reclamation project team have evaluated 19 storage and conveyance scenarios for the North-of-the-Delta Offstream Storage project (NODOS). The project h...

	Indicator Name	Indicator Description
☑	FC1 - initiation	Fremont Cottonwood - relative initiation success
☑	FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
☐	GS1	Green Sturgeon Egg Temperature Preferences
☐	ID1 - Egeria suppression	Brazilian waterweed (Egeria densa) suppression
☐	ID2 - Corbula supression	Asian overbite clam (Corbula amurensis) larvae and recruit suppression
☐	ID3 - Corbicula supression	Asian clam (Corbicula fluminea) larvae and recruit suppression
☐	LWD	Large Woody Debris Recruitment
☐	SS - SS1	Suitable Spawning Habitat (Splittail)
☐	SS - SS2	Stranding Risk (Splittail)
☐	ST1	WUA Spawning - Steelhead
☐	ST2	WUA Rearing - Steelhead
☐	ST3	Egg-to-Fry Survival - Steelhead

	Year
☑	1920
☑	1921
☑	1922
☑	1923
☑	1924
☑	1925
☑	1926
☑	1927
☑	1928
☑	1929
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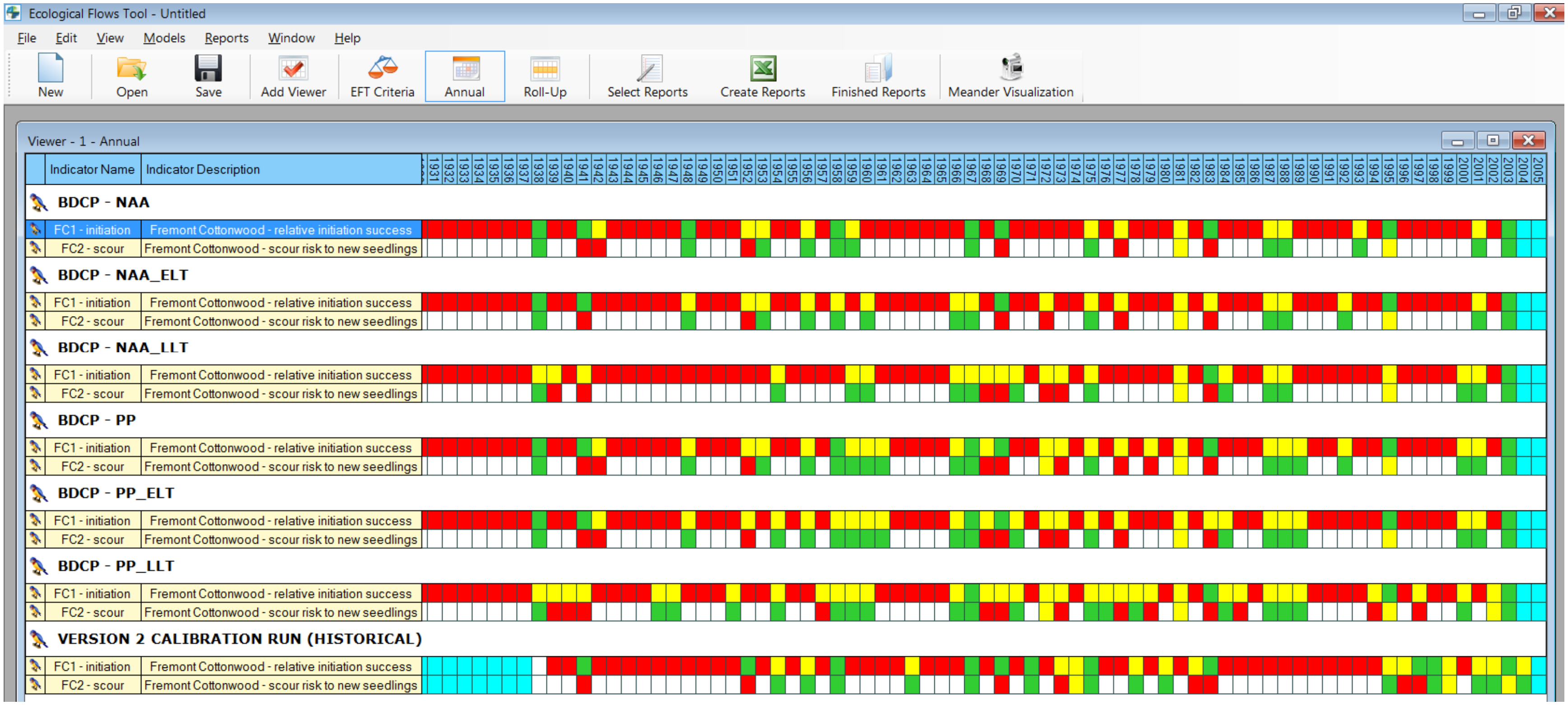
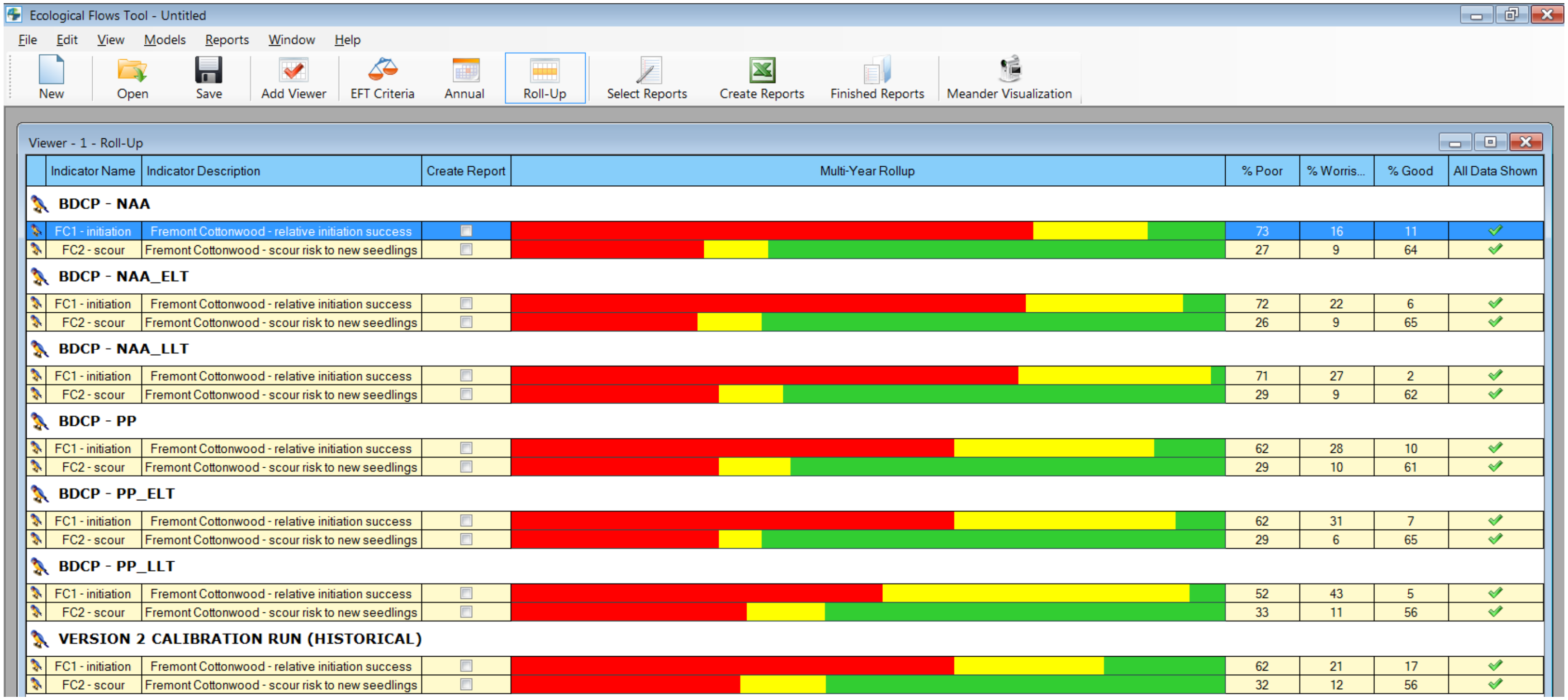
☑	1948
☑	1949
☑	1950
☑	1951
☑	1952
☑	1953
☑	1954
☑	1955
☑	1956
☑	1957
☑	1958

Figure 3.6: EFT’s main screen, showing the Criteria selection dialogue used for choosing scenarios, indicators and simulation years.



Indicator Name	Indicator Description
BDCP - NAA	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
BDCP - NAA_ELT	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
BDCP - NAA_LLT	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
BDCP - PP	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
BDCP - PP_ELT	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
BDCP - PP_LLT	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings
VERSION 2 CALIBRATION RUN (HISTORICAL)	
FC1 - initiation	Fremont Cottonwood - relative initiation success
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings

Figure 3.7: An example of EFT's Output Viewer screen in Annual View, showing a multi-scenario comparison for two performance measures and the tool's signature "traffic light" hazard assessment or indicator rating system over multiple years. The hazard assessment tool provides a rapid visual summary of a scenarios' overall ecological performance, and can be used as a navigational aid to drill into the details.

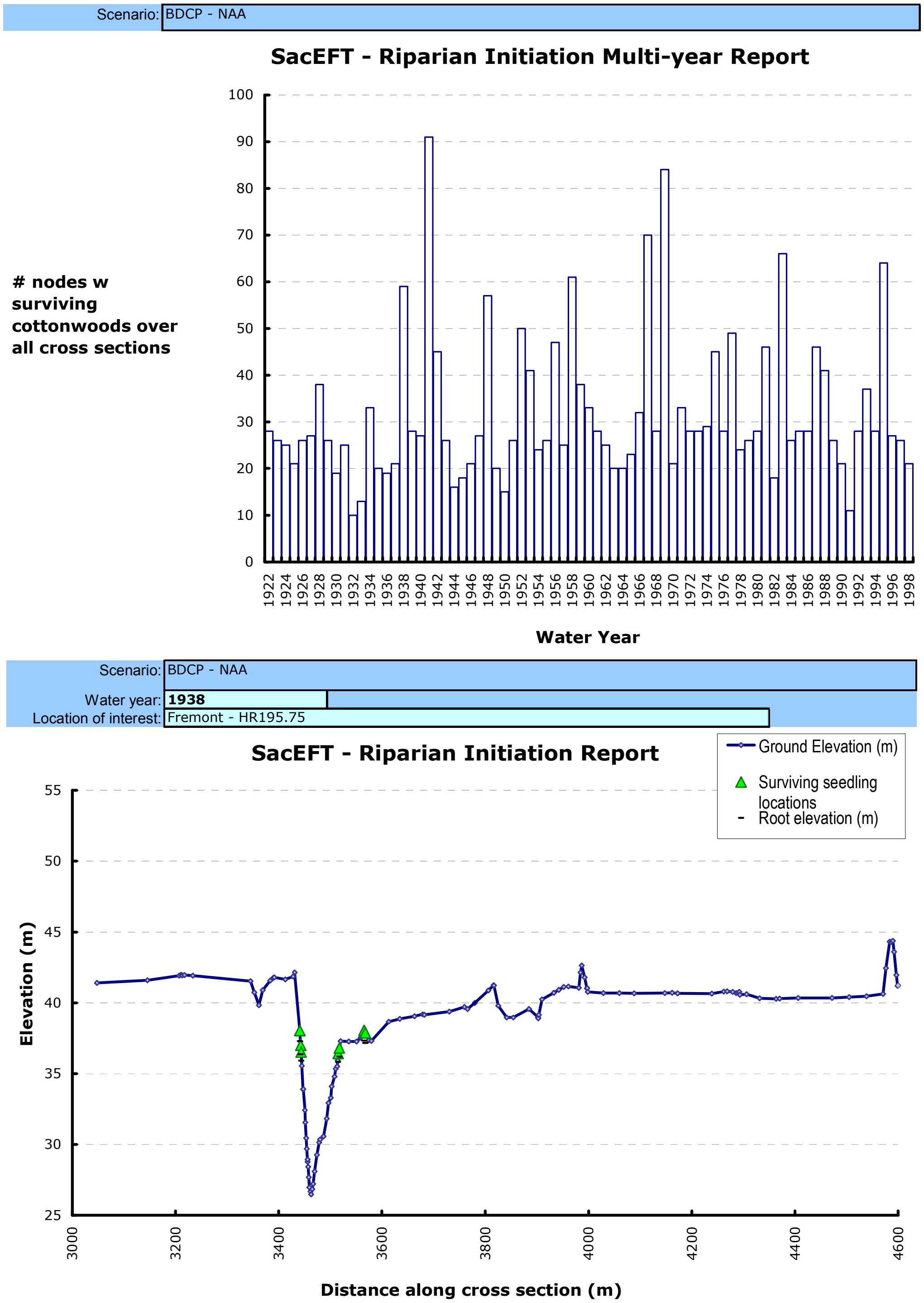


Indicator Name	Indicator Description	Create Report	Multi-Year Rollup	% Poor	% Worris...	% Good	All Data Shown
BDCP - NAA							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	73	16	11	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	27	9	64	✓
BDCP - NAA_ELT							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	72	22	6	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	26	9	65	✓
BDCP - NAA_LLT							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	71	27	2	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	29	9	62	✓
BDCP - PP							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	62	28	10	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	29	10	61	✓
BDCP - PP_ELT							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	62	31	7	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	29	6	65	✓
BDCP - PP_LLT							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	52	43	5	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	33	11	56	✓
VERSION 2 CALIBRATION RUN (HISTORICAL)							
FC1 - initiation	Fremont Cottonwood - relative initiation success	☐	🟥🟨🟩	62	21	17	✓
FC2 - scour	Fremont Cottonwood - scour risk to new seedlings	☐	🟥🟨🟩	32	12	56	✓

Figure 3.8: An example of EFT's Output Viewer screen, showing the same information as Figure 3.7, but in multi-year Rollup View. This is the best view for quickly assessing the relative differences in performance among scenarios.

EXCEL OUTPUT REPORTS

MS Excel graphs and tables serve as the primary method for delivering detailed outputs. An example of SacEFT's v.2.00 Fremont Cottonwood initiation model is given in Figure 3.9.



Scenario: BDCP - NAA

SacEFT - Riparian Initiation Multi-year Report

Scenario: BDCP - NAA

Water year: 1938

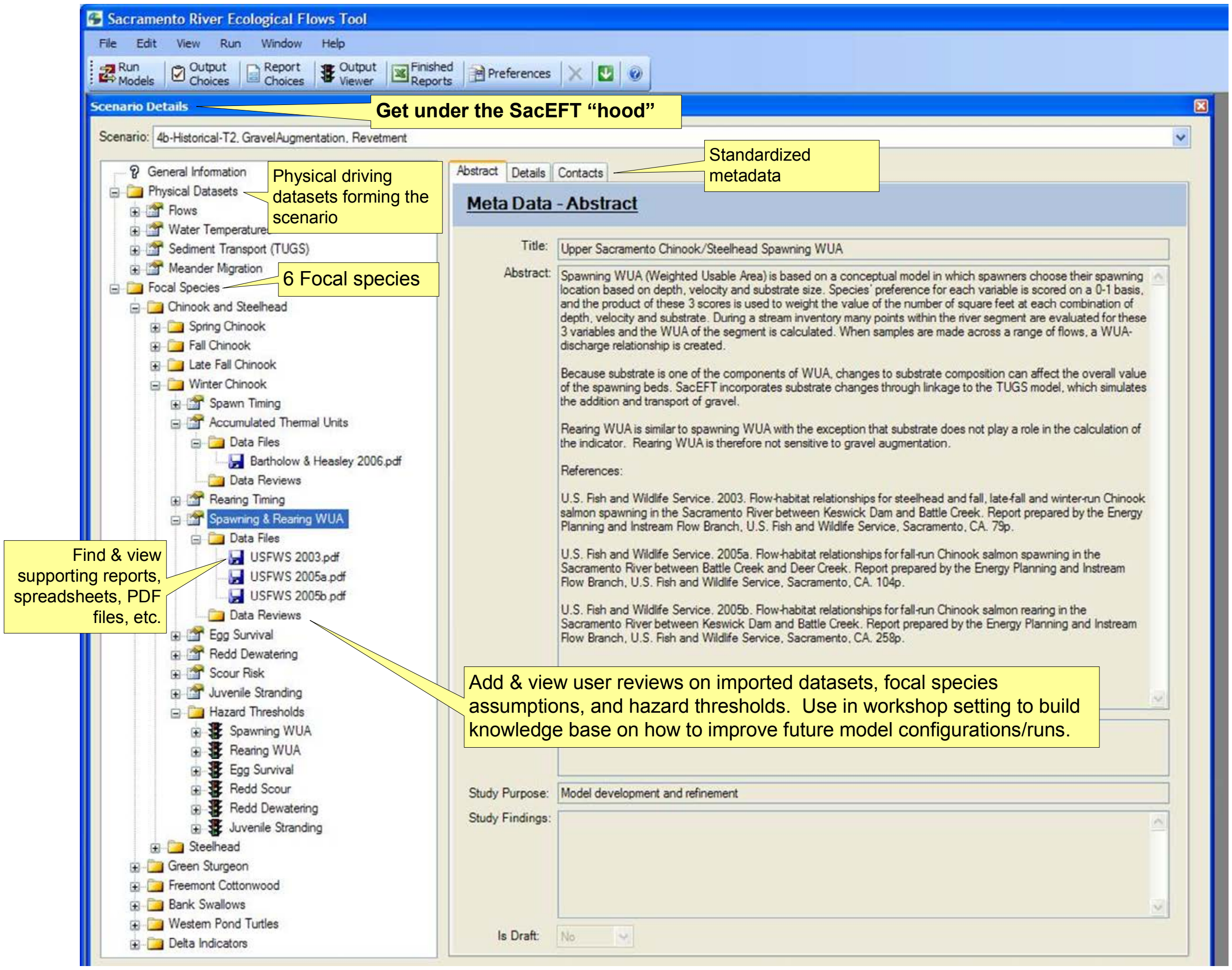
Location of interest: Fremont - HR195.75

SacEFT - Riparian Initiation Report

Figure 3.9: EFT provides detailed output on a scenario × year × performance measure basis in Excel. Refer back to Figure 3.7 for context.

SCENARIO DETAILS AND METADATA

SacEFT provides a Scenario Details and Reviews feature to allow users to find additional information on a given scenario or model component (Figure 3.10).



Get under the SacEFT "hood"

Standardized metadata

Physical driving datasets forming the scenario

6 Focal species

Find & view supporting reports, spreadsheets, PDF files, etc.

Add & view user reviews on imported datasets, focal species assumptions, and hazard thresholds. Use in workshop setting to build knowledge base on how to improve future model configurations/runs.

Scenario: 4b-Historical-T2. GravelAugmentation. Revetment

Title: Upper Sacramento Chinook/Steelhead Spawning WUA

Abstract: Spawning WUA (Weighted Usable Area) is based on a conceptual model in which spawners choose their spawning location based on depth, velocity and substrate size. Species' preference for each variable is scored on a 0-1 basis, and the product of these 3 scores is used to weight the value of the number of square feet at each combination of depth, velocity and substrate. During a stream inventory many points within the river segment are evaluated for these 3 variables and the WUA of the segment is calculated. When samples are made across a range of flows, a WUA-discharge relationship is created.

Because substrate is one of the components of WUA, changes to substrate composition can affect the overall value of the spawning beds. SacEFT incorporates substrate changes through linkage to the TUGS model, which simulates the addition and transport of gravel.

Rearing WUA is similar to spawning WUA with the exception that substrate does not play a role in the calculation of the indicator. Rearing WUA is therefore not sensitive to gravel augmentation.

References:

U.S. Fish and Wildlife Service. 2003. Flow-habitat relationships for steelhead and fall, late-fall and winter-run Chinook salmon spawning in the Sacramento River between Keswick Dam and Battle Creek. Report prepared by the Energy Planning and Instream Flow Branch, U.S. Fish and Wildlife Service, Sacramento, CA. 79p.

U.S. Fish and Wildlife Service. 2005a. Flow-habitat relationships for fall-run Chinook salmon spawning in the Sacramento River between Battle Creek and Deer Creek. Report prepared by the Energy Planning and Instream Flow Branch, U.S. Fish and Wildlife Service, Sacramento, CA. 104p.

U.S. Fish and Wildlife Service. 2005b. Flow-habitat relationships for fall-run Chinook salmon rearing in the Sacramento River between Keswick Dam and Battle Creek. Report prepared by the Energy Planning and Instream Flow Branch, U.S. Fish and Wildlife Service, Sacramento, CA. 258p.

Study Purpose: Model development and refinement

Study Findings:

Is Draft: No

Figure 3.10: EFT's Scenario Details and Reviews dialogue for learning more about imported datasets and focal species assumptions.

4. SacEFT Submodels: Functional Details

4.1 Physical driving submodels

The physical data sets used by SacEFT originate with several high-profile planning models. The intent of SacEFT is to leverage the extensive existing efforts made to develop, maintain and calibrate these systems, to supply key inputs necessary to calculate focal species performance measures. In addition to these models, selected mainstem Sacramento River gauging records have been used for river discharge and water temperatures. Using data from both models and stream gauges permits a mix of prospective and retrospective analyses.

4.1.1 Flow / hydrology

HISTORICAL/ACTUAL FLOWS: STREAM GAUGES

Table 4.1 lists the *historical* Sacramento River stream gauge records that have been imported into the SacEFT database. The finest temporal resolution of these historical records is the daily average.

Table 4.1. An example of the mainstem Sacramento River United States Geological Survey (USGS) stream gauges included in SacEFT. These gauges were selected because each provides a lengthy and complete or nearly-complete record of average daily flow. *Source:* The USGS surface water data web site (waterdata.usgs.gov/usa/nwis) and related web service (river.sdsc.edu/NWISTS/nwis.asmx).

Native Site Code	Name	UTM Zone	UTM Datum	UTM_N	UTM_E	RM	Elev (ft)	Owner Agency
11370500	SACRAMENTO R A KESWICK CA	10T	NAD27	4,494,415.947	547,098.993	301	479.8	USGS
11377100	SACRAMENTO R AB BEND BRIDGE NR RED BLUFF CA	10T	NAD27	4,459,898.695	569,229.379	260		USGS
11378000	SACRAMENTO R NR RED BLUFF CA	10T	NAD27	4,443,331.523	569,713.045	243	253.6	USGS
11383730	SACRAMENTO R A VINA BRIDGE NR VINA CA	10S	NAD27	4,417,891.359	577,616.258	218	197.0	USGS
11383800	SACRAMENTO R NR HAMILTON CITY CA	10S	NAD27	4,400,469.206	586,147.110	199	145.0	USGS
11389000	SACRAMENTO R A BUTTE CITY CA	10S	NAD27	4,367,853.628	586,631.562	168		USGS
11389500	SACRAMENTO R A COLUSA CA	10S	NAD27	4,340,812.116	586,405.165	143		USGS

Approximately 66 years of daily historical records were gathered in this manner and used in retrospective and calibration scenarios. This historical gauging data includes use of pre-existing data files supplied by project contributors.

Note: an extensive survey of the NWIS web service showed a total of 28 stations with some data, but many of these had incomplete time series. Even the 10 gauges with reasonably complete series (Table 4.1) had some gaps in daily average flow. Two missing data segments at VINA (1/Oct/1938 to 12/Apr/1945; 1/Oct/1978 to 30/Sep/2004) were interpolated by linear regression of the incomplete "SACRAMENTO R A VINA BRIDGE NR VINA CA" vs. complete "SACRAMENTO R AB BEND

BRIDGE NR RED BLUFF CA": (1.2459 x BendBridge – 1364.5) (Yantao Cui, Stillwater Sciences, *pers. comm.*). Three missing data segments at this station (1/Oct/1938 to 20/Apr/1945; 15/Jan/1956 to 18/Jun/1956; 3/Oct/1980 to 30/Sep/2004) were interpolated by linear regression of incomplete "SACRAMENTO R NR HAMILTON CITY CA" vs. complete "SACRAMENTO R AB BEND BRIDGE NR RED BLUFF CA": (1.2047 x BendBridge – 1987.4) (Yantao Cui, Stillwater Sciences, *pers. comm.*). Finally, numerous winter gaps (typically Nov–May; 1921–1940) in COLUSA R A COLUSA CA were imputed using a nonlinear relationship with SACRAMENTO R AB BEND BRIDGE NR RED BLUFF CA discharge, even though that station is >100mi upstream. The best predictive relationship obtained for Colusa discharge day on day ***t*** was found to be given by Bend Bridge on day ***t-1*** (*i.e.,* a 1 day lag). Loess smoothing with a span of 2.5% was used to develop a fairly smooth predictive relationship, which was applied to the missing Colusa dates.

With these gaps filled, the available historical flow data span a continuous common period from 1/Oct/1938 to 30/Sep/2004: Water Years 1939-2004, a minimum of 24,107 historical records for each location.

FUTURE/PROSPECTIVE FLOWS AND WATER TEMPERATURES: UPPER SACRAMENTO WATER QUALITY MODEL (USRWQM) / UPPER SACRAMENTO RIVER DAILY OPERATIONS MODEL (USRDOM)

SacEFT prospective daily flow datasets are dependent on the input data provided to them. The Upper Sacramento River Daily Operations Model (USRDOM) was developed to simulate reservoir operations and hydrologic stream routing in the upper Sacramento River from Keswick Dam to Knights Landing on a daily timescale. The simulated daily flows from USRDOM can be used as inputs to several biological and habitat models. Upper Sacramento Water Quality Model (USRWQM) was developed to simulate daily temperature conditions in the Sacramento River based on the daily flow conditions. The geographical extent of the model is similar to the USRDOM. The simulated daily temperatures from USRWQM can be used as inputs to biological and habitat models. Both of these models depend on CalSim.

CalSim is a generalized water resource planning tool developed jointly by CWDR and the US Bureau of Reclamation Mid-Pacific Region. The primary purpose of the CalSim II model is to evaluate the performance of Central Valley Project (CVP) and State Water Project (SWP) at current and prospective future levels of water supply and demand. A mass balance model, CalSim is used as a framework to evaluate water delivery scenarios associated with expansion of project facilities as well as changes in hydrosystem operation criteria. Water routing and operational decisions are formalized into algorithms that include subjective judgments, rules and weights on various objectives. Explicit operating rules define what action is to be taken at each time-step given the state of the hydrosystem.

METADATA NEEDED TO DEVELOP SCENARIO COMPATIBILITY LISTS

By design, SacEFT requires no pre-requisite knowledge or experience in the operation of CalSim, USRDOM and USRWQM. Rather than become CalSim – USRDOM – USRWQM experts, SacEFT users are tasked with aligning model assumptions between a given imported dataset and other related physical models (TUGS, Meander Migration). This requires the ability to quickly summarize the key embedded assumptions, inputs, and other important characteristics of a CalSim – USRDOM – SRWQM DSS database in a format that non-CalSim experts can understand. To achieve this, we apply the metadata standard shown in Figure 4.1 to all physical submodel datasets that are imported into SacEFT.

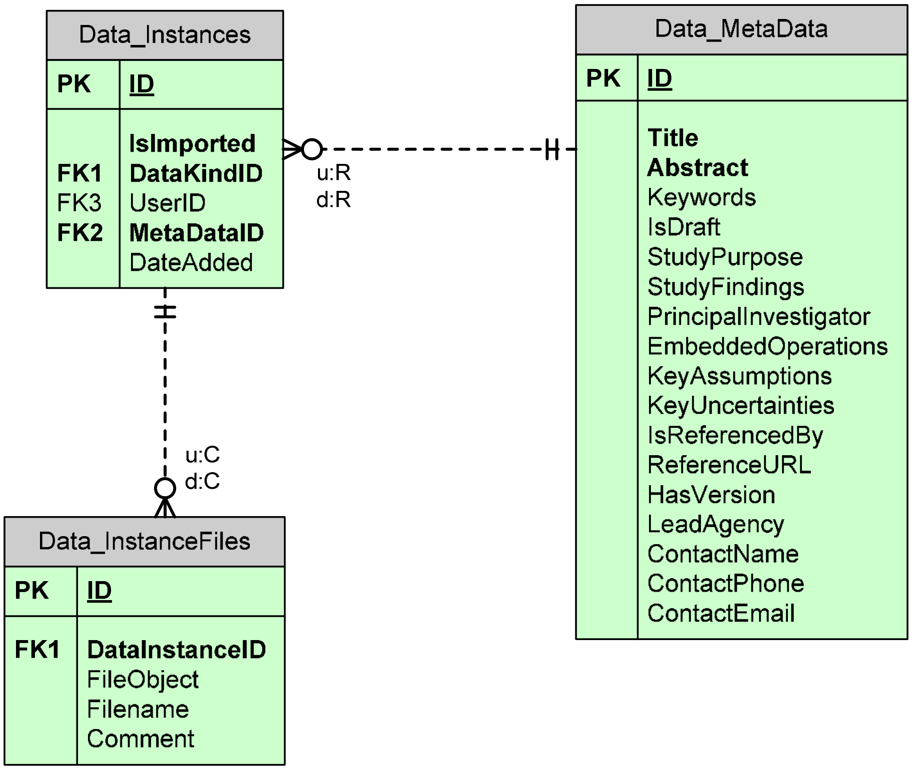


Figure 4.1. Underlying database design showing how each imported DSS file from CalSim (and any other data from an external physical model) is associated with a DataInstance and a set of MetaData. A considerable number of the fields in Data_MetaData are optional.

Note: **The metadata standard shown in Figure 4.1 is also applied to focal species submodels in SacEFT**. In other words, the concept of a DataInstance refers both to *imported data sets*, as well as *resident generic rules* for a particular focal species submodel. For example, one riparian submodel scenario may use a different tap-root growth rate from another riparian scenario. While this does not require nearly as great a level of detail in metadata documentation as a CalSim DataInstance, the rationale for one growth rate over another is the kind of information that can be tracked using the metadata standard.

4.1.2 Water temperature

HISTORICAL/ACTUAL WATER TEMPERATURES: GAUGES

The same USGS stream gauges listed in Table 4.1 were polled for water temperature information. These records can also be accessed using the NWIS web service, using a method call along the following lines:

```
oNWIS.GetWQValues(sUSGSStatCode, sWaterTempCode1, "1880-01-01", "2008-11-25")
```

We attempted to use this data source to gather historical water temperature records but found that the existing historical temperature records are ephemeral. There are no temperature data corresponding to the

---

[1] The parameter code for water temperature in NWIS is: “00010”

long continuous records available for discharge. Instead, Table 2.4 shows the 10 gauge locations (themselves modeled) between Bend Bridge and Keswick (RM 260-301) over the period 1-Jan-1970 to 31-Dec-2001.

SPATIAL RESOLUTION AND INTERPRETATION OF NODE LINKS

SacEFT treats USRWQM water temperatures as adequately representative of defined segments using a fixed river mile start and end value. Of the approximately 159 mile mainstem Sacramento River study area, the USBR model provides 10 nodes/arcs of interest (Table 4.2). The approximate river miles shown in the table are based on the U.S Army Corps of Engineers (1991). Additional nodes of interest can be provided, requiring only minor modifications to the software.

Table 4.2. USBR Temperature Model spatial nodes of interest on mainstem Sacramento River.

USBR Temperature Model Node / Arc Name	River mile
KESWICK	301
SAC_AT_COW_CR	280
BALLS_FERRY	277
JELLYS_FERRY	267
BEND_BR	260
RED_BLUFF	243
WOODSON_BR	218
HAMILTON_CITY	199
BUTTE_CITY	168
COLUSA	143

METADATA NEEDED TO DEVELOP SCENARIO COMPATIBILITY LISTS

As with CalSim – USRDOM results, SacEFT users must align model assumptions between a given USRWQM run and other related physical models (USRDOM, TUGS, Meander Migration). This requires the ability to quickly summarize the key embedded assumptions, inputs, and other important characteristics of a USBR Temperature Model DSS database in a form that non-USBR experts can understand. As described earlier in Section 4.1.1, we apply a metadata standard to document the context for all imported data (see Figure 4.1).

4.1.3 Stage-discharge

Some focal species submodels require information on water surface elevation (stage) at specific points along a cross-section, as a function of river discharge. These stage-discharge relationships are site specific and dependent on numerous variables that govern hydraulic behavior. Cross-sections themselves, that is – ground surface elevation profiles as a function of distance along a transect – are typically surveyed in the field by some means of bathymetric observation. The process of collecting this information from direct field measurement is time consuming, and often the flows of interest are not presented in a timely or predictable fashion. For these reasons, hydraulic simulation models have become widely used, especially tools developed by the U.S. Army Corps of Engineers Hydrologic Engineering Center (HEC).

A variety of groups have used HEC software or UNET models on the Sacramento River (*e.g.*, California Department of Water Resources Comprehensive Study, U.S. Geological Survey, U.S. Fish and Wildlife Service, Ayers and Associates consultants, and The Nature Conservancy. Unfortunately, many of these studies only consider large flood recurrence discharges (50-, 100-, and 200-year events) and largely ignore lower-magnitude discharges needed to study in-channel and near-bank dynamics. Other academic researchers have developed detailed elevation models that provide stage-elevation and wetted area relations, but the output of these models is not readily available.

It is important to understand that in SacEFT, this information **is only needed where**:

1. A focal species submodel needs to know this information; and
2. Where geometric data and HEC (or other model) implementations already exist or can readily supply the ground surface profile and an in-channel stage-discharge relationship.

SITES OF INTEREST AND SPATIAL RESOLUTION

Cottonwood initiation is currently the only consideration in SacEFT driving the choice of matched stage-discharge and ground surface elevation data. During our reconnaissance leading up to the model design workshop in December 2005, three sites at RM 172, 183 and 192 – examined during the 2003 Beehive Bend study (Roberts *et al.* 2002, Roberts 2003) met the two criteria above. These sites were assumed to be representative of the Colusa to Red Bluff section of the Sacramento River, and SacEFT's riparian initiation submodel is therefore applied to these 3 sites. In subsequent development work additional locations have been added, so that Version 2 contains cross sections from these 10 locations: RM 164, 165, 172, 183, 185.5, 192, 195.75, 199.75, 206 and 208.25.

METADATA NEEDED

As with any other dataset in SacEFT, these manually imported data are tagged with a DataInstance ID, which allows key background information to be tracked using SacEFT's metadata standard.

4.1.4 Sediment transport and bed composition

Stillwater Sciences has developed The Unified Gravel-Sand (TUGS) model to simulate how bed mobilization and scour affect grain size distribution, including the fraction of sand in both the surface and subsurface layers. The model can be used to assess the effects of different management scenarios (*e.g.*, gravel augmentation, flow releases to increase the frequency of bed mobilization and scour, reduction in fine sediment supply) on salmonid spawning habitat.

Though existing bedload transport models can predict sediment transport rates and bed surface/subsurface textures as a function of sediment supply and routing, they generally have ignored the presence of sand. Including fractions of sand in surface and subsurface grain size distributions is of interest for evaluating the extent and quality of salmonid spawning habitat. Surface grain size distributions can support estimates of available spawning habitat in terms of the availability of spawning-sized gravel, and subsurface grain size distributions, especially the fraction of sand, can support estimates of spawning gravel quality. The TUGS model is designed to fulfill this need by simulating how bed mobilization and scour affect grain size distribution, including the fraction of sand, in both the surface and subsurface.

As described in Cui (2007), The Unified Gravel-Sand (TUGS) Model employs:

a) the surface-based bedload equation of Wilcock and Crowe (2003);
b) a combination of the backwater equation and the quasi-normal flow assumption for flow;
c) Exner equations for sediment continuity on a fractional basis, including both gravel and sand, and the process of gravel abrasion;

d) the bedload, surface layer, and subsurface gravel transfer function of Hoey and Ferguson (1994) and Toro-Escobar *et al.* (1996); and

e) a hypothetical surface-subsurface sand transfer function.

The Wilcock and Crowe (2003) sediment transport equation calculates the transport rate of both coarse sediment (gravel and coarser) and sand based on the surface grain size distribution and on local shear stress. The Wilcock and Crowe equation assumes no relationship among surface, subsurface, and bedload grain size, which limits the application of the equation to field conditions. However, the research of Toro-Escobar *et al.* (1996) and Hoey and Ferguson (1994) identified a correlation among subsurface, surface, and bedload grain size distributions for coarse sediment, and Cui and Parker (1998) showed that the subsurface sand fraction is strongly correlated with the standard deviation of the grain size distribution of the coarse sediment. It is therefore possible to hypothesize a relation among the subsurface, surface, and bedload grain size distributions, and to combine these relations with the Wilcock and Crowe sediment transport equation to develop a numerical model that can be applied to field conditions. The hypothetical surface-subsurface sand transfer function is structured so that the subsurface sand fraction increases with the increase in the surface sand fraction and decreases with the increase in the subsurface gravel geometric standard deviation. Comparison with field data from several rivers indicates that the hypothetical surface-subsurface sand transfer function produces estimates of subsurface sand fraction within the general range measured in the field. Simulation of the Sandy River produced reasonable trend for surface/subsurface sand fractions under various hypothetical management scenarios.

The TUGS model was developed using a dataset developed in the Sandy River in Oregon. It is a one-dimensional model that predicts reach-average channel bed elevation and grain size distribution variations. A reach is defined as a length equal to a few channel widths. Because of limitations in current sediment transport modeling theories and techniques, TUGS model cannot simulate grain size distributions at the scale of local channel features, such as alternate bars or pool-riffle sequences. As with any sediment transport model, TUGS model results are most useful for comparing different management alternatives to assess their effectiveness in achieving defined goals (*e.g.*, increasing gravel deposition, reducing fine sediment, *etc.*). The model also uses existing cross-sections developed by the Army Corps of Engineers and CDWR as part of the Comprehensive Study.

SPATIAL HORIZON AND RESOLUTION

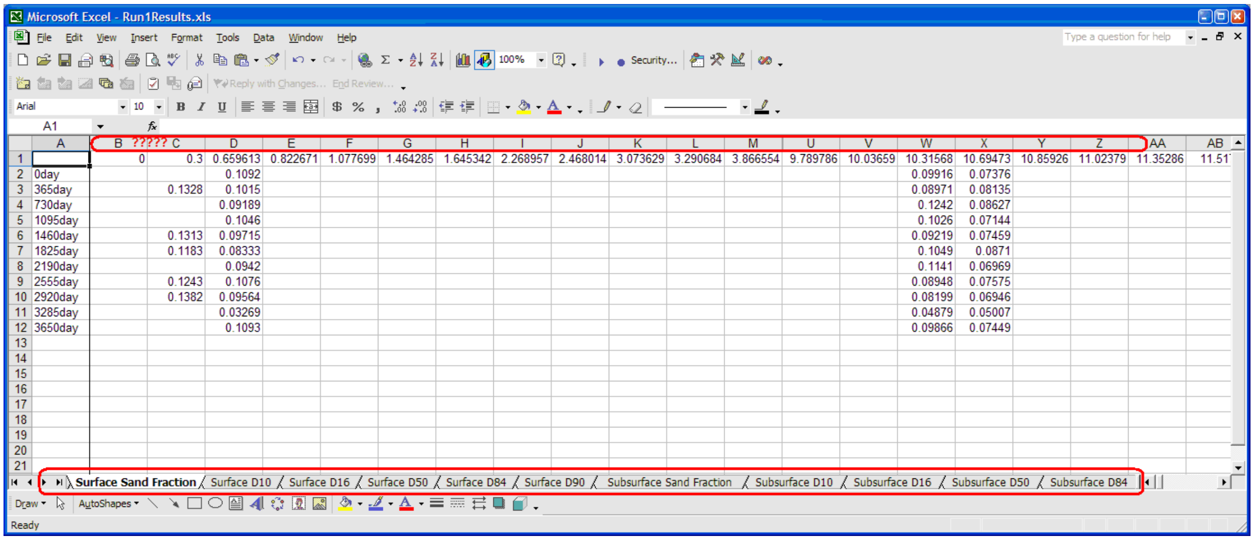
The TUGS model can be applied to any reach of the Sacramento River for which channel cross-sections and surface and subsurface grain size data are available, and has been calibrated for the Sacramento River using existing bulk sampling data collected by CDWR in 1980, 1984, and 1994. Stillwater Sciences has added to the dataset by collecting new bulk samples in the upper and middle Sacramento River in 2005, at locations sampled previously by CDWR. Table 4.3 displays the river miles where the CDWR bulk samples and Stillwater 2005 bulk samples were collected. Generally, sediment transport and routing models including TUGS require a very high initial effort to calibrate.

Table 4.3. Bulk sampling sites in the Sacramento River where surface and subsurface grain size distribution data are available.

Upper Sacramento River		Middle Sacramento River	
RM	**Site Name**	**RM**	**Site Name**
298.3	Caldwell Park	242.7	Red Bluff Diversion Dam
296.9	Turtle Bay Upstream	240.4	Above Blackberry Island
292.7	Golf Course	238.5	Above Todd Island
291.3	Below Tobiasson	236.1	Below Todd Island
289.1	Clear Creek confluence	233.0	Oat Creek
288.1	Above I-5 embankment	228.3	Tehama
287.3	At I-5 embankment	225.6	Thomes Creek
286.3	n/a	221.2	Copeland Bar
282.6	Anderson outfall	218.6	Woodson Bar
281.1	Stillwater Creek	215.3	Above Cutoff
280.2	Cow Creek	211.6	Upstream of Foster Island
279.1	Below Cow Creek	208.9	Upstream of Shaded Slough
278.3	Above Bear Creek	201.8	McIntosh Landing
275.7	Anderson Creek	197.9	Upstream of Pine Creek
273.3	Cottonwood Creek	163.5	Princeton

FORM OF TUGS OUTPUT TO BE ACCESSED AND IMPORTED: EXCEL

TUGS is capable of providing a variety of grain size specific transport estimates for gravel and sand, and of tracking these two classes of sediment by their proportions in surface and subsurface layers. The current output format for the model is shown in Figure 4.2.



	A	B	C	D	E	F	G	H	I	J	K	L	M	U	V	W	X	Y	Z	AA	AB
1		0	0.3	0.659613	0.822671	1.077699	1.464285	1.645342	2.268957	2.468014	3.073629	3.290684	3.866554	9.789786	10.03659	10.31568	10.69473	10.85926	11.02379	11.35286	11.51
2	0day			0.1092												0.09916	0.07376				
3	365day		0.1328	0.1015												0.08971	0.08135				
4	730day			0.09189												0.1242	0.08627				
5	1095day			0.1046												0.1026	0.07144				
6	1460day		0.1313	0.09715												0.09219	0.07459				
7	1825day		0.1183	0.08333												0.1049	0.0871				
8	2190day			0.0942												0.1141	0.06969				
9	2555day		0.1243	0.1076												0.08948	0.07575				
10	2920day		0.1382	0.09564												0.08199	0.06946				
11	3285day			0.03269												0.04879	0.05007				
12	3650day			0.1093												0.09866	0.07449				

Figure 4.2. Current raw output from TUGS model. Numerous worksheets contain results for specific performance measures. As shown, it is not always clear what distance (location) or time period is associated with a particular value. An Excel template was developed to better organize and streamline this information for orderly import into the SacEFT database.

With the benefit of a new Excel template, TUGS output is bulk loaded into SacEFT's database in the relational form shown in Figure 4.3.

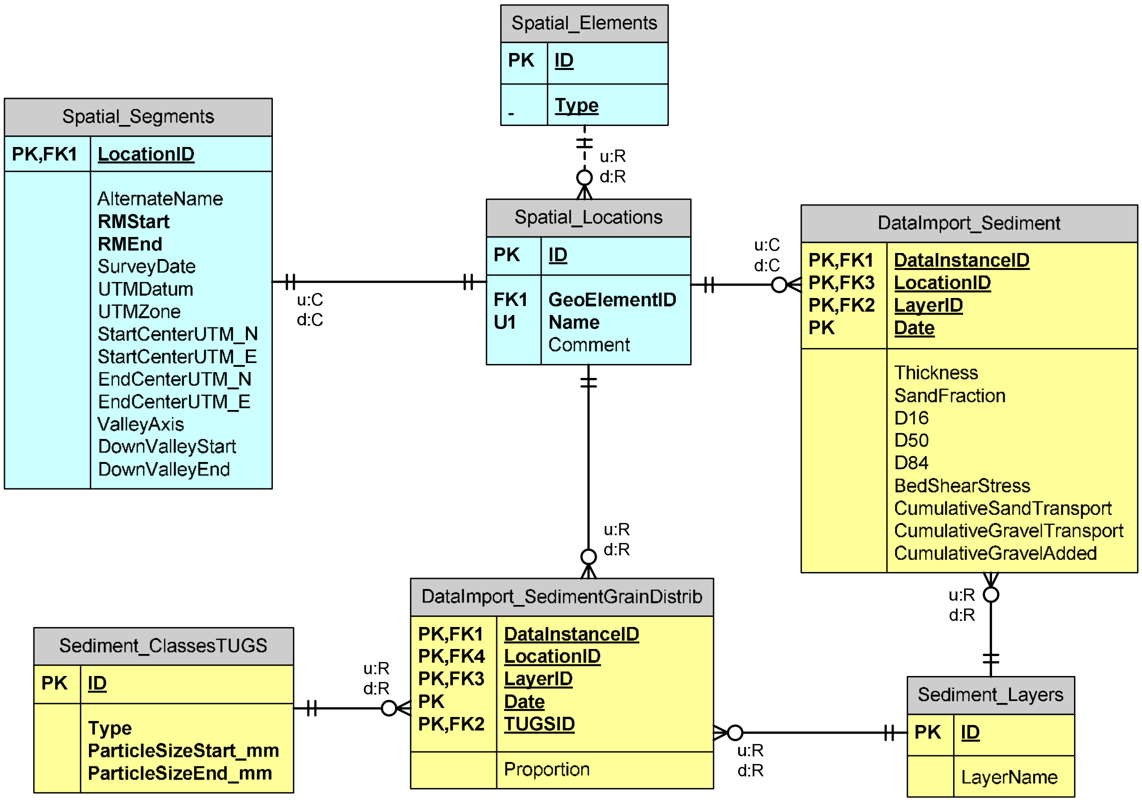


Figure 4.3. Relational database design used by SacEFT for storing TUGS model output.

After consultations between Stillwater Sciences and TNC, two scenarios were incorporated into SacEFT for **v.2.00**: a "No Gravel" scenario that assumes no gravel injection to the rivers, although small amounts of natural sand and gravel are present. The second scenario "Gravel Injection" contains a single gravel injection in Water Year 1940, with no subsequent additions. The scenarios were simulated using historical, NODOS and Shasta discharges at Keswick (RM 301) and implemented over 5 reaches as shown in Table 4.4. The results of the TUGS scenarios are incorporated into the calculation of Spawning WUA (Weighted Usable Area) for Chinook and steelhead, as described in Section 4.2.5.

Table 4.4. Location of TUGS simulation segments and amount of supplementary gravel added for "Gravel Injection" scenarios.

Upper RM	**Lower RM**	**Gravel Injection (m^3) (when present)**
301.956	299.800	
299.800	297.000	179,423$^{\delta}$ (234,677 yd^3)
297.000	295.600	
295.600	292.400	188,662$^{\delta}$ (246,760 yd^3)
292.400	289.375	

$^{\delta}$ These are bulk amounts, assuming a gravel porosity of 0.4.

Note: As part of the TUGS calibration process a third "zero gravel" scenario was also developed using historical flow at Keswick and *historical* gravel additions from 1981-2006.

4.1.5 Meander migration

UC Davis researchers have developed a Meander Migration Model (Larsen 1995, Larsen and Greco 2002, Larsen *et al.* 2006b) using MATLAB software, that calculates channel migration using a simplified form of equations for fluid flow and sediment transport developed by Johannesson and Parker (1989). One version of the Meander Migration Model predicts meander migration as a function of a single, representative, geomorphically effective discharge ("characteristic discharge"). The model has been modified to consider the effects of a variable hydrograph on meander migration rates. This is believed to provide a more accurate depiction of the conditions in which meander migration occurs. The underlying hypothesis is that the bank migration rate, when thresholds are excluded, in a specified time interval is linearly related to the sum of the cumulative excess stream power in the same time interval (Larsen *et al.* in review).

The meander migration MATLAB code that is used to assess ecological flows is similar to the code used in other applications (*i.e.,* Larsen and Greco 2002) but incorporates a variable flow, where channel migration in yearly time steps is a function of annual flow rates, through the measure of scaled annual cumulative excess stream power (Larsen *et al.* 2006a).

The migration model requires the following six input values, which reflect the hydrology of the watershed and the hydraulic characteristics of the channel: initial channel planform location, "characteristic discharge", reach-average median particle size of the bed material, reach-average width, depth, and slope. The crux of the model is the calculation of the velocity field. The analytic solution for the velocity results from the simultaneous solution of six partial differential equations representing fluid flow and bedload transport. An initial calibration also plays a critical role. To calibrate the model, researchers use the channel planform centerline from two years for which centerlines can be accurately delineated from digitized aerial photos. The calibration process consists of adjusting the erosion and hydraulic parameters, in the Meander Migration Model until the simulated migration closely matches the observed migration. The erosion potential map is initially determined from GIS coverages and delineates areas of higher and lower erosion potential due to differences in land cover, soil, and geology. The erosion potential map is then adjusted in the near-channel-bank areas by calibrating the channel centerlines between the two time periods. See Larsen and Greco 2002 for details.

Conceptually, the Meander Migration Model produces a temporal series of channel centerlines that are imported into ArcInfo where bends and lateral change polygons are defined and studied for movement in terms of progressive migration (Larsen and Greco 2002, Larsen *et al.* 2006). GIS tools are used to automate the spatially explicit measurements.

SPATIAL HORIZON AND RESOLUTION

As applied and configured for SacEFT, the Meander Migration Model focuses on three river segments located between RM 170-185, 185-201, and 201-218. The model has also been previously applied in various locations between Red Bluff (RM 243) and Colusa (RM 143).

The finest unit of resolution of interest in SacEFT is **a bend**. We apply a fixed zonal concept based on segments, using the locally well-known concept of river miles to reference these bends. While we recognize the channel alignment has changed significantly since the U.S. Army Corps of Engineers 1964 centerline survey, the critical consideration is that these locations be "well-known" and consistent across

SacEFT's submodels. This in no way inhibits the spatial accuracy of meander migration calculations, just simplifies the manner in which specific bends are identified. As described earlier, for purposes of determining the suitability of bank swallow nesting habitat, the exact locations of individual bends of interest is still in *approximately* the same zones whether at RM 191 or RM 208. Knowing ***exactly*** where it is does not help us answer questions about bank swallow nesting habitat.

While SacEFT treats locations as fixed throughout model simulations for purposes of generating focal species performance measures, variables like centerline change, which are inherently spatial, may still be handled in a fully spatially explicit fashion. The distinction we draw is one of a need for "visualization" vs. an empirical summary performance measure that is transferred to a submodel of lower resolution and precision. Highly visual, dynamic map-based outputs usually require spatially explicit treatment; other variables do not.

4.1.6 Bank erosion model

ESSA has developed a GIS-based erosion model that allows users to combine the predictions from the Meander Migration Model with other spatial information, such as soil and vegetation information. Each year, the model simulates the location of the river channel, the area of eroded banks and the location of the banks at the end of the year. The location of the river channel is calculated from the centerline using two simplifying assumptions regarding the river channel: (1) that it is symmetrical around the centerline; and (2) that the local channel width for a given section of the river is unchanged during the simulation. The eroded area for each year is defined as the channel area overlapping the previous year's banks. The river banks at the end of the year are calculated by subtracting the eroded area from the banks at the start of the year. Figure 4.4 shows an example of change of centerlines simulated by the Meander Migration Model over a period of 56 years.

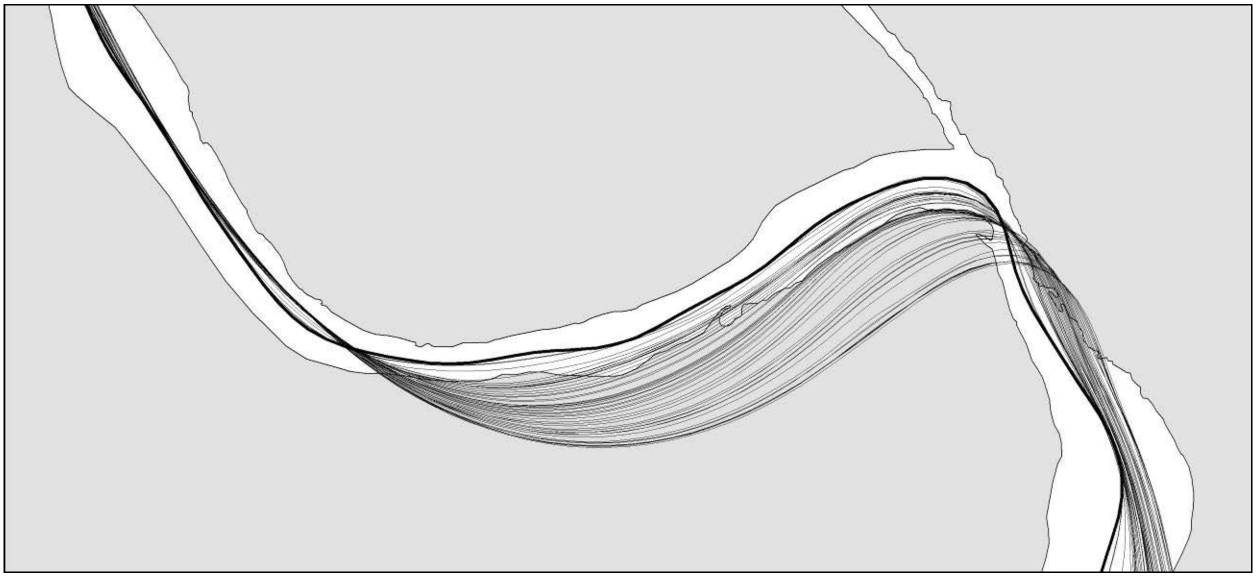


Figure 4.4. Example of centerlines for 56 years for one scenario.

The initial simplified channel is based on the measured location of banks in 2004. The centerline was divided into segments and the local channel was determined as the distance to the nearest bank. Then, a simplified channel was created by buffering each centerline segment by the local channel width (Figure 4.5).

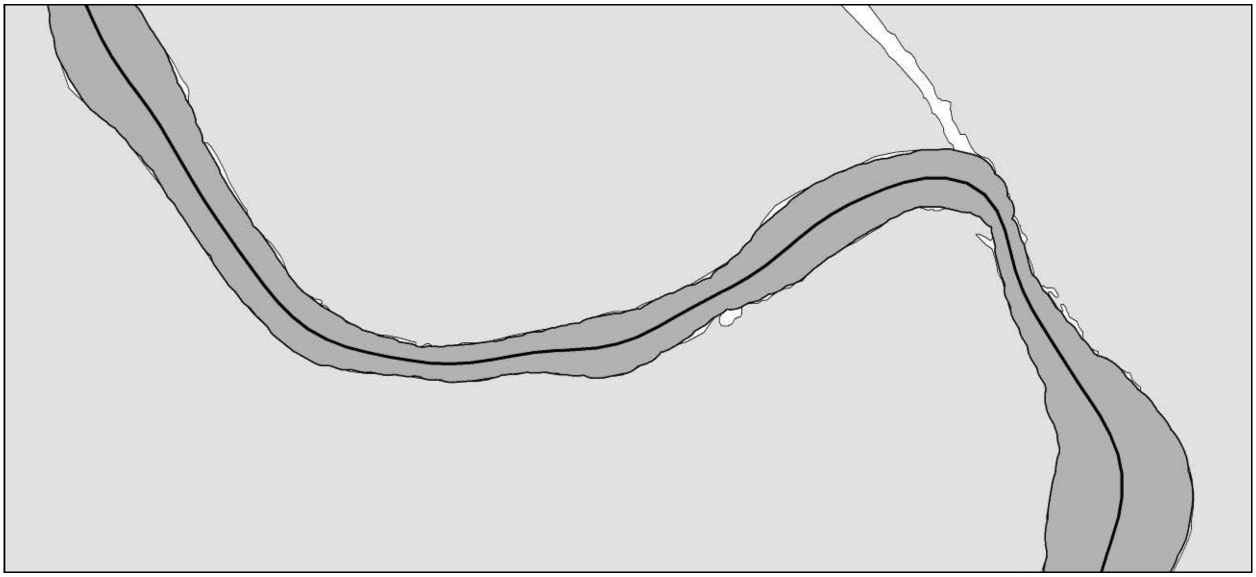
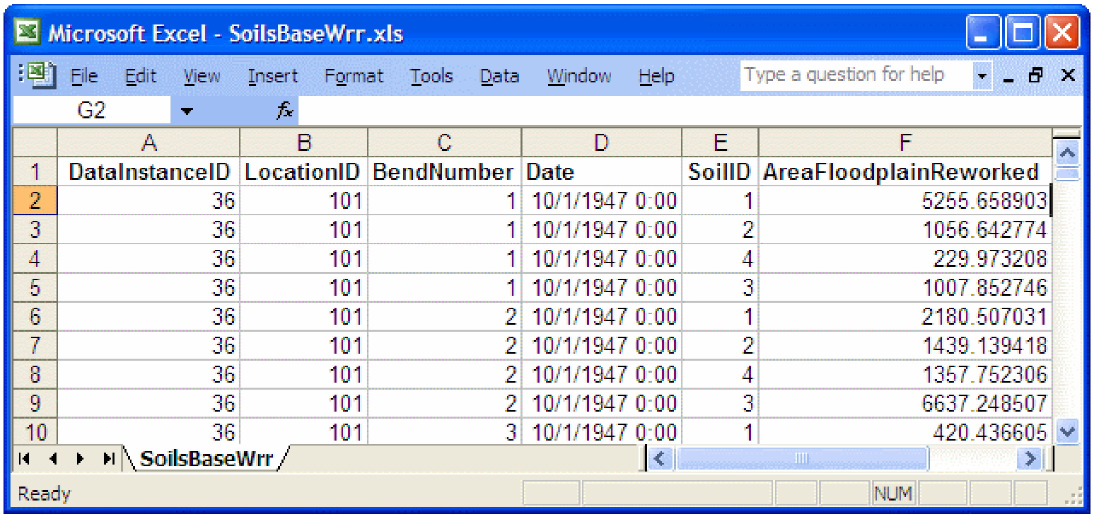


Figure 4.5. Simplified channel for initial conditions.

Each future channel is simulated based on the previous centerline and on the local channel width for each centerline segment. The new centerline is then divided into segments based on the proximity to the segment of the previous year's centerline. Next, the channel for the year is created by buffering the new centerline by the channel width for the closest location matching the previous year's centerline. Finally, the locations of eroded bank are defined as the area of the new channel that overlap the previous year's bank. Finally, the new bank locations are used to calculate the next year's erosion.

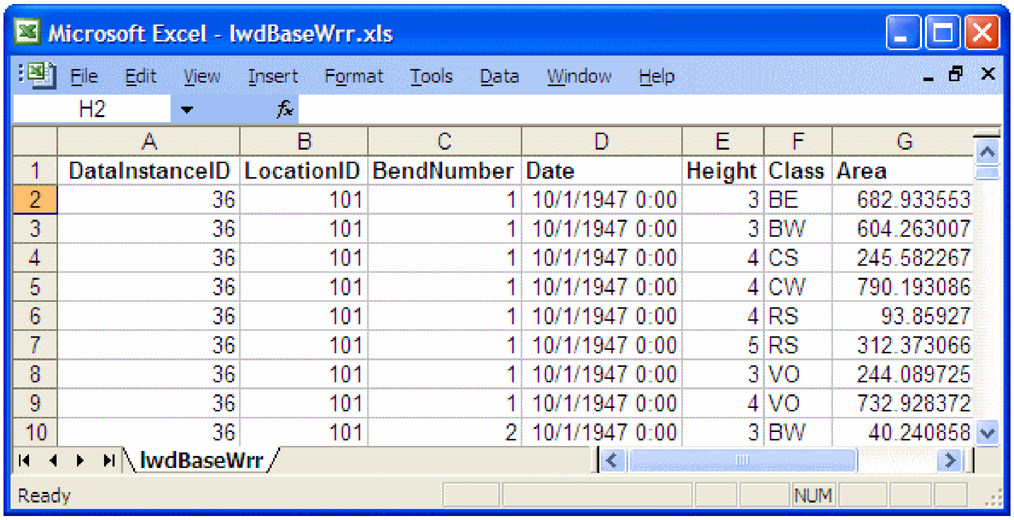
FORM OF EROSION OUTPUT TO BE ACCESSED AND IMPORTED: SHAPE FILE AND EXCEL

The erosion model produces three outputs: (1) GIS layers with eroded area for each year, (2) the vegetation for the eroded areas and (3) the soil composition of the eroded areas. The soil composition is divided into 4 types based on bank swallow preference and prevalence in the eroded areas. The eroded areas are overlaid on the amalgamated Soil Survey Geographic (SSURGO) soil data to derive soils data for the bank swallow model (Figure 4.6). The eroded areas are also overlaid on vegetation data to provide input to the large woody debris indicator (Figure 4.7).



	A	B	C	D	E	F
1	DataInstanceID	LocationID	BendNumber	Date	SoilID	AreaFloodplainReworked
2	36	101	1	10/1/1947 0:00	1	5255.658903
3	36	101	1	10/1/1947 0:00	2	1056.642774
4	36	101	1	10/1/1947 0:00	4	229.973208
5	36	101	1	10/1/1947 0:00	3	1007.852746
6	36	101	2	10/1/1947 0:00	1	2180.507031
7	36	101	2	10/1/1947 0:00	2	1439.139418
8	36	101	2	10/1/1947 0:00	4	1357.752306
9	36	101	2	10/1/1947 0:00	3	6637.248507
10	36	101	3	10/1/1947 0:00	1	420.436605

Figure 4.6. Example of soil composition data for eroded areas in Excel.



	A	B	C	D	E	F	G
1	DataInstanceID	LocationID	BendNumber	Date	Height	Class	Area
2	36	101	1	10/1/1947 0:00	3	BE	682.933553
3	36	101	1	10/1/1947 0:00	3	BW	604.263007
4	36	101	1	10/1/1947 0:00	4	CS	245.582267
5	36	101	1	10/1/1947 0:00	4	CW	790.193086
6	36	101	1	10/1/1947 0:00	4	RS	93.85927
7	36	101	1	10/1/1947 0:00	5	RS	312.373066
8	36	101	1	10/1/1947 0:00	3	VO	244.089725
9	36	101	1	10/1/1947 0:00	4	VO	732.928372
10	36	101	2	10/1/1947 0:00	3	BW	40.240858

Figure 4.7. Example of vegetation data for eroded areas in Excel.

4.2 Integration of physical data, linked models and SacEFT submodels

4.2.1 Water year conventions for simulations and outputs

By convention, SacEFT uses the Water Year (WY) as its annual simulation framework. Each Water Year (*y*) begins on October 1 of calendar year (*y-1*) and ends on September 30 of calendar year (*y*). Spring-run Chinook salmon spawn across the (*y-1*):(*y*) boundary, and are accounted for with the run-types spawning in WY *y*.

4.2.2 Matching physical variables to focal species locations of interest

The model underlying each PM is designed to accommodate the temporal framework of its input data: daily for flow and temperature and annual for TUGS and Meander Migration data. SacEFT accepts inputs that may be point-based (*e.g.,* discharge and temperature) or segment-based (*e.g.*, TUGS data). It links these inputs to PMs that may themselves be point-based (*e.g.,* GS1 – Green Sturgeon spawning locations) or segment-based (*e.g.,* CS1 – Chinook spawning WUA).

The guiding principle for this linkage is to first fill gaps that may be present in the input data. The second principle is to use the input data that are nearest to the location where the PM is modeled. To do this, SacEFT uses the concept of a neighbor zone: any input data located within a user-defined river mile tolerance zone are considered a perfect match. Failing a match within the tolerance zone, the nearest upstream data are usually selected. In some cases, such as the riparian initiation submodel, flows are interpolated based on the nearest available upstream and downstream source of flow data for the cross-section of interest.

Some matches require overlaying segment-based data from multiple sources (*e.g.,* TUGS data and salmonid spawning segments). When this occurs, segments that are completely-contained and segments that overlap are weighted by the proportion of their length contained in the common segment. For example, if a short TUGS segment is completely contained in a longer spawning segment along with an adjacent TUGS segment that is half in the spawning segment, the sediment data from the first segment are given a weight of 1.0 and the data from the second segment a weight of 0.5.

In the unique case of salmonid rearing habitat, there are some rearing-reaches without spawning and therefore without any natural way to predict the egg-emergence that eventually follows spawning and marks the initiation of rearing. In these cases, the average emergence of the *upstream* segments is used to create an egg-emergence distribution for the downstream rearing segment.

Finally, in cases where there are multiple data sources within a salmonid reach segment for flow or temperature, those data are averaged to provide a single pooled estimate for the reach-based calculations.

4.2.3 Extending TUGS locations to Chinook and steelhead locations

The initial surface substrate conditions for TUGS simulations consisted of the substrate size categories in two river segments (see Section 4.2.5). Changes to these initial distributions were then modeled over time with the two gravel scenarios.

When applying TUGS data for Chinook and steelhead spawning WUA, it was generally necessary to apply annual location-based TUGS results to portions of the river that are outside the area where TUGS was calibrated (compare red and pink segments in Table 2.5). In accordance with our nearest-neighbor principle, the predicted substrate composition of the most downstream of the five TUGS simulation segments (near RM 289) is mapped to the downstream segments used by the Chinook and steelhead submodels each year for each of the combinations of flow scenarios and gravel scenarios. In the case of fall Chinook, the most distant segment can extend downstream over 70 miles to Vina (RM 218), implying that the distribution of surface substrate size classes (sand through boulder) is comparable across this entire range. It also assumes that gravel injection simulations at upstream locations can be plausibly extended at the downstream locations. The further the spatial extrapolation, the more tenuous this assumption becomes. The solution to this extrapolation problem can be resolved by obtaining TUGS simulation results calibrated and tested for these more downstream reaches of the Sacramento River.

4.2.4 Extending Chinook and steelhead WUA relationships across locations and run-types

Chinook and steelhead spawning and rearing WUA performance measures (CS1, CS2) are parameterized for three upstream reaches only. The detailed empirical substrate information required to estimate site-specific spawning WUA (and its relationship to gravel injection) is not available at the 2 downstream segments. This is shown graphically in Table 2.5 where parameterized reaches are shown in dark blue and mapped reaches in light blue. The parameterization methodology developed and applied at the 2 downstream reaches is described more fully in Section 4.2.5.

Similarly, spawning and rearing WUA relationships (when they exist) have been parameterized for steelhead and for fall-, late fall- and winter- Chinook run-types. Habitat preferences for spring Chinook are not available and we assumed they follow those of fall Chinook (Mark Gard, USFWS, *pers. comm.*).

4.2.5 Linking Chinook and steelhead WUA relationships to TUGS substrate classes

The Chinook and steelhead spawning Weighted Usable Area (WUA) models are based on Gard's habitat preference models (U.S. Fish and Wildlife Service 2003, 2005a, 2005b). These models assume that spawners prefer habitats with optimal combinations of depth, velocity and gravel size, and that given an environment in which all three of the characteristics vary, their overall preference can be empirically modeled as the product of 0-1 preferences for each of these 3 variables. When one square foot of habitat is optimal (1.0) for all 3 preferences, it has a weighted usable area (WUA) of 1.0 ft^2; otherwise it has some smaller value. Gard's results are based on the River-2D hydrodynamic model (Steffler and Blackburn 2002, U.S. Fish and Wildlife Service 2006a), a 2-dimensional hydrodynamic simulation of river segments. River-2D takes as input discharge at the upstream segment transect and surface elevation at the downstream transect, along with empirical measurements of the river bottom topography and composition, and estimates the velocity field over the points of the segment's triangular irregular network (TIN), producing an estimate of WUA for each node of the TIN. When these TIN nodes are summed up, an estimate for the reach is produced and finally, when the reaches are summed in proportion to their presence in the entire segment, an overall segment WUA is obtained.

Using original data provided by Gard, we re-ran all the River-2D analyses and used raw River-2D output to determine $\boldsymbol{a_s}$, the proportional area contribution of each of the 11 substrate size categories in each river reach, across a range of discharges. When $\boldsymbol{A_i}$ is the absolute area in any substrate size class, $\boldsymbol{a_s}$ is:

$$a_s = \frac{A_s}{\sum_{s=1}^{11} A_i}$$

The $\boldsymbol{a_s}$ vector was found to be fairly insensitive to discharge, and we therefore took the average a-vector across the full range of flows (3,250 to 31,000 cfs), allowing us to develop a relationship that was independent of discharge. This calculation implicitly collapses two-dimensional information about substrate size categories across each reach into a one-dimensional summary. To provide a consistent set of size categories, the $\boldsymbol{a_s}$ vector calculated by River-2D was transformed to the 8 size categories ($\boldsymbol{a_8}$) used by TUGS by linear interpolation between overlapping size classes. After this operation, the $\boldsymbol{a_8}$ vector was provided as an initial condition for the TUGS simulations.

In SacEFT model runs, along with the actual surface substrate size distribution $\boldsymbol{a^*_s}$ predicted annually by TUGS gravel augmentation scenarios, the reference size distribution vector $\boldsymbol{a_s}$ is combined with substrate preference $\boldsymbol{p_{r,s}}$ to modify Gard's reference spawning discharge relationship $\boldsymbol{WUA_{r,Q}}$ for each species $\boldsymbol{r}$. The actual WUA available each day to spawners $\boldsymbol{WUA^{*}_{r,Q}}$ is computed by the ratio of the reference conditions (denominator) to the current conditions (numerator), making WUA sensitive to changes in substrate:

$$WUA^{*}_{r,Q} = WUA_{r,Q} \times \frac{\sum_{s=1}^{8} p_{r,s}\, a^{*}_{s}}{\sum_{s=1}^{8} p_{r,s}\, a_{s}}$$

4.3 Focal species submodels

4.3.1 Chinook salmon & steelhead trout

The salmonid conceptual model is shown in Figure 4.8. Readers are referred to ESSA Technologies Ltd. (2005) for details on the development of this model and the decisions that led to its current structure.

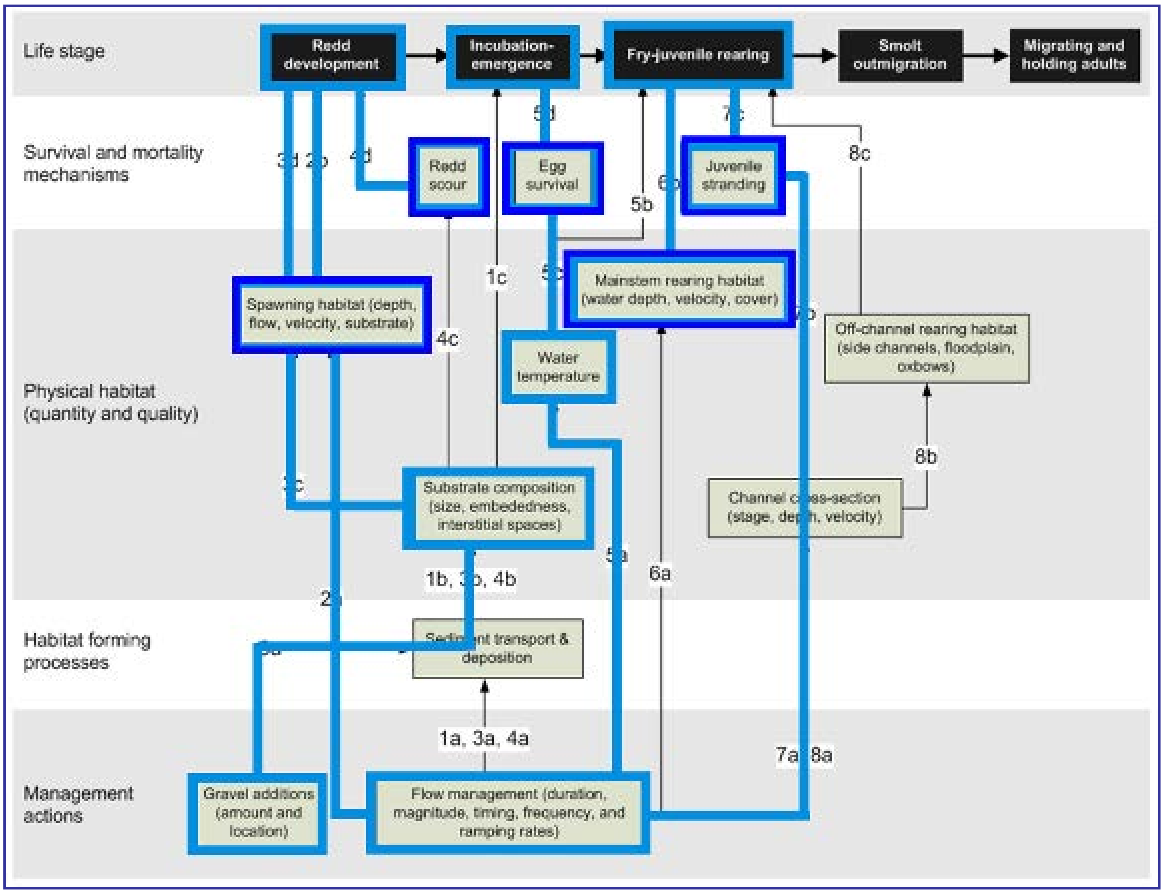


Figure 4.8. The salmonid conceptual model. Heavy lines show the processes and linkages that are currently implemented. See ESSA Technologies Ltd. (2005) for additional context and detail on processes and linkages shown here.

SacEFT includes six performance measures (PMs) that describe changes in the physical habitat available for salmonid spawning and rearing. These performance measures are shown in Table 4.5.

Table 4.5. Performance Measures (PMs) for Chinook salmon and steelhead trout.

Performance Measure	Synonyms	PM code	Units
Weighted Usable Area for Spawning	Spawning WUA	CS1	Square feet
Redd Dewatering		CS6	Proportion
Redd Scour Potential		CS5	Hazard category
Egg-to-Fry Thermal Mortality	Egg Survival	CS3	Proportion
Weighted Usable Area for Rearing	Rearing WUA	CS2	Square feet
Juvenile Stranding Potential		CS4	Index

Steelhead trout and four Chinook salmon run-types are modeled using the common modeling framework described in this section. Our approach and data are largely based on research results provided by Mark Gard of the U.S. Fish and Wildlife Service in Sacramento (U.S. Fish and Wildlife Service 2003, 2005a, 2005b). As described below, additional temperature-emergence and temperature-mortality data have been provided from relationships published for the SALMOD model (Bartholow and Heasley 2006) and by Crisp (1981).

The salmonid performance measures broadly cover key features of the spawning and rearing portions of the juvenile life history, and are simulated in up to 5 segments of the mainstem, as shown in Table 2.5 and Table 4.5. Because parameterized relationships were not always available for every location and PM, relationship mapping was carried out by assuming that relationships parameterized for a run-type or location could be applied to another run-type or location (Mark Gard, USFWS, *pers. comm.*).[1] For example, based on U.S. Fish and Wildlife Service (1995), the distribution of rearing habitat for *spring-run* Chinook is almost entirely concentrated below Battle Creek but uses *fall-run* rearing WUA relationships. Likewise, rearing WUA relationships are not available for locations *downstream* from Battle Creek, and currently make use of *upstream* WUA relationships.

SacEFT presents the results for each PM at up to 3 scales. First, at the system-wide resolution (which we term the *rollup*), each annual PM is evaluated by comparing the results against those of a benchmark historical run scenario (historical flow and temperature, no gravel augmentation, no bank revetment). The distribution range of the benchmark annual PM is used, employing obvious discontinuities in the distribution to create a heuristic R/Y/G classification called the *Indicator Rating*. (If there are no obvious discontinuities, the tercile points – measurements taken at the 1/3 and 2/3 points of the sorted PM distribution – are used to assign the Indicator Rating.) At the *Annual* scale (not graphed in v.2.00) the terciles of the annual average for the PM are used to create indicator ratings. At the *Daily* scale, the indicator rating is represented using horizontal color bars on some Excel reports. This scale of indicator uses the terciles of the *daily* historic flow and temperature to assign a daily R/Y/G indicator rating.

Although each model operates internally on the basis of a daily cohort, the distributional and cumulative results shown on the Excel report often portray the cumulative (summed) distribution of all day-cohorts each day. This way it is possible to see daily changes to the entire population in the face of fluctuations in flow and temperature, even though internally, each day-cohort is tracked separately.

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[1] One reviewer of Version 1 documentation noted that "the conventional wisdom is that rearing above Battle Creek is insignificant" and that "in-river rearing for all four named varieties of Chinook extends at least down to Ord Bend." (Andrew Hamilton, *pers. comm.*). If additional rearing WUA estimates are available for downstream locations, they can easily be accommodated in subsequent versions.

Table 4.6. Reaches with calibrated or mapped spawning (CS1) and rearing (CS2) WUA relationships. Spawning WUA-substrate relationships for some reaches (light blue) are based on parameterizations (dark blue) from the nearest segment. Rearing relationships downstream from Battle Creek are based on WUA-Flow relationships from the nearest upstream segment (abstracted from Table 2.5).

		Spawning PMs					**Rearing PMs**				
Upstream	**Downstream**	***Spring***	***Fall***	***Late Fall***	***Winter***	***Steelhead***	***Spring***	***Fall***	***Late Fall***	***Winter***	***Steelhead***
Keswick	ACID		🟦	🟦	🟦	🟪		🟦	🟦	🟦	🟪
ACID	Cow Creek	□	🟦	🟦	🟦	🟪	□	🟦	🟦	🟦	🟪
Cow Creek	Battle Creek	□	🟦	🟦	🟦	🟪	□	🟦	🟦	🟦	🟪
Battle Creek	Red Bluff		□				□	□	□	□	
Red Bluff	Deer Creek		□				□	□	□	□	

In developing the initial design for SacEFT, our intention was that each PM be a measure of habitat suitability *only*, and that for consistency with the PMs of other species, we try to avoid designs where one PM depended on another and which can therefore resemble population-based models. In general we have adhered to this principle; but where the linkage between closely related PMs seemed robust, we have in one case allowed WUA Spawning (CS1) to affect a subsequent indicator.

In addition to modeling each PM at specific locations, each species spawns according to a timing-relationship developed at the design workshop (Table 2.7). The duration and amounts shown in this table strongly resemble the timing relationships used by SALMOD (Figure 3 in Bartholow and Heasley (2006), derived from Vogel and Marine (1991)). Rearing relationships were originally part of the design, but these became superfluous once we incorporated temperature-based egg maturation from SALMOD. As a result of this emergence relationship, eggs from each day-cohort remain in the gravel until the temperature-driven emergence relationship predicts their maturation. The relationship we adopted is not strictly egg-maturation, but covers the period to free swimming emergence.

The six performance measures described here are necessarily simplistic and generally do not attempt to account for interactions that naturally occur. For example, redd dewatering, temperature-driven egg mortality and redd scour risk all occur during the incubation period and the processes together would predict a different outcome than each process taken alone. Additionally, the cross-sectional data used to parameterize the models of WUA-based performance measures are a snapshot in time of conditions in the mainstem, and mainstem habitat locations may change slowly or episodically as a result of meanders. Habitat is therefore assumed to be in an equilibrium state in which the spatial arrangement of particular habitats may change, but the segment-wide non-spatial proportions do not.

Calibrating the Chinook and Steelhead Models

To calibrate SacEFT Version 2 we used the same historical data used for the Version 1 calibration: empirically measured historical flow data and a mix of empirical and modelled upstream temperature data. These provide about 30 years (WY 1971-2003) of paired observations that are required to calibrate all the models, some of which depend on temperature (the shorter time series) which drives the timing of egg maturation for later life history PMs.

Using these empirical historical data, up to 3 calibration measures are computed for some CS1, CS3, CS4 and CS6 (Spawning and Rearing WUA, Juvenile Stranding and Redd Dewatering) indicators:

1. **Daily Indicator Rating** – Daily ratings are computed separately for each run-type, making use of daily values from all reaches and years for the run-type. The PM values are then sorted from largest to smallest (*e.g.,* the population-proportion weighted square feet of Rearing WUA on each day in the case of CS2). Values that define the upper third and lower thirds of the sorted values are termed daily Hazard Threshold boundaries and are shown as horizontal R/Y/G lines on some of the Excel Reports. They give a system-wide daily comparison of how the PM score compares to other days and reaches. Consistently high (Green) days in a reach show that the reach contributes strongly to the PM's performance in a given year. Daily indicator ratings are never weighted across multiple reaches. Because they are close to raw measurements, intrinsic differences between reaches need to be considered when looking at daily ratings. For example, a reach may have intrinsically low Rearing WUA simply because it is shorter than another reach, and could show a lower (Yellow or Red) daily rating compared to a reach with higher Rearing WUA.

2. **Annual Indicator Rating** – Annual summaries of the PM are computed separately for each run-type, pooling the daily values into combinations of year and reach for the reach-type. These values are sorted from largest to smallest and the terciles computed. This provides each reach with a Hazard Threshold boundary; a ranking of its PM relative to other reaches and years. These ranking data are stored as output, **but are not currently used**.

3. **Annual Rollup Indicator Rating –** Annual summaries of the PM are computed separately for each run type, taking the average value of all reaches within the year. These data are sorted and then graphed to create a cumulative distribution. Generally the distributions are fairly uniform and taking terciles is a reasonable default approach. In some situations there may be a marked discontinuity in the distribution and in these cases the discontinuity may be used as an alternative breakpoint. These alternative distributions can be seen by examining the annual roll-ups for the calibration data sets. In cases that use the tercile approach, the R/Y/G bars are evenly divided (or nearly so, given round-off). In cases that use discontinuities, the division is not even. In both cases however, comparison across matched scenarios (*e.g.*, calibration versus a management scenario) will show differences in the distribution of years. These differences can be used to infer changes in the system, relative to the calibration.

An example of the approach for the Annual Rollup Indicator is shown below (Figure 4.9) for steelhead CS6 – Redd Dewatering. The sorted distribution of the annual average of all reaches shows a fairly even slope with the possibility of some discontinuities. However, the terciles have been used to select the Indicator Rating boundaries.

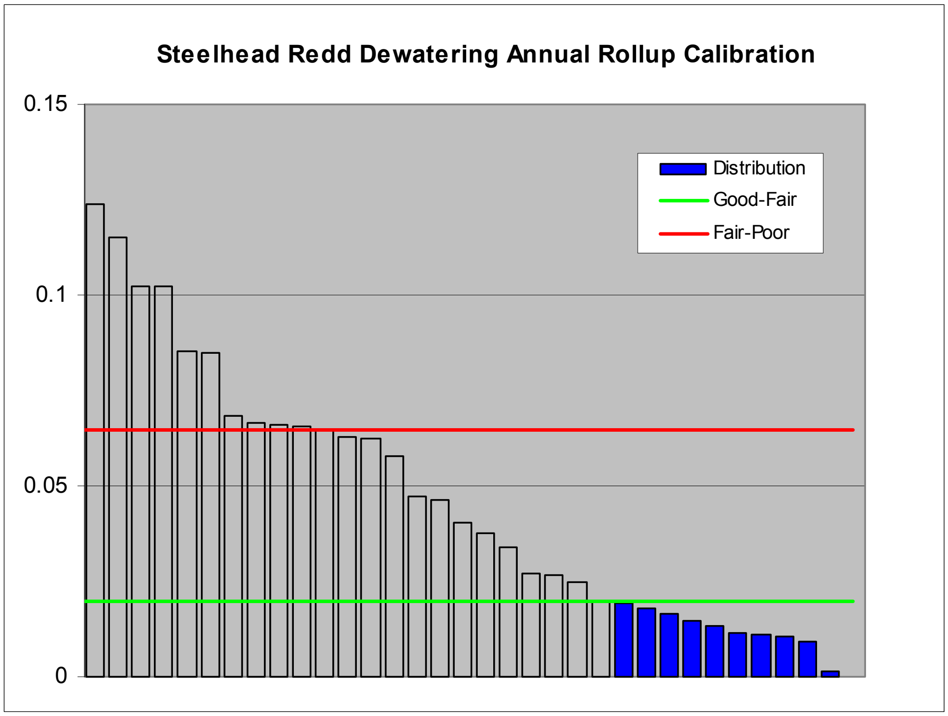

Figure 4.9. An example showing the distribution of the Redd Dewatering (CS6) index for steelhead trout based on the average annual value for all reaches, sorted by year from largest to smallest value. Similar graphs are created for all 3 temporal resolutions (daily, annual, and annual rollup) for 5 salmonid run-types for CS1, CS2 and CS6, a total of 60 graphs. Note that for this PM a lower value indicates a better condition: the green line is lower than the red line. For some PMs "more is better" and the lines are reversed.

Calibration of the CS3 and CS5 (Egg-to-Fry Thermal Mortality and Redd Scour) indicators follows a slightly different logic than the calibration of Spawning and Rearing WUA, Juvenile Stranding and Redd Dewatering. CS3 and CS5 are based on fixed Indicator Threshold boundaries such as % survival or 1-in-10 year flood flows. These differences are noted below in the descriptions of the individual PMs.

The calibration exercise affects the interpretation of all SacEFT outputs and assumes that the calibration period is the norm for the Sacramento system. While it provides a necessary benchmark, it should be borne in mind that if the calibration period is somehow abnormal ("very good", "very bad" "a time of extreme change," *etc.*), conclusions based on the benchmark will need to be critically examined. For PMs which are cued to absolute values like % survival, a poor benchmark causes fewer problems than PMs like redd dewatering which are often analyzed in a comparative way that hinges on the correct interpretation of changes in relative distributions.

CS1 – WEIGHTED USABLE AREA FOR SPAWNING

Spawning WUA is calculated using daily cohorts of spawners for each run-type and river segment. The historical or simulated gauges provide daily average flow *(Q)* over the spawning period *D* for each location *(l)* and run-type *(r)* combination[1].

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[1] 'Run-types' are sometimes referred to as 'races.' We recognize four Chinook run-types and Steelhead trout as separate salmonid species.

The *daily* performance measure is computed each day by interpolating the WUA-flow relationship – possibly modified by changes in substrate size composition from the TUGS model – $f(l,r,Q^*)$ to predict Weighted Usable Area (WUA, square feet). The PM accounts for spawning area only, and subsequent exposure to thermal mortality or redd dewatering is not included. Linear interpolation is used to calculate WUAs between the tabular values found in Gard's studies of spawning WUA (U.S. Fish and Wildlife Service 2003, 2005a).

The *rollup* PM is computed by averaging across all locations (*L*). It uses a 1/L average rather than a sum, so that system-wide thresholds are more meaningful should the number of locations vary across years and/or run-types, based upon the availability of the underlying flow and water temperature data.

$$CS1_r = \frac{1}{L}\sum_{l=1}^{L}\left(\frac{1}{D}\sum_{d=1}^{D} f(l,r,Q_d^*)\, w_d\right)$$

During the model review leading up to the release of Version 2, we considered using empirically driven measures of reach-usage (see "Field" columns in Table 4.7) to add further realism to the rollup. But a re-reading of U.S. Fish and Wildlife Service (2005b) makes it clear that this is not necessary: reach-weights from U.S. Fish and Wildlife Service (2003) were ***already*** incorporated in the study which produced WUA Spawning estimates for SacEFT Version 1. Moreover, estimates shown in Table 4.7 are based on 1989-1994 redd counts that preceded two very high flood events, and the WUA estimates developed by Gard (U.S. Fish and Wildlife Service 2005b) represent post-flooding conditions that changed substantially in the more downstream reaches, with downgraded habitat availability below Battle Creek.

Whichever WUA prediction model is incorporated, SacEFT assumes that WUA predictions are statistically stationary over time, an assumption that loses strength as simulation time periods move away from the time period of the field assessments that generated the underlying WUA curves. A comparison of "Field" and "SacEFT" Spawning WUA for three run-types shown in Table 4.7 shows fair agreement in most situations. SacEFT estimates reflect the dramatic change in available habitat below Battle Creek. No matching estimates are available for Spring Chinook or steelhead.

Table 4.7. 1989-1994 observations of field redd distribution (%) compared to simulated SacEFT Version 2 Spawning WUA (%) for three run-types.

Segment		Fall (%)		Late Fall (%)		Winter (%)	
Upper boundary	**Lower boundary**	**Field**	**SacEFT**	**Field**	**SacEFT**	**Field**	**SacEFT**
Keswick	ACID	9	8	24	20	2	25
ACID	Cow Creek	38	21	52	48	80	62
Cow Creek	Battle Creek	13	5	8	33	3	12
Battle Creek	Red Bluff	16	39	7	-	9	-
Red Bluff	Deer Creek	25	27	8	-	6	-

Breakpoints for the R/Y/G Indicator Ratings are taken using terciles of the sorted river-segment distribution for the daily and annual results, using discontinuities in the annual distribution for the rollup where those exist.

Indicator Reliability

The indicator credibility rankings for CS1 are shown in Table 4.8.

Table 4.8. CS1 - Spawning WUA indicator credibility assignments following the workshop.

	Category				
	I	**U**	**R**	**F**	**P**
Winter-run Chinook		H	H	H	H
Spring-run Chinook		M	M	H	M
Fall-run Chinook		H	H	H	H
Late-fall-run Chinook		H	H	H	H
Steelhead		M	H	M	M/H

Excel Reports

An example of the Version 2 Excel report is shown in Figure 4.10.

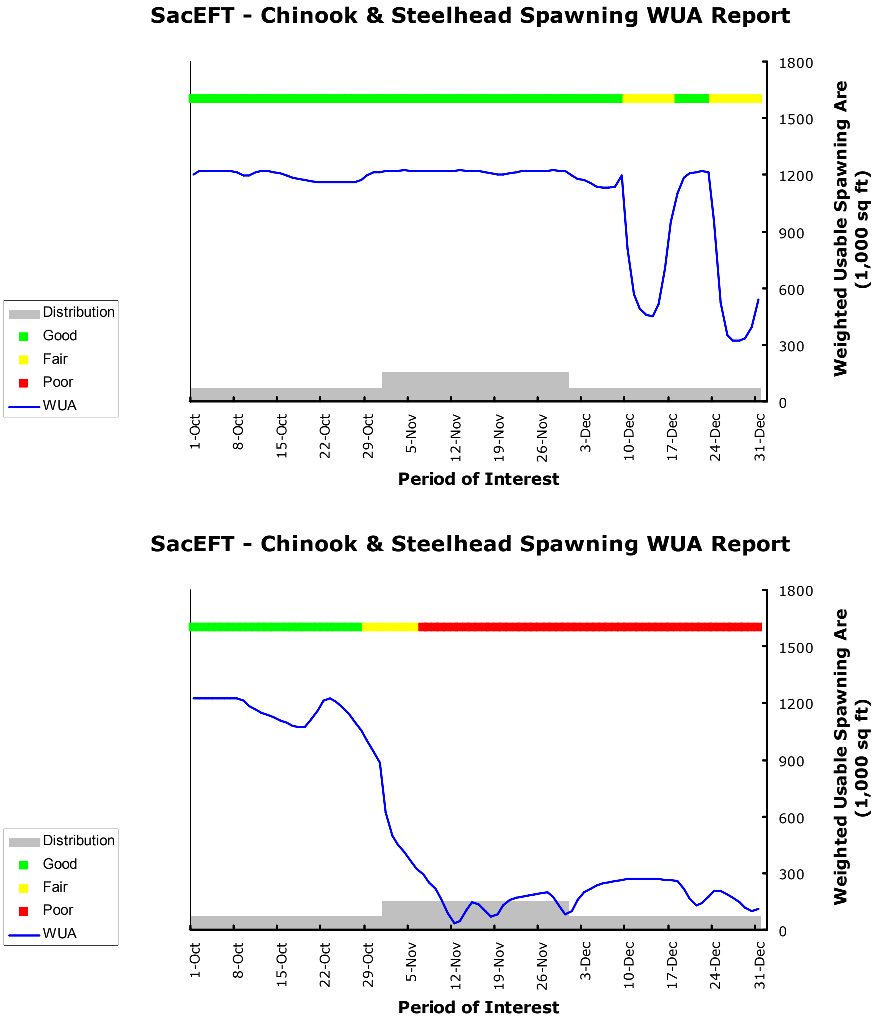

Figure 4.10. The CS1 – Spawning WUA daily Performance Measure as implemented in SacEFT Version 2. The upper and lower panels show results for fall-run Chinook in Reach 2 in 1969 and 1974: Good and Bad years respectively. In each panel, the horizontal R/Y/G bar shows the scoring of daily cohorts relative to the distribution of all day-cohorts over all years. To save space, the figure excludes a comparative graph of discharge which is produced as part of the Excel report. It also excludes an additional graph of field data showing redd proportion by reach for the period 1989-1994.

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for Spawning WUA are shown in Table 4.9. The indicator and its rating calibration have units of square feet of spawning habitat. The breakpoints for the *Daily Indicator* rating for each run-type are based on the estimated daily WUA over all reaches over all days of the spawning period, over all years. Typically, several thousand simulation observations contribute to the sorted daily WUA distribution. Run-types with longer spawning periods have a longer period to accumulate WUA and therefore have more observations and higher breakpoint values, other conditions being equal. The primary *Rollup Indicator* rating is based on a daily average across all reaches over all years, and there are typically a few dozen simulated observations for the distribution of this indicator; one for each simulation year.[1]

In the case of Spawning WUA, differences between the indicator rating breakpoints of the five run-types are notable, and can vary by a factor of 50. Besides differences in flow regime and substrate preferences, this large range is due to differences in the number of reaches and the length of the spawning periods amongst the run-types. The great difference in scales among run-types is part of the rationale for using independent breakpoints for each run. Readers are also reminded that the indicator is a measure of habitat potential (availability) and not a population of spawners or number of redds.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Spawning WUA. Because of this gap and the hesitancy of experts to reveal their opinions, we instead calculated the sorted distribution of weighted annual results and selected terciles (the lower-, middle- and upper thirds of the sorted distribution) as an initial reference to categorize the results.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant. In the last column of Table 4.9 we attempt to flag cases where there are major gradients in performance indicator thresholds.

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[1] We have also defined and calibrated an ***Annual Indicator*** rating based on calculating an average daily value for each reach. This indicator is calculated in SacEFT Version 2 and results are stored in the database, but are not currently presented in any of the output reports. For the Annual Indicator, the contribution of each daily value to the average is weighted by the proportion of the spawning population present on each day. Since a typical spawning period is about 100 days (see Table 2.7 for details), Annual Indicator thresholds for Spawning WUA are about 1% of the Daily Indicator thresholds, and there are typically about 100 simulated observations in the distribution, depending on the number of years and reaches available for simulation. The Annual and Rollup indicator ratings have a similar numerical ranges for each run-type, but are not identical, since the calculated breakpoints use observations of simulation results which are near, but hardly ever exactly identical for the 33% and 67% percentiles of the two sorted distributions.

Table 4.9. CS1 - Spawning WUA indicator rating breakpoints used for Version 2.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Winter-run Chinook	430060	195486	2880	2475	• Criteria: statistical distribution, terciles, “more” is better • Units: square feet • Flow, spawning period, habitat preferences, affect distribution
Spring-run Chinook	607975	217913	5825	4775	
Fall-run Chinook	1006472	29967	8470	5500	
Late-fall-run Chinook	520424	280581	4250	2760	
Steelhead	18692	13447	135	106	

CS2 – WEIGHTED USABLE AREA FOR REARING

Rearing WUA is calculated using daily cohorts of juveniles after emergence, for each run-type and river segment. The historical or simulated gauges provide daily average flow (*Q)* and daily average temperature over the rearing residency period (*D)* for each location *(l)* and run-type *(r)* combination.

Daily juvenile rearing weights are notably different from daily spawning weights. In the case of rearing weight, each day-cohort is the result of the temperature-driven egg-emergence function instead of a deterministic spawning-calendar. This creates a linkage to the spawning performance measures CS1, with a delay between the day on which a cohort of eggs is spawned and the day on which the cohort emerges. Over the year the juvenile distribution is created by adding each daily juvenile cohort (c_e) from its date of emergence (*e*) using a run-type-dependent residence period (*r*) after emergence, with the variable *r* set to 90 days for all Chinook run-types and 365 days for steelhead. The proportion of juveniles (w_d) present on any given day (*d)* is therefore given as the sum of all emerged day-cohorts less than *r* days old:

$$w_d = \sum c_e \quad where\ (e \le d),\ and\ ((e + r - 1) \le d)$$

The emergence function makes it possible to have multiple spawning day cohorts emerge on the same day, particularly during periods of warming water. After emergence, each juvenile day-cohort is followed for a residency period of *r* days, providing an internally consistent way of evaluating both juvenile rearing WUA and juvenile stranding (CS4). Since emergence is driven by Accumulated Thermal Units (ATUs; see the CS3 description on pg. 63 for further information), this distribution will vary across locations and years due to location and temperature variations. After *r* days have elapsed, the day-cohort is no longer tracked. SacEFT does not track movement of cohorts between reaches, and during their residence period they are assumed to remain in the reach they were spawned.

The *daily* PM is computed by interpolating the WUA-flow relationship *f(l,r,Q)* (which for rearing does *not* vary with substrate composition) to predict Weighted Usable Area for rearing (WUA, square feet). Prior events such as thermal mortality or redd dewatering are not accounted for by this PM, which measures rearing area only. Linear interpolation is used to calculate rearing WUAs between the tabular values found in Gard’s studies (U.S. Fish and Wildlife Service 2005b). As already noted, while each model operates internally on the basis of a daily cohort, the distributional and cumulative results shown in the Excel report portray the aggregated juvenile day-cohorts present each day and use that proportion to scale the Indicator Rating assigned to the WUA. This makes it possible to see daily changes to the entire population in the face of fluctuations in flow and temperature (see Figure 4.11), even though internally, each day-cohort is tracked separately.

The *rollup* PM is computed by averaging across all locations (*L*). An average is used rather than a sum, so that thresholds are more meaningful should the number of locations vary across years and/or run-types, based upon the availability of the underlying flow and water temperature data.

$$CS2_r = \frac{1}{L}\sum_{l=1}^{L}\left(\sum_{d=1}^{D} f(l,r,Q_d)\,w_d\right)$$

Breakpoints for the R/Y/G Indicator Ratings are taken using terciles of the sorted river-segment distribution for the daily and annual results, and using discontinuities in the annual distribution for the rollup.

Indicator Reliability

The indicator credibility rankings for CS2 are shown in Table 4.10.

Table 4.10. CS2 – Rearing WUA indicator credibility assignments following the workshop. These ratings apply to those reaches of the Sacramento River where data have been directly acquired for the indicated run types (*i.e.,* depth, velocity, preference curves). If relationships derived from one reach are applied to another reach, both the U and R scores reduced, since the channel cross-section could lead to different curves of Rearing WUA vs. flow.

	Category				
	I	**U**	**R**	**F**	**P**
Winter-run Chinook		H	H	H	H
Spring-run Chinook		M	M	H	M
Fall-run Chinook		H	H	H	H
Late-fall-run Chinook		H	H	H	H
Steelhead		M	M	H	M

Excel Reports

An example of the Version 2 Excel report is shown in Figure 4.11. The relative performance of a specific reach year can a compared with the historical range of Rearing WUA, by comparing the purple cumulative PM line to the vertical R/Y/G bar on the right of each graph. The vertical R/Y/G bar shows the distribution of annual rollup values across all years and reaches. The daily distribution is shown by the horizontal R/Y/G bar at the top of each pane.

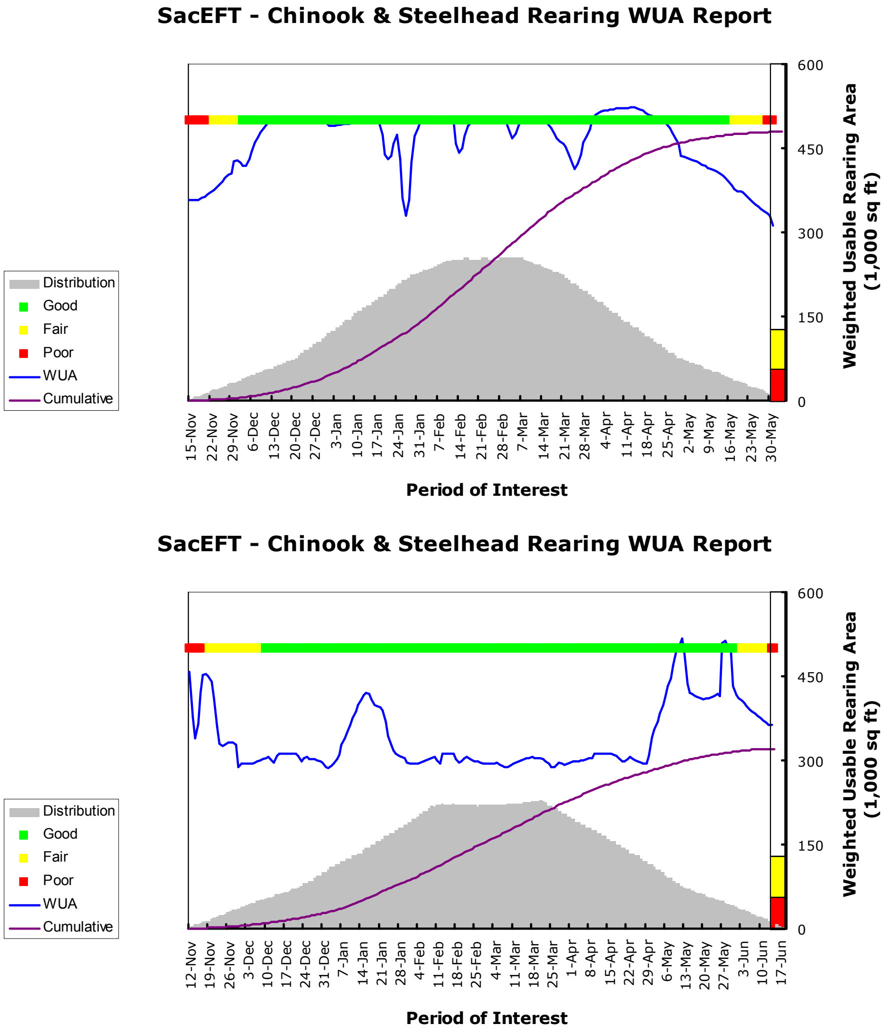

Figure 4.11. An example of the Version 2 Excel report for CS2 – Chinook juvenile rearing WUA using fall-run Chinook from Reach 5 in 1981 and 1982 in the upper and lower panels, respectively. The purple cumulative distribution lines show that Reach 5 receives a Good (Green) ranking relative to all reaches in both years. But because some other reaches scored poorly in one of the two years, ***system-wide*** 1981 was a Good (Green), while 1982 was a Bad (Red) year. To save space, the figure excludes a comparative graph of discharge which is produced as part of the Excel report.

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for Rearing WUA are shown in Table 4.11. The indicator and its rating calibration have units of square feet of rearing habitat. The breakpoints for the *Daily Indicator* rating for each run-type are based on the estimated daily WUA over all reaches over all days of the juvenile rearing period, over all years. For Rearing WUA, the observation for each simulation day is weighted by the proportion of the total population present in each day-cohort, meaning that days with more emerging juveniles are given more importance, but longer spawning and residency periods do not contribute to the magnitude of the indicator. Typically, several thousand simulation observations contribute to this sorted daily distribution. The primary *Rollup Indicator* rating has units of “sum of daily square feet” and is based on calculating a *cumulative* daily value for each reach, over the residency period (typically 90 days for Chinook and 365 days for steelhead (see Table 2.7 for details)) for each simulation year, and then taking the average value over all the reaches to produce an annual average value. The practice of using a cumulative total for this indicator leads to much larger indicator values for the Rollup, and there are typically a few dozen simulated observations for the distribution of this indicator; one for each simulation year.

In the case of Rearing WUA, there is about a two-fold range among the breakpoints of the five run-types. These differences are due to differences in the flow regime and number of reaches for each run-type. Difference in scales among run-types is part of the rationale for using independent breakpoints for each run. Readers are also reminded that the indicator is a measure of potential habitat (availability) and not a population of juveniles.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Rearing WUA. Because of this gap and the hesitancy of experts to reveal their opinions, we instead calculated the sorted distribution of weighted annual results and selected terciles (the lower-, middle- and upper thirds of the sorted distribution) as an initial reference to categorize the results.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are “better” than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as “Good” (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as “Poor” (Red) may be biologically insignificant. In the last column of Table 4.11 we attempt to flag cases where there are major gradients in performance indicator thresholds.

Table 4.11. CS2 – Rearing WUA indicator rating breakpoints.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Winter-run Chinook	39675	10987	10250137	9997544	• Criteria: statistical distribution, terciles, “more” is better • Daily units: square feet • Rollup units: cumulative square feet • Flow, number of reaches affect distribution
Spring-run Chinook	109294	33678	24800719	19200148	
Fall-run Chinook	51872	20539	18341766	14048587	
Late-fall-run Chinook	47481	18283	13306025	11936239	
Steelhead	49501	14292	18160595	16361215	

CS3 – EGG-TO-FRY THERMAL MORTALITY

Temperature contributes to two opposing processes in SacEFT. Warmer water makes development faster through the temperature-maturation relationship discussed below, reducing the period of exposure to thermal (and other sources of) mortality. At the same time, development in warmer water produces higher thermal mortality.

Maturation is driven by Accumulated Thermal Units (ATUs) calculated from daily temperature. Following the model review workshop we enhanced the ATU calculation originally derived from SALMOD. Based on a review of Myrick and Cech (2010), Version 2 uses Chinook and rainbow trout (*Salmo gairdneri = O. mykiss*) relationships developed by Crisp (1981). Besides providing a unique set of steelhead coefficients, the coefficients adopted for Version 2 are also improved for Chinook, since those in Version 1 were interpolated from enlarged drawings found in the SALMOD documentation (Bartholow and Heasley 2006)[1], and those in Version 2 are taken directly from Crisp’s models, where δ is the total days of egg development time at temperature T (°C) (see Figure 4.12):

$$\log_{10}\delta = -1.8126 \times \log_{10}(T+6) + 3.9166 \qquad \textbf{Chinook}$$

$$\log_{10}\delta = -2.0961 \times \log_{10}(T+6) + 4.0313 \qquad \textbf{Steelhead}$$

Proportion maturation per day is then the reciprocal of δ. The original SALMOD functions remain in the EFT model and can be used in a run scenario, if desired.

Given a development period determined by temperature, daily egg survival is calculated using daily egg cohorts over their development period (δ) following spawning, for each combination of location *(l)* and run-type *(r)*. Survival *s(T)* declines at warmer temperature (Table 11, Bartholow and Heasley 2006; see Figure 4.13). Chinook and steelhead use a ***common*** thermal mortality relationship, following Myrick and Cech (2010; see Figure TT.5 and TT.6), who conclude that any notion of run-type-specific mortality for steelhead is more closely related to what they term “genetic strains”, and that the very wide range in mortality makes it very difficult to predict steelhead egg mortality with any precision.

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[1] ***Note:*** Over the course of model development we also evaluated the USBR egg mortality model but later adopted SALMOD models since that model corrected some mathematical errors present in the USBR model we examined.

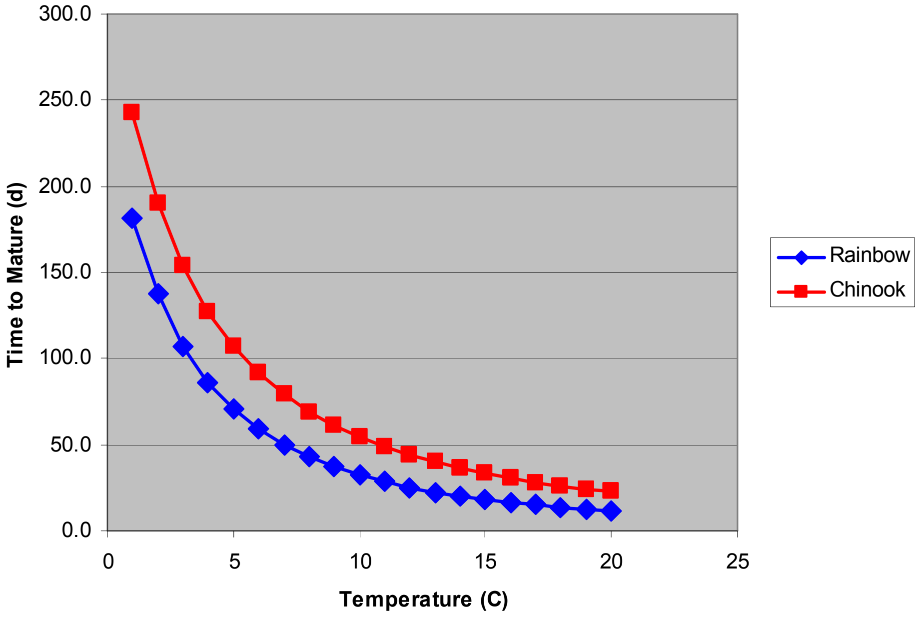


Figure 4.12 Based on relationships developed by Crisp (1981) for Chinook salmon and rainbow trout (= steelhead), eggs at a given temperature will mature in a corresponding number of days. The reciprocal of the number of days is the proportion of maturation occurring over one day, and the maturation period (*δ*) is complete when the cumulative proportion of daily maturation reaches 1.0.

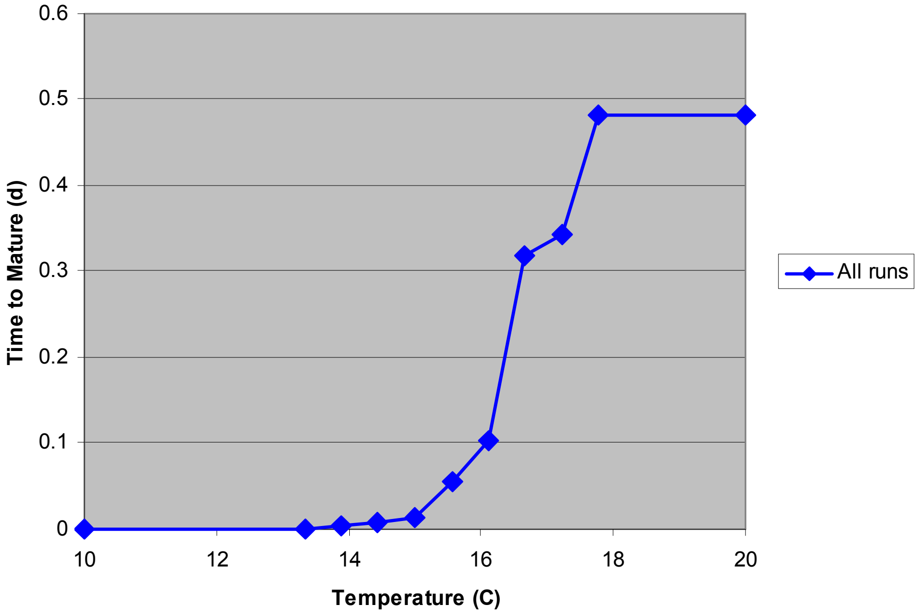


Figure 4.13 Daily thermal mortality is based on SALMOD relationships for all species (Bartholow and Heasley, 2006).

As noted above, longer egg development in colder water also increases the cumulative exposure to other potential mortality sources, a set of processes not accounted for in SacEFT. The influence of each day-cohort is expressed as the proportion (w_d) spawning each day over the egg development period. Unlike the Rearing WUA performance measure, which shows relative abundance of rearing salmonids, the Excel

Report for egg survival portrays the spawning-day distribution only and not the relative abundance of in-gravel eggs.

The *daily* PM is calculated by following each spawning day-cohort over the course of its development up to emergence, evaluating its daily survival *s(T)* as a function of water temperature and taking the product of daily survival. Exposure to events such as redd dewatering are not accounted for by this PM, which calculates thermal mortality only:

$$CS3_{l,r,d} = \prod_{\delta} s(T)$$

The *rollup* PM is calculated by averaging over all river segments (*L*), weighting each segment by the using the average proportion of total spawning WUA (CS1) for the segment relative to the river-wide average Spawning WUA.

$$CS3_{r} = \sum_{l=1}^{L} \left(\frac{CS1_{\overline{x,l}}}{CS1_{\bar{x}}} \right) \left(\sum_{d=1}^{D} w_{d} \prod_{\delta} s(T) \right)$$

Indicator Reliability

The indicator credibility rankings for CS3 are shown in Table 4.12.

Table 4.12. CS3 – Egg thermal mortality indicator credibility assignments following the workshop.

	Category[1]				
	I	**U**	**R**	**F**	**P**
Winter-run Chinook		H	H	H	H
Spring-run Chinook		H	H	H	H
Fall-run Chinook		H	H	H	H
Late-fall-run Chinook		H	H	H	H
Steelhead		H	M	H	M/H

[1] see Table 2.3 for category definitions.

Excel Reports

The Excel Report for Egg-to-fry Thermal Mortality (CS3) follows the style of the Rearing WUA (CS2) report shown in Figure 4.14, using a vertical bar to show the distribution of the annual rollup for the PM. Note that the orientation of the vertical R/Y/G bars are reversed in these two reports, since “more Rearing WUA” is better, but “more Thermal Mortality” is worse. The report shows two graphs. The upper panel shows the spawning-day distribution in gray, the incubation period mortality for each day cohort and the cumulative population mortality across all cohorts. The lower graph shows daily temperatures and R and Y thresholds for daily mortality. The x-axes are identical and span the first day of spawning to the last date of emergence. Note that the incubation period for a day-cohort is typically around 100 days and therefore the mortality for a day-cohort spawned on day *t* (and graphed on day *t*) can be high due to increased temperatures and higher mortality at a later date (for example day *t+50*).

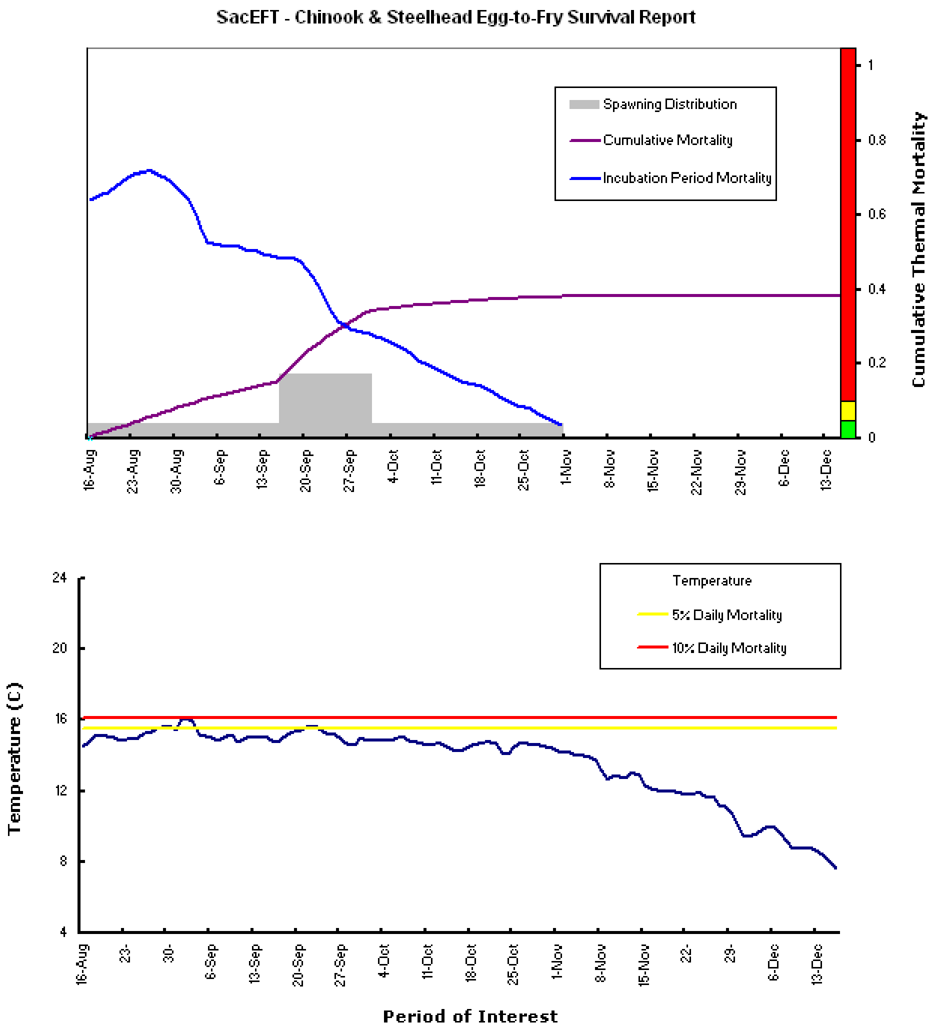


Figure 4.14. An example of the Version 2 Excel Report for CS3 – Egg-to-fry thermal mortality using spring-run Chinook from Reach 4 in 1988. System-wide this year was reported as a Red year. To save space, the figure excludes some of the additional explanatory text that accompanies the Excel report.

Indicator Threshold Calibration

Based on absolute mortality values of 5% and 10%, the Indicator Rating boundaries for Egg-to-fry thermal mortality are shown in Table 4.13. The same units and values are used for *Daily* and *Rollup* indicator ratings. The rationale for this choice of indicator at all scales is that it has an unambiguous meaning, in contrast to other indicators which are either more abstract, or are unit-free indices. Readers should note that 5% mortality at the Daily indicator scale means that 5% of the eggs spawned on that day and in that reach will die because of elevated temperature. At the Rollup level, the same number means that 5% of the entire multi-reach population of eggs will die in that year, due to elevated temperature.

The *Daily* indicator is calculated by accumulating thermal mortality over the egg-development period, which is determined by spawning day and water temperature, and differs for Chinook and steelhead. The *Rollup* indicator has the same units as the Daily rating, goes one step further and calculates an annual average across all reaches, using the relative amount of Spawning WUA in each reach to calculate a weighted average. There are typically a few dozen simulated observations for the distribution of this indicator.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Egg-to-fry thermal mortality. Neither are there universally accepted mortality levels – conceptually similar to LD_{50} values for pollutants – for measuring the impact of thermal mortality. Because of this gap and the hesitancy of experts to reveal their opinions, we instead chose arbitrary mortality breakpoints of 5% and 10% as initial reference points to categorize the results.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant. In the last column of Table 4.13 we attempt to flag cases where there are major gradients in performance indicator thresholds.

Table 4.13. CS3 – Egg-to-fry Thermal Mortality indicator rating breakpoints.

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Winter-run Chinook	5	10	5	10	• Criteria: absolute values, "less" is better • Units: % mortality • Common threshold for all run-types
Spring-run Chinook	5	10	5	10	
Fall-run Chinook	5	10	5	10	
Late-fall-run Chinook	5	10	5	10	
Steelhead	5	10	5	10	

CS4 – JUVENILE STRANDING

Juvenile stranding is modeled using daily declining changes in discharge *(Q)* over the juvenile rearing period *(D)* for each location *(l)* and run-type *(r)* combination. The daily distribution of rearing juveniles is based on the emergence function and the distribution (c_e) derived for juvenile rearing WUA (*i.e.*, from CS2). In the case of juvenile stranding the daily weight (w_d) is conditioned on events that take place as the cohort ages through the subsequent juvenile residency period. In particular, a daily cohort may experience losses (as described in the next section) when the flow declines from one day to the next. The cohort weight on a given day $c_{e,d}$ becomes:

$$c_{e,d} = \begin{cases} c_e \quad when\ (e \le d < (e+1)) \\ c_e\left(1 - \sum_{i=e+1}^{d-1} f(l, Q_{i-l}, Q_i)\right) \quad when\ (e < (d-1))\ and\ \ ((e+j-1) \le d) \\ 0.0 \quad otherwise, e.g.\ when\ ((e+j-1) < d < e) \end{cases}$$

By definition, no losses occur on the day a cohort emerges. If a drop occurs on the second day the loss is accounted for at the end of the second day, causing the cohort weight to decline on the third day (*e=1, d=3*). In SacEFT Version 2, Chinook juveniles reside in their natal reach for 90 days; steelhead for 365 days. Over this residency period, declining flows affect each day-cohort in a cumulative fashion. Based upon the formula above, the weight (w_d) for any given day is then assigned to the sum of all the cohort weights that are present on that day:

$$w_d = \sum c_{e,d}$$

The *Daily* indicator uses Gard's juvenile stranding research (U.S. Fish and Wildlife Service 2006b) to estimate the proportional decrease in habitat over the period between juvenile emergence and the end of the juvenile residence period. Mark Gard kindly made his raw results available to us so that his system-level tables could be disaggregated to the reach level used by SacEFT. Gard's results do not include time explicitly. Rather, his model estimates the proportion of rearing WUA lost (if any) at each location (*l*) between the day of emergence and the end of the residency period. Although run-types are modeled separately in SacEFT, they all use a single all-species flow-decline relationship. Based on discussions with Gard, we adapted this relationship in a way that is mathematically consistent with the original results, but which can be disaggregated to the daily scale of the juvenile stranding model. To calculate the daily PM, the model compares the previous day's flow, Q_{d-l}, and the flow on day Q_d. If there is a drop, then some proportion of juveniles are potentially stranded: $f(l, Q_{d-1}, Q_d)$, and bilinear interpolation is used to calculate proportional losses between the tabular values found in Gard's tables (U.S. Fish and Wildlife Service 2006b).

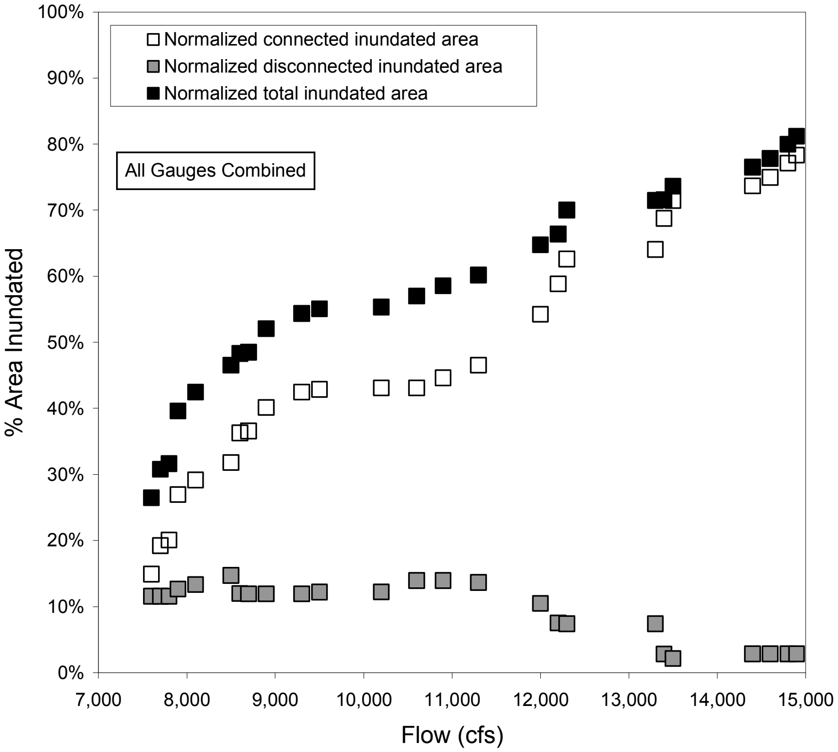


Figure 4.15. Normalized connected (white symbols), disconnected (gray symbols), and total inundated area (black symbols) averaged over all study sites for varying flows on the Sacramento River. Each site is normalized by the maximum potential inundated area, such that they each have equal weight in determining average percent inundated area. The stepped pattern of area versus flow highlights what appears to be a significant river-wide increase in inundated area at about 12,000 cfs. A significant decrease in inundated area appears to occur at roughly 8,500 cfs (Stillwater Sciences 2007; p. 33).

During the Version 1 model review workshop, the salmon sub-group agreed that while the structure of the indicator is good, its usefulness is constrained by the absence of stranding relationships ***below Red Bluff Diversion Dam***. Many juveniles are known to rear in these lower portions of the river and it would be useful to have stranding relationships for these locations as well as the more upstream segments. We explored pre-existing datasets from side channel studies described in the Stillwater Sciences (2007) (Figure 4.15). Mark Gard (USFWS, *pers. comm.*) has suggested that these might be adapted to the tabular model structure adopted for the U.S. Fish and Wildlife Service (2006b) report, and that the "normalized disconnected inundated area" from this figure corresponds most closely to the methodology used to estimate stranding at upstream locations. We compared the Stillwater range of data to Gard's and found that the flows shown in the Stillwater results are much higher than those measured in Gard's studies. This discontinuity makes it hard to see how downstream locations could be included in a comparable way. Even if this were possible, there is an additional data gap between 3,750 cfs (below which stranding will never be a problem) and 7,500 cfs, the lowest flow value shown in Figure 4.15. Thus, stranding relationships below Red Bluff Diversion Dam remain a model gap.

The daily proportional changes to rearing habitat create an *index* of stranding potential which is calculated by using the sum of proportions lost over the residency period, but which is not synonymous with the proportion of the juveniles lost. Because juveniles are mobile and may possess behaviors that help them avoid stranding (unlike eggs in redds), the use of an index of stranding potential is more appropriate, even though the underlying model measures declining fluctuations in rearing WUA.

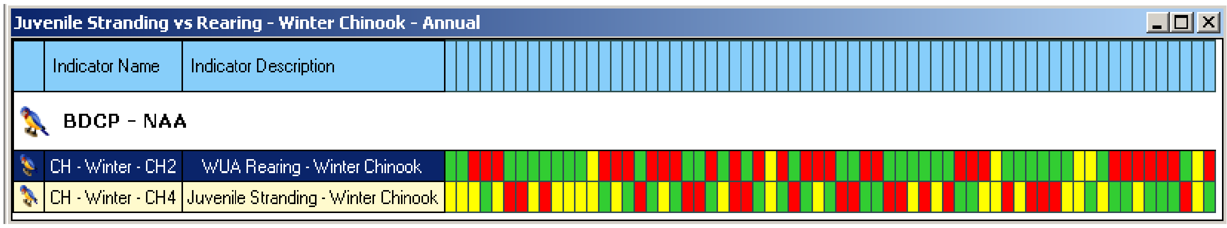
The *Rollup* indicator for juvenile stranding is calculated by taking the average across locations (*L*). An average is used rather than a sum, so that thresholds are more meaningful should the number of locations vary across years and/or run-types, based upon the availability of the underlying flow and water temperature data.

$$CS4_r = \frac{1}{L}\sum_{l=1}^{L}\sum_{i=1}^{D}(c_{i,D+1} - c_{i,D})$$

Breakpoints for the R/Y/G Indicator Ratings are taken using terciles of the sorted river-segment distribution for the daily and annual results, and using discontinuities in the annual distribution for the rollup.

Comment on Correlated CS2 and CS4 Behavior

In a review of 6 BDCP scenarios carried out with Version 2, an apparent negative correlation between juvenile rearing (CS2) and juvenile stranding (CS4) was reported for some run-types:



Juvenile Stranding vs Rearing - Winter Chinook - Annual

BDCP - NAA

Indicator Name	Indicator Description
CH - Winter - CH2	WUA Rearing - Winter Chinook
CH - Winter - CH4	Juvenile Stranding - Winter Chinook

Our analysis found that the negative correlation arises from the fact that the amount of potential rearing habitat is used as an **input** to weight the impact of juvenile stranding, making it inevitable that as more habitat is created (regardless of the details of the daily flow regime and the exact nature of the flow-stage recession relationship) it exposes proportionally more juveniles to stage-flow recession events when they inevitably occur. Since increased WUA Rearing area results in a Green Indicator Rating while an increased Stranding Index results in a Red Indicator Rating, the two measures become negatively correlated. A more complete analysis of this negative correlation is found in Robinson (2010).

Indicator Reliability

The indicator credibility rankings for CS1 are shown in Table 4.14.

Table 4.14. CS4 – Juvenile stranding indicator credibility assignments following the workshop.

	Category				
	I	U	R	F	P
Winter-run Chinook		M/H	H	H	M/H
Spring-run Chinook		M/H	H	H	M/H
Fall-run Chinook		M/H	H	H	M/H
Late-fall-run Chinook		M/H	H	H	M/H
Steelhead		M/H	H	H	M/H

Excel Reports

An example of the Version 2 Excel report is shown in Figure 4.16. The relative performance of a specific reach and year can a compared with the historical range of the Juvenile Stranding index, by comparing the purple cumulative PM line to the vertical R/Y/G bar on the right of each graph. The vertical R/Y/G bar shows the distribution of annual rollup Stranding values across all years and reaches. The daily distribution is shown by the horizontal R/Y/G bar at the top of each pane.

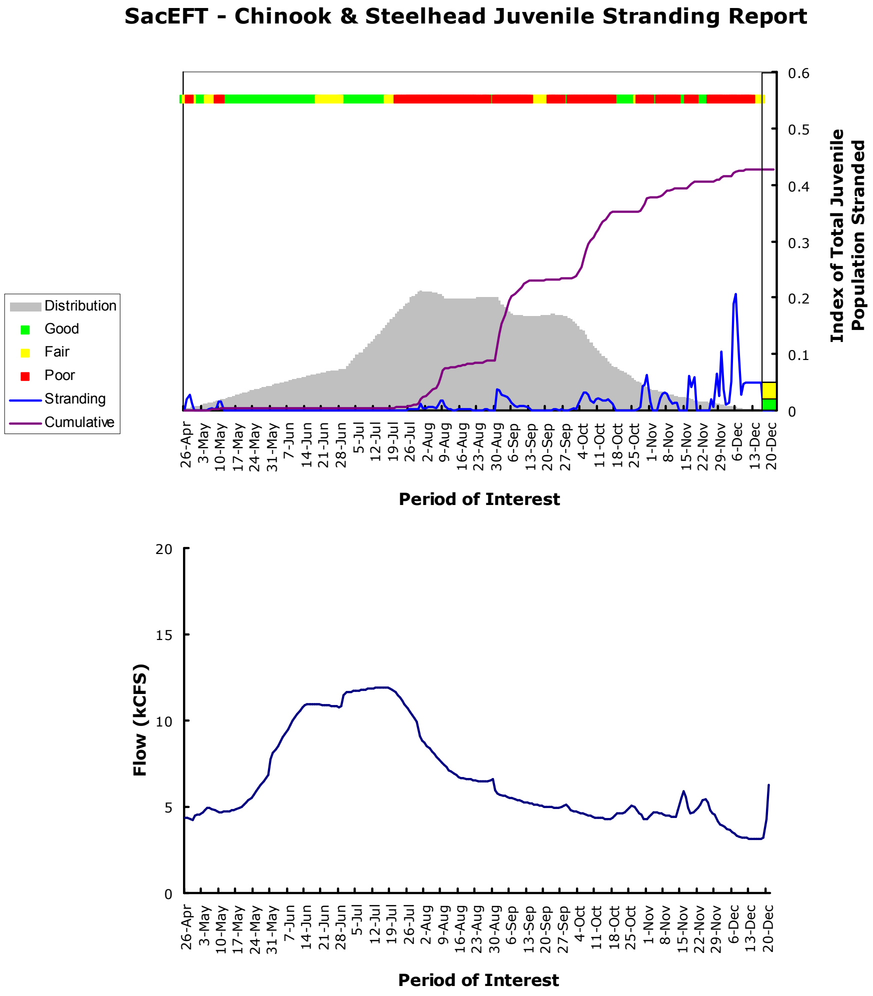


Figure 4.16. Excel Report for CS4 – Juvenile Stranding, showing winter-run Chinook in Reach 5 for 1979. The index is very sensitive to declining changes in flow, even though the discharge is quite low. The upper horizontal bar shows the index R/Y/G score relative to the daily scoring across all reaches and years; the vertical horizontal R/Y/G shows the cumulative distribution of the reach and year relative to the annual rollup distribution. The impact of stranding index upon the juvenile distribution can be seen in the quick declines of the bell-shaped gray distribution that accompany drops in flow, coupled to a sharp jump in the Stranding index.

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for Juvenile Stranding are shown in Table 4.15. The indicator and its rating calibration are treated as dimensionless index, although technically it is a sum of proportional changes in rearing area. The breakpoints for the *Daily Indicator* rating for each run-type are based on the estimated daily proportional change in rearing area over all reaches over all days of the juvenile rearing period, over all years. Each simulation day's observation is weighted by the proportion of the total rearing population present in each day-cohort, meaning that days with more juveniles are given more importance, with longer residency periods also contributing to the magnitude of the indicator. Typically, several thousand simulation observations contribute to this sorted daily distribution. The primary *Rollup Indicator* rating is also a dimensionless index, and is based on calculating a *cumulative* daily value for each reach, over the residency period (typically 90 days for Chinook and 365 days for steelhead (see Table 2.7 for details)) for each simulation year, and then taking the average value over all the reaches to produce an annual average value. The practice of using a cumulative total for this indicator leads to much larger indicator values for the Rollup, and there are typically a few dozen simulated observations for the distribution of this indicator; one for each simulation year.

In the case of Juvenile Stranding, there is about a two-fold range among the breakpoints of the five run-types. These differences are due to differences in the flow regime and number of reaches for each run-type. There are also some notable differences within run-types. For example, most run-types have lower and upper rollup thresholds that differ by about a factor of two (*e.g.,* 0.08 and 0.16 for winter-run Chinook). But in the case of late-fall Chinook, the difference in thresholds is much smaller (0.06 and 0.08), making the assignment more sensitive to small changes. The biological importance of this difference is unknown: it is simply a measure of the narrower historical range of fluctuations during the late-fall Chinook juvenile residence period. Difference in scales among run-types is part of the rationale for using independent breakpoints for each run. Readers are reminded that the indicator is a measure of potential habitat change (availability) and not a measure of actual stranding.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Juvenile Stranding. Because of this gap and the hesitancy of experts to reveal their opinions, we instead calculated the sorted distribution of weighted annual results and selected terciles (the lower-, middle- and upper thirds of the sorted distribution) as an initial reference to categorize the results.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant. In the last column of Table 4.15 we attempt to flag cases where there are major gradients in performance indicator thresholds.

Table 4.15. CS4 – Juvenile Stranding indicator rating breakpoints.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Winter-run Chinook	4.517E-05	3.528E-04	0.0804	0.1622	• Criteria: statistical distribution, terciles, "less" is better • Daily units: index • Rollup units: cumulative index • Flow, number of reaches affect distribution • *Late-fall-run may be more sensitive-responsive*
Spring-run Chinook	1.483E-04	8.852E-04	0.1472	0.2738	
Fall-run Chinook	1.083E-04	5.476E-04	0.1299	0.2161	
Late-fall-run Chinook	6.330E-05	2.249E-04	0.0654	0.0814	
Steelhead	9.964E-05	1.202E-03	0.1255	0.1845	

CS5 – REDD SCOUR

Redd scour risk is modeled using the daily proportion of eggs present by run type (r) and location (l) coupled to categorical hazard classes at times when flow exceeds user-configured threshold values. Threshold values that correspond to the 90th percentile of 10-year peak flow (75,000 cfs) and 80th percentile of 5-year peak flow (55,000 cfs) define the Fair/Poor and Good/Fair thresholds, respectively. The model couples these thresholds to each run-type's spawning distribution and uses the ATU-driven emergence function (see Figure 4.12) to create an aggregated egg distribution based on day-cohorts. In a final step, the daily weight is scaled by the relative daily proportion of spawning WUA at the given location, as is done for CS3. Thus, the daily proportion of redds (w_d) exposed to scour incorporates the joint influence of the original spawning distribution, temperature driven egg-development distribution and the proportion of total spawning WUA available in the reach.

Daily indicator values are calculated by multiplying the population-proportion weighted by daily flow. If flow is below the 55,000 cfs threshold, the daily indicator is given a value of zero. If flow exceeds the lower threshold, then the daily indicator is the product of the flow and the value (w_d) of the incubation distribution for that day and reach. Annual *Rollup* values are calculated by using a WUA-weighted average of the cumulative sum of daily weights across all reaches, for each simulation year.

Indicator Reliability

The PM scores shown in are generally lower than other salmonid PMs because they are based on more subjective opinions about scouring flow thresholds with no direct evidence. These scores are themselves only moderately quantitative, and are open to revision.

Table 4.16. CS5 – Redd scour indicator credibility assignments following the workshop.

	Category				
	I	U	R	F	P
Winter-run Chinook		L/M	M	H	M
Spring-run Chinook		L/M	M	H	M
Fall-run Chinook		L/M	M	H	M
Late-fall-run Chinook		L/M	M	H	M
Steelhead		L/M	M	H	M

Excel Reports

An example of the Version 2 Excel report is shown in

Figure 4.17.

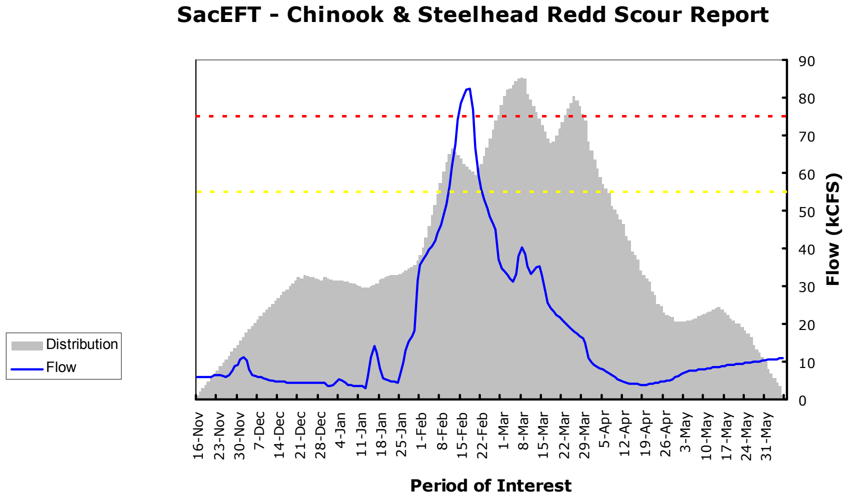


Figure 4.17. Excel Report for CS5 – Redd Scour risk, showing steelhead in Reach 4 for 1986. The Fair/Poor and Good/Fair thresholds are shown by dotted lines. System-wide, 1986 was a Poor year for steelhead scour risk.

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for Redd scour are shown in Table 4.17. The units of the *Rollup* indicators are flow (cfs)[1]. The calibration process for the Redd Scour indicator is based on critical flow threshold values suggested by the salmonid subgroup at the Version 1 review workshop, of 55,000 cfs and 75,000 cfs. These two flows represent the 80th percentile of 5-year peak main stem flow and the 90th percentile of 10-year peak main stem flow respectively. When daily flow is less than 55,000 cfs, the indicator is given a value of zero. On days when eggs are present and flows exceed this lower threshold, the daily indicator is the product of the flow and a weight given by the proportion of the total egg population present in each day-cohort. In this way, days with a higher proportion of eggs are given more importance, and longer spawning runs can potentially

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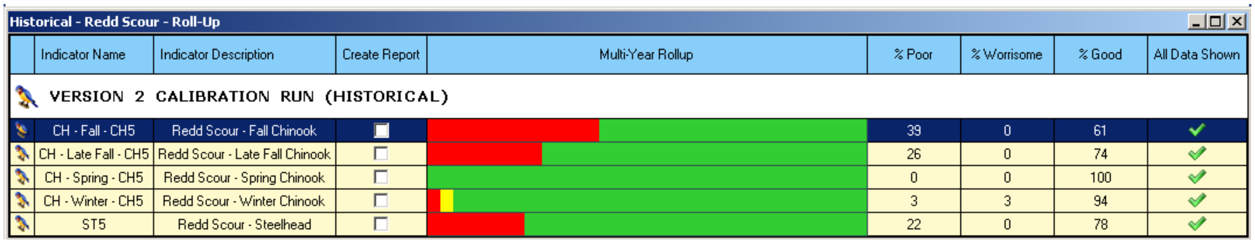
[1] A *Daily* indicator is calculated for Redd Scour is calculated and stored in the SacEFT database, but is not currently displayed. This indicator is derived from the terciles of the sorted daily distribution of weighted flow, over all run-types, reaches and years.

expose the run-type to a wider range of flows. Daily weighted flows are subsequently processed using a set of flow-based rules. At the peak of the egg-distribution, a flow event above 75,000 cfs (*i.e.*, with a high daily indicator value from the product of flow and weight) is sufficient to give a Poor assignment to the year. In addition, years with more than 2 days of flow between 55,000 and 75,000 cfs are also assigned to the Poor class. Years with high flows in the tails of the distribution are assigned as Fair years, and all other years are considered Good. By iteratively adjusting the thresholds and evaluating the frequency of Bad years, rollup thresholds were set to 5,000 (Good/Fair) and 10,000 (Fair/Poor) cfs.



Historical - Redd Scour - Roll-Up

Indicator Name	Indicator Description	Create Report	Multi-Year Rollup	% Poor	% Worrisome	% Good	All Data Shown
VERSION 2 CALIBRATION RUN (HISTORICAL)							
CH - Fall - CH5	Redd Scour - Fall Chinook	☐		39	0	61	✓
CH - Late Fall - CH5	Redd Scour - Late Fall Chinook	☐		26	0	74	✓
CH - Spring - CH5	Redd Scour - Spring Chinook	☐		0	0	100	✓
CH - Winter - CH5	Redd Scour - Winter Chinook	☐		3	3	94	✓
ST5	Redd Scour - Steelhead	☐		22	0	78	✓

Figure 4.18. Annual Rollup report for CS5 – Redd Scour risk, showing results for all calibration years (1970-2001) and all run-types.

The Redd Scour risk indicator has no threshold differences among run-types at the Rollup scale. The rationale for this behavior is that scour is a physical process; that run-types which spawn during periods of high flow are likely to experience greater exposure to scour, and that these inherent physical risks should be reflected in the indicator, much the same way that thermal mortality should affect some run-types more than others. Using these thresholds, results for the historical scenario are shown in Figure 4.18. They shows that Spring-run Chinook are intrinsically less sensitive to redd scour compared to Fall-run Chinook, which experience high risk flows about every 3 years. Averaged over all run-types, 81% of years are Good, fewer than 1% are Fair, and 18% are Poor. A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Redd Scour risk. Because of this gap and the hesitancy of experts to reveal their opinions, we instead adopted the heuristic indicator described above, to categorize years with extreme flow events.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant.

Table 4.17. CS5 – Redd scour indicator rating breakpoints.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Winter-run Chinook	N/A	N/A	5000	10000	• Criteria: calibrated to 80% Good years, “less” is better • Units: index flow (cfs) • No daily estimate • Common physical threshold for all run-types • *Very low risk for spring- , winter-runs*
Spring-run Chinook	N/A	N/A	5000	10000	
Fall-run Chinook	N/A	N/A	5000	10000	
Late-fall-run Chinook	N/A	N/A	5000	10000	
Steelhead	N/A	N/A	5000	10000	

CS6 – REDD DEWATERING

Redd dewatering is modeled using daily declining changes in discharge *(Q)* over the egg development period for each location *(l)* and run-type *(r)* combination to calculate estimates of proportional redd losses. The dewatering model tracks the daily proportion of spawned eggs based on each spawning day cohort (c_s) up to the day of its temperature-driven emergence (e). The weight of a spawning day cohort on any day ($c_{s,d}$) is based upon the original spawning cohort weight, c_s, conditioned on dewatering events that may take place as the egg-cohort matures through the egg development period and as flow may decline from one day to the next. The cohort weight on a given day $c_{s,d}$ becomes:

$$c_{s,d} = \begin{cases} c_s \quad when\ (s \le d < (s+1)) \\ c_s\left(1 - f(l, r, Q_s, Q_{d-1})\right) \quad when\ (s < (d-1))\ and\ up\ to\ emergence\ (d < e) \\ 0.0 \quad otherwise, e.g.\ when\ (d < s)\ or\ (d \ge e) \end{cases}$$

By definition, no losses occur on the day an egg cohort is spawned. If a drop occurs on the second day the loss is accounted for at the end of the second day, causing the cohort weight to decline on the third day ($e=1, d=3$). Over the egg-development period, declining flows affect each spawning day-cohort in a cumulative fashion. Based upon this formula above, the river-segment weight (w_d) for any given day is the sum of all the cohort weights present on that day:

$$w_d = \sum c_{s,d}$$

In a final step, the daily weight is further scaled by the relative daily proportion of spawning WUA at the given location. Thus, the weight (w_d) incorporates the joint influence of the original spawning distribution, temperature driven egg-development distribution and the proportion of total spawning WUA available in the river segment.

The model makes use of Gard’s redd dewatering research (U.S. Fish and Wildlife Service 2006b), which estimates proportional decrease in redds over the period between spawning and the emergence of juveniles. Mark Gard kindly made his raw results available to us so that his system-level tables could be disaggregated to the segment level used by SacEFT. Gard’s results do not include time explicitly. Rather, his model estimates the proportion of spawning redds lost (if any) at each location (l) between the time a day-cohort is spawned (c_s) and the end of the cohort’s egg development period. Gard’s tabular results include fall- and winter-Chinook salmon and steelhead trout only, and relationships for spring- and late-fall Chinook salmon are mapped from fall-run Chinook. Based on discussions with Gard, we adapted this relationship in a way that is mathematically consistent with the original results, but which can be disaggregated to the daily scale of the dewatering model. If there is no decline in flow then no loss occurs. To calculate the daily PM, the model compares the previous day's flow, Q_{d-l}, and the flow on day Q_d. If there is a drop, then some proportion of eggs are potentially dewatered: $f(l, Q_{d-1}, Q_d)$, and bilinear interpolation is used to calculate proportional loss the tabular values found in Gard's tables (U.S. Fish and Wildlife Service 2006b).

To calculate a *Daily* performance measure, the model finds the proportion of incubating eggs lost to declines in flow during the egg-development phase of each spawning day cohort, summing all of the cohort's individual losses occurring on that day:

$$CS6_{l,r,d} = \sum_{i=1}^{d} (c_{i,d+1} - c_{i,d})$$

Summing losses on previous days gives cumulative losses up to and including day (*d*):

$$CS6_{l,r,d} = \sum_{p=1}^{d} \sum_{i=1}^{d} (c_{i,p+1} - c_{i,p})$$

The *Rollup* indicator is based on taking the cumulative loss, summed across locations (*L*). Because of the way that the cohort weight incorporates the proportional spawning WUA, the rollup PM represents the percentage of redds dewatered for all reaches:

$$CS6_r = \sum_{l=1}^{L} \sum_{p=1}^{D} \sum_{i=1}^{D} (c_{i,p+1} - c_{i,p})$$

Breakpoints for the R/Y/G Indicator Ratings are taken using terciles of the sorted river-segment distribution for the daily and annual results, sometimes using discontinuities in the annual distribution for the rollup.

Indicator Reliability

The PM reliability rating for redd dewatering is shown in Table 4.18. The lower rating for spring and late fall Chinook is due to the absence of direct observation for those run-types. Reliability scores are equally high because the data are drawn from studies that have been subject to peer review, and because the functional relationships are being applied within the same reaches, but to different runs.

Table 4.18. CS6 – Redd dewatering indicator credibility assignments following the workshop.

	Category				
	I	U	R	F	P
Winter-run Chinook		H	H	H	H
Spring-run Chinook		M	H	H	M/H
Fall-run Chinook		H	H	H	H
Late-fall-run Chinook		M	H	H	M/H
Steelhead		H	H	H	H

Excel Reports

An example of the Version 2 Excel report for Redd Dewatering is shown in Figure 4.19. The amount of dewatering in a specific reach and year can be compared with the historical range of redd dewatering by comparing the purple cumulative PM line to the vertical R/Y/G bar on the right of each graph. The vertical R/Y/G bar shows the distribution of annual rollup values across all years and reaches. The daily distribution is shown by the horizontal R/Y/G bar at the top of each pane.

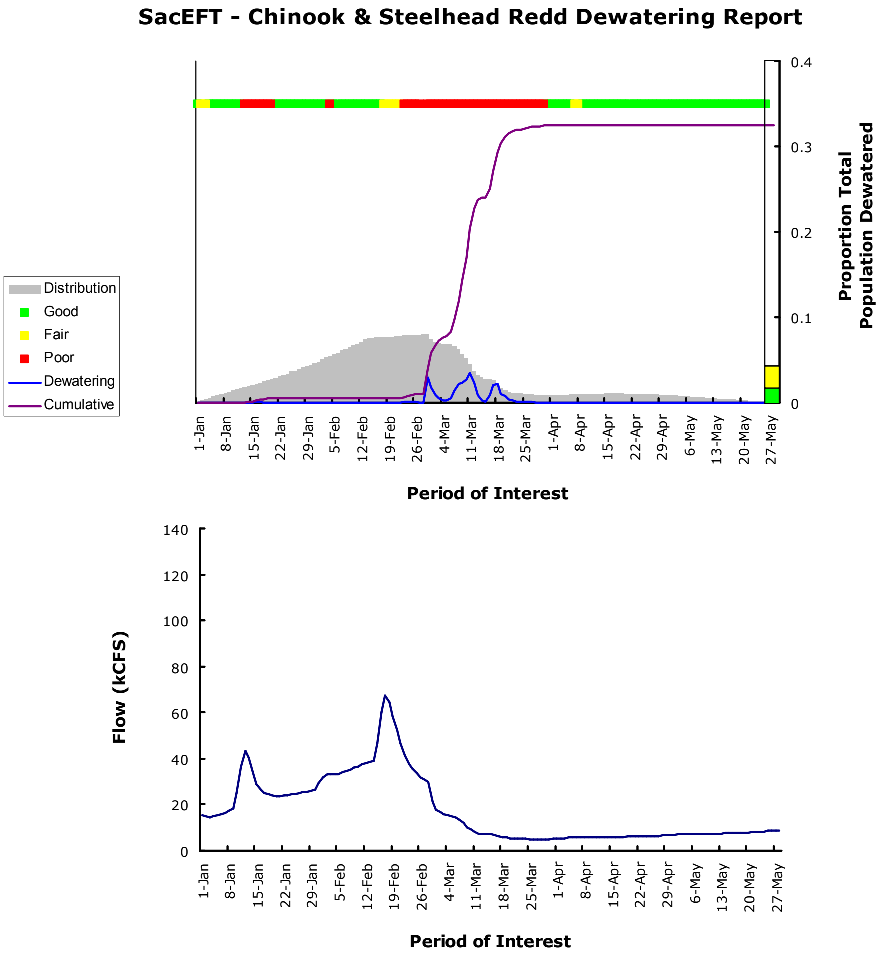


Figure 4.19. Excel Report for CS6 – Redd dewatering showing late-fall-run Chinook in Reach 4 for 1980. The index is sensitive to declining changes in flow. The upper horizontal bar shows the index R/Y/G score relative to the daily scoring across all reaches and years; the vertical horizontal R/Y/G shows the cumulative distribution of the reach and year relative to the annual rollup distribution. The impact of dewatering upon the egg distribution can be seen in the decline of the bell-shaped gray distribution that accompanies drops in flow and the sharp pulse of high dewatering index.

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for Redd Dewatering are shown in Table 4.19. The indicator and its rating calibration are treated as dimensionless index, although technically it is a sum of proportional changes in spawning area. The breakpoints for the *Daily Indicator* rating for each run-type are based on the estimated daily proportional change in WUA spawning area over all reaches over all days of the egg development period, over all years. Redd dewatering is similar in some ways to juvenile stranding, but because eggs remain fixed in the spawning redd and are not mobile, the details of the calculation of cumulative dewatering differ slightly from the calculation of juvenile stranding (CS4). Each simulation day's observation is weighted by the proportion of the total egg population present in each day-cohort, meaning that days with more developing eggs present are given more importance, with longer spawning periods and development times also contributing to the magnitude of the indicator. Typically, several thousand simulation observations contribute to this sorted daily distribution. The primary *Rollup Indicator* rating is also a dimensionless index correlated with mortality risk, and is based on calculating a *cumulative* daily value for each reach, over the egg development period for each simulation year, and then taking the average value over all the reaches to produce an annual average value. The practice of using a cumulative total for this indicator leads to much larger indicator values for the Rollup, and there are typically a few dozen simulated observations for the distribution of this indicator; one for each simulation year.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance. However, our repeated survey efforts of fisheries experts (e.g., Mark Gard, USFWS, *pers. comm.*; Matt Brown, USFWS, *pers. comm.*) and a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for Redd Dewatering. Because of this gap and the hesitancy of experts to reveal their opinions, we instead calculated the sorted distribution of weighted annual results and selected terciles (the lower-, middle- and upper thirds of the sorted distribution) as an initial reference to categorize the results.

Within run-types, the lower and upper rollup thresholds differ by about a factor of two (*e.g.,* 0.05 and 0.09 for the fall-run Chinook rollup). These differences are due to differences in the flow regime and number of reaches for each run-type. But comparison across run-types shows that there is about a five-fold range among the breakpoints of the five run-types. Comparison across run-types shows an obvious limitation of the statistical approach to creating threshold boundaries. For example, the Good/Fair rollup boundary for winter-run Chinook is about 15% that of steelhead: 0.015 compared to 0.10.

Since the Redd Dewatering indicator is an index that should be highly correlated with potential egg loss, it might be more sensible to establish indicator rating thresholds that are mortality-like and not distributional. Reasonable choices for such boundaries remain an open question, however. Although the distributional method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant. In the last column of Table 4.19 we attempt to flag cases where there are major gradients in performance indicator thresholds.

Table 4.19. CS6 – Redd dewatering indicator rating breakpoints. Units are population-proportion-weighted redd dewatering index for Daily resolution; cumulative for the Annual and Rollup scales

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Winter-run Chinook	3.976E-06	4.042E-05	0.02	0.03	• Criteria: statistical distribution, terciles, “less” is better • Daily units: proportion stranded • Rollup units: cumulative proportion stranded • Flow, spawning period, habitat preferences, affect distribution • *Very low risk for winter-run* • *Higher sensitivity for Late-fall run Chinook*
Spring-run Chinook	6.184E-05	7.333E-04	0.07	0.13	
Fall-run Chinook	1.597E-05	1.910E-04	0.05	0.09	
Late-fall-run Chinook	1.336E-05	1.846E-04	0.12	0.22	
Steelhead	1.181E-05	1.428E-04	0.10	0.17	

4.3.2 Green sturgeon

The salmonid conceptual model is shown in Figure 4.20. Readers are referred to ESSA Technologies Ltd. (2005) for details on the development of this model and the decisions that led to its current structure.

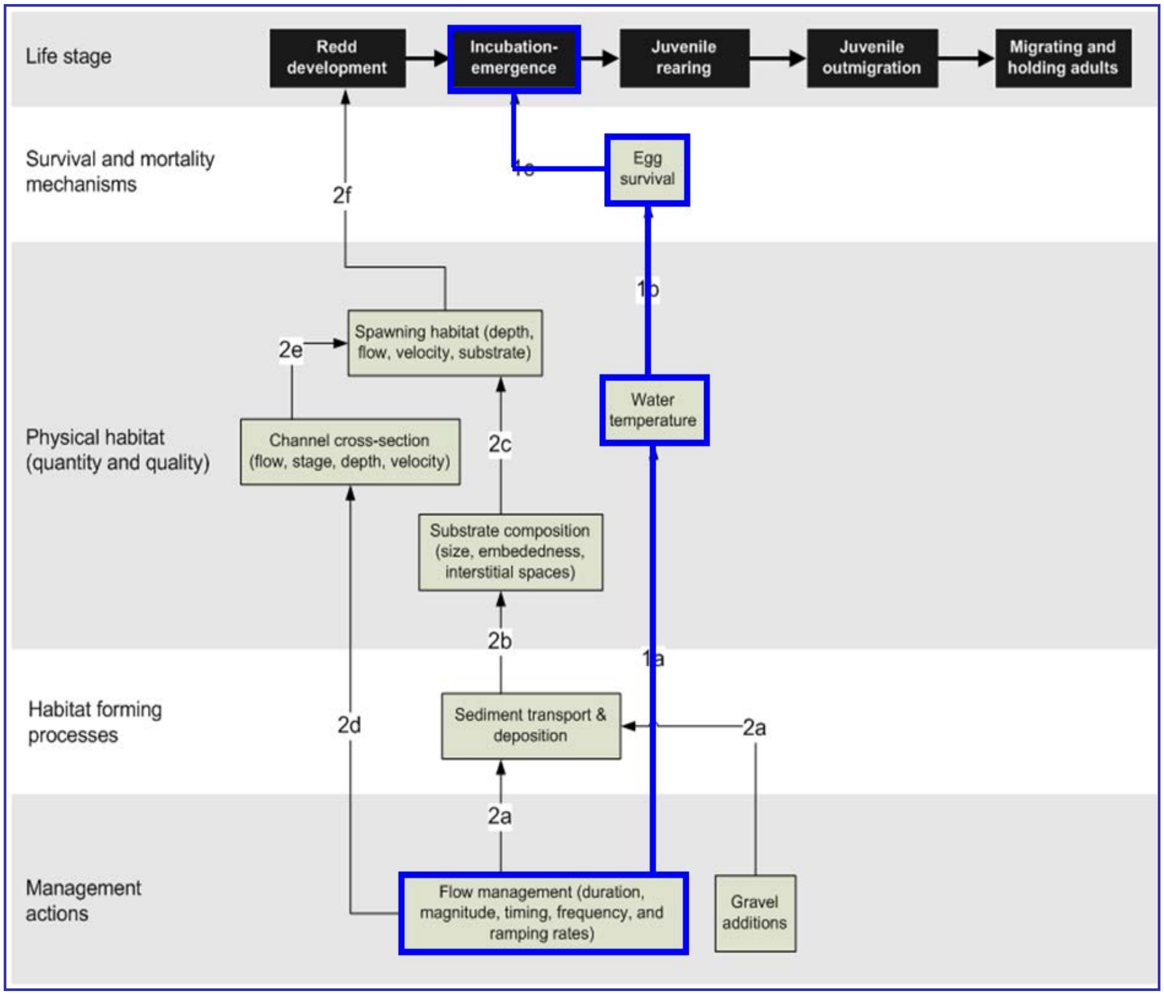


Figure 4.20. The green sturgeon conceptual model. Heavy lines show the processes and linkages that are currently implemented. See ESSA Technologies Ltd. (2005) for additional context and detail on processes and linkages shown here.

The impact of water temperature on green sturgeon eggs is modeled using daily changes in temperature over the egg development period at each location. From the daily average temperature, estimates of exposure to the hazard of warm water are modeled using two temperature breakpoints: 17^0C and 20^0C, to mark temperature excursions into zones of moderate and high risk. Each day the model tracks spawned eggs over a fixed development period of 14 days, tracking each day-cohort separately. The simplicity of the model stems from the lack of information about temperature-based mortality and uses the categorical grouping created by Cech *et al.* (2000) to assign “healthy”, “moderate” and “lethal” outcomes. Other measures of green sturgeon life history (*e.g.*, flow-habitat; juvenile entrainment; fishing and poaching, discharge-migration cues) were found to be lacking in quantitative knowledge and therefore are not included in SacEFT v.2.00.

Following the model review workshop the habitat scoring rule was modified so that it approximates a temperature-mortality relationship with full survival below 17°C and complete mortality above 20°C, with linear interpolation between these two temperatures. Daily cohort survival above 95% is scored as Good for the year-cohort; survival between 90-95% is scored as Fair, and survival lower than 90% is ranked as 'Poor.' A recommendation that Vina be included as a third possible spawning location was deferred, since simulated temperature data below RBDD were not yet considered reliable.

The *annual* PM at each location is the most frequent outcome for each location, with each day's Indicator Rating contribution weighted by the spawning distribution weight (w_d) for the day.

The *rollup* PM is calculated by combining the daily PMs across all locations over the spawning and development period, with the contribution of each day's Indicator Rating weighted by the spawning distribution weight (w_d) for the day.

Indicator Reliability

The PM reliability rating for green sturgeon thermal egg mortality is shown in Table 4.20. The low ratings reflect the uncertain linkage between laboratory studies of egg maturation with field observations of larval development.

Table 4.20. GS1 – Green sturgeon indicator credibility assignments following the workshop.

	Category				
	I	**U**	**R**	**F**	**P**
GS1 – Thermal Egg Mortality		M	M	H	M

Excel Reports

The Excel Report for Green Sturgeon thermal egg mortality (GS1) follows the style of the style of the Salmonid thermal mortality (CS3) report, using a vertical bar to show the distribution of the annual rollup for the PM (Figure 4.21). The report shows two graphs: the upper panel shows the spawning distribution in gray, the incubation period mortality for each day-cohort and the cumulative population mortality across all cohorts. The lower graph shows daily temperatures and R and Y thresholds for daily mortality. The x-axes are identical and span the first day of spawning to the last date of emergence.

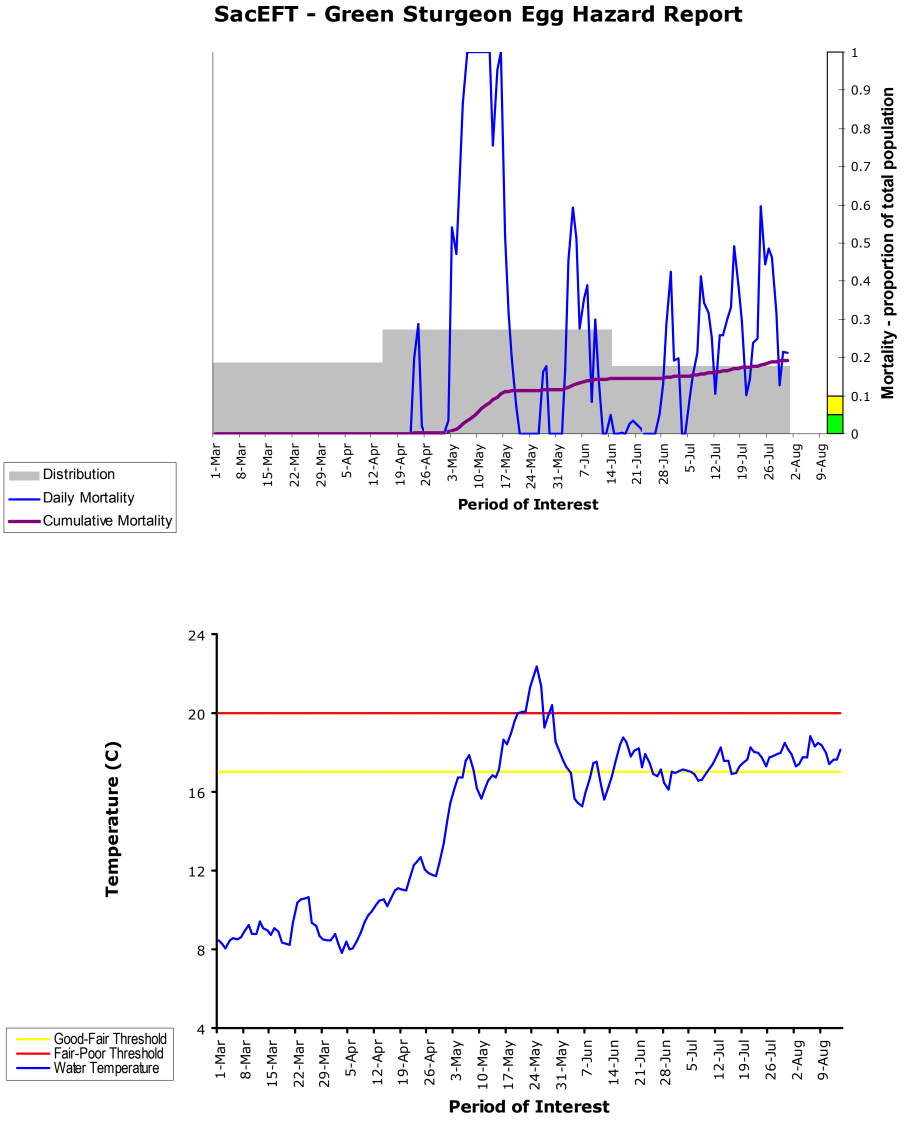


Figure 4.21. Excel Report for GS1 – Green sturgeon egg hazard for location GS1 (Hamilton City) in 1982. The vertical horizontal R/Y/G shows the cumulative mortality. The lower panel shows water temperature with the Good-Fair and Fair-Poor thresholds.

Indicator Threshold Calibration

Based on absolute mortality values of 5% and 10%, the Indicator Rating boundaries for thermal egg mortality are shown in Table 4.21. The same units and values are used for *Daily* and *Rollup* indicator ratings. The rationale for this choice of indicator at all scales is that it has an unambiguous meaning, in contrast to other indicators which are either more abstract, or are unit-free indices. Readers should note that 5% mortality at the Daily indicator scale means that 5% of the eggs spawned on that day and location will die because of elevated temperature over their 14 day development period. At the Rollup level, the same number means that 5% of the entire multi-reach population of eggs will die in that year, due to elevated temperature.

The *Daily* indicator is calculated by accumulating thermal mortality over the 14 day egg-development period, which is determined by spawning day and water temperature. The *Rollup* indicator has the same units as the Daily rating, goes one step further and calculates an annual average across all reaches, for all simulation years, using the equal weighting for all locations to calculate a weighted average. There are typically a few dozen simulated observations for the distribution of this indicator.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years and run-types with Good or Poor performance, or to include robust studies of temperature-based mortality. Our efforts of survey fisheries experts through a questionnaire sent to fisheries biologists prior to the 2008 SacEFT Version 1 review workshop, revealed that there were no known synoptic studies of this kind for green sturgeon thermal mortality. Neither are there universally accepted field mortality levels – conceptually similar to LD_{50} values for pollutants – for measuring the impact of thermal mortality. The best information we were able to use is based on *in vitro* studies (Cech *et al.* 2000) of larval development, which we adapted to create a quasi-mortality model in which larvae experience no mortality at temperatures below 17°C and complete mortality at temperatures at and above 20°C. Added to this simple model and the hesitancy of experts to reveal their opinions, we instead chose arbitrary mortality breakpoints of 5% and 10% as initial reference points to categorize the results.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant. In the last column of Table 4.13 we attempt to flag cases where there are major gradients in performance indicator thresholds.

Table 4.21. GS1 – Thermal egg mortality indicator rating breakpoints. Units are % Mortality and are intentionally held constant across all temporal scales. Annual and Rollup scales incorporate population-proportion weights.

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Thermal Egg Mortality	5	10	5	10	• Criteria: absolute values, "less" is better • Units: % mortality

4.3.3 Bank swallow

The bank swallow conceptual model is shown in Figure 4.22 . Readers are referred to ESSA Technologies Ltd. (2005) for details on the development of this model and the decisions that led to its current structure.

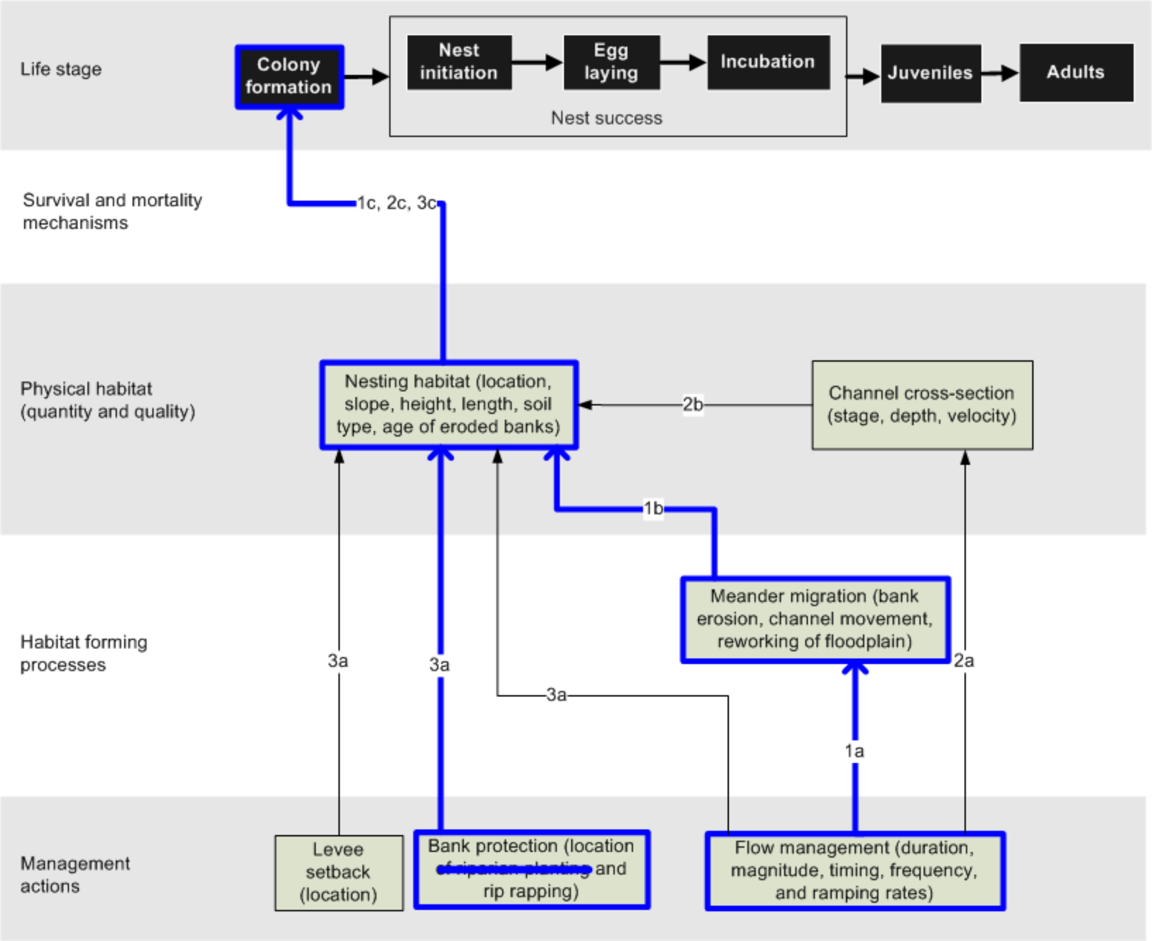


Figure 4.22. The bank swallow conceptual model. Blue heavy lines show the processes and linkages that are currently implemented.

SacEFT includes two performance measures (PMs) that describe changes in the physical habitat available for bank swallow nesting success. Prime bank swallow nesting habitat is limited to friable soils in vertical bank faces (Garrison 1998a, 1999). These bank and soil characteristics render nesting habitat susceptible to collapse when undercut by the river during high flows. Minor bank sloughing can degrade habitat quality by reducing bank slope and creating debris piles below nesting sites. Erosive processes such as lateral river migration are therefore periodically necessary in order to create new nesting habitat with steep slopes and fresh surfaces for new nests (Garrison 1999). Two performance measures describe changes in the physical habitats available for bank swallow. The first of these (BASW1) provides an annual estimate of the weighted useable length of newly eroded bank for nesting. The second of these provides daily estimates of the potential for bank sloughing during the nesting period, with high flows creating a high potential for bank failure (BASW2).

The models used to generate BASW1 and BASW2 are based on Garrison's (1989) habitat suitability index (HSI) model and refinements proposed by Stillwater Sciences (SWS) in its Sacramento River

Linkages Report (Stillwater Sciences 2007). Of the four variables identified in Garrison's model – soil texture, bank slope, bank height, and bank length – and the additional four variables identified by Stillwater Sciences (2007) – distance to nearest grassland, bank age, peak flow during nesting period, and stage increase above base flow during the nesting period – only **newly eroded bank length** and **peak flow during nesting** were available for incorporation into SacEFT v.2.00, and are the key components of the BASW1 and BASW2 performance measures.

Although they reflect the best available information at SacEFT's spatial scale, it is clear that these two PMs are a very simplified picture of the factors affecting the quality and quantity of bank swallow habitat. For example, because the model has no memory of flow over time, the BASW2 indicator is not able to capture the possible cumulative effects of changes in discharge, nor the role of bank height in predicting bank sloughing.

BASW1 – BANK SWALLOW HABITAT POTENTIAL/SUITABILITY

Based on previous studies (*e.g.*, references cited in Stillwater Sciences 2007), the functional relationship for Bank Swallow habitat potential is based on three factors:

1. the length of bank erosion;
2. time since a major erosion event (defined as horizontal erosion ≥1m); and
3. the length of this erosion that is in soils of suitable type.

Based on feedback from the Bank Swallow Technical Advisory Committee[1] regarding the observation of bank length of less than 10 m being important habitat, it was decided to model only the second and third factors. Consequently, a weighted useable length (WUL, measured in meters) – or habitat potential – is calculated for each bank segment based on two weighting factors: years since last major erosion event (w_e) and soil suitability (w_s):

$$WUL_b = w_e \times w_s \times L_b$$

A conceptual example for the BASW1 Habitat Potential indicator is shown in Figure 4.23.

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[1] February 2011 review presentation

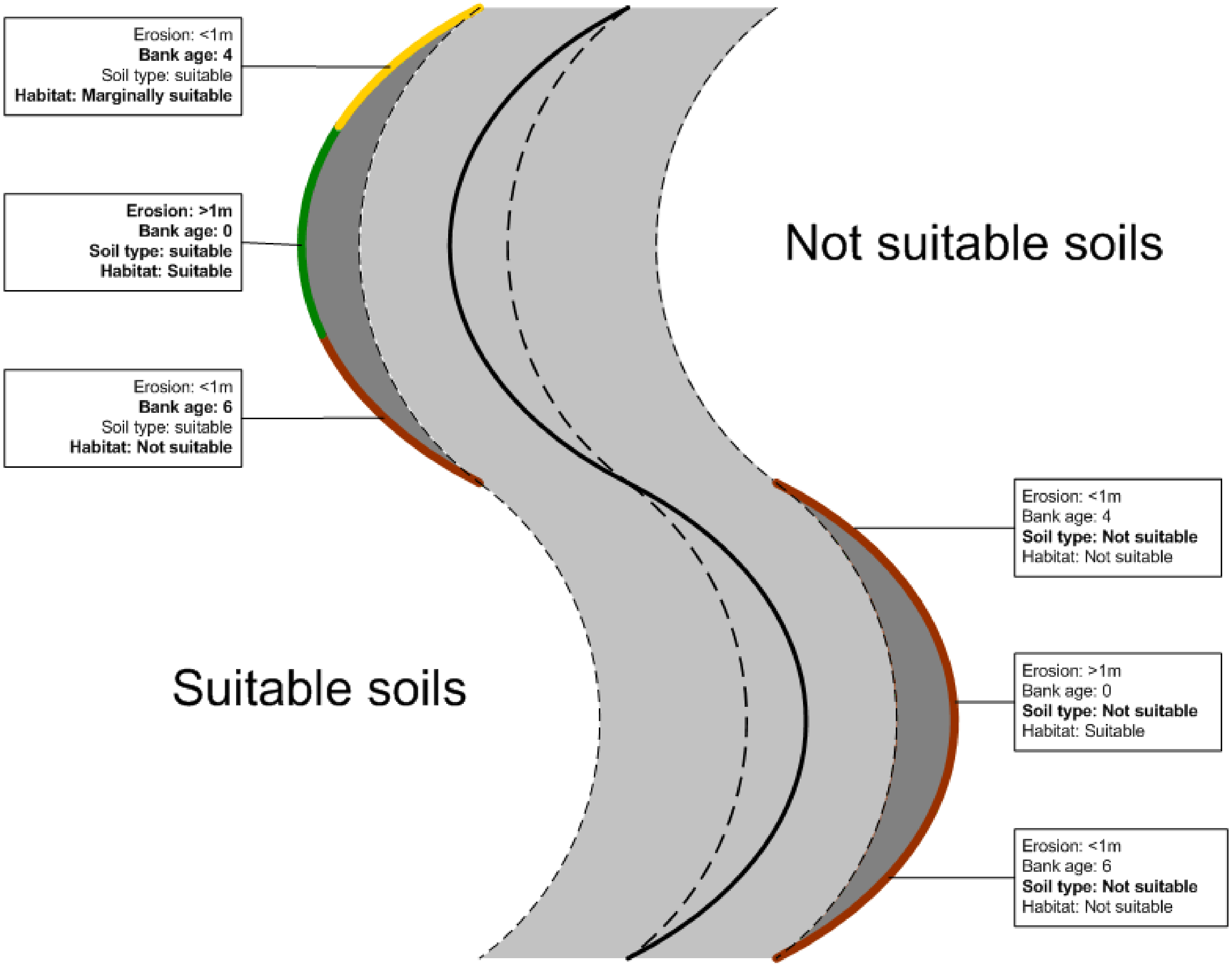


Figure 4.23. Conceptual example for the BASW1 Habitat Potential (or WUL) indicator. Note that all banks on the right hand side are not suitable because of soils, whereas the bank of the left hand side illustrates the effect of different bank ages. See text for details.

Biophysically, the need for periodic renewal of nesting habitat is dictated by the progressive decline in burrow quality due to erosion that reduces bank slopes (and thus provides easier access for predators) and infestation by fleas and other nest ectoparasites. Most of the colonies in the Sacramento valley are used for no more than 7 consecutive years in the absence of a major erosion event (see Stillwater Sciences 2007). After three years, habitat suitability drops rapidly because of high levels of ectoparasites and little room for new nests (Stillwater Sciences 2007). Recent research (Heneberg 2009) suggests that bank swallows will also abandon soils that become too hard to penetrate due to increased soil compactness with age.

The desired frequency of horizontal erosive events ≥1m for habitat renewal is about once every 3 years (*i.e.*, it does not need to occur annually). The SacEFT *BASW1* habitat potential indicator also takes into consideration that burrows can be reused for up to 3 years without significant renewal taking place. Additionally, the model is capable of accounting for cumulative erosion events over multiple years. Based on discussions at the SacEFT refinements workshop (ESSA Technologies Ltd. 2008a), the functional relationship for habitat potential in response to depth of horizontal erosion is a linear decay function where newly eroded banks (*i.e.,* horizontal erosion ≥ 1m) receive a habitat suitability index of 1. Habitat potential declines linearly each year until year 3, after which habitat potential/suitability is zero for those bank areas that have not experienced a major erosion event (see Figure 4.24).

A major erosion event is defined as a horizontal erosion depth ≥1m. Erosion less than 1m deep is considered contributing to reduced bank slopes by bank sloughing. The time since last major erosion event ($t_{erosion}$) is defined as the number of years since the bank was eroded to a depth of at least 1m within a single year.

The weighting scheme for the time component reflects habitat degradation in the absence of a major erosion event:

$$w_e = \begin{cases} 1 \quad when\ (t_{erosion} < 3 years) \\ 1 - \dfrac{t_{erosion} - 3}{2} \quad when\ (3 years \le t_{erosion} < 5 years) \\ 0 \quad when\ (t_{erosion} \ge 5 years) \end{cases}$$

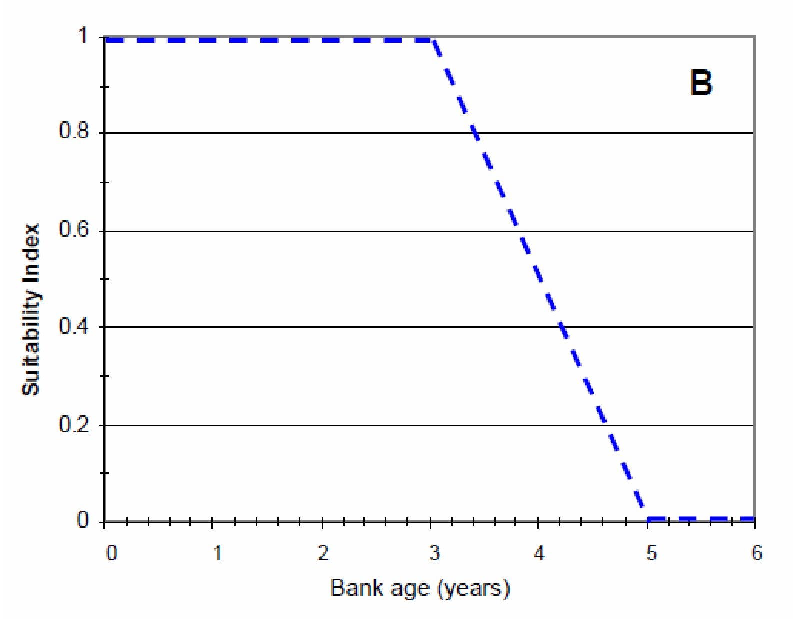


Figure 4.24. Habitat Potential vs. bank age (time since last major bank erosion event). Habitat decreases rapidly after 3 years because of ectoparasites. Most of the colonies in the Sacramento valley are used for no more than 7 consecutive years in the absence of erosion (see Stillwater Sciences 2007).

The bank age ($t_{erosion}$) is calculated based on the location of the current and the previous year's banks as simulated by the bank erosion model (see Section 4.1.6). Any bank segments that are more than 1m away from the previous year's banks are considered renewed in the current year and are assigned a bank age of zero. If the bank segment has not been renewed, the bank age is calculated as the age of the nearest banks from the previous year plus one year (see Figure 4.25 for an example).

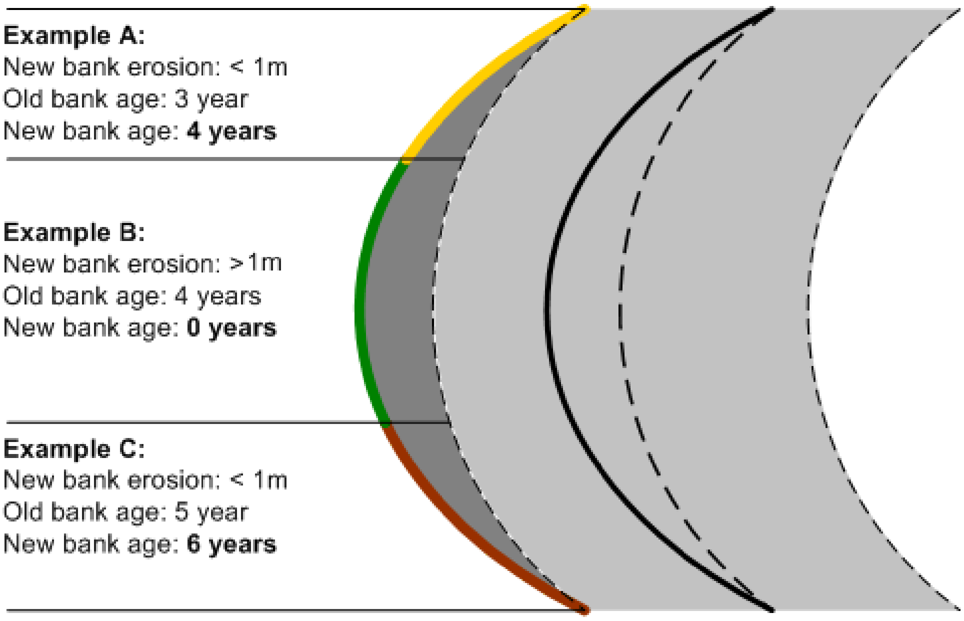


Figure 4.25. Bank age example. If the bank segment has been eroded more than 1m, the new bank age is always 0, see 'B'. If the bank segment has not been eroded this year, the new bank age is calculated as age of the nearest old bank + 1 year, see 'A' and 'C'. Note that the new bank segment in 'A' is now considered marginal habitat according to the weighting scheme, whereas the bank segment in 'C' is no longer suitable.

Not all soils are suitable for bank swallow burrows. Bank swallows prefer banks with soft sand or sandy loam soil (Garrison 1999**).** Furthermore, recent fieldwork has indicated that Bank swallows may also utilize the local vertical bank stratification to select favorable burrow location, *e.g.,* Bank swallows have been found in the field to burrow into coarse soils between lenses of silt that then function as the 'roof' and 'ceiling' of the burrow (Dean Burkett, Natural Resources Conservation Service, *pers. comm.* 2011). SacEFT's BASW1 soil suitability component is based on SSURGO soil data (Natural Resources Conservation Service 2011). The soils were divided into 4 categories based on the dominant soils near the Sacramento River: Gianella loams, Columbia loam, Riverwash and other soils. Based on communication with Dean Burkett, highlighting some of the limitations in the resolution of SSURGO soil data, it was decided that it is not currently possible to assign different weights to these four soil types with the current data, and it would be preferable to consider only 2 classes: suitable ($w_s = 1$) and unsuitable ($w_{est} = 0$). Based on field observations, Columbia Loam and Gianella Loams are considered suitable ($w_{Columbia,}$ $w_{Gianella} = 1$) and riverwash and other soils are considered unsuitable ($w_{Riverwash}$, $w_{Others} = 0$). We recognize that soil data give only a snapshot in time, *i.e.,* they represent the river banks in a single year, whereas the bank observations cover almost a decade, during which the river banks have moved.

The length of bank in each soil type is determined in a GIS by overlying the bank locations simulation by the bank erosion model with the soil data (see Figure 4.26).

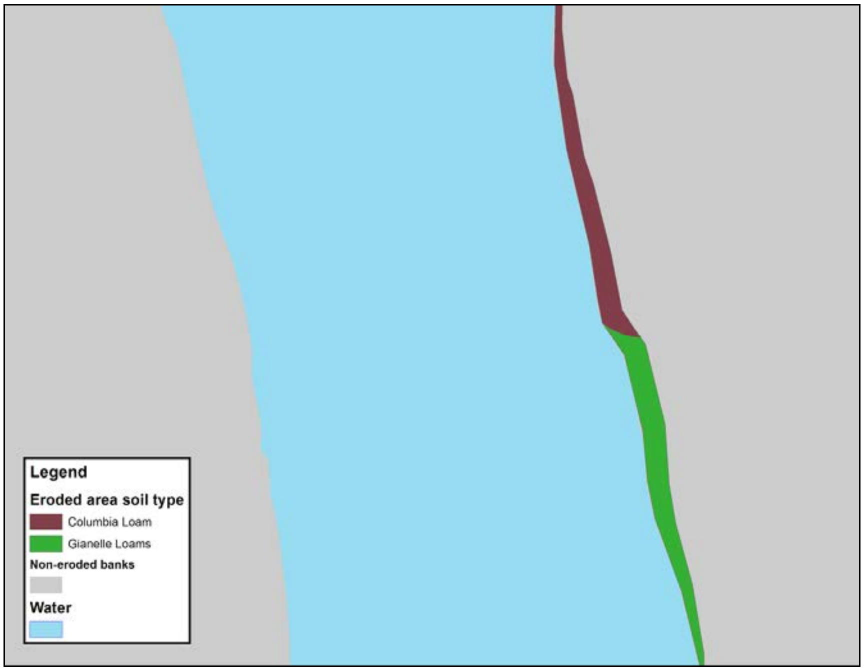


Figure 4.26. Conceptual example of eroded bank area divided into soil types.

The *annual* PM for BASW1 sums the weighted length of eroded bank across all river segments (***S***) and bends (***B***).

$$BASW1=\sum_{i=1}^{S}\sum_{b=1}^{B}w_e\times w_s\times L_b$$

The *rollup* PM is based on the terciles of total length taken from a historical run with no bank revetment. These terciles determine set the thresholds for performance of BASW1 in any given year (*i.e.*, assignment of R/Y/G to BASW1).

Indicator Reliability

The indicator credibility rankings for BASW1 are shown in Table 4.22.

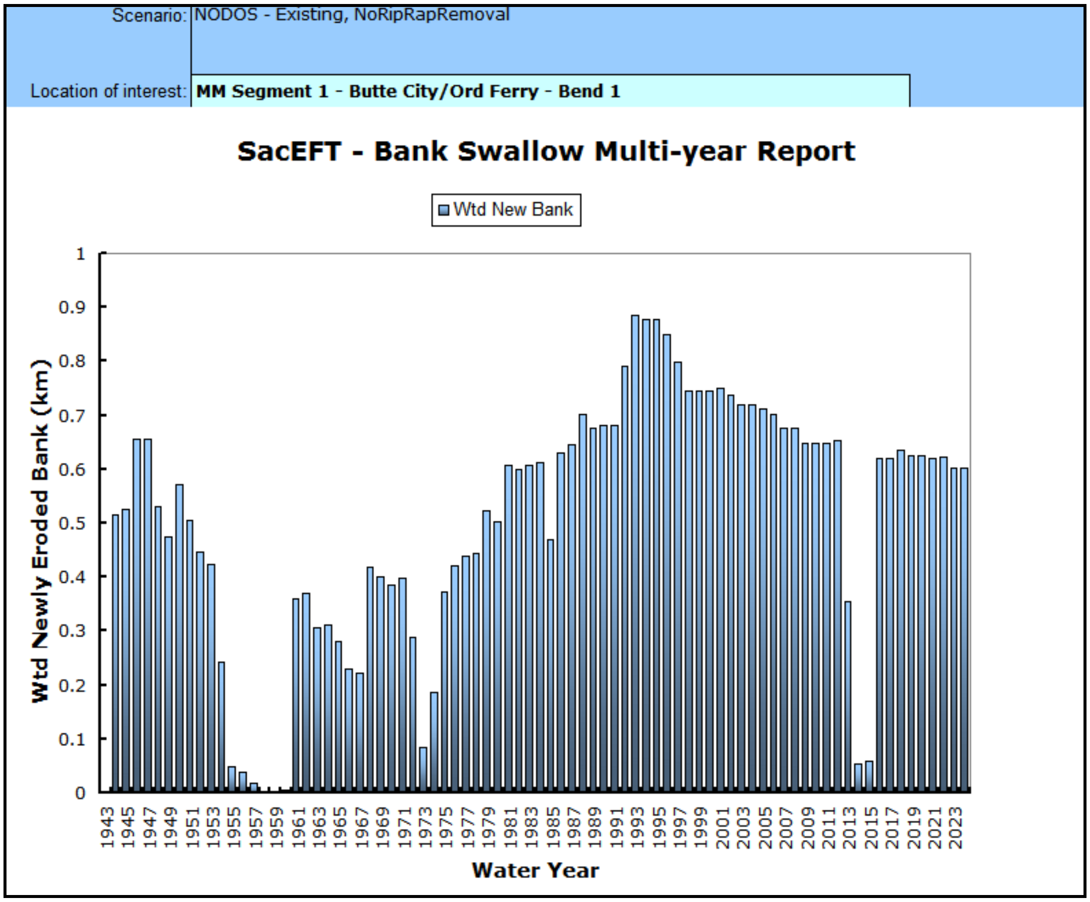
Table 4.22. BASW1 – Habitat Potential/Suitability - indicator credibility assignments following the workshop. These ratings apply to those reaches of the Sacramento River where it is possible to have estimates of floodplain area reworked from the Meander Migration Model.

	Category				
	I	U	R	F	P
BASW1 – Habitat potential/suitability	H	H	H	M	H

BASW1 received a score of Medium for feasibility because the performance measure only captures some of the important characteristics with respect to nest habitat suitability.

Excel Reports

An example of an Excel report for BASW1 is shown in Figure 4.27. The habitat potential (weighted useable length (WUL)) for each year in a specific location is shown in kilometers.



Scenario: NODOS - Existing, NoRipRapRemoval

Location of interest: **MM Segment 1 - Butte City/Ord Ferry - Bend 1**

Figure 4.27. An example of an Excel report for BASW1 – Habitat potential/Suitability. This example shows the Weighted Useable Length (WUL; km)) for each year for Bend 1 in the Butte City/Ord Ferry segment.

Indicator Threshold Calibration

To calibrate the BASW1 indicator, we used empirically measured historical flow data with no rip-rap removal. Annual BASW1 weighted useable length was summed across all locations for each year and the PM values sorted from largest to smallest. Discontinuities (and not exact terciles) of the sorted values were used to establish the roll-up Hazard Threshold boundaries (see Figure 4.28 and Table 4.23).

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years with Good or Poor performance. It is possible that Bank Swallow Experts can create a list of years with Good or Poor performance based on field surveys of bank swallow burrows, including abandoned burrows. However, at the time of this report, we are not aware of a suitable processed dataset.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are “better” than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as “Good” (Green) with this method may still be biologically suboptimal. Conversely, a year that ranks as “Poor” (Red) may be biologically insignificant.

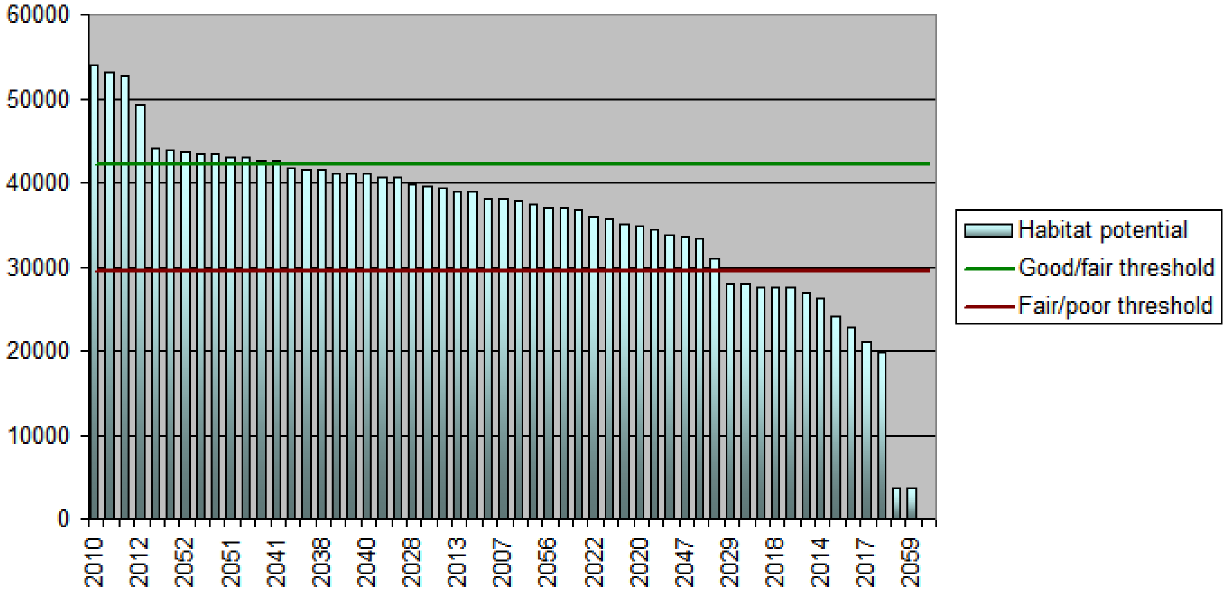


Figure 4.28. Calibration results for BASW1. Bars are the sorted total weighted length of newly eroded bank for each year of the Historical simulation.

Table 4.23. BASW1 – Length of newly eroded bank indicator rating breakpoints. Units are weighted useable length (WUL) in meters.

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Habitat potential	N/A	N/A	42200	29500	• Criteria: statistical distribution using discontinuities, “more” is better • Units: meters suitable habitat • No daily estimate

BASW2 – PEAK FLOW DURING NESTING PERIOD

High flows during nesting have the potential to adversely affect bank swallow colonies through two mechanisms: inundation of nests and bank sloughing/collapse (Garrison 1998b; Moffatt *et al.* 2005). The exact magnitude of flow required to initiate bank sloughing is not definitively known. However, growing evidence suggests that flows in the range of 20,000 cfs to 50,000 cfs will typically erode some banks, causing partial collapse. Flows above 50,000 cfs are more than likely to cause widespread erosion leading to widespread colony failure at many sites if breeding swallows are present (Stillwater Sciences 2007).

During the SacEFT refinements workshop we were informed that about half of all nest burrows are located in the upper one quarter of the bank. Hence, the flow that is observed to reach this point should be the natural flow threshold for high risk. Informal observations at Hamilton City suggest that all nests at that location that are ≤ 3m above a stage of 130.19 feet (flow of 7,250 cfs)[1] would be inundated at 50,000 cfs, which corresponds to a stage of about 139 feet. Extrapolating the Hamilton city rating curve to the larger area between Red Bluff and Colusa, approximately 50% of nests are ≤ 3m above stage (130.19 feet), and would consequently be at least partially inundated at 50,000 cfs. This is likely a conservative estimate because the rating curve at Hamilton City is steeper than at most nesting sites. The specifics of the stage-discharge relationship for other bank swallow nesting sites are still unavailable. Consequently, the current value of 50,000 cfs appears to be a reasonable threshold.

The impact of peak flow during the nesting period is calculated using daily average flow (*Q)* coupled to estimates of exposure to the hazard of bank-sloughing flows in three river segments (see Table 2.4) during the April 15 to July 31 (Table 2.7) nesting period (ESSA Technologies Ltd. 2008a). Hazard is modeled using two flow breakpoints: 20,000 cfs and 50,000 cfs, to provide estimates of risk during flow excursions into zones of moderate and high flow, respectively.

The *daily* performance measure is calculated by an indicator that assigns an influence to the day's flow at each location, based on the breakpoint values:

$$BASW2=\begin{cases}1 \quad when\ (Q<20kCFS)\\ 1-\left(\dfrac{Q-20}{30}\right) \quad when\ (20kCFS\le Q<50kCFS)\\ 0 \quad when\ (Q\ge 50kCFS)\end{cases}$$

The R/Y/G Indicator Ratings for BASW2 are based on a heuristic developed from the distribution of the BASW2 indicator, using a historical flow scenario across all river locations. Based on the flow thresholds, ***Q*** < 20,000 cfs is considered low risk and receives a score of 1, whereas ***Q*** ≥ 50,000 cfs is considered high risk and receives a score of 0. BASW2 is calculated at three locations along the river. Because of the fast ramping of flooding flows during the nesting period, days assigned a Yellow Indicator rating are infrequent.

Indicator Reliability

The indicator credibility rankings for BASW2 are shown in Table 4.24.

Table 4.24. BASW2 – Peak flow during nesting period - indicator credibility assignments following the workshop. These ratings apply to those reaches of the Sacramento River where it is possible to have estimates of floodplain area reworked from the Meander Migration Model.

	Category				
	I	**U**	**R**	**F**	**P**
BASW2 – Peak flow during nesting periods	H	M	M	M	H

With respect to understanding and rigor, BASW2 receives a score of Medium. Although there is strong evidence to support the flow threshold values for moderate and high risk, there remains some uncertainty around the exact magnitude of flow required to initiate substantial bank erosion, and hence bank collapse during nesting periods. Feasibility receives a score of Medium because the input data required to create more representative flow thresholds for high risk are not currently available.

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[1] A rating table for Sacramento at Hamilton City showing the relationship between flow and stage is available at: http://cdec.water.ca.gov/rtables/HMC1.html.

Excel reports

The Version 2 Excel report is shown in Figure 4.29 using a vertical bar to show the annual rollup for the PM.

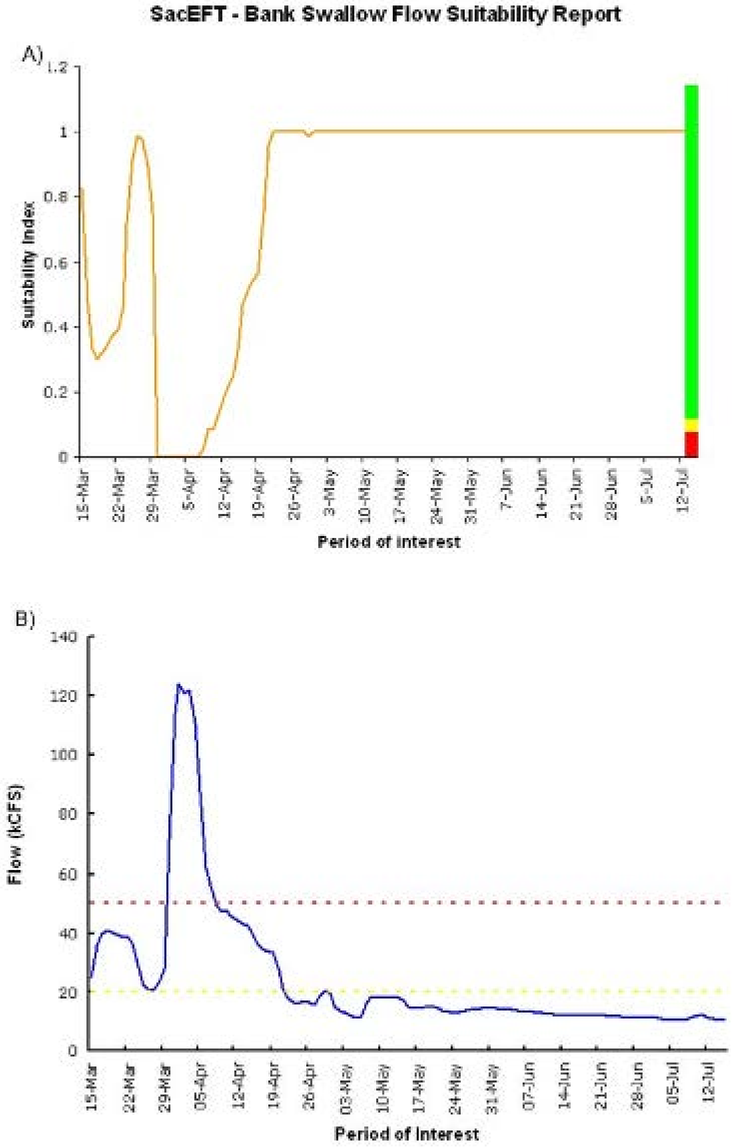

Figure 4.29 A) Daily roll up for BASW2 during the nesting period (April 15 to July 31). A suitability index score ≥ 0.1 is ranked as Good. A suitability score between 0.01 and 0.1 is ranked as Fair, and a suitability score ≤ 0.01 is ranked as Poor. B) Maximum daily flow during the nesting period. Flows ≥ 50,000 cfs (red dashed line) are automatically assigned a suitability index of 0 (Poor). Flows < 20,000 cfs are automatically assigned a suitability index of 1 (Good).

Indicator Threshold Calibration

Based on model behavior using historical flow and temperature, the indicator rating thresholds for peak flow during nesting period are shown in Table 4.25. *Daily* suitability indices of BASW2 are assigned based on a heuristic developed from the historical distribution of the BASW2 indicator across all river locations:

$$BASW2 \quad suitability \quad index = \begin{cases} green \quad when\ (BASW2 \geq 0.1;[Q \leq 20kcfs]) \\ yellow \quad when\ (BASW2 > 0.01;[20kcfs < Q < 50kcfs]) \\ red \quad when\ (BASW2 \leq 0.01;[Q \geq 50kcfs]) \end{cases}$$

The *Rollup* PM for BASW2 is based on a similar heuristic that aggregates the annual PM across all locations based on peak flow during nesting. Using the same flow thresholds as the daily indicator, peak flow is used to assign an annual value for each nesting location. The rollup indicator is assigned a Good rating if 2 or more locations have a Good indicator rating for the year. The annual rollup is assigned a Poor rating if no locations are ranked as Good.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years with Good or Poor performance. It is possible that Bank Swallow Experts can create a list of years with Good or Poor performance based on field surveys of inundated bank swallow burrows, however at the time of this report, we are not aware of a suitable processed dataset.

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others) and is based on discussions at the Version 1 review workshop, it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant.

Table 4.25. BASW2 – Peak flow during nesting. Units are flow (cfs), weighted 1 below 20,000 cfs and 0 above 50,000 cfs.

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Nesting Peak Flow	47000	49700	≥ 2	< 1 (zero)	• Criteria: flow thresholds based on expert opinion, "less" is better • Daily units: flow (cfs) • Rollup units: count of Good locations

4.3.4 Fremont cottonwood

The Fremont cottonwood conceptual model is shown in Figure 4.30. Readers are referred to ESSA Technologies Ltd. (2007) or details on the development of this model and the decisions that led to its current structure.

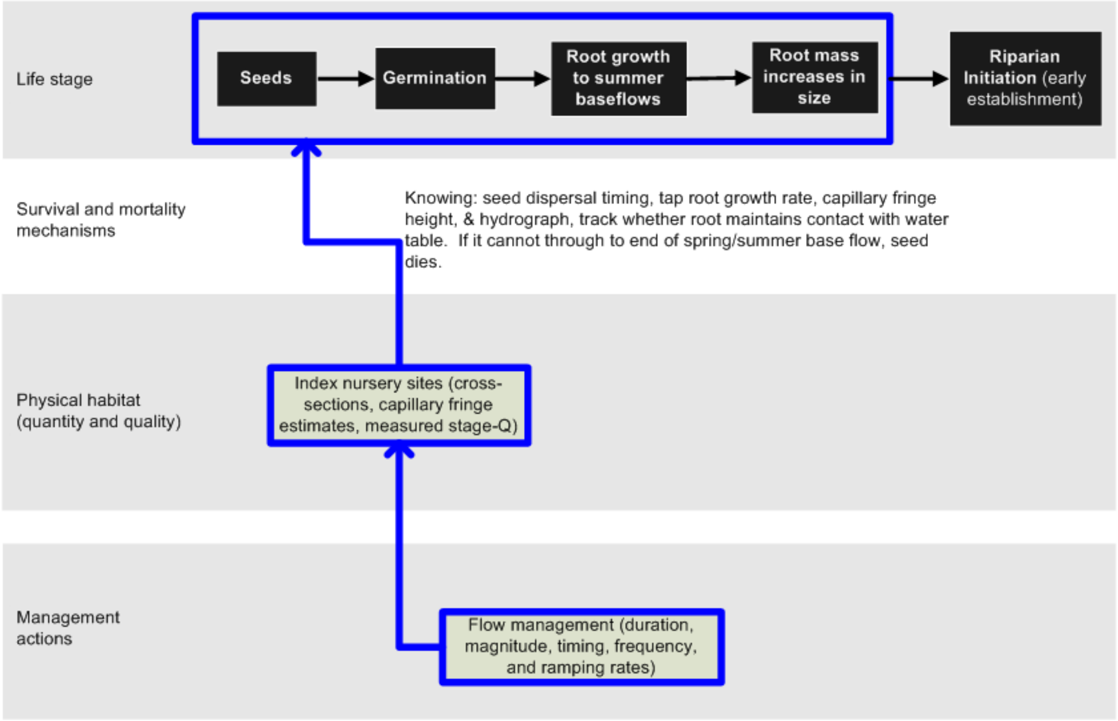

Figure 4.30 The Fremont cottonwood conceptual model. Blue heavy lines show the processes and linkages that are currently implemented.

SacEFT includes one performance measure (PM) that describes the potential for successful Fremont cottonwood initiation, along with a second performance measure designed to capture changes in the physical habitat that could negate successful initiation.

RIPARIAN INITIATION (FC1)

A single performance measure predicts the biological response of seedling Fremont cottonwood to changes in flow management at eleven (11) index locations along the Sacramento River. The FC1 indicator is based on Mahoney and Rood's (1998) recruitment box model, which predicts the success of riparian initiation as a function of changes in the timing of flows and water surface elevations. Important biological parameters, such as taproot growth rate, seed dispersal timing, capillary fringe, drought tolerance and viable root depths are also integrated. As summarized in Table 4.26, two field studies (Roberts *et al.* 2002; Roberts 2003) provide the bulk of the data necessary to apply this model to eleven index locations on the Sacramento River. These cross sections are located at RM159, 164, 165, 172, 183, 185.5, 192, 195.75, 199.75, 206 and 208.25.

Table 4.26. Data requirements for FC1 – a measure of successful riparian initiation.

Focal species performance measure	Required input	Data source
FC1	Daily average flow hydrograph	Hydrological data from historical discharge and USRDOM
	Stage-discharge relations	Roberts *et al.* 2002; Roberts 2003 (RM 192, 183, and 172); HEC-RAS
	Channel cross-sections	Roberts *et al.* 2002; Roberts 2003 (RM 192, 183, and 172); HEC-RAS
	Capillary fringe height = 30 cm	FC experts
	Seed dispersal timing (start and end) Apr-15 to 21-June	FC experts
	Seedling tap root growth rate = 22 mm/d	Roberts *et al.* 2002; Roberts 2003 (based on actual field observations)
	Drought tolerance = 5 days	FC experts
	Viable rooting depth = 50 cm	FC experts
	<u>Other assumptions:</u> Standard recruitment box model Sampled cross section nodes, if non-uniform, are representative of the overall cross-sectional characteristics. ▪ Drought tolerance of 5 days (roots can be out of contact with water table for 5 continuous days without being declared dead) ▪ Cottonwood seedlings whose roots reach a depth of 50 cm are assumed to be successful in reaching some type of ephemeral groundwater moisture sufficient to keep them alive through the remainder of their first year (based on dialogue with John Bair, McBain and Trush, *pers. comm.*). **Note**: all these assumptions are fully configurable in the SacEFT database.	

An adapted version of the TARGETS model (Alexander 2004) is used to determine whether cottonwood seedlings will successfully initiate at a given node along a cross section. Cottonwood seeds are released within a dispersal window (April 15 to June 21, as shown in Table 2.7). Seeds that land on non-inundated ground[1] begin to grow roots downward from the elevation at which they were deposited. While accounting for optional capillary fringe height along the cross section (*e.g.*, 30 cm), the rate of stage decline determines whether the cottonwood's root is able to maintain contact with the water table. As soon as the root depth is above the surface elevation + capillary fringe height, the seedling becomes non-viable (dies). Hence for successful initiation, the rate of stage decline cannot occur at a rate faster than the taproot growth rate (we use a taproot growth rate of 22 mm/day). Cottonwood seedlings whose roots

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[1] Seeds/seedlings that are submerged are not declared "dead" but instead the process of tap-root growth is suspended.

reach a depth of 50 cm are assumed to be successful in reaching some type of ephemeral groundwater moisture sufficient to keep them alive through the remainder of their first year. ***Note:*** All these assumptions are configurable in the SacEFT database.

The cottonwood performance measure tallies the number of initiation successes and failures across years and across the three cross-sections used in the model. Based on inspection of the all year results, counts of successfully initiating nodes are used to assign R/Y/G indicator ratings.

The **node concept** is important and sometimes confuses investigators interpreting the model's cross-section specific results (Figure 4.31). *SacEFT's riparian initiation model does not provide a count of surviving stems or seedlings. Rather, based on the inherent spatial resolution present for each cross-section dataset, every survey point (whether real or interpolated) is treated as/called a '"node". The model calculates whether a single seedling in the center of each of these "nodes" would or would not survive.* The node count of surviving seedlings is then used as an index of seedling initiation success (more being better). Any change in the number of cross sections evaluated or the resolution of existing cross-sections would result in requiring re-calibration of R/Y/G threshold cut-offs.

Indicator Reliability

The indicator credibility rankings for FC1 are shown in Table 4.27.

Table 4.27. FC1 – Riparian initiation - indicator credibility assignments following the workshop. These ratings apply to those point bars in the Sacramento River that have detailed stage-discharge relationships available.

	Category				
	I	**U**	**R**	**F**	**P**
FC1 – Riparian initiation	H	M	H	H	H

FC1 scores High with respect to rigor because the model is based on field observation data derived for the Sacramento River. Understanding is scored as Medium ("strong evidence but not conclusive, only medium strength predictive power, some evidence for competing hypotheses and/or confounding factors"). Riparian initiation is a site specific process, influenced by local factors such as substrate soil characteristics, presence of ephemeral water and other site specific factors that influence initial seed viability.

Excel reports

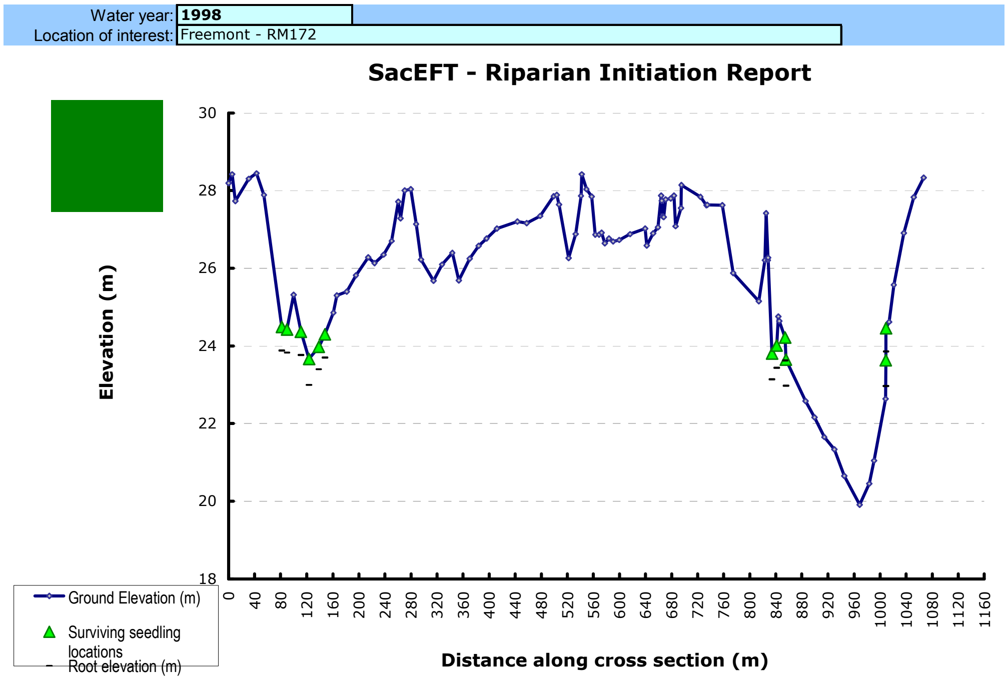
Water year: **1998**
Location of interest: Freemont - RM172

Figure 4.31: SacEFT Fremont Cottonwood seedling initiation success: 1998 (good year).

Indicator Threshold Calibration

The cottonwood performance measure tallies the number of initiation successes and failures across years and across the three cross-sections used in the model. Based on inspection of the all year results, counts of successfully initiating nodes are used to assign R/Y/G indicator ratings. SacEFT's riparian initiation model calculates whether a single seedling in the center of each of these "nodes" would or would not survive. **The node count of surviving seedlings** is then used as an index of seedling initiation success (more being better).

In making R/Y/G assignments for a particular water year, the value in the *ARollGoodCountAssignGood* field in the SacEFT database (*SummaryOut_PMThresholds* table) represents a count of cross-sectional nodes, **in the target zone for initiation** (*i.e.*, anything above 8,500 cfs elevation + 3ft), where surviving seedlings were found. At present, with the existing eleven cross-sections, the value 53 was found by visual inspection to represent "good" (*i.e.,* Green) initiation success, from historical flow data sorted descending (best to worst counts for each year) over the 66 year historical record. Likewise, *ARollGoodCountAssignBad* represents the equivalent information, defining the lower bound on successfully initiating nodes before the color Red is assigned (node count ≤ 36) (see Figure 4.32 and Table 4.28).

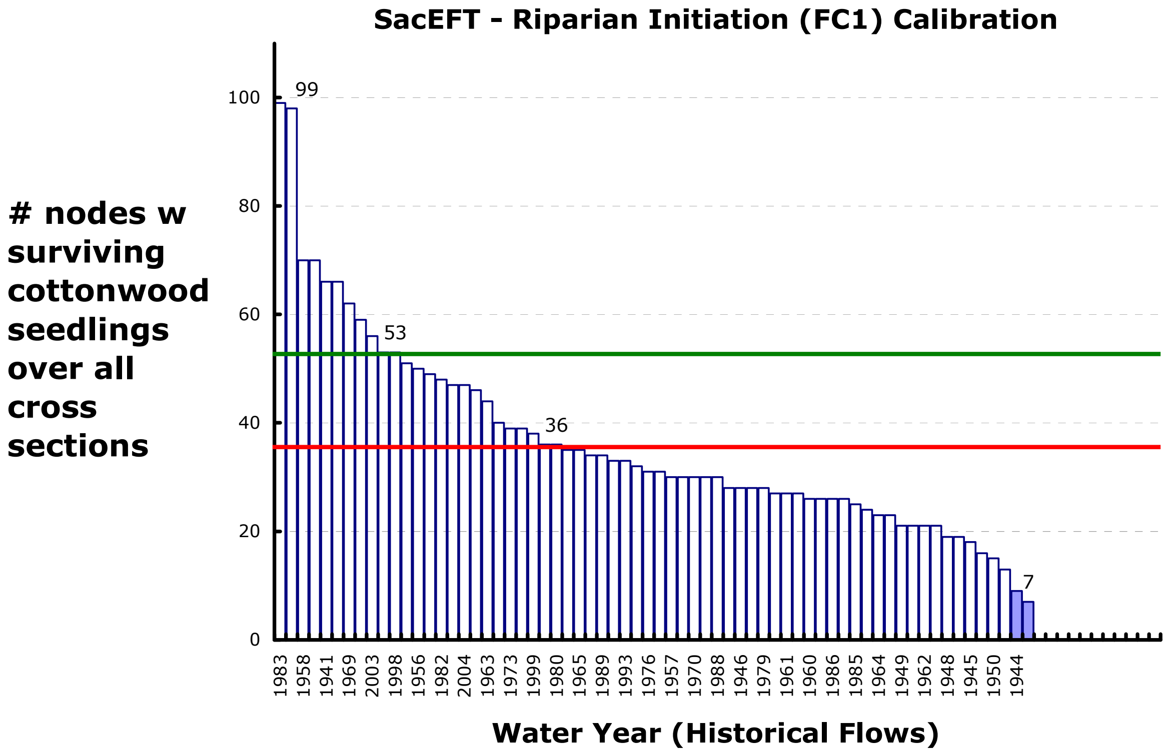

Figure 4.32: Annual roll-up results for the SacEFT Fremont cottonwood initiation (FC1) performance measure run using historic observed flows (1938–2003).

This indicator threshold calibration also takes into consideration comparisons with aerial photographs of historically strong Cottonwood recruitment at study sites vs. model results. At present, years revealed by SacEFT as having the potential for strong riparian initiation success are: 1941, 1952, 1952, 1958, 1967, 1969, 1971, 1975, 1983, 1997, 1999 and 2003 (historical data in SacEFT currently do not extend beyond 2004). However, after considering riparian scour potential (FC2), only **1958, 1967, 1971, 1975, 1999 and 2003** are predicted to show strong initiating cohorts of riparian seedlings (1941, 1952, 1969, 1983, 1997 predicted to suffer high risk of seedling scour following successful initiation).

Note: Any change in the number of cross sections evaluated or the resolution of existing cross-sections would result in requiring re-calibration of R/Y/G threshold cut-offs.

Table 4.28. FC1 – Riparian initiation success. Units are counts of successful initiation at the index nodes.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Riparian Initiation Success	N/A	N/A	53	36	• Criteria: thresholds based on expert opinion and observation of Good initiation years, "more" is better • Units: count of cross section nodes with surviving stems or seedlings. • No daily estimate

RIPARIAN SCOUR (FC2)

Based on recommendations from the SacEFT refinements workshop, a second performance measure has been included in SacEFT v.2 to capture the effects of scour events following riparian initiation. The rationale for including this second performance measure is that gains made after successful riparian initiation are moot if the seedlings are scoured out in the following year, *i.e.*, there is no point expending large volumes of water to achieve riparian initiation, and then wiping out these benefits in year t+1 with a scouring flow (Figure 4.33).

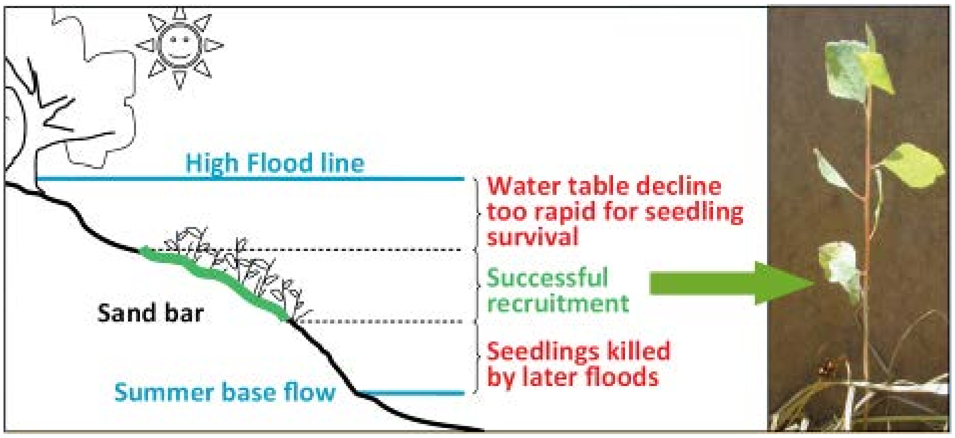

Figure 4.33. Generalized pattern of successful seedling initiation observed for cottonwoods along alluvial rivers. Seedlings that germinate too high on the bank cannot grow roots fast enough to keep up with the receding water table and soil moisture level during the hot summer months, while seedlings that initiate too low on the bank are removed by scour during high flow events during the subsequent winter or spring. Seedlings in the target initiation zone may also be scoured and killed by high flows. *Source*: Stillwater Sciences poster presentation, Calfed Science Conference (2008).

This performance measure is by design only calculated in years following Fair (Yellow) or Good (Green) FC1 initiation success. Considering riparian scour potential (FC2), the following strong initiating cohorts of riparian seedlings (FC1) are predicted to suffer high (Red) rates of scour following successful initiation: 1941, 1952, 1969, 1983, 1997 (*i.e.*, approx. 5 in 11 years successfully initiating cohorts may be wiped out by subsequent high flows).

Indicator Reliability

The indicator credibility rankings for FC2 are shown in Table 4.29.

Table 4.29. FC2 – Riparian scour - indicator credibility assignments following the workshop. These ratings apply to those point bars in the Sacramento River that have stage-discharge relationships and scour depth as a function of flow.

	Category				
	I	**U**	**R**	**F**	**P**
FC2 – Riparian scour risk	H	M	M/L	H	H

The FC2 indicator scores Medium on understanding because the sensitivity of this measure and its stability across multiple sites is theoretical, and alternative hypotheses and confounding factors will exist.

Excel Reports

None.

Indicator Threshold Calibration

Initial scour thresholds for assignment of R/Y/G proposed by riparian subgroup participants were identified as follows. A flow of ≥ 90,000 cfs would *ensure* 100% scour mortality of riparian seedlings ≤ 1 years (*i.e.*, = Red classification), wiping out recruitment success of the previous year. Flows of ≥ 90,000 cfs are expected to generate gravel mobilization down to 2 feet or more, based on scour chain observations. Flows of ≥ 80,000 cfs (and < 90,000 cfs) are expected to generate gravel mobilization producing a Yellow classification risk for seedling scour.

Note: these thresholds are readily configurable in the SacEFT database.

Table 4.30. FC2 – Riparian scour risk. Units are threshold flows (cfs) for bank mobilization events.

	Daily		Rollup		Notes
	Good-Fair	Fair-Poor	Good-Fair	Fair-Poor	
Riparian Scour Risk	N/A	N/A	80000	90000	• Criteria: thresholds based on expert opinion of scour events, “less” is better • Units: flow (cfs) • No daily estimate

4.3.5 Large woody debris recruitment to mainstem Sacramento River

Large Woody Debris recruitment (LWD) is a proxy indicator for Western Pond Turtle (WPT) habitat quality. The indicator is based on the assumption provided by professional herpetologists at SacEFT design workshops that recruitment of LWD into the main channel of the Sacramento River will create more hospitable habitat conditions for WPT. To estimate LWD recruitment to the main channel, the area eroded with older forest vegetation is used as a measurement of how much potential large woody debris is recruited each year.

A GIS layer representing mature vegetation was created from the 2007 Riparian vegetation data for the Sacramento River; obtained from the Sacramento River GIS portal[1]. The GIS dataset includes vegetation class and height category. For the purpose of the recruitment of LWD, forests taller than 34 ft (height class 4 or higher) are considered old forest. The vegetation class itself is not used in this version of the LWD model as it is not clear whether WPT would preferentially use different types of LWD. An important simplifying caveat is that the LWD model assumes that the distribution of forest size classes is static during SacEFT simulations, *i.e.,* the vegetation cover map input at the start of the model simulation does not or change in species composition.

The performance measure for this indicator is computed for each location as the area eroded with old vegetation. The area is found in a GIS by overlaying the predicted eroded areas from the bank erosion model (see Section 4.1.6) with the old growth GIS layer (see Figure 4.34). Areas where the eroded area and the old vegetation locations overlap are considered to be the sources of LWD. Finally, the old vegetation areas are divided into 38 bends located in 3 different river segments for reporting purposes.

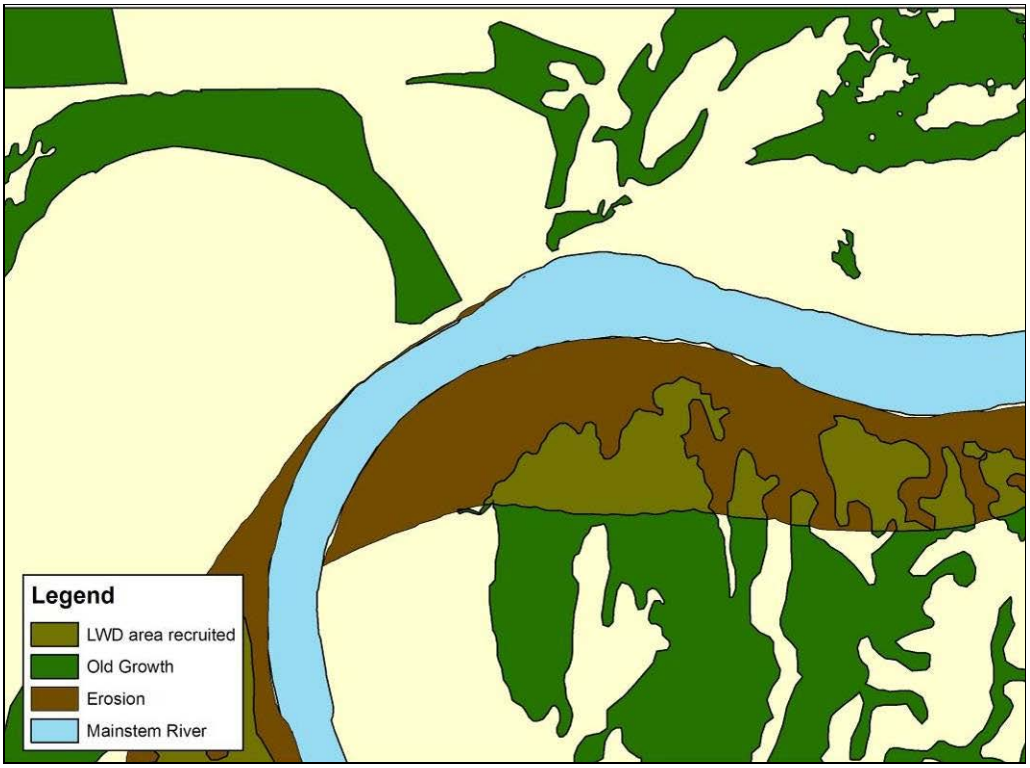

Figure 4.34: Map illustrating vegetation classes used to compute LWD recruitment for SacEFT.

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[1] http://www.sacramentoriver.org/srcaf/index.php?id=data

The *Rollup* indicator is then computed by summing the area eroded in old growth forest across all locations (L):

$$LWD = \sum_{l=1}^{L} LWD_l$$

Indicator Reliability

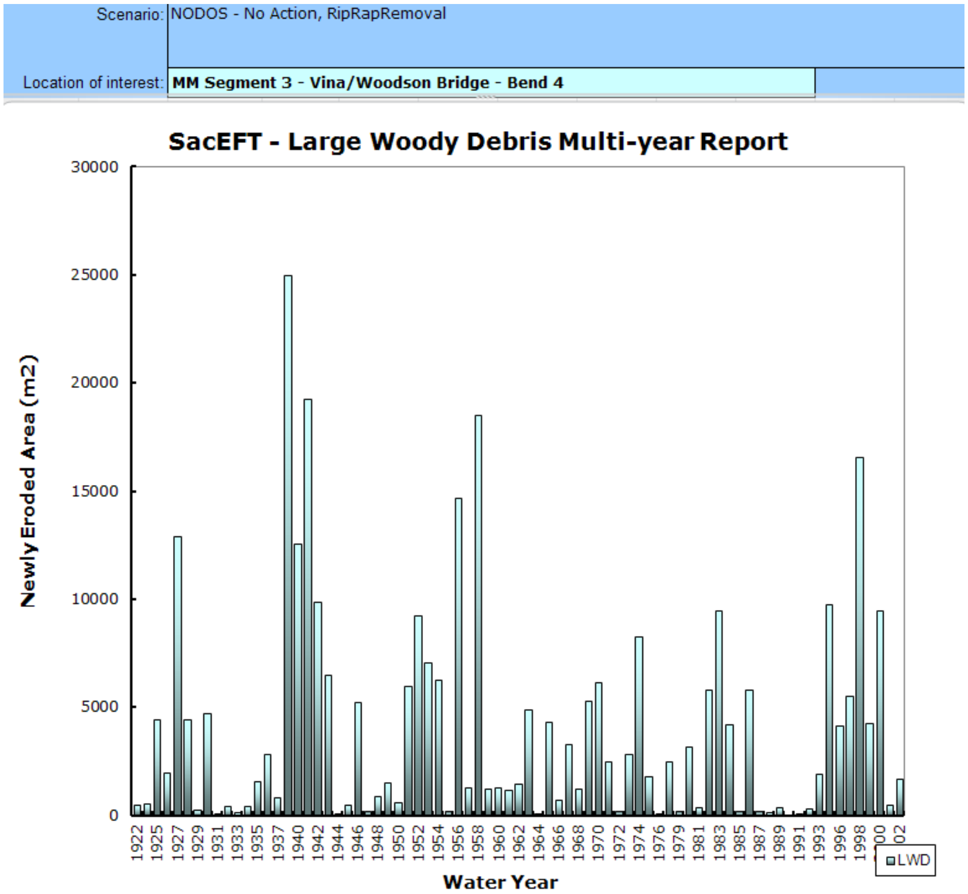
LWD is assigned the reliability shown in Table 4.31. This is a semi-quantitative proxy performance indicator reliant on the results of the Meander Migration Model, which are post-processed to create the Bank Erosion model.

Table 4.31. Credibility assignment for LWD – Large woody debris recruitment.

	Category				
	I	**U**	**R**	**F**	**P**
Large woody debris recruitment		M	M	L/M?	L/M

Excel Reports

An example of a SacEFT v.2 Excel report for LWD is shown in Figure 4.35.



Scenario: NODOS - No Action, RipRapRemoval

Location of interest: **MM Segment 3 - Vina/Woodson Bridge - Bend 4**

Figure 4.35. An example of an Excel report for LWD – Large Woody Debris recruitment. This example shows the square meters eroded each year for Bend 4 in the Vina/Woodson Bridget segment, as a proxy for WPT habitat.

Indicator Threshold Calibration

To calibrate the LWD indicator, we used empirically measured historical flow data with no rip-rap removal. LWD areas are summed for all locations for each year and the PM values were sorted from largest to smallest. Values that define the upper-, middle and lower thirds (terciles) of the sorted values are termed roll-up Hazard Threshold boundaries (see Figure 4.36 and Table 4.32).

Although this method provides an internally consistent way to compare results (*i.e.*, it will always provide a consistent ranking of which water management scenarios are "better" than others), it does not provide any concrete inferences about the biological significance of the three categories. For example, it is possible that a year that ranks as "Good" (Green)) with this method may still be biologically suboptimal. Conversely, a year that ranks as "Poor" (Red) may be biologically insignificant.

A preferred method for calibrating the indicator and categorizing annual variation across different hydrosystem scenarios is to identify historical years with Good or Poor performance. However, to our knowledge, there does not exist a dataset that estimate the amount of LWD recruited to the main-stem Sacramento River, so it is not currently possible to evaluate year with Good or Poor performance.

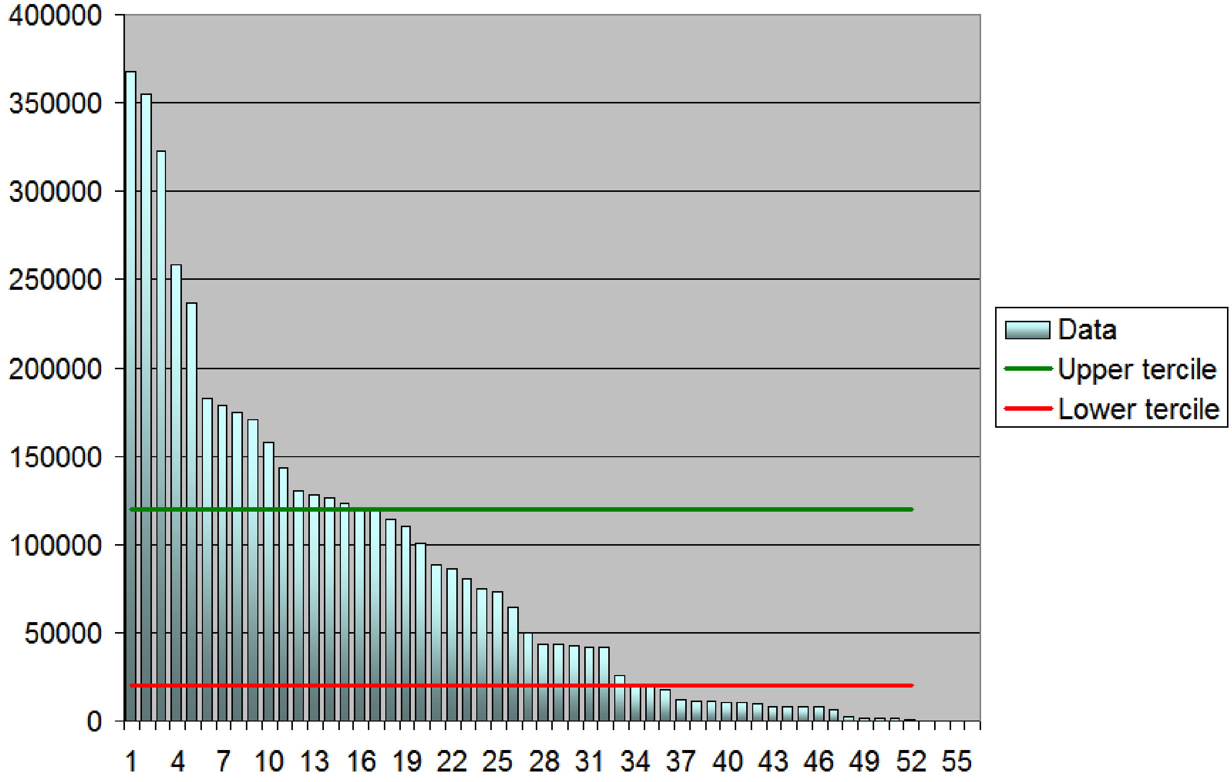


Figure 4.36. Calibration assumptions for LWD. Units on the y-axis are square meters riparian forest eroded to mainstem Sacramento River having forests taller than 34 ft (height class 4 or higher).

Table 4.32. LWD – Large Woody Debris indicator rating breakpoints, in units of square meters.

	Daily		**Rollup**		**Notes**
	Good-Fair	**Fair-Poor**	**Good-Fair**	**Fair-Poor**	
Large Woody Debris recruitment	N/A	N/A	120000	20000	• Criteria: statistical distribution, terciles, “more” is better • Units: square meters riparian forest eroded to mainstem Sacramento River having forests taller than 34 ft (height class 4 or higher). • No daily estimate

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Appendix A – Invited Workshop Participants

SacEFT v.1 design workshop (Dec. 5-6, 2005 Davis, CA):

Name	Subgroup	Area of Expertise	Organization	Phone / Fax	Email
Ryan Luster	Riparian / wildlife	Project Manager / habitat restoration	The Nature Conservancy	530-897-6370 ext 213	rluster@tnc.org
Greg Golet	Riparian / Wildlife	Focal species / functional relationships	The Nature Conservancy	530-897-6370 ext. 212	ggolet@tnc.org
Anthony Saracino	Physical	Water Policy	The Nature Conservancy	916-449-2850 ext. 22	asaracino@tnc.org
Mike Roberts	Fish	Hydrology	The Nature Conservancy	801-842-9482	mike_roberts@tnc.org
David Marmorek	Fish	DA tool, tradeoff evaluations	ESSA Technologies	604-733-2996	dmarmorek@essa.com
Clint Alexander	Physical	DA Tool construction	ESSA Technologies	250-860-3824	calexander@essa.com
Marc Nelitz	Riparian / Wildlife	DA Tool construction	ESSA Technologies	604-733-2996	mnelitz@essa.com
Michael Fainter	Fish	Focal species info, SOS Report, Field Studies	Stillwater Sciences	510-848-8098 ext. 127	mike@stillwatersci.com
Bruce Orr	Riparian / Wildlife	Focal species info, SOS Report, Field Studies	Stillwater Sciences	510-848-8098 ext. 111	bruce@stillwatersci.com
Frank Ligon	Fish	Focal species info, SOS Report, Field Studies	Stillwater Sciences	707-822-9607 ext. 213	frank@stillwatersci.com
Yantao Cui	Physical	TUGS, Oxbow Cut-off models	Stillwater Sciences	510-848-8098 ext. 120	yantao@stillwatersci.com
Eric Larsen	Physical	Meander Migration Model	UC Davis	530-752-8336	ewlarsen@ucdavis.edu
Matt Kondolf	Physical	Oxbow studies, fluvial geomorphology	University of California, Berkeley	510-644-8381	kondolf@calmail.berkeley.edu
Rebecca Fris		CBDA Ecosystem Restoration Program coordinator	CALFED	916-445-5031	rebeccaf@calwater.ca.gov
Tom Morstein-Marx	Physical	CalSim II operator	USBR	916-979-2196	tmorsteinmarx@mp.usbr.gov
Dan Easton	Physical	CalSim II operator	Water Resources Engineer, Department of Water Resources, Bay-Delta Office, Modeling Support Branch	916-653-7695	deaston@water.ca.gov
Ken Kirby	Physical	Hydrosystem consultant	Active Curiosity	916-646-4361	kkirby@activecuriosity.com
Lisa Micheli	Physical	Physical / sediment transport processes	Sonoma Ecology Center	415-264-2018	micheli@vom.com
Koll Buer	Physical	Physical / sediment transport processes	CDWR (retired)	530-527-1417	kollbuer@gmail.com
Mike Singer	Physical	Physical / sediment transport processes	UC Santa Barbara	510-643-2161	bliss@bren.ucsb.edu
Stacey Cepello	Physical	HEC-RAS upper Sac	CDWR	530-529-7352	cepello@water.ca.gov
Russ Yaworsky	Physical	USBR Upper Sacramento River Temperature Model	USBR	916-978-5099	ryaworsky@mp.usbr.gov

Name	Subgroup	Area of Expertise	Organization	Phone / Fax	Email
Tom Smith	Physical	HEC-RAS middle Sac	Ayres Associates	916-563-7700	smitht@AyresAssociates.com
Harry Rectenwald	Fish	Chinook salmon	CDFG	530-225-2368	hrectenw@dfg.ca.gov
Jim Smith	Fish	Chinook salmon	USFW, Red Bluff	530-527-3043	Jim_Smith@fws.gov
Dennis McEwan	Fish	Steelhead	CDFG	916-327-8850	dmcewan@dfg.ca.gov
Rob Titus	Fish	Steelhead	CDFG	916-227-6399	rtitus@dfg.ca.gov
Peter Klimley	Fish	Green sturgeon	UC Davis	530-752-5830	apklimley@ucdavis.edu
Kurt Brown	Fish	Green sturgeon	USFWS – Coleman Hatchery		brown_kurtis@fws.gov
Wim Kimmerer	Fish	Chinook salmon modeling	San Francisco State Univ.	415-338-3515	kimmerer@sfsu.edu
Mark Gard	Fish	PHABSIM, River 2D, juvenile stranding surveys	USFWS	916-414-6600	Mark_Gard@fws.gov
Dave Germano	Riparian / Wildlife	Western pond turtle	CSU, Bakersfield	661-664-2471	David_Germano@firstclass1.csubak.edu
Bruce Bury	Riparian / Wildlife	Western pond turtle	USGS	541-750-1010	Bruce_Bury@usgs.gov
Tag Engstrom	Riparian / Wildlife	Western pond turtle	California State University, Chico	530-898-6748	tengstrom@csuchico.edu
Ron Schlorff	Riparian / Wildlife	Bank swallow	CDFG	916-654-4262	RSchlorf@dfg.ca.gov
Barrett Garrison	Riparian / Wildlife	Bank swallow	CDFG, Rancho Cordova	916-358-2945	bagarris@hq.dfg.ca.gov
Joe Silveira	Riparian / Wildlife	Bank swallow	USFWS	530-934-2801	joe_silveira@fws.gov
Naduv Nur	Riparian / Wildlife	Riparian and songbirds	PRBO	415-868-1221 ext 315	nnur@prbo.org
John Bair	Riparian / Wildlife	TARGETS	McBain & Trush	707-826-7794	john@mcbaintrush.com
Steve Greco	Riparian / Wildlife	riparian-bird community	UC Davis	530-754-5983	segreco@ucdavis.edu

SacEFT v.2 design workshop (October 7-8 2008, Chico CA):

Invited water managers for Day 1: October 7

Ron Ganzfried
Maurice Hall
John Hannon
Derek Hilts
Buford Holt
Campbell Ingram
Aric Lester
Tom Morstein-Marx
Steve Roberts
Anthony Saracino
Sean Sou
Joseph Terry
Jim Weiking

Invited biologists for Days 1 and 2: October 7 and 8

Colleen Harvey Arrison
Don Ashton
John Bair
Ed Ballard
Randy Benthin
Mike Berry
Tricia Brachter
Howard Brown
Larry Brown
Matt Brown
Daniel Burmester
Bruce Bury
Bradley Cavallo
Richard Corwin
Yantao Cui
Chris Eilers
Tag Engstrom
Mark Gard
Dave Germano
Adam Henderson
Josh Israel
Doug Killam
Jason Kindopp
Peter Klimley
Ryan Kurtis
Eric Larsen
Alice Low
Dennis McEwan
Tracy McReynolds
Rod McInnis
Bruce Oppenheim
Bruce Orr
Steve Lindley
Keith Marine
Nadav Nur
Bill Poytress
Bruce Ross
Ron Schlorff
Joe Silveira
Jim Smith
Alicia Steinholz
Rob Titus
Mike Tucker
Dave Vogel
Dave Zezulack

Attachment 5C.C
Water Temperature

Contents

List of Tables

Acronyms and Abbreviations

BDCP	Bay Delta Conservatio Plan
Delta	Sacramento–San Joaquin River Delta
EBC	existing biological conditions
ELT	early long-term
LLT	late long-term
LSZ	low salinity zone
PP	preliminary proposal

Attachment 5C.C
Water Temperature

Although the primary factor determining water temperatures in the Sacramento–San Joaquin River Delta (Delta) is atmospheric temperature, water temperature could be affected by water operations if residence time, depth, and water velocity change. Analysis presented in this attachment includes the Bay Delta Conservation Plan's (BDCP) preliminary proposal, i.e., Alternative 1A of the EIR-EIS. As shown below, generally there is little difference between BDCP scenarios and existing or future conditions without the BDCP—for this reason, the analyses were not redone for the BDCP's evaluated starting operations, high-outflow, or low-outflow scenarios (i.e., Alternative 4 of the EIR-EIS). The results shown here are provided for context.

In brief, daily water temperature was estimated for each model scenario using the DSM2-QUAL nutrient model, which covers water years 1976–1991. Daily data for a number of stations were averaged by subregion (Table 5C.C-1); in the South Delta subregion, the San Joaquin River stations were kept separate from other stations because they had notably higher flows than the remaining stations.

Table 5C.C-1. DSM2-QUAL Stations Used to Analyze Temperature Effects in the Plan Area

Subregion	Stations
Cache Slough/Sacramento Deepwater Ship Channel	Cache Ryer; ALL_YOLO_OUT; CHAN 405_0; CHAN 409_0; CHAN 402_LENGTH
North Delta	RSAC155; RSAC139; RSAC128; RSAC123; SLSBT011
East Delta	RSMKL024; RSMKL008; RMKL005; RMKL019
South Delta	RMID015; RMID027; CHVCT000; ROLD014; ROLD040; Mildred
San Joaquin	RSAN058; SJR_Brandt_Br; RSAN087
West Delta	RSAC101; RSAC092; PO-649; Franks Tract; RSAN032; Twitchell; RSAC081; RSAC077; Sherman Lake; RSAN007; RSAN018
Suisun Bay	Suisun-Volanti; MontSl_Bend2; SLMZU011; SLGYR003
Suisun Marsh	RSAC054; RSAC064; SLM001 (SLML001); Grizzly; Honker

For each species and life stage, the number of days above certain temperature thresholds or in certain temperature ranges was calculated by year and month to describe differences between existing biological conditions and BDCP scenarios (Table 5C.C-2). For delta smelt, the median spawning date based on a spawning temperature range of 15–20 degrees Celsius (°C) in winter-spring also was assessed because temperature changes may shift the spawning period in relation to other potentially important variables such as flow and day length (Wagner et al. 2011). As described in Appendix 2.A, *Species Accounts*, juvenile delta smelt are found in the low salinity zone (LSZ) and may migrate upstream and downstream in association with it, although other factors contribute to their distribution. There is the potential for delta smelt to move into habitat of a different temperature as salinity (or some other habitat feature associated with salinity) changes location in relation to water operations. In summer, X2 generally moves upstream under the BDCP's preliminary proposal (see *Results* below), and juvenile delta smelt generally would be expected to move upstream as well. Therefore, a greater proportion of the population would be expected to move into the West Delta subregion from the Suisun Bay subregion. The potential effects of such a movement were examined by comparing the number of stressful (20–25°C) and lethal (>25°C) days in the Suisun Bay subregion under future conditions without the BDCP in the early long-term (ELT) and late long-term (LLT) with the number of stressful and lethal days under the preliminary proposal (PP) in the same timeframes in the West Delta subregion, for each water year in the 1976–1991 DSM2-QUAL simulation.

The modeling scenarios used in this analysis are described below.

- Existing biological conditions:
  - **EBC1.** Current operations, based on the U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (2009) BiOps, but excluding the September–November outflows in wet and above normal years required to achieve the Fall X2 provisions of the U.S. Fish and Wildlife Service (2008) BiOp.
  - **EBC2.** Current operations based on the U.S. Fish and Wildlife Service (2008) and National Marine Fisheries Service (2009) BiOps, including the September–November outflows in wet and above normal years required to achieve the Fall X2 provisions of the U.S. Fish and Wildlife Service (2008) BiOp. Slightly different demand and facilities assumptions than EBC1.
- Project future conditions without the BDCP:
  - **EBC2_ELT.** EBC2 projected into Year 15 (2025) accounting for climate change conditions expected at that time.
  - **EBC2_LLT.** EBC2 projected into Year 50 (2060) accounting for climate changes conditions expected at that time.
- Projected future conditions with the BDCP:
  - **PP_ELT.** The preliminary proposal operations in Year 15; assumes the new intake facility is operational but restoration actions are not fully implemented.
  - **PP_LLT.** The preliminary proposal operations in Year 50; assumes the new intake facility is operational and restoration actions are fully implemented.

Table 5C.C-2. Temperature Thresholds or Ranges Examined for Differences between BDCP and Existing Biological Conditions Scenarios

Species	Life Stage (Function)	Threshold or Range	Reference
Steelhead	Juvenile (Rearing)	Suboptimal (<10°C), optimal (10–18°C), supraoptimal (>18°C–26°C), lethal (26°C)	Moyle et al. 2008
	Juvenile (Smoltification)	Suboptimal (<7°C), optimal (7–15°C), supraoptimal (>15°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Adult (Migration)	Suboptimal (<10°C), optimal (10–20°C), supraoptimal (>20°C–23°C), lethal (>23°C)	Moyle et al. 2008
Chinook Salmon	Juvenile (Rearing)	Suboptimal (<13°C), optimal (13–20°C), supraoptimal (>20°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Juvenile (Smoltification)	Suboptimal (<10°C), optimal (10–19°C), supraoptimal (>19°C–24°C), lethal (>24°C)	Moyle et al. 2008
	Adult (Migration)	Suboptimal (<10°C), optimal (10–20°C), supraoptimal (>20°C–21°C), lethal (>21°C)	Moyle et al. 2008
Delta Smelt	Juvenile (Rearing)	Stress (20°C–25°C), lethal (>25°C)	Wagner et al. 2011
	Adult (Spawning)	Median day of the year (15°C–20°C)	Wagner et al. 2011
Longfin Smelt	Juvenile (Rearing) and Adult (Residence)	>20°C	Moyle 2002
White Sturgeon	Juvenile (Rearing), Adult (Migration)	Stress (>20°C), upper limit (>25°C)	Cech et al. 1984; Geist et al. 2005; Israel et al. 2009
Green Sturgeon	Juvenile (Rearing)	>18.9°C (supraoptimal), >24°C (upper limit), >27°C (lethal)	Israel and Klimley 2008; National Marine Fisheries Service (74 FR 52300)
	Adult (Migration)	>24°C (upper limit of oxygen binding), >27°C (lethal)	Erickson et al. 2002; Heublein et al. 2009
Pacific Lamprey and River Lamprey	Macropthalmia and Adult (Migration)	>25°C	Moyle et al. 1995

5C.C.1 Steelhead

5C.C.1.1 Juvenile

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in juvenile rearing temperatures for steelhead in the Cache Slough subregion (Table 5C.C-3). The average number of optimal days[1] was 193–194 days under EBC1 and EBC2 and 182–185 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 127 under EBC1 and EBC2, 143–145 under PP_ELT and EBC2_ELT, and 161–162 under PP_LLT and EBC2_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in juvenile rearing temperatures for steelhead in the East Delta subregion (Table 5C.C-4) differed little when accounting for climate change. The average number of optimal days was 190–191 days under EBC1 and EBC2 and 186–187 days under EBC2_ELT, EBC2_LLT, and 184–185 under PP_LLT, and PP_ELT, respectively. The average number of supraoptimal days was 136 for EBC1 and EBC2, 149 days under EBC2_ELT and PP_ELT, and 165–166 under EBC2_LLT and PP_LLT. There was one lethal day for EBC2_ELT in 1988, but the average number of lethal days was zero.

EBC scenarios and PP scenarios in juvenile rearing temperatures for steelhead in the North Delta subregion (Table 5C.C-5) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 173 for EBC1 and EBC2, and between 169 and 184 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 133 days under EBC1 and EBC2, and ranged from 143 to 157 days under EBC2_ELT and EBC2_LLT, and from 143 to 158 under PP_ELT and PP_LLT. A total of 17 days with lethal temperatures occurred during the modeling period and on average, lethal water temperatures were reached on one day under the EBC2_LLT scenario.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in juvenile rearing temperatures for steelhead in the San Joaquin portion of the South Delta subregion (Table 5C.C-6). Optimal water temperatures occurred on 191–192 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 186 to 192. Supraoptimal temperatures were reached on average for 137 and 136 days under EBC1 and EBC2, respectively. Under all other scenarios, this number ranged from 150 to 156 days. There were no lethal temperature days under any scenario.

Water temperatures in the South Delta for rearing steelhead juveniles were generally similar among the different scenarios (considering climate change) (Table 5C.C-7). Suboptimal temperatures occurred on 36–37 days under EBC1 and EBC2, and on 15–27 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Under EBC1 and EBC2, optimal water temperatures occurred on 195 days per year, on average. Optimal temperature conditions occurred on 186–188 days per year under EBC2_ELT, EBC2_LLT, PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 134 days under EBC1 and EBC2, and on 153–163 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

In the Suisun Bay subregion, juvenile rearing temperatures for steelhead were similar among scenarios (Table 5C.C-8) after accounting for changing climate. Optimal water temperatures were

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[1] "Days" correspond to days per calendar year throughout this attachment.

reached on average on 188 days under EBC1 and 179–181 days for all other scenarios. EBC1 and EBC2 averaged 135 and 134 days of supraoptimal days, respectively, while the number of days for EBC_ELT, EBC1_LLT, PP_ELT and PP_LLT varied from 147–158 days. There were no lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for juvenile steelhead were minor, after climate change was taken into consideration (Table 5C.C-9). Optimal temperatures occurred on average on 191 days under EBC1 and EBC2, and on 180–182 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 128 days under EBC1 and EBC2, and on 147–161 days under all other scenarios (i.e., EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Water temperatures in the West Delta for rearing steelhead juveniles were generally similar among the different scenarios (considering climate change) (Table 5C.C-10). Under EBC1 and EBC2, optimal water temperatures occurred on 189 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 180–185 days per year, and on 182–185 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 129 days under EBC1 and EBC2, and on 147–162 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

Table 5C.C-3. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (>10°C)**							**Optimal (≥10°C and ≤18°C)**					
1976	40	40	35	15	35	16		201	201	188	189	188	188
1977	60	60	49	30	48	35		190	192	179	176	181	172
1978	4	5	0	0	2	0		233	232	209	188	211	196
1979	52	51	46	25	62	38		161	162	161	173	146	163
1980	35	32	24	3	40	10		209	211	218	206	204	201
1981	42	41	30	4	32	4		182	183	179	208	180	207
1982	42	42	26	3	43	17		211	211	215	223	199	205
1983	48	48	34	17	38	19		187	187	183	198	182	196
1984	35	35	57	4	58	10		194	193	170	192	168	186
1985	61	61	27	55	25	56		192	193	203	153	209	153
1986	36	36	42	21	45	21		214	214	160	193	159	195
1987	48	48	40	28	41	27		178	179	180	160	183	163
1988	47	45	34	15	37	15		186	188	177	178	178	180
1989	63	63	53	28	55	26		179	179	159	156	162	157
1990	59	60	40	22	48	26		182	181	184	171	178	165
1991	42	43	31	25	30	25		196	195	188	195	189	195
Avg	45	44	36	18	40	22		193	194	185	185	182	183
	Supraoptimal (>18°C and ≤26°C)							**Lethal (>26°C)**					
1976	125	125	143	162	143	162		0	0	0	0	0	0
1977	115	113	137	159	136	158		0	0	0	0	0	0
1978	128	128	156	177	152	169		0	0	0	0	0	0
1979	152	152	158	167	157	164		0	0	0	0	0	0
1980	122	123	124	157	122	155		0	0	0	0	0	0
1981	141	141	156	153	153	154		0	0	0	0	0	0
1982	112	112	124	139	123	143		0	0	0	0	0	0
1983	130	130	148	150	145	150		0	0	0	0	0	0
1984	137	138	139	170	140	170		0	0	0	0	0	0
1985	112	111	135	157	131	156		0	0	0	0	0	0
1986	115	115	163	151	161	149		0	0	0	0	0	0
1987	139	138	145	177	141	175		0	0	0	0	0	0
1988	133	133	155	173	151	171		0	0	0	0	0	0
1989	123	123	153	181	148	182		0	0	0	0	0	0
1990	124	124	141	172	139	174		0	0	0	0	0	0
1991	127	127	146	145	146	145		0	0	0	0	0	0
Avg	127	127	145	162	143	161		0	0	0	0	0	0

Table 5C.C-4. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	39	39	30	5	32	6		189	190	185	199	185	198
1977	59	53	45	13	46	25		180	188	175	190	176	180
1978	4	4	0	0	0	0		219	220	205	194	204	185
1979	46	45	41	22	43	25		164	165	165	179	163	173
1980	31	30	32	9	27	5		199	200	204	192	211	195
1981	42	42	30	4	26	4		181	181	181	202	182	204
1982	45	47	29	8	25	6		200	198	195	204	201	207
1983	38	38	15	9	16	10		193	195	197	202	200	200
1984	41	41	55	9	55	5		184	185	175	185	170	186
1985	59	59	25	33	24	51		181	181	190	172	195	155
1986	24	23	23	20	33	17		213	213	185	189	163	193
1987	47	47	36	20	39	24		171	172	182	162	178	158
1988	20	20	14	7	21	12		210	209	204	186	193	180
1989	50	52	38	17	45	24		175	174	174	168	165	158
1990	46	47	39	16	28	19		187	186	177	174	192	169
1991	33	32	29	20	31	23		198	198	185	194	186	195
Avg	39	39	30	13	31	16		190	191	186	187	185	184
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	138	137	151	162	149	162		0	0	0	0	0	0
1977	126	124	145	162	143	160		0	0	0	0	0	0
1978	142	141	160	171	161	180		0	0	0	0	0	0
1979	155	155	159	164	159	167		0	0	0	0	0	0
1980	136	136	130	165	128	166		0	0	0	0	0	0
1981	142	142	154	159	157	157		0	0	0	0	0	0
1982	120	120	141	153	139	152		0	0	0	0	0	0
1983	134	132	153	154	149	155		0	0	0	0	0	0
1984	141	140	136	172	141	175		0	0	0	0	0	0
1985	125	125	150	160	146	159		0	0	0	0	0	0
1986	128	129	157	156	169	155		0	0	0	0	0	0
1987	147	146	147	183	148	183		0	0	0	0	0	0
1988	136	137	148	172	152	174		0	0	0	1	0	0
1989	140	139	153	180	155	183		0	0	0	0	0	0
1990	132	132	149	175	145	177		0	0	0	0	0	0
1991	134	135	151	151	148	147		0	0	0	0	0	0
Avg	136	136	149	165	149	166		0	0	0	0	0	0

Table 5C.C-5. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	61	59	36	15	34	14		174	176	182	194	185	193
1977	63	63	51	23	51	29		179	177	181	188	181	182
1978	51	50	37	7	39	6		178	176	175	196	173	196
1979	70	67	62	34	62	34		149	150	151	168	150	170
1980	53	53	53	23	52	22		183	182	188	191	191	192
1981	48	48	53	12	52	13		181	181	166	201	166	201
1982	58	58	50	23	50	24		191	191	180	192	177	190
1983	62	62	52	22	52	22		164	165	162	190	162	190
1984	57	57	59	17	58	17		170	169	175	188	174	186
1985	68	67	63	42	64	45		174	175	159	174	159	171
1986	57	56	49	23	50	25		189	187	172	190	165	190
1987	67	67	51	30	53	28		155	155	173	165	170	167
1988	55	55	45	19	47	19		179	180	178	189	175	189
1989	63	63	63	28	61	29		158	159	154	168	154	164
1990	66	66	64	29	65	30		172	172	153	163	153	163
1991	60	60	49	24	48	22		164	165	174	190	176	194
Avg	60	59	52	23	52	24		173	173	170	184	169	184
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	131	131	148	157	147	159		0	0	0	0	0	0
1977	123	125	133	154	133	154		0	0	0	0	0	0
1978	136	139	153	162	153	163		0	0	0	0	0	0
1979	146	148	152	163	153	161		0	0	0	0	0	0
1980	130	131	125	150	123	152		0	0	0	2	0	0
1981	136	136	146	151	147	151		0	0	0	1	0	0
1982	116	116	135	150	138	151		0	0	0	0	0	0
1983	139	138	151	153	151	153		0	0	0	0	0	0
1984	139	140	132	159	134	160		0	0	0	2	0	3
1985	123	123	143	148	142	148		0	0	0	1	0	1
1986	119	122	144	152	150	150		0	0	0	0	0	0
1987	143	143	141	170	142	170		0	0	0	0	0	0
1988	132	131	143	154	144	157		0	0	0	4	0	1
1989	144	143	148	169	150	172		0	0	0	0	0	0
1990	127	127	148	173	147	172		0	0	0	0	0	0
1991	141	140	142	150	141	149		0	0	0	1	0	0
Avg	133	133	143	157	143	158		0	0	0	1	0	0

Table 5C.C-6. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	37	38	37	15	35	12		189	191	184	195	184	196
1977	53	53	45	27	45	27		189	189	181	188	181	187
1978	0	1	0	0	0	0		222	222	208	209	210	210
1979	44	44	40	32	38	29		169	169	166	167	168	170
1980	24	24	18	8	16	8		204	206	216	213	216	212
1981	38	38	22	2	20	0		180	180	190	210	192	211
1982	25	25	17	14	15	12		216	216	206	216	208	217
1983	31	31	20	19	25	20		192	192	193	183	185	188
1984	24	24	50	8	48	8		198	198	170	191	170	189
1985	59	59	27	49	27	50		179	180	187	178	192	174
1986	27	26	30	15	30	15		203	205	173	203	173	199
1987	45	45	36	27	35	22		165	167	182	171	183	173
1988	40	40	25	14	25	12		190	193	186	201	189	195
1989	55	56	46	26	46	27		177	176	159	171	158	169
1990	46	47	30	19	30	19		194	193	189	184	189	179
1991	41	40	32	23	31	24		195	196	186	194	187	191
Avg	37	37	30	19	29	18		191	192	186	192	187	191
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	140	137	145	156	147	158		0	0	0	0	0	0
1977	123	123	139	150	139	151		0	0	0	0	0	0
1978	143	142	157	156	155	155		0	0	0	0	0	0
1979	152	152	159	166	159	166		0	0	0	0	0	0
1980	138	136	132	145	134	146		0	0	0	0	0	0
1981	147	147	153	153	153	154		0	0	0	0	0	0
1982	124	124	142	135	142	136		0	0	0	0	0	0
1983	142	142	152	163	155	157		0	0	0	0	0	0
1984	144	144	146	167	148	169		0	0	0	0	0	0
1985	127	126	151	138	146	141		0	0	0	0	0	0
1986	135	134	162	147	162	151		0	0	0	0	0	0
1987	155	153	147	167	147	170		0	0	0	0	0	0
1988	136	133	155	151	152	159		0	0	0	0	0	0
1989	133	133	160	168	161	169		0	0	0	0	0	0
1990	125	125	146	162	146	167		0	0	0	0	0	0
1991	129	129	147	148	147	150		0	0	0	0	0	0
Avg	137	136	150	155	150	156		0	0	0	0	0	0

Table 5C.C-7. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	38	38	36	5	35	2		192	192	180	198	180	202
1977	52	52	44	16	44	17		182	182	173	188	173	189
1978	0	0	0	0	0	0		228	229	205	204	202	204
1979	51	49	36	25	35	24		159	160	170	171	170	172
1980	22	22	8	4	10	6		216	216	230	208	228	207
1981	38	38	15	0	11	0		180	181	190	206	195	208
1982	19	20	7	0	5	0		229	228	226	230	227	230
1983	30	31	12	15	18	16		200	198	201	192	193	193
1984	23	24	54	3	49	10		196	195	160	195	171	187
1985	60	60	25	51	25	51		185	187	200	156	200	156
1986	27	27	35	16	33	16		212	212	157	200	161	199
1987	46	46	36	17	33	14		168	169	180	170	183	173
1988	36	36	31	12	31	12		196	196	173	174	172	170
1989	58	59	39	27	39	24		174	174	152	157	153	161
1990	46	46	25	20	25	19		192	192	193	169	192	172
1991	36	36	30	23	29	23		203	203	178	187	180	186
Avg	36	37	27	15	26	15		195	195	186	188	186	188
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	136	136	150	163	151	162		0	0	0	0	0	0
1977	131	131	148	161	148	159		0	0	0	0	0	0
1978	137	136	160	161	163	161		0	0	0	0	0	0
1979	155	156	159	169	160	169		0	0	0	0	0	0
1980	128	128	128	154	128	153		0	0	0	0	0	0
1981	147	146	160	159	159	157		0	0	0	0	0	0
1982	117	117	132	135	133	135		0	0	0	0	0	0
1983	135	136	152	158	154	156		0	0	0	0	0	0
1984	147	147	152	168	146	169		0	0	0	0	0	0
1985	120	118	140	158	140	158		0	0	0	0	0	0
1986	126	126	173	149	171	150		0	0	0	0	0	0
1987	151	150	149	178	149	178		0	0	0	0	0	0
1988	134	134	162	180	163	184		0	0	0	0	0	0
1989	133	132	174	181	173	180		0	0	0	0	0	0
1990	127	127	147	176	148	174		0	0	0	0	0	0
1991	126	126	157	155	156	156		0	0	0	0	0	0
Avg	134	134	153	163	153	163		0	0	0	0	0	0

Table 5C.C-8. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	37	35	42	22	41	21		194	196	175	185	176	186
1977	49	49	50	43	50	43		186	186	178	174	179	174
1978	10	10	3	0	1	0		215	215	205	203	207	203
1979	55	56	49	40	51	41		156	156	159	158	157	157
1980	36	37	33	16	33	17		203	203	206	191	203	190
1981	38	39	24	16	23	13		183	181	190	194	191	197
1982	51	51	40	22	41	22		195	197	197	193	196	193
1983	47	47	34	24	33	24		183	183	178	185	179	187
1984	38	37	57	17	57	16		183	185	167	183	166	185
1985	60	60	35	58	35	58		176	176	183	159	184	158
1986	35	36	36	29	37	31		207	207	166	188	164	190
1987	42	43	35	38	35	35		177	177	185	158	186	159
1988	43	44	36	23	37	24		183	182	178	184	178	183
1989	50	54	45	46	45	46		178	176	165	150	164	150
1990	55	55	41	36	39	34		186	186	182	168	185	168
1991	44	43	30	27	31	28		195	195	185	185	184	184
Avg	43	44	37	29	37	28		188	188	181	179	181	179
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	135	135	149	159	149	159		0	0	0	0	0	0
1977	130	130	137	148	136	148		0	0	0	0	0	0
1978	140	140	157	162	157	162		0	0	0	0	0	0
1979	154	153	157	167	157	167		0	0	0	0	0	0
1980	127	126	127	159	130	159		0	0	0	0	0	0
1981	144	145	151	155	151	155		0	0	0	0	0	0
1982	119	117	128	150	128	150		0	0	0	0	0	0
1983	135	135	153	156	153	154		0	0	0	0	0	0
1984	145	144	142	166	143	165		0	0	0	0	0	0
1985	129	129	147	148	146	149		0	0	0	0	0	0
1986	123	122	163	148	164	144		0	0	0	0	0	0
1987	146	145	145	169	144	171		0	0	0	0	0	0
1988	140	140	152	159	151	159		0	0	0	0	0	0
1989	137	135	155	169	156	169		0	0	0	0	0	0
1990	124	124	142	161	141	163		0	0	0	0	0	0
1991	126	127	150	153	150	153		0	0	0	0	0	0
Avg	135	134	147	158	147	158		0	0	0	0	0	0

Table 5C.C-9. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (>10°C)							Optimal (≥10°C and ≤18°C)					
1976	40	40	38	16	37	20		197	196	180	188	182	185
1977	53	52	48	39	49	41		189	191	178	168	176	168
1978	1	1	0	0	0	0		235	239	210	189	211	191
1979	62	63	60	37	57	40		151	149	147	160	149	158
1980	40	40	29	5	27	13		206	206	215	207	215	197
1981	40	40	22	4	24	16		181	181	186	204	185	194
1982	47	47	41	24	38	24		208	206	201	196	204	196
1983	64	65	35	29	34	29		171	170	184	191	185	190
1984	38	38	60	11	60	8		188	189	164	184	166	187
1985	63	62	28	55	27	57		192	195	199	153	201	155
1986	37	36	38	21	42	23		213	215	159	199	156	199
1987	49	49	39	30	39	31		175	175	180	162	181	162
1988	45	44	34	20	35	22		187	187	176	173	175	176
1989	60	59	51	36	52	41		184	183	151	149	149	150
1990	60	60	39	24	34	26		179	179	185	172	189	172
1991	47	43	31	25	31	27		193	197	186	191	186	193
Avg	47	46	37	24	37	26		191	191	181	180	182	180
	Supraoptimal (>18°C and ≤26°C)							Lethal (>26°C)					
1976	129	130	148	162	147	161		0	0	0	0	0	0
1977	123	122	139	158	140	156		0	0	0	0	0	0
1978	129	125	155	176	154	174		0	0	0	0	0	0
1979	152	153	158	168	159	167		0	0	0	0	0	0
1980	120	120	122	154	124	156		0	0	0	0	0	0
1981	144	144	157	157	156	155		0	0	0	0	0	0
1982	110	112	123	145	123	145		0	0	0	0	0	0
1983	130	130	146	145	146	146		0	0	0	0	0	0
1984	140	139	142	171	140	171		0	0	0	0	0	0
1985	110	108	138	157	137	153		0	0	0	0	0	0
1986	115	114	168	145	167	143		0	0	0	0	0	0
1987	141	141	146	173	145	172		0	0	0	0	0	0
1988	134	135	156	173	156	168		0	0	0	0	0	0
1989	121	123	163	180	164	174		0	0	0	0	0	0
1990	126	126	141	169	142	167		0	0	0	0	0	0
1991	125	125	148	149	148	145		0	0	0	0	0	0
Avg	128	128	147	161	147	160		0	0	0	0	0	0

Table 5C.C-10. Number of Days within Temperature Requirements for Steelhead Juvenile Rearing in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (>10°C)**							**Optimal (≥10°C and ≤18°C)**					
1976	41	41	34	14	32	14		195	195	181	195	183	196
1977	54	53	48	24	47	34		184	187	176	184	179	173
1978	9	9	0	0	0	0		223	223	206	196	208	198
1979	60	61	58	26	56	28		153	152	150	171	151	170
1980	39	39	34	6	31	4		203	202	210	207	215	211
1981	43	44	24	0	20	0		177	175	184	206	188	207
1982	53	53	44	15	38	11		199	199	195	207	202	214
1983	48	48	34	17	33	16		188	188	181	191	184	196
1984	42	42	57	5	57	5		187	186	168	199	166	186
1985	62	62	35	53	32	53		188	188	190	165	194	162
1986	35	35	38	19	37	21		214	214	159	191	161	192
1987	48	49	37	29	36	29		174	172	186	155	187	158
1988	51	51	34	14	34	15		186	186	180	177	180	175
1989	58	58	54	30	53	29		185	185	155	153	156	155
1990	65	66	44	18	42	19		176	175	178	177	182	177
1991	48	42	31	25	31	25		196	202	176	180	178	183
Avg	47	47	38	18	36	19		189	189	180	185	182	185
	Supraoptimal (>18°C and ≤26°C)							**Lethal (>26°C)**					
1976	130	130	151	157	151	156		0	0	0	0	0	0
1977	127	125	141	157	139	158		0	0	0	0	0	0
1978	133	133	159	169	157	167		0	0	0	0	0	0
1979	152	152	157	168	158	167		0	0	0	0	0	0
1980	124	125	122	153	120	151		0	0	0	0	0	0
1981	145	146	157	159	157	158		0	0	0	0	0	0
1982	113	113	126	143	125	140		0	0	0	0	0	0
1983	129	129	150	157	148	153		0	0	0	0	0	0
1984	137	138	141	162	143	175		0	0	0	0	0	0
1985	115	115	140	147	139	150		0	0	0	0	0	0
1986	116	116	168	155	167	152		0	0	0	0	0	0
1987	143	144	142	181	142	178		0	0	0	0	0	0
1988	129	129	152	175	152	176		0	0	0	0	0	0
1989	122	122	156	182	156	181		0	0	0	0	0	0
1990	124	124	143	170	141	169		0	0	0	0	0	0
1991	121	121	158	160	156	157		0	0	0	0	0	0
Avg	129	129	148	162	147	162		0	0	0	0	0	0

5C.C.1.2 Smoltification

Water temperatures for steelhead smoltification in the Cache Slough subregion differed little among scenarios, considering climate change effects (Table 5C.C-11). Optimal temperatures occurred during 163 and 162 days under EBC1 and EBC2, averaged 120 and 147 days under EBC2_LLT and EBC2_ELT, and 148 and 123 days under PP_ELT and PP_LLT, respectively. Supraoptimal water temperature conditions averaged 200–201 days under EBC1 and EBC2, 216–237 days under EBC2_ELT and EBC2_LLT, and 215 and 235 days under PP_ELT and PP_LLT, respectively. Overall, model runs from 1976 to 1991 resulted in a total of 271 days with lethal water temperatures in Cache Slough. Annually, no lethal temperatures occurred under EBC1 and EBC2, but EBC2_ELT and EBC2_LLT and PP_ELT and PP_LLT averaged 1 to 7 days when water temperatures reached lethal levels.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in rearing temperatures for steelhead smolts in the East Delta subregion (Table 5C.C-12). Optimal water temperatures occurred on average on 160 days under both EBC scenarios, and on 148 and 122 days under EBC2_ELT and EBC2_LLT, respectively. The number of optimal days was slightly lower for both PP scenarios, 146 for PP_ELT and 120 days for PP_LLT. Supraoptimal temperature regimes were more frequent than optimal, but again the difference among scenarios was small. Supraoptimal temperatures for steelhead smolts occurred on 204 days for EBC1 and EBC2, and on 217 to 237 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). No lethal conditions occurred under EBC1, EBC2, and EBC2_ELT, but the average number of days with lethal temperatures for steelhead smolts was 13 under EBC2_LLT. In comparison, the average number of days with lethal temperatures was lower under PP_ELT (1) and under PP_LLT (9).

In the North Delta, water temperature regimes were similar across the scenarios for steelhead smolts, but minor differences due to climate change occurred (Table 5C.C-13). The average frequency of optimal temperature days for smolts was 166 (under EBC1 and EBC2), 159 and 133 days (under EBC2_ELT and EBC2_LLT) and 159 and 134 days (under PP_ELT and PP_LLT). Supraoptimal temperature patterns were similar: 198 days for EBC1 and EBC2, 204 and 211 days under EBC2_ELT and EBC2_LTT, and 204 and 214 days under PP_ELT and PP_LLT, respectively. The number of days of lethal temperature during the entire time period (1976 to 1991) was 642 days, and annual averages were 0 under EBC1 and EBC2, 1 and 21 days under EBC2_ELT and EBC2_LLT, and 1 and 18 days under PP_ELT and PP_LLT, respectively.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in smolt rearing temperatures for steelhead in the San Joaquin portion of the South Delta subregion (Table 5C.C-14). The average number of optimal days was 152 days under EBC1 and EBC2 and 139–129 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 212 under EBC1 and EBC2, 223–232 under EBC2_ELT and EBC2_LLT, and 223–235 under PP_ELT and PP_LLT. Lethal water temperatures for smolts occurred on average on 2–3 days under EBC2_ELT, EBC2_LLT, PP_ELT and PP_LLT, but no lethal temperature days occurred under EBC1 and EBC2.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in smolt rearing temperatures for steelhead in the South Delta subregion (Table 5C.C-15). Suboptimal water temperatures occurred on average on 1 days under EBC1, EBC2, EBC2_ELT, and PP_ELT scenarios and on 0 days under EBC2_LLT and PP_LLT. Optimal water temperatures occurred on average on 151-152 days under EBC1 and EBC2, on 121-134 days under EBC2_ELT and EBC2_LLT, and on 122-134 days under PP_ELT and PP_LLT. Supraoptimal temperatures for steelhead smolts occurred on 213 days for EBC1 and EBC2, and on 228 to 237 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). No lethal conditions occurred under EBC1, EBC2. Lethal water temperatures occurred on average on 3 to 7 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT).

There was little difference between EBC scenarios and PP scenarios in water temperatures for steelhead smolts in the Suisun Bay subregion (Table 5C.C-16) after accounting for climate change. The average number of optimal days was 155 days under EBC1 and EBC2, 143–134 days under EBC2_ELT and EBC2_LLT, respectively, and 143–133 days under PP_ELT and PP_LLT, respectively. The average number of supraoptimal days was 210 under EBC1 and EBC2. Under EBC2_ELT and PP_ELT, the average number of supraoptimal temperature days was 222–223. Supraoptimal days numbered 230–231 under EBC2_LLT and PP_LLT. There was on average 1 lethal day under the EBC_LLT and the PP_LLT scenarios.

In Suisun Marsh, the temperature regimes for steelhead smolts differed little between preliminary proposal and EBC2 scenarios (Table 5C.C-17) after the effects of climate change were accounted for. The average number of optimal temperature days in Suisun Marsh was 161 and 160 days under the EBC1 and EBC2 scenarios, respectively. The number of optimal days ranged from 123 to 143 for all other scenarios. Supraoptimal conditions occurred on average 204 days under EBC1 and EBC2 scenarios. Under EBC2_ELT and EBC2_LLT, supraoptimal temperature conditions occurred on 220 and 238 days, and on 220 and 235 days under PP_ELT and PP_LLT. The average number of days with lethal temperatures was zero for EBC1 and EBC2, and increased to 2 and 5 under the EBC2_ELT and PP_ELT and the EBC2_LLT and PP_LLT scenarios, respectively.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in smolt rearing temperatures for steelhead in the West Delta subregion (Table 5C.C-18). Optimal water temperatures occurred on average on 162 and 163 days under EBC1 and EBC2 scenarios, respectively, and on 146 and 123 days, respectively, under EBC2_ELT and EBC2_LLT. The number of optimal days was slightly lower for PP_ELT and PP_LLT scenarios at 145 and 121 days, respectively. Supraoptimal temperatures for steelhead smolts occurred on 203 days for EBC1 and EBC2, and on 219 to 240 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). No lethal conditions occurred under EBC1, EBC2, and EBC2_ELT, but the number of days with lethal temperatures for steelhead smolts was 5 under EBC2_LLT. In comparison, the average number of days with lethal temperatures was 1 for PP_ELT and 4 under PP_LLT.

Table 5C.C-11. Number of Days within Temperature Requirements for Steelhead Smoltification in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		164	163	162	143	165	142
1977	0	0	0	0	0	0		172	172	135	117	136	120
1978	0	0	0	0	0	0		158	157	152	106	152	116
1979	5	6	0	0	0	0		175	173	160	121	158	122
1980	0	0	0	0	0	0		168	168	169	125	173	130
1981	0	0	0	0	0	0		181	181	166	119	165	121
1982	0	0	0	0	0	0		189	189	170	140	169	139
1983	0	0	0	0	0	0		185	187	151	133	156	147
1984	0	0	0	0	0	0		140	140	159	111	160	111
1985	4	5	2	0	6	0		163	161	133	140	133	138
1986	0	0	0	0	0	0		147	147	129	106	128	115
1987	0	0	0	0	0	0		136	136	132	107	133	107
1988	0	0	0	0	0	0		159	159	126	108	129	108
1989	4	6	0	0	6	0		161	159	133	113	131	115
1990	0	0	0	0	0	0		160	159	140	118	139	118
1991	17	17	15	3	16	4		147	147	136	117	136	119
Avg	2	2	1	0	2	0		163	162	147	120	148	123
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	202	203	204	220	201	222		0	0	0	3	0	2
1977	193	193	230	245	229	242		0	0	0	3	0	3
1978	207	208	213	241	213	232		0	0	0	18	0	17
1979	185	186	205	236	207	238		0	0	0	8	0	5
1980	198	198	197	232	193	228		0	0	0	9	0	8
1981	184	184	199	243	199	241		0	0	0	3	1	3
1982	176	176	195	225	196	226		0	0	0	0	0	0
1983	180	178	210	232	204	218		0	0	4	0	5	0
1984	224	224	206	230	204	231		2	2	1	25	2	24
1985	198	199	230	213	226	213		0	0	0	12	0	14
1986	218	218	236	259	237	250		0	0	0	0	0	0
1987	229	229	233	258	230	258		0	0	0	0	2	0
1988	207	207	231	240	226	240		0	0	9	18	11	18
1989	200	200	232	248	228	246		0	0	0	4	0	4
1990	205	206	225	231	226	232		0	0	0	16	0	15
1991	201	201	214	245	213	242		0	0	0	0	0	0
Avg	200	201	216	237	215	235		0	0	1	7	1	7

Table 5C.C-12. Number of Days within Temperature Requirements for Steelhead Smoltification in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		169	167	160	143	162	139
1977	0	0	0	0	0	0		161	159	136	116	134	112
1978	0	0	0	0	0	0		158	157	148	112	146	104
1979	0	0	0	0	0	0		169	169	164	119	159	117
1980	0	0	0	0	0	0		162	162	164	129	167	127
1981	0	0	0	0	0	0		172	172	157	123	160	117
1982	0	0	0	0	0	0		173	173	159	137	160	139
1983	0	0	0	0	0	0		177	177	150	141	157	143
1984	0	0	0	0	0	0		149	149	151	118	158	112
1985	0	0	0	0	0	0		161	163	156	131	146	134
1986	0	0	0	0	0	0		154	155	140	115	131	114
1987	0	0	0	0	0	0		139	139	133	106	129	104
1988	0	0	0	0	0	0		146	147	130	111	126	106
1989	0	0	0	0	0	0		161	160	140	116	134	114
1990	0	0	0	0	0	0		157	158	139	125	131	121
1991	10	9	9	0	13	0		155	158	138	116	133	117
Avg	1	1	1	0	1	0		160	160	148	122	146	120
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	197	199	200	212	202	222		0	0	6	11	2	5
1977	204	206	229	245	231	249		0	0	0	4	0	4
1978	207	208	217	228	219	238		0	0	0	25	0	23
1979	196	196	201	231	206	242		0	0	0	15	0	6
1980	204	204	202	224	199	230		0	0	0	13	0	9
1981	193	193	208	238	205	246		0	0	0	4	0	2
1982	192	192	206	221	205	226		0	0	0	7	0	0
1983	188	188	215	218	208	220		0	0	0	6	0	2
1984	217	217	215	220	208	224		0	0	0	28	0	30
1985	204	202	209	214	219	216		0	0	0	20	0	15
1986	211	210	225	244	234	251		0	0	0	6	0	0
1987	226	226	232	250	236	261		0	0	0	9	0	0
1988	220	219	236	233	233	241		0	0	0	22	7	19
1989	204	205	225	236	231	247		0	0	0	13	0	4
1990	208	207	226	214	234	225		0	0	0	26	0	19
1991	200	198	218	245	219	248		0	0	0	4	0	0
Avg	204	204	217	230	218	237		0	0	0	13	1	9

Table 5C.C-13. Number of Days within Temperature Requirements for Steelhead Smoltification in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		177	175	165	145	166	145
1977	0	0	2	0	2	0		164	166	150	127	147	128
1978	0	0	0	0	0	0		169	170	156	134	157	132
1979	3	3	0	1	0	1		175	174	167	134	168	134
1980	0	0	0	0	0	0		165	165	165	140	165	139
1981	0	0	0	0	0	0		174	173	164	133	166	135
1982	0	0	2	0	2	0		183	183	167	142	166	142
1983	4	4	1	0	2	0		171	172	158	145	158	145
1984	1	1	2	0	2	0		154	153	156	127	158	130
1985	2	2	0	0	0	0		170	171	174	140	175	145
1986	0	0	0	0	0	0		165	166	158	123	160	124
1987	1	0	0	0	0	0		150	151	150	128	149	128
1988	1	1	0	1	0	1		157	157	164	128	163	128
1989	4	4	0	2	0	2		161	161	149	119	149	119
1990	3	3	2	0	2	0		159	161	150	133	151	132
1991	7	7	7	2	8	2		160	160	152	132	151	131
Avg	2	2	1	0	1	0		166	166	159	133	159	134
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	189	191	189	201	192	208		0	0	12	20	8	13
1977	201	199	213	230	216	227		0	0	0	8	0	10
1978	196	195	209	200	208	201		0	0	0	31	0	32
1979	187	188	198	212	197	219		0	0	0	18	0	11
1980	201	201	201	210	201	213		0	0	0	16	0	14
1981	191	192	201	215	199	215		0	0	0	17	0	15
1982	182	182	196	206	197	212		0	0	0	17	0	11
1983	190	189	206	209	205	211		0	0	0	11	0	9
1984	211	212	208	205	206	206		0	0	0	34	0	30
1985	193	192	191	200	190	195		0	0	0	25	0	25
1986	200	199	207	225	205	228		0	0	0	17	0	13
1987	214	214	215	224	216	227		0	0	0	13	0	10
1988	208	208	202	204	203	209		0	0	0	33	0	28
1989	200	200	216	214	216	221		0	0	0	30	0	23
1990	203	201	212	206	211	208		0	0	1	26	1	25
1991	198	198	205	213	206	216		0	0	1	18	0	16
Avg	198	198	204	211	204	214		0	0	1	21	1	18

Table 5C.C-14. Number of Days within Temperature Requirements for Steelhead Smoltification in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		163	162	165	143	165	137
1977	0	0	0	0	0	0		156	157	129	132	128	125
1978	0	0	0	0	0	0		145	145	142	127	139	125
1979	1	1	0	0	0	0		154	154	146	132	144	130
1980	0	0	0	0	0	0		155	155	152	145	152	141
1981	0	0	0	0	0	0		168	167	147	128	145	124
1982	0	0	0	0	0	0		170	170	142	146	144	142
1983	0	0	0	0	0	0		167	167	139	152	138	156
1984	0	0	0	0	0	0		128	128	153	116	153	114
1985	0	0	0	0	0	0		159	159	140	138	139	140
1986	0	0	0	0	0	0		126	127	117	133	116	133
1987	0	0	0	0	0	0		135	135	126	112	125	110
1988	0	0	0	0	0	0		142	144	126	116	125	113
1989	0	0	0	0	0	0		157	157	129	118	126	114
1990	0	0	0	0	0	0		157	157	136	118	138	117
1991	7	8	6	0	6	0		156	155	142	144	144	141
Avg	1	1	0	0	0	0		152	152	139	131	139	129
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	203	204	201	223	201	229		0	0	0	0	0	0
1977	209	208	236	233	237	240		0	0	0	0	0	0
1978	219	219	223	238	226	240		1	1	0	0	0	0
1979	210	210	219	233	221	235		0	0	0	0	0	0
1980	210	210	210	221	210	225		1	1	4	0	4	0
1981	197	198	218	237	220	241		0	0	0	0	0	0
1982	195	195	223	219	221	223		0	0	0	0	0	0
1983	197	197	207	213	205	209		1	1	19	0	22	0
1984	237	237	211	247	210	246		1	1	2	3	3	6
1985	206	206	225	226	226	223		0	0	0	1	0	2
1986	239	238	248	232	249	232		0	0	0	0	0	0
1987	230	230	236	253	233	255		0	0	3	0	7	0
1988	224	222	231	235	229	238		0	0	9	15	12	15
1989	208	208	236	247	239	251		0	0	0	0	0	0
1990	208	208	229	240	227	241		0	0	0	7	0	7
1991	202	202	217	221	215	224		0	0	0	0	0	0
Avg	212	212	223	232	223	235		0	0	2	2	3	2

Table 5C.C-15. Number of Days within Temperature Requirements for Steelhead Smoltification in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		161	161	162	131	164	131
1977	0	0	0	0	0	0		160	160	123	114	123	114
1978	0	0	0	0	0	0		139	139	136	112	135	118
1979	0	0	0	0	0	0		163	163	138	124	142	127
1980	0	0	0	0	0	0		159	158	150	135	148	135
1981	0	0	0	0	0	0		168	166	150	114	151	112
1982	0	0	0	0	0	0		170	171	145	138	149	138
1983	0	0	0	0	0	0		168	169	143	152	139	150
1984	0	0	0	0	0	0		126	126	159	111	158	114
1985	0	0	0	0	0	0		162	162	116	139	115	136
1986	0	0	0	0	0	0		118	120	97	124	98	128
1987	0	0	0	0	0	0		126	128	121	103	120	103
1988	0	0	0	0	0	0		143	144	117	98	116	96
1989	0	0	0	0	0	0		151	151	122	113	121	114
1990	0	0	0	0	0	0		155	155	132	112	131	114
1991	11	11	10	0	9	0		152	152	126	119	128	121
Avg	1	1	1	0	1	0		151	152	134	121	134	122
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	205	205	204	233	202	233		0	0	0	2	0	2
1977	205	205	241	247	242	248		0	0	1	4	0	3
1978	226	226	229	237	229	233		0	0	0	16	1	14
1979	202	202	227	237	223	235		0	0	0	4	0	3
1980	207	208	215	223	215	227		0	0	1	8	3	4
1981	197	199	214	244	213	245		0	0	1	7	1	8
1982	195	194	220	227	216	227		0	0	0	0	0	0
1983	196	195	206	213	211	215		1	1	16	0	15	0
1984	235	235	203	225	201	227		5	5	4	30	7	25
1985	203	203	249	216	250	220		0	0	0	10	0	9
1986	247	245	268	241	267	237		0	0	0	0	0	0
1987	239	237	232	262	232	262		0	0	12	0	13	0
1988	223	222	235	250	236	252		0	0	14	18	14	18
1989	214	214	243	248	244	248		0	0	0	4	0	3
1990	210	210	233	238	234	241		0	0	0	15	0	10
1991	202	202	229	246	228	244		0	0	0	0	0	0
Avg	213	213	228	237	228	237		0	0	3	7	3	6

Table 5C.C-16. Number of Days within Temperature Requirements for Steelhead Smoltification in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		167	166	167	156	166	153
1977	0	0	0	0	0	0		149	149	132	134	132	133
1978	0	0	0	0	0	0		143	143	136	121	137	121
1979	0	0	0	0	0	0		167	170	156	129	154	128
1980	0	0	0	0	0	0		164	165	155	141	155	141
1981	0	0	0	0	0	0		167	170	157	133	156	132
1982	0	0	0	0	0	0		159	160	148	148	149	147
1983	0	0	0	0	0	0		182	181	150	144	151	147
1984	0	0	0	0	0	0		139	139	152	117	153	112
1985	0	0	0	0	0	0		156	156	144	148	144	146
1986	0	0	0	0	0	0		153	153	130	120	130	120
1987	0	0	0	0	0	0		135	134	128	125	127	125
1988	0	0	0	0	0	0		142	142	126	128	126	127
1989	0	0	0	0	0	0		151	152	136	121	135	120
1990	0	0	0	0	0	0		140	140	124	126	124	124
1991	0	0	0	0	0	0		163	163	143	147	143	146
Avg	0	0	0	0	0	0		155	155	143	134	143	133
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	199	200	199	210	200	213		0	0	0	0	0	0
1977	216	216	233	231	233	232		0	0	0	0	0	0
1978	222	222	229	241	228	240		0	0	0	3	0	4
1979	198	195	209	236	211	237		0	0	0	0	0	0
1980	202	201	211	224	211	225		0	0	0	1	0	0
1981	198	195	208	232	209	233		0	0	0	0	0	0
1982	206	205	217	217	216	218		0	0	0	0	0	0
1983	183	184	214	221	212	218		0	0	1	0	2	0
1984	227	227	214	243	213	248		0	0	0	6	0	6
1985	209	209	221	217	221	218		0	0	0	0	0	1
1986	212	212	235	245	235	245		0	0	0	0	0	0
1987	230	231	237	240	238	240		0	0	0	0	0	0
1988	224	224	240	233	240	234		0	0	0	5	0	5
1989	214	213	229	244	230	245		0	0	0	0	0	0
1990	225	225	241	234	241	235		0	0	0	5	0	6
1991	202	202	222	218	222	219		0	0	0	0	0	0
Avg	210	210	222	230	223	231		0	0	0	1	0	1

Table 5C.C-17. Number of Days within Temperature Requirements for Steelhead Smoltification in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		161	161	166	138	165	144
1977	0	0	0	0	0	0		165	165	126	127	131	124
1978	0	0	0	0	0	0		158	159	155	107	154	114
1979	0	1	0	0	0	0		180	177	143	120	144	124
1980	0	0	0	0	0	0		169	170	159	122	160	124
1981	0	0	0	0	0	0		178	177	163	120	160	125
1982	0	0	0	0	0	0		187	188	163	136	161	137
1983	0	2	0	0	0	0		188	185	158	145	157	141
1984	0	0	0	0	0	0		133	132	160	109	159	108
1985	8	10	0	0	0	0		156	154	120	145	119	144
1986	0	0	0	0	0	0		147	146	123	111	127	111
1987	0	0	0	0	0	0		129	132	124	105	125	107
1988	0	0	0	0	0	0		149	150	122	106	123	121
1989	0	0	0	0	0	0		155	155	124	114	124	117
1990	0	0	0	0	0	0		156	156	136	117	129	120
1991	6	8	6	0	11	0		157	155	140	140	136	145
Avg	1	1	0	0	1	0		161	160	143	123	142	125
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	205	205	200	228	201	222		0	0	0	0	0	0
1977	200	200	239	236	234	238		0	0	0	2	0	3
1978	207	206	210	248	211	242		0	0	0	10	0	9
1979	185	187	222	242	221	239		0	0	0	3	0	2
1980	197	196	207	239	206	238		0	0	0	5	0	4
1981	187	188	201	238	203	237		0	0	1	7	2	3
1982	178	177	202	229	204	228		0	0	0	0	0	0
1983	177	178	193	220	194	224		0	0	14	0	14	0
1984	229	230	201	237	202	239		4	4	5	20	5	19
1985	201	201	245	213	246	215		0	0	0	7	0	6
1986	218	219	242	254	238	254		0	0	0	0	0	0
1987	236	233	234	260	234	258		0	0	7	0	6	0
1988	217	216	233	245	232	229		0	0	11	15	11	16
1989	210	210	241	250	241	247		0	0	0	1	0	1
1990	209	209	229	238	236	234		0	0	0	10	0	11
1991	202	202	219	225	218	220		0	0	0	0	0	0
Avg	204	204	220	238	220	235		0	0	2	5	2	5

Table 5C.C-18. Number of Days within Temperature Requirements for Steelhead Smoltification in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<7°C)							Optimal (≥7°C and ≤15°C)					
1976	0	0	0	0	0	0		167	167	163	139	162	133
1977	0	0	0	0	0	0		162	162	134	122	133	121
1978	0	0	0	0	0	0		157	158	151	108	147	108
1979	0	0	0	0	0	0		184	184	162	118	157	120
1980	0	0	0	0	0	0		167	167	158	131	158	129
1981	0	0	0	0	0	0		180	180	162	120	162	115
1982	0	0	0	0	0	0		185	187	159	141	159	138
1983	0	0	0	0	0	0		183	183	154	144	152	146
1984	0	0	0	0	0	0		144	144	157	116	158	112
1985	0	0	0	0	0	0		162	162	140	144	139	142
1986	0	0	0	0	0	0		153	153	121	114	120	113
1987	0	0	0	0	0	0		133	134	130	109	128	106
1988	0	0	0	0	0	0		149	149	124	105	125	102
1989	0	0	0	0	0	0		151	151	137	111	137	110
1990	0	0	0	0	0	0		158	158	140	116	140	115
1991	0	0	0	0	0	0		163	163	148	135	148	133
Avg	0	0	0	0	0	0		162	163	146	123	145	121
	Supraoptimal (>15°C and ≤24°C)							Lethal (>24°C)					
1976	199	199	203	227	204	233		0	0	0	0	0	0
1977	203	203	231	243	232	244		0	0	0	0	0	0
1978	208	207	214	242	218	246		0	0	0	15	0	11
1979	181	181	203	246	208	245		0	0	0	1	0	0
1980	199	199	208	226	208	234		0	0	0	9	0	3
1981	185	185	203	245	203	250		0	0	0	0	0	0
1982	180	178	206	224	206	227		0	0	0	0	0	0
1983	182	182	208	221	205	219		0	0	3	0	8	0
1984	222	222	209	233	207	237		0	0	0	17	1	17
1985	203	203	225	212	226	215		0	0	0	9	0	8
1986	212	212	244	251	245	252		0	0	0	0	0	0
1987	232	231	235	256	237	259		0	0	0	0	0	0
1988	217	217	240	246	235	249		0	0	2	15	6	15
1989	214	214	228	254	228	255		0	0	0	0	0	0
1990	207	207	225	241	225	243		0	0	0	8	0	7
1991	202	202	217	230	217	232		0	0	0	0	0	0
Avg	203	203	219	237	219	240		0	0	0	5	1	4

5C.C.1.3 Adult

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult steelhead in the Cache Slough subregion (Table 5C.C-19). The average number of optimal days was 186 days under EBC1 and EBC2 and varied from 189 to 197 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 11 and 12 under EBC1 and EBC2, 15 to 23 days under EBC2_ELT and PP_ELT, and 25 to 23 days under EBC2_LLT and PP_LLT. On average there were 2 lethal days under EBC2_LLT and 3 lethal days under the PP_LTT scenario.

EBC scenarios and PP scenarios in water temperatures for adult steelhead in the East Delta subregion (Table 5C.C-20) differed little when accounting for climate change. The average number of optimal days was 190 under EBC1 and EBC2, 195–199 under EBC2_ELT and EBC2_LLT, and 196 to 197 under PP_ELT and PP_LLT, respectively. The average number of supraoptimal days was 14 for EBC1 and EBC2, 17 and 27 days under EBC2_ELT and EBC2_LLT, and 16 and 26 days under PP_ELT and PP_LLT. There was an average of 3 lethal temperature days for EBC2_LLT and PP_LLT, respectively.

Water temperatures for adult steelhead in the North Delta subregion (Table 5C.C-21) were similar across scenarios, considering climate change effects on water temperature. The average number of optimal water temperature days was 169 for EBC1 and EBC2 and varied between 173 and 188 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 13 days under EBC1 and EBC2, and ranged from 17 to 28 days under EBC2_ELT, EBC2_LLT, and from 16 to 28 under PP_ELT and PP_LLT. There were no days with lethal temperatures under any scenario.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult steelhead in the San Joaquin portion of the South Delta subregion (Table 5C.C-22). A moderate difference was observed in the evaluation of suboptimal water temperatures for adult steelhead. Suboptimal water temperatures occurred on average on 16 days under EBC1 and EBC2. In the early long-term period, suboptimal conditions occurred on 19 and 29 days, respectively, under EBC2_ELT and PP_ELT, representing a moderate adverse effect of the preliminary proposal. In the late long-term, suboptimal conditions occurred on 23 and 18 days, respectively, under EBC2_LLT and PP_LLT, representing a small benefit of the preliminary proposal. Optimal water temperatures occurred on 189 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 195 to 201. Supraoptimal and lethal temperatures were not observed under any scenario.

Water temperatures in the South Delta for adult steelhead were generally similar among the different scenarios (considering climate change) (Table 5C.C-23). Suboptimal water temperatures occurred on 36–37 days on average under EBC1 and EBC2, and on 15–27 days under the remaining alternatives (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Under EBC1 and EBC2, optimal water temperatures occurred on 192 days per year, on average. Under EBC2_ELT, and EBC2_LLT, optimal temperature conditions occurred on 198 to 199 days per year; and on 198 to 200 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 14 days under EBC1 and EBC2, and on 17 to 26 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Lethal temperature days occurred on average on 0 to 3 days under model scenarios.

In the Suisun Bay subregion, water temperatures for adult steelhead were similar among scenarios (Table 5C.C-24) after accounting for changing climate. Optimal water temperatures were reached on average on 189 and 188 days under EBC1 and EBC2 scenarios. The number of days of optimal water temperature conditions was 192 and 189 days for all other scenarios. EBC1 and EBC2 averaged 10 and 11 days of supraoptimal days, respectively, while the number of days for EBC2_ELT and EBC2_LTT and PP_ELT and PP_LLT varied from 13 to 25 days. There were no lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for adult steelhead were minor, after climate change was taken into consideration (Table 5C.C-25). Optimal temperatures occurred on average on 186 days under EBC1 and EBC2 and on 191 to 194 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 10 days under EBC1 and EBC2, and on 13 to 23 days under all other scenarios (i.e., EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did occur on average on only 2 days under the EBC2_LLT and PP_LLT scenarios.

Water temperatures in the West Delta for adult steelhead were generally similar among the different scenarios (considering climate change) (Table 5C.C-26). Under EBC1 and EBC2, optimal water temperatures occurred on 183 days per year, on average. Under EBC2_ELT, and EBC2_LLT, optimal temperature conditions occurred on 188 to 194 days per year; and on 190 to 194 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 13 and 12 days under EBC1 and EBC2, respectively, and on 16 to 29 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Lethal temperature days occurred on average once annually under the EBC2_LLT and PP_LLT scenarios.

Table 5C.C-19. Number of Days within Temperature Requirements for Steelhead Adults in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	40	40	35	15	35	16		190	190	189	207	190	207
1977	60	60	49	30	48	35		169	169	179	189	181	185
1978	4	5	0	0	2	0		238	237	234	213	233	214
1979	52	51	46	25	62	38		166	167	170	174	153	164
1980	35	32	24	3	40	10		208	211	208	223	198	219
1981	42	41	30	4	32	4		181	182	185	203	184	203
1982	42	42	26	3	43	17		188	188	200	220	184	207
1983	48	48	34	17	38	19		177	177	178	198	175	196
1984	35	35	57	4	58	10		186	185	180	208	181	203
1985	61	61	27	55	25	56		178	178	205	169	209	170
1986	36	36	42	21	45	21		201	199	195	201	191	201
1987	48	48	40	28	41	27		192	192	184	187	183	190
1988	47	45	34	15	37	15		175	177	197	195	194	197
1989	63	63	53	28	55	26		173	173	181	193	181	196
1990	59	60	40	22	48	26		172	170	189	193	182	189
1991	42	43	31	25	30	25		184	183	198	176	200	177
Avg	45	44	36	18	40	22		186	186	192	197	189	195
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	13	13	19	21	18	20		0	0	0	0	0	0
1977	13	13	14	19	13	20		0	0	0	4	0	2
1978	0	0	8	28	7	27		0	0	0	1	0	1
1979	24	24	23	36	23	31		0	0	3	7	4	9
1980	0	0	11	17	5	14		0	0	0	0	0	0
1981	19	19	27	35	26	35		0	0	0	0	0	0
1982	12	12	16	16	15	14		0	0	0	3	0	4
1983	17	17	30	24	29	23		0	0	0	3	0	4
1984	22	23	6	19	4	14		0	0	0	12	0	16
1985	3	3	10	18	8	16		0	0	0	0	0	0
1986	5	7	5	20	6	20		0	0	0	0	0	0
1987	2	2	18	26	18	24		0	0	0	1	0	1
1988	18	18	12	26	12	24		3	3	0	7	0	7
1989	6	6	8	21	6	20		0	0	0	0	0	0
1990	11	12	13	27	12	27		0	0	0	0	0	0
1991	16	16	13	40	12	38		0	0	0	1	0	2
Avg	11	12	15	25	13	23		0	0	0	2	0	3

Table 5C.C-20. Number of Days within Temperature Requirements for Steelhead Adults in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	39	39	30	5	32	6		193	193	194	216	192	217
1977	59	53	45	13	46	25		170	176	182	204	181	194
1978	4	4	0	0	0	0		229	229	225	214	230	213
1979	46	45	41	22	43	25		175	176	171	183	172	174
1980	31	30	32	9	27	5		205	204	197	206	203	217
1981	42	42	30	4	26	4		179	179	189	202	190	202
1982	45	47	29	8	25	6		182	180	198	209	201	217
1983	38	38	15	9	16	10		181	181	202	205	197	204
1984	41	41	55	9	55	5		178	178	176	197	179	206
1985	59	59	25	33	24	51		178	178	205	186	208	168
1986	24	23	23	20	33	17		210	211	209	201	204	205
1987	47	47	36	20	39	24		191	193	196	185	186	186
1988	20	20	14	7	21	12		206	205	216	202	210	196
1989	50	52	38	17	45	24		189	187	191	199	188	191
1990	46	47	39	16	28	19		175	174	183	194	196	192
1991	33	32	29	20	31	23		193	196	193	182	193	176
Avg	39	39	30	13	31	16		190	190	195	199	196	197
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	11	11	16	19	18	20		0	0	3	3	1	0
1977	13	13	15	20	15	19		0	0	0	5	0	4
1978	9	9	17	26	12	28		0	0	0	2	0	1
1979	21	21	30	31	27	35		0	0	0	6	0	8
1980	7	9	14	28	13	21		0	0	0	0	0	0
1981	21	21	23	35	26	36		0	0	0	1	0	0
1982	15	15	15	22	16	14		0	0	0	3	0	5
1983	23	23	25	28	29	25		0	0	0	0	0	3
1984	24	24	12	28	9	16		0	0	0	9	0	16
1985	5	5	12	23	10	23		0	0	0	0	0	0
1986	8	8	10	21	5	20		0	0	0	0	0	0
1987	4	2	10	36	17	29		0	0	0	1	0	3
1988	17	18	13	26	12	27		0	0	0	8	0	8
1989	3	3	13	26	9	27		0	0	0	0	0	0
1990	21	21	20	32	18	31		0	0	0	0	0	0
1991	16	14	20	35	18	40		0	0	0	5	0	3
Avg	14	14	17	27	16	26		0	0	0	3	0	3

Table 5C.C-21. Number of Days within Temperature Requirements for Steelhead Adults in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	61	59	36	15	34	14		172	174	186	204	187	208
1977	63	63	51	23	51	29		169	169	176	192	177	187
1978	51	50	37	7	39	6		180	176	186	205	187	207
1979	70	67	62	34	62	34		151	155	150	171	151	170
1980	53	53	53	23	52	22		181	178	175	191	179	193
1981	48	48	53	12	52	13		174	177	170	194	168	194
1982	58	58	50	23	50	24		166	165	179	192	181	189
1983	62	62	52	22	52	22		160	160	169	191	169	189
1984	57	57	59	17	58	17		164	165	169	191	176	192
1985	68	67	63	42	64	45		168	170	166	175	166	173
1986	57	56	49	23	50	25		177	177	178	195	183	196
1987	67	67	51	30	53	28		164	170	180	178	178	180
1988	55	55	45	19	47	19		175	174	182	191	178	188
1989	63	63	63	28	61	29		173	174	166	183	168	184
1990	66	66	64	29	65	30		157	157	157	178	156	178
1991	60	60	49	24	48	22		170	170	175	180	177	182
Avg	60	59	52	23	52	24		169	169	173	188	174	188
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	10	10	19	21	20	18		0	0	0	0	0	0
1977	10	10	15	22	14	21		0	0	0	0	0	0
1978	11	16	19	28	16	25		0	0	0	0	0	0
1979	21	20	30	33	29	35		0	0	0	0	0	0
1980	9	12	15	29	12	28		0	0	0	0	0	0
1981	20	17	19	34	22	33		0	0	0	0	0	0
1982	18	19	13	25	11	29		0	0	0	0	0	0
1983	20	20	21	26	21	29		0	0	0	0	0	0
1984	22	21	15	31	9	29		0	0	0	0	0	0
1985	6	5	13	25	12	24		0	0	0	0	0	0
1986	8	9	15	22	9	20		0	0	0	0	0	0
1987	11	5	11	33	11	33		0	0	0	0	0	0
1988	12	13	16	25	18	29		0	0	0	0	0	0
1989	6	5	13	31	13	29		0	0	0	0	0	0
1990	19	19	21	34	21	31		0	0	0	0	0	0
1991	12	12	18	33	17	33		0	0	0	0	0	0
Avg	13	13	17	28	16	28		0	0	0	0	0	0

Table 5C.C-22. Number of Days within Temperature Requirements for Steelhead Adults in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	14	15	16	16	35	12		192	190	190	212	193	215
1977	12	12	13	16	45	27		177	177	184	199	183	199
1978	13	12	17	26	0	0		229	229	225	216	225	214
1979	28	29	34	35	38	29		170	169	168	175	170	176
1980	11	10	16	14	16	8		208	209	209	221	211	222
1981	23	23	30	33	20	0		181	181	190	207	194	208
1982	18	18	19	18	15	12		199	199	206	210	208	210
1983	27	27	29	26	25	20		184	184	193	197	187	196
1984	28	28	14	30	48	8		191	191	179	205	184	205
1985	7	7	18	12	27	50		176	176	197	181	198	178
1986	12	12	13	17	30	15		203	204	199	210	200	210
1987	7	6	20	19	35	22		190	191	186	196	188	200
1988	19	17	14	24	25	12		182	184	204	201	204	201
1989	6	6	12	16	46	27		181	180	184	200	184	196
1990	18	17	17	26	30	19		178	178	195	197	194	197
1991	17	15	20	35	31	24		184	187	190	184	194	181
Avg	16	16	19	23	29	18		189	189	194	201	195	201
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		2	2	0	4	0	4
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-23. Number of Days within Temperature Requirements for Steelhead Adults in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	38	38	36	5	35	2		192	192	188	215	189	219
1977	52	52	44	16	44	17		177	177	184	204	184	203
1978	0	0	0	0	0	0		240	240	231	213	229	214
1979	51	49	36	25	35	24		162	164	176	169	175	170
1980	22	22	8	4	10	6		221	221	216	222	214	223
1981	38	38	15	0	11	0		181	181	198	204	203	206
1982	19	20	7	0	5	0		209	208	219	221	221	222
1983	30	31	12	15	18	16		187	186	200	200	194	200
1984	23	24	54	3	49	10		194	193	180	208	187	201
1985	60	60	25	51	25	51		178	178	204	171	204	171
1986	27	27	35	16	33	16		208	207	199	205	201	205
1987	46	46	36	17	33	14		194	195	185	199	188	202
1988	36	36	31	12	31	12		186	186	197	195	197	196
1989	58	59	39	27	39	24		177	176	194	192	194	194
1990	46	46	25	20	25	19		180	180	197	194	200	195
1991	36	36	30	23	29	23		186	186	192	176	194	176
Avg	36	37	27	15	26	15		192	192	198	199	198	200
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	13	13	19	23	19	22		0	0	0	0	0	0
1977	13	13	14	18	14	18		0	0	0	4	0	4
1978	2	2	11	28	13	28		0	0	0	1	0	0
1979	29	29	25	40	27	40		0	0	5	8	5	8
1980	0	0	19	17	19	14		0	0	0	0	0	0
1981	23	23	29	38	28	36		0	0	0	0	0	0
1982	14	14	16	21	16	20		0	0	0	0	0	0
1983	25	25	26	25	25	24		0	0	4	2	5	2
1984	26	26	9	15	7	15		0	0	0	17	0	17
1985	4	4	13	20	13	20		0	0	0	0	0	0
1986	7	8	8	21	8	21		0	0	0	0	0	0
1987	2	1	21	25	21	25		0	0	0	1	0	1
1988	18	18	15	28	15	28		3	3	0	8	0	7
1989	7	7	9	23	9	24		0	0	0	0	0	0
1990	16	16	20	28	17	28		0	0	0	0	0	0
1991	20	20	20	41	19	41		0	0	0	2	0	2
Avg	14	14	17	26	17	25		0	0	1	3	1	3

Table 5C.C-24. Number of Days within Temperature Requirements for Steelhead Adults in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	37	35	42	22	41	21		194	196	182	203	183	204
1977	49	49	50	43	50	43		181	181	179	181	179	180
1978	10	10	3	0	1	0		230	230	231	212	233	213
1979	55	56	49	40	51	41		164	163	171	165	169	163
1980	36	37	33	16	33	17		207	206	201	211	201	209
1981	38	39	24	16	23	13		194	192	200	192	200	194
1982	51	51	40	22	41	22		178	178	186	199	185	199
1983	47	47	34	24	33	24		177	177	178	190	179	191
1984	38	37	57	17	57	16		181	182	179	195	182	196
1985	60	60	35	58	35	58		179	179	197	166	198	166
1986	35	36	36	29	37	31		200	199	199	196	198	194
1987	42	43	35	38	35	35		198	197	195	182	194	185
1988	43	44	36	23	37	24		186	184	192	191	191	190
1989	50	54	45	46	45	46		187	182	190	177	190	177
1990	55	55	41	36	39	34		177	177	190	180	192	182
1991	44	43	30	27	31	28		186	187	202	180	200	179
Avg	43	44	37	29	37	28		189	188	192	189	192	189
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	12	12	19	18	19	18		0	0	0	0	0	0
1977	12	12	13	18	13	19		0	0	0	0	0	0
1978	2	2	8	30	8	29		0	0	0	0	0	0
1979	23	23	22	37	22	38		0	0	0	0	0	0
1980	0	0	9	16	9	17		0	0	0	0	0	0
1981	10	11	18	34	19	35		0	0	0	0	0	0
1982	13	13	16	21	16	21		0	0	0	0	0	0
1983	18	18	30	28	30	27		0	0	0	0	0	0
1984	24	24	7	31	4	31		0	0	0	0	0	0
1985	3	3	10	18	9	18		0	0	0	0	0	0
1986	7	7	7	17	7	17		0	0	0	0	0	0
1987	2	2	12	22	13	22		0	0	0	0	0	0
1988	14	15	15	27	15	26		0	0	0	2	0	3
1989	5	6	7	19	7	19		0	0	0	0	0	0
1990	10	10	11	26	11	26		0	0	0	0	0	0
1991	12	12	10	35	11	35		0	0	0	0	0	0
Avg	10	11	13	25	13	25		0	0	0	0	0	0

Table 5C.C-25. Number of Days within Temperature Requirements for Steelhead Adults in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	40	40	38	16	37	20		190	190	186	210	188	207
1977	53	52	48	39	49	41		176	177	180	182	180	180
1978	1	1	0	0	0	0		241	241	238	214	236	214
1979	62	63	60	37	57	40		160	157	157	161	159	161
1980	40	40	29	5	27	13		203	203	206	226	208	218
1981	40	40	22	4	24	16		185	184	197	203	192	191
1982	47	47	41	24	38	24		184	184	185	200	188	200
1983	64	65	35	29	34	29		163	162	177	186	178	186
1984	38	38	60	11	60	8		182	182	180	202	180	205
1985	63	62	28	55	27	57		177	177	208	169	206	170
1986	37	36	38	21	42	23		200	201	199	201	193	200
1987	49	49	39	30	39	31		193	192	184	191	185	189
1988	45	44	34	20	35	22		182	182	197	192	197	190
1989	60	59	51	36	52	41		181	180	188	191	182	184
1990	60	60	39	24	34	26		175	174	193	192	197	190
1991	47	43	31	25	31	27		183	186	202	180	200	178
Avg	47	46	37	24	37	26		186	186	192	194	192	191
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	13	13	19	17	18	16		0	0	0	0	0	0
1977	13	13	14	20	13	20		0	0	0	1	0	1
1978	0	0	4	28	6	28		0	0	0	0	0	0
1979	20	22	21	40	21	37		0	0	4	4	5	4
1980	0	0	8	12	8	12		0	0	0	0	0	0
1981	17	18	23	35	26	35		0	0	0	0	0	0
1982	11	11	16	18	16	18		0	0	0	0	0	0
1983	15	15	30	25	30	25		0	0	0	2	0	2
1984	23	23	3	17	3	21		0	0	0	13	0	9
1985	2	3	6	18	9	15		0	0	0	0	0	0
1986	5	5	5	20	7	19		0	0	0	0	0	0
1987	0	1	19	21	18	22		0	0	0	0	0	0
1988	15	16	12	24	11	24		1	1	0	7	0	7
1989	1	3	3	15	8	17		0	0	0	0	0	0
1990	7	8	10	26	11	26		0	0	0	0	0	0
1991	12	13	9	37	11	36		0	0	0	0	0	1
Avg	10	10	13	23	14	23		0	0	0	2	0	2

Table 5C.C-26. Number of Days within Temperature Requirements for Steelhead Adults in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	41	41	34	14	32	14		188	188	189	203	191	204
1977	54	53	48	24	47	34		174	175	179	197	180	187
1978	9	9	0	0	0	0		233	233	235	212	237	212
1979	60	61	58	26	56	28		158	158	152	165	154	164
1980	39	39	34	6	31	4		204	204	192	220	199	223
1981	43	44	24	0	20	0		176	175	191	202	196	202
1982	53	53	44	15	38	11		176	176	181	203	187	205
1983	48	48	34	17	33	16		172	173	178	195	179	196
1984	42	42	57	5	57	5		176	178	177	203	179	204
1985	62	62	35	53	32	53		176	176	197	168	200	168
1986	35	35	38	19	37	21		199	199	197	202	199	200
1987	48	49	37	29	36	29		194	193	185	184	185	186
1988	51	51	34	14	34	15		174	174	192	193	193	192
1989	58	58	54	30	53	29		179	179	183	190	184	192
1990	65	66	44	18	42	19		164	163	180	194	184	193
1991	48	42	31	25	31	25		177	183	199	172	199	172
Avg	47	47	38	18	36	19		183	183	188	194	190	194
	Supraoptimal (>20°C and ≤23°C)							Lethal (>23°C)					
1976	14	14	20	26	20	25		0	0	0	0	0	0
1977	14	14	15	21	15	21		0	0	0	0	0	0
1978	0	0	7	30	5	30		0	0	0	0	0	0
1979	24	23	32	51	32	50		0	0	0	0	0	0
1980	0	0	17	17	13	16		0	0	0	0	0	0
1981	23	23	27	40	26	40		0	0	0	0	0	0
1982	13	13	17	24	17	26		0	0	0	0	0	0
1983	22	21	30	30	30	30		0	0	0	0	0	0
1984	25	23	9	24	7	19		0	0	0	11	0	15
1985	4	4	10	21	10	21		0	0	0	0	0	0
1986	8	8	7	21	6	21		0	0	0	0	0	0
1987	0	0	20	29	21	27		0	0	0	0	0	0
1988	18	18	17	28	16	28		0	0	0	8	0	8
1989	5	5	5	22	5	21		0	0	0	0	0	0
1990	13	13	18	30	16	30		0	0	0	0	0	0
1991	17	17	12	45	12	45		0	0	0	0	0	0
Avg	13	12	16	29	16	28		0	0	0	1	0	1

5C.C.2 Winter-Run Chinook Salmon

5C.C.2.1 Juvenile

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile winter-run Chinook salmon in the Cache Slough subregion (Table 5C.C-27). The average number of optimal days over the 16 simulated years was 76 and 77 days under EBC1 and EBC2 and 82 to 99 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. On average there were no supraoptimal or lethal days under any scenario, although 1 day in 1987 had supraoptimal conditions under EBC2_LLT and PP_LLT scenarios.

EBC scenarios and PP scenarios in water temperatures for juvenile winter-run Chinook salmon in the East Delta subregion (Table 5C.C-28) differed little when accounting for climate change. The average number of optimal days was 70 days under EBC1 and EBC2 and 77 and 100 days under EBC2_ELT and EBC2_LLT, respectively, and 83 and 102 days under PP_ELT and PP_LLT, respectively. The average number of supraoptimal and lethal temperature days was zero under all scenarios.

EBC scenarios and PP scenarios in water temperatures for juvenile winter-run Chinook salmon in the North Delta subregion (Table 5C.C-29) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 58 for EBC1 and EBC2, and between 64 and 88 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). No supraoptimal or lethal water temperatures were reached during the modeling period under any scenario.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile winter-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-30). Optimal water temperatures occurred on 79 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the average number of days with optimal water temperatures ranged from 86 to 95. Supraoptimal or lethal temperatures were not reached under any scenario.

Water temperatures in the South Delta for juvenile winter-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-31). Suboptimal water temperatures occurred on 95 days per year on average under EBC1 and EBC2, and on 80–87 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Under EBC1 and EBC2, optimal water temperatures occurred on 86 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 94 and 102 days per year, respectively; and on 94 and 101 days under PP_ELT and PP_LLT. There were no days with supraoptimal or lethal temperatures under any scenario.

In the Suisun Bay subregion, water temperatures for juvenile winter-run Chinook salmon were similar among scenarios (Table 5C.C-32) after accounting for changing climate. Optimal water temperatures were reached on average on 75 and 74 days under EBC1 and EBC2. The average number of optimal days for all other scenarios ranged from 80 to 87. There were no supraoptimal or lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for juvenile winter-run Chinook salmon were minor, after climate change was taken into consideration (Table 5C.C-33). Optimal temperatures occurred on average on 78 days under EBC1 and EBC2, and on 86 to 96 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal or lethal water temperature conditions did not occur under any scenario.

Water temperatures in the West Delta for juvenile winter-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-34). Under EBC1 and EBC2, optimal water temperatures occurred on 73 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 80 and 96 days per year, respectively; and on 85 and 98 days under PP_ELT and PP_LLT. Days with supraoptimal or lethal temperatures did not occur under any scenario.

Table 5C.C-27. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	123	121	104	90	108	89		59	61	78	92	74	93
1977	96	95	83	80	84	80		85	86	98	101	97	101
1978	91	91	82	57	85	70		90	90	99	124	96	111
1979	112	112	111	92	113	99		69	69	70	89	68	82
1980	104	104	94	75	103	86		78	78	88	107	79	96
1981	106	102	89	79	91	78		75	79	92	102	90	103
1982	111	112	101	81	109	82		70	69	80	100	72	99
1983	115	115	108	88	117	92		66	66	73	93	64	89
1984	105	106	103	92	108	92		77	76	79	90	74	90
1985	108	106	97	90	96	91		73	75	84	91	85	90
1986	98	97	83	84	98	91		83	84	98	97	83	90
1987	102	101	90	77	89	78		79	80	91	103	92	102
1988	91	88	85	75	86	73		91	94	97	107	96	109
1989	111	111	102	94	102	93		70	70	79	87	79	88
1990	105	105	100	89	99	88		76	76	81	92	82	93
1991	108	108	98	80	104	81		73	73	83	101	77	100
Avg	105	105	96	83	100	85		76	77	86	99	82	96
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	1	0	1		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-28. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	114	112	103	89	98	84		68	70	79	93	84	98
1977	97	101	86	77	82	79		84	80	95	104	99	102
1978	91	91	83	59	76	55		90	90	98	122	105	126
1979	119	118	116	91	111	86		62	63	65	90	70	95
1980	118	118	120	76	108	73		64	64	62	106	74	109
1981	124	121	99	72	91	77		57	60	82	109	90	104
1982	119	119	115	87	111	82		62	62	66	94	70	99
1983	133	133	108	85	113	84		48	48	73	96	68	97
1984	109	109	119	92	108	89		73	73	63	90	74	93
1985	113	113	113	89	103	89		68	68	68	92	78	92
1986	117	117	111	80	102	80		64	64	70	101	79	101
1987	103	103	97	71	86	74		78	78	84	110	95	107
1988	89	90	89	67	86	69		93	92	93	115	96	113
1989	113	113	104	90	102	90		68	68	77	91	79	91
1990	110	111	106	90	96	87		71	70	75	91	85	94
1991	104	106	100	78	95	77		77	75	81	103	86	104
Avg	111	111	104	81	98	80		70	70	77	100	83	102
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-29. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	125	124	108	98	108	99		57	58	74	84	74	83
1977	131	132	117	86	118	83		50	49	64	95	63	98
1978	115	115	108	82	110	83		66	66	73	99	71	98
1979	131	130	125	103	123	102		50	51	56	78	58	79
1980	125	125	128	93	126	92		57	57	54	89	56	90
1981	131	130	117	92	119	93		50	51	64	89	62	88
1982	127	127	118	96	118	96		54	54	63	85	63	85
1983	141	141	113	99	112	99		40	40	68	82	69	82
1984	117	117	126	93	125	92		65	65	56	89	57	90
1985	123	124	137	102	135	102		58	57	44	79	46	79
1986	123	123	114	93	114	93		58	58	67	88	67	88
1987	113	112	116	87	116	87		68	69	65	94	65	94
1988	104	106	109	77	110	77		78	76	73	105	72	105
1989	122	122	110	100	110	101		59	59	71	81	71	80
1990	116	117	110	103	109	101		65	64	71	78	72	80
1991	128	127	123	89	121	89		53	54	58	92	60	92
Avg	123	123	117	93	117	93		58	58	64	88	64	88
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-30. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	108	107	109	95	110	91		74	75	73	87	72	91
1977	98	99	82	81	82	77		83	82	99	100	99	104
1978	92	92	81	78	80	78		89	89	100	103	101	103
1979	113	113	108	95	107	92		68	68	73	86	74	89
1980	101	100	91	89	92	88		81	82	91	93	90	94
1981	96	94	91	77	89	76		85	87	90	104	92	105
1982	101	101	92	102	89	100		80	80	89	79	92	81
1983	108	107	103	96	103	96		73	74	78	85	78	85
1984	104	104	106	92	103	92		78	78	76	90	79	90
1985	110	109	104	91	104	92		71	72	77	90	77	89
1986	104	104	84	94	80	92		77	77	97	87	101	89
1987	96	96	91	86	88	76		85	85	90	95	93	105
1988	89	90	87	73	84	68		93	92	95	109	98	114
1989	111	110	102	98	101	94		70	71	79	83	80	87
1990	105	105	98	87	96	84		76	76	83	94	85	97
1991	98	100	90	83	87	77		83	81	91	98	94	104
Avg	102	102	95	89	93	86		79	79	86	93	88	95
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-31. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	114	117	102	85	104	83		68	65	80	97	78	99
1977	89	89	81	79	81	79		92	92	100	102	100	102
1978	78	78	66	54	63	57		103	103	115	127	118	124
1979	110	110	107	95	107	95		71	71	74	86	74	86
1980	92	92	86	77	86	81		90	90	96	105	96	101
1981	84	84	82	73	82	71		97	97	99	108	99	110
1982	92	92	83	87	85	97		89	89	98	94	96	84
1983	103	103	105	99	106	98		78	78	76	82	75	83
1984	102	102	92	92	95	89		80	80	90	90	87	93
1985	96	97	91	90	91	90		85	84	90	91	90	91
1986	91	91	66	74	63	78		90	90	115	107	118	103
1987	91	91	79	65	79	62		90	90	102	116	102	118
1988	81	82	82	64	81	63		101	100	100	118	101	119
1989	107	108	96	87	96	86		74	73	85	94	85	95
1990	102	102	94	78	92	79		79	79	87	103	89	102
1991	86	86	79	77	79	76		95	95	102	104	102	105
Avg	95	95	87	80	87	80		86	86	94	102	94	101
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	1		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-32. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	108	111	112	102	110	101		74	71	70	80	72	81
1977	105	107	98	100	96	98		76	74	83	81	85	83
1978	83	84	82	80	82	80		98	97	99	101	99	101
1979	107	107	105	99	105	103		74	74	76	82	76	78
1980	110	111	99	90	93	89		72	71	83	92	89	93
1981	109	109	97	88	94	89		72	72	84	93	87	92
1982	114	115	109	85	104	83		67	66	72	96	77	98
1983	127	128	114	99	113	98		54	53	67	82	68	83
1984	106	106	109	96	102	94		76	76	73	86	80	88
1985	113	111	100	106	100	105		68	70	81	75	81	76
1986	108	106	95	93	87	90		73	75	86	88	94	91
1987	102	103	97	95	95	93		79	78	84	86	86	88
1988	93	93	92	86	93	85		89	89	90	96	89	97
1989	107	108	102	103	100	102		74	73	79	78	81	79
1990	107	107	105	109	105	104		74	74	76	72	76	77
1991	109	109	99	96	99	91		72	72	82	85	82	90
Avg	107	107	101	95	99	94		75	74	80	86	83	87
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-33. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	117	123	111	95	107	98		65	59	71	87	75	84
1977	95	93	84	81	84	82		86	88	97	100	97	99
1978	81	81	80	73	78	73		100	100	101	108	103	108
1979	112	111	110	96	111	102		69	70	71	85	70	79
1980	102	102	94	82	92	85		80	80	88	100	90	97
1981	86	86	83	77	83	83		95	95	98	104	98	98
1982	116	116	113	85	109	84		65	65	68	96	72	97
1983	126	125	111	91	110	91		55	56	70	90	71	90
1984	104	105	95	90	93	89		78	77	87	92	89	93
1985	107	106	94	96	95	96		74	75	87	85	86	85
1986	101	102	84	89	89	89		80	79	97	92	92	92
1987	99	98	85	78	82	81		82	83	96	103	99	100
1988	91	90	89	75	84	76		91	92	93	107	98	106
1989	111	110	104	96	101	98		70	71	77	85	80	83
1990	107	107	97	83	97	94		74	74	84	98	84	87
1991	100	101	91	81	92	85		81	80	90	100	89	96
Avg	103	104	95	86	94	88		78	78	86	96	87	93
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-34. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Juvenile Rearing in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	117	117	107	94	106	89		65	65	75	88	76	93
1977	101	101	85	78	84	77		80	80	96	103	97	104
1978	81	81	83	72	77	69		100	100	98	109	104	112
1979	111	112	109	94	106	92		70	69	72	87	75	89
1980	115	115	103	84	92	83		67	67	79	98	90	99
1981	113	113	100	76	89	76		68	68	81	105	92	105
1982	121	119	115	82	102	81		60	62	66	99	79	100
1983	127	127	112	95	112	92		54	54	69	86	69	89
1984	107	107	113	97	105	96		75	75	69	85	77	86
1985	115	113	102	93	100	93		66	68	79	88	81	88
1986	104	103	92	87	84	88		77	78	89	94	97	93
1987	104	105	93	76	91	70		77	76	88	105	90	111
1988	91	91	89	77	88	71		91	91	93	105	94	111
1989	112	112	104	97	104	96		69	69	77	84	77	85
1990	110	110	106	82	103	82		71	71	75	99	78	99
1991	107	107	101	75	99	75		74	74	80	106	82	106
Avg	109	108	101	85	96	83		73	73	80	96	85	98
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.2.2 Smoltification

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt winter-run Chinook salmon in the Cache Slough subregion (Table 5C.C-35). The average number of optimal days was 137 days under EBC1 and EBC2 and 146 to 162 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was zero under EBC1 and EBC2, 0 under EBC2_ELT and PP_ELT, and 1 to 2 under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in water temperatures for smolt winter-run Chinook salmon in the East Delta subregion (Table 5C.C-36) differed little when accounting for climate change. The average number of optimal days was 142 and 143 days under EBC1 and EBC2, respectively; 151 and 167 days under EBC2_ELT and EBC2_LLT, respectively, and 151 and 164 under PP_ELT, and PP_LLT, respectively. The average number of supraoptimal days was 0 for EBC1 and EBC2, 0 under EBC2_ELT and PP_ELT, and 1 under EBC2_LLT and PP_LLT. There were no days with lethal temperatures.

EBC scenarios and PP scenarios in water temperatures for smolt winter-run Chinook salmon in the North Delta subregion (Table 5C.C-37) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 121 and 122 for EBC1 and EBC2, respectively, and between 129 and 157 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 0 days under EBC1 and EBC2, and ranged from 0 to 1 day under EBC2_ELT EBC2_LLT and from 0 to 1 under PP_ELT and PP_LLT. No days with lethal temperatures occurred during the modeling period.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt winter-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-38). Optimal water temperatures occurred on 144 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 152 to 163. There were no supraoptimal or lethal temperature average days under any scenario.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt winter-run Chinook salmon in the South Delta subregion (Table 5C.C-39). Suboptimal water temperatures occurred on 36-37 days per year on average under EBC1 and EBC2, and 15–26 days per year under the remaining model scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Optimal water temperatures occurred on 145 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 154 to 166. There were no days in which supraoptimal temperatures occurred on average under EBC1, EBC2, EBC2_ELT, and PP_ELT. There was 1 day per year on average on which supraoptimal temperatures occurred under EBC2_LLT and PP_LLT. There were no supraoptimal or lethal temperature average days under any scenario.

In the Suisun Bay subregion, water temperatures for smolt winter-run Chinook salmon were similar among scenarios (Table 5C.C-40) after accounting for changing climate. Optimal water temperatures were reached on average on 138 days under EBC1 and EBC2 and 144 to 153 days under all other scenarios. There were no supraoptimal or lethal temperature average days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for smolt winter-run Chinook salmon were minor, after climate change was taken into consideration (Table 5C.C-41). Optimal temperatures occurred on average on 135 days under EBC1 and EBC2, and on 144 to 157 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on average on 0 days under EBC1 and EBC2, and on 0 to 1 day under all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Water temperatures in the West Delta for smolt winter-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-42). Under EBC1 and EBC2, optimal water temperatures occurred on 134 days per year, on average. Under EBC2_ELT, and PP_ELT, optimal temperature conditions occurred on 143 to 145 days per year; and on 163 to 162 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature average days under any scenario.

Table 5C.C-35. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							**Optimal (≥10°C and ≤19°C)**					
1976	40	40	35	15	35	16		142	142	147	167	147	166
1977	60	60	49	30	48	35		121	121	132	148	133	143
1978	4	5	0	0	2	0		177	176	181	181	179	181
1979	52	51	46	25	62	38		129	130	135	156	119	143
1980	35	32	24	3	40	10		147	150	158	179	142	172
1981	42	41	30	4	32	4		139	140	151	177	149	177
1982	42	42	26	3	43	17		139	139	155	178	138	164
1983	48	48	34	17	38	19		133	133	147	164	143	162
1984	35	35	57	4	58	10		147	147	125	178	124	172
1985	61	61	27	55	25	56		120	120	154	126	156	123
1986	36	36	42	21	45	21		145	145	138	160	135	160
1987	48	48	40	28	41	27		133	133	141	147	140	147
1988	47	45	34	15	37	15		135	137	148	162	145	161
1989	63	63	53	28	55	26		118	118	128	150	126	151
1990	59	60	40	22	48	26		122	121	141	158	133	152
1991	42	43	31	25	30	25		139	138	150	156	151	156
Avg	45	44	36	18	40	22		137	137	146	162	141	158
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	2		0	0	0	0	0	0
1986	0	0	1	0	1	0		0	0	0	0	0	0
1987	0	0	0	6	0	7		0	0	0	0	0	0
1988	0	0	0	5	0	6		0	0	0	0	0	0
1989	0	0	0	3	0	4		0	0	0	0	0	0
1990	0	0	0	1	0	3		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	1	0	2		0	0	0	0	0	0

Table 5C.C-36. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	39	39	30	5	32	6		143	143	152	177	150	176
1977	59	53	45	13	46	25		122	128	136	165	135	153
1978	4	4	0	0	0	0		177	177	181	181	181	181
1979	46	45	41	22	43	25		135	136	140	159	138	156
1980	31	30	32	9	27	5		151	152	150	173	155	177
1981	42	42	30	4	26	4		139	139	151	177	155	177
1982	45	47	29	8	25	6		136	134	152	173	156	175
1983	38	38	15	9	16	10		143	143	166	172	165	171
1984	41	41	55	9	55	5		141	141	127	173	127	177
1985	59	59	25	33	24	51		122	122	156	148	157	130
1986	24	23	23	20	33	17		157	158	158	161	148	164
1987	47	47	36	20	39	24		134	134	145	154	142	151
1988	20	20	14	7	21	12		162	162	168	175	161	167
1989	50	52	38	17	45	24		131	129	143	163	136	155
1990	46	47	39	16	28	19		135	134	142	161	153	161
1991	33	32	29	20	31	23		148	149	152	161	150	158
Avg	39	39	30	13	31	16		142	143	151	167	151	164
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	7	0	6		0	0	0	0	0	0
1988	0	0	0	0	0	3		0	0	0	0	0	0
1989	0	0	0	1	0	2		0	0	0	0	0	0
1990	0	0	0	4	0	1		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	1	0	1		0	0	0	0	0	0

Table 5C.C-37. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	61	59	36	15	34	14		121	123	146	167	148	168
1977	63	63	51	23	51	29		118	118	130	158	130	152
1978	51	50	37	7	39	6		130	131	144	173	142	175
1979	70	67	62	34	62	34		111	114	119	147	119	147
1980	53	53	53	23	52	22		129	129	129	159	130	160
1981	48	48	53	12	52	13		133	133	128	169	129	168
1982	58	58	50	23	50	24		123	123	131	158	131	157
1983	62	62	52	22	52	22		119	119	129	159	129	159
1984	57	57	59	17	58	17		125	125	123	164	124	164
1985	68	67	63	42	64	45		113	114	118	137	117	134
1986	57	56	49	23	50	25		124	125	132	157	131	155
1987	67	67	51	30	53	28		114	114	130	149	127	150
1988	55	55	45	19	47	19		127	127	137	163	135	163
1989	63	63	63	28	61	29		118	118	118	150	120	152
1990	66	66	64	29	65	30		115	115	117	146	116	145
1991	60	60	49	24	48	22		121	121	132	157	133	159
Avg	60	59	52	23	52	24		121	122	129	157	129	157
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	1	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	1	0	1		0	0	0	0	0	0
1985	0	0	0	2	0	2		0	0	0	0	0	0
1986	0	0	0	1	0	1		0	0	0	0	0	0
1987	0	0	0	2	1	3		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	3	0	0		0	0	0	0	0	0
1990	0	0	0	6	0	6		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	1	0	1		0	0	0	0	0	0

Table 5C.C-38. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	37	38	37	15	35	12		145	144	145	167	147	170
1977	53	53	45	27	45	27		128	128	136	154	136	154
1978	0	1	0	0	0	0		181	180	181	181	181	181
1979	44	44	40	32	38	29		137	137	141	149	143	152
1980	24	24	18	8	16	8		158	158	164	174	166	174
1981	38	38	22	2	20	0		143	143	159	179	161	181
1982	25	25	17	14	15	12		156	156	164	167	166	169
1983	31	31	20	19	25	20		150	150	161	162	156	161
1984	24	24	50	8	48	8		158	158	132	174	134	174
1985	59	59	27	49	27	50		122	122	154	132	154	131
1986	27	26	30	15	30	15		154	155	151	166	151	166
1987	45	45	36	27	35	22		136	136	145	153	146	157
1988	40	40	25	14	25	12		142	142	157	168	157	170
1989	55	56	46	26	46	27		126	125	135	155	135	154
1990	46	47	30	19	30	19		135	134	151	162	151	162
1991	41	40	32	23	31	24		140	141	149	158	150	157
Avg	37	37	30	19	29	18		144	144	152	163	152	163
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	1	0	2		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-39. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	38	38	36	5	35	2		144	144	146	177	147	180
1977	52	52	44	16	44	17		129	129	136	162	137	162
1978	0	0	0	0	0	0		181	181	181	181	181	181
1979	51	49	36	25	35	24		130	132	145	156	146	157
1980	22	22	8	4	10	6		160	160	174	178	172	176
1981	38	38	15	0	11	0		143	143	166	181	170	181
1982	19	20	7	0	5	0		162	161	174	181	176	181
1983	30	31	12	15	18	16		151	150	169	166	163	165
1984	23	24	54	3	49	10		159	158	128	179	133	172
1985	60	60	25	51	25	51		121	121	156	130	156	130
1986	27	27	35	16	33	16		154	154	146	165	148	165
1987	46	46	36	17	33	14		135	135	145	157	148	160
1988	36	36	31	12	31	12		146	146	151	168	151	167
1989	58	59	39	27	39	24		123	122	139	151	139	154
1990	46	46	25	20	25	19		135	135	156	159	156	161
1991	36	36	30	23	29	23		145	145	151	158	152	158
Avg	36	37	27	15	26	15		145	145	154	166	155	166
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	1	3	0	2		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	7	0	7		0	0	0	0	0	0
1988	0	0	0	2	0	3		0	0	0	0	0	0
1989	0	0	3	3	3	3		0	0	0	0	0	0
1990	0	0	0	2	0	1		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	1	0	1		0	0	0	0	0	0

Table 5C.C-40. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	37	35	42	22	41	21		145	147	140	160	141	161
1977	49	49	50	43	50	43		132	132	131	138	131	138
1978	10	10	3	0	1	0		171	171	178	181	180	181
1979	55	56	49	40	51	41		126	125	132	141	130	140
1980	36	37	33	16	33	17		146	145	149	166	149	165
1981	38	39	24	16	23	13		143	142	157	165	158	168
1982	51	51	40	22	41	22		130	130	141	159	140	159
1983	47	47	34	24	33	24		134	134	147	157	148	157
1984	38	37	57	17	57	16		144	145	125	165	125	166
1985	60	60	35	58	35	58		121	121	146	123	146	123
1986	35	36	36	29	37	31		146	145	145	152	144	150
1987	42	43	35	38	35	35		139	138	146	141	146	144
1988	43	44	36	23	37	24		139	138	146	159	145	158
1989	50	54	45	46	45	46		131	127	136	135	136	135
1990	55	55	41	36	39	34		126	126	140	144	142	146
1991	44	43	30	27	31	28		137	138	151	154	150	153
Avg	43	44	37	29	37	28		138	138	144	153	144	153
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	2	0	2		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	1	0	1		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-41. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	40	40	38	16	37	20		142	142	144	166	145	162
1977	53	52	48	39	49	41		128	129	133	140	132	138
1978	1	1	0	0	0	0		180	180	181	181	181	181
1979	62	63	60	37	57	40		119	118	121	144	124	141
1980	40	40	29	5	27	13		142	142	153	177	155	169
1981	40	40	22	4	24	16		141	141	159	177	157	165
1982	47	47	41	24	38	24		134	134	140	157	143	157
1983	64	65	35	29	34	29		117	116	146	152	147	152
1984	38	38	60	11	60	8		144	144	122	171	122	174
1985	63	62	28	55	27	57		118	119	153	126	154	124
1986	37	36	38	21	42	23		144	145	139	160	136	158
1987	49	49	39	30	39	31		132	132	142	145	142	144
1988	45	44	34	20	35	22		137	138	148	162	147	160
1989	60	59	51	36	52	41		121	122	129	142	128	138
1990	60	60	39	24	34	26		121	121	142	156	147	154
1991	47	43	31	25	31	27		134	138	150	156	150	154
Avg	47	46	37	24	37	26		135	135	144	157	144	154
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	2	0	2		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	4	0	3	0		0	0	0	0	0	0
1987	0	0	0	6	0	6		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	1	3	1	2		0	0	0	0	0	0
1990	0	0	0	1	0	1		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	1	0	1		0	0	0	0	0	0

Table 5C.C-42. Number of Days within Temperature Requirements for Winter-Run Chinook Salmon Smoltification in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	41	41	34	14	32	14		141	141	148	168	150	168
1977	54	53	48	24	47	34		127	128	133	157	134	147
1978	9	9	0	0	0	0		172	172	181	181	181	181
1979	60	61	58	26	56	28		121	120	123	155	125	153
1980	39	39	34	6	31	4		143	143	148	176	151	178
1981	43	44	24	0	20	0		138	137	157	181	161	181
1982	53	53	44	15	38	11		128	128	137	166	143	170
1983	48	48	34	17	33	16		133	133	147	164	148	165
1984	42	42	57	5	57	5		140	140	125	177	125	177
1985	62	62	35	53	32	53		119	119	146	128	149	128
1986	35	35	38	19	37	21		146	146	143	162	144	160
1987	48	49	37	29	36	29		133	132	144	150	145	150
1988	51	51	34	14	34	15		131	131	148	168	148	167
1989	58	58	54	30	53	29		123	123	127	150	128	151
1990	65	66	44	18	42	19		116	115	137	163	139	162
1991	48	42	31	25	31	25		133	139	150	156	150	156
Avg	47	47	38	18	36	19		134	134	143	163	145	162
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	2	0	2		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	1	0	1		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.2.3 Adult

Modeling results for adult Chinook salmon did not differ between late fall-runs and winter-runs. Therefore, only winter–run results are reported here.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult winter–run Chinook salmon in the Cache Slough subregion (Table 5C.C-43). The average number of optimal days was 46 and 47 days under EBC1 and EBC2, respectively; 55 and 72 days under EBC2_ELT and EBC2_LLT, respectively; and 51 and 69 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature days under any scenario.

EBC scenarios and PP scenarios in water temperatures for adult winter–run Chinook salmon in the East Delta subregion (Table 5C.C-44) differed little when accounting for climate change. The average number of optimal days was 51 and 52 days under EBC1 and EBC2, respectively. Optimal temperatures occurred on average on 60 and 77 days under EBC2_ELT and EBC2_LLT, respectively. Under PP_ELT and PP_LLT, that number was 60 and 74 days, respectively. There were no supraoptimal or lethal temperature days under any scenario for the entire modeling period.

EBC scenarios and PP scenarios in water temperatures for adult winter–run Chinook salmon in the North Delta subregion (Table 5C.C-45) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 32 for EBC1 and EBC2, and between 39 and 68 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). The number of supraoptimal or lethal temperature days under any scenario was zero.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult winter–run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-46). Optimal water temperatures occurred on 53 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 61 to 72. There were no supraoptimal or lethal temperature days under any scenario.

Water temperatures in the South Delta for adult winter–run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-47). Suboptimal water temperatures occurred on 36 and 37 days per year on average for EBC1 and EBC2, respectively, 27 and 15 days under EBC2_ELT and EBC2_LLT, respectively, and 26 and 15 days for PP_ELT and PP_LLT respectively. Under EBC1 and EBC2, optimal water temperatures occurred on 54 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 76 and 64 days per year, respectively and on 64 and 76 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature days under any scenario.

In the Suisun Bay subregion, water temperatures for adult winter–run Chinook salmon were similar among scenarios (Table 5C.C-48) after accounting for changing climate. Optimal water temperatures were reached on average on 47 days under EBC1 and EBC2, on 53 days for both ELT other scenarios, and on 62 days under the two LLT scenarios. There were no supraoptimal or lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for adult winter–run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-49). Optimal temperatures occurred on average on 44 and 45 days under EBC1 and EBC2, respectively;

on 53 to 67 days under EBC2_ELT and EBC2_LLT, respectively, and on 54 and 64 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature days under any scenario.

Water temperatures in the West Delta for adult winter–run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-50). Under EBC1 and EBC2, optimal water temperatures occurred on 43 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 52 and 72 days per year and under PP_ELT and PP_LLT on 54 to 71 days. There were no supraoptimal or lethal temperature days under any scenario.

Table 5C.C-43. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	40	40	35	15	35	16		51	51	56	76	56	75
1977	60	60	49	30	48	35		30	30	41	60	42	55
1978	4	5	0	0	2	0		86	85	90	90	88	90
1979	52	51	45	25	59	38		38	39	45	65	31	52
1980	35	32	24	3	40	10		56	59	67	88	51	81
1981	42	41	30	4	32	4		48	49	60	86	58	86
1982	42	42	26	3	43	17		48	48	64	87	47	73
1983	46	46	34	17	38	19		44	44	56	73	52	71
1984	35	35	57	4	58	9		56	56	34	87	33	82
1985	61	61	27	55	24	56		29	29	63	35	66	34
1986	31	28	42	21	45	21		59	62	48	69	45	69
1987	48	48	40	28	41	27		42	42	50	62	49	63
1988	47	45	34	15	37	15		44	46	57	76	54	76
1989	63	63	53	28	55	26		27	27	37	62	35	64
1990	59	60	40	22	48	26		31	30	50	68	42	64
1991	42	43	31	25	30	25		48	47	59	65	60	65
Avg	44	44	35	18	40	22		46	47	55	72	51	69
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-44. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	39	39	30	5	32	6		52	52	61	86	59	85
1977	59	53	45	13	46	25		31	37	45	77	44	65
1978	4	4	0	0	0	0		86	86	90	90	90	90
1979	46	45	41	22	43	25		44	45	49	68	47	65
1980	31	30	32	9	27	5		60	61	59	82	64	86
1981	42	42	30	4	26	4		48	48	60	86	64	86
1982	45	47	29	8	25	6		45	43	61	82	65	84
1983	38	38	15	9	16	10		52	52	75	81	74	80
1984	41	41	55	9	55	5		50	50	36	82	36	86
1985	59	59	25	33	24	51		31	31	65	57	66	39
1986	22	21	23	20	33	17		68	69	67	70	57	73
1987	47	47	36	20	39	24		43	43	54	70	51	66
1988	20	20	14	7	21	12		71	71	77	84	70	79
1989	50	52	38	17	45	24		40	38	52	73	45	66
1990	46	47	39	16	28	19		44	43	51	74	62	71
1991	33	32	29	20	31	23		57	58	61	70	59	67
Avg	39	39	30	13	31	16		51	52	60	77	60	74
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-45. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	59	57	35	15	34	14		32	34	56	76	57	77
1977	63	62	51	23	51	29		27	28	39	67	39	61
1978	50	49	37	7	39	6		40	41	53	83	51	84
1979	67	64	61	34	61	34		23	26	29	56	29	56
1980	51	51	52	21	51	20		40	40	39	70	40	71
1981	48	48	53	12	52	13		42	42	37	78	38	77
1982	57	57	50	23	50	24		33	33	40	67	40	66
1983	59	59	51	22	51	22		31	31	39	68	39	68
1984	57	57	57	15	56	15		34	34	34	76	35	76
1985	62	63	60	42	62	45		28	27	30	48	28	45
1986	54	53	49	22	50	23		36	37	41	68	40	67
1987	65	65	51	29	53	28		25	25	39	61	37	62
1988	55	55	43	19	45	19		36	36	48	72	46	72
1989	61	61	61	26	59	28		29	29	29	64	31	62
1990	66	66	64	29	65	30		24	24	26	61	25	60
1991	58	58	47	24	47	22		32	32	43	66	43	68
Avg	58	58	51	23	52	23		32	32	39	68	39	67
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-46. Number of Days within Temperature Requirements for Winter-Run and Late Fall–Run Chinook Salmon Adults in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	37	38	37	15	35	12		54	53	54	76	56	79
1977	53	53	45	27	45	27		37	37	45	63	45	63
1978	0	1	0	0	0	0		90	89	90	90	90	90
1979	44	44	38	32	37	29		46	46	52	58	53	61
1980	24	24	18	8	16	8		67	67	73	83	75	83
1981	38	38	22	2	20	0		52	52	68	88	70	90
1982	25	25	17	14	15	12		65	65	73	76	75	78
1983	31	31	20	19	25	20		59	59	70	71	65	70
1984	24	24	50	8	48	8		67	67	41	83	43	83
1985	59	59	27	49	27	50		31	31	63	41	63	40
1986	27	26	30	15	30	15		63	64	60	75	60	75
1987	45	45	36	27	35	22		45	45	54	63	55	68
1988	40	40	25	14	25	12		51	51	66	77	66	79
1989	55	56	46	26	46	27		35	34	44	64	44	63
1990	46	47	30	19	30	19		44	43	60	71	60	71
1991	41	40	32	23	31	24		49	50	58	67	59	66
Avg	37	37	30	19	29	18		53	53	61	72	61	72
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-47. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	38	38	36	5	35	2		53	53	55	86	56	89
1977	52	52	44	16	44	17		38	38	46	74	46	73
1978	0	0	0	0	0	0		90	90	90	90	90	90
1979	51	49	36	25	35	24		39	41	54	65	55	66
1980	22	22	8	4	10	6		69	69	83	87	81	85
1981	38	38	15	0	11	0		52	52	75	90	79	90
1982	19	20	7	0	5	0		71	70	83	90	85	90
1983	30	31	12	15	18	16		60	59	78	75	72	74
1984	23	24	54	3	49	10		68	67	37	88	42	81
1985	60	60	25	51	25	51		30	30	65	39	65	39
1986	27	27	35	16	33	16		63	63	55	74	57	74
1987	46	46	36	17	33	14		44	44	54	73	57	76
1988	36	36	31	12	31	12		55	55	60	79	60	79
1989	58	59	39	27	39	24		32	31	51	63	51	66
1990	46	46	25	20	25	19		44	44	65	70	65	71
1991	36	36	30	23	29	23		54	54	60	67	61	67
Avg	36	37	27	15	26	15		54	54	63	76	64	76
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-48. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	37	35	42	22	41	21		54	56	49	69	50	70
1977	49	49	50	43	50	43		41	41	40	47	40	47
1978	10	10	3	0	1	0		80	80	87	90	89	90
1979	55	56	49	40	51	41		35	34	41	50	39	49
1980	36	37	33	16	33	17		55	54	58	75	58	74
1981	38	39	24	16	23	13		52	51	66	74	67	77
1982	51	51	40	22	41	22		39	39	50	68	49	68
1983	47	47	34	24	33	24		43	43	56	66	57	66
1984	38	37	57	17	57	16		53	54	34	74	34	75
1985	60	60	35	58	35	58		30	30	55	32	55	32
1986	35	36	36	29	37	31		55	54	54	61	53	59
1987	42	43	35	38	35	35		48	47	55	52	55	55
1988	43	44	36	23	37	24		48	47	55	68	54	67
1989	50	54	45	46	45	46		40	36	45	44	45	44
1990	55	55	41	36	39	34		35	35	49	54	51	56
1991	44	43	30	27	31	28		46	47	60	63	59	62
Avg	43	44	37	29	37	28		47	47	53	62	53	62
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-49. Number of Days within Temperature Requirements for Winter-Run and Late Fall-Run Chinook Salmon Adults in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	40	40	38	16	37	20		51	51	53	75	54	71
1977	53	52	48	39	49	41		37	38	42	51	41	49
1978	1	1	0	0	0	0		89	89	90	90	90	90
1979	62	63	60	37	57	40		28	27	30	53	33	50
1980	40	40	29	5	27	13		51	51	62	86	64	78
1981	40	40	22	4	24	16		50	50	68	86	66	74
1982	47	47	41	24	38	24		43	43	49	66	52	66
1983	55	54	35	29	34	29		35	36	55	61	56	61
1984	38	38	60	11	60	8		53	53	31	80	31	83
1985	63	62	28	55	27	57		27	28	62	35	63	33
1986	37	36	38	21	42	23		53	54	52	69	48	67
1987	49	49	39	30	39	31		41	41	51	60	51	59
1988	45	44	34	20	35	22		46	47	57	71	56	69
1989	60	59	51	36	52	41		30	31	39	54	38	49
1990	60	60	39	24	34	26		30	30	51	66	56	64
1991	47	43	31	25	31	27		43	47	59	65	59	63
Avg	46	46	37	24	37	26		44	45	53	67	54	64
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-50. Number of Days within Temperature Requirements for Winter-Run and Late Fall–Run Chinook Salmon Adults in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	41	41	34	14	32	14		50	50	57	77	59	77
1977	54	53	48	24	47	34		36	37	42	66	43	56
1978	9	9	0	0	0	0		81	81	90	90	90	90
1979	60	61	58	26	56	28		30	29	32	64	34	62
1980	39	39	34	6	31	4		52	52	57	85	60	87
1981	43	44	24	0	20	0		47	46	66	90	70	90
1982	53	53	44	15	38	11		37	37	46	75	52	79
1983	48	48	34	17	33	16		42	42	56	73	57	74
1984	42	42	57	5	57	5		49	49	34	86	34	86
1985	62	62	35	53	32	53		28	28	55	37	58	37
1986	35	35	38	19	37	21		55	55	52	71	53	69
1987	48	49	37	29	36	29		42	41	53	61	54	61
1988	51	51	34	14	34	15		40	40	57	77	57	76
1989	58	58	54	30	53	29		32	32	36	60	37	61
1990	65	66	44	18	42	19		25	24	46	72	48	71
1991	48	42	31	25	31	25		42	48	59	65	59	65
Avg	47	47	38	18	36	19		43	43	52	72	54	71
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.3 Spring-Run Chinook Salmon

5C.C.3.1 Juvenile

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile spring-run Chinook salmon in the Cache Slough subregion (Table 5C.C-51). The average number of optimal days was 86 and 87 days, respectively under EBC1 and EBC2 and varied from 89 to 100 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 2 under EBC1 and EBC2, 3 and 4 under EBC2_ELT and PP_ELT, and 5 under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios for water temperatures for juvenile spring-run Chinook salmon in the East Delta subregion (Table 5C.C-52) differed little when accounting for climate change. The average number of optimal days was 80 days under EBC1 and EBC2, 83 to 102 days under EBC2_ELT, EBC2_LLT, and 89 to 103 under PP_ELT, and PP_LLT, respectively. The average number of supraoptimal days was 2 for EBC1 and EBC2, 3 and 4 days under EBC2_ELT and PP_ELT, and 6 days under EBC2_LLT and PP_LLT. The average number of lethal days was zero.

EBC scenarios and PP scenarios in water temperatures for juvenile spring-run Chinook salmon in the North Delta subregion (Table 5C.C-53) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 69 for EBC1 and EBC2, and between 71 and 94 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 2 days under EBC1 and EBC2, and ranged from 4 to 5 days under EBC2_ELT, EBC2_LLT, and from 4 to 5 under PP_ELT, and PP_LLT. No days with lethal temperatures occurred during the modeling period.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile spring-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-54). Optimal water temperatures occurred on 89 and 90 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 93 to 97. Supraoptimal temperatures were reached on average for 2 days under EBC1 and EBC2. Under all other scenarios, this number ranged from 2 to 3 days. There were zero lethal temperature days under any scenario.

Water temperatures in the South Delta for juvenile spring-run Chinook salmon were largely similar among the different scenarios (considering climate change) (Table 5C.C-55). Suboptimal water temperatures were reached on average on 86 days under EBC1 and EBC2, and 76 to 80 days for all other scenarios. Under EBC1 and EBC2, optimal water temperatures occurred on 94 days per year, on average. Optimal temperature conditions occurred on 99 to 102 days per year under all other scenarios. Supraoptimal temperatures occurred on 2 days under EBC1 and EBC2, and on 4 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

In the Suisun Bay subregion, water temperatures for juvenile spring-run Chinook salmon were similar among scenarios (Table 5C.C-56) after accounting for changing climate. Optimal water temperatures were reached on average on 82 days under EBC1 and EBC2, and 85 to 92 days for all other scenarios. EBC1 and EBC2 averaged 1 day of supraoptimal conditions, while the number of days for EBC_ELT, EBC1_LLT, PP_ELT, and PP_LLT varied from 2 to 4 days. There were zero lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for juvenile spring-run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-57). Optimal temperatures occurred on average on 87 days under EBC1 and EBC2, and on 91 to 97 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 1 and 2 days under EBC1 and EBC2, respectively, and on 3 to 5 days under all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Water temperatures in the West Delta for juvenile spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-58). Under EBC1 and EBC2, optimal water temperatures occurred on 81 days per year, on average. Under EBC2_ELT, and EBC2_LLT, optimal temperature conditions occurred on 86 to 99 days per year and under PP_ELT and PP_LLT on 90 to 100 days. Supraoptimal temperatures occurred on 1 day under EBC1 and EBC2, and on 2 to 3 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

Table 5C.C-51. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	100	99	90	79	90	79		83	84	88	95	88	93
1977	90	89	78	76	78	76		92	93	104	106	104	106
1978	85	85	79	57	82	70		96	96	101	123	98	109
1979	96	96	95	78	96	85		84	84	85	95	84	87
1980	93	93	84	67	92	79		90	90	99	116	91	104
1981	95	91	83	73	85	71		83	87	94	101	91	103
1982	106	107	97	79	104	79		75	74	83	100	75	100
1983	95	95	90	71	97	75		87	87	83	106	73	100
1984	95	96	94	83	96	82		82	81	89	89	87	89
1985	97	95	81	80	78	80		85	87	98	102	101	102
1986	82	81	81	71	95	75		100	101	89	109	76	105
1987	98	97	84	76	83	76		75	76	98	92	99	92
1988	83	80	76	71	75	69		100	103	107	106	108	108
1989	98	98	92	88	91	87		82	82	86	91	86	92
1990	100	100	97	86	95	84		82	82	76	89	79	92
1991	99	99	93	76	97	76		83	83	89	106	85	106
Avg	95	94	87	76	90	78		86	87	92	102	89	99
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	5	9	5	11		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	2	2	3		0	0	0	0	0	0
1979	2	2	2	9	2	10		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	5	8	6	8		0	0	0	0	0	0
1982	1	1	2	3	3	3		0	0	0	0	0	0
1983	0	0	9	5	12	7		0	0	0	0	0	0
1984	6	6	0	11	0	12		0	0	0	0	0	0
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	12	2	11	2		0	0	0	0	0	0
1987	9	9	0	14	0	14		0	0	0	0	0	0
1988	0	0	0	6	0	6		0	0	0	0	0	0
1989	2	2	4	3	5	3		0	0	0	0	0	0
1990	0	0	9	7	8	6		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	2	2	3	5	4	5		0	0	0	0	0	0

Table 5C.C-52. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	100	100	90	78	85	73		82	82	87	91	93	98
1977	90	94	80	74	77	75		92	88	102	108	105	107
1978	86	86	82	57	76	55		94	94	97	122	104	123
1979	102	101	98	74	95	73		78	79	78	97	83	99
1980	107	107	109	68	98	68		76	76	74	115	85	115
1981	114	111	93	69	85	71		64	67	83	106	92	104
1982	114	114	110	84	107	81		66	66	70	94	71	97
1983	114	114	101	76	100	74		65	65	71	95	71	97
1984	99	99	109	83	100	80		77	77	74	91	83	94
1985	104	104	95	79	86	79		78	78	83	103	93	103
1986	99	99	100	64	99	65		83	83	79	115	74	113
1987	98	98	93	70	81	73		76	76	89	99	101	96
1988	84	84	79	63	76	65		99	99	104	113	107	112
1989	100	100	95	83	92	85		82	82	83	95	85	94
1990	105	106	103	86	94	84		77	76	71	89	80	91
1991	95	96	95	73	90	73		87	86	86	106	92	109
Avg	101	101	96	74	90	73		80	80	83	102	89	103
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	1	1	6	14	5	12		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	2	2	3	3	2	4		0	0	0	0	0	0
1979	2	2	6	11	4	10		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	6	7	5	7		0	0	0	0	0	0
1982	2	2	2	4	4	4		0	0	0	0	0	0
1983	3	3	10	11	11	11		0	0	0	0	0	0
1984	7	7	0	9	0	9		0	0	0	0	0	0
1985	0	0	4	0	3	0		0	0	0	0	0	0
1986	0	0	3	3	9	4		0	0	0	0	0	0
1987	8	8	0	13	0	13		0	0	0	0	0	0
1988	0	0	0	7	0	6		0	0	0	0	0	0
1989	0	0	4	4	5	3		0	0	0	0	0	0
1990	0	0	8	7	8	7		0	0	0	0	0	0
1991	0	0	1	3	0	0		0	0	0	0	0	0
Avg	2	2	3	6	4	6		0	0	0	0	0	0

Table 5C.C-53. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	109	110	94	87	94	87		72	71	86	93	86	93
1977	121	121	111	80	112	77		61	61	71	102	70	105
1978	107	107	101	76	103	76		72	72	76	99	74	100
1979	114	114	110	88	107	86		67	67	64	87	67	89
1980	112	112	115	83	114	83		70	71	67	97	68	97
1981	120	118	106	86	108	86		61	63	68	94	65	94
1982	121	121	112	91	112	91		58	58	66	89	67	88
1983	118	118	103	82	103	82		60	60	70	89	70	89
1984	104	104	115	83	114	82		72	72	67	93	68	93
1985	111	113	118	90	118	90		71	69	57	91	56	90
1986	104	104	101	75	101	76		76	76	79	103	79	101
1987	106	106	108	84	109	84		74	74	72	95	71	95
1988	97	97	99	71	100	71		85	85	79	104	78	104
1989	108	108	100	90	100	90		71	71	78	84	79	84
1990	110	111	104	95	104	94		72	71	73	81	73	82
1991	117	117	114	82	112	82		64	64	67	96	69	96
Avg	111	111	107	84	107	84		69	69	71	94	71	94
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	2	2	3	3	3	3		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	3	3	5	7	5	6		0	0	0	0	0	0
1979	1	1	8	7	8	7		0	0	0	0	0	0
1980	1	0	1	3	1	3		0	0	0	0	0	0
1981	1	1	8	2	9	2		0	0	0	0	0	0
1982	3	3	4	2	3	3		0	0	0	0	0	0
1983	4	4	9	11	9	11		0	0	0	0	0	0
1984	7	7	1	7	1	8		0	0	0	0	0	0
1985	0	0	7	1	8	2		0	0	0	0	0	0
1986	2	2	2	4	2	5		0	0	0	0	0	0
1987	2	2	2	3	2	3		0	0	0	0	0	0
1988	1	1	5	8	5	8		0	0	0	0	0	0
1989	3	3	4	8	3	8		0	0	0	0	0	0
1990	0	0	5	6	5	6		0	0	0	0	0	0
1991	1	1	1	4	1	4		0	0	0	0	0	0
Avg	2	2	4	5	4	5		0	0	0	0	0	0

Table 5C.C-54. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<13°C)**							**Optimal (≥13°C and ≤20°C)**					
1976	94	94	96	87	95	85		89	89	84	92	85	93
1977	90	91	77	77	77	76		92	91	105	105	105	106
1978	82	82	77	78	77	78		97	97	102	104	102	104
1979	95	95	90	91	90	90		83	83	89	91	89	91
1980	90	89	80	86	81	85		93	94	103	97	102	98
1981	88	86	84	77	84	76		93	95	91	105	91	106
1982	96	96	88	101	86	100		83	83	88	81	90	82
1983	88	87	89	95	89	94		91	92	83	87	84	88
1984	92	92	94	86	92	86		84	84	89	90	91	90
1985	98	97	85	84	85	85		84	85	92	98	92	97
1986	86	86	80	83	77	82		96	96	99	99	102	100
1987	92	92	87	84	84	75		84	84	95	88	98	96
1988	81	82	77	70	75	65		102	101	105	113	107	117
1989	97	96	91	93	91	90		85	86	90	88	90	91
1990	100	100	94	87	93	84		82	82	81	91	82	93
1991	89	90	84	82	83	77		93	92	98	100	99	105
Avg	91	91	86	85	85	83		89	90	93	96	94	97
	Supraoptimal (>20°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	3	4	3	5		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	3	3	3	0	3	0		0	0	0	0	0	0
1979	4	4	3	0	3	1		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	1	1	7	0	7	0		0	0	0	0	0	0
1982	3	3	6	0	6	0		0	0	0	0	0	0
1983	3	3	10	0	9	0		0	0	0	0	0	0
1984	7	7	0	7	0	7		0	0	0	0	0	0
1985	0	0	5	0	5	0		0	0	0	0	0	0
1986	0	0	3	0	3	0		0	0	0	0	0	0
1987	6	6	0	10	0	11		0	0	0	0	0	0
1988	0	0	1	0	1	1		0	0	0	0	0	0
1989	0	0	1	1	1	1		0	0	0	0	0	0
1990	0	0	7	4	7	5		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	2	2	3	2	3	2		0	0	0	0	0	0

Table 5C.C-55. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	96	96	86	76	85	76		86	86	92	94	93	95
1977	83	83	77	76	77	77		99	99	105	106	105	105
1978	78	78	66	54	63	57		102	102	113	126	116	123
1979	95	95	91	89	91	91		82	82	87	86	89	85
1980	81	81	76	74	77	78		102	102	107	109	106	105
1981	78	78	77	72	77	71		100	100	99	103	99	104
1982	89	89	81	87	83	97		90	90	95	95	92	85
1983	83	83	88	93	88	93		96	98	83	89	82	89
1984	92	92	82	87	85	84		85	85	100	86	97	89
1985	86	86	78	81	78	81		96	96	101	101	101	101
1986	76	76	66	63	63	67		106	106	109	117	109	113
1987	88	87	75	65	75	62		85	86	107	103	107	105
1988	75	76	76	61	75	61		108	107	107	116	108	120
1989	95	96	89	84	89	83		86	85	89	95	89	96
1990	97	97	93	78	91	79		85	85	80	97	82	97
1991	81	81	77	74	77	73		101	101	104	108	104	109
Avg	86	86	80	76	80	77		94	94	99	102	99	101
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	1	1	5	13	5	12		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	2	2	3	2	3	2		0	0	0	0	0	0
1979	5	5	4	7	2	6		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	6	7	6	7		0	0	0	0	0	0
1982	3	3	6	0	7	0		0	0	0	0	0	0
1983	3	1	11	0	12	0		0	0	0	0	0	0
1984	6	6	1	10	1	10		0	0	0	0	0	0
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	7	2	10	2		0	0	0	0	0	0
1987	9	9	0	14	0	15		0	0	0	0	0	0
1988	0	0	0	6	0	2		0	0	0	0	0	0
1989	1	1	4	3	4	3		0	0	0	0	0	0
1990	0	0	9	7	9	6		0	0	0	0	0	0
1991	0	0	1	0	1	0		0	0	0	0	0	0
Avg	2	2	4	4	4	4		0	0	0	0	0	0

Table 5C.C-56. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	99	98	99	93	99	91		84	85	83	86	82	88
1977	101	102	91	93	89	91		81	80	91	89	93	91
1978	83	84	82	79	82	78		98	97	98	100	98	101
1979	96	96	96	92	95	92		86	86	86	82	87	81
1980	104	104	97	84	90	83		79	79	86	99	93	100
1981	104	103	93	84	90	84		78	79	87	96	90	96
1982	110	111	106	83	101	81		72	71	76	98	81	100
1983	109	109	98	84	97	84		73	73	76	95	77	97
1984	98	98	101	88	94	86		79	79	82	87	89	89
1985	103	101	87	95	87	94		79	81	95	86	95	87
1986	93	91	94	78	87	77		89	91	79	101	87	103
1987	99	100	94	92	92	90		79	78	88	80	90	82
1988	89	89	87	81	88	80		94	94	96	96	95	97
1989	99	99	97	96	95	96		83	83	84	86	85	85
1990	103	103	104	104	104	99		79	79	74	72	74	77
1991	105	105	97	92	96	87		77	77	85	86	86	91
Avg	100	100	95	89	93	87		82	82	85	90	88	92
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	1	4	2	4		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	3	2	3		0	0	0	0	0	0
1979	0	0	0	8	0	9		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	2	2	2		0	0	0	0	0	0
1982	0	0	0	1	0	1		0	0	0	0	0	0
1983	0	0	8	3	8	1		0	0	0	0	0	0
1984	6	6	0	8	0	8		0	0	0	0	0	0
1985	0	0	0	1	0	1		0	0	0	0	0	0
1986	0	0	9	3	8	2		0	0	0	0	0	0
1987	4	4	0	10	0	10		0	0	0	0	0	0
1988	0	0	0	6	0	6		0	0	0	0	0	0
1989	0	0	1	0	2	1		0	0	0	0	0	0
1990	0	0	4	6	4	6		0	0	0	0	0	0
1991	0	0	0	4	0	4		0	0	0	0	0	0
Avg	1	1	2	4	2	4		0	0	0	0	0	0

Table 5C.C-57. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	99	99	94	85	94	87		84	84	85	87	84	87
1977	90	87	79	78	78	77		92	95	103	104	104	105
1978	81	81	80	73	77	70		100	100	100	107	103	110
1979	97	96	95	88	95	87		84	84	86	87	86	84
1980	92	92	85	79	82	79		91	91	98	104	101	104
1981	80	80	78	76	78	77		99	98	99	97	98	98
1982	113	113	111	84	106	83		69	69	69	96	74	93
1983	107	106	92	74	91	74		75	76	79	102	80	102
1984	95	95	85	83	83	82		82	82	98	88	99	90
1985	93	91	80	85	79	85		89	91	99	97	100	97
1986	86	86	84	76	88	74		96	96	85	104	82	105
1987	96	95	81	78	77	79		77	78	101	90	105	90
1988	85	84	83	72	76	72		98	99	100	105	107	104
1989	99	98	97	91	92	92		83	82	81	88	86	87
1990	103	102	96	83	95	90		79	80	79	93	79	86
1991	96	96	89	78	89	80		86	86	93	104	92	102
Avg	95	94	88	80	86	81		87	87	91	97	93	97
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	4	11	5	9		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	2	2	2		0	0	0	0	0	0
1979	1	2	1	7	1	11		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	3	4	5	9	6	7		0	0	0	0	0	0
1982	0	0	2	2	2	6		0	0	0	0	0	0
1983	0	0	11	6	11	6		0	0	0	0	0	0
1984	6	6	0	12	1	11		0	0	0	0	0	0
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	13	2	12	3		0	0	0	0	0	0
1987	9	9	0	14	0	13		0	0	0	0	0	0
1988	0	0	0	6	0	7		0	0	0	0	0	0
1989	0	2	4	3	4	3		0	0	0	0	0	0
1990	0	0	7	6	8	6		0	0	0	0	0	0
1991	0	0	0	0	1	0		0	0	0	0	0	0
Avg	1	2	3	5	4	5		0	0	0	0	0	0

Table 5C.C-58. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Juvenile Rearing in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	102	102	94	85	93	84		81	81	89	91	90	93
1977	97	97	83	78	82	77		85	85	99	104	100	105
1978	81	81	83	72	77	69		101	101	98	109	104	112
1979	97	98	96	88	96	88		85	84	86	89	86	89
1980	106	106	95	81	86	80		77	77	88	102	97	103
1981	108	107	95	76	85	76		74	75	85	103	95	102
1982	116	115	111	81	99	80		66	67	71	101	83	102
1983	108	108	96	80	96	79		74	74	79	96	78	98
1984	98	98	104	88	97	87		80	80	79	88	86	89
1985	105	103	88	84	86	84		77	79	94	98	96	98
1986	91	90	92	77	84	76		91	92	79	105	86	106
1987	102	103	89	76	88	70		72	71	93	94	94	100
1988	87	87	85	77	84	71		96	96	98	106	99	112
1989	101	101	99	94	99	94		81	81	83	88	83	88
1990	107	107	106	82	103	82		75	75	71	97	74	96
1991	105	105	101	75	99	75		77	77	81	107	83	107
Avg	101	101	95	81	91	80		81	81	86	99	90	100
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	7	0	6		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	1	1	1	1		0	0	0	0	0	0
1979	0	0	0	5	0	5		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	3	2	4		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	7	6	8	5		0	0	0	0	0	0
1984	5	5	0	7	0	7		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	11	0	12	0		0	0	0	0	0	0
1987	8	8	0	12	0	12		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	5	3	5	4		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	1	1	2	3	2	3		0	0	0	0	0	0

5C.C.3.2 Smoltification

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt spring-run Chinook salmon in the Cache Slough subregion (Table 5C.C-59). The average number of optimal days was 134 under EBC1 and EBC2 and 135 to 151 under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 4 under EBC1 and EBC2, 8 under EBC2_ELT and PP_ELT, and 13 under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in water temperatures for smolt spring-run Chinook salmon in the East Delta subregion (Table 5C.C-60) differed little when accounting for climate change. The average number of optimal days was 138 under EBC1 and EBC2, 143 to 156 under EBC2_ELT and EBC2_LLT, and 143 to 154 under PP_ELT, and PP_LLT, respectively. The average number of supraoptimal days was 5 for EBC1 and EBC2, 10 to 13 days under EBC2_ELT and EBC2_LLT, and 9 to 13 under PP_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in water temperatures for smolt spring-run Chinook salmon in the North Delta subregion (Table 5C.C-61) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 118 for EBC1 and EBC2, and between 121 and 148 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 5 days under EBC1 and EBC2, and ranged from 9 to 12 days under EBC2_ELT and EBC2_LLT, and from 9 to 11 under PP_ELT and PP_LLT. Lethal water temperatures were not reached under any scenario.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt spring-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-62). Optimal water temperatures occurred on 141 and 140 days under the EBC1 and EBC2 scenarios, respectively. Under all other scenarios, the number of days with optimal water temperatures ranged from 145 to 158. Supraoptimal temperatures were reached on average for 5 days under EBC1 and EBC2. Under all other scenarios, this number ranged from 7 to 8 days. There were no lethal temperature days under any scenario.

Water temperatures in the South Delta for smolt spring-run Chinook salmon were generally similar among the different scenarios (considering climate change)(Table 5C.C-63). Suboptimal water temperature conditions occurred on 36 to 37 days per year on average under EBC1 and EBC2, and 15-27 days under all other model scenarios. Under EBC1 and EBC2, optimal water temperatures occurred on 141 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 146 and 156 days per year, respectively; and on 147 to 157 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 5 days under EBC1 and EBC2, and on 9 to 12 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

In the Suisun Bay subregion, water temperatures for smolt spring-run Chinook salmon were similar among scenarios (Table 5C.C-64) after accounting for changing climate. Optimal water temperatures were reached on average on 136 days under EBC1 and 135 days under EBC2. The number of optimal temperature conditions was 139 and 143 for all other scenarios. EBC1 and EBC2 averaged 3 days of supraoptimal days, while the number of days for EBC2_ELT and EBC2_LLT and PP_ELT and PP_LLT varied from 6 to 11 days. There were no lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for smolt spring-run Chinook salmon were minor, after climate change was taken into consideration (Table 5C.C-65). Optimal temperatures occurred on average on 132 and 133 days under EBC1 and EBC2, on 137 to 146 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 4 days under EBC1 and EBC2, and on 8 to 12 days under all other scenarios (i.e., EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Water temperatures in the West Delta for smolt spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-66). Under EBC1 and EBC2, optimal water temperatures occurred on 133 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 138 and 154 days per year, respectively; and on 140 to 154 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 3 days under EBC1 and EBC2, and on 6 to 10 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

Table 5C.C-59. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	40	40	35	15	35	16		140	140	135	146	137	145
1977	60	60	49	30	48	35		122	122	133	149	134	144
1978	4	5	0	0	2	0		176	175	178	170	176	170
1979	52	51	45	25	59	38		121	122	129	142	114	130
1980	35	32	24	3	40	10		148	151	159	175	143	168
1981	42	41	30	4	32	4		132	133	140	165	137	165
1982	42	42	26	3	43	17		136	136	148	165	132	151
1983	46	46	34	17	38	19		128	128	131	149	127	147
1984	35	35	57	4	58	9		141	141	120	160	120	155
1985	61	61	27	55	24	56		121	121	146	123	148	121
1986	31	28	42	21	45	21		147	150	124	150	121	150
1987	48	48	40	28	41	27		121	121	137	132	137	132
1988	47	45	34	15	37	15		135	137	144	153	141	152
1989	63	63	53	28	55	26		114	114	123	145	120	145
1990	59	60	40	22	48	26		116	115	131	146	124	140
1991	42	43	31	25	30	25		140	139	145	151	148	150
Avg	44	44	35	18	40	22		134	134	139	151	135	148
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	3	3	13	22	11	22		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	2	2	4	12	4	12		0	0	0	0	0	0
1979	9	9	8	15	9	14		0	0	0	0	0	0
1980	0	0	0	5	0	5		0	0	0	0	0	0
1981	8	8	12	13	13	13		0	0	0	0	0	0
1982	4	4	8	14	7	14		0	0	0	0	0	0
1983	8	8	17	16	17	16		0	0	0	0	0	0
1984	7	7	6	19	5	19		0	0	0	0	0	0
1985	0	0	9	4	10	5		0	0	0	0	0	0
1986	4	4	16	11	16	11		0	0	0	0	0	0
1987	13	13	5	22	4	23		0	0	0	0	0	0
1988	1	1	5	15	5	16		0	0	0	0	0	0
1989	5	5	6	9	7	11		0	0	0	0	0	0
1990	7	7	11	14	10	16		0	0	0	0	0	0
1991	0	0	6	6	4	7		0	0	0	0	0	0
Avg	4	4	8	13	8	13		0	0	0	0	0	0

Table 5C.C-60. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	39	39	30	5	32	6		140	140	134	156	134	155
1977	59	53	45	13	46	25		123	129	137	166	136	154
1978	4	4	0	0	0	0		175	174	174	167	176	169
1979	46	45	41	22	43	25		126	127	129	143	129	141
1980	31	30	32	9	27	5		150	151	148	168	156	172
1981	42	42	30	4	26	4		133	133	139	165	143	165
1982	45	47	29	8	25	6		132	130	140	163	145	166
1983	38	38	15	9	16	10		135	135	149	157	147	156
1984	41	41	55	9	55	5		130	130	124	155	124	159
1985	59	59	25	33	24	51		123	123	146	144	148	127
1986	22	21	23	20	33	17		154	156	143	149	136	153
1987	47	47	36	20	39	24		122	122	141	138	138	135
1988	20	20	14	7	21	12		161	161	162	165	156	158
1989	50	52	38	17	45	24		128	126	138	155	130	149
1990	46	47	39	16	28	19		129	128	130	148	141	148
1991	33	32	29	20	31	23		147	147	148	155	145	152
Avg	39	39	30	13	31	16		138	138	143	156	143	154
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	4	4	19	22	17	22		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	3	4	8	15	6	13		0	0	0	0	0	0
1979	10	10	12	17	10	16		0	0	0	0	0	0
1980	2	2	3	6	0	6		0	0	0	0	0	0
1981	7	7	13	13	13	13		0	0	0	0	0	0
1982	5	5	13	11	12	10		0	0	0	0	0	0
1983	9	9	18	16	19	16		0	0	0	0	0	0
1984	12	12	4	19	4	19		0	0	0	0	0	0
1985	0	0	11	5	10	4		0	0	0	0	0	0
1986	6	5	16	13	13	12		0	0	0	0	0	0
1987	13	13	5	24	5	23		0	0	0	0	0	0
1988	2	2	7	11	6	13		0	0	0	0	0	0
1989	4	4	6	10	7	9		0	0	0	0	0	0
1990	7	7	13	18	13	15		0	0	0	0	0	0
1991	2	3	5	7	6	7		0	0	0	0	0	0
Avg	5	5	10	13	9	13		0	0	0	0	0	0

Table 5C.C-61. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the North Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	60	58	35	15	34	14		117	119	132	150	134	152
1977	63	62	51	23	51	29		119	120	131	159	131	153
1978	51	50	37	7	39	6		126	127	134	162	132	164
1979	68	65	61	34	61	34		106	109	106	133	107	132
1980	51	51	53	21	52	20		129	129	127	157	128	159
1981	48	48	53	12	52	13		126	126	117	159	118	159
1982	57	57	50	23	50	24		120	120	121	150	121	149
1983	60	60	51	22	51	22		116	115	114	146	114	146
1984	57	57	59	15	58	15		116	116	120	154	121	155
1985	68	67	61	42	63	45		112	112	109	131	107	128
1986	54	53	49	22	50	23		124	125	125	150	125	148
1987	66	66	51	29	53	28		106	106	128	139	125	139
1988	55	55	43	19	45	19		125	126	127	152	125	151
1989	61	61	63	26	61	28		115	115	110	140	110	142
1990	66	66	64	29	65	30		110	110	110	136	109	137
1991	60	60	49	24	48	22		119	119	129	151	131	153
Avg	59	59	52	23	52	23		118	118	121	148	121	148
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	6	6	16	18	15	17		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	5	5	11	13	11	12		0	0	0	0	0	0
1979	8	8	15	15	14	16		0	0	0	0	0	0
1980	3	3	3	5	3	4		0	0	0	0	0	0
1981	8	8	12	11	12	10		0	0	0	0	0	0
1982	5	5	11	9	11	9		0	0	0	0	0	0
1983	6	7	17	14	17	14		0	0	0	0	0	0
1984	10	10	4	14	4	13		0	0	0	0	0	0
1985	2	3	12	9	12	9		0	0	0	0	0	0
1986	4	4	8	10	7	11		0	0	0	0	0	0
1987	10	10	3	14	4	15		0	0	0	0	0	0
1988	3	2	13	12	13	13		0	0	0	0	0	0
1989	6	6	9	16	11	12		0	0	0	0	0	0
1990	6	6	8	17	8	15		0	0	0	0	0	0
1991	3	3	4	7	3	7		0	0	0	0	0	0
Avg	5	5	9	12	9	11		0	0	0	0	0	0

Table 5C.C-62. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	37	38	37	15	35	12		144	143	138	147	140	150
1977	53	53	45	27	45	27		129	129	137	155	137	155
1978	0	1	0	0	0	0		177	176	174	177	174	177
1979	44	44	38	32	37	29		129	129	133	142	134	145
1980	24	24	18	8	16	8		159	159	164	175	166	175
1981	38	38	22	2	20	0		137	136	146	173	148	174
1982	25	25	17	14	15	12		149	149	153	166	155	168
1983	31	31	20	19	25	20		141	141	146	156	142	157
1984	24	24	50	8	48	8		148	148	129	164	131	163
1985	59	59	27	49	27	50		123	123	144	132	144	131
1986	27	26	30	15	30	15		151	152	136	162	135	162
1987	45	45	36	27	35	22		123	123	143	139	145	141
1988	40	40	25	14	25	12		142	142	151	162	151	164
1989	55	56	46	26	46	27		124	122	131	152	131	150
1990	46	47	30	19	30	19		133	132	143	154	143	154
1991	41	40	32	23	31	24		140	141	148	156	149	154
Avg	37	37	30	19	29	18		141	140	145	157	145	158
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	2	2	8	21	8	21		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	5	5	8	5	8	5		0	0	0	0	0	0
1979	9	9	11	8	11	8		0	0	0	0	0	0
1980	0	0	1	0	1	0		0	0	0	0	0	0
1981	7	8	14	7	14	8		0	0	0	0	0	0
1982	8	8	12	2	12	2		0	0	0	0	0	0
1983	10	10	16	7	15	5		0	0	0	0	0	0
1984	11	11	4	11	4	12		0	0	0	0	0	0
1985	0	0	11	1	11	1		0	0	0	0	0	0
1986	4	4	16	5	17	5		0	0	0	0	0	0
1987	14	14	3	16	2	19		0	0	0	0	0	0
1988	1	1	7	7	7	7		0	0	0	0	0	0
1989	3	4	5	4	5	5		0	0	0	0	0	0
1990	3	3	9	9	9	9		0	0	0	0	0	0
1991	1	1	2	3	2	4		0	0	0	0	0	0
Avg	5	5	8	7	8	7		0	0	0	0	0	0

Table 5C.C-63. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	38	38	36	5	35	2		141	141	129	156	130	159
1977	52	52	44	16	44	17		130	130	137	162	138	162
1978	0	0	0	0	0	0		177	177	174	171	174	172
1979	51	49	36	25	35	24		123	125	136	143	138	145
1980	22	22	8	4	10	6		161	161	175	176	173	174
1981	38	38	15	0	11	0		135	135	154	169	158	169
1982	19	20	7	0	5	0		159	158	165	177	166	177
1983	30	31	12	15	18	16		141	140	155	159	149	158
1984	23	24	54	3	49	10		151	150	122	160	127	153
1985	60	60	25	51	25	51		122	122	147	127	147	127
1986	27	27	35	16	33	16		151	151	130	155	132	156
1987	46	46	36	17	33	14		123	123	141	138	144	141
1988	36	36	31	12	31	12		146	146	147	159	147	159
1989	58	59	39	27	39	24		120	119	134	146	134	149
1990	46	46	25	20	25	19		130	130	145	147	145	150
1991	36	36	30	23	29	23		146	146	146	152	147	153
Avg	36	37	27	15	26	15		141	141	146	156	147	157
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	4	4	18	22	18	22		0	0	0	0	0	0
1977	0	0	1	4	0	3		0	0	0	0	0	0
1978	5	5	8	11	8	10		0	0	0	0	0	0
1979	8	8	10	14	9	13		0	0	0	0	0	0
1980	0	0	0	3	0	3		0	0	0	0	0	0
1981	9	9	13	13	13	13		0	0	0	0	0	0
1982	4	4	10	5	11	5		0	0	0	0	0	0
1983	11	11	15	8	15	8		0	0	0	0	0	0
1984	9	9	7	20	7	20		0	0	0	0	0	0
1985	0	0	10	4	10	4		0	0	0	0	0	0
1986	4	4	17	11	17	10		0	0	0	0	0	0
1987	13	13	5	27	5	27		0	0	0	0	0	0
1988	1	1	5	12	5	12		0	0	0	0	0	0
1989	4	4	9	9	9	9		0	0	0	0	0	0
1990	6	6	12	15	12	13		0	0	0	0	0	0
1991	0	0	6	7	6	6		0	0	0	0	0	0
Avg	5	5	9	12	9	11		0	0	0	0	0	0

Table 5C.C-64. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	37	35	42	22	41	21		145	146	130	146	131	146
1977	49	49	50	43	50	43		133	133	132	138	132	138
1978	10	10	3	0	1	0		169	169	176	173	178	174
1979	55	56	49	40	51	41		119	118	126	127	124	126
1980	36	37	33	16	33	17		147	146	150	162	150	161
1981	38	39	24	16	23	13		137	136	150	156	150	159
1982	51	51	40	22	41	22		129	128	134	151	134	149
1983	47	47	34	24	33	24		131	131	133	142	134	142
1984	38	37	57	17	57	16		138	139	124	150	124	151
1985	60	60	35	58	35	58		122	122	139	121	139	121
1986	35	36	36	29	37	31		144	143	130	144	129	141
1987	42	43	35	38	35	35		128	127	147	125	147	128
1988	43	44	36	23	37	24		140	139	142	149	143	147
1989	50	54	45	46	45	46		129	124	132	129	132	129
1990	55	55	41	36	39	34		125	125	133	133	134	135
1991	44	43	30	27	31	28		138	139	150	148	149	147
Avg	43	44	37	29	37	28		136	135	139	143	139	143
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	1	2	11	15	11	16		0	0	0	0	0	0
1977	0	0	0	1	0	1		0	0	0	0	0	0
1978	3	3	3	9	3	8		0	0	0	0	0	0
1979	8	8	7	15	7	15		0	0	0	0	0	0
1980	0	0	0	5	0	5		0	0	0	0	0	0
1981	7	7	8	10	9	10		0	0	0	0	0	0
1982	2	3	8	9	7	11		0	0	0	0	0	0
1983	4	4	15	16	15	16		0	0	0	0	0	0
1984	7	7	2	16	2	16		0	0	0	0	0	0
1985	0	0	8	3	8	3		0	0	0	0	0	0
1986	3	3	16	9	16	10		0	0	0	0	0	0
1987	12	12	0	19	0	19		0	0	0	0	0	0
1988	0	0	5	11	3	12		0	0	0	0	0	0
1989	3	4	5	7	5	7		0	0	0	0	0	0
1990	2	2	8	13	9	13		0	0	0	0	0	0
1991	0	0	2	7	2	7		0	0	0	0	0	0
Avg	3	3	6	10	6	11		0	0	0	0	0	0

Table 5C.C-65. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	40	40	38	16	37	20		140	140	128	145	133	141
1977	53	52	48	39	49	41		129	130	134	141	133	139
1978	1	1	0	0	0	0		179	179	179	171	179	171
1979	62	63	60	37	57	40		113	112	115	129	118	127
1980	40	40	29	5	27	13		143	143	154	172	156	164
1981	40	40	22	4	24	16		133	132	147	165	145	153
1982	47	47	41	24	38	24		132	132	134	141	136	141
1983	55	54	35	29	34	29		123	123	132	140	132	139
1984	38	38	60	11	60	8		138	137	117	153	117	156
1985	63	62	28	55	27	57		119	120	145	123	146	122
1986	37	36	38	21	42	23		143	142	121	151	120	148
1987	49	49	39	30	39	31		119	119	138	126	138	128
1988	45	44	34	20	35	22		137	138	143	153	143	151
1989	60	59	51	36	52	41		118	119	123	138	123	133
1990	60	60	39	24	34	26		116	115	133	143	138	143
1991	47	43	31	25	31	27		135	139	145	151	145	148
Avg	46	46	37	24	37	26		132	133	137	146	138	144
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	3	3	17	22	13	22		0	0	0	0	0	0
1977	0	0	0	2	0	2		0	0	0	0	0	0
1978	2	2	3	11	3	11		0	0	0	0	0	0
1979	7	7	7	16	7	15		0	0	0	0	0	0
1980	0	0	0	6	0	6		0	0	0	0	0	0
1981	9	10	13	13	13	13		0	0	0	0	0	0
1982	3	3	7	17	8	17		0	0	0	0	0	0
1983	4	5	15	13	16	14		0	0	0	0	0	0
1984	7	8	6	19	6	19		0	0	0	0	0	0
1985	0	0	9	4	9	3		0	0	0	0	0	0
1986	2	4	23	10	20	11		0	0	0	0	0	0
1987	14	14	5	26	5	23		0	0	0	0	0	0
1988	1	1	6	10	5	10		0	0	0	0	0	0
1989	4	4	8	8	7	8		0	0	0	0	0	0
1990	6	7	10	15	10	13		0	0	0	0	0	0
1991	0	0	6	6	6	7		0	0	0	0	0	0
Avg	4	4	8	12	8	12		0	0	0	0	0	0

Table 5C.C-66. Number of Days within Temperature Requirements for Spring-Run Chinook Salmon Smoltification in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	41	41	34	14	32	14		142	142	131	148	133	148
1977	54	53	48	24	47	34		128	129	134	158	135	148
1978	9	9	0	0	0	0		172	172	179	172	179	173
1979	60	61	58	26	56	28		115	114	119	143	121	142
1980	39	39	34	6	31	4		144	144	149	177	152	179
1981	43	44	24	0	20	0		134	133	150	171	154	171
1982	53	53	44	15	38	11		127	127	130	160	137	161
1983	48	48	34	17	33	16		126	126	133	150	134	152
1984	42	42	57	5	57	5		135	135	125	161	125	161
1985	62	62	35	53	32	53		120	120	142	129	146	129
1986	35	35	38	19	37	21		147	147	126	156	127	154
1987	48	49	37	29	36	29		123	122	145	131	146	131
1988	51	51	34	14	34	15		132	132	147	160	147	159
1989	58	58	54	30	53	29		124	124	123	147	124	147
1990	65	66	44	18	42	19		117	116	127	150	129	149
1991	48	42	31	25	31	25		134	140	151	156	151	156
Avg	47	47	38	18	36	19		133	133	138	154	140	154
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	18	21	18	21		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	3	10	3	9		0	0	0	0	0	0
1979	7	7	5	13	5	12		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	5	5	8	11	8	11		0	0	0	0	0	0
1982	2	2	8	7	7	10		0	0	0	0	0	0
1983	8	8	15	15	15	14		0	0	0	0	0	0
1984	6	6	1	17	1	17		0	0	0	0	0	0
1985	0	0	5	0	4	0		0	0	0	0	0	0
1986	0	0	18	7	18	7		0	0	0	0	0	0
1987	11	11	0	22	0	22		0	0	0	0	0	0
1988	0	0	2	9	2	9		0	0	0	0	0	0
1989	0	0	5	5	5	6		0	0	0	0	0	0
1990	0	0	11	14	11	14		0	0	0	0	0	0
1991	0	0	0	1	0	1		0	0	0	0	0	0
Avg	3	3	6	10	6	10		0	0	0	0	0	0

5C.C.3.3 Adult

Although there is no spring-run Chinook salmon population currently in the San Joaquin River currently, it is expected that a population will be present by the early long-term implementation period as a result of the San Joaquin River Restoration Program. Therefore, spring-run Chinook salmon results are presented separately for Sacramento River origin and San Joaquin River origin fish here.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult spring-run Chinook salmon in the Cache Slough subregion (Table 5C.C-67, Table 5C.C-68). The average number of optimal days was 59 under EBC1 and EBC2 and between 56 and 58 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 1 under EBC1 and EBC2, 2 under EBC2_ELT and PP_ELT, and 4 under EBC2_LLT and PP_LLT. There was on average 1 lethal day under all scenarios except for PP_LLT where there were 2.

EBC scenarios and PP scenarios in water temperatures for adult spring-run Chinook salmon in the East Delta subregion (Table 5C.C-69, Table 5C.C-70) differed little when accounting for climate change. The average number of optimal days was 59 under EBC1 and EBC2, 58 and 55 under EBC2_ELT and EBC2_LLT, respectively, and 58 and 55 under PP_ELT and PP_LLT, respectively. The average number of supraoptimal days was 1 for EBC1 and EBC2, 3 under EBC2_ELT and PP_ELT, and 4 under EBC2_LLT and PP_LLT. There was 1 lethal day under EBC1 and EBC2, 0 and 1 under EBC2_ELT and PP2_ELT and 2 days under EBC2_LLT and PP_LLT, respectively.

EBC scenarios and PP scenarios in water temperatures for adult spring-run Chinook salmon in the North Delta subregion (Table 5C.C-71, Table 5C.C-72) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 59 for EBC1 and EBC2, and between 56 and 57 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 2 and 1 days under EBC1 and EBC2, respectively, and on 3 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. No average days with lethal temperatures occurred under EBC1 and EBC2, but 1 day of lethal temperatures was observed under EBC2_ELT and PP_ELT, and 2 days were observed under EBC2_LLT and PP_LLT.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult spring-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-73, Table 5C.C-74). Optimal water temperatures occurred on 59 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 58 to 59 days. Supraoptimal temperatures were reached on average for 1 day under EBC1 and EBC2, and 1 to 2 days for all other scenarios. There were no lethal temperature days under EBC1 and EBC2 scenarios, but 1 day of lethal temperatures occurred on average under all remaining scenarios.

Water temperatures in the South Delta for adult spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-75, Table 5C.C-76). There were no days in any model scenario in which water temperatures were suboptimal. Under EBC1 and EBC2, optimal water temperatures occurred on 59 days per year, on average. Water temperatures were optimal on 57 days per year on average for the rest of the model scenarios. Supraoptimal temperatures occurred on 1 day per year on average under EBC1 and EBC2, and on 3 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Lethal water temperatures occurred on 1 day per year on average under EBC1, EBC2, EBC2_ELT, PP_ELT, and PP_LLT and on 2 days per year under EBC2_LLT.

In the Suisun Bay subregion, water temperatures for adult spring-run Chinook salmon were similar among scenarios (Table 5C.C-77, Table 5C.C-78) after accounting for changing climate. Optimal water temperatures were reached on average on 60 days under EBC1 and EBC2, and 57 to 59 days for all other scenarios. Supraoptimal conditions occurred on average on 1 day under EBC1 and EBC2 as well as under EBC2_ELT and PP_ELT. Supraoptimal conditions occurred on average for 3 days under EBC2_LLT and PP_LLT. Lethal conditions occurred on average for 1 day in all model scenarios except EBC1 and EBC2.

In Suisun Marsh, the differences among scenarios of water temperatures for adult spring-run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-79, Table 5C.C-80). Optimal temperatures occurred on average on 60 days under EBC1 and EBC2, and on 56 to 58 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 1 day under EBC1 and EBC2, and on 2 to 4 days under all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures occurred on average on 1 day per year for all scenarios, except PP_ELT, where the number of days was 2.

Water temperatures in the West Delta for adult spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-81, Table 5C.C-82). Under EBC1 and EBC2, optimal water temperatures occurred on 60 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 59 and 58 days per year and under PP_ELT and PP_LLT on 59 and 58 days, respectively. Supraoptimal temperatures occurred on 1 day under EBC1 and EBC2 and from 1 to 2 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under EBC1 and EBC2, but 1 day with lethal temperatures occurred on average annually under all other scenarios.

Table 5C.C-67. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		61	61	56	52	56	50
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		60	60	59	59	59	58
1979	0	0	0	0	0	0		59	59	59	52	59	51
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		57	57	56	53	55	53
1982	0	0	0	0	0	0		60	60	59	58	58	58
1983	0	0	0	0	0	0		61	61	52	56	49	54
1984	0	0	0	0	0	0		55	55	61	50	61	49
1985	0	0	0	0	0	0		61	61	58	61	58	61
1986	0	0	0	0	0	0		61	61	49	59	50	59
1987	0	0	0	0	0	0		52	52	61	47	61	47
1988	0	0	0	0	0	0		61	61	61	55	61	55
1989	0	0	0	0	0	0		59	59	57	58	56	58
1990	0	0	0	0	0	0		61	61	52	54	53	55
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		59	59	58	56	57	56
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	5	9	5	10		0	0	0	0	0	1
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	1	1	1	2		0	0	1	1	1	1
1979	2	2	2	5	2	5		0	0	0	4	0	5
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	5	8	6	7		0	0	0	0	0	1
1982	1	1	2	3	3	3		0	0	0	0	0	0
1983	0	0	2	5	5	7		0	0	7	0	7	0
1984	1	1	0	5	0	5		5	5	0	6	0	7
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	3	2	1	2		0	0	9	0	10	0
1987	5	5	0	5	0	5		4	4	0	9	0	9
1988	0	0	0	6	0	6		0	0	0	0	0	0
1989	2	2	3	2	2	1		0	0	1	1	3	2
1990	0	0	7	5	6	4		0	0	2	2	2	2
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	1	1	2	4	2	4		1	1	1	1	1	2

Table 5C.C-68. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	60	61	60
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	1	0	1		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-69. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		60	60	55	47	56	49
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		59	59	58	58	59	57
1979	0	0	0	0	0	0		59	59	55	50	57	51
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		57	57	55	54	56	54
1982	0	0	0	0	0	0		59	59	59	57	57	57
1983	0	0	0	0	0	0		58	58	51	50	50	50
1984	0	0	0	0	0	0		54	54	61	52	61	52
1985	0	0	0	0	0	0		61	61	57	61	58	61
1986	0	0	0	0	0	0		61	61	58	58	52	57
1987	0	0	0	0	0	0		53	53	61	48	61	48
1988	0	0	0	0	0	0		61	61	61	54	61	55
1989	0	0	0	0	0	0		61	61	57	57	56	58
1990	0	0	0	0	0	0		61	61	53	54	53	54
1991	0	0	0	0	0	0		61	61	60	58	61	61
Avg	0	0	0	0	0	0		59	59	58	55	58	55
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	1	1	6	13	5	11		0	0	0	1	0	1
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	2	2	3		1	1	1	1	0	1
1979	2	2	6	8	4	6		0	0	0	3	0	4
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	6	7	5	7		0	0	0	0	0	0
1982	2	2	2	3	4	4		0	0	0	1	0	0
1983	3	3	6	8	7	10		0	0	4	3	4	1
1984	2	2	0	2	0	2		5	5	0	7	0	7
1985	0	0	4	0	3	0		0	0	0	0	0	0
1986	0	0	2	3	7	4		0	0	1	0	2	0
1987	3	3	0	6	0	4		5	5	0	7	0	9
1988	0	0	0	7	0	6		0	0	0	0	0	0
1989	0	0	4	4	4	2		0	0	0	0	1	1
1990	0	0	7	5	6	5		0	0	1	2	2	2
1991	0	0	1	3	0	0		0	0	0	0	0	0
Avg	1	1	3	4	3	4		1	1	0	2	1	2

Table 5C.C-70. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-71. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the North Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		59	59	58	58	58	58
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		58	58	56	54	56	55
1979	0	0	0	0	0	0		60	60	53	54	53	54
1980	0	0	0	0	0	0		60	61	60	58	60	58
1981	0	0	0	0	0	0		60	60	53	59	52	59
1982	0	0	0	0	0	0		58	58	57	59	58	58
1983	0	0	0	0	0	0		57	57	52	50	52	50
1984	0	0	0	0	0	0		54	54	60	54	60	53
1985	0	0	0	0	0	0		61	61	54	60	53	59
1986	0	0	0	0	0	0		59	59	59	57	59	56
1987	0	0	0	0	0	0		59	59	59	58	59	58
1988	0	0	0	0	0	0		60	60	56	53	56	53
1989	0	0	0	0	0	0		58	58	57	53	58	53
1990	0	0	0	0	0	0		61	61	56	55	56	55
1991	0	0	0	0	0	0		60	60	60	57	60	57
Avg	0	0	0	0	0	0		59	59	57	56	57	56
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	2	2	3	3	3	3		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	2	1	3	5	3	4		1	2	2	2	2	2
1979	1	1	7	2	7	3		0	0	1	5	1	4
1980	1	0	1	3	1	3		0	0	0	0	0	0
1981	1	1	6	2	7	2		0	0	2	0	2	0
1982	2	2	4	0	3	1		1	1	0	2	0	2
1983	3	3	4	7	4	7		1	1	5	4	5	4
1984	5	5	1	1	1	2		2	2	0	6	0	6
1985	0	0	5	1	5	2		0	0	2	0	3	0
1986	2	2	2	4	2	5		0	0	0	0	0	0
1987	1	1	2	3	2	3		1	1	0	0	0	0
1988	1	1	5	6	5	6		0	0	0	2	0	2
1989	3	3	2	6	2	5		0	0	2	2	1	3
1990	0	0	5	4	5	4		0	0	0	2	0	2
1991	1	1	1	2	1	2		0	0	0	2	0	2
Avg	2	1	3	3	3	3		0	0	1	2	1	2

Table 5C.C-72. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	1	1	0	0	0	0		60	60	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	1	1	0	0	0	0		60	60	61	61	61	61
1979	1	1	0	0	0	0		60	60	61	61	61	61
1980	0	0	1	0	1	0		61	61	60	61	60	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	1	1	0	0	0	0		60	60	61	61	61	61
1984	0	0	2	0	2	0		61	61	59	61	59	61
1985	6	4	1	0	1	0		55	57	60	61	60	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	1	1	0	0	0	0		60	60	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	2	0	2	0		61	61	59	61	59	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	2	2	2	0	1	0		59	59	59	61	60	61
Avg	1	1	1	0	0	0		60	60	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-73. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	58	57	58	56
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		58	58	58	61	58	61
1979	0	0	0	0	0	0		57	57	58	61	58	60
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		60	60	54	61	54	61
1982	0	0	0	0	0	0		58	58	55	61	55	61
1983	0	0	0	0	0	0		58	58	51	61	52	61
1984	0	0	0	0	0	0		54	54	61	54	61	54
1985	0	0	0	0	0	0		61	61	56	61	56	61
1986	0	0	0	0	0	0		61	61	58	61	58	61
1987	0	0	0	0	0	0		55	55	61	51	61	50
1988	0	0	0	0	0	0		61	61	60	61	60	60
1989	0	0	0	0	0	0		61	61	60	60	60	60
1990	0	0	0	0	0	0		61	61	54	57	54	56
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		59	59	58	59	58	59
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	3	4	3	5		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	2	2	0	0	0	0		1	1	3	0	3	0
1979	4	4	3	0	3	1		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	1	1	6	0	6	0		0	0	1	0	1	0
1982	3	3	6	0	6	0		0	0	0	0	0	0
1983	3	3	2	0	1	0		0	0	8	0	8	0
1984	3	3	0	2	0	2		4	4	0	5	0	5
1985	0	0	3	0	3	0		0	0	2	0	2	0
1986	0	0	3	0	3	0		0	0	0	0	0	0
1987	5	5	0	6	0	7		1	1	0	4	0	4
1988	0	0	1	0	1	1		0	0	0	0	0	0
1989	0	0	1	1	1	1		0	0	0	0	0	0
1990	0	0	7	4	7	5		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	1	1	2	1	2	1		0	0	1	1	1	1

Table 5C.C-74. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-75. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		60	60	56	48	56	49
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		59	59	58	59	58	59
1979	0	0	0	0	0	0		56	56	57	54	59	55
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		57	57	55	54	55	54
1982	0	0	0	0	0	0		58	58	55	61	54	61
1983	0	0	0	0	0	0		58	60	50	61	49	61
1984	0	0	0	0	0	0		55	55	60	51	60	51
1985	0	0	0	0	0	0		61	61	58	61	58	61
1986	0	0	0	0	0	0		61	61	54	59	51	59
1987	0	0	0	0	0	0		52	52	61	47	61	46
1988	0	0	0	0	0	0		61	61	61	55	61	59
1989	0	0	0	0	0	0		60	60	57	58	57	58
1990	0	0	0	0	0	0		61	61	52	54	52	55
1991	0	0	0	0	0	0		61	61	60	61	60	61
Avg	0	0	0	0	0	0		59	59	57	57	57	57
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	1	1	5	9	5	10		0	0	0	4	0	2
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	1	1	1	1		1	1	2	1	2	1
1979	5	5	3	7	2	6		0	0	1	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	6	6	6	6		0	0	0	1	0	1
1982	3	3	6	0	6	0		0	0	0	0	1	0
1983	3	1	3	0	4	0		0	0	8	0	8	0
1984	1	1	1	4	1	3		5	5	0	6	0	7
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	4	2	4	2		0	0	3	0	6	0
1987	3	3	0	4	0	5		6	6	0	10	0	10
1988	0	0	0	6	0	2		0	0	0	0	0	0
1989	1	1	4	3	4	3		0	0	0	0	0	0
1990	0	0	6	5	6	4		0	0	3	2	3	2
1991	0	0	1	0	1	0		0	0	0	0	0	0
Avg	1	1	3	3	3	3		1	1	1	2	1	1

Table 5C.C-76. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	60
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	1		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-77. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	60	57	59	57
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		60	60	59	58	59	58
1979	0	0	0	0	0	0		61	61	61	53	61	52
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	59	59	59	59
1982	0	0	0	0	0	0		61	61	61	60	61	60
1983	0	0	0	0	0	0		61	61	53	58	53	60
1984	0	0	0	0	0	0		55	55	61	53	61	53
1985	0	0	0	0	0	0		61	61	61	60	61	60
1986	0	0	0	0	0	0		61	61	52	58	53	59
1987	0	0	0	0	0	0		57	57	61	51	61	51
1988	0	0	0	0	0	0		61	61	61	55	61	55
1989	0	0	0	0	0	0		61	61	60	61	59	60
1990	0	0	0	0	0	0		61	61	57	55	57	55
1991	0	0	0	0	0	0		61	61	61	57	61	57
Avg	0	0	0	0	0	0		60	60	59	57	59	57
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	1	4	2	4		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	3	2	3		0	0	0	0	0	0
1979	0	0	0	8	0	9		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	2	2	2		0	0	0	0	0	0
1982	0	0	0	1	0	1		0	0	0	0	0	0
1983	0	0	2	3	2	1		0	0	6	0	6	0
1984	6	6	0	3	0	2		0	0	0	5	0	6
1985	0	0	0	1	0	1		0	0	0	0	0	0
1986	0	0	7	3	6	2		0	0	2	0	2	0
1987	4	3	0	8	0	7		0	1	0	2	0	3
1988	0	0	0	5	0	4		0	0	0	1	0	2
1989	0	0	1	0	2	1		0	0	0	0	0	0
1990	0	0	4	6	4	6		0	0	0	0	0	0
1991	0	0	0	4	0	4		0	0	0	0	0	0
Avg	1	1	1	3	1	3		0	0	1	1	1	1

Table 5C.C-78. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-79. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	57	50	56	52
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		60	60	59	59	59	59
1979	0	0	0	0	0	0		60	59	60	54	60	50
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		58	57	56	52	55	54
1982	0	0	0	0	0	0		61	61	59	59	59	55
1983	0	0	0	0	0	0		61	61	50	55	50	55
1984	0	0	0	0	0	0		55	55	61	49	60	50
1985	0	0	0	0	0	0		61	61	58	61	58	61
1986	0	0	0	0	0	0		61	61	48	59	49	58
1987	0	0	0	0	0	0		52	52	61	47	61	48
1988	0	0	0	0	0	0		61	61	61	55	61	54
1989	0	0	0	0	0	0		61	59	57	58	57	58
1990	0	0	0	0	0	0		61	61	54	55	53	55
1991	0	0	0	0	0	0		61	61	61	61	60	61
Avg	0	0	0	0	0	0		60	60	58	56	58	56
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	4	11	5	9		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	1	1	1	1		0	0	1	1	1	1
1979	1	2	1	6	1	9		0	0	0	1	0	2
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	3	4	5	8	6	6		0	0	0	1	0	1
1982	0	0	2	2	2	6		0	0	0	0	0	0
1983	0	0	4	6	4	6		0	0	7	0	7	0
1984	2	2	0	6	1	5		4	4	0	6	0	6
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	3	2	2	3		0	0	10	0	10	0
1987	4	4	0	4	0	4		5	5	0	10	0	9
1988	0	0	0	6	0	7		0	0	0	0	0	0
1989	0	2	4	3	2	3		0	0	0	0	2	0
1990	0	0	5	4	4	3		0	0	2	2	4	3
1991	0	0	0	0	1	0		0	0	0	0	0	0
Avg	1	1	2	4	2	4		1	1	1	1	2	1

Table 5C.C-80. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-81. Number of Days within Temperature Requirements for Sacramento River–Origin Spring-Run Chinook Salmon Adults in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		61	61	61	54	61	55
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	60	60	60	60
1979	0	0	0	0	0	0		61	61	61	56	61	56
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	59	58	59	57
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	54	55	53	56
1984	0	0	0	0	0	0		56	56	61	54	61	54
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	50	61	49	61
1987	0	0	0	0	0	0		53	53	61	49	61	49
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	56	58	56	57
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		60	60	59	58	59	58
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	0	7	0	6		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	1	1	1	1		0	0	0	0	0	0
1979	0	0	0	5	0	5		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	3	2	4		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	1	6	2	5		0	0	6	0	6	0
1984	3	3	0	2	0	2		2	2	0	5	0	5
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	7	0	8	0		0	0	4	0	4	0
1987	6	6	0	6	0	6		2	2	0	6	0	6
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	5	3	5	4		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	1	1	1	2	1	2		0	0	1	1	1	1

Table 5C.C-82. Number of Days within Temperature Requirements for San Joaquin River–Origin Spring-Run Chinook Salmon Adults in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	**EBC2**	**EBC2_ELT**	**EBC2_LLT**	**PP_ELT**	**PP_LLT**		**EBC1**	**EBC2**	**EBC2_ELT**	**EBC2_LLT**	**PP_ELT**	**PP_LLT**
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤20°C)**					
1976	0	0	0	0	0	0		61	61	61	61	61	61
1977	0	0	0	0	0	0		61	61	61	61	61	61
1978	0	0	0	0	0	0		61	61	61	61	61	61
1979	0	0	0	0	0	0		61	61	61	61	61	61
1980	0	0	0	0	0	0		61	61	61	61	61	61
1981	0	0	0	0	0	0		61	61	61	61	61	61
1982	0	0	0	0	0	0		61	61	61	61	61	61
1983	0	0	0	0	0	0		61	61	61	61	61	61
1984	0	0	0	0	0	0		61	61	61	61	61	61
1985	0	0	0	0	0	0		61	61	61	61	61	61
1986	0	0	0	0	0	0		61	61	61	61	61	61
1987	0	0	0	0	0	0		61	61	61	61	61	61
1988	0	0	0	0	0	0		61	61	61	61	61	61
1989	0	0	0	0	0	0		61	61	61	61	61	61
1990	0	0	0	0	0	0		61	61	61	61	61	61
1991	0	0	0	0	0	0		61	61	61	61	61	61
Avg	0	0	0	0	0	0		61	61	61	61	61	61
	Supraoptimal (>20°C and ≤21°C)							**Lethal (>21°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.4 Fall-Run Chinook Salmon

5C.C.4.1 Juvenile

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile fall-run Chinook salmon in the Cache Slough subregion (Table 5C.C-83). The average number of optimal days was 86 and 87 under EBC1 and EBC2, and ranged from 89 to 100 under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 2 under EBC1 and EBC2, 3 to 4 under EBC2_ELT and PP_ELT, respectively, and 5 under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios for water temperatures for juvenile fall-run Chinook salmon in the East Delta subregion (Table 5C.C-84) differed little when accounting for climate change. The average number of optimal days was 80 days under EBC1 and EBC2 and 83 to 100 under EBC2_ELT and EBC2_LLT, and 88 to 101 days under PP_ELT and PP_LLT, respectively. The average number of supraoptimal days was 2 days for EBC1 and EBC2, 3 to 4 days under EBC2_ELT and PP_ELT, respectively, and 6 days under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios for water temperatures for juvenile fall-run Chinook salmon in the North Delta subregion (Table 5C.C-85) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 69 for EBC1 and EBC2, and between 71 and 92 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 2 days under EBC1 and EBC2, and ranged from 4 to 5 days under EBC2_ELT and EBC2_LLT, and from 4 to 5 days under PP_ELT and PP_LLT, respectively. No days with lethal temperatures occurred during the modeling period under any of the scenarios considered.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile fall-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-86). Optimal water temperatures occurred on 89 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 93 to 94 days. Supraoptimal temperatures were reached on average on 2 days under EBC1 and EBC2. Under all other scenarios, this number ranged from 2 to 3 days. There were no lethal temperature days under any scenario.

Water temperatures in the South Delta for juvenile fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-87). Suboptimal water temperature conditions occurred on 24 days per year on average under EBC1 and EBC2, and 18–20 days under all other model scenarios. optimal water temperatures occurred on 94 days per year, on average under EBC1 and EBC2, and on 97–98 days per year for all other scenarios. Supraoptimal temperatures occurred on 2 days under EBC1 and EBC2, and on 4 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days

In the Suisun Bay subregion, water temperatures for juvenile fall-run Chinook salmon were similar among scenarios (Table 5C.C-88) after accounting for changing climate. Optimal water temperatures were reached on average on 81 and 82 days under EBC1 and EBC2, respectively, and ranged from 84 to 91 days for all other scenarios. EBC1 and EBC2 both averaged 1 day of supraoptimal temperature, while the number of days for all other scenarios varied from 2 to 4 days. There were no lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for juvenile fall-run Chinook salmon were minor, after climate change was taken into consideration (Table 5C.C-89). Optimal temperatures occurred on average on 86 and 87 days under EBC1 and EBC2, respectively. Under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT, the number of optimal temperature days varied from 90 to 96. Supraoptimal water temperature conditions on average occurred on 1 and 2 days under EBC1 and EBC2, respectively, and on 3 to 5 days under all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Water temperatures in the West Delta for juvenile fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-90). Under EBC1 and EBC2, optimal water temperatures occurred on 80 days per year, on average. Under EBC2_ELT, and EBC2_LLT, optimal temperature conditions occurred on 85 and 97 days per year, respectively, and on 89 to 98 days under PP_ELT and PP_LLT, respectively. Supraoptimal temperatures occurred on average on 1 day under EBC1 and EBC2, and on 2 and 3 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

Table 5C.C-83. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<13°C)**							**Optimal (≥13°C and ≤20°C)**					
1976	38	37	28	18	28	18		83	84	88	94	88	92
1977	28	27	16	14	16	14		92	93	104	106	104	106
1978	23	23	26	13	29	18		96	96	92	105	89	99
1979	34	34	33	16	34	23		84	84	85	95	84	87
1980	31	31	22	5	30	17		90	90	99	116	91	104
1981	33	29	21	11	23	9		83	87	94	101	91	103
1982	44	45	35	17	42	17		75	74	83	100	75	100
1983	33	33	28	9	35	13		87	87	83	106	73	100
1984	33	34	32	21	34	20		82	81	89	89	87	89
1985	35	33	19	18	16	18		85	87	98	102	101	102
1986	20	19	19	9	33	13		100	101	89	109	76	105
1987	36	35	22	14	21	14		75	76	98	92	99	92
1988	21	18	14	11	13	10		100	103	107	104	108	105
1989	36	36	30	26	29	25		82	82	86	91	86	92
1990	38	38	35	26	33	26		82	82	76	87	79	88
1991	37	37	31	14	35	14		83	83	89	106	85	106
Avg	33	32	26	15	28	17		86	87	91	100	89	98
	Supraoptimal (>20°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	5	9	5	11		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	2	2	3		0	0	0	0	0	0
1979	2	2	2	9	2	10		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	5	8	6	8		0	0	0	0	0	0
1982	1	1	2	3	3	3		0	0	0	0	0	0
1983	0	0	9	5	12	7		0	0	0	0	0	0
1984	6	6	0	11	0	12		0	0	0	0	0	0
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	12	2	11	2		0	0	0	0	0	0
1987	9	9	0	14	0	14		0	0	0	0	0	0
1988	0	0	0	6	0	6		0	0	0	0	0	0
1989	2	2	4	3	5	3		0	0	0	0	0	0
1990	0	0	9	7	8	6		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	2	2	3	5	4	5		0	0	0	0	0	0

Table 5C.C-84. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	38	38	28	18	23	13		82	82	87	89	93	96
1977	28	32	18	12	15	13		92	88	102	108	105	107
1978	26	26	29	11	24	11		92	92	88	106	94	105
1979	40	39	36	12	33	11		78	79	78	97	83	99
1980	45	45	47	8	36	7		76	76	74	113	85	114
1981	52	49	31	7	23	9		64	67	83	106	92	104
1982	52	52	48	22	45	19		66	66	70	94	71	97
1983	52	52	39	14	38	12		65	65	71	95	71	97
1984	37	37	47	21	38	18		77	77	74	91	83	94
1985	42	42	33	17	24	17		78	78	83	103	93	103
1986	37	37	38	5	37	5		83	83	79	112	74	111
1987	36	36	31	10	19	11		76	76	89	97	101	96
1988	22	22	18	10	14	10		99	99	103	104	107	105
1989	38	38	33	22	30	23		82	82	83	94	85	94
1990	43	44	41	24	32	25		77	76	71	89	80	88
1991	33	34	33	11	28	11		87	86	86	106	92	109
Avg	39	39	34	14	29	13		80	80	83	100	88	101
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	1	1	6	14	5	12		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	2	2	3	3	2	4		0	0	0	0	0	0
1979	2	2	6	11	4	10		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	4	4	6	7	5	7		0	0	0	0	0	0
1982	2	2	2	4	4	4		0	0	0	0	0	0
1983	3	3	10	11	11	11		0	0	0	0	0	0
1984	7	7	0	9	0	9		0	0	0	0	0	0
1985	0	0	4	0	3	0		0	0	0	0	0	0
1986	0	0	3	3	9	4		0	0	0	0	0	0
1987	8	8	0	13	0	13		0	0	0	0	0	0
1988	0	0	0	7	0	6		0	0	0	0	0	0
1989	0	0	4	4	5	3		0	0	0	0	0	0
1990	0	0	8	7	8	7		0	0	0	0	0	0
1991	0	0	1	3	0	0		0	0	0	0	0	0
Avg	2	2	3	6	4	6		0	0	0	0	0	0

Table 5C.C-85. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	47	48	32	27	32	27		72	71	86	91	86	91
1977	59	59	49	18	50	15		61	61	71	102	70	105
1978	45	45	42	18	44	18		72	72	73	95	71	96
1979	52	52	48	26	45	24		67	67	64	87	67	89
1980	50	50	53	24	52	24		70	71	67	94	68	94
1981	58	56	44	25	46	25		61	63	68	93	65	93
1982	60	60	50	29	50	29		57	57	66	89	67	88
1983	56	56	41	20	41	20		60	60	70	89	70	89
1984	42	42	53	21	52	20		72	72	67	93	68	93
1985	49	51	56	29	56	29		71	69	57	90	56	89
1986	42	42	40	17	40	17		76	76	78	99	78	98
1987	44	44	46	24	47	24		74	74	72	93	71	93
1988	35	35	38	12	39	12		85	85	78	101	77	101
1989	46	46	38	30	38	30		71	71	78	82	79	82
1990	48	49	42	34	42	34		72	71	73	80	73	80
1991	55	55	52	20	50	20		64	64	67	96	69	96
Avg	49	49	45	23	45	23		69	69	71	92	71	92
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	2	2	3	3	3	3		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	3	3	5	7	5	6		0	0	0	0	0	0
1979	1	1	8	7	8	7		0	0	0	0	0	0
1980	1	0	1	3	1	3		0	0	0	0	0	0
1981	1	1	8	2	9	2		0	0	0	0	0	0
1982	3	3	4	2	3	3		0	0	0	0	0	0
1983	4	4	9	11	9	11		0	0	0	0	0	0
1984	7	7	1	7	1	8		0	0	0	0	0	0
1985	0	0	7	1	8	2		0	0	0	0	0	0
1986	2	2	2	4	2	5		0	0	0	0	0	0
1987	2	2	2	3	2	3		0	0	0	0	0	0
1988	1	1	5	8	5	8		0	0	0	0	0	0
1989	3	3	4	8	3	8		0	0	0	0	0	0
1990	0	0	5	6	5	6		0	0	0	0	0	0
1991	1	1	1	4	1	4		0	0	0	0	0	0
Avg	2	2	4	5	4	5		0	0	0	0	0	0

Table 5C.C-86. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	32	32	34	25	33	23		89	89	84	92	85	93
1977	28	29	15	15	15	15		92	91	105	105	105	105
1978	23	23	24	25	23	25		94	94	93	95	94	95
1979	33	33	28	31	28	31		83	83	89	89	89	88
1980	28	27	18	24	19	26		93	94	103	97	102	95
1981	26	24	22	16	22	15		93	95	91	104	91	105
1982	34	34	26	39	24	39		83	83	88	81	90	81
1983	26	25	27	36	27	35		91	92	83	84	84	85
1984	30	30	32	25	30	25		84	84	89	89	91	89
1985	36	35	23	22	23	23		84	85	92	98	92	97
1986	24	24	18	21	16	21		96	96	99	99	101	99
1987	30	30	25	23	22	20		84	84	95	87	98	89
1988	19	20	15	14	13	13		102	101	105	107	107	107
1989	35	34	29	32	29	32		85	86	90	87	90	87
1990	38	38	32	30	31	30		82	82	81	86	82	85
1991	27	28	22	20	21	16		93	92	98	100	99	104
Avg	29	29	24	25	24	24		89	89	93	94	94	94
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	3	4	3	5		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	3	3	3	0	3	0		0	0	0	0	0	0
1979	4	4	3	0	3	1		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	1	1	7	0	7	0		0	0	0	0	0	0
1982	3	3	6	0	6	0		0	0	0	0	0	0
1983	3	3	10	0	9	0		0	0	0	0	0	0
1984	7	7	0	7	0	7		0	0	0	0	0	0
1985	0	0	5	0	5	0		0	0	0	0	0	0
1986	0	0	3	0	3	0		0	0	0	0	0	0
1987	6	6	0	10	0	11		0	0	0	0	0	0
1988	0	0	1	0	1	1		0	0	0	0	0	0
1989	0	0	1	1	1	1		0	0	0	0	0	0
1990	0	0	7	4	7	5		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	2	2	3	2	3	2		0	0	0	0	0	0

Table 5C.C-87. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)						Optimal (≥13°C and ≤20°C)					
1976	34	34	24	14	23	15	86	86	92	94	93	94
1977	21	21	15	14	15	15	99	99	105	106	105	105
1978	23	23	22	16	20	18	95	95	95	102	97	100
1979	33	33	29	27	29	29	82	82	87	86	89	85
1980	19	19	14	17	15	22	102	102	107	104	106	99
1981	16	16	15	11	15	11	100	100	99	102	99	102
1982	27	27	19	25	21	35	90	90	95	95	92	85
1983	21	21	26	32	26	32	96	98	83	88	82	88
1984	30	30	20	25	23	25	85	85	100	86	97	86
1985	24	24	16	19	16	19	96	96	101	101	101	101
1986	14	14	9	3	8	7	106	106	104	115	102	111
1987	26	25	13	12	13	10	85	86	107	94	107	95
1988	13	14	14	10	13	10	108	107	107	105	108	109
1989	33	34	27	25	27	26	86	85	89	92	89	91
1990	35	35	31	26	29	27	85	85	80	87	82	87
1991	19	19	15	12	15	11	101	101	104	108	104	109
Avg	24	24	19	18	19	20	94	94	97	98	97	97
	Supraoptimal (>20°C and ≤24°C)						Lethal (>24°C)					
1976	1	1	5	13	5	12	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	2	2	3	2	3	2	0	0	0	0	0	0
1979	5	5	4	7	2	6	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	4	4	6	7	6	7	0	0	0	0	0	0
1982	3	3	6	0	7	0	0	0	0	0	0	0
1983	3	1	11	0	12	0	0	0	0	0	0	0
1984	6	6	1	10	1	10	0	0	0	0	0	0
1985	0	0	3	0	3	0	0	0	0	0	0	0
1986	0	0	7	2	10	2	0	0	0	0	0	0
1987	9	9	0	14	0	15	0	0	0	0	0	0
1988	0	0	0	6	0	2	0	0	0	0	0	0
1989	1	1	4	3	4	3	0	0	0	0	0	0
1990	0	0	9	7	9	6	0	0	0	0	0	0
1991	0	0	1	0	1	0	0	0	0	0	0	0
Avg	2	2	4	4	4	4	0	0	0	0	0	0

Table 5C.C-88. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	37	36	37	31	37	29		84	85	83	86	82	88
1977	39	40	29	31	27	29		81	80	91	89	93	91
1978	28	28	29	23	29	23		91	91	89	94	89	94
1979	34	34	34	30	33	30		86	86	86	82	87	81
1980	42	42	36	22	30	21		79	79	85	99	91	100
1981	42	41	31	22	28	22		78	79	87	96	90	96
1982	48	49	44	21	39	19		72	71	76	98	81	100
1983	47	47	36	22	35	22		73	73	76	95	77	97
1984	36	36	39	26	32	24		79	79	82	87	89	89
1985	41	39	25	33	25	32		79	81	95	86	95	87
1986	31	29	34	16	28	15		89	91	77	101	84	103
1987	38	38	33	31	31	29		78	78	87	79	89	81
1988	27	27	26	21	26	20		94	94	95	94	95	95
1989	37	37	35	34	33	34		83	83	84	86	85	85
1990	43	43	43	42	42	38		77	77	73	72	74	76
1991	43	43	36	30	34	25		77	77	84	86	86	91
Avg	38	38	34	27	32	26		81	82	84	89	87	91
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	1	4	2	4		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	3	2	3		0	0	0	0	0	0
1979	0	0	0	8	0	9		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	2	2	2		0	0	0	0	0	0
1982	0	0	0	1	0	1		0	0	0	0	0	0
1983	0	0	8	3	8	1		0	0	0	0	0	0
1984	6	6	0	8	0	8		0	0	0	0	0	0
1985	0	0	0	1	0	1		0	0	0	0	0	0
1986	0	0	9	3	8	2		0	0	0	0	0	0
1987	4	4	0	10	0	10		0	0	0	0	0	0
1988	0	0	0	6	0	6		0	0	0	0	0	0
1989	0	0	1	0	2	1		0	0	0	0	0	0
1990	0	0	4	6	4	6		0	0	0	0	0	0
1991	0	0	0	4	0	4		0	0	0	0	0	0
Avg	1	1	2	4	2	4		0	0	0	0	0	0

Table 5C.C-89. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	37	37	32	23	32	25		84	84	85	87	84	87
1977	28	25	17	16	16	15		92	95	103	104	104	105
1978	27	26	28	20	25	20		92	93	90	98	93	98
1979	35	34	33	26	33	25		84	84	86	87	86	84
1980	30	30	23	17	20	17		91	91	98	104	101	104
1981	18	18	16	14	16	15		99	98	99	97	98	98
1982	51	51	49	22	44	21		69	69	69	96	74	93
1983	45	44	30	12	29	12		75	76	79	102	80	102
1984	33	33	23	21	21	20		82	82	98	88	99	90
1985	31	29	18	23	17	23		89	91	99	97	100	97
1986	24	24	28	14	28	12		96	96	79	104	80	105
1987	34	33	19	17	15	17		77	78	101	89	105	90
1988	23	22	21	12	14	12		98	99	100	103	107	102
1989	37	36	35	29	30	30		83	82	81	88	86	87
1990	41	40	34	29	33	29		79	80	79	85	79	85
1991	34	34	27	16	27	18		86	86	93	104	92	102
Avg	33	32	27	19	25	19		86	87	90	96	92	96
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	4	11	5	9		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	2	2	2	2		0	0	0	0	0	0
1979	1	2	1	7	1	11		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	3	4	5	9	6	7		0	0	0	0	0	0
1982	0	0	2	2	2	6		0	0	0	0	0	0
1983	0	0	11	6	11	6		0	0	0	0	0	0
1984	6	6	0	12	1	11		0	0	0	0	0	0
1985	0	0	3	0	3	0		0	0	0	0	0	0
1986	0	0	13	2	12	3		0	0	0	0	0	0
1987	9	9	0	14	0	13		0	0	0	0	0	0
1988	0	0	0	6	0	7		0	0	0	0	0	0
1989	0	2	4	3	4	3		0	0	0	0	0	0
1990	0	0	7	6	8	6		0	0	0	0	0	0
1991	0	0	0	0	1	0		0	0	0	0	0	0
Avg	1	2	3	5	4	5		0	0	0	0	0	0

Table 5C.C-90. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Juvenile Rearing in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	40	40	32	23	31	22		81	81	89	91	90	93
1977	35	35	21	17	20	16		85	85	99	103	100	104
1978	27	27	34	20	28	20		93	93	85	99	91	99
1979	35	36	34	26	34	26		85	84	86	89	86	89
1980	44	44	33	19	24	18		77	77	88	102	97	103
1981	46	45	33	14	23	14		74	75	85	103	95	102
1982	54	53	49	19	37	18		66	67	71	101	83	102
1983	46	46	34	18	34	17		74	74	79	96	78	98
1984	36	36	42	26	35	25		80	80	79	88	86	89
1985	43	41	26	22	24	22		77	79	94	98	96	98
1986	29	28	31	15	25	14		91	92	78	105	83	106
1987	40	41	27	17	26	16		72	71	93	91	94	92
1988	25	25	23	15	22	14		96	96	98	106	99	107
1989	39	39	37	32	37	32		81	81	83	88	83	88
1990	45	45	44	30	42	30		75	75	71	87	73	86
1991	43	43	40	14	38	14		77	77	80	106	82	106
Avg	39	39	34	20	30	20		80	80	85	97	89	98
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	7	0	6		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	1	1	1	1		0	0	0	0	0	0
1979	0	0	0	5	0	5		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	2	3	2	4		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	7	6	8	5		0	0	0	0	0	0
1984	5	5	0	7	0	7		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	11	0	12	0		0	0	0	0	0	0
1987	8	8	0	12	0	12		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	5	3	5	4		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	1	1	2	3	2	3		0	0	0	0	0	0

5C.C.4.2 Smoltification

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt fall-run Chinook salmon in the Cache Slough subregion (Table 5C.C-91). The average number of optimal days was 111 days under EBC1 and EBC2 and 106 to 110 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 4 under EBC1 and EBC2, 8 under EBC2_ELT and PP_ELT, and 13 under EBC2_LLT and PP_LLT. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in water temperatures for smolt fall-run Chinook salmon in the East Delta subregion (Table 5C.C-92) differed little when accounting for climate change. The average number of optimal days was 111 days under EBC1 and EBC2, 108 and 109 days under EBC2_ELT and PP_ELT, respectively, and 107 days under EBC2_LLT and PP_LLT. The average number of supraoptimal days was 5 for EBC1 and EBC2, 10 to 9 days under EBC2_ELT and PP_ELT, and 13 to 9 days under EBC2_LLT and PP_LLT. There were no lethal days observed under any scenario.

EBC scenarios and PP scenarios in water temperatures for smolt fall-run Chinook salmon in the North Delta subregion (Table 5C.C-93) were similar, considering climate change effects on water temperature. The average number of days of optimal water temperatures was 102 for EBC1 and EBC2 and between 102 and 108 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on average on 5 days under EBC1 and EBC2, on 9 days under EBC2_ELT and PP_ELT, and on 12 and 11 days under EBC2_LLT and PP_LLT, respectively. No days with lethal temperatures occurred during the modeling period.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt fall-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-94). Optimal water temperatures occurred on average on 113 and 112 days under the EBC1 and EBC2 scenarios, respectively. Under all other scenarios, the number of days with optimal water temperatures ranged from 111 to 113. Supraoptimal temperatures were reached on average for 5 days under EBC1 and EBC2. Under all other scenarios, this number ranged from 7 to 8 days. There were no lethal temperature days under any scenario.

Water temperatures in the South Delta for smolt fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-95). Suboptimal water temperature conditions occurred on 3 days per year on average under EBC1 and EBC2, and on 1 day under all other model scenarios. Under EBC1 and EBC2, optimal water temperatures occurred on 112 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 110 and 108 days per year, respectively; and on 110 to 108 days under PP_ELT and PP_LLT, respectively. Supraoptimal temperatures occurred on 5 days under EBC1 and EBC2, and on 9 to 12 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days

In the Suisun Bay subregion, water temperatures for smolt fall-run Chinook salmon were similar among scenarios (Table 5C.C-96) after accounting for changing climate. Optimal water temperatures were reached on average on 111 days under EBC1 and 107 to 111 days for all other scenarios. EBC1 and EBC2 averaged 3 days of supraoptimal days, while the number of days for EBC_ELT andEBC1_LLT and PP_ELT and PP_LLT varied from 6 to 11 days. There were no lethal temperature days under any scenario.

Water temperatures in the Suisun Marsh for smolt fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-97). Under EBC1 and EBC2, optimal water temperatures occurred on 110 days per year, on average. Under EBC2_ELT, and PP_ELT, optimal temperature conditions occurred on 108 to 109 days per year; and on 106 days under PP_ELT and PP_LLT. Supraoptimal temperatures occurred on 4 days under EBC1 and EBC2, and on 8 to 12 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no lethal temperature days under any scenario.

In the West Delta, the differences among scenarios of water temperatures for smolt fall-run Chinook salmon were minor, after climate change was taken into consideration (Table 5C.C-98). Optimal temperatures occurred on average on 110 days under EBC1 and EBC2 and on 109 to 111 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal water temperature conditions occurred on 3 days under EBC1 and EBC2 and on 6 to 10 days under all other scenarios (i.e., EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures did not occur under any scenario.

Table 5C.C-91. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	0	0	0	0	0	0		118	118	108	99	110	99
1977	9	9	8	2	7	5		111	111	112	115	113	112
1978	0	0	0	0	0	0		118	118	116	108	116	108
1979	5	5	5	2	6	6		106	106	107	103	105	100
1980	2	1	0	0	2	0		119	120	121	116	119	116
1981	2	1	0	0	1	0		110	111	108	107	106	107
1982	8	8	0	0	5	0		108	108	112	106	108	106
1983	0	0	0	0	0	0		112	112	103	104	103	104
1984	1	1	13	0	12	0		113	113	102	102	104	102
1985	14	14	0	10	0	10		106	106	111	106	110	105
1986	0	0	0	0	1	0		116	116	104	109	103	109
1987	0	0	0	0	0	0		107	107	115	98	116	97
1988	4	3	0	0	0	0		116	117	116	106	116	105
1989	17	17	12	0	13	0		98	98	102	111	100	109
1990	14	14	7	2	11	3		99	99	102	104	99	101
1991	3	4	0	0	0	0		117	116	114	114	116	113
Avg	5	5	3	1	4	2		111	111	110	107	109	106
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	3	3	13	22	11	22		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	2	2	4	12	4	12		0	0	0	0	0	0
1979	9	9	8	15	9	14		0	0	0	0	0	0
1980	0	0	0	5	0	5		0	0	0	0	0	0
1981	8	8	12	13	13	13		0	0	0	0	0	0
1982	4	4	8	14	7	14		0	0	0	0	0	0
1983	8	8	17	16	17	16		0	0	0	0	0	0
1984	7	7	6	19	5	19		0	0	0	0	0	0
1985	0	0	9	4	10	5		0	0	0	0	0	0
1986	4	4	16	11	16	11		0	0	0	0	0	0
1987	13	13	5	22	4	23		0	0	0	0	0	0
1988	1	1	5	15	5	16		0	0	0	0	0	0
1989	5	5	6	9	7	11		0	0	0	0	0	0
1990	7	7	11	14	10	16		0	0	0	0	0	0
1991	0	0	6	6	4	7		0	0	0	0	0	0
Avg	4	4	8	13	8	13		0	0	0	0	0	0

Table 5C.C-92. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the East Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	0	0	0	0	0	0		117	117	102	99	104	99
1977	8	7	6	0	6	0		112	113	114	117	114	117
1978	0	0	0	0	0	0		117	116	112	105	114	107
1979	3	2	2	0	2	0		107	108	106	103	108	104
1980	1	1	0	0	0	0		118	118	118	115	121	115
1981	2	2	3	0	0	0		111	111	104	107	107	107
1982	11	11	5	0	1	0		104	104	102	109	107	110
1983	0	0	0	0	0	0		111	111	102	104	101	104
1984	5	5	12	0	12	0		104	104	105	102	105	102
1985	13	13	0	1	0	7		107	107	109	114	110	109
1986	0	0	0	0	0	0		114	115	104	107	107	108
1987	0	0	0	0	0	0		107	107	115	96	115	97
1988	0	0	0	0	0	0		119	119	114	110	115	108
1989	8	9	6	0	7	0		108	107	108	110	106	111
1990	7	7	7	0	6	0		106	106	100	102	101	105
1991	0	0	0	0	0	0		118	117	115	113	114	113
Avg	4	4	3	0	2	0		111	111	108	107	109	107
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	4	4	19	22	17	22		0	0	0	0	0	0
1977	0	0	0	3	0	3		0	0	0	0	0	0
1978	3	4	8	15	6	13		0	0	0	0	0	0
1979	10	10	12	17	10	16		0	0	0	0	0	0
1980	2	2	3	6	0	6		0	0	0	0	0	0
1981	7	7	13	13	13	13		0	0	0	0	0	0
1982	5	5	13	11	12	10		0	0	0	0	0	0
1983	9	9	18	16	19	16		0	0	0	0	0	0
1984	12	12	4	19	4	19		0	0	0	0	0	0
1985	0	0	11	5	10	4		0	0	0	0	0	0
1986	6	5	16	13	13	12		0	0	0	0	0	0
1987	13	13	5	24	5	23		0	0	0	0	0	0
1988	2	2	7	11	6	13		0	0	0	0	0	0
1989	4	4	6	10	7	9		0	0	0	0	0	0
1990	7	7	13	18	13	15		0	0	0	0	0	0
1991	2	3	5	7	6	7		0	0	0	0	0	0
Avg	5	5	10	13	9	13		0	0	0	0	0	0

Table 5C.C-93. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	11	10	1	1	1	1		104	105	104	102	105	103
1977	13	12	7	1	6	1		107	108	113	119	114	119
1978	16	16	8	0	8	0		99	99	101	107	101	108
1979	17	16	9	5	9	5		95	96	96	100	97	99
1980	11	11	6	0	6	0		107	107	112	116	112	117
1981	4	4	7	0	7	0		108	108	101	109	101	110
1982	15	15	9	0	9	0		100	100	100	111	100	111
1983	9	9	13	0	13	0		105	104	90	106	90	106
1984	15	15	14	0	14	0		96	96	103	107	103	108
1985	19	17	10	4	11	5		99	100	98	107	97	106
1986	8	8	7	0	7	0		108	108	105	110	106	109
1987	14	14	6	0	6	0		96	96	111	106	110	105
1988	7	7	5	0	6	0		111	112	103	109	102	108
1989	16	16	19	3	17	3		98	98	92	101	92	105
1990	23	23	18	5	18	5		91	91	94	98	94	100
1991	13	13	9	0	8	0		104	104	107	113	109	113
Avg	13	13	9	1	9	1		102	102	102	108	102	108
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	6	6	16	18	15	17		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	5	5	11	13	11	12		0	0	0	0	0	0
1979	8	8	15	15	14	16		0	0	0	0	0	0
1980	3	3	3	5	3	4		0	0	0	0	0	0
1981	8	8	12	11	12	10		0	0	0	0	0	0
1982	5	5	11	9	11	9		0	0	0	0	0	0
1983	6	7	17	14	17	14		0	0	0	0	0	0
1984	10	10	4	14	4	13		0	0	0	0	0	0
1985	2	3	12	9	12	9		0	0	0	0	0	0
1986	4	4	8	10	7	11		0	0	0	0	0	0
1987	10	10	3	14	4	15		0	0	0	0	0	0
1988	3	2	13	12	13	13		0	0	0	0	0	0
1989	6	6	9	16	11	12		0	0	0	0	0	0
1990	6	6	8	17	8	15		0	0	0	0	0	0
1991	3	3	4	7	3	7		0	0	0	0	0	0
Avg	5	5	9	12	9	11		0	0	0	0	0	0

Table 5C.C-94. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	0	0	0	0	0	0		119	119	113	100	113	100
1977	7	7	5	0	5	1		113	113	115	120	115	119
1978	0	0	0	0	0	0		115	115	112	115	112	115
1979	3	3	2	5	2	4		108	108	107	107	107	108
1980	0	0	0	1	0	1		121	121	120	120	120	120
1981	0	0	0	0	0	0		113	112	106	113	106	112
1982	0	0	0	0	0	0		112	112	108	118	108	118
1983	0	0	0	0	0	0		110	110	104	113	105	115
1984	0	0	5	0	4	0		110	110	112	110	113	109
1985	12	12	0	8	0	9		108	108	109	111	109	110
1986	0	0	0	0	0	0		116	116	104	115	103	115
1987	0	0	0	0	0	0		106	106	117	104	118	101
1988	1	1	0	0	0	0		119	119	114	114	114	114
1989	13	14	7	0	7	0		104	102	108	116	108	115
1990	8	8	8	0	8	1		109	109	103	111	103	110
1991	2	2	0	0	0	0		117	117	118	117	118	116
Avg	3	3	2	1	2	1		113	112	111	113	111	112
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	2	2	8	21	8	21		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	5	5	8	5	8	5		0	0	0	0	0	0
1979	9	9	11	8	11	8		0	0	0	0	0	0
1980	0	0	1	0	1	0		0	0	0	0	0	0
1981	7	8	14	7	14	8		0	0	0	0	0	0
1982	8	8	12	2	12	2		0	0	0	0	0	0
1983	10	10	16	7	15	5		0	0	0	0	0	0
1984	11	11	4	11	4	12		0	0	0	0	0	0
1985	0	0	11	1	11	1		0	0	0	0	0	0
1986	4	4	16	5	17	5		0	0	0	0	0	0
1987	14	14	3	16	2	19		0	0	0	0	0	0
1988	1	1	7	7	7	7		0	0	0	0	0	0
1989	3	4	5	4	5	5		0	0	0	0	0	0
1990	3	3	9	9	9	9		0	0	0	0	0	0
1991	1	1	2	3	2	4		0	0	0	0	0	0
Avg	5	5	8	7	8	7		0	0	0	0	0	0

Table 5C.C-95. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	0	0	0	0	0	0		117	117	103	99	103	99
1977	8	8	6	0	6	0		112	112	113	116	114	117
1978	0	0	0	0	0	0		115	115	112	109	112	110
1979	4	4	2	4	2	4		108	108	108	102	109	103
1980	0	0	0	0	0	0		121	121	121	118	121	118
1981	0	0	0	0	0	0		111	111	107	107	107	107
1982	0	0	0	0	0	0		116	116	110	115	109	115
1983	0	0	0	0	0	0		109	109	105	112	105	112
1984	0	0	9	0	5	0		112	112	105	101	109	101
1985	14	14	0	10	0	10		106	106	110	106	110	106
1986	0	0	0	0	0	0		116	116	103	109	103	110
1987	0	0	0	0	0	0		107	107	115	93	115	93
1988	0	0	0	0	0	0		120	120	116	109	116	109
1989	14	15	3	0	3	0		102	101	108	111	108	111
1990	7	7	3	1	3	1		107	107	105	104	105	106
1991	0	0	0	0	0	0		120	120	114	113	114	114
Avg	3	3	1	1	1	1		112	112	110	108	110	108
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	4	4	18	22	18	22		0	0	0	0	0	0
1977	0	0	1	4	0	3		0	0	0	0	0	0
1978	5	5	8	11	8	10		0	0	0	0	0	0
1979	8	8	10	14	9	13		0	0	0	0	0	0
1980	0	0	0	3	0	3		0	0	0	0	0	0
1981	9	9	13	13	13	13		0	0	0	0	0	0
1982	4	4	10	5	11	5		0	0	0	0	0	0
1983	11	11	15	8	15	8		0	0	0	0	0	0
1984	9	9	7	20	7	20		0	0	0	0	0	0
1985	0	0	10	4	10	4		0	0	0	0	0	0
1986	4	4	17	11	17	10		0	0	0	0	0	0
1987	13	13	5	27	5	27		0	0	0	0	0	0
1988	1	1	5	12	5	12		0	0	0	0	0	0
1989	4	4	9	9	9	9		0	0	0	0	0	0
1990	6	6	12	15	12	13		0	0	0	0	0	0
1991	0	0	6	7	6	6		0	0	0	0	0	0
Avg	5	5	9	12	9	11		0	0	0	0	0	0

Table 5C.C-96. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	0	0	0	0	0	0		120	119	110	106	110	105
1977	7	7	7	5	7	5		113	113	113	114	113	114
1978	3	3	0	0	0	0		114	114	117	111	117	112
1979	8	8	6	6	6	6		104	104	107	99	107	99
1980	3	3	2	1	2	2		118	118	119	115	119	114
1981	2	2	3	0	2	0		111	111	109	110	109	110
1982	13	13	3	0	4	0		105	104	109	111	109	109
1983	1	1	0	0	0	0		115	115	105	104	105	104
1984	1	1	12	0	12	0		113	113	107	105	107	105
1985	13	13	0	13	0	13		107	107	112	104	112	104
1986	1	1	0	0	0	0		116	116	104	111	104	110
1987	1	1	1	2	1	0		107	107	119	99	119	101
1988	5	6	3	0	4	0		116	115	113	110	114	109
1989	12	15	6	9	6	9		105	101	109	104	109	104
1990	16	16	7	7	7	7		102	102	105	100	104	100
1991	3	3	0	0	0	0		117	117	118	113	118	113
Avg	6	6	3	3	3	3		111	111	111	107	111	107
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	1	2	11	15	11	16		0	0	0	0	0	0
1977	0	0	0	1	0	1		0	0	0	0	0	0
1978	3	3	3	9	3	8		0	0	0	0	0	0
1979	8	8	7	15	7	15		0	0	0	0	0	0
1980	0	0	0	5	0	5		0	0	0	0	0	0
1981	7	7	8	10	9	10		0	0	0	0	0	0
1982	2	3	8	9	7	11		0	0	0	0	0	0
1983	4	4	15	16	15	16		0	0	0	0	0	0
1984	7	7	2	16	2	16		0	0	0	0	0	0
1985	0	0	8	3	8	3		0	0	0	0	0	0
1986	3	3	16	9	16	10		0	0	0	0	0	0
1987	12	12	0	19	0	19		0	0	0	0	0	0
1988	0	0	5	11	3	12		0	0	0	0	0	0
1989	3	4	5	7	5	7		0	0	0	0	0	0
1990	2	2	8	13	9	13		0	0	0	0	0	0
1991	0	0	2	7	2	7		0	0	0	0	0	0
Avg	3	3	6	10	6	11		0	0	0	0	0	0

Table 5C.C-97. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	0	0	0	0	0	0		118	118	104	99	108	99
1977	10	9	8	6	7	6		110	111	112	112	113	112
1978	0	0	0	0	0	0		118	118	117	109	117	109
1979	9	9	7	7	7	7		104	104	106	97	106	98
1980	5	5	4	2	3	2		116	116	117	113	118	113
1981	0	0	0	0	0	0		111	110	107	107	107	107
1982	14	14	11	0	9	0		103	103	102	103	103	103
1983	5	4	0	0	0	0		111	111	105	107	104	106
1984	0	0	13	0	13	0		114	113	102	102	102	102
1985	16	15	0	12	0	12		104	105	111	104	111	105
1986	0	0	0	0	0	0		118	116	97	110	100	109
1987	0	0	0	0	0	0		106	106	115	94	115	97
1988	6	6	0	0	0	0		114	114	115	111	116	111
1989	18	17	13	4	12	6		98	99	99	108	101	106
1990	15	15	8	4	8	5		99	98	102	101	102	102
1991	4	3	1	0	0	0		116	117	113	114	114	113
Avg	6	6	4	2	4	2		110	110	108	106	109	106
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	3	3	17	22	13	22		0	0	0	0	0	0
1977	0	0	0	2	0	2		0	0	0	0	0	0
1978	2	2	3	11	3	11		0	0	0	0	0	0
1979	7	7	7	16	7	15		0	0	0	0	0	0
1980	0	0	0	6	0	6		0	0	0	0	0	0
1981	9	10	13	13	13	13		0	0	0	0	0	0
1982	3	3	7	17	8	17		0	0	0	0	0	0
1983	4	5	15	13	16	14		0	0	0	0	0	0
1984	7	8	6	19	6	19		0	0	0	0	0	0
1985	0	0	9	4	9	3		0	0	0	0	0	0
1986	2	4	23	10	20	11		0	0	0	0	0	0
1987	14	14	5	26	5	23		0	0	0	0	0	0
1988	1	1	6	10	5	10		0	0	0	0	0	0
1989	4	4	8	8	7	8		0	0	0	0	0	0
1990	6	7	10	15	10	13		0	0	0	0	0	0
1991	0	0	6	6	6	7		0	0	0	0	0	0
Avg	4	4	8	12	8	12		0	0	0	0	0	0

Table 5C.C-98. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Smoltification in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							**Optimal (≥10°C and ≤19°C)**					
1976	0	0	0	0	0	0		121	121	103	100	103	100
1977	12	12	10	0	9	5		108	108	110	120	111	115
1978	3	3	0	0	0	0		116	116	117	110	117	111
1979	9	9	7	5	7	5		104	104	108	102	108	103
1980	3	3	3	0	2	0		118	118	118	121	119	121
1981	3	4	1	0	0	0		112	111	111	109	112	109
1982	14	14	7	0	2	0		104	104	105	113	111	110
1983	1	1	0	0	0	0		111	111	105	105	105	106
1984	4	4	13	0	13	0		111	111	107	104	107	104
1985	16	16	0	11	0	12		104	104	115	109	116	108
1986	0	0	1	0	0	0		120	120	101	113	102	113
1987	1	1	0	0	0	0		108	108	120	98	120	98
1988	8	8	0	0	0	0		113	113	119	112	119	112
1989	19	19	15	0	14	0		101	101	100	115	101	114
1990	22	23	7	0	7	0		98	97	102	106	102	106
1991	4	4	0	0	0	0		116	116	120	119	120	119
Avg	7	8	4	1	3	1		110	110	110	110	111	109
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	18	21	18	21		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	1	1	3	10	3	9		0	0	0	0	0	0
1979	7	7	5	13	5	12		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	5	5	8	11	8	11		0	0	0	0	0	0
1982	2	2	8	7	7	10		0	0	0	0	0	0
1983	8	8	15	15	15	14		0	0	0	0	0	0
1984	6	6	1	17	1	17		0	0	0	0	0	0
1985	0	0	5	0	4	0		0	0	0	0	0	0
1986	0	0	18	7	18	7		0	0	0	0	0	0
1987	11	11	0	22	0	22		0	0	0	0	0	0
1988	0	0	2	9	2	9		0	0	0	0	0	0
1989	0	0	5	5	5	6		0	0	0	0	0	0
1990	0	0	11	14	11	14		0	0	0	0	0	0
1991	0	0	0	1	0	1		0	0	0	0	0	0
Avg	3	3	6	10	6	10		0	0	0	0	0	0

5C.C.4.3 Adult

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult fall-run Chinook salmon in the Cache Slough subregion (Table 5C.C-99). The average number of optimal days was 50 and 49 days under EBC1 and EBC2, respectively, and 34 to 47 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was 7 under EBC1 and EBC2, 8 and 7 under EBC2_ELT and PP_ELT, respectively, and 10 and 9 under EBC2_LLT and PP_LLT, respectively. On average lethal water temperatures occurred during 5 days under EBC1 and EBC2. Lethal conditions occurred under EBC2_ELT and PP_ELT on 7 and 6 days, respectively. Lethal temperatures occurred on 17 and 16 days under EBC2_LLT and PP_LLT, respectively.

EBC scenarios and PP scenarios in water temperatures for adult fall-run Chinook salmon in the East Delta subregion (Table 5C.C-100) differed little when accounting for climate change. The average number of optimal days was 47 days under EBC1 and EBC2, 44 and 45 days under EBC2_ELT and PP_ELT, respectively, and 31 and 32 days under EBC2_LLT and PP_LLT, respectively. The average number of supraoptimal days was 9 for EBC1 and EBC2, 11 and 9 days under EBC2_ELT and PP_ELT, and 10 and 11 under EBC2_LLT and PP_LLT, respectively. There were 5 lethal days under EBC1 and EBC2. The average number of lethal days ranged from 6 to 7 for EBC2_ELT and PP_ELT and 20 and 18 for EBC2_LLT and PP_LLT, respectively.

EBC scenarios and PP scenarios in water temperatures for adult fall-run Chinook salmon in the North Delta subregion (Table 5C.C-101) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 48 for EBC1 and EBC2 and between 30 and 45 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal water temperatures were reached on 10 and 9 days under EBC1 and EBC2, and ranged from 10 to 13 days under all other scenarios. A total of 4 days with lethal temperatures occurred under EBC1 and EBC2 during the modeling period, and on average, lethal water temperatures were reached on 4 and 21 days under the EBC2_ELT and EBC2_LLT scenarios, and on 4 to 20 days under PP_ELT and PP_LLT, respectively.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for adult fall-run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-102). Optimal water temperatures occurred on 45 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 37 to 43. Supraoptimal temperatures were reached on average for 10 and 9 days under EBC1 and EBC2, respectively. Under all other scenarios, this number ranged from 11 to 12 days. There were 7 lethal temperature days under the EBC1 and EBC2 scenarios. Under EBC2_ELT and EBC2_LLT, lethal temperatures occurred on 8 and 11 days, respectively. For PP_ELT and PP_LLT scenarios, the number of lethal temperature days was 7 and 12, respectively.

Water temperatures in the South Delta for adult fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-103). There were no days with suboptimal water temperature conditions. Under EBC1 and EBC2, optimal water temperatures occurred on 47 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 43 and 33 days per year, respectively; and on 44 to 33 days under PP_ELT and PP_LLT, respectively. Supraoptimal temperatures occurred on 8 days under EBC1 and EBC2, and on 10 to 11 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Lethal temperature occurred on 6 days per year on average under EBC1 and EBC2, 8 to 18 days per year under EBC2_ELT and EBC2-LLT, and on 8 to 17 days per year under PP_ELT and PP_LLT.

In the Suisun Bay subregion, water temperatures for adult fall-run Chinook salmon were similar among scenarios (Table 5C.C-104) after accounting for changing climate. Optimal water temperatures were reached on average on 51 and 50 days under EBC1 and EBC2, and from 36 to 48 days under all other scenarios. There were 8 supraoptimal temperature days recorded under EBC1 and EBC2, 9 and 11 supraoptimal temperature days under EBC2_ELT and EBC2_LLT, respectively, and 8 and 11 days under PP_ELT and PP_LLT. Three lethal temperature days occurred under EBC1 and EBC2. Lethal conditions under EBC2_ELT and PP_ELT occurred for an average of 5 days, and under EBC2_LLT and PP_LLT for an average of 14 days.

In Suisun Marsh, the differences among scenarios of water temperatures for adult fall-run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-105). Optimal temperatures occurred on average on 51 days under EBC1 and EBC2 and ranged from 36 to 48 days for all other scenarios. Supraoptimal water temperature conditions occurred on 5 and 6 days under EBC1 and EBC2, respectively, and on 7 to 10 days under all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Lethal temperatures occurred on 4 days on average for EBC1 and EBC2 and between 6 and 15 days for all other scenarios.

Water temperatures in the West Delta for adult fall-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-106). Under EBC1 and EBC2, optimal water temperatures occurred on 49 days per year on average. Under EBC2_ELT and PP_ELT, optimal temperature conditions occurred on 45, and under EBC2_LLT and PP_LLT, optimal temperatures occurred for an average of 31 days. Supraoptimal temperatures occurred on 8 and 7 days under EBC1 and EBC2, respectively, and on 9 to 13 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Lethal temperature average days were 5 under EBC1 and EBC2, 7 under EBC2_ELT and PP_ELT, and 18 and 17 under EBC2_LLT and PP_LLT, respectively.

Table 5C.C-99. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		48	48	42	40	43	41
1977	0	0	0	0	0	0		48	48	47	38	48	39
1978	0	0	0	0	0	0		61	61	53	32	54	33
1979	0	0	0	0	0	0		37	37	35	18	34	21
1980	0	0	0	0	0	0		61	61	50	44	56	47
1981	0	0	0	0	0	0		42	42	34	26	35	26
1982	0	0	0	0	0	0		49	49	45	42	46	43
1983	0	0	0	0	0	0		44	44	31	34	32	34
1984	0	0	0	0	0	0		39	38	55	30	57	31
1985	0	0	0	0	0	0		58	58	51	43	53	45
1986	0	0	0	0	0	0		56	54	56	41	55	41
1987	0	0	0	0	0	0		59	59	43	35	43	37
1988	0	0	0	0	0	0		40	40	49	28	49	30
1989	0	0	0	0	0	0		55	55	53	40	55	41
1990	0	0	0	0	0	0		50	49	48	34	49	34
1991	0	0	0	0	0	0		45	45	48	20	49	21
Avg	0	0	0	0	0	0		50	49	46	34	47	35
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	3	3	7	5	7	4		10	10	12	16	11	16
1977	2	2	3	9	4	8		11	11	11	14	9	14
1978	0	0	8	12	7	14		0	0	0	17	0	14
1979	13	13	10	14	11	13		11	11	16	29	16	27
1980	0	0	11	14	5	14		0	0	0	3	0	0
1981	18	19	21	9	22	10		1	0	6	26	4	25
1982	5	4	6	6	4	5		7	8	10	13	11	13
1983	13	13	8	3	6	3		4	4	22	24	23	24
1984	3	7	5	1	3	1		19	16	1	30	1	29
1985	3	3	10	11	8	9		0	0	0	7	0	7
1986	5	7	1	6	3	7		0	0	4	14	3	13
1987	2	2	7	15	8	12		0	0	11	11	10	12
1988	10	10	4	11	5	10		11	11	8	22	7	21
1989	6	6	8	14	6	13		0	0	0	7	0	7
1990	11	12	11	8	9	8		0	0	2	19	3	19
1991	11	11	10	21	9	20		5	5	3	20	3	20
Avg	7	7	8	10	7	9		5	5	7	17	6	16

Table 5C.C-100. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		50	50	42	39	42	41
1977	0	0	0	0	0	0		48	48	46	36	46	38
1978	0	0	0	0	0	0		52	52	44	33	49	32
1979	0	0	0	0	0	0		40	40	31	24	34	18
1980	0	0	0	0	0	0		54	52	47	33	48	40
1981	0	0	0	0	0	0		40	40	38	25	35	25
1982	0	0	0	0	0	0		46	46	46	36	45	42
1983	0	0	0	0	0	0		38	38	36	33	32	33
1984	0	0	0	0	0	0		37	37	49	24	52	29
1985	0	0	0	0	0	0		56	56	49	38	51	38
1986	0	0	0	0	0	0		53	53	51	40	56	41
1987	0	0	0	0	0	0		57	59	51	24	44	29
1988	0	0	0	0	0	0		44	43	48	27	49	26
1989	0	0	0	0	0	0		58	58	48	35	52	34
1990	0	0	0	0	0	0		40	40	41	29	43	30
1991	0	0	0	0	0	0		45	47	41	21	43	18
Avg	0	0	0	0	0	0		47	47	44	31	45	32
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	1	1	6	6	7	4		10	10	13	16	12	16
1977	5	5	6	11	6	9		8	8	9	14	9	14
1978	9	9	17	9	12	14		0	0	0	19	0	15
1979	10	11	17	3	12	10		11	10	13	34	15	33
1980	7	9	12	13	13	18		0	0	2	15	0	3
1981	19	19	17	9	18	10		2	2	6	27	8	26
1982	10	10	10	8	5	4		5	5	5	17	11	15
1983	16	16	10	3	7	3		7	7	15	25	22	25
1984	14	10	10	7	8	2		10	14	2	30	1	30
1985	3	3	12	13	10	16		2	2	0	10	0	7
1986	6	4	7	5	1	4		2	4	3	16	4	16
1987	3	2	2	21	8	21		1	0	8	16	9	11
1988	8	9	6	12	4	12		9	9	7	22	8	23
1989	3	3	13	12	9	18		0	0	0	14	0	9
1990	21	21	15	12	15	11		0	0	5	20	3	20
1991	9	8	16	12	14	22		7	6	4	28	4	21
Avg	9	9	11	10	9	11		5	5	6	20	7	18

Table 5C.C-101. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the North Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		51	51	40	37	39	40
1977	0	0	0	0	0	0		51	51	46	34	47	35
1978	0	0	0	0	0	0		50	45	42	31	45	32
1979	0	0	0	0	0	0		40	41	31	24	32	23
1980	0	0	0	0	0	0		52	49	46	32	49	33
1981	0	0	0	0	0	0		41	44	42	25	39	26
1982	0	0	0	0	0	0		43	42	48	34	50	32
1983	0	0	0	0	0	0		41	41	40	32	40	30
1984	0	0	0	0	0	0		39	40	46	26	52	27
1985	0	0	0	0	0	0		55	56	48	36	49	37
1986	0	0	0	0	0	0		53	52	46	37	52	40
1987	0	0	0	0	0	0		50	56	50	27	50	27
1988	0	0	0	0	0	0		48	47	45	28	43	25
1989	0	0	0	0	0	0		55	56	48	30	48	32
1990	0	0	0	0	0	0		42	42	40	26	40	27
1991	0	0	0	0	0	0		49	49	43	23	44	23
Avg	0	0	0	0	0	0		48	48	44	30	45	31
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	4	3	9	8	10	5		6	7	12	16	12	16
1977	3	3	8	12	7	12		7	7	7	15	7	14
1978	11	13	15	9	14	11		0	3	4	21	2	18
1979	17	15	24	7	23	6		4	5	6	30	6	32
1980	9	11	12	10	11	13		0	1	3	19	1	15
1981	18	15	12	12	16	10		2	2	7	24	6	25
1982	12	14	13	8	11	11		6	5	0	19	0	18
1983	10	10	18	7	17	8		10	10	3	22	4	23
1984	16	13	11	8	8	8		6	8	4	27	1	26
1985	5	4	12	12	12	12		1	1	1	13	0	12
1986	5	4	13	9	6	7		3	5	2	15	3	14
1987	9	5	6	13	6	14		2	0	5	21	5	20
1988	6	7	11	11	13	11		7	7	5	22	5	25
1989	6	5	13	13	12	12		0	0	0	18	1	17
1990	19	19	15	14	15	13		0	0	6	21	6	21
1991	6	6	14	8	13	8		6	6	4	30	4	30
Avg	10	9	13	10	12	10		4	4	4	21	4	20

Table 5C.C-102. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		47	46	45	45	46	45
1977	0	0	0	0	0	0		49	49	48	45	47	45
1978	0	0	0	0	0	0		48	49	44	35	44	33
1979	0	0	0	0	0	0		33	32	27	26	27	24
1980	0	0	0	0	0	0		50	51	45	47	45	48
1981	0	0	0	0	0	0		38	38	31	28	33	27
1982	0	0	0	0	0	0		43	43	42	43	42	41
1983	0	0	0	0	0	0		34	34	32	35	31	35
1984	0	0	0	0	0	0		33	33	47	31	50	31
1985	0	0	0	0	0	0		54	54	43	49	44	47
1986	0	0	0	0	0	0		49	49	48	44	49	44
1987	0	0	0	0	0	0		54	55	41	42	42	41
1988	0	0	0	0	0	0		40	42	47	33	47	31
1989	0	0	0	0	0	0		55	55	49	45	49	42
1990	0	0	0	0	0	0		43	44	44	35	43	35
1991	0	0	0	0	0	0		44	46	41	26	44	24
Avg	0	0	0	0	0	0		45	45	42	38	43	37
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	4	5	5	2	8	1		10	10	11	14	7	15
1977	4	5	3	4	3	3		8	7	10	12	11	13
1978	13	12	14	18	17	20		0	0	3	8	0	8
1979	16	17	16	15	18	16		12	12	18	20	16	21
1980	11	10	15	14	15	13		0	0	1	0	1	0
1981	17	17	19	17	17	17		6	6	11	16	11	17
1982	6	6	3	5	3	7		12	12	16	13	16	13
1983	10	11	6	11	6	11		17	16	23	15	24	15
1984	7	7	12	11	9	8		21	21	2	19	2	22
1985	6	6	14	6	15	8		1	1	4	6	2	6
1986	6	7	8	12	8	11		6	5	5	5	4	6
1987	7	6	12	12	11	11		0	0	8	7	8	9
1988	10	8	7	13	7	13		11	11	7	15	7	17
1989	6	6	11	12	12	16		0	0	1	4	0	3
1990	18	17	16	10	17	8		0	0	1	16	1	18
1991	12	10	17	23	14	22		5	5	3	12	3	15
Avg	10	9	11	12	11	12		7	7	8	11	7	12

Table 5C.C-103. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		48	48	42	38	42	39
1977	0	0	0	0	0	0		48	48	47	39	47	39
1978	0	0	0	0	0	0		59	59	50	32	48	33
1979	0	0	0	0	0	0		32	32	31	13	29	13
1980	0	0	0	0	0	0		61	61	42	44	42	47
1981	0	0	0	0	0	0		38	38	32	23	33	25
1982	0	0	0	0	0	0		47	47	45	40	45	41
1983	0	0	0	0	0	0		36	36	31	34	31	35
1984	0	0	0	0	0	0		35	35	52	29	54	29
1985	0	0	0	0	0	0		57	57	48	41	48	41
1986	0	0	0	0	0	0		54	53	53	40	53	40
1987	0	0	0	0	0	0		59	60	40	35	40	36
1988	0	0	0	0	0	0		40	40	46	25	46	26
1989	0	0	0	0	0	0		54	54	52	38	52	37
1990	0	0	0	0	0	0		45	45	41	33	44	33
1991	0	0	0	0	0	0		41	41	41	18	42	18
Avg	0	0	0	0	0	0		47	47	43	33	44	33
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	3	3	7	7	7	6		10	10	12	16	12	16
1977	2	2	2	8	3	8		11	11	12	14	11	14
1978	2	2	11	12	13	14		0	0	0	17	0	14
1979	15	15	13	16	15	18		14	14	17	32	17	30
1980	0	0	19	16	19	14		0	0	0	1	0	0
1981	20	20	19	9	18	8		3	3	10	29	10	28
1982	5	5	1	7	1	7		9	9	15	14	15	13
1983	14	14	2	3	4	5		11	11	28	24	26	21
1984	5	5	8	2	6	2		21	21	1	30	1	30
1985	4	4	13	13	13	13		0	0	0	7	0	7
1986	5	6	4	8	4	7		2	2	4	13	4	14
1987	2	1	8	15	7	13		0	0	13	11	14	12
1988	9	9	6	13	6	11		12	12	9	23	9	24
1989	7	7	9	14	9	17		0	0	0	9	0	7
1990	16	16	18	8	15	8		0	0	2	20	2	20
1991	14	14	16	22	16	23		6	6	4	21	3	20
Avg	8	8	10	11	10	11		6	6	8	18	8	17

Table 5C.C-104. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		49	49	42	43	42	43
1977	0	0	0	0	0	0		49	49	48	43	48	42
1978	0	0	0	0	0	0		59	59	53	31	53	32
1979	0	0	0	0	0	0		38	38	39	24	39	23
1980	0	0	0	0	0	0		61	61	52	45	52	44
1981	0	0	0	0	0	0		51	50	43	27	42	26
1982	0	0	0	0	0	0		48	48	45	40	45	40
1983	0	0	0	0	0	0		43	43	31	33	31	34
1984	0	0	0	0	0	0		37	37	54	30	57	30
1985	0	0	0	0	0	0		58	58	51	43	52	43
1986	0	0	0	0	0	0		54	54	54	44	54	44
1987	0	0	0	0	0	0		59	59	49	39	48	39
1988	0	0	0	0	0	0		47	46	46	32	46	32
1989	0	0	0	0	0	0		56	55	54	42	54	42
1990	0	0	0	0	0	0		51	51	50	35	50	35
1991	0	0	0	0	0	0		49	49	51	26	50	26
Avg	0	0	0	0	0	0		51	50	48	36	48	36
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	6	6	7	4	7	4		6	6	12	14	12	14
1977	6	6	6	5	6	6		6	6	7	13	7	13
1978	2	2	8	16	8	15		0	0	0	14	0	14
1979	18	17	10	12	10	13		5	6	12	25	12	25
1980	0	0	9	15	9	16		0	0	0	1	0	1
1981	10	11	16	17	17	17		0	0	2	17	2	18
1982	9	9	6	7	6	7		4	4	10	14	10	14
1983	16	16	11	5	10	4		2	2	19	23	20	23
1984	12	12	7	5	4	6		12	12	0	26	0	25
1985	3	3	10	12	9	12		0	0	0	6	0	6
1986	7	7	4	9	4	10		0	0	3	8	3	7
1987	2	2	5	12	5	12		0	0	7	10	8	10
1988	6	7	10	12	10	11		8	8	5	17	5	18
1989	5	6	7	14	7	14		0	0	0	5	0	5
1990	10	10	11	10	11	9		0	0	0	16	0	17
1991	11	11	10	23	11	20		1	1	0	12	0	15
Avg	8	8	9	11	8	11		3	3	5	14	5	14

Table 5C.C-105. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		48	48	42	44	43	45
1977	0	0	0	0	0	0		48	48	47	40	48	40
1978	0	0	0	0	0	0		61	61	57	33	55	33
1979	0	0	0	0	0	0		41	39	36	17	35	20
1980	0	0	0	0	0	0		61	61	53	49	53	49
1981	0	0	0	0	0	0		44	43	38	26	35	26
1982	0	0	0	0	0	0		50	50	45	43	45	43
1983	0	0	0	0	0	0		46	46	31	34	31	34
1984	0	0	0	0	0	0		38	38	58	31	58	31
1985	0	0	0	0	0	0		59	58	55	43	52	46
1986	0	0	0	0	0	0		56	56	56	41	54	42
1987	0	0	0	0	0	0		61	60	42	40	43	39
1988	0	0	0	0	0	0		45	44	49	30	50	30
1989	0	0	0	0	0	0		60	58	58	46	53	44
1990	0	0	0	0	0	0		54	53	51	35	50	35
1991	0	0	0	0	0	0		49	48	52	24	50	24
Avg	0	0	0	0	0	0		51	51	48	36	47	36
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	3	3	8	2	7	1		10	10	11	15	11	15
1977	3	3	3	8	4	8		10	10	11	13	9	13
1978	0	0	4	18	6	16		0	0	0	10	0	12
1979	10	12	11	18	12	15		10	10	14	26	14	26
1980	0	0	8	12	8	12		0	0	0	0	0	0
1981	17	18	20	11	23	11		0	0	3	24	3	24
1982	4	4	4	4	5	5		7	7	12	14	11	13
1983	15	13	5	3	6	3		0	2	25	24	24	24
1984	4	4	2	1	2	3		19	19	1	29	1	27
1985	2	3	6	11	9	8		0	0	0	7	0	7
1986	5	5	2	10	3	9		0	0	3	10	4	10
1987	0	1	9	12	8	12		0	0	10	9	10	10
1988	8	9	5	12	4	10		8	8	7	19	7	21
1989	1	3	3	10	8	11		0	0	0	5	0	6
1990	7	8	10	10	10	8		0	0	0	16	1	18
1991	8	9	7	22	9	20		4	4	2	15	2	17
Avg	5	6	7	10	8	10		4	4	6	15	6	15

Table 5C.C-106. Number of Days within Temperature Requirements for Fall-Run Chinook Salmon Adults in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤20°C)					
1976	0	0	0	0	0	0		47	47	41	35	41	36
1977	0	0	0	0	0	0		47	47	46	40	46	40
1978	0	0	0	0	0	0		61	61	54	31	56	31
1979	0	0	0	0	0	0		37	38	29	10	29	11
1980	0	0	0	0	0	0		61	61	44	44	48	45
1981	0	0	0	0	0	0		38	38	34	21	35	21
1982	0	0	0	0	0	0		48	48	44	37	44	35
1983	0	0	0	0	0	0		39	40	31	31	31	31
1984	0	0	0	0	0	0		36	38	52	26	54	27
1985	0	0	0	0	0	0		57	57	51	40	51	40
1986	0	0	0	0	0	0		53	53	54	40	55	40
1987	0	0	0	0	0	0		61	61	41	32	40	34
1988	0	0	0	0	0	0		43	43	44	25	45	25
1989	0	0	0	0	0	0		56	56	56	39	56	40
1990	0	0	0	0	0	0		48	48	43	31	45	31
1991	0	0	0	0	0	0		44	44	49	16	49	16
Avg	0	0	0	0	0	0		49	49	45	31	45	31
	Supraoptimal (>20°C and ≤21°C)							Lethal (>21°C)					
1976	3	3	5	10	6	9		11	11	15	16	14	16
1977	2	2	2	6	2	6		12	12	13	15	13	15
1978	0	0	7	14	5	18		0	0	0	16	0	12
1979	14	13	18	16	17	19		10	10	14	35	15	31
1980	0	0	17	17	13	16		0	0	0	0	0	0
1981	23	23	20	11	22	12		0	0	7	29	4	28
1982	5	5	6	8	4	10		8	8	11	16	13	16
1983	20	19	7	4	1	4		2	2	23	26	29	26
1984	5	4	8	5	7	4		20	19	1	30	0	30
1985	4	4	10	13	10	13		0	0	0	8	0	8
1986	8	8	3	7	2	8		0	0	4	14	4	13
1987	0	0	10	18	11	17		0	0	10	11	10	10
1988	6	6	8	11	7	13		12	12	9	25	9	23
1989	5	5	5	15	5	16		0	0	0	7	0	5
1990	13	13	18	10	16	10		0	0	0	20	0	20
1991	14	14	12	28	12	27		3	3	0	17	0	18
Avg	8	7	10	12	9	13		5	5	7	18	7	17

5C.C.5 Late Fall-Run Chinook Salmon

5C.C.5.1 Juvenile

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile late fall–run Chinook salmon in the Cache Slough subregion (Table 5C.C-107). The average number of optimal days was 28 days under EBC1 and EBC2 and between 32 and 45 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. The average number of supraoptimal days was zero under all scenarios. There were no lethal days under any scenario.

EBC scenarios and PP scenarios in water temperatures for juvenile late fall–run Chinook salmon in the East Delta subregion (Table 5C.C-108) differed little when accounting for climate change. The average number of optimal days was 21 days under EBC1 and EBC2, 25 to 46 days under EBC2_ELT and EBC2_LLT, respectively, and 31 and 47 under PP_ELT, and PP_LLT, respectively. The average number of supraoptimal and lethal days was zero for all model scenarios.

EBC scenarios and PP scenarios in water temperatures for juvenile late fall–run Chinook salmon in the North Delta subregion (Table 5C.C-109) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 12 for EBC1 and EBC2, and between 16 and 36 days for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal or lethal water temperatures were not reached during the modeling period under any scenario.

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for juvenile late fall–run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-110). Optimal water temperatures occurred on 30–31 days under the EBC1 and EBC2 scenarios. Under all other scenarios, the number of days with optimal water temperatures ranged from 34 to 36. Supraoptimal or lethal temperatures were not reached on any days under any scenario.

Water temperatures in the South Delta for smolt spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-111). Suboptimal water temperature conditions occurred on 55 days per year on average under EBC1 and EBC2, and 48–50 days under all other model scenarios. Under EBC1 and EBC2, optimal water temperatures occurred on 35 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 40 and 42 days per year, respectively; and on 40 to 41 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature days under any scenario.

In the Suisun Bay subregion, water temperatures for juvenile late fall–run Chinook salmon were similar among scenarios (Table 5C.C-112) after accounting for changing climate. Optimal water temperatures were reached on average on 22 days under EBC1 and EBC2 and 25 to 34 days for all other scenarios. There were no supraoptimal or lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for juvenile late fall–run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-113). Optimal temperatures occurred on average on 27 and 28 days under EBC1 and EBC2, respectively. On 33 and 40 days, temperatures reached an optimal level under EBC2_ELT and EBC2_LLT, and on

35 and 40 days under the PP_ELT and PP_LLT scenarios, respectively. Supraoptimal or lethal water temperature conditions did not occur under any scenario.

Water temperatures in the West Delta for juvenile late fall–run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-114). Under EBC1 and EBC2, optimal water temperatures occurred on 21 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on an average of 26 and 39 days per year, and under PP_ELT and PP_LLT on 30 and 39 days, respectively. There were no supraoptimal or lethal temperature days under any scenario.

Table 5C.C-107. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	69	68	59	47	59	46		22	23	32	44	32	45
1977	56	55	47	45	47	45		34	35	43	45	43	45
1978	54	54	57	35	59	48		36	36	33	55	31	42
1979	65	65	64	47	64	54		25	25	26	43	26	36
1980	62	62	53	36	61	48		29	29	38	55	30	43
1981	61	58	52	42	54	40		29	32	38	48	36	50
1982	69	70	62	48	70	48		21	20	28	42	20	42
1983	64	64	59	40	64	44		26	26	31	50	26	46
1984	64	65	63	52	65	51		27	26	28	39	26	40
1985	66	64	50	49	47	49		24	26	40	41	43	41
1986	51	50	50	40	64	44		39	40	40	50	26	46
1987	67	66	53	45	52	45		23	24	37	45	38	45
1988	52	49	45	42	44	41		39	42	46	49	47	50
1989	67	67	61	57	60	56		23	23	29	33	30	34
1990	69	69	66	57	64	57		21	21	24	33	26	33
1991	64	64	62	45	66	45		26	26	28	45	24	45
Avg	63	62	56	45	59	48		28	28	34	45	32	43
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-108. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	69	69	59	47	54	42		22	22	32	44	37	49
1977	57	60	49	43	46	44		33	30	41	47	44	46
1978	57	57	60	35	55	33		33	33	30	55	35	57
1979	71	70	67	43	64	42		19	20	23	47	26	48
1980	76	76	77	39	67	38		15	15	14	52	24	53
1981	79	76	62	38	54	40		11	14	28	52	36	50
1982	77	77	76	53	73	50		13	13	14	37	17	40
1983	83	83	68	45	67	43		7	7	22	45	23	47
1984	67	67	78	52	69	49		24	24	13	39	22	42
1985	73	73	64	48	55	48		17	17	26	42	35	42
1986	68	68	69	36	68	35		22	22	21	54	22	55
1987	67	67	62	41	50	42		23	23	28	49	40	48
1988	53	53	49	40	45	41		38	38	42	51	46	50
1989	68	68	64	53	61	54		22	22	26	37	29	36
1990	74	75	72	55	63	56		16	15	18	35	27	34
1991	63	64	64	42	59	42		27	26	26	48	31	48
Avg	69	69	65	44	59	44		21	21	25	46	31	47
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-109. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	73	74	63	58	63	58		18	17	28	33	28	33
1977	86	86	80	49	81	46		4	4	10	41	9	44
1978	72	72	69	49	70	49		18	18	21	41	20	41
1979	82	82	78	57	76	55		8	8	12	33	14	35
1980	81	81	80	55	79	55		10	10	11	36	12	36
1981	86	84	75	56	77	56		4	6	15	34	13	34
1982	85	85	78	60	78	60		5	5	12	30	12	30
1983	85	85	68	51	68	51		5	5	22	39	22	39
1984	71	71	84	52	83	51		20	20	7	39	8	40
1985	80	81	82	60	82	60		10	9	8	30	8	30
1986	73	73	71	48	71	48		17	17	19	42	19	42
1987	75	75	77	55	77	55		15	15	13	35	13	35
1988	66	66	69	43	70	43		25	25	22	48	21	48
1989	75	75	68	61	68	61		15	15	22	29	22	29
1990	76	76	72	65	72	65		14	14	18	25	18	25
1991	82	82	81	51	79	51		8	8	9	39	11	39
Avg	78	78	75	54	75	54		12	12	16	36	16	36
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-110. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	63	63	65	56	64	54		28	28	26	35	27	37
1977	58	58	46	46	46	46		32	32	44	44	44	44
1978	54	54	55	56	54	56		36	36	35	34	36	34
1979	64	64	59	62	59	62		26	26	31	28	31	28
1980	59	58	49	55	50	57		32	33	42	36	41	34
1981	57	55	53	47	53	46		33	35	37	43	37	44
1982	63	63	57	70	55	70		27	27	33	20	35	20
1983	57	56	58	67	58	66		33	34	32	23	32	24
1984	61	61	63	56	61	56		30	30	28	35	30	35
1985	67	66	54	53	54	54		23	24	36	37	36	36
1986	55	55	49	52	47	52		35	35	41	38	43	38
1987	61	61	56	54	53	51		29	29	34	36	37	39
1988	50	51	46	45	44	44		41	40	45	46	47	47
1989	66	65	60	63	60	63		24	25	30	27	30	27
1990	69	69	63	61	62	61		21	21	27	29	28	29
1991	57	57	53	51	52	47		33	33	37	39	38	43
Avg	60	60	55	56	55	55		30	31	35	34	36	35
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-111. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the South Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	65	65	55	44	54	43		26	26	36	47	37	48
1977	50	50	46	45	46	46		40	40	44	45	44	44
1978	54	54	48	36	45	39		36	36	42	54	45	51
1979	64	64	60	58	60	60		26	26	30	32	30	30
1980	50	50	45	48	46	53		41	41	46	43	45	38
1981	47	47	46	42	46	42		43	43	44	48	44	48
1982	55	55	50	56	52	65		35	35	40	34	38	25
1983	52	52	57	63	57	63		38	38	33	27	33	27
1984	61	61	51	56	54	56		30	30	40	35	37	35
1985	55	55	47	50	47	50		35	35	43	40	43	40
1986	45	45	40	32	39	36		45	45	50	58	51	54
1987	57	56	44	43	44	41		33	34	46	47	46	49
1988	44	45	45	41	44	41		47	46	46	50	47	50
1989	64	65	58	56	58	57		26	25	32	34	32	33
1990	66	66	62	57	60	58		24	24	28	33	30	32
1991	48	48	46	43	46	42		42	42	44	47	44	48
Avg	55	55	50	48	50	50		35	35	40	42	40	41
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-112. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	68	67	68	62	68	60		23	24	23	29	23	31
1977	69	70	60	62	58	60		21	20	30	28	32	30
1978	59	59	60	54	60	54		31	31	30	36	30	36
1979	65	65	65	61	64	61		25	25	25	29	26	29
1980	73	73	67	53	61	52		18	18	24	38	30	39
1981	72	71	62	53	59	53		18	19	28	37	31	37
1982	74	74	71	52	66	50		16	16	19	38	24	40
1983	78	78	67	53	66	53		12	12	23	37	24	37
1984	67	67	70	57	63	55		24	24	21	34	28	36
1985	72	70	56	64	56	63		18	20	34	26	34	27
1986	62	60	65	47	59	46		28	30	25	43	31	44
1987	69	69	64	62	62	60		21	21	26	28	28	30
1988	58	58	57	52	57	51		33	33	34	39	34	40
1989	68	68	66	65	64	65		22	22	24	25	26	25
1990	74	74	74	73	73	69		16	16	16	17	17	21
1991	72	72	67	61	65	56		18	18	23	29	25	34
Avg	69	68	65	58	63	57		22	22	25	32	28	34
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-113. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<13°C)							Optimal (≥13°C and ≤20°C)					
1976	68	68	63	53	63	54		23	23	28	38	28	37
1977	58	55	48	47	47	46		32	35	42	43	43	44
1978	58	57	59	51	56	48		32	33	31	39	34	42
1979	66	65	64	57	64	56		24	25	26	33	26	34
1980	61	61	54	48	51	48		30	30	37	43	40	43
1981	49	49	47	45	47	46		41	41	43	45	43	44
1982	72	72	66	48	61	47		18	18	24	42	29	43
1983	76	75	61	43	60	43		14	15	29	47	30	47
1984	64	64	54	52	52	51		27	27	37	39	39	40
1985	62	60	49	54	48	54		28	30	41	36	42	36
1986	55	55	59	45	59	43		35	35	31	45	31	47
1987	65	64	50	48	46	48		25	26	40	42	44	42
1988	54	53	52	43	45	43		37	38	39	48	46	48
1989	68	67	66	60	61	61		22	23	24	30	29	29
1990	72	71	65	60	64	60		18	19	25	30	26	30
1991	62	62	58	47	58	49		28	28	32	43	32	41
Avg	63	62	57	50	55	50		27	28	33	40	35	40
	Supraoptimal (>20°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-114. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Juvenile Rearing in the West Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<13°C)**							**Optimal (≥13°C and ≤20°C)**					
1976	71	71	63	54	62	53		20	20	28	37	29	38
1977	66	66	52	48	51	47		24	24	38	42	39	43
1978	58	58	65	51	59	51		32	32	25	39	31	39
1979	66	67	65	57	65	57		24	23	25	33	25	33
1980	75	75	64	50	55	49		16	16	27	41	36	42
1981	74	73	64	45	54	45		16	17	26	45	36	45
1982	78	77	76	50	64	49		12	13	14	40	26	41
1983	77	77	65	49	65	48		13	13	25	41	25	42
1984	67	67	73	57	66	56		24	24	18	34	25	35
1985	74	72	57	53	55	53		16	18	33	37	35	37
1986	60	59	62	46	56	45		30	31	28	44	34	45
1987	71	72	58	48	57	47		19	18	32	42	33	43
1988	56	56	54	46	53	45		35	35	37	45	38	46
1989	70	70	68	63	68	63		20	20	22	27	22	27
1990	76	76	75	61	73	61		14	14	15	29	17	29
1991	74	74	71	45	69	45		16	16	19	45	21	45
Avg	70	69	65	51	61	51		21	21	26	39	30	39
	Supraoptimal (>20°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.5.2 Smoltification

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt late fall–run Chinook salmon in the Cache Slough subregion (Table 5C.C-115). The average number of optimal days was 62 and 63 under EBC1 and EBC2, respectively and 68 to 79 under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. There were no supraoptimal or lethal temperature days on average under any scenario, although 4 actual days under EBC2_LLT and 5 actual days under PP_LLT had supraoptimal conditions in 1988.

EBC scenarios and PP scenarios in water temperatures for smolt late fall–run Chinook salmon in the East Delta subregion (Table 5C.C-116) differed little when accounting for climate change. The average number of optimal days was 67 under EBC1 and EBC2, 73 to 72 under EBC2_ELT and PP_ELT, respectively, and 84 to 81 under EBC2_LLT and PP_LLT, respectively. No supraoptimal or lethal temperature average days occurred during the modeling period under any scenario, but 2 actual supraoptimal days occurred under PP_LLT in 1988.

EBC scenarios and PP scenarios in water temperatures for smolt late fall–run Chinook salmon in the North Delta subregion (Table 5C.C-117) were similar, considering climate change effects on water temperature. The average number of optimal water temperature days was 50 and 51 for EBC1 and EBC2, respectively, and between 55 and 79 for all other scenarios (EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT). Supraoptimal or lethal water temperatures were not reached during the modeling period except for 1 supraoptimal day under EBC2_LLT and PP_LLT in 1986.

After accounting for climate change, there was little difference between EBC scenarios and PP scenarios in water temperatures for smolt late fall–run Chinook salmon in the San Joaquin portion of the South Delta subregion (Table 5C.C-118). Optimal water temperatures occurred on 68 days on average under the EBC1 and EBC2 scenarios. Under all other scenarios, the average number of days with optimal water temperatures ranged from 73 to 78. Supraoptimal or lethal temperatures were not reached on any days under any scenario.

Water temperatures in the South Delta for smolt spring-run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-119). Suboptimal water temperature conditions occurred on 23 days per year on average under EBC1 and EBC2, and 10 to 17 days under all other model scenarios. Under EBC1 and EBC2, optimal water temperatures occurred on 68 days per year, on average. Under EBC2_ELT and EBC2_LLT, optimal temperature conditions occurred on 73 and 80 days per year, respectively; and on 74 to 80 days under PP_ELT and PP_LLT, respectively. There were no supraoptimal or lethal temperature days under any scenario.

In the Suisun Bay subregion, water temperatures for smolt late fall–run Chinook salmon were similar among scenarios (Table 5C.C-120) after accounting for changing climate. Optimal water temperatures were reached on average on 59 days under EBC1 and EBC2 and 63 to 70 days for all other scenarios. There were no supraoptimal or lethal temperature days under any scenario.

In Suisun Marsh, the differences among scenarios of water temperatures for smolt late fall–run Chinook salmon were minor after climate change was taken into consideration (Table 5C.C-121). Optimal temperatures occurred on average on 58 and 59 days under EBC1 and EBC2, respectively, and on 64 to 73 days under EBC2_ELT, EBC2_LLT, PP_ELT, and PP_LLT. Supraoptimal or lethal water temperature conditions did not occur under any scenario.

Water temperatures in the West Delta for smolt late fall–run Chinook salmon were generally similar among the different scenarios (considering climate change) (Table 5C.C-122). Under EBC1 and EBC2, optimal water temperatures occurred on 56 days per year, on average. Under EBC2_ELT, and EBC2_LLT, optimal temperature conditions occurred on 63 and 77 days per year, respectively; and under PP_ELT and PP_LLT on 64 to 76 days, respectively. No supraoptimal or lethal temperature days were recorded under any scenario.

Table 5C.C-115. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the Cache Slough Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	21	21	18	13	17	14		70	70	73	78	74	77
1977	40	40	39	25	38	30		50	50	51	65	52	60
1978	0	0	0	0	1	0		90	90	90	90	89	90
1979	29	28	22	10	35	20		61	62	68	80	55	70
1980	22	19	12	0	24	4		69	72	79	91	67	87
1981	19	18	15	0	18	0		71	72	75	90	72	90
1982	39	39	22	3	36	16		51	51	68	87	54	74
1983	27	27	22	9	22	10		63	63	68	81	68	80
1984	26	26	44	2	43	5		65	65	47	89	48	86
1985	45	45	6	41	3	41		45	45	84	49	87	49
1986	11	9	26	2	26	2		79	81	64	88	64	88
1987	27	27	25	21	25	20		63	63	65	69	65	70
1988	31	29	22	9	22	9		60	62	69	78	69	77
1989	48	48	41	21	41	18		42	42	49	69	49	72
1990	42	43	24	10	30	14		48	47	66	80	60	76
1991	23	24	16	13	14	12		67	66	74	77	76	78
Avg	28	28	22	11	25	13		62	63	68	79	66	77
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	4	0	5		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-116. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the East Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	19	19	14	4	16	5		72	72	77	87	75	86
1977	39	38	36	10	37	22		51	52	54	80	53	68
1978	2	2	0	0	0	0		88	88	90	90	90	90
1979	24	23	19	5	19	8		66	67	71	85	71	82
1980	18	17	17	5	15	2		73	74	74	86	76	89
1981	18	18	18	0	14	0		72	72	72	90	76	90
1982	38	38	22	8	19	6		52	52	68	82	71	84
1983	22	22	6	3	7	5		68	68	84	87	83	85
1984	32	32	43	5	43	4		59	59	48	86	48	87
1985	44	44	5	20	4	38		46	46	85	70	86	52
1986	2	1	8	0	18	1		88	89	82	90	72	89
1987	25	25	19	10	23	17		65	65	71	80	67	73
1988	12	12	8	4	13	8		79	79	83	87	78	81
1989	38	39	26	11	33	18		52	51	64	79	57	72
1990	27	28	22	4	15	7		63	62	68	86	75	83
1991	14	13	13	9	15	12		76	77	77	81	75	78
Avg	23	23	17	6	18	10		67	67	73	84	72	81
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	2		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-117. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the North Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	40	38	18	8	17	8		51	53	73	83	74	83
1977	44	43	38	14	37	20		46	47	52	76	53	70
1978	35	35	28	3	29	2		55	55	62	87	61	88
1979	45	44	38	16	38	16		45	46	52	74	52	74
1980	36	36	33	8	32	8		55	55	58	83	59	83
1981	23	23	30	6	30	7		67	67	60	84	60	83
1982	44	44	36	17	36	18		46	46	54	73	54	72
1983	39	39	37	10	37	10		51	51	53	80	53	80
1984	44	44	45	8	44	8		47	47	46	83	47	83
1985	48	47	39	26	41	28		42	43	51	64	49	62
1986	29	28	32	2	33	2		61	62	58	87	57	87
1987	44	44	32	13	33	13		46	46	58	77	57	77
1988	35	35	29	6	31	6		56	56	62	85	60	85
1989	46	46	47	14	45	16		44	44	43	76	45	74
1990	48	48	44	13	46	13		42	42	46	77	44	77
1991	38	38	31	9	30	8		52	52	59	81	60	82
Avg	40	40	35	11	35	11		50	51	55	79	55	79
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	1	0	1		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-118. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the San Joaquin River Portion of the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	**Suboptimal (<10°C)**							**Optimal (≥10°C and ≤19°C)**					
1976	19	19	20	14	18	12		72	72	71	77	73	79
1977	38	38	36	22	36	24		52	52	54	68	54	66
1978	0	0	0	0	0	0		90	90	90	90	90	90
1979	21	21	15	20	16	18		69	69	75	70	74	72
1980	11	11	8	6	6	7		80	80	83	85	85	84
1981	15	15	11	2	11	0		75	75	79	88	79	90
1982	25	25	14	14	13	12		65	65	76	76	77	78
1983	18	18	11	13	15	14		72	72	79	77	75	76
1984	15	15	35	8	33	7		76	76	56	83	58	84
1985	43	43	7	39	7	40		47	47	83	51	83	50
1986	7	6	15	1	16	1		83	84	75	89	74	89
1987	25	25	22	20	21	18		65	65	68	70	69	72
1988	24	24	17	9	17	8		67	67	74	82	74	83
1989	42	43	34	20	34	21		48	47	56	70	56	69
1990	30	30	17	8	17	8		60	60	73	82	73	82
1991	22	21	15	12	15	13		68	69	75	78	75	77
Avg	22	22	17	13	17	13		68	68	73	77	73	78
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-119. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the South Delta Subregion, Based on DSM2-QUAL Modeling

	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
Year	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	19	19	19	5	18	2		72	72	72	86	73	89
1977	39	39	37	16	37	17		51	51	53	74	53	73
1978	0	0	0	0	0	0		90	90	90	90	90	90
1979	28	26	13	13	13	13		62	64	77	77	77	77
1980	9	9	2	4	5	6		82	82	89	87	86	85
1981	17	17	12	0	10	0		73	73	78	90	80	90
1982	19	20	7	0	5	0		71	70	83	90	85	90
1983	17	17	6	10	7	10		73	73	84	80	83	80
1984	14	15	39	3	34	9		77	76	52	88	57	82
1985	45	45	5	41	5	41		45	45	85	49	85	49
1986	8	8	25	1	24	1		82	82	65	89	66	89
1987	27	27	24	13	21	10		63	63	66	77	69	80
1988	25	25	22	9	22	9		66	66	69	80	69	80
1989	45	46	29	21	29	19		45	44	61	69	61	71
1990	32	32	13	9	13	9		58	58	77	81	77	81
1991	18	18	16	12	15	12		72	72	74	78	75	78
Avg	23	23	17	10	16	10		68	68	73	80	74	80
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	2	0	2		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-120. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the Suisun Bay Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							**Optimal (≥10°C and ≤19°C)**					
1976	26	24	29	17	28	17		65	67	62	74	63	74
1977	38	38	38	36	38	36		52	52	52	54	52	54
1978	10	10	3	0	1	0		80	80	87	90	89	90
1979	39	39	36	26	37	27		51	51	54	64	53	63
1980	26	26	24	8	24	8		65	65	67	83	67	83
1981	22	22	21	10	20	10		68	68	69	80	70	80
1982	44	44	33	22	34	22		46	46	57	68	56	68
1983	31	31	23	18	23	18		59	59	67	72	67	72
1984	28	27	43	14	43	13		63	64	48	77	48	78
1985	44	44	17	44	16	44		46	46	73	46	74	46
1986	18	18	26	11	26	11		72	72	64	79	64	79
1987	30	30	27	28	27	26		60	60	63	62	63	64
1988	32	33	27	14	28	15		59	58	64	77	63	76
1989	42	45	35	37	35	37		48	45	55	53	55	53
1990	44	44	30	22	28	21		46	46	60	68	62	69
1991	30	29	17	12	18	13		60	61	73	78	72	77
Avg	32	32	27	20	27	20		59	59	63	70	64	70
	Supraoptimal (>19°C and ≤24°C)							**Lethal (>24°C)**					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-121. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the Suisun Marsh Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	22	22	21	16	20	16		69	69	70	75	71	75
1977	41	40	39	35	38	34		49	50	51	55	52	56
1978	1	1	0	0	0	0		89	89	90	90	90	90
1979	40	40	38	25	37	25		50	50	52	65	53	65
1980	27	27	21	2	18	4		64	64	70	89	73	87
1981	19	19	15	4	16	12		71	71	75	86	74	78
1982	45	45	40	24	38	24		45	45	50	66	52	66
1983	36	35	24	23	23	23		54	55	66	67	67	67
1984	28	28	44	7	44	7		63	63	47	84	47	84
1985	47	46	7	43	6	43		43	44	83	47	84	47
1986	18	17	27	5	27	4		72	73	63	85	63	86
1987	31	31	26	25	25	24		59	59	64	65	65	66
1988	34	33	25	14	25	15		57	58	66	77	66	76
1989	49	48	42	30	41	32		41	42	48	60	49	58
1990	46	46	27	13	21	14		44	44	63	77	69	76
1991	31	27	18	14	16	13		59	63	72	76	74	77
Avg	32	32	26	18	25	18		58	59	64	73	66	72
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

Table 5C.C-122. Number of Days within Temperature Requirements for Late Fall–Run Chinook Salmon Smoltification in the West Delta Subregion, Based on DSM2-QUAL Modeling

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT		EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
	Suboptimal (<10°C)							Optimal (≥10°C and ≤19°C)					
1976	24	24	21	14	19	14		67	67	70	77	72	77
1977	43	43	41	24	40	34		47	47	49	66	50	56
1978	9	9	0	0	0	0		81	81	90	90	90	90
1979	40	40	38	16	38	17		50	50	52	74	52	73
1980	28	28	26	3	24	2		63	63	65	88	67	89
1981	23	24	19	0	16	0		67	66	71	90	74	90
1982	45	45	37	15	31	11		45	45	53	75	59	79
1983	31	31	22	10	22	10		59	59	68	80	68	80
1984	33	33	44	3	44	3		58	58	47	88	47	88
1985	47	47	16	42	13	43		43	43	74	48	77	47
1986	17	17	28	5	27	6		73	73	62	85	63	84
1987	32	32	27	25	27	25		58	58	63	65	63	65
1988	39	39	26	10	26	11		52	52	65	81	65	80
1989	50	50	45	25	44	24		40	40	45	65	46	66
1990	53	54	33	9	31	9		37	36	57	81	59	81
1991	34	27	19	15	19	15		56	63	71	75	71	75
Avg	34	34	28	14	26	14		56	56	63	77	64	76
	Supraoptimal (>19°C and ≤24°C)							Lethal (>24°C)					
1976	0	0	0	0	0	0		0	0	0	0	0	0
1977	0	0	0	0	0	0		0	0	0	0	0	0
1978	0	0	0	0	0	0		0	0	0	0	0	0
1979	0	0	0	0	0	0		0	0	0	0	0	0
1980	0	0	0	0	0	0		0	0	0	0	0	0
1981	0	0	0	0	0	0		0	0	0	0	0	0
1982	0	0	0	0	0	0		0	0	0	0	0	0
1983	0	0	0	0	0	0		0	0	0	0	0	0
1984	0	0	0	0	0	0		0	0	0	0	0	0
1985	0	0	0	0	0	0		0	0	0	0	0	0
1986	0	0	0	0	0	0		0	0	0	0	0	0
1987	0	0	0	0	0	0		0	0	0	0	0	0
1988	0	0	0	0	0	0		0	0	0	0	0	0
1989	0	0	0	0	0	0		0	0	0	0	0	0
1990	0	0	0	0	0	0		0	0	0	0	0	0
1991	0	0	0	0	0	0		0	0	0	0	0	0
Avg	0	0	0	0	0	0		0	0	0	0	0	0

5C.C.5.3 Adult

Due to similarities in model results between late fall–run and winter-run Chinook salmon adults, see Section C.5.4.3.6 for late fall–run adult results.

5C.C.6 Delta Smelt

5C.C.6.1 Median Spawning Day (Adult)

For delta smelt, the median spawning day of the year (based on a 15–20°C temperature range for spawning) (Wagner et al. 2011) was essentially the same for EBC1 and EBC2 scenarios (Table 5C.C-123 to Table 5C.C-130), ranging from an average of day 125 (South Delta and San Joaquin) to day 136 (West Delta). Median spawning day shifted earlier in the year between EBC1/EBC2 and PP_ELT by averages ranging from 3 days (North Delta) to 8 days (Suisun Marsh). Between EBC1/EBC2 and PP_LLT, median spawning day shifted earlier in the year by an average of 2 days (San Joaquin) to 19 days (West Delta). Accounting for climate change (i.e., comparing EBC2_ELT with PP_ELT and comparing EBC2_LLT with PP_LLT), there generally was very little change in the median spawning day between existing biological conditions and preliminary proposal scenarios: average changes were always below 2 days (Table 5C.C-123 to Table 5C.C-130).

Table 5C.C-123. Median Spawning Day for Delta Smelt in the Cache Slough Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	125	125	122	119	122	119
1977	139	140	127	118	127	119
1978	128	128	127	119	128	120
1979	125	125	121	122	123	122
1980	132	132	140	118	140	118
1981	126	126	127	111	118	111
1982	143	143	127	123	144	125
1983	125	125	119	107	120	108
1984	122	122	127	114	127	113
1985	134	134	119	108	119	107
1986	118	118	129	106	129	107
1987	133	133	122	121	124	121
1988	119	119	116	111	118	111
1989	132	132	126	117	125	117
1990	126	125	125	119	125	119
1991	150	150	139	115	138	115
Avg	130	130	126	116	127	116

Table 5C.C-124. Median Spawning Day for Delta Smelt in the East Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	125	125	119	119	120	118
1977	128	128	127	111	127	111
1978	129	129	128	116	128	115
1979	138	138	133	122	128	122
1980	131	131	140	115	140	118
1981	132	132	126	114	126	108
1982	141	141	136	123	136	123
1983	142	142	116	107	117	107
1984	127	127	133	112	126	111
1985	135	135	130	106	119	107
1986	126	126	127	106	128	106
1987	131	131	126	118	124	120
1988	122	122	124	111	116	111
1989	138	138	125	124	125	117
1990	129	129	125	123	125	113
1991	135	135	135	114	138	115
Avg	132	132	128	115	126	114

Table 5C.C-125. Median Spawning Day for Delta Smelt in the North Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	125	125	119	116	119	116
1977	127	127	128	120	127	120
1978	129	129	127	120	126	113
1979	140	140	132	121	132	121
1980	130	130	136	115	136	115
1981	125	125	124	113	124	113
1982	140	140	135	123	135	122
1983	135	142	119	120	119	120
1984	128	128	133	111	131	111
1985	135	135	140	106	142	114
1986	130	130	127	113	127	113
1987	132	132	127	118	127	118
1988	124	124	125	111	125	111
1989	136	136	125	123	125	123
1990	130	130	125	106	125	106
1991	135	135	135	119	135	119
Avg	131	132	129	116	128	116

Table 5C.C-126. Median Spawning Day for Delta Smelt in the San Joaquin Portion of the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	124	124	124	120	124	120
1977	127	127	126	120	126	119
1978	122	122	127	126	122	122
1979	124	124	119	124	119	124
1980	130	130	117	128	118	128
1981	125	125	118	118	107	112
1982	124	124	118	133	120	143
1983	113	113	115	120	114	122
1984	118	120	124	120	124	120
1985	127	127	118	121	118	121
1986	113	113	113	124	113	124
1987	130	130	123	122	123	122
1988	118	118	118	120	118	115
1989	133	132	125	117	125	117
1990	129	129	125	124	125	124
1991	138	138	119	136	119	136
Avg	125	125	121	123	120	123

Table 5C.C-127. Median Spawning Day for Delta Smelt in the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	124	124	123	119	123	119
1977	127	127	121	117	121	117
1978	122	122	123	120	122	121
1979	124	124	119	124	119	124
1980	130	119	118	128	118	128
1981	125	125	107	107	107	100
1982	125	125	125	126	125	127
1983	113	113	116	114	116	118
1984	121	121	127	113	126	116
1985	128	128	115	108	115	109
1986	114	114	114	112	115	119
1987	123	123	116	121	116	121
1988	118	118	115	112	115	111
1989	123	123	125	117	125	117
1990	125	125	125	114	125	122
1991	150	150	119	115	119	115
Avg	125	124	119	117	119	118

Table 5C.C-128. Median Spawning Day for Delta Smelt in the Suisun Bay Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	127	124	123	120	123	120
1977	127	127	127	126	127	125
1978	129	129	128	122	128	122
1979	142	142	132	120	131	120
1980	142	141	139	119	139	119
1981	137	137	128	124	120	118
1982	145	145	144	126	144	126
1983	151	151	121	110	121	111
1984	126	126	127	114	127	114
1985	128	128	128	119	128	119
1986	128	128	129	113	129	113
1987	132	132	126	125	126	123
1988	124	124	123	122	123	122
1989	138	138	131	117	131	117
1990	128	128	125	124	125	124
1991	149	149	138	137	138	137
Avg	135	134	129	121	129	121

Table 5C.C-129. Median Spawning Day for Delta Smelt in the Suisun Marsh Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	125	125	124	120	123	120
1977	140	139	127	120	127	119
1978	129	129	129	119	128	119
1979	127	126	121	123	120	123
1980	135	135	133	120	131	120
1981	127	127	108	108	118	112
1982	145	145	145	126	127	126
1983	152	135	121	109	121	109
1984	122	122	127	115	127	112
1985	128	128	116	109	116	108
1986	120	120	130	109	130	108
1987	133	132	116	122	116	122
1988	119	119	117	112	116	112
1989	133	132	126	118	126	117
1990	126	126	125	118	125	124
1991	150	150	139	119	138	119
Avg	132	131	125	117	124	117

Table 5C.C-130. Median Spawning Day for Delta Smelt in the West Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	128	128	124	121	124	120
1977	141	140	130	120	130	120
1978	130	130	129	121	128	121
1979	152	152	130	123	129	124
1980	133	133	141	119	141	119
1981	141	141	126	112	126	109
1982	145	145	144	126	144	126
1983	149	149	118	111	118	111
1984	128	128	128	107	128	106
1985	129	129	128	122	129	122
1986	129	129	129	108	129	108
1987	133	133	126	122	125	122
1988	124	124	124	116	124	114
1989	132	132	124	118	124	118
1990	130	130	128	119	128	119
1991	150	150	139	136	139	119
Avg	136	136	129	119	129	117

5C.C.6.2 Number of Stressful Days (Juvenile)

The number of stressful days (daily average temperatures of 20°C–25°C) for juvenile delta smelt in each of the subregions increased into the future under both EBC and PP scenarios but was little changed between preliminary proposal and existing biological conditions scenarios when accounting for climate change, i.e., when comparing EBC2_ELT to PP_ELT and EBC2_LLT to PP_LLT (Table 5C.C-131 to Table 5C.C-138). The average number of stressful days under EBC1 and EBC2 scenarios was very similar and ranged from 72 days in Suisun Marsh to 91 days in the San Joaquin. The average increase in the number of stressful days from the EBC1/EBC2 scenarios to the PP_ELT scenario ranged from 8 (San Joaquin) to 16 (Suisun Marsh). The average increase in the number of stressful days from the EBC1/EBC2 scenarios to the PP_LLT scenario ranged from 12 (San Joaquin) to 38 (Suisun Bay). However, accounting for climate change, there was very little difference in the number of stressful days when comparing EBC2_ELT to PP_ELT and EBC2_LLT to PP_LLT: the average change ranged from an increase of 2 days (PP_LLT compared to the EBC2_LLT in the San Joaquin) to a decrease of 4 days (PP_ELT compared to the EBC2_ELT in Cache Slough).

If, as a result of upstream shifts in X2 under the preliminary proposal, juvenile delta smelt were found mostly in the West Delta subregion rather than the Suisun Bay subregion, there generally would be little difference in the number of stressful days between PP and EBC scenarios (Table 5C.C-139). There was an average of 2 more stressful days per year under PP_ELT (West Delta subregion) compared to EBC2_ELT (Suisun Bay subregion), with a range from 4 fewer stressful days under PP_ELT in 1976 to 15 more stressful days under PP_ELT in 1979. There was no difference in the average number of stressful days per year under PP_LLT (West Delta subregion) compared to EBC2_LLT (Suisun Bay subregion), with a range from 7 fewer stressful days under PP_ELT in 1980 to 14 more stressful days under PP_ELT in 1981 (Table 5C.C-139).

Table 5C.C-131. Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the Cache Slough Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	64	64	97	109	93	108
1977	83	81	91	105	88	105
1978	57	57	75	112	71	113
1979	86	87	110	134	107	129
1980	42	44	66	79	54	67
1981	103	104	118	132	111	131
1982	59	59	75	92	71	88
1983	80	81	118	122	118	123
1984	97	98	84	124	81	124
1985	73	73	88	102	85	100
1986	73	76	87	106	81	106
1987	60	59	97	120	94	116
1988	93	92	92	110	89	109
1989	76	76	79	104	73	102
1990	73	74	94	114	92	112
1991	62	61	74	111	71	110
Avg	74	74	90	111	86	109

Table 5C.C-132. Number of Stressful Days (Daily Average Temperature of 20–25°C) for Delta Smelt in the East Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	82	82	104	117	101	113
1977	88	88	92	111	92	108
1978	72	72	91	114	80	118
1979	94	95	122	136	116	138
1980	68	70	79	100	75	88
1981	109	109	117	130	120	135
1982	73	73	79	103	85	99
1983	103	98	116	130	122	130
1984	106	107	95	129	89	127
1985	80	81	93	107	90	108
1986	76	77	87	109	88	109
1987	69	64	90	138	95	128
1988	96	97	92	110	92	111
1989	73	73	93	111	87	112
1990	89	90	103	118	102	120
1991	77	75	90	119	82	114
Avg	85	84	96	118	95	116

Table 5C.C-133. Number of Stressful Days (Daily Average Temperature of 20–25°C) for Delta Smelt in the North Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	82	82	104	102	105	98
1977	83	83	90	110	90	109
1978	77	82	95	111	92	114
1979	91	90	114	127	113	131
1980	69	71	77	101	72	104
1981	103	100	111	114	116	113
1982	69	71	77	100	74	109
1983	89	89	110	129	111	131
1984	99	97	96	121	93	126
1985	81	80	97	109	97	108
1986	72	74	86	114	82	110
1987	69	61	92	124	93	124
1988	93	94	95	111	97	114
1989	79	78	95	117	93	117
1990	83	83	100	117	99	117
1991	79	79	86	117	87	117
Avg	82	82	95	114	95	115

Table 5C.C-134. Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the San Joaquin Portion of the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	79	80	87	97	86	98
1977	84	83	89	96	90	97
1978	91	89	102	102	101	106
1979	106	107	125	114	125	117
1980	81	80	91	69	88	68
1981	109	109	127	120	126	122
1982	94	94	104	81	100	83
1983	115	115	123	111	119	109
1984	115	114	101	118	98	122
1985	89	88	101	94	98	96
1986	89	89	102	98	101	97
1987	78	74	97	105	96	108
1988	94	92	93	106	93	109
1989	79	78	85	95	87	99
1990	83	82	96	112	97	113
1991	68	62	85	102	82	105
Avg	91	90	101	101	99	103

Table 5C.C-135. Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	73	73	96	117	95	115
1977	86	86	90	108	90	107
1978	64	63	86	116	88	112
1979	99	99	118	137	117	133
1980	54	54	86	75	85	68
1981	111	111	124	137	123	133
1982	76	76	88	87	88	86
1983	113	111	122	116	119	112
1984	105	105	89	124	87	124
1985	81	81	93	105	91	103
1986	80	81	92	108	94	107
1987	75	74	100	120	100	118
1988	96	96	95	113	95	109
1989	85	85	88	109	87	108
1990	84	84	101	116	98	115
1991	74	74	87	114	85	113
Avg	85	85	97	113	96	110

Table 5C.C-136. Number of Stressful Days (Daily Average Temperature of 20–25°C) for Delta Smelt in the Suisun Bay Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	66	97	103	98	104
1977	86	86	88	104	89	105
1978	57	57	76	120	75	118
1979	85	86	100	135	100	134
1980	40	41	65	81	64	79
1981	86	87	106	122	107	124
1982	58	59	72	84	72	84
1983	90	89	116	122	116	119
1984	104	104	86	126	83	126
1985	76	76	81	107	80	107
1986	77	78	86	105	87	104
1987	55	58	89	117	90	116
1988	88	89	93	116	94	116
1989	67	68	74	103	75	104
1990	71	72	87	115	87	115
1991	57	59	72	111	75	111
Avg	73	73	87	111	87	110

Table 5C.C-137. Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the Suisun Marsh Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	63	63	93	106	94	102
1977	85	85	91	104	89	106
1978	57	59	70	114	72	114
1979	82	84	109	132	108	132
1980	40	41	63	69	61	70
1981	100	103	115	133	115	129
1982	57	57	76	81	78	86
1983	82	82	119	123	118	123
1984	99	100	80	128	82	129
1985	73	73	83	103	86	101
1986	74	74	87	106	89	107
1987	63	64	98	116	97	115
1988	88	88	91	112	91	116
1989	67	72	69	98	74	100
1990	71	72	89	116	91	112
1991	54	55	69	108	73	109
Avg	72	73	88	109	89	109

Table 5C.C-138. Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the West Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	65	95	111	93	109
1977	82	83	88	101	88	101
1978	57	56	76	113	74	113
1979	85	84	117	147	115	140
1980	41	41	72	81	66	74
1981	104	104	120	134	118	136
1982	63	63	73	85	73	85
1983	96	95	119	125	119	124
1984	103	100	88	134	86	133
1985	79	79	79	103	79	103
1986	76	76	83	104	81	104
1987	63	63	97	123	97	117
1988	92	92	92	112	91	112
1989	80	80	76	101	75	100
1990	75	77	92	116	90	117
1991	67	67	76	113	75	112
Avg	77	77	90	113	89	111

Table 5C.C-139. Comparison of Number of Stressful Days (Daily Average Temperature of 20°C–25°C) for Delta Smelt in the Suisun Bay and West Delta Subregions during the Early and Late Long-Term Periods

Year	Early Long-Term				Late Long-Term			
	Suisun Bay EBC2_ELT	West Delta PP_ELT	Difference	% Difference	Suisun Bay EBC2_LLT	West Delta PP_LLT	Difference	% Difference
1976	97	93	-4	-4%	103	109	6	6%
1977	88	88	0	0%	104	101	-3	-3%
1978	76	74	-2	-3%	120	113	-7	-6%
1979	100	115	15	15%	135	140	5	4%
1980	65	66	1	2%	81	74	-7	-9%
1981	106	118	12	11%	122	136	14	11%
1982	72	73	1	1%	84	85	1	1%
1983	116	119	3	3%	122	124	2	2%
1984	86	86	0	0%	126	133	7	6%
1985	81	79	-2	-2%	107	103	-4	-4%
1986	86	81	-5	-6%	105	104	-1	-1%
1987	89	97	8	9%	117	117	0	0%
1988	93	91	-2	-2%	116	112	-4	-3%
1989	74	75	1	1%	103	100	-3	-3%
1990	87	90	3	3%	115	117	2	2%
1991	72	75	3	4%	111	112	1	1%
Avg	87	89	2	2%	111	111	0.6	0%

5C.C.6.3 Number of Lethal Days

There were no lethal days (daily average temperatures greater than 25°C) in any of the subregions for the EBC1 and EBC2 scenarios (Table 5C.C-140 to Table 5C.C-145), and there were no lethal days under any scenario in the Suisun Bay and West Delta subregions. The only lethal days in the ELT occurred in 1983 in the South Delta and San Joaquin, wherein the number of lethal days increased from 2 under EBC2_ELT to 6 under PP_ELT. In the LLT, the average number of lethal days was generally similar between PP_LLT and EBC2_LLT and when differences did occur, they generally consisted of decreases under PP_LLT relative to EBC2_LLT.

Table 5C.C-140. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the Cache Slough Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	3	0	1
1979	0	0	0	0	0	0
1980	0	0	0	1	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	3	0	3
1985	0	0	0	1	0	1
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	7	0	6
1989	0	0	0	0	0	0
1990	0	0	0	2	0	3
1991	0	0	0	0	0	0
Avg	0	0	0	1	0	1

Table 5C.C-141. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the East Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	7	0	4
1979	0	0	0	1	0	0
1980	0	0	0	3	0	1
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	4	0	2
1985	0	0	0	3	0	1
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	14	0	9
1989	0	0	0	0	0	0
1990	0	0	0	7	0	3
1991	0	0	0	0	0	0
Avg	0	0	0	2	0	1

Table 5C.C-142. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the North Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	2	6	2	5
1977	0	0	0	2	0	2
1978	0	0	0	11	0	11
1979	0	0	0	5	0	1
1980	0	0	0	7	0	4
1981	0	0	0	5	0	5
1982	0	0	0	2	0	1
1983	0	0	0	1	0	1
1984	0	0	0	8	0	4
1985	0	0	0	5	0	5
1986	0	0	0	0	0	0
1987	0	0	0	2	0	1
1988	0	0	0	14	0	14
1989	0	0	0	5	0	3
1990	0	0	0	12	0	11
1991	0	0	0	3	0	2
Avg	0	0	0	6	0	4

Table 5C.C-143. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the San Joaquin Portion of the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	2	0	6	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	0	0	0	0	0	0

Table 5C.C-144. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the South Delta Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	1	0	1
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	2	0	6	0
1984	0	0	0	7	0	6
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	8	0	6
1989	0	0	0	0	0	0
1990	0	0	0	3	0	2
1991	0	0	0	0	0	0
Avg	0	0	0	1	0	1

Table 5C.C-145. Number of Lethal Days (Daily Average Temperature >25°C) for Delta Smelt in the Suisun Marsh Subregion

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	3	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	3	0	1
1989	0	0	0	0	0	0
1990	0	0	0	0	0	2
1991	0	0	0	0	0	0
Avg	0	0	0	0	0	0

5C.C.7 Longfin Smelt

5C.C.7.1 Juvenile

Temperature exceedance data for juvenile longfin smelt were applicable only to the San Joaquin River, the San Joaquin River portion of the South Delta subregion, Suisun Bay, Suisun Marsh, and the West Delta.

In the San Joaquin River, exceedance of the 20°C temperature threshold for longfin smelt juveniles (August–May) differed little between EBC and PP scenarios. On average, the number of days exceeding this threshold was 47 and 46 under EBC1 and EBC2, respectively, 52 and 55 under EBC2_ELT and EBC2_LLT, respectively, and 51 and 57 under PP_ELT and PP_LLT, respectively (Table 5C.C-146).

Accounting for climate change, there was little difference between EBC scenarios and PP scenarios in the number of days exceeding 20°C in the San Joaquin River portion of the South Delta subregion during the longfin smelt juvenile period (March–June). The number of days exceeding this threshold was 16 under EBC1 and EBC2, 21 and 18 under EBC2_ELT and EBC2_LLT, respectively, and 21 and 19 days under PP_ELT and PP_LLT, respectively (Table 5C.C-147).

Comparing the number of days exceeding 20°C in the South Delta subregion during the longfin smelt juvenile period (March–June) suggested little difference between EBC scenarios and PP scenarios. The number of days exceeding 20°C was 15 under EBC1 and EBC2, 20 and 25 under EBC2_ELT and EBC2_LLT, respectively, and 20 and 23 days under PP_ELT and PP_LLT, respectively (Table 5C.C-148).

The differences between EBC scenarios and PP scenarios in the exceedance of the 20°C threshold for longfin smelt juveniles in Suisun Bay year-round were minor when accounting for climate change. On average, the 20°C threshold was exceeded 73 days under EBC1 and EBC2, 87 and 111 days under EBC2_ELT and EBC2_LLT, respectively, and 87 and 110 days under PP_ELT and PP_LLT, respectively (Table 5C.C-149).

For longfin smelt juveniles in the West Delta, there was little difference between EBC and PP scenarios for the number of days when water temperatures exceeded 20°C during August and May. The number of days exceeding 20°C was 40 and 39 under EBC1 and EBC2, respectively. Exceedances were 48 and 64 days under EBC2_ELT and EBC2_LLT, respectively, and 47 and 63 days under PP_ELT and PP_LLT, respectively (Table 5C.C-150).

Table 5C.C-146. Number of Days Exceeding 20°C in the San Joaquin River Portion of the South Delta Subregion during the Longfin Smelt Juvenile Period (August–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	38	39	44	49	43	50
1977	43	43	44	47	45	47
1978	47	46	51	57	51	59
1979	63	64	68	66	68	69
1980	41	40	47	43	46	42
1981	52	52	67	62	65	63
1982	52	52	56	49	56	51
1983	61	61	70	57	70	57
1984	66	66	45	68	42	68
1985	38	37	54	43	53	45
1986	43	43	46	48	45	48
1987	33	30	51	60	50	62
1988	50	48	46	59	46	62
1989	36	35	42	48	43	51
1990	44	43	55	61	56	62
1991	39	33	44	66	41	68
Avg	47	46	52	55	51	57

Table 5C.C-147. Number of Days Exceeding 20°C in the San Joaquin River Portion of the South Delta Subregion during the Longfin Smelt Juvenile Period (March–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	10	10	15	21	15	22
1977	11	11	14	18	14	19
1978	16	15	23	14	23	16
1979	26	26	29	21	29	22
1980	10	10	14	4	12	4
1981	27	27	36	27	37	28
1982	14	14	23	4	19	4
1983	26	26	34	23	33	21
1984	25	24	25	26	25	30
1985	20	20	21	20	19	20
1986	15	15	28	19	28	18
1987	21	20	15	27	15	29
1988	13	13	17	16	17	17
1989	12	12	16	19	17	19
1990	9	9	17	24	17	25
1991	2	2	11	6	11	7
Avg	16	16	21	18	21	19

Table 5C.C-148. Number of Days Exceeding 20°C in the South Delta Subregion during the Longfin Smelt Juvenile Period (March–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	13	13	19	32	19	31
1977	11	11	14	24	14	23
1978	12	12	20	26	20	23
1979	24	24	29	30	26	27
1980	4	4	9	5	8	4
1981	31	31	36	37	36	37
1982	4	4	10	8	10	8
1983	26	24	32	27	33	24
1984	20	20	22	37	22	36
1985	19	19	18	23	16	21
1986	11	11	26	25	28	24
1987	27	27	17	35	17	34
1988	13	13	18	23	18	18
1989	18	18	20	24	20	23
1990	10	10	19	29	19	27
1991	1	1	12	10	12	9
Avg	15	15	20	25	20	23

Table 5C.C-149. Number of Days Exceeding 20°C in the Suisun Bay Subregion during the Longfin Smelt Juvenile Period (Year-Round)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	66	97	103	98	104
1977	86	86	88	104	89	105
1978	57	57	76	120	75	118
1979	85	86	100	135	100	134
1980	40	41	65	81	64	79
1981	86	87	106	122	107	124
1982	58	59	72	84	72	84
1983	90	89	116	122	116	119
1984	104	104	86	126	83	126
1985	76	76	81	107	80	107
1986	77	78	86	105	87	104
1987	55	58	89	117	90	116
1988	88	89	93	116	94	116
1989	67	68	74	103	75	104
1990	71	72	87	115	87	115
1991	57	59	72	111	75	111
Avg	73	73	87	111	87	110

Table 5C.C-150. Number of Days Exceeding 20°C in the West Delta Subregion during the Longfin Smelt Juvenile Period (August–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	26	26	51	64	50	62
1977	45	45	46	52	46	52
1978	27	26	37	62	35	62
1979	51	50	63	87	63	86
1980	21	21	45	48	40	47
1981	51	51	59	74	57	75
1982	43	43	48	55	48	57
1983	52	51	68	67	69	66
1984	60	57	37	73	35	72
1985	30	30	41	52	41	52
1986	39	39	45	52	43	52
1987	25	25	51	72	52	70
1988	49	49	48	67	47	67
1989	36	36	35	53	34	52
1990	40	40	54	64	52	65
1991	39	39	39	76	38	76
Avg	40	39	48	64	47	63

5C.C.7.2 Adult

Water temperature exceedance (>20°C) data for adult longfin smelt were modeled for Cache Slough, the North Delta, the East Delta, the San Joaquin River, South Delta, Suisun Bay, Suisun Marsh, and the West Delta.

There were no days exceeding the 20°C threshold for any scenario during December–April for adult longfin smelt in the North Delta subregion, East Delta subregion, and San Joaquin portion of the South Delta subregion. There was a single exceedance of the threshold in 1987 in the Cache Slough subregion under both the EBC2_LLT and PP_LLT scenarios. There was also a single exceedance of the threshold in 1987 in the South Delta subregion PP_LLT scenario alone.

In the San Joaquin River, December through April temperature thresholds for adult longfin smelt were exceeded on average on 45 and 44 days under the EBC1 and EBC2 scenarios, on 44 and 49 days under EBC2_ELT and EBC2_LLT, and on 48 and 55 days under PP_ELT and PP_LLT scenarios (Table 5C.C-151).

In Suisun Bay, the number of days when water temperatures exceeded 20°C year-round for adult longfin smelt was 73 for EBC1 and EBC2. Under EBC2_ELT and PP_ELT the number of temperature exceedance days was 87, and under EBC2_LLT and PP_LLT, 111 and 110 days, respectively (Table 5C.C-152).

Year-round temperature in Suisun Marsh exceeded the threshold on 72 and 73 days under EBC1 and EBC2, respectively, on 88 and 110 days under EBC2_ELT and EBC_LLT, respectively, and on 89 and 110 days under PP_ELT and PP_LLT (Table 5C.C-153).

In the West Delta, August–March water temperatures were generally similar among EBC and PP scenarios. Under EBC1 and EBC2, the number of exceedance days was 39 and 38 days respectively. Under EBC2_ELT and EBC2_LLT, the number was 46 and 61 days, respectively. For the PP scenarios, the number of days with water temperatures above 20°C was 45 for PP_ELT and 111 for PP_LLT (Table 5C.C-154).

Table 5C.C-151. Number of Days Exceeding 20°C in the San Joaquin River Portion of the South Delta Subregion during the Longfin Smelt Adult Period (August–March)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	38	39	41	45	40	45
1977	43	43	44	47	45	47
1978	44	43	48	57	48	59
1979	59	60	65	66	65	68
1980	41	40	47	43	46	42
1981	51	51	60	62	58	63
1982	49	49	50	49	50	51
1983	58	58	60	57	61	57
1984	59	59	45	61	42	61
1985	38	37	49	43	48	45
1986	43	43	43	48	42	48
1987	27	24	51	50	50	51
1988	50	48	45	59	45	61
1989	36	35	41	47	42	50
1990	44	43	48	57	49	57
1991	39	33	44	66	41	68
Avg	45	44	49	54	48	55

Table 5C.C-152. Number of Days Exceeding 20°C in the Suisun Bay Subregion during the Longfin Smelt Adult Period (Year-Round)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	66	97	103	98	104
1977	86	86	88	104	89	105
1978	57	57	76	120	75	118
1979	85	86	100	135	100	134
1980	40	41	65	81	64	79
1981	86	87	106	122	107	124
1982	58	59	72	84	72	84
1983	90	89	116	122	116	119
1984	104	104	86	126	83	126
1985	76	76	81	107	80	107
1986	77	78	86	105	87	104
1987	55	58	89	117	90	116
1988	88	89	93	116	94	116
1989	67	68	74	103	75	104
1990	71	72	87	115	87	115
1991	57	59	72	111	75	111
Avg	73	73	87	111	87	110

Table 5C.C-153. Number of Days Exceeding 20°C in the Suisun Marsh Subregion during the Longfin Smelt Adult Period (Year-Round)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	63	63	93	106	94	102
1977	85	85	91	104	89	106
1978	57	59	70	114	72	114
1979	82	84	109	132	108	132
1980	40	41	63	69	61	70
1981	100	103	115	133	115	129
1982	57	57	76	81	78	86
1983	82	82	119	123	118	123
1984	99	100	80	131	82	129
1985	73	73	83	103	86	101
1986	74	74	87	106	89	107
1987	63	64	98	116	97	115
1988	88	88	91	115	91	117
1989	67	72	69	98	74	100
1990	71	72	89	116	91	114
1991	54	55	69	108	73	109
Avg	72	73	88	110	89	110

Table 5C.C-154. Number of Days Exceeding 20°C in the West Delta Subregion during the Longfin Smelt Adult Period (August–March)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	26	26	51	57	50	56
1977	45	45	46	52	46	52
1978	27	26	36	61	34	61
1979	51	50	63	82	63	81
1980	21	21	45	48	40	47
1981	51	51	57	71	55	71
1982	43	43	48	55	48	57
1983	52	51	61	61	61	61
1984	55	52	37	66	35	65
1985	30	30	41	52	41	52
1986	39	39	34	52	31	52
1987	17	17	51	60	52	58
1988	49	49	48	67	47	67
1989	36	36	35	53	34	52
1990	40	40	49	61	47	61
1991	39	39	39	76	38	76
Avg	39	38	46	61	45	61

5C.C.8 White Sturgeon

5C.C.8.1 Juvenile

Water temperatures during June through October in the Cache Slough area exceeded the 20°C threshold for juvenile white sturgeon on 72 and 73 days, respectively under EBC1 and EBC2. Differences between EBC and PP scenarios were also minor: 87 versus 83 days under EBC2_ELT and PP_ELT, and 107 and 105 days under EBC2_LLT and PP_LLT (Table 5C.C-155).

In the east Delta, exceedance frequency for water temperatures above 20°C during June through October was 83 days for EBC1 and EBC2. On 93 and 114 days, water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT, respectively, and on 91 and 112 days under PP_ELT and PP_LLT (Table 5C.C-156).

For the North Delta, the frequency at which water temperatures exceeded 20°C during June through October was 80 days for EBC1 and EBC2. On 91 and 115 days, water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT. Under the PP scenarios, these numbers remained unchanged (Table 5C.C-157).

Water temperatures during June through October in the San Joaquin area exceeded the 20° threshold for juvenile white sturgeon on 89 and 88 days, respectively under EBC1 and EBC2. Differences between EBC and PP scenarios were also minor: 98 versus 97 days under EBC2_ELT and PP_ELT, and 100 and 101 days under EBC2_LLT and PP_LLT (Table 5C.C-158).

June through October water temperature in the South Delta exceeded the 20°C threshold for juvenile white sturgeon on 83 days under EBC1 and EBC2, on 94 and 109 days under EBC2_ELT and EBC_LLT, respectively, and on 93 and 107 days under PP_ELT and PP_LLT (Table 5C.C-159).

Water temperatures during June through October in Suisun Bay area exceeded the 20° threshold for juvenile white sturgeon on 72 and 73 days, respectively under EBC1 and EBC2. There were no differences in the frequency of exceedance days between EBC and PP scenarios: 85 days under EBC2_ELT and PP_ELT, and 107 days under EBC2_LLT and PP_LLT (Table 5C.C-160).

For the Suisun Marsh, the frequency at which water temperatures exceeded 20°C during June through October was 71 and 72 days for EBC1 and EBC2, respectively. Water temperatures exceeded this threshold on 84 and 105 days under EBC2_ELT and EBC2_LLT, and on 85 and 104 days under PP_ELT and PP_LLT scenarios, respectively (Table 5C.C-161).

Lastly, water temperatures in the West Delta reached levels above the exceedance threshold of 20°C on 76 days under EBC1 and EBC2. On average, 89 and 110 days of exceedance occurred under the EBC2_ET and EBC2_LLT scenarios. Water temperatures exceeded the threshold on 87 and 109 days under PP_ELT and PPL_LLT (Table 5C.C-162).

Table 5C.C-155. Number of Days Exceeding 20°C in the Cache Slough Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	64	64	92	100	88	97
1977	83	81	91	105	88	105
1978	56	56	73	113	69	111
1979	84	85	108	125	105	119
1980	42	44	66	80	54	67
1981	99	100	113	124	105	123
1982	58	58	73	89	68	85
1983	80	81	109	117	106	116
1984	91	92	84	116	81	115
1985	73	73	85	103	82	101
1986	73	76	75	104	70	104
1987	51	50	97	106	94	102
1988	93	92	92	111	89	109
1989	74	74	75	101	68	99
1990	73	74	85	109	84	109
1991	62	61	74	111	71	110
Avg	72	73	87	107	83	105

Table 5C.C-156. Number of Days Exceeding 20°C in the East Delta Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	81	81	98	103	96	101
1977	88	88	92	111	92	108
1978	70	70	88	118	78	118
1979	92	93	116	126	112	128
1980	68	70	79	103	75	89
1981	105	105	111	123	115	128
1982	71	71	77	99	81	95
1983	100	95	106	119	111	119
1984	99	100	95	124	89	120
1985	80	81	89	110	87	109
1986	76	77	84	106	79	105
1987	61	56	90	125	95	115
1988	96	97	92	117	92	114
1989	73	73	89	107	82	109
1990	89	90	95	118	94	116
1991	77	75	89	116	82	114
Avg	83	83	93	114	91	112

Table 5C.C-157. Number of Days Exceeding 20°C in the North Delta Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	80	80	103	105	104	100
1977	83	83	90	112	90	111
1978	74	79	90	115	87	119
1979	90	89	106	125	105	125
1980	68	71	76	105	71	105
1981	102	99	103	117	107	116
1982	66	68	73	100	71	107
1983	85	85	101	119	102	121
1984	92	90	95	122	92	122
1985	81	80	90	113	89	111
1986	70	72	84	110	80	105
1987	67	59	90	123	91	122
1988	92	93	90	117	92	120
1989	76	75	91	114	90	112
1990	83	83	95	123	94	122
1991	78	78	85	116	86	115
Avg	80	80	91	115	91	115

Table 5C.C-158. Number of Days Exceeding 20°C in the San Joaquin River Portion of the South Delta Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	79	80	84	93	83	93
1977	84	83	89	96	90	97
1978	88	86	99	102	98	106
1979	102	103	122	114	122	116
1980	81	80	91	69	88	68
1981	108	108	120	120	119	122
1982	91	91	98	81	94	83
1983	112	112	115	111	116	109
1984	108	107	101	111	98	115
1985	89	88	96	94	93	96
1986	89	89	99	98	98	97
1987	72	68	97	95	96	97
1988	94	92	92	106	92	108
1989	79	78	84	94	86	98
1990	83	82	89	108	90	108
1991	68	62	85	102	82	105
Avg	89	88	98	100	97	101

Table 5C.C-159. Number of Days Exceeding 20°C in the South Delta Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	72	72	91	104	90	103
1977	86	86	90	108	90	107
1978	62	61	83	115	85	111
1979	94	94	114	130	115	127
1980	54	54	86	75	85	68
1981	107	107	118	130	117	126
1982	73	73	82	87	81	86
1983	110	110	113	116	113	112
1984	99	99	88	121	86	120
1985	81	81	90	105	88	103
1986	80	81	85	106	84	105
1987	66	65	100	106	100	103
1988	96	96	95	115	95	113
1989	84	84	84	106	83	105
1990	84	84	92	112	89	111
1991	74	74	86	114	84	113
Avg	83	83	94	109	93	107

Table 5C.C-160. Number of Days Exceeding 20°C in the Suisun Bay Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	66	96	99	96	100
1977	86	86	88	104	89	105
1978	56	56	74	117	73	115
1979	85	86	100	127	100	125
1980	40	41	65	81	64	79
1981	86	87	104	120	105	122
1982	58	59	72	83	72	83
1983	90	89	108	119	108	118
1984	98	98	86	118	83	118
1985	76	76	81	106	80	106
1986	77	78	77	102	79	102
1987	51	54	89	107	90	106
1988	88	89	93	110	94	110
1989	67	68	73	103	73	103
1990	71	72	83	109	83	109
1991	57	59	72	107	75	107
Avg	72	73	85	107	85	107

Table 5C.C-161. Number of Days Exceeding 20°C in the Suisun Marsh Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	63	63	89	95	89	93
1977	85	85	91	104	89	106
1978	56	58	68	112	70	112
1979	81	82	108	125	107	121
1980	40	41	63	69	61	70
1981	97	99	110	124	109	122
1982	57	57	74	79	76	80
1983	82	82	108	117	107	117
1984	93	94	80	119	81	118
1985	73	73	80	103	83	101
1986	74	74	74	104	77	104
1987	54	55	98	102	97	102
1988	88	88	91	109	91	110
1989	67	70	65	95	70	97
1990	71	72	82	110	83	108
1991	54	55	69	108	72	109
Avg	71	72	84	105	85	104

Table 5C.C-162. Number of Days Exceeding 20°C in the West Delta Subregion during the White Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	65	65	95	104	93	103
1977	82	83	88	101	88	101
1978	57	56	75	112	73	112
1979	85	84	117	142	115	135
1980	41	41	72	81	66	74
1981	104	104	118	131	116	132
1982	63	63	73	85	73	85
1983	96	95	112	119	111	119
1984	98	95	88	127	86	126
1985	79	79	79	103	79	103
1986	76	76	72	104	69	104
1987	55	55	97	111	97	105
1988	92	92	92	112	91	112
1989	80	80	76	101	75	100
1990	75	77	87	113	85	113
1991	67	67	76	113	75	112
Avg	76	76	89	110	87	109

5C.C.8.2 Adult

In Cache slough, the number of days when water temperatures exceeded 20°C for adult white sturgeon was small: 2 days under EBC1 and EBC2, 3 and 5 days under EBC2_ELT and EBC_LLT, and 4 and 5 days under PP_ELT and PP_LLT (Table 5C.C-163).

The number of days when water temperatures exceeded 20°C for adult white sturgeon from January through May in the North Delta was similar under EBC and PP scenarios. Temperature thresholds were exceeded on 2 days under EBC1 and EBC2 and on 4 and 5 days under EBC2_ELT and EBC_LLT. These numbers remained unchanged under the PP_ELT and PP_LLT scenarios (Table 5C.C-164).

Comparing the number of days exceeding 20°C in the North Delta subregion during January through May suggested little difference between EBC scenarios and PP scenarios. The number of days exceeding 20°C was 2 under EBC1 and EBC2, 4 and 5 under EBC2_ELT and EBC2_LLT, respectively, and 4 and 5 days under PP_ELT and PP_LLT, respectively (Table 5C.C-165).

In the San Joaquin River, the number of days when water temperatures exceeded 20°C for adult white sturgeon was small: 2 days under EBC1 and EBC2, 3 and 2 days under EBC2_ELT and EBC_LLT, and 3 and 2 days under PP_ELT and PP_LLT (Table 5C.C-166).

For the South Delta, the frequency at which water temperatures exceeded 20°C during January through May was 2 days for EBC1 and EBC2. Water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT on 4 days, and under PP_ELT and PP_LLT scenarios on 5 days (Table 5C.C-167).

For Suisun Bay, the frequency at which water temperatures exceeded 20°C during January through May was 1 day for EBC1 and EBC2. Water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT on 2 and 4 days, respectively. The number of exceedance days was identical for PP_ELT and PP_LLT scenarios (Table 5C.C-168).

In Suisun Marsh, water temperatures rarely reached levels above 20°C during January to May. The numbers were 1 and 2 days for EBC1 and EBC2, respectively, 3 and 5 days under EBC2_ELT and EBC2_LLT, respectively, and 4 and 5 days under PP_ELT and PP_LLT scenarios, respectively (Table 5C.C-169).

The number of days when water temperatures exceeded 20°C for adult white sturgeon from January through May in the North Delta was similar under EBC and PP scenarios. Temperature thresholds were exceeded on 1 day under EBC1 and EBC2 and on 2 and 3 days under EBC2_ELT and EBC_LLT, respectively. These numbers remained unchanged under the PP_ELT and PP_LLT scenarios (Table 5C.C-170).

Exceedances in January–May of the >25°C threshold were not examined for adult white sturgeon under any of the modeled scenarios or in any subregion.

Table 5C.C-163. Number of Days Exceeding 20°C in the Cache Slough Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	5	9	5	11
1977	0	0	0	0	0	0
1978	1	1	2	2	2	3
1979	2	2	2	9	2	10
1980	0	0	0	0	0	0
1981	4	4	5	8	6	8
1982	1	1	2	3	3	3
1983	0	0	9	5	12	7
1984	6	6	0	11	0	12
1985	0	0	3	0	3	0
1986	0	0	12	2	11	2
1987	9	9	0	14	0	14
1988	0	0	0	6	0	6
1989	2	2	4	3	5	3
1990	0	0	9	7	8	6
1991	0	0	0	0	0	0
Avg	2	2	3	5	4	5

Table 5C.C-164. Number of Days Exceeding 20°C in the East Delta Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	1	1	6	14	5	12
1977	0	0	0	0	0	0
1978	2	2	3	3	2	4
1979	2	2	6	11	4	10
1980	0	0	0	0	0	0
1981	4	4	6	7	5	7
1982	2	2	2	4	4	4
1983	3	3	10	11	11	11
1984	7	7	0	9	0	9
1985	0	0	4	0	3	0
1986	0	0	3	3	9	4
1987	8	8	0	13	0	13
1988	0	0	0	7	0	6
1989	0	0	4	4	5	3
1990	0	0	8	7	8	7
1991	0	0	1	3	0	0
Avg	2	2	3	6	4	6

Table 5C.C-165. Number of Days Exceeding 20°C in the North Delta Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	2	2	3	3	3	3
1977	0	0	0	0	0	0
1978	3	3	5	7	5	6
1979	1	1	8	7	8	7
1980	1	0	1	3	1	3
1981	1	1	8	2	9	2
1982	3	3	4	2	3	3
1983	4	4	9	11	9	11
1984	7	7	1	7	1	8
1985	0	0	7	1	8	2
1986	2	2	2	4	2	5
1987	2	2	2	3	2	3
1988	1	1	5	8	5	8
1989	3	3	4	8	3	8
1990	0	0	5	6	5	6
1991	1	1	1	4	1	4
Avg	2	2	4	5	4	5

Table 5C.C-166. Number of Days Exceeding 20°C in the San Joaquin River Portion of the South Delta Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	3	4	3	5
1977	0	0	0	0	0	0
1978	3	3	3	0	3	0
1979	4	4	3	0	3	1
1980	0	0	0	0	0	0
1981	1	1	7	0	7	0
1982	3	3	6	0	6	0
1983	3	3	10	0	9	0
1984	7	7	0	7	0	7
1985	0	0	5	0	5	0
1986	0	0	3	0	3	0
1987	6	6	0	10	0	11
1988	0	0	1	0	1	1
1989	0	0	1	1	1	1
1990	0	0	7	4	7	5
1991	0	0	0	0	0	0
Avg	2	2	3	2	3	2

Table 5C.C-167. Number of Days Exceeding 20°C in the South Delta Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	1	1	5	13	5	12
1977	0	0	0	0	0	0
1978	2	2	3	2	3	2
1979	5	5	4	7	2	6
1980	0	0	0	0	0	0
1981	4	4	6	7	6	7
1982	3	3	6	0	7	0
1983	3	1	11	0	12	0
1984	6	6	1	10	1	10
1985	0	0	3	0	3	0
1986	0	0	7	2	10	2
1987	9	9	0	14	0	15
1988	0	0	0	6	0	2
1989	1	1	4	3	4	3
1990	0	0	9	7	9	6
1991	0	0	1	0	1	0
Avg	2	2	4	4	4	4

Table 5C.C-168. Number of Days Exceeding 20°C in the Suisun Bay Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	1	4	2	4
1977	0	0	0	0	0	0
1978	1	1	2	3	2	3
1979	0	0	0	8	0	9
1980	0	0	0	0	0	0
1981	0	0	2	2	2	2
1982	0	0	0	1	0	1
1983	0	0	8	3	8	1
1984	6	6	0	8	0	8
1985	0	0	0	1	0	1
1986	0	0	9	3	8	2
1987	4	4	0	10	0	10
1988	0	0	0	6	0	6
1989	0	0	1	0	2	1
1990	0	0	4	6	4	6
1991	0	0	0	4	0	4
Avg	1	1	2	4	2	4

Table 5C.C-169. Number of Days Exceeding 20°C in the Suisun Marsh Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	4	11	5	9
1977	0	0	0	0	0	0
1978	1	1	2	2	2	2
1979	1	2	1	7	1	11
1980	0	0	0	0	0	0
1981	3	4	5	9	6	7
1982	0	0	2	2	2	6
1983	0	0	11	6	11	6
1984	6	6	0	12	1	11
1985	0	0	3	0	3	0
1986	0	0	13	2	12	3
1987	9	9	0	14	0	13
1988	0	0	0	6	0	7
1989	0	2	4	3	4	3
1990	0	0	7	6	8	6
1991	0	0	0	0	1	0
Avg	1	2	3	5	4	5

Table 5C.C-170. Number of Days Exceeding 20°C in the West Delta Subregion during the White Sturgeon Adult Period (January–May)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	7	0	6
1977	0	0	0	0	0	0
1978	0	0	1	1	1	1
1979	0	0	0	5	0	5
1980	0	0	0	0	0	0
1981	0	0	2	3	2	4
1982	0	0	0	0	0	0
1983	0	0	7	6	8	5
1984	5	5	0	7	0	7
1985	0	0	0	0	0	0
1986	0	0	11	0	12	0
1987	8	8	0	12	0	12
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	5	3	5	4
1991	0	0	0	0	0	0
Avg	1	1	2	3	2	3

5C.C.9 Green Sturgeon

5C.C.9.1 Juvenile

The critical temperature threshold for juvenile green sturgeon is 18.9°C. This threshold was exceeded on 103 and 104 days under EBC1 and EBC2, respectively, from June through October. Under EBC2_ELT and EBC2_LLT, the number of exceedance days was 113 and 127, respectively. The PP scenarios showed slightly lower exceedance frequencies: 110 and 126 days for PP_ELT and PP_LLT (Table 5C.C-171).

In the East Delta, water temperatures rarely reached levels above 18.9°C during June to May. The exceedance frequencies were 109 days for EBC1 and EBC2, 117 and 130 days under EBC2_ELT and EBC2_LLT, respectively, and 127 and 129 days under PP_ELT and PP_LLT scenarios, respectively (Table 5C.C-172).

The number of days when water temperatures exceeded 18.9°C for juvenile green sturgeon from January through May in the North Delta was similar under EBC and PP scenarios. Temperature thresholds were exceeded on 108 days under EBC1 and EBC2, and on 116 and 129 days under EBC2_ELT and EBC2_LLT, respectively. These numbers remained virtually unchanged under the PP_ELT and PP_LLT scenarios: 116 and 130 days (Table 5C.C-173).

For the San Joaquin River, the frequency at which water temperatures exceeded 18.9°C during June to October was 111 and 110 days for EBC1 and EBC2, respectively. Water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT on 120 and 125 days. The number of exceedance days was similar for PP_ELT and PP_LLT scenarios: 119 and 126 days, respectively (Table 5C.C-174).

For the South Delta, the frequency at which water temperatures exceeded 18.9°C during June through October was 108 days for EBC1 and EBC2. Water temperatures exceeded this threshold under EBC2_ELT and EBC2_LLT on 108 and 128 days, respectively, and on 118 and 127 days under PP_ELT and PP_LLT scenarios, respectively (Table 5C.C-175).

Water temperatures during June through October in Suisun Bay area exceeded the 19.8° threshold for juvenile green sturgeon on 107 days under EBC1 and EBC2. There were no differences in the frequency of exceedance days between EBC and PP scenarios: 116 days under EBC2_ELT and PP_ELT, and 127 days under EBC2_LLT and PP_LLT (Table 5C.C-176).

Water temperatures during June through October in Suisun Marsh exceeded the water temperature threshold for juvenile green sturgeon on 103 days under EBC1 and EBC2. The frequency of exceedance days did not differ greatly between EBC and PP scenarios. Under EBC2_ELT and PP_ELT, water temperatures exceeded the threshold on 113 and 112 days, and under EBC2_LLT and PP_LLT on 126 days (Table 5C.C-177).

In the West Delta, water temperatures reached levels above 18.9°C during June to May on 106 days for EBC1 and EBC2, respectively, 117 days under EBC2_ELT and EBC2_LLT, and 130 and 127 days under PP_ELT and PP_LLT scenarios, respectively (Table 5C.C-178).

Table 5C.C-171. Number of Days Exceeding 18.9°C in the Cache Slough Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	106	107	111	120	108	119
1977	91	91	107	131	106	131
1978	92	93	113	129	107	129
1979	121	121	138	144	134	143
1980	96	93	104	114	99	111
1981	124	125	129	134	127	133
1982	96	96	94	109	91	107
1983	114	114	121	122	118	122
1984	113	113	108	135	103	135
1985	92	91	101	122	101	119
1986	95	95	113	117	111	115
1987	99	99	116	131	113	129
1988	111	111	115	126	112	124
1989	99	99	108	139	103	136
1990	100	100	109	123	108	126
1991	106	106	124	131	119	129
Avg	103	103	113	127	110	126

Table 5C.C-172. Number of Days Exceeding 18.9°C in the East Delta Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	106	104	117	124	116	120
1977	94	93	110	135	112	133
1978	108	109	115	133	116	129
1979	125	123	133	140	137	144
1980	104	104	107	122	108	120
1981	122	122	127	132	131	133
1982	100	101	109	124	100	117
1983	115	115	119	128	122	122
1984	114	116	115	133	111	136
1985	105	105	115	128	108	128
1986	98	100	119	124	123	119
1987	116	115	124	133	120	131
1988	111	111	118	128	118	129
1989	105	104	112	136	113	139
1990	108	109	116	130	115	128
1991	115	116	122	133	121	132
Avg	109	109	117	130	117	129

Table 5C.C-173. Number of Days Exceeding 18.9°C in the North Delta Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	99	99	117	122	117	123
1977	96	96	113	134	115	136
1978	109	107	115	133	116	132
1979	125	125	128	136	128	136
1980	103	106	104	119	103	122
1981	118	119	122	130	123	130
1982	98	97	109	121	108	125
1983	110	109	119	126	119	127
1984	111	110	116	128	111	127
1985	104	104	117	127	118	128
1986	97	97	114	123	113	126
1987	111	112	119	133	119	133
1988	113	113	119	127	119	127
1989	106	107	114	132	111	132
1990	104	103	113	132	113	135
1991	119	117	122	133	121	134
Avg	108	108	116	129	116	130

Table 5C.C-174. Number of Days Exceeding 18.9°C in the San Joaquin River Portion of the South Delta Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	109	109	112	119	113	120
1977	91	91	109	130	109	135
1978	119	119	124	125	121	127
1979	127	127	135	142	136	143
1980	111	111	113	116	112	116
1981	124	124	131	133	131	133
1982	108	107	123	109	121	109
1983	118	118	128	121	128	120
1984	118	117	123	132	122	133
1985	104	104	111	122	107	125
1986	102	102	126	114	125	115
1987	116	115	121	130	120	125
1988	113	112	121	124	119	125
1989	105	103	113	135	108	136
1990	100	99	110	120	110	121
1991	107	106	122	126	121	129
Avg	111	110	120	125	119	126

Table 5C.C-175. Number of Days Exceeding 18.9°C in the South Delta Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	110	110	118	121	117	121
1977	94	94	113	138	112	131
1978	99	97	114	129	113	128
1979	125	125	140	145	139	145
1980	104	103	107	120	105	118
1981	125	125	133	134	133	133
1982	104	104	105	108	104	107
1983	117	117	121	120	122	120
1984	120	118	116	136	115	135
1985	92	92	108	126	106	125
1986	100	100	125	117	124	117
1987	104	103	118	128	118	128
1988	116	116	121	129	121	126
1989	104	104	113	143	112	140
1990	104	104	110	124	110	123
1991	109	109	133	133	133	132
Avg	108	108	118	128	118	127

Table 5C.C-176. Number of Days Exceeding 18.9°C in the Suisun Bay Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	108	111	114	124	114	124
1977	97	96	109	138	110	138
1978	105	103	119	128	119	128
1979	126	126	134	141	134	141
1980	99	98	108	118	108	117
1981	123	123	130	133	130	133
1982	98	99	100	111	100	110
1983	116	115	122	122	122	122
1984	118	118	115	132	115	131
1985	98	98	108	125	107	124
1986	98	98	119	116	119	117
1987	107	107	122	130	121	132
1988	114	113	115	130	116	130
1989	101	101	108	132	108	132
1990	103	105	111	125	111	124
1991	108	108	118	134	118	133
Avg	107	107	116	127	116	127

Table 5C.C-177. Number of Days Exceeding 18.9°C in the Suisun Marsh Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	108	108	115	120	108	120
1977	91	91	110	131	109	132
1978	93	92	110	126	109	129
1979	123	123	138	145	136	144
1980	89	88	99	114	103	113
1981	124	124	129	134	129	133
1982	96	97	92	108	93	107
1983	108	109	121	122	121	122
1984	116	116	105	136	106	135
1985	90	90	102	122	101	120
1986	96	96	113	116	117	114
1987	96	97	115	126	116	128
1988	112	109	113	128	113	128
1989	102	101	106	137	108	134
1990	99	100	108	121	108	122
1991	104	105	124	132	121	128
Avg	103	103	113	126	112	126

Table 5C.C-178. Number of Days Exceeding 18.9°C in the West Delta Subregion during the Green Sturgeon Juvenile Period (June–October)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	109	109	115	124	117	122
1977	92	92	112	143	112	143
1978	94	98	118	126	117	127
1979	130	131	141	147	141	145
1980	91	95	102	120	100	119
1981	127	127	135	137	135	136
1982	99	99	101	110	99	109
1983	117	117	120	122	120	122
1984	122	122	118	136	111	138
1985	94	93	108	128	107	129
1986	95	96	119	122	121	121
1987	103	99	115	128	116	126
1988	117	117	116	129	116	129
1989	104	104	113	145	113	144
1990	103	103	110	122	109	122
1991	105	105	132	134	131	133
Avg	106	107	117	130	117	129

5C.C.9.2 Adult

There were no exceedances in November–May of the two thresholds (>24°C and >27°C) examined for adult green sturgeon under any of the modeled scenarios or in any subregion.

5C.C.10 Pacific Lamprey

5C.C.10.1 Macropthalmia

There were no exceedances in December–March of the >25°C threshold examined for Pacific lamprey macropthalmia under any of the modeled scenarios or in any subregion.

5C.C.10.2 Adult

For a temperature threshold of 22°C, model scenarios were examined for adult Pacific lamprey for the period from January through August.

In Cache Slough, the frequency of exceedances averaged 13 days for EBC1 and EBC2, 25 and 23 days for EBC2_ELT and PP_ELT, respectively, and 47 and 44 days for EBC2_LLT and PP_LLT, respectively (Table 5C.C-179).

In the East Delta, average exceedances of the 22˚C threshold were 12 days under EBC1 and EBC2, 21 and 60 days under EBC2_ELT and EBC2_LLT, respectively, and 25 and 53 days under PP_ELT and PP_LLT, respectively (Table 5C.C-180).

Similarly, exceedances in the North Delta were 10 and 11 days, respectively for EBC1 and EBC2, 18 and 64 days for EBC2_ELT and EBC2_LLT, respectively, and 18 and 63 days for PP_ELT and PP_LLT, respectively (Table 5C.C-181).

In the San Joaquin River, temperatures exceeded the threshold of 22°C for Pacific lamprey adults on 22 and 21 days, respectively, under EBC1 and EBC2 scenarios. Exceedance frequencies under EBC2_ELT and EBC2_LLT (31 days each) were similar to those under PP_ELT and PP_LLT (32 days) (Table 5C.C-182).

Temperature exceedance in the South Delta for Pacific lamprey adults occurred on 19 days on average under EBC1 and EBC2. Under the near term, EBC2_ELT was identical to PP_ELT (32 days), but long-term averages were higher under EBC2_LLT (47 days) than under PP_LLT (43 days) (Table 5C.C-183).

Water temperatures exceeded the 22°C threshold for adult Pacific lamprey on 4 and 5 days under EBC1 and EBC2. On average the threshold was exceeded under EBC2_ELT and EBC2_LLT on 13 and 38 days, respectively. These numbers remained the same under PP_ELT and PP_LLT (Table 5C.C-184).

In Suisun Marsh, water temperatures were warmer than 22° on 12 and 13 days on average under EBC1 and EBC2. The exceedance frequency under EBC2_ELT (25 days) and EBC2_LLT (41 days) was similar to frequencies under PP_ELT (24 days) and PP_LLT (41 days) (Table 5C.C-185).

Water temperatures in the West Delta reached temperatures exceeding the threshold for adult Pacific lamprey on 10 days under EBC1 and EBC2. The frequencies under EBC2_ELT and EBC2_LLT

(22 and 24 days, respectively) were similar to frequencies under PP_ELT (22 days) and PP_LLT (41 days) (Table 5C.C-186).

Under a 25°C threshold, only Cache Slough, the North, East, and South Delta subregions had days when water temperatures exceeded this threshold. In Cache Slough, the frequency of exceedance was 1 day each under EBC2_LLT and PP_LLT. No exceedances were noted under any other scenario (Table 5C.C-187).

Temperature exceedance in the East Delta occurred on 2 days and 1 day under EBC2_LLT and PP_LLT, respectively. All other scenarios did not exceed this threshold (Table 5C.C-188).

In the North Delta, water temperatures were warmer than 25°C on 5 and 4 days under EBC2_LLT and PP_LLT, respectively. Exceedances were zero for all other scenarios (Table 5C.C-189).

In the San Joaquin portion of the South Delta, there were no days in any model scenario when temperatures exceeded 25°C (Table 5C.C-190)

In the South Delta, water temperatures warmer than 25°C occurred on average on 1 day under EBC2_LLT and PP_LLT, and all other scenario exceedances averaged zero (Table 5C.C-191).

Although the average exceedance for Suisun Marsh was zero days, there were 3 days on which water temperatures exceeding 25˚C in EBC2_LLT in both 1984 and 1988. Also, under PP_LLT, there were 1 and 2 days exceeding 25˚C in 1988 and 1990, respectively. On average, however, these frequencies are zero (Table 5C.C-192).

Table 5C.C-179. Number of Days Exceeding 22°C in the Cache Slough Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	7	7	28	40	25	39
1977	7	7	28	44	25	43
1978	18	18	27	48	26	45
1979	12	12	29	42	27	43
1980	12	12	12	34	11	25
1981	14	14	29	63	26	56
1982	0	0	14	41	14	37
1983	15	15	51	40	51	35
1984	23	23	33	71	31	71
1985	15	15	4	53	3	56
1986	1	0	11	58	10	50
1987	4	4	30	30	28	27
1988	36	36	36	63	29	62
1989	13	13	25	44	24	42
1990	27	27	30	45	28	45
1991	2	2	9	28	8	26
Avg	13	13	25	47	23	44

Table 5C.C-180. Number of Days Exceeding 22°C in the East Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	16	16	50	58	36	44
1977	13	14	24	61	29	52
1978	13	13	20	56	26	51
1979	9	9	17	52	29	44
1980	11	12	15	42	15	35
1981	10	10	16	65	22	65
1982	6	6	7	53	14	49
1983	12	13	35	66	49	63
1984	15	15	28	76	35	74
1985	11	11	5	66	7	63
1986	1	1	9	70	8	60
1987	6	5	8	47	27	34
1988	31	34	29	69	36	66
1989	11	11	26	66	28	55
1990	23	23	26	57	30	46
1991	4	4	15	52	11	40
Avg	12	12	21	60	25	53

Table 5C.C-181. Number of Days Exceeding 22°C in the North Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	18	19	64	67	56	66
1977	13	13	13	66	13	66
1978	10	10	13	65	14	64
1979	7	7	11	64	13	56
1980	7	8	17	54	17	44
1981	7	8	14	62	11	59
1982	9	8	5	59	5	59
1983	10	11	21	61	24	58
1984	11	11	14	77	13	80
1985	8	8	11	71	13	73
1986	3	6	11	68	8	68
1987	6	4	7	59	10	53
1988	21	23	23	66	26	67
1989	12	12	28	70	24	67
1990	17	16	22	66	22	68
1991	6	5	17	54	16	52
Avg	10	11	18	64	18	63

Table 5C.C-182. Number of Days Exceeding 22°C in the San Joaquin River Portion of the South Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	13	12	21	33	17	32
1977	6	7	25	34	29	44
1978	35	35	40	30	43	34
1979	19	17	37	30	37	30
1980	22	22	27	14	27	17
1981	24	23	31	46	32	46
1982	28	28	38	19	38	17
1983	48	44	68	14	71	14
1984	36	33	44	48	47	49
1985	23	23	13	38	12	46
1986	19	18	17	21	16	19
1987	3	3	30	16	32	13
1988	36	35	31	55	36	59
1989	14	14	25	37	24	36
1990	29	28	34	44	38	44
1991	1	1	7	18	7	19
Avg	22	21	31	31	32	32

Table 5C.C-183. Number of Days Exceeding 22°C in the South Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	15	15	30	42	26	41
1977	10	10	35	50	34	47
1978	25	25	36	41	38	41
1979	14	14	34	45	35	39
1980	13	13	16	29	17	25
1981	29	29	35	65	34	58
1982	5	5	20	37	21	33
1983	32	30	70	33	73	28
1984	33	33	46	75	46	72
1985	29	29	13	59	11	55
1986	5	4	9	58	8	52
1987	6	6	41	30	41	26
1988	41	43	42	65	43	63
1989	14	14	34	47	31	42
1990	36	34	39	46	39	46
1991	1	1	7	29	8	26
Avg	19	19	32	47	32	43

Table 5C.C-184. Number of Days Exceeding 22°C in the Suisun Bay Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	17	36	18	36
1977	1	2	7	44	8	44
1978	9	11	15	40	15	41
1979	0	0	16	37	17	37
1980	8	8	9	25	9	24
1981	8	8	15	44	16	44
1982	0	0	1	34	1	31
1983	8	8	45	32	45	32
1984	9	10	23	60	23	60
1985	3	3	0	43	0	44
1986	0	0	0	34	1	34
1987	0	0	15	18	16	18
1988	13	16	17	59	17	60
1989	1	1	5	41	5	40
1990	6	7	20	43	20	44
1991	0	0	0	23	0	22
Avg	4	5	13	38	13	38

Table 5C.C-185. Number of Days Exceeding 22°C in the Suisun Marsh Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	3	5	24	39	26	39
1977	5	5	29	45	27	46
1978	19	19	30	36	27	37
1979	10	11	30	40	30	42
1980	12	11	11	24	12	24
1981	21	22	29	52	28	52
1982	0	0	14	31	15	31
1983	14	15	59	33	56	31
1984	24	25	35	68	35	67
1985	18	19	1	50	3	49
1986	0	0	11	49	10	44
1987	0	2	30	23	31	24
1988	31	35	31	61	28	61
1989	13	14	23	39	23	38
1990	26	26	33	44	29	45
1991	0	0	6	23	8	24
Avg	12	13	25	41	24	41

Table 5C.C-186. Number of Days Exceeding 22°C in the West Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	30	39	25	39
1977	4	4	18	47	18	44
1978	18	18	30	44	30	40
1979	4	6	30	39	30	37
1980	11	11	11	33	11	28
1981	14	15	24	61	27	53
1982	0	0	8	45	8	34
1983	14	14	57	45	61	41
1984	16	16	30	69	31	67
1985	13	13	0	52	0	51
1986	0	0	7	58	5	52
1987	0	0	24	20	25	16
1988	26	26	28	62	28	61
1989	6	7	17	50	15	40
1990	28	28	33	45	35	45
1991	0	0	0	24	0	15
Avg	10	10	22	46	22	41

Table 5C.C-187. Number of Days Exceeding 25°C in the Cache Slough Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	3	0	1
1979	0	0	0	0	0	0
1980	0	0	0	1	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	3	0	3
1985	0	0	0	1	0	1
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	7	0	6
1989	0	0	0	0	0	0
1990	0	0	0	2	0	3
1991	0	0	0	0	0	0
Avg	0	0	0	1	0	1

Table 5C.C-188. Number of Days Exceeding 25°C in the East Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	7	0	4
1979	0	0	0	1	0	0
1980	0	0	0	3	0	1
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	4	0	2
1985	0	0	0	3	0	1
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	14	0	9
1989	0	0	0	0	0	0
1990	0	0	0	7	0	3
1991	0	0	0	0	0	0
Avg	0	0	0	2	0	1

Table 5C.C-189. Number of Days Exceeding 25°C in the North Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	2	6	2	5
1977	0	0	0	2	0	2
1978	0	0	0	11	0	11
1979	0	0	0	5	0	1
1980	0	0	0	7	0	4
1981	0	0	0	5	0	5
1982	0	0	0	2	0	1
1983	0	0	0	1	0	1
1984	0	0	0	7	0	4
1985	0	0	0	5	0	5
1986	0	0	0	0	0	0
1987	0	0	0	2	0	1
1988	0	0	0	14	0	14
1989	0	0	0	5	0	3
1990	0	0	0	12	0	11
1991	0	0	0	3	0	2
Avg	0	0	0	5	0	4

Table 5C.C-190. Number of Days Exceeding 25°C in the San Joaquin River Portion of the South Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	2	0	6	0
1984	0	0	0	0	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	0	0	0	0	0	0

Table 5C.C-191. Number of Days Exceeding 25°C in the South Delta Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	1	0	1
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	2	0	6	0
1984	0	0	0	7	0	6
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	8	0	6
1989	0	0	0	0	0	0
1990	0	0	0	3	0	2
1991	0	0	0	0	0	0
Avg	0	0	0	1	0	1

Table 5C.C-192. Number of Days Exceeding 25°C in the Suisun Marsh Subregion during the Pacific Lamprey Adult Period (January–August)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	0	0	0	0
1977	0	0	0	0	0	0
1978	0	0	0	0	0	0
1979	0	0	0	0	0	0
1980	0	0	0	0	0	0
1981	0	0	0	0	0	0
1982	0	0	0	0	0	0
1983	0	0	0	0	0	0
1984	0	0	0	3	0	0
1985	0	0	0	0	0	0
1986	0	0	0	0	0	0
1987	0	0	0	0	0	0
1988	0	0	0	3	0	1
1989	0	0	0	0	0	0
1990	0	0	0	0	0	2
1991	0	0	0	0	0	0
Avg	0	0	0	0	0	0

5C.C.11 River Lamprey

5C.C.11.1 Macropthalmia

There were no exceedances in December–March of the >25°C threshold examined for river lamprey macropthalmia under any of the modeled scenarios or in any subregion.

5C.C.11.2 Adult

For adult river lamprey from February through June, the number of days when water temperatures exceeded a 22°C threshold in Cache Slough was 2 for EBC1 and EBC2, 4 and 6 days for EBC2_ELT and EBC2_LLT, respectively, and 4 and 7 days for PP_ELT and PP_LLT, respectively (Table 5C.C-193).

In the East Delta, temperature exceedances for adult river lamprey were 2 days for EBC1 and EBC2, 3 and 9 days for EBC2_ELT and EBC2_LLT respectively, and 3 and 8 days for PP_ELT and PP_LLT, respectively (Table 5C.C-194).

Water temperatures in the North Delta exceeded the threshold for adult river lamprey on 1 and 2 days under EBC1 and EBC2, respectively. Under near-term scenarios, frequencies were 2 days for EBC2_ELT and PP_ELT, and in long-term scenarios, the threshold was exceeded on 10 days under EBC2_LLT and PP_LLT (Table 5C.C-195).

For the San Joaquin River, the water temperature threshold was exceeded on 2 days on average under EBC1 and EBC2, respectively. Warmer temperatures occurred on 4 and 3 days, respectively under the near-term (EBC2_ELT and PP_ELT) and long-term scenarios (EBC2_LLT and PP_LLT) (Table 5C.C-196).

Water temperature thresholds for adult river lamprey were exceeded on average on 3 days during February through June under the EBC1 and EBC2 scenarios. Frequencies of exceedance days were 4 and 7 days under EBC2_ELT and PP_ELT, respectively, and 5 and 6 days under EBC2_LLT and PP_LLT, respectively (Table 5C.C-197).

In Suisun Bay, the number of days with water temperatures warmer than 22°C was 1 under EBC1 and EBC2, 2 under EBC2_ELT and PP_ELT, and 4 under EBC2_LLT and PP_LLT (Table 5C.C-198).

Suisun Marsh water temperatures exceeded the adult river lamprey temperature threshold of 22°C on 2 days under EBC1 and EBC2, on 4 days under EBC2_ELT and PP_ELT, and on 6 days under EBC2_LLT and PP_LLT (Table 5C.C-199).

Water temperatures in the West Delta exceeded the threshold on 1 day under EBC1 and EBC2. These exceedances were 2 days (for EC2_ELT and PP_ELT) and 4 days (for EBC2_LLT and PP_LLT) (Table 5C.C-200).

There were no exceedances in February–June of the >25°C threshold examined for river lamprey adults under any of the modeled scenarios or in any subregion.

Table 5C.C-193. Number of Days Exceeding 22°C in the Cache Slough Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	4	4	7	8	7	7
1977	2	2	4	8	3	8
1978	0	0	0	2	1	2
1979	0	0	2	8	2	9
1980	0	0	0	0	0	0
1981	11	11	16	15	16	15
1982	0	0	0	0	0	0
1983	0	0	7	3	8	4
1984	2	2	9	14	9	14
1985	3	3	0	11	0	11
1986	0	0	3	6	2	6
1987	1	1	1	7	2	8
1988	7	7	3	12	2	12
1989	2	2	5	9	4	9
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	2	2	4	6	4	7

Table 5C.C-194. Number of Days Exceeding 22°C in the East Delta Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	5	5	7	11	7	10
1977	6	6	3	11	4	8
1978	0	0	0	4	0	3
1979	0	0	0	9	1	8
1980	0	0	0	2	0	0
1981	6	6	12	11	16	14
1982	0	0	0	0	0	0
1983	0	0	3	17	5	15
1984	0	0	9	17	11	15
1985	1	1	0	12	0	12
1986	0	0	0	10	0	7
1987	1	1	1	10	3	7
1988	6	6	3	12	3	12
1989	1	1	3	11	5	9
1990	0	0	0	4	0	1
1991	0	0	0	0	0	0
Avg	2	2	3	9	3	8

Table 5C.C-195. Number of Days Exceeding 22°C in the North Delta Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	6	6	10	12	10	12
1977	5	5	3	11	3	11
1978	0	0	1	7	1	8
1979	0	0	1	11	1	11
1980	0	0	0	3	0	3
1981	2	3	8	5	7	5
1982	1	1	0	2	0	2
1983	0	0	1	16	1	15
1984	0	0	4	18	5	21
1985	3	3	0	15	0	15
1986	1	1	0	10	0	11
1987	0	0	3	11	3	11
1988	4	4	3	9	3	9
1989	1	1	3	11	4	11
1990	0	0	0	12	0	11
1991	0	0	0	0	0	0
Avg	1	2	2	10	2	10

Table 5C.C-196. Number of Days Exceeding 22°C in the San Joaquin River Portion of the South Delta Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	4	4	6	6	6	6
1977	0	0	3	7	3	7
1978	3	3	6	0	6	0
1979	2	2	5	0	5	0
1980	0	0	2	0	2	0
1981	12	12	16	11	17	13
1982	0	0	0	0	0	0
1983	2	0	10	0	12	0
1984	1	1	8	4	11	3
1985	2	2	0	6	0	7
1986	1	1	0	0	0	1
1987	0	0	1	2	2	2
1988	5	5	1	8	2	8
1989	2	2	3	8	3	8
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	2	2	4	3	4	3

Table 5C.C-197. Number of Days Exceeding 22°C in the South Delta Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	6	6	7	9	7	8
1977	0	0	3	8	3	7
1978	1	1	4	2	4	2
1979	3	3	2	9	3	6
1980	0	0	0	0	0	0
1981	12	12	17	16	16	16
1982	0	0	0	0	0	0
1983	1	1	11	0	14	0
1984	5	5	12	13	11	12
1985	5	5	0	12	0	11
1986	0	0	0	6	0	6
1987	3	3	5	9	5	8
1988	8	8	5	11	5	9
1989	2	2	4	9	4	9
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	3	3	4	7	5	6

Table 5C.C-198. Number of Days Exceeding 22°C in the Suisun Bay Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	6	7	6	7
1977	0	0	0	6	0	6
1978	0	0	0	0	0	0
1979	0	0	0	6	0	7
1980	0	0	0	0	0	0
1981	8	8	12	9	13	9
1982	0	0	0	0	0	0
1983	0	0	5	1	5	0
1984	0	0	3	7	3	7
1985	0	0	0	5	0	6
1986	0	0	0	0	0	1
1987	0	0	0	1	0	2
1988	0	0	0	9	0	9
1989	0	0	0	7	0	7
1990	0	0	0	1	0	1
1991	0	0	0	0	0	0
Avg	1	1	2	4	2	4

Table 5C.C-199. Number of Days Exceeding 22°C in the Suisun Marsh Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	3	5	7	7	7	10
1977	0	0	4	8	5	10
1978	0	0	0	0	1	2
1979	0	0	2	9	3	9
1980	0	0	0	0	0	0
1981	11	11	16	15	16	15
1982	0	0	0	0	0	0
1983	0	0	9	1	10	2
1984	0	1	8	13	9	12
1985	4	5	0	11	0	10
1986	0	0	4	7	3	6
1987	0	1	1	7	2	7
1988	5	6	3	12	3	12
1989	1	2	3	9	3	8
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	2	2	4	6	4	6

Table 5C.C-200. Number of Days Exceeding 22°C in the West Delta Subregion during the River Lamprey Adult Period (February–June)

Year	EBC1	EBC2	EBC2_ELT	EBC2_LLT	PP_ELT	PP_LLT
1976	0	0	5	6	5	6
1977	0	0	0	5	0	5
1978	0	0	0	0	0	0
1979	0	0	0	5	0	5
1980	0	0	0	0	0	0
1981	9	9	14	11	14	11
1982	0	0	0	0	0	0
1983	0	0	5	3	7	0
1984	0	0	4	7	4	7
1985	0	0	0	8	0	8
1986	0	0	0	5	0	5
1987	0	0	0	0	0	2
1988	0	0	0	8	0	8
1989	0	0	0	6	0	6
1990	0	0	0	0	0	0
1991	0	0	0	0	0	0
Avg	1	1	2	4	2	4

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