Chapter 12
Fish and Aquatic Resources

This chapter describes the environmental setting and study area for fish and aquatic resources; analyzes impacts that could result from construction, operation, and maintenance of the project; and provides mitigation measures to reduce the effects of potentially significant impacts. This chapter also analyzes the impacts that could result from implementation of compensatory mitigation required for the project and describes any additional mitigation necessary to reduce those impacts, and analyzes the impacts that could result from other mitigation measures associated with other resource chapters in this Draft Environmental Impact Report (Draft EIR).

12.0 Summary Comparison of Alternatives

Table 12-0 provides a summary comparison of significant impacts requiring mitigation on fish and aquatic resources by alternative. The table presents the CEQA findings after all mitigation is applied. This table provides information on the magnitude of the most pertinent and quantifiable impacts on fish and aquatic resources that are expected to result from implementation of the alternatives. Potentially significant impacts requiring mitigation include Impact AQUA-1: *Effects of Construction of Water Conveyance Facilities on Fish and Aquatic Species*; Impact AQUA-2: *Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon*; Impact AQUA-3: *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon*; Impact AQUA-5: *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Steelhead*; Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*; and Impact AQUA-7: *Effects of Operations and Maintenance of Water Conveyance Facilities on Longfin Smelt*. Impacts AQUA-1, AQUA-2, AQUA-3, AQUA-5, and AQUA-6, and AQUA-7 are less than significant with mitigation.

Less-than-significant impacts include Impact AQUA-4: *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon*; Impact AQUA-8: *Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon*; Impact AQUA-9: *Effects of Operations and Maintenance of Water Conveyance Facilities on White Sturgeon*; Impact AQUA-10: *Effects of Operations and Maintenance of Water Conveyance Facilities on Pacific Lamprey and River Lamprey*; Impact AQUA-11: *Effects of Operations and Maintenance of Water Conveyance Facilities on Native Minnows (Sacramento Hitch, Sacramento Splittail, Hardhead, and Central California Roach)*; Impact AQUA-12: *Effects of Operations and Maintenance of Water Conveyance Facilities on Starry Flounder*; Impact AQUA-13: *Effects of Operations and Maintenance of Water Conveyance Facilities on Northern Anchovy*; Impact AQUA-14: *Effects of Operations and Maintenance of Water Conveyance Facilities on Striped Bass*; Impact AQUA-15: *Effects of Operations and Maintenance of Water Conveyance Facilities on American Shad*; Impact AQUA-16: *Effects of Operations and Maintenance of Water Conveyance Facilities on Threadfin Shad*; Impact AQUA-17: *Effects of Operations and Maintenance of Water Conveyance Facilities on Black Bass*; Impact AQUA-18: *Effects of Operations and Maintenance of Water Conveyance Facilities on California Bay Shrimp*; and Impact AQUA-19: *Effects of Operations and Maintenance of Water Conveyance Facilities on Southern Resident Killer Whale*.

Table ES-2 in the Executive Summary provides a summary of all impacts disclosed in this chapter.

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Table 12-0. Comparison of Impacts on Fish and Aquatic Resources by Alternative [a]

	Alternative								
Chapter 12 – Fish and Aquatic Resources	1	2a	2b	2c	3	4a	4b	4c	5
Impact AQUA-1: Effects of Construction of Water Conveyance Facilities on Fish and Aquatic Species	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Tidal perennial habitat (acres)—Temporary	8.585	8.908	7.888	8.530	2.410	2.732	1.712	2.354	1.548
Tidal perennial habitat (acres)—Permanent	15.719	17.080	13.068	15.034	12.614	13.974	9.963	11.928	5.574
Channel margin habitat (feet)—Temporary	494	571	63	457	494	571	63	457	494
Channel margin habitat (feet)—Permanent	3,124	4,309	1,651	2,762	3,124	4,309	1,651	2,762	3,124
Impact pile driving for intake cofferdams and training walls (acres/day)	20–21 days (2 sites)	14-21 days (3 sites)	21 days (1 site)	14–21 days (2 sites)	20–21 days (2 sites)	14-22 days (3 sites)	21 days (1 site)	14–21 days (2 sites)	20–21 days (2 sites)
206-dB threshold	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
187-dB threshold	6.72–12.30	6.72–15.20	6.72	6.72–12.30	6.72–12.30	6.72–15.20	6.72	6.72–12.30	6.72–12.30
183-dB threshold	18.47–25.06	18.47–33.44	18.47	18.47–25.06	18.47–25.06	18.47–33.44	18.47	18.47–25.06	18.47–25.06
150-dB threshold	67.69–134.10	67.69–231.35	134.10	67.69–134.10	67.69–134.10	67.69–231.35	134.10	67.69–134.10	67.69–134.10
Impact pile driving for log booms (acres/day)	4 days (2 sites)	2–4 days (3 sites)	4 days (1 site)	2–4 days (2 sites)	4 days (2 sites)	2–4 days (3 sites)	4 days (1 site)	2–4 days (2 sites)	4 days (2 sites)
206-dB threshold	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
187-dB threshold	27.2–66.4	27.2–52.6	27.2	27.2–66.4	27.2–66.4	27.2–52.6	27.2	27.2–66.4	27.2–66.4
183-dB threshold	51.7–66.4	51.7–97.8	51.7	51.7–66.4	51.7–66.4	51.7–97.8	51.7	51.7–66.4	51.7–66.4
150-dB threshold	69.3–117.9	69.3–229.0	117.9	69.3–117.9	69.3–117.9	69.3–229.0	117.9	69.3–117.9	69.3–117.9
Impact pile driving for bridge crossings (acres/day)	5–45 days (3 sites)	5–45 days (3 sites)	5–45 days (3 sites)	5–45 days (3 sites)	5–9 days (2 sites)	5–9 days (2 sites)	5–9 days (2 sites)	5–9 days (2 sites)	5–9 days (2 sites)
206-dB threshold	0.04–0.90	0.04–0.90	0.04–0.90	0.04–0.90	0.04–0.47	0.04–0.47	0.04–0.47	0.04–0.47	0.04–0.47
187-dB threshold	4.12–20.36	4.12–20.36	4.12–20.36	4.12–20.36	4.12–12.38	4.12–12.38	4.12–12.38	4.12–12.38	4.12–12.38
183-dB threshold	7.34–27.40	7.34–27.40	7.34–27.40	7.34–27.40	7.34–12.36	7.34–12.36	7.34–12.36	7.34–12.36	7.34–12.36
150-dB threshold	25.45–108.73	25.45–108.73	25.45–108.73	25.45–108.73	12.37–25.45	12.37–25.45	12.37–25.45	12.37–25.45	12.37–25.45
Impact pile driving for test piles (acres/day)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)	3 days (1 site)
206-dB threshold	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15	0.06–0.15
187-dB threshold	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46	0.18–0.46
183-dB threshold	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28	0.60–1.28
150-dB threshold	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64	58.41–58.64
Suspended sediment plume downstream of each intake (acres)	4.2	5.9	2.5	4.2	4.2	5.9	2.5	4.2	4.2
Number of barge trips	186	230	90	172	188	232	92	174	188
Days of dredging for riprap	47	57	19	42	47	57	19	42	47
Impact AQUA-2: Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Juvenile south Delta entrainment/ Salvage-density method [b]	SWP: -10% – -6% CVP: 0% – +5%	SWP: -9% – -1% CVP: -3% – +5%	SWP: -8% – 0% CVP: 0% – +3%	SWP: -11% – -2% CVP: +1% – +5%	SWP: -10% – -6% CVP: 0% – +5%	SWP: -9% – -1% CVP: -3% – +5%	SWP: -8% – 0% CVP: 0% – +3%	SWP: -11% – -2% CVP: +1% – +5%	SWP: -10% – -6% CVP: +1% – +5%
Juvenile south Delta entrainment/ Zeug and Cavallo (2014) [b]	-17% – -1%	-18% – 0%	-13% – +1%	-15% – 0%	-17% – -1%	-18% – 0%	-13% – +1%	-15% – 0%	-18% – -1%

	Alternative								
Chapter 12 – Fish and Aquatic Resources	1	2a	2b	2c	3	4a	4b	4c	5
Channel velocity downstream of Intake C (September–June)/DSM2	-14% – +1%	-13% – +2%	-12% – +1%	-13% – +1%	-14% – +1%	-13% – +2%	-12% – +1%	-13% – +1%	-14% – +1%
Reverse flow downstream of Georgiana Slough (number of hours/%, September–June)/DSM2	-6.4 – +22.9 (-3% – +23%)	-7.2 – +22.3 (-3% – +23%)	-3.8 – +18.5 (-2% – +19%)	-6.6 – +21.4 (-3% – +22%)	-6.4 – +22.9 (-3% – +23%	-7.2 – +22.3 (-3% – +23%)	-3.8 – +18.5 (-2% – +19%)	-6.6 – +21.4 (-3% – +22%)	-6.4 – +22.9 (-3% – +23%)
Juvenile through-Delta survival (September–June)/Perry et al. (2018)	-10% – +3%	-10% – +3%	-8% – +3%	-9% – +3%	-10% – +3%	-10% – +3%	-8% – +3%	-9% – +3%	-10% – +2%
Juvenile through-Delta survival/ Delta Passage Model	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%
Riparian and wetland bench inundation (rearing habitat, linear feet)/DSM2	-2,519	-2,847	-1,613	-2,198	-2,519	-2,847	-1,613	-2,198	-2,540
Water temperature (°C)/DSM2	0	0	0	0	0	0	0	0	0
Spawner abundance/Winter Run Chinook Salmon Life Cycle Model	+5.0%	+5.9%	+5.7%	+5.9%	+5.0%	+5.9%	+5.7%	+5.9%	+5.2%
Adult female escapement/IOS	-9%	-12%	-7%	-9%	-9%	-12%	-7%	-9%	-9%
Juvenile through-Delta survival/IOS	-5% – -1%	-5% – -1%	-3% – -1%	-4% – -1%	-5% – -1%	-5% – -1%	-3% – -1%	-4% – -1%	-5% – -1%
Egg survival/IOS	0% – +3%	0% – +4%	0% – +4%	0% – +4%	0% – +3%	0% – +4%	0% – +4%	0% – +4%	0% – +3%
Fry survival/IOS	0% – +2%	0% – +3%	0% – +3%	0% – +3%	0% – +2%	0% – +3%	0% – +3%	0% – +3%	0% – +2%
River survival/IOS	0%	0%	0%	0%	0%	0%	0%	0%	0%
Adult escapement/OBAN[c]	-13%	-3%	-6%	-7%	-13%	-3%	-6%	-7%	-12%
Impact AQUA-3: Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon [d]	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Juvenile south Delta entrainment/ Salvage-density method [b]	SWP: -12% – 0% CVP: 0% – +8%	SWP: -7% – 0% CVP: -3% – +7%	SWP: -3% – +3% CVP: +1% – +4%	SWP: -9% – -1% CVP: +1% – +6%	SWP: -12% – 0% CVP: 0% – +8%	SWP: -7% – 0% CVP: -3% – +7%	SWP: -3% – +3% CVP: +1% – +4%	SWP: -9% – -1% CVP: +1% – +6%	SWP: -12% – 0% CVP: 0% – +8%
Juvenile through-Delta survival/Delta Passage Model	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%
Juvenile through-Delta survival (San Joaquin River basin spring-run)/ Structured Decision Model	-1% – +8%	-3% – +8%	-3% – +8%	-1% – +8%	-1% – +8%	-3% – +8%	-3% – +8%	-1% – +8%	-1% – +8%
Impact AQUA-5: Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Steelhead [d]	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Juvenile south Delta entrainment/Salvage-density method [b]	SWP: -10% – -5% CVP: +2% – +6%	SWP: -9% – 0% CVP: -1% – +5%	SWP: -7% – +3% CVP: +1% – +3%	SWP: -9% – -3% CVP: +2% – +5%	SWP: -10% – -5% CVP: +2% – +6%	SWP: -9% – 0% CVP: -1% – +5%	SWP: -7% – +3% CVP: +1% – +3%	SWP: -9% – -3% CVP: +2% – +5%	SWP: -11% – -5% CVP: +1% – +6%
Juvenile Mokelumne River south Delta entrainment (March–June south Delta exports)/CalSim	-7% – +4%	-7% – +4%	-5% – +3%	-6% – +5%	-7% – +4%	-7% – +4%	-5% – +3%	-6% – +5%	-7% – +4%
Juvenile San Joaquin River basin through-Delta survival (February–May Vernalis flow)/CalSim	0%	0% – +1%	0%	0%	0%	0% – +1%	0%	0%	0%

	Alternative								
Chapter 12 – Fish and Aquatic Resources	1	2a	2b	2c	3	4a	4b	4c	5
Impact AQUA-6: Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Larval NDD entrainment median [range in parentheses] % of March–June Sacramento River flow diverted)/CalSim	0% – 7% (0% – 21%)	0% – 7% (0% –22%)	0% – 6% (0% – 16%)	0% – 7% (0% – 19%)	0% – 7% (0% – 21%)	0% – 7% (0% –22%)	0% – 6% (0% – 16%)	0% – 7% (0% – 19%)	0% – 7% (0% – 21%)
Adult south Delta entrainment (December–March OMR flow)/CalSim [b, e]	-3% – +34%	-3% – +39%	-7% – +19%	-4% – +29%	-3% – +34%	-3% – +39%	-7% – +19%	-4% – +29%	-3% – +35%
Larval/early juvenile south Delta entrainment (March–June OMR flow)/ CalSim [b, e]	-7% – +45%	-6% – +49%	-12% – +32%	-7% – +41%	-7% – +45%	-6% – +49%	-12% – +32%	-7% – +41%	-7% – +45%
Larval/early juvenile south Delta and NBA entrainment/DSM2-PTM [b]	-7% – +9%	-8% – +9%	-4% – +6%	-4% – +8%	-7% – +9%	-8% – +9%	-4% – +6%	-4% – +8%	-7% – +9%
NDD suspended sediment entrainment (total % of suspended sediment at Freeport, 1922–2015)/CalSim	5%	5%	4%	5%	5%	5%	4%	5%	5%
Eurytemora affinis food availability/ X2-abundance regression	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%	-3% – -1%	-2% – -1%	-3% – -1%	-3% – -1%
Pseudodiaptomus forbesi food availability (Delta outflow, June–October)/CalSim	-14% – +1%	-14% – +2%	-11% – +2%	-13% – +1%	-14% – +1%	-14% – +2%	-11% – +2%	-13% – +1%	-14% – +1%
Pseudodiaptomus forbesi food availability (% of years with positive July–October QWEST)/CalSim	-11% – +12%	-11% – +10%	-15% – +12%	-15% – +10%	-11% – +12%	-11% – +10%	-15% – +12%	-15% – +10%	-11% – +12%
Pseudodiaptomus forbesi food availability (July–October QWEST)/CalSim [f]	-67% – +212%	-86% – +195%	-44% – +283%	-76% – +227%	-67% – +212%	-86% – +195%	-44% – +283%	-76% – +227%	-72% – +211%
NDD phytoplankton carbon entrainment (range from 5th–95th percentile entrainment at minimum and maximum Delta stock sizes)/DSM2	0.0% – 7.4%	0.0% – 8.2%	0.0% – 4.4%	0.0% – 6.0%	0.0% – 7.4%	0.0% – 8.2%	0.0% – 4.4%	0.0% – 6.0%	0.0% – 7.4%
Juvenile/subadult habitat extent (percentage of years with X2 less than 85 km, June–December)/CalSim	-5% – 0%	-3% – 0%	-5% – 0%	-8% – 0%	-5% – 0%	-3% – 0%	-5% – 0%	-8% – 0%	-5% – 0%
Predator (silversides) abundance (south Delta exports, March–May)/CalSim	-4% – +1%	-4% – +1%	-2% – +1%	-3% – +1%	-4% – +1%	-4% – +1%	-2% – +1%	-3% – +1%	-4% – +1%
Predator (silversides) abundance (Delta inflow, June–September)/CalSim	-1% – +1%	-1% – 0%	-1% – 0%	-1% – +1%	-1% – +1%	-1% – 0%	-1% – 0%	-1% – +1%	-1% – +1%
Cyanobacteria harmful algal blooms/ DSM2	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)	LTS (See Impact WQ-14 in Chapter 9)
Selenium (increase in exceedance of threshold for physical deformities)/DSM2	0	0	0	0	0	0	0	0	0

	Alternative								
Chapter 12 – Fish and Aquatic Resources	1	2a	2b	2c	3	4a	4b	4c	5
Impact AQUA-7: Effects of Operations and Maintenance of Water Conveyance Facilities on Longfin Smelt [g]	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS	LTS
Larval south Delta and NBA entrainment (neutrally buoyant particles)/DSM2-PTM [b]	-2% – +11%	-3% – +11%	0% – +9%	0% – +10%	-2% – +11%	-3% – +11%	0% – +9%	0% – +10%	-2% – +11%
Larval south Delta and NBA entrainment (surface-oriented particles)/DSM2-PTM [b]	-1% – +13%	-3% – +13%	-3% – +11%	-1% – +12%	-1% – +13%	-3% – +13%	-3% – +11%	-1% – +12%	-1% – +13%
Larval entry into south Delta (neutrally buoyant particles)/DSM2-PTM [f]	-4% – +257%	-5% – +275%	0% – +199%	0% – +251%	-4% – +257%	-5% – +275%	0% – +199%	0% – +251%	-3% – +279%
Larval entry into south Delta (surface-oriented particles)/DSM2-PTM [f]	0% – +383%	-2% – +389%	-2% – +282%	0% – +390%	0% – +383%	-2% – +389%	-2% – +282%	0% – +390%	-1% – +393%
Larval passage past Chipps Island (neutrally buoyant particles)/DSM2-PTM	-2% – 0%	-2% – 0%	-3% – 0%	-2% – 0%	-2% – 0%	-2% – 0%	-3% – 0%	-2% – 0%	-4% – 0%
Larval passage past Chipps Island (surface-oriented particles)/DSM2-PTM	-3% – 0%	-3% – 0%	-4% – 0%	-3% – 0%	-3% – 0%	-3% – 0%	-4% – 0%	-3% – 0%	-4% – 0%
Juvenile south Delta entrainment/ OMR-salvage regression [b]	-8% – 0%	-9% – +1%	-5% – +1%	-7% – 0%	-8% – 0%	-9% – +1%	-5% – +1%	-7% – 0%	-8% – 0%
Delta outflow-abundance/Delta outflow-abundance index method	-10% – -3%	-10% – -3%	-7% – -2%	-9% – -3%	-10% – -3%	-10% – -3%	-7% – -2%	-9% – -3%	-10% – -4%

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[a] First line of each impact gives level of significance (LTS = less than significant) with necessary mitigation measures. Other lines give quantities of impact (acres, etc.) prior to mitigation. Operations impacts generally give % difference compared to existing conditions, unless indicated otherwise in the leftmost column where effect and method are noted in the form 'Effect/method'; cells generally give range of differences in mean by water year type for each alternative.

[b] Various regulatory requirements from existing conditions would also be implemented into all alternatives to minimize entrainment effects.

[c] See Table 12-43 in Impact AQUA-2: *Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon* for sensitivity analyses for additional through-Delta mortality of 5% and 10% representing near- or far-field mortality not captured by the OBAN model.

[d] See also results for channel velocity, juvenile through-Delta survival based on Perry et al. (2018), riparian and wetland bench inundation, and water temperature under Impact AQUA-2: *Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon*.

[e] Note that large percentage changes reflect differences in low absolute values of OMR flow, particularly when bracketing zero, and do not necessarily indicate large differences in entrainment potential (see also footnote c above); see, for example, Tables 12-92 and 12-93 in Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*.

[f] Note that large percentage changes reflect differences in low absolute values, particularly when bracketing zero, and do not necessarily indicate large differences; see, for example, Tables 12-139 and 12-140 in Impact AQUA-7: *Effects of Operations and Maintenance of Water Conveyance Facilities on Longfin Smelt*.

[g] See also results for *Eurytemora affinis* food availability under Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*.

12.1 Environmental Setting

This section describes the environmental setting for fish and aquatic resources in the study area (additional background information is provided in Appendix 12A, *Environmental Setting Background Information*). The main area of potential impacts is the Delta and Suisun Bay/Marsh. Other areas considered for potential impacts include the Sacramento River and its tributaries upstream of the Delta, San Joaquin and Stanislaus Rivers, Trinity River (plus the lower Klamath River), and San Pablo and San Francisco Bays. Background information about species that are fished recreationally is provided and supports analyses of those effects on those species in Chapter 16, *Recreation*. For each waterway or waterbody, a description of the physical and biological attributes is provided, including a description of the fish species of management concern, habitat conditions, and existing environmental stressors.

12.1.1 Study Area

The study area is based on the location of State Water Project (SWP) facilities, for which construction of new facilities or new/changed operations as a result of the alternatives could affect fish and aquatic resources[1]. The primary focus area is the Delta and Suisun Bay/Marsh, including consideration of San Pablo and San Francisco Bays based on overlapping species distributions (e.g., longfin smelt). A number of other areas were considered, as follows.

- Sacramento River (including Shasta and Keswick Reservoirs)
- Feather River (including Oroville Reservoir and Thermalito Afterbay)
- Trinity River Basin (including Trinity and Lewiston Reservoirs and lower Klamath River)
- Whiskeytown Reservoir and Clear Creek
- American River and Folsom Lake
- Stanislaus River and New Melones Reservoir
- San Joaquin River and Millerton Reservoir

12.1.2 Fish and Aquatic Species of Management Concern

Fish and aquatic species were selected for analysis in this Draft EIR based on their importance, vulnerability, and potential to be affected by construction activities and changes in SWP, and where appropriate Central Valley Project (CVP), operations implemented under the project alternatives (Table 12-1). These fish species, referred to herein as the species of management concern, include species listed by state or federal agencies as endangered or threatened or listed by Moyle et al. (2015) as California Species of Special Concern (critical, high, or moderate status). Species of management concern also include species of Tribal, commercial, or recreational importance. In addition to the species listed in Table 12-1, southern resident killer whale (*Orcinus orca*, federally listed as endangered) is considered because of potential effects on their Chinook salmon (*Oncorhynchus tshawytscha*) prey. The species of management concern for this Draft EIR that are analyzed for potential impacts in this chapter are listed in Table 12-1. Species descriptions are provided in Appendix 12A, Section 12A.1, *Fish and Aquatic Resources Species Descriptions*.

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[1] Differences in CVP operations were also considered where appropriate.

Table 12-1. Fish and Aquatic Species of Management Concern Potentially Affected by the Project Alternatives

Species and *ESU/DPS*	Federal Status	State Status	Tribal [a], Commercial, or Recreational Importance
Winter-run Chinook salmon *Sacramento River ESU*	Endangered	Endangered	Yes [b]
Spring-run Chinook salmon *Central Valley ESU*	Threatened	Threatened	Yes [b]
Fall-run/late fall–run Chinook salmon *Central Valley ESU*	Species of Concern	Species of Special Concern	Yes [b]
Steelhead *Central Valley DPS*	Threatened	None	Yes
Delta smelt	Threatened	Endangered	Yes
Longfin smelt	Candidate	Threatened, Species of Special Concern	Yes
Green sturgeon *Southern DPS*	Threatened	Species of Special Concern	Yes
White sturgeon	None	Species of Special Concern	Yes
Pacific lamprey	Species of Concern	Species of Special Concern	Yes
River lamprey	None	Species of Special Concern	Yes
Sacramento hitch	None	Species of Special Concern	Yes
Sacramento splittail	None	Species of Special Concern	Yes
Hardhead	None	Species of Special Concern	Yes
Central California roach	None	Species of Special Concern	Yes
Starry flounder	None	None	Yes [b]
Northern anchovy	None	None	Yes [b]
Striped bass	None	None	Yes
American shad	None	None	Yes
Threadfin shad	None	None	Yes
Black bass (largemouth, smallmouth, spotted)	None	None	Yes
California bay shrimp	None	None	Yes

ESU = evolutionarily significant unit; DPS = distinct population segment.

a Tribal importance was noted based on Shilling et al. (2014:15–46). b Commercially important species with Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act.

12.1.3 Habitat Conditions and Environmental Stressors

The sections below concern habitats with attributes, resources, and resource conditions needed to support the different life stages of the fish species of management concern that rely on the geographic area being evaluated. The major environmental stressors are factors that limit a habitat's capacity to support the life stages present. The descriptions focus on stressors that potentially would be affected by the project. For example, turbidity may affect predation risk of fish species of management concern. Major environmental stressors potentially limiting turbidity include the supply of suspended sediment entering the Delta and invasive aquatic macrophytes slowing water velocity and allowing suspended sediment to settle.

12.1.4 Delta and Suisun Bay/Marsh

12.1.4.1 Description of Delta and Suisun Bay/Marsh

Ecologically, the Delta consists of three major landscapes and geographic regions: (1) the north Delta freshwater flood basins composed primarily of freshwater inflow from the Sacramento River system; (2) the south Delta distributary channels composed of predominantly San Joaquin River system inflow; and (3) the central Delta tidal islands landscape wherein the Sacramento, San Joaquin, and eastside tributary flows converge and tidal influences from San Francisco Bay are greater.

Suisun Bay and Marsh are ecologically linked with the central Delta, although with different tidal and salinity conditions than are found upstream (e.g., greater tidal and salinity influence in Suisun Bay than in the Delta). Suisun Bay and Marsh are the largest expanse of remaining tidal marsh habitat within the greater San Francisco Estuary ecosystem and include Honker, Suisun, and Grizzly Bays; Montezuma and Suisun Sloughs; and numerous other smaller channels and sloughs.

The Yolo Bypass conveys flood flows from the Sacramento Valley, including the Sacramento River, Feather River, American River, Sutter Bypass, and westside tributaries.

12.1.4.2 Habitat Conditions and Environmental Stressors in Delta and Suisun Bay/Marsh

A summary of habitat conditions and environmental stressors in the Delta and Suisun Bay/Marsh was recently provided by the California Department of Water Resources (DWR) (2020a) in the Final EIR for Long-Term Operation of the SWP. The following is largely taken from that description and includes consideration of the Delta and Suisun Bay/Marsh as well as the Yolo Bypass.

Delta

Aquatic Habitat

Flow management in the Delta altered the aquatic habitat by (1) changing aspects of the historical flow regime (timing, magnitude, duration) that supported life history traits of native species; (2) limiting access to or quality of habitat; (3) contributing to conditions better suited to invasive, nonnative species (reduced spring flows, increased summer inflows and exports, and low and less-variable interior Delta salinity [Moyle and Bennett 2008] as a result of adopted regulations such as Delta water quality objectives for south Delta exports and in-Delta water users); and (4) causing net reverse flows in channels leading to project export facilities that can entrain fish (Mount et al. 2012). Native species of the Delta are adapted to and depend on variable flow conditions at multiple scales, which is influenced by the region’s dramatic seasonal and interannual climatic variation. In particular, most native fishes evolved reproductive or outmigration timing associated with historical peak flows during spring (Moyle 2002).

A variety of researchers have studied the effects of water export on Delta flow and velocity using hydrodynamic models. The Salmonid Scoping Team (SST) recently provided a summary of these effects (Salmonid Scoping Team 2017). The SST concluded that the effect of the SWP and CVP water exports on Delta flow and velocity varied as a function of distance from the facility as well as a function of export volume, total Delta inflow, and tidal action. While export rates had little effect on distributaries such as Georgiana Slough, a much greater effect exists in the south Delta, particularly in Old River near the export facilities.

Water temperatures in the Delta follow a seasonal pattern of winter coldwater conditions and summer warmwater conditions, largely because of the region's Mediterranean climate with its alternating cool/wet and hot/dry seasons. Ambient air is the main driver of water temperature, with upstream effects such as reservoir releases having limited influence by the time the water reaches the Delta (Kimmerer 2004; Mount et al. 2012; National Research Council 2012:141; Wagner et al. 2011). Water temperatures in summer approach or exceed the upper thermal tolerances (e.g., 20 degrees Celsius [°C] to 25°C) for coldwater fish species such as salmonids and Delta-dependent species such as delta smelt (*Hypomesus transpacificus*). This is especially true in parts of the south Delta and San Joaquin River (Kimmerer 2004), potentially restricting the distribution of these species and precluding previously important rearing areas (National Research Council 2012:144). Halverson et al. (2022) found that thermally unsuitable habitat for delta smelt, indicated by annual maximum water surface temperatures exceeding the critical thermal maximum temperature, increased by 1.5 square kilometers per year from 1985 to 2019, with unsuitable conditions for delta smelt observed in large portions of the Delta in 2017 (see also Flow Alteration - Management, Analysis, and Synthesis Team 2020:232). A recent study reaffirmed older observations that Chinook salmon smolts must transit the Delta before water temperature reaches 20°C or mortality will be nearly 100% (Nobriga et al. 2021).

Landscape-scale changes resulting from flood management infrastructure such as levees, along with flow modification, have eliminated most of the historical hydrologic connectivity of floodplains and aquatic ecosystems in the Delta and its tributaries, thereby degrading and diminishing Delta habitats for native plant and animal communities (Mount et al. 2012). In addition, large-scale reclamation of tidal wetlands has also contributed to the degradation of habitat for Delta fishes. The large reduction of hydrologic variability and landscape complexity has supported invasive aquatic species that have further degraded conditions for native species (see, for example, discussion related to the submerged aquatic vegetation species *Egeria densa* by Conrad et al. 2016:251). Because of the combination of these and other factors, the Delta appears to have undergone ecological regime shifts generally represented by lower abundance of pelagic species, including natives such as delta smelt and longfin smelt (Mac Nally et al. 2010; Thomson et al. 2010; Stompe et al. 2020), and higher abundance of littoral species primarily made up of nonnatives (Mahardja et al. 2017).

In response to these landscape conditions, DWR is leading California EcoRestore (see also the below discussion related to regulatory setting) to advance the restoration of at least 30,000 acres of tidal wetland, floodplain habitat, and riparian habitat throughout the Delta. DWR is the lead agency on the majority of EcoRestore projects, including but not limited to, projects such as Decker Island, Bradmoor Island, Lookout Slough Tidal Habitat Restoration and Flood Improvement Project, Winter Island, and the Tule Red Project (California Department of Water Resources 2019a); these examples are some of the projects required by federal mandates and are necessary for continued operations of the SWP and the CVP. Once the projects are constructed, they will be adaptively managed to improve habitat for delta smelt and other species. DWR is also working with other resource agencies, including the California Department of Fish and Wildlife (CDFW), to explore the feasibility of restoring a portion of Franks Tract to reduce invasive weeds and predation while increasing turbidity and fish food production (California Department of Fish and Wildlife 2018). This has led to the completion of feasibility study (California Department of Fish and Wildlife 2020b). Recent research on the Sacramento Deep Water Ship Channel illustrated that longitudinal variations in tidal connectivity and exchange with adjacent areas lead to differing pelagic community and food web structure along the Channel, which informs restoration efforts (Young et al. 2021).

Salinity is a critical factor influencing the distribution of plant and animal communities in the Delta. Although estuarine fish species are generally tolerant of a range of salinity, this tolerance varies by species and life stage. Some species can be highly sensitive to excessively low or high salinity during physiologically vulnerable periods, such as reproductive and early life stages. Although the Delta is tidally influenced, most of the Delta contains fresh water year-round due to inflows from rivers and reservoir releases to maintain water quality standards (Hutton et al. 2015:04015069-6). However, the south Delta can have low levels of salinity greater than tidal freshwater because of salts in agricultural return water (Monsen et al. 2007:4). In addition, the tidally influenced low-salinity zone can move upstream into the central Delta, with distance upstream depending on freshwater outflow, tides, and other factors such as weather fronts influencing air pressure (Kimmerer 2004:27).

A measure of the spatial geography of salinity in the western Delta is X2, which is the distance in kilometers from the Golden Gate Bridge to the point where the salinity near the bottom of the water column is 2 parts per thousand. X2 is an index of the response of the San Francisco Estuary to freshwater flow (Kimmerer 2004:27), with X2 being influenced by freshwater inflow to the Delta, diversions within the Delta and at the south Delta export facilities, and other factors mentioned above (e.g., tides and weather fronts; Kimmerer 2004:27). X2 has been used to help define the extent of habitat available for oligohaline pelagic organisms and their prey and has been correlated with the abundance of some species and the amount of suitable habitat for delta smelt in fall (Feyrer et al. 2007, 2011; U.S. Fish and Wildlife Service 2008:235). Based on an analysis of historical monitoring data, Feyrer et al. (2007) defined the abiotic habitat of delta smelt as a specific envelope of salinity and turbidity that changes over the course of the species' life cycle. However, Murphy and Weiland (2019) suggest that the low-salinity zone is not a reliable indicator of delta smelt habitat and by extension the distribution of the species within the Delta, given that the species frequently occurs outside the zone or that large parts of the zone do not have delta smelt. This topic is controversial and has generated scientific debate (Manly et al. 2015; Feyrer et al. 2015a). Some analyses have shown no relationship of fall X2 (ICF 2017) or the volume of the low salinity zone (Polansky et al. 2021) with juvenile delta smelt abundance/survival, whereas Polansky et al. (2021) found some evidence for lower fall X2 being positively related with delta smelt recruitment in the following spring. In recent decades, it has been suggested that lower outflows have tended to shift X2 during fall farther upstream out of the wide expanse of Suisun Bay into the much narrower channels near the confluence of the Sacramento and San Joaquin Rivers (near Collinsville), thereby reducing the spatial extent of low-salinity habitat believed to be important for some species such as delta smelt (U.S. Fish and Wildlife Service 2008:235; Baxter et al. 2010). A recent study by Hutton et al. (2015) assessed trends in Delta outflow during pre-SWP (1922–1967) and post-SWP (1968–2012) time periods. Based on observed data, there was a statistically significant increase in X2 from 1922 through 2012 in November through June and a statistically significant decrease in X2 in August and September (Hutton et al. 2015:04015069-9). During the post-SWP period (1968–2021), there was a statistically significant increase in X2 from September through December (Hutton et al. 2015:04015069-9).

Feyrer et al. (2007, 2011) conclude that an overall negative trend in abiotic habitat quality has occurred for delta smelt and striped bass (*Morone saxatilis*) (and potentially other fish species), as measured by water quality attributes and midwater trawl catch data since 1967, with delta smelt and striped bass experiencing the most apparent declines in abundance, distribution, and a related index of environmental quality. Mac Nally et al. (2010) evaluated 54 potential relationships between the four pelagic organism decline (POD) species' declines and environmental factors and found that few covariate relationships were expressed clearly for more than one of the four declining fish species. X2 in spring had a strong negative relationship with indices of abundance for longfin smelt, spring calanoids, and mysids (i.e., indices of abundance increased as X2 decreased),), but X2 in spring was not correlated with any of the other POD species, while X2 in fall was negatively related only to the striped bass index of abundance. Other factors, such as the introduction of nonnative clam species (Feyrer et al. 2003; Kimmerer et al. 1994), shifts in phytoplankton and zooplankton community composition (Winder and Jassby 2011; Glibert et al. 2011), expansion of invasive aquatic weeds (Hestir et al. 2016), and contaminants (Fong et al. 2016), also contribute to reducing habitat quality. The abundance indices of several taxa have been correlated with X2 (Jassby et al. 1995; Kimmerer 2002a, 2002b; Tamburello et al. 2019), suggesting that the quantity or suitability of estuarine habitat for some species may increase when outflows are high. However, recent analyses by Kimmerer et al. (2009) indicated that neither changes in area nor volume of low salinity water (habitat) appear to account for this relationship, except for striped bass and American shad, which suggests that X2 may be indexing other environmental variables or processes rather than simple extent of habitat (Baxter et al. 2010).

Nutrients and Foodweb Support

Nutrients are essential components of terrestrial and aquatic environments because they provide a resource base for primary producers. Typically, in freshwater aquatic environments, phosphorus is the primary limiting macronutrient, whereas in marine aquatic environments, nitrogen tends to be limiting. A balanced range of abundant nutrients provides optimal conditions for maximum primary production, a robust foodweb, and productive fish populations. However, changes in nutrient loadings and forms, excessive amounts of nutrients, and altered nutrient ratios can lead to a suite of problems in aquatic ecosystems, such as low dissolved oxygen (DO) concentrations, un-ionized ammonia, excessive growth of toxic forms of cyanobacteria, and changes in components of the foodweb. Nutrient concentrations in the Delta have been well studied (Jassby et al. 2002; Kimmerer 2004; Van Nieuwenhuyse 2007; Glibert et al. 2011, 2014).

Estuaries are commonly characterized as highly productive nursery areas for numerous aquatic organisms. Nixon (1988) noted that there is a broad continuum of primary productivity levels in different estuaries, which affects fish production and abundance. Compared to other estuaries, pelagic primary productivity in the upper San Francisco Estuary is relatively poor, and a relatively low fish yield is expected (Wilkerson et al. 2006). In the Delta and Suisun Marsh, this appears to result from relatively high turbidity, clam grazing (Jassby et al. 2002), and nitrogen and phosphorus dynamics (Wilkerson et al. 2006; Van Nieuwenhuyse 2007; Glibert et al. 2011, 2014).

A significant long-term decline in phytoplankton biomass (represented by chlorophyll a) and phytoplankton primary productivity to low levels has occurred in the Suisun Bay region and the Delta (Jassby et al. 2002; Dahm et al. 2016). Shifts in nutrient concentrations, such as high levels of ammonium and nitrogen relative to phosphorus (i.e., the ratios of nitrogen to phosphorus and ammonium to nitrate), may contribute to the phytoplankton reduction and to changes in algal species composition in the San Francisco Estuary (Wilkerson et al. 2006; Dugdale et al. 2007; Lehman et al. 2005, 2008a, 2010; Glibert et al. 2011, 2014). However, a recent analysis concluded high ammonium loading is not a driver of low productivity in the Delta area (Strong et al. 2021). Low and declining primary productivity in the estuary may be contributing to the long-term pattern of relatively low and declining biomass of pelagic fishes (Jassby et al. 2002), although the statistical analyses by Mac Nally et al. (2010) and Thomson et al. (2010) found limited statistical evidence for a linkage between chlorophyll and pelagic fish.

The introductions of two clams from Asia have led to alterations in the foodweb in the Delta. Overbite clams (*Potamocorbula amurensis*; invaded in approximately the mid-1980s [Carlton et al. 1990]) are most abundant in the brackish and saline water of Suisun Bay and the western Delta, and Asian clams (*Corbicula fluminea;* invaded in approximately 1945 [Brown et al. 2007]) are most abundant in the fresh water of the central Delta. These filter feeders reduce the phytoplankton and zooplankton concentrations in the water column, reducing food availability for native fishes such as delta smelt and young Chinook salmon (Feyrer et al. 2007; Kimmerer 2002a; Kimmerer and Thompson 2014).

In addition, introduction of the clams, in particular *P. amurensis*, led to the decline of native copepods of higher food quality and the establishment of poorer quality nonnative copepods. The clams have been associated with the decline in *Neomysis mercedis* (Orsi and Mecum 1996; Feyrer et al. 2003), the shift in distribution of anchovies (Kimmerer 2006) and young-of-the-year striped bass (Kimmerer et al. 2000; Feyrer et al. 2003; Sommer et al. 2007), as well as the decline in diatoms (Kimmerer 2005) and several zooplankton species (Kimmerer et al. 1994). The impact of the clams on chlorophyll a and the Delta ecosystem is also reflected by a shift in many of the original correlations between species abundance indices and X2, that occurred after the establishment of the clams (Kimmerer 2002b; Sommer et al. 2007). Thus, for example, the intercept of the statistical regression relationship between the longfin smelt fall midwater trawl abundance index and January–June X2 shifted downward following *P. amurensis* establishment in the mid-1980s, so that there was a lower abundance index for a given X2 (Kimmerer 2002b).

More recently, the cyclopoid copepod, *Limnoithona*, has rapidly become the most abundant copepod in the Delta since its introduction in 1993 (Hennessy and Enderlein 2013). This species is approximately one-tenth the size of other copepods and therefore may be less suitable prey for delta smelt, in addition to potentially competing with other copepods (Gould and Kimmerer 2010:175). This species was shown to be consumed by delta smelt and striped bass larvae less than 20 days old in proportion to its availability in the environment in a laboratory setting; once over 20 days old, the fish larvae shifted diet selection to larger copepods (*P. forbesi* and *E. affinis*; Sullivan et al. 2016). In the wild, Slater and Baxter (2014) found neutral or negative selection by delta smelt juveniles for *Limnoithona* during April through July. *Limnoitona* may have facilitated higher abundance of the copepod *Acartiella sinensis*, which through predation contributed to the reduction in the delta smelt copepod prey *Pseudodiaptomus forbesi* (Kayfetz and Kimmerer 2017). The overbite clam also has been implicated in the reduction of the native opossum shrimp, a preferred food of Delta native fishes such as Sacramento splittail and longfin smelt (Feyrer et al. 2003).

Several studies have documented or suggested food limitations for aquatic species in the San Francisco Estuary, including zooplankton (Mueller-Solger et al. 2002; Kimmerer et al. 2005; Kimmerer et al. 2014), delta smelt (Bennett 2005; Bennett et al. 2008; Slater and Baxter 2014; Hammock et al. 2015), Chinook salmon (Sommer et al. 2001a, 2001b), Sacramento splittail (Greenfield et al. 2008), striped bass (Loboschefsky et al. 2012), and largemouth bass (Nobriga 2009). Recent analyses suggest that the combination of clam grazing and south Delta exports have negatively affected pelagic productivity in the San Francisco Estuary (Hammock et al. 2019a; see further discussion of this study in Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*).

Turbidity

Turbidity is a measure of the relative clarity of water and is an important water quality component in the Delta that affects physical habitat through sedimentation and foodweb dynamics by means of attenuation of light in the water column. Light attenuation, in turn, affects the extent of the photic zone where primary production can occur and the ability of predators to visually locate prey and for prey to escape predation. Suspended solids affect turbidity and reflect the contribution of mostly inorganic materials (e.g., fine sediments) as well as a relatively small contribution from organic materials such as phytoplankton (Schoellhamer et al. 2012:4–5).

Turbidity has been declining in the Delta since the 1950s according to sediment data collected by the U.S. Geological Survey (Wright and Schoellhamer 2004). The decline has important implications for foodweb dynamics and predation. Higher water clarity is at least partially caused by increased water filtration and plankton grazing by highly abundant overbite clams and other benthic organisms (Kimmerer 2004; Greene et al. 2011) and potentially by filtration by high densities of aquatic vegetation (Hestir et al. 2016). High nutrient loads coupled with reduced sediment loads and higher water clarity were hypothesized to contribute to plankton and algal blooms and overall increased eutrophic conditions in some areas (Kimmerer 2004). Recent modeling examining future climate scenarios, however, predicts significant increases in large flow events and sediment loading to the Delta from the Sacramento River over the next century for two representative greenhouse gas concentration pathways, which could increase turbidity (Stern et al. 2020). Water clarity may affect detection of some pelagic fish species in the San Francisco Estuary as a result of the combined effects of turbidity on abundance (i.e., species being more abundant in more turbid conditions) and capture probability (i.e., species being less able to detect and avoid sampling gear in more turbid conditions) (Peterson and Barajas 2018:21). Higher turbidity has been shown to reduce predation risk, for example in delta smelt (Ferrari et al. 2014).

The first high-flow events of winter create turbid conditions in the Delta, which can be drawn into the south Delta during reverse flow conditions in Old and Middle River. In general, delta smelt may follow turbid waters into the southern Delta, migrating upstream through use of tidal flows (Bennett and Burau 2015), potentially increasing their proximity to project export facilities and, therefore, their entrainment risk (U.S. Fish and Wildlife Service 2008:210; Grimaldo et al. 2009, 2021). Investigations suggest that movement behavior is complex and may respond to turbidity and other cues such as changes in salinity (Gross et al. 2021; Korman et al. 2021). Monitoring of turbidity in the Delta is one of the main indicators used to minimize south Delta entrainment risk through adjustments to south Delta operations under the U.S. Fish and Wildlife (USFWS) 2019 SWP/CVP Biological Opinion and CDFW 2020a SWP Incidental Take Permit (ITP).

In response to the Delta Smelt Resiliency Strategy, DWR assessed the feasibility of adding sediment to increase turbidity in the low-salinity zone of the Delta to improve delta smelt habitat conditions. Computer modeling was performed to assess (1) whether sediment supplementation is a feasible action to effectively increase turbidity in the low salinity zone, (2) the magnitude of sediment supplementation that would be required in order to have a measurable effect on turbidity in the low salinity zone, and (3) the spatial and temporal extent over which supplementation would influence turbidity (Bever and MacWilliams 2018). The results of the modeling suggested that it was feasible to increase turbidity by sediment supplementation and showed that 3,550 cubic yards per day of sediment release was needed to increase turbidity by 10 nephelometric turbidity units (NTU) between Emmaton and Mallard Island during May through September (Bever and MacWilliams 2018); this is a geographic area consistently occupied by delta smelt during all life stages (e.g., Murphy and Hamilton 2013). The modeled sediment supplementation occurred continuously in the form of batch slurry of approximately 180 cfs, from May through September, with little difference in turbidity in October after supplementation ceased and limited effects downstream of Mallard Island.

Contaminants

Contaminants can change ecosystem functions and productivity through numerous pathways. A large body of research has been conducted on contaminant occurrence and effects on aquatic organisms in the Delta (Johnson et al. 2010:1; Brooks et al. 2012; Fong et al. 2016). A wide array of contaminants, including pesticides, metals, pharmaceuticals, and personal care products, have been detected in Delta water and sediment. Recent monitoring programs are routinely detecting multiple pesticides in each water sample from the Delta (De Parsia et al. 2018, 2019; Jabusch et al. 2018). Fong et al. (2016) reported that "[f]or example, 27 pesticides or degradation products were detected in Sacramento River samples, and the average number of pesticides per sample was six. In San Joaquin River samples, 26 pesticides or degradation products were detected, and the average number detected per sample was 9. Water quality objectives do not exist for most of these compounds. However, these were targeted chemical analyses, and hundreds of compounds have been detected in individual Delta water samples using other non-targeted techniques." The effects of chemical mixtures on aquatic organisms is generally unknown but many chemicals may have additive or synergistic effects. Anthropogenic toxins cause significant disruption to development, reduce growth and recruitment, and increase mortality (Johnson et al. 2010:73).

In addition to anthropogenic contaminants, natural toxins are associated with blooms of *Microcystis aeruginosa*, a cyanobacterium that releases a potent toxin known as microcystin. Toxic microcystins cause foodweb impacts at multiple trophic levels, and histopathological studies of fish liver tissue suggest that fish exposed to elevated concentrations of microcystins have developed liver damage and tumors (Deng et al. 2010; Lehman et al. 2005, 2008a, 2010; Acuña et al. 2012a, 2012b). Other potentially toxic cyanobacteria (*Aphanizomenon* and *Dolichospermum*) can occur with *Microcystis* in the Delta (Lehman et al. 2021).

There are longstanding concerns related to mercury and selenium in the Sacramento and San Joaquin watersheds, the Delta, and San Francisco Bay (Brooks et al. 2012). Conversion of inorganic mercury to toxic methylmercury occurs in anaerobic environments, including some wetlands, with greater amounts of methylmercury tending to occur in less frequently inundated areas (Alpers et al. 2008:1). DWR is conducting an additional study to determine imports and exports of mercury and methylmercury from freshwater tidal wetlands in the Delta and Suisun Marsh per the Sacramento San Joaquin Delta Methylmercury TMDL and Basin Plan Amendment (Lee and Manning 2020; Wood et al. 2010). Current research shows that tidal wetlands do not export mercury or methylmercury in large amounts, although seasonal differences occur and imports and exports are heavily influenced by flow and whether the wetland is associated with a floodplain (Mitchell et al. 2012; Lee and Manning 2020:25–77). Methylmercury increases in concentration at each level in the food chain and can cause concern for people and birds that eat piscivorous fish (e.g., striped bass) and benthic fishes such as sturgeon. Studies summarized by Alpers et al. (2008) indicate that mercury in fish has been linked to hormonal and reproductive effects, liver necrosis, and altered behavior in fish. A study by Lee et al. (2011) on dietary methylmercury noted significant abnormalities in the liver and kidneys, lower growth rates, and higher mortality in both green sturgeon and white sturgeon, but particularly in green sturgeon.

With regard to selenium, benthic foragers like diving ducks, sturgeon, and Sacramento splittail have the greatest risk of selenium toxicity because of selenium presence in nonnative benthic bivalves. Beckon and Maurer (2008) suggest that salmonids are probably among the species that are most sensitive to selenium, while delta smelt are likely to be at low risk of selenium toxicity. The invasion of the nonnative bivalves (e.g., overbite clams) has resulted in increased bioavailability of selenium to benthivores in San Francisco Bay (Linville et al. 2002). A recent study of Sacramento splittail based on otolith chemical composition has shown that juveniles acquired selenium toxicity while feeding in the freshwaters of the San Joaquin River but already started with significantly higher selenium burdens from maternal transfer by females maturing in the estuary (Johnson et al. 2020).

Phytoplankton growth rates may be inhibited by localized high concentrations of herbicides (Edmunds et al. 1999), with recent laboratory studies indicating that among three tested herbicides (glyphosphate, imazomox, and fluridone), only fluridone inhibited phytoplankton at environmentally relevant concentrations (Lam et al. 2020). Toxicity to invertebrates has been noted in water and sediments from the Delta and associated watersheds (Kuivila and Foe 1995; Weston et al. 2004, 2014, 2019). The 2004 Weston study of sediment toxicity recommended additional study of the effects of the pyrethroid insecticides on benthic organisms. Undiluted drainwater from agricultural drains in the San Joaquin River watershed can be acutely toxic (i.e., quickly lethal) to fish (e.g., Chinook salmon and striped bass) and have chronic effects on growth, likely because of high concentrations of major ions (e.g., sodium, sulfates) and trace elements (e.g., chromium, mercury, selenium) (Saiki et al. 1992).

A more recent synthesis of contaminant studies described multiple lines of evidence showing that contaminants negatively affect species of management concern in the Delta (Fong et al. 2016). Fong et al. (2016) reported that many contaminants detected in Delta waters exceed regulatory standards and most water samples contain multiple contaminants. They also summarize the multiple studies that have found sublethal, lethal, chronic, and acute toxicity of Delta water to test species and species of management concern in the Delta, including delta smelt and salmon.

Fish Passage and Entrainment

With its complex network of channels, low eastern and southern tributary inflows, and reverse currents created by pumping for water exports, the Delta presents a challenge for anadromous and resident fish during upstream and downstream migration. These complex conditions can lead to straying, extended exposure to predators, and entrainment during outmigration. Tidal elevations, salinity, turbidity, Delta inflow, meteorological conditions, season, habitat conditions, and project exports all have the potential to influence fish movement, currents, and ultimately the level of entrainment and fish passage success and survival (see, for example, the review by Salmonid Scoping Team 2017).

North Delta Fish Passage and Entrainment

In the north Delta (i.e., the Sacramento River and associated waterways), migrating fish have multiple potential pathways as they move to or from the Sacramento or Mokelumne River systems. Michel et al. (2015) used acoustic telemetry to examine survival of late fall–run Chinook salmon smolts outmigrating from the Sacramento River through the Delta and San Francisco Estuary. Survival was lowest in the Bays (defined as the region from Chipps Island to the Golden Gate Bridge), highest in the lower Sacramento River upstream of the Delta, and intermediate in the Delta and the upper Sacramento River portion of the migration route.

Outmigrating juvenile fish moving down the mainstem Sacramento River can enter the CVP's Delta Cross Channel (DCC) when the gates are open and travel through the Delta via the Mokelumne and San Joaquin River channels. In the case of juvenile salmonids, this shifted route from the north Delta to the central Delta increases their mortality rate (Kjelson and Brandes 1989; Brandes and McLain 2001; Newman and Brandes 2010; Perry et al. 2010, 2012). Steel et al. (2012) found that the best predictor of which route was selected was the ratio of mean water velocity between the two routes. Salmon migration studies show losses of approximately 65% for groups of outmigrating fish that are diverted from the mainstem Sacramento River into the waterways of the central and south Delta (Brandes and McLain 2001; Vogel 2004, 2008a; Perry and Skalski 2008). Perry and Skalski (2008) found that, by closing the DCC gates, total through-Delta survival of marked fish to Chipps Island increased by nearly 50% for fish moving downstream in the Sacramento River system; subsequent studies have found the increase to be 25%–50% depending on Sacramento River flow (Perry et al. 2018). Closing the DCC gates appears to redirect the migratory path of outmigrating fish into Sutter and Steamboat Sloughs and the Sacramento River and away from Georgiana Slough, resulting in higher survival rates. Species that may be affected include juvenile green sturgeon, steelhead, and winter-run and spring-run Chinook salmon (National Marine Fisheries Service 2009:404), although only the salmonids have had quantitative studies confirming this link (e.g., Singer et al. 2013; Perry et al. 2018). Singer et al. (2020) found the through-Delta migration pathway via Steamboat Slough to be of particular importance for juvenile Chinook salmon outmigration survival during the 2013 through 2015 drought conditions.

Analysis by Perry et al. (2015, 2018) suggests, however, that the mechanisms governing route selection are more complex. Their analysis revealed the strong influence of tidal forcing on the probability of fish entrainment into the interior Delta. The probability of entrainment into both Georgiana Slough and the DCC was highest during reverse-flow flood tides, and the probability of fish remaining in the Sacramento River was near zero (with DCC open) or 5% to 10% (with DCC closed) during flow reversals (Perry et al. 2015:452). Perry et al. (2015:453) noted that the magnitude and duration of reverse flows at this river junction decrease as inflow of the Sacramento River increases. Consequently, reduced Sacramento River inflow increases the frequency of reverse flows at this junction (Perry et al. 2015:453), thereby increasing the proportion of fish that are entrained into the interior Delta, where mortality is high (Perry 2010:172). In addition to influencing migratory pathways, Sacramento River flow is positively correlated with juvenile Chinook salmon survival in river reaches transitioning from bidirectional (tidal) flow to unidirectional (downstream) flow with increased river flow (i.e., Sacramento River from Georgiana Slough to Rio Vista; Sutter and Steamboat Slough; and Georgiana Slough) (Perry et al. 2018).

The SWP Barker Slough Pumping Plant, located on a tributary to Cache Slough, may cause larval fish entrainment. The intake is equipped with a positive barrier fish screen to prevent fish at least 25 millimeters (mm) in size from being entrained. CDFW found low levels of entrainment of larval delta smelt less than 20 mm at Barker Slough during the mid-1990s to mid-2000s, and more recent entrainment monitoring in the pump bays behind the fish screens in 2014–2016 only collected one delta smelt (Yip et al. 2019:29–30). Per the CDFW (2020a) SWP ITP and the USFWS (2019) SWP/CVP biological opinion (for delta smelt),), pumping rates are reduced when longfin smelt or delta smelt larvae are present in the vicinity to minimize entrainment into the North Bay Aqueduct.

Marston et al. (2012) studied stray rates for immigrating San Joaquin River Basin adult salmon that stray into the Sacramento River Basin. Results indicated that it was unclear whether reduced San Joaquin River pulse flows or elevated exports caused increased stray rates; the statistical results indicated that flow is the primary factor, but empirical data indicate that little if any pulse flow leaves the Delta when south Delta exports are elevated, so exports in combination with pulse flows may explain the elevated stray rates (Marston et al. 2012). The DCC, when open, can divert fish into the interior Delta from the Sacramento River as they outmigrate. The opening of the DCC when salmon are returning to spawn to the Mokelumne and Cosumnes Rivers is believed to lead to increased straying of these fish into the American and Sacramento Rivers because of confusion over olfactory cues. Experimental DCC closures have been scheduled during the fall-run Chinook salmon migration season for selected days, coupled with pulsed flow releases from reservoirs on the Mokelumne River, in an attempt to reduce straying rates of returning adults. These closures have corresponded with reduced recoveries of Mokelumne River Hatchery fish in the American River system and increased returns to the Mokelumne River Hatchery (East Bay Municipal Utility District 2012).

Water quality can also affect fish passage in the north Delta. Water quality in the mainstem Sacramento River and its distributary sloughs can be poor at times during summer, creating conditions that may stress migrating fish or even impede migration. These conditions include low DO and high water temperatures. For adult Chinook salmon, DO concentration less than 3 to 5 milligrams per liter (mg/L) can impede migration (Hallock et al. 1970), as can mean daily water temperatures of 70 degrees Fahrenheit (°F) to 73°F (approximately 21°C to 23°C), depending on whether water temperatures are rising or falling (Strange 2010). The U.S. Environmental Protection Agency (2003:25) recommended a 68°F maximum 7-day average of the daily maximums for salmon (including Chinook salmon) and trout (including steelhead) migration for the Pacific Northwest. DO levels are generally greater than 5 mg/L throughout the Delta, but water temperatures can exceed these thresholds during summer and fall. Contaminants such as pesticides and copper at concentrations that have been detected in the Delta have also been found to impair olfactory responses in many fish, which can lead to straying (Fong et al. 2016; Sandahl et al. 2007; Tierney et al. 2010).

Central and South Delta Fish Passage and Entrainment

The south Delta intake facilities include the SWP and CVP export facilities; local agency intakes, including Contra Costa Water District intakes; and agricultural intakes. Contra Costa Water District intakes, the Rock Slough Intake at the Contra Costa Canal, and the City of Stockton intake include fish screens. There are also agricultural intakes in the central Delta, and most do not include fish screens. Water flow patterns in the south Delta are influenced by water diversion actions and operations, seasonal temporary barriers, and tides and river inflows to the Delta (Kimmerer and Nobriga 2008). Depending on hydrological conditions and water operations, around 20% to 60% of flow from the San Joaquin River enters the Head of Old River (Cavallo et al. 2015) and moves through the channels of the Old and Middle Rivers and Grant Line and Fabian-Bell Canals toward the south Delta intake facilities. When the net flow of water to the north of the diversion points for the two facilities moves southward (upstream), the net flow is negative (toward) the pumps. When seasonal temporary barriers are installed from April through November to improve water levels for diverters in the south Delta, internal reverse circulation is created within the channels isolated by the barriers from other portions of the south Delta. These conditions are most pronounced during late spring through fall when San Joaquin River inflows are low and water diversion rates are typically high. Drier hydrologic years in combination with water diversions from the Delta also reduce the frequency of net downstream flows in the south Delta and mainstem San Joaquin River. While Delta flows are tidal and naturally reverse twice daily, Delta diversions can create net reverse flows, which may draw some fish toward project facilities (Arthur et al. 1996; Kimmerer et al. 2008; Grimaldo et al. 2009; see also discussion of tidal variation by Kimmerer 2004:26).

A portion of fish that enter the Jones Pumping Plant approach channel and the Clifton Court Forebay are salvaged at screening and fish salvage facilities, transported downstream by trucks, and released. The National Marine Fisheries Service (NMFS) (2009:352) estimated that the direct loss of fish from the screening and salvage process is in the range of 65% to 83.5% for fish from the point they enter the Clifton Court Forebay or encounter the trash racks at the CVP facilities. These estimates include an assumed 10% loss at release, which does not account for other potential effects of the salvage process such as injury and increased risk for disease contraction suggested by CDFW (2020a, Attachment 8:66). Mark-recapture experiments indicate that many fish are probably subject to predation prior to reaching the fish salvage facilities (e.g., in the Clifton Court Forebay) (Gingras 1997; Clark et al. 2009:4; Castillo et al. 2012; Miranda 2019). Aquatic organisms (e.g., phytoplankton and zooplankton) that serve as food for fish also are entrained and removed from the Delta (Jassby et al. 2002; Kimmerer et al. 2008; Brown et al. 1996). Fish entrainment and salvage historically were noted to be higher in dry years when the distributions of young striped bass, delta smelt, longfin smelt, and other migratory fish species may shift closer to the project facilities (Stevens et al. 1985; Sommer et al. 1997), although the USFWS (2019) SWP/CVP biological opinion and CDFW (2020a) SWP ITP limit the potential for entrainment.

Salvage estimates reflect the number of fish entrained by project exports from surrounding waterways and sampled at the fish salvage facilities, but these numbers alone do not account for other sources of mortality related to the export facilities. These numbers alone do not include prescreen losses that occur in the waterways leading to the diversion facilities, which may in some cases reduce the number of salvageable fish (e.g., losses within the SWP's Clifton Court Forebay) (Gingras 1997; Clark et al. 2009:4; Castillo et al. 2012; Miranda 2019). Prescreen losses are estimated to account for most adult and juvenile delta smelt mortality at the SWP export facility (Castillo et al. 2012). In addition, larval fish are not salvaged because they cannot be diverted from the export facilities by existing fish screens. The number of fish salvaged also does not include losses of fish that pass through the louvers intended to guide fish into the fish collection facilities or the losses during collection, handling, transport, and release back into the Delta. Such additional losses are included in estimates of overall loss such as those described above by NMFS (2009:352).

The life stage of the fish at which entrainment by the south Delta export facilities occurs may be important for population dynamics (Independent Review Panel 2010:18). For example, loss of a pre-spawn adult female delta smelt or one containing mature or maturing eggs is a much greater loss to the future population than loss of a larva, an adult male, or a spent female (Independent Review Panel 2010:18). The USFWS (2019) and NMFS (2019) SWP/CVP Biological Opinions (BiOps) and CDFW (2020a) SWP ITP collectively limit the potential for entrainment of listed fish through restrictions on south Delta export pumping during life stages that are vulnerable to entrainment.

While swimming through south Delta channels, fish can be subjected to stress from poor water quality (seasonally high temperatures, low DO, high water transparency, and *Microcystis* blooms) and low water velocities, which create lacustrine-like conditions. Any of these factors can cause elevated mortality rates by weakening or disorienting the fish and increasing their vulnerability to predators (Vogel 2011).

Considerable debate remains regarding the relationship between ratios of exports and inflow on the survival of fall-run Chinook salmon and Central Valley steelhead. The Salmonid Scoping Team (SST) evaluated data from multiple studies for the effects of spring ratios of San Joaquin River inflow to exports (I:E) and through-Delta survival of San Joaquin River fall-run Chinook salmon. The SST summarized their findings as follows (Salmonid Scoping Team 2017:E-105–E-106):[2]

- Coded-wire-tagged Chinook salmon data show increased through-Delta survival for higher levels of I:E, up to approximately I:E=3, in the presence of a physical barrier at the head of Old River, but no relationship in the absence of the barrier.
- Acoustically tagged Chinook salmon data show a similar pattern for I:E less than 3, but mostly in the absence of a physical barrier at the head of Old River.
- Both coded-wire-tagged and acoustically tagged Chinook salmon data show more variable but mostly lower through-Delta survival estimates for I:E between 3 and 5, all in the absence of a physical barrier at the head of Old River.
- Few observations from tagging data are available for I:E greater than 5, and all are from coded-wire-tagged data.
- Comparison of adult Chinook salmon escapement to the San Joaquin River basin between 1951 and 2003 with San Joaquin River I:E two and a half years before adult return showed a positive association (1951–2012); I:E values ranged up to greater than 300 during this time period, although most observations were less than 10.
- Acoustically tagged [juvenile] Chinook salmon data, in the absence of a physical barrier at the head of Old River, show a positive trend in survival between Mossdale and the Turner Cut junction with [increasing] I:E, a negative trend for survival between Turner Cut junction and Chipps Island, and no relationship for survival through the facilities to Chipps Island. (Salmonid Scoping Team 2017:E-105–E-106)

Buchanan and Skalski (2020) found that I:E ratio was positively correlated with juvenile Chinook survival in the south Delta but less well supported as a predictor of survival than various other flow and environmental measures. For steelhead, the SST's (2017) review of available data found survival in the south Delta tended to increase for higher levels of I:E, but observations are limited to 2 years of acoustic tag data available (2011 and 2012). Survival increased from the Turner Cut junction to Chipps Island, and overall from Mossdale to Chipps Island, as the April to May I:E increased. However, the pattern was weaker than the survival pattern observed for inflow based on SST scatterplots. Survival estimates from Mossdale to the Turner Cut junction were similar regardless of I:E based on SST scatterplots. Survival from the CVP trash rack through the facility to Chipps Island, and from the Clifton Court Forebay radial gates to Chipps Island, increased with I:E for fish released during April and May (Salmonid Scoping Team 2017). They further concluded that the high correlation between inflow and exports limits the ability to evaluate survival over a range of I:E ratios. Although not directly comparable, this contrasts with the results of Zeug and Cavallo (2012), who also found little evidence that large-scale water exports or inflows influenced coded-wire tag recovery rates in the ocean from 1993 to 2003.

Delaney et al. (2014) reported results of a mark-recapture experiment examining the survival and movement patterns of acoustically tagged juvenile steelhead outmigrating through the central Delta and south Delta following release at Buckley Cove in the lower San Joaquin River at Stockton. Their results indicated that most tagged steelhead remained in the mainstem San Joaquin River (77.6%). However, approximately one quarter (22.4%) of tagged steelhead entered Turner Cut. Route-specific survival probability for tagged steelhead using the Turner Cut route was 27.0%. The survival probability for tagged steelhead using the mainstem route was 56.7% (Delaney et al.

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[2] A summary of the export and inflow data used in the analysis is provided by Salmonid Scoping Team 2017:E-17–E-23.

2014:ES-3). Travel times for tagged steelhead also differed between these two routes, with steelhead using the mainstem route reaching Chipps Island significantly sooner than those that used the Turner Cut route. Travel time was not significantly affected by the limited Old and Middle River flow treatments examined in their study. While not significant, there was some evidence that fish movement toward each export facility could be influenced by the relative volume of water entering the export facility (Delaney et al. 2014:5-1).

Beyond considerations of just south Delta flows and exports, Cunningham et al. (2015) found a negative correlation between overall Delta export/inflow (E:I) ratio and the through-Delta survival of juvenile fall-run Chinook salmon populations and a negative correlation of total Delta exports with the through-Delta survival of juvenile spring-run Chinook salmon populations. Based on the Cunningham et al. (2015) statistical analysis, an increase in total February–April exports (including diversions/transfers, i.e., DAYFLOW output QEXPORTS) of 1 standard deviation from the 1967 to 2010 average is predicted to result in a 68.1% reduction in the survival of the Deer, Mill, and Butte Creek populations of spring-run Chinook salmon (Cunningham et al. 2015:35). Similarly, the results of the statistical analysis suggested an increase in the mean February–May ratio of Delta water exports to Delta inflow (E:I) of 1 standard deviation would reduce survival of the four fall-run Chinook salmon populations by 57.8% (Cunningham et al. 2015:35). Note that the levels of Delta exports were relatively high during this historical period relative to current management under the NMFS (2019) and USFWS (2019) SWP/CVP BiOps and the CDFW (2020a) SWP ITP: the annual mean February–April Delta exports during 1967–2010 was approximately 6,000 cfs with a standard deviation of approximately 2,100 cfs (compared to approximately 3,800 cfs in 2020), the mean annual E:I during 1967–2010 was 0.21 with a standard deviation of 0.14 (compared to approximately 0.20 in 2020). Although a mechanistic explanation for the reduction in survival remains elusive, "direct entrainment mortality seems an unlikely mechanism given the success of reclamation and transport procedures, even given increased predation potential at the release site. Changes to water routing may provide a more reasonable explanation for the estimated survival influence of Delta water exports" (Cunningham et al. 2015).

Low DO levels have been measured in the San Joaquin River, in particular in the Deep Water Ship Channel from the Port of Stockton 7 miles downstream to Turner Cut (Lee and Jones-Lee 2003). These conditions are the result of increased residence time of water combined with high oxygen demand in the anthropogenically modified channel, which leads to DO depletion, particularly near the sediment-water interface (San Joaquin Tributaries Authority 2012:21). During the 1960s, Hallock et al. (1970) found that adult radio-tagged Chinook salmon delayed their upstream migration whenever DO concentrations were less than 5 mg/L at Stockton. Peterson et al. (2017) found that upstream migration of adult fall-run Chinook salmon into the Stanislaus River from 2003 through 2014 increased with increasing DO measured at Stockton and, consistent with Hallock et al. (1970), found very few fish migrated when DO was below 5 to 6 mg/L. It has been shown that low DO conditions in the San Joaquin River can be ameliorated somewhat through installation of a barrier at the head of Old River, which increases San Joaquin River flows (San Joaquin Tributaries Authority 2012:21). Aeration facilities are operated by the Port of Stockton to ameliorate low dissolved oxygen conditions (Port of Stockton 2021). The aeration facilities and upgrades to the City of Stockton Regional Wastewater Control Facility in 2007 reduced the annual percentage of DO data points below the water quality objective (6 mg/L between Turner Cut and Stockton, September 1 through November 30) from as high as greater than 40% down to less than 1% (Central Valley Regional Water Quality Control Board 2014:3).

There are more than 2,200 diversions in the Delta (Herren and Kawasaki 2001). These irrigation diversion pipes are shore-based, typically small (30 to 60 centimeters pipe diameter), and operated via pumps or gravity flow, and most lack fish screens. These diversions increase total fish entrainment and losses and alter local fish movement patterns (Kimmerer and Nobriga 2008). Delta smelt have been found in samples of typical Delta diversions (Nobriga et al. 2004). However, Nobriga et al. (2004) found that the low and inconsistent entrainment of delta smelt measured in their study of typical irrigation diversions reflected general offshore habitat use by delta smelt and the nearshore and relatively small hydrodynamic influence of the diversions. Concerns were expressed by Kneib (2019) about potential entrainment effects given the relatively limited study of entrainment by Nobriga et al. 2004, such as the need to consider cumulative losses at all diversions (Kneib 2019:13). Nobriga and Herbold (2009:25–26) expanded on the discussion by Nobriga et al. (2004) to conclude that irrigations at small diversions are not a major stressor to delta smelt because 1) as noted above, most diversions have very small hydrodynamic footprints and delta smelt tend to occupy offshore habitat away from the diversions, 2) many of the diversions are not diverting water every day, 3) many diversions are located in the south Delta, where habitat conditions are unsuitable for delta smelt during summer/fall, and 4) agricultural water demand has not increased since the 1930s. Citing some of these reasons, Baxter et al. (2010:41) considered small within-Delta irrigation diversions to be unlikely to have had an effect on POD species, including delta smelt and longfin smelt. The temporal overlap of juvenile salmonid occurrence in the Delta with irrigation diversions is limited and therefore also not thought to be of population-level consequence (Vogel 2011:94).

Nonnative Invasive Species

Nonnative invasive species influence the Delta ecosystem by increasing competition and predation on native species, reducing habitat quality (as result of invasive aquatic macrophyte growth), and reducing food supplies by altering the aquatic foodweb. Not all nonnative species are considered invasive. CDFW defines invasive species as “species that establish and reproduce rapidly outside of their native range and may threaten the diversity or abundance of native species through competition for resources, predation, parasitism, hybridization with native populations, introduction of pathogens, or physical or chemical alteration of the invaded habitat” (California Department of Fish and Game 2008:1). Some introduced species have minimal ability to spread or increase in abundance. Others have commercial or recreational value (e.g., striped bass, American shad, largemouth bass).

Many nonnative fishes have been introduced into the Delta, for example, for sport fishing (game fish such as striped bass, largemouth bass, smallmouth bass, bluegill [*Lepomis macrochirus*], and other sunfish), as forage for game fish (threadfin shad, golden shiner [*Notemigonus crysoleucas*], and fathead minnow [*Pimephales promelas*]), for vector control (inland silverside [*Menidia beryllina*], western mosquitofish [*Gambusia affinis*]), for human food use (common carp [*Cyprinus carpio*], brown bullhead, and white catfish [*Ameiurus catus*]), and from accidental releases (yellowfin goby [*Acanthogobius flavimanus*], Shimofuri goby [*Tridentiger bifasciatus*], and Shokihaze goby [*Tridentiger barbatus*]) (Dill and Cordone 1997; Moyle 2002). Introduced fish may compete with native fish for resources and, in some cases, prey on native species.

Invasive species are among the environmental stressors implicated in the decline in abundance of native fishes throughout the region (Matern et al. 2002; Brown and Michniuk 2007; Sommer et al. 2007; Mount et al. 2012; Hamilton and Murphy 2018; Polansky et al. 2021). Habitat degradation, changes in hydrology and water quality, and stabilization of natural environmental variability are all factors that generally favor nonnative, invasive species (Mount et al. 2012; Moyle et al. 2012).

As described in the discussion of nutrients and foodweb support above, the introductions of two clams from Asia have led to major alterations in the foodweb in the Delta. *Potamocorbula* and *Corbicula* clams significantly reduce the phytoplankton and zooplankton concentrations in the water column, reducing food availability for native fishes, such as delta smelt and young Chinook salmon (Feyrer et al. 2007; Kimmerer 2002b). The upstream distribution of *Potamocorbula* into the Delta increases with decreasing Delta outflow (e.g., drought conditions) and greater salinity, increasing overlap with *Corbicula* and greater overall clam grazing (Kimmerer et al. 2019a).

Predation

Predation is an important factor that influences the behavior, distribution, and abundance of prey species in aquatic communities to varying degrees. Predation can have differing effects on a population of fish, depending on the size or age selectivity, mode of capture, mortality rates, and other factors. Predation is a part of every foodweb, and native Delta fishes were part of the historical Delta foodweb. Because of the magnitude of change in the Delta from historical times and the introduction of nonnative predatory fish, it is logical to conclude that predation may have increased in importance as a mortality factor for Delta fishes, with some observers suggesting that it is likely the primary source of mortality for juvenile salmonids in the Delta (Vogel 2011). NMFS (2014a:27) rated predation of juvenile winter-run Chinook salmon and spring-run Chinook salmon during rearing and outmigration as a stressor of “Very High” importance. Predation occurs by fish, birds, and mammals, including sea lions.

A panel of experts was convened to review data on predation in the Delta and draw preliminary conclusions on the effects of predation on salmonids. The panel acknowledged that the system supports large populations of fish predators that consume juvenile salmonids (Grossman et al. 2013:16). However, the panel concluded that because of extensive flow modification, altered habitat conditions, native and nonnative fish and avian predators, temperature and DO limitations, and the overall reduction in salmon population size, it was unclear what proportion of juvenile salmonid mortality could be attributed to predation. The panel further indicated that predation, while the proximate cause of mortality, may be influenced by a combination of other stressors that make fish more vulnerable to predation.

Striped bass, channel catfish, largemouth bass and other centrarchids, and silversides are among the introduced, nonnative species that are predators of early life stages or smaller-bodied fish species and juveniles of larger species in the Delta (Grossman 2016). Along with largemouth bass, striped bass are believed to be major predators on larger-bodied fish in the Delta. In open-water habitats, striped bass are most likely the primary predator of juvenile and adult delta smelt (California Department of Water Resources et al. 2013:11-205) and can be an important open-water predator on juvenile salmonids (Johnston and Kumagai 2012). Native Sacramento pikeminnow (*Ptychocheilus grandis*) may also prey on juvenile salmonids and other fishes. Limited sampling of smaller pikeminnows did not find evidence of salmonids in the foregut of Sacramento pikeminnow (Nobriga and Feyrer 2007) and none were found in more recent genetic studies by Brandl et al. (2021), but this does not mean that Sacramento pikeminnow do not prey on salmonids in the Delta given that the species has been shown to prey on juvenile salmonids upstream of the Delta (Tucker et al. 1998).

Largemouth bass abundance has increased in the Delta over the past few decades (Brown and Michniuk 2007). Although largemouth bass are not pelagic, their presence at the boundary between the littoral and pelagic zones makes it probable that they opportunistically consume mostly pelagic fishes, particularly during periods that pelagic species enter littoral zones (e.g., for spawning or as part of ebb tide inshore movement during tidal upstream migration in the case of delta smelt; Bennett and Burau 2015). The increase in salvage of largemouth bass occurred during the time period when Brazilian waterweed (*Egeria densa*) was expanding its range in the Delta (Brown and Michniuk 2007). The beds of Brazilian waterweed provide good habitat for largemouth bass and other species of centrarchids. Largemouth bass have a much more limited distribution in the estuary than striped bass, but a higher per capita impact on small fishes (Nobriga and Feyrer 2007; although see also Michel et al. 2018). Increases in largemouth bass may have had a particularly important effect on threadfin shad and striped bass, whose earlier life stages occur in littoral habitat (Grimaldo et al. 2004; Nobriga and Feyrer 2007). Michel et al. (2018) estimated that during the 2014/2015 spring outmigration period of juvenile fall-run Chinook salmon, largemouth bass consumed 3 to 5 Chinook salmon per day per kilometer (0.011 salmon per predator per day), compared to 0 to 24 Chinook salmon per day for striped bass (0.019 salmon per predator per day). Michel et al. (2018) also found channel catfish had a higher frequency (27.8%) of juvenile Chinook salmon in their stomachs than striped bass, largemouth bass, or white catfish (2.8%–4.8%). Genetic studies of stomach contents have suggested a more limited role for largemouth bass predation of native fishes than striped bass in the Delta (Weinersmith et al. 2019; Brandl et al. 2021). Although much focus has been on largemouth bass, other predatory black bass species (smallmouth bass and spotted bass) occur in greater abundance in the more riverine sections of the Delta (e.g., Sacramento River in the north Delta; California Department of Water Resources 2016:3-256–3-260)

Invasive Mississippi silverside (*Menidia audens*) is another potentially important predator of larval fishes in the Delta. This introduced species was not believed to be an important predator on delta smelt, but studies using DNA techniques detected the presence of delta smelt in the guts of 12.5% of Mississippi silversides sampled across a variety of habitats in the north Delta and found a greater probability of predation in less turbid, clearer water (Schreier et al. 2016). Schreier et al.'s (2016) study was consistent with an earlier study by Baerwald et al. (2012) that found a higher proportion of Mississippi silversides in offshore habitats sampled by Kodiak trawling had preyed upon delta smelt. These findings may suggest that predation impacts could be significant, given the increasing numbers of Mississippi silversides in the Delta (Mahardja et al. 2016) and decreasing trends in turbidity (Nobriga et al. 2008; although as noted above in the discussion of *Turbidity*, increases in suspended sediment/turbidity may occur in the future under climate change scenarios [Stern et al. 2020]), and as supported by recent statistical analyses examining the potential influence of Mississippi silverside abundance on delta smelt population dynamics (Hamilton and Murphy 2018; Polansky et al. 2021).

Predation of fish in the Delta is known to occur in specific areas, for example at channel junctions and areas that constrict flow or confuse migrating fish and provide cover for predatory fish (Vogel 2011). Sabal (2014) found similar results at Woodbridge Dam on the Mokelumne River where the dam was associated with increased striped bass per capita salmon consumption, which decreased outmigrant juvenile salmon survival by 10% to 29%. CDFW identified subadult striped bass as the major predatory fish in the Clifton Court Forebay (California Department of Fish and Game 1992). In 1993, for example, striped bass made up 96% of the predators removed (Vogel 2011). Cavallo et al. (2012) studied tagged salmon smolts to test the effects of predator removal on outmigrating juvenile Chinook salmon in the south Delta. Their results suggested that predator abundance and migration rates strongly influenced survival of salmon smolts. Exposure time to predators has been found to be important for influencing survival of outmigrating salmon in other studies in the Delta (Perry et al. 2012). Michel et al. (2020) investigated factors affecting survival of juvenile Chinook salmon using predation event recorders in the south Delta and found that increased predation risk was correlated with increasing water temperature, time of day (i.e., greatest risk within 50 minutes after sunset), closer proximity to predators, and increased river bottom roughness.

DWR examined the species distribution and abundance of salvaged fish at DWR's south Delta SWP pumping facilities to determine whether alternative release scenarios between salvaged delta smelt and predatory species would increase smelt survival. An initial evaluation of historical records on species distribution of salvaged fish led to the conclusion that adjusting DWR's salvage operations to stop returning predatory fish to the Delta would have little impact on delta smelt survival (California Natural Resources Agency 2017:3).

Aquatic Macrophytes

Aquatic macrophytes are an important component of the biotic community of Delta wetlands and can provide habitat for aquatic species, serve as food, produce detritus, and influence water quality through nutrient cycling and DO fluctuations. Whipple et al. (2012) described likely historical conditions in the Delta, which have been modified extensively, with major impacts on the aquatic macrophyte community composition and distribution. The primary change has been a shift from a high percentage of emergent aquatic macrophyte wetlands to open water and hardened channels.

The introduction of two nonnative invasive aquatic plants, water hyacinth (*Eichhornia crassipes*) and Brazilian waterweed, has reduced habitat quantity and value for many native fishes. Water hyacinth forms floating mats that greatly reduce light penetration into the water column, which can significantly reduce primary productivity and available food for fish in the underlying water column. Brazilian waterweed grows along the margins of channels in dense stands that prohibit access by native juvenile fish to shallow water habitat. In addition, the thick cover of these two invasive plants provides excellent habitat for nonnative ambush predators such as bass, which prey on native fish species. Studies indicate low abundance of native fish, such as delta smelt, Chinook salmon, and Sacramento splittail, in areas of the Delta where submerged aquatic vegetation infestations are thick (Grimaldo et al. 2004, 2012; Nobriga et al. 2005).

Invasive aquatic macrophytes are expanding within the Delta, and resulting habitat changes are ongoing (Conrad et al. 2020), with negative impacts on habitats and foodwebs of native fish species (Toft et al. 2003; Grimaldo et al. 2009; Mahardja et al. 2017). Concerns about invasive aquatic macrophytes are centered on their ability to form large, dense growth that can clog waterways, block fish passage, increase water clarity, provide cover for predatory fish, and cause high biological oxygen demand. DWR is actively engaged in a program of aquatic weed control. Building on the state's existing herbicide treatment program, DWR targeted 200 acres of delta smelt habitat at Decker Island in the western Delta and the Cache Slough complex in the north Delta. Recent field studies investigated the effect of herbicide treatment on delta smelt habitat (California Natural Resources Agency 2017). For example, studies of water hyacinth treatment have found that while hyacinth may lower DO and increase turbidity in and near hyacinth, herbicide treatment of the hyacinth restores conditions to those representative of the broader region (Tobias et al. 2019). Conrad et al. (2020:3) concluded that recent science demonstrates that current treatment methods and monitoring for submerged aquatic vegetation (SAV) are not sufficient for reducing coverage, particularly in habitats similar to those targeted for restoration. It is unknown whether management of nutrients could reduce the distribution and coverage of invasive aquatic macrophytes in the Delta (Dahm et al. 2016).

Interagency Ecological Program Monitoring

The Interagency Ecological Program (IEP) is a consortium of California State and U.S. federal agencies that guides and performs scientific research on the aquatic ecosystem of the Sacramento–San Joaquin Delta and San Francisco Bay. Beginning in 1970, the IEP has overseen a monitoring program that investigates the conditions of a number of ecosystem parameters, both biotic and abiotic in nature. Information gathered from these investigations, along with modeling and related research, is synthesized for use by the consortium agencies for decision-making purposes. DWR has contributed to the IEP for many years, both in terms of program governance (participating in and funding oversight and coordination, and helping to develop goals, strategies, and annual work plans) as well as performance or funding of the scientific activities, or both, of annual work plans. Table 12-2 highlights the 2021 IEP Work Plan activities that DWR is either performing or funding that are relevant to native fishes. The name and description of each activity is taken directly from the 2021 IEP Work Plan Element Details (Interagency Ecological Program 2021). As described by Interagency Ecological Program (2021:10), Reclamation and CDFW initiated an expedited review and redesign process so that potential survey improvements can be implemented as soon as possible. This applies to the Fall Midwater Trawl survey, the Summer Townet Survey, the Spring Kodiak Trawl survey, the 20-mm Survey, and the Smelt Larva Survey.

Table 12-2. Interagency Ecological Program 2021 Work Plan Activities Performed or Funded by the California Department of Water Resources

Action	Description
Fall Midwater Trawl Survey	The FMWT Survey provides long-term abundance trend information for age-0 striped bass, age-0 American shad, splittail, threadfin shad, delta smelt, and longfin smelt. These data will be used by CDFW personnel in conjunction with other survey data to determine species status and to evaluate the success of various mitigation and restoration plans for fishes in the estuary.
Summer Townet Survey	The Summer Townet Survey samples throughout the summer with a towed, small mesh net from eastern San Pablo Bay throughout the Delta to monitor the annual abundance and distribution of juvenile fish in the upper estuary and evaluate factors affecting abundance. Annual delta smelt and striped bass indices are used to track long-term trends of relative abundance. Water quality profile and simultaneous zooplankton samples are collected as well. Data from this element was used to help determine the conservation status of delta smelt, longfin smelt, and splittail.
Estuarine and Marine Fish Abundance and Distribution Survey	The primary objective of this element is to determine the effects of freshwater outflow and outflow-related mechanisms on the abundance and distribution of estuarine and marine fishes and brachyuran crabs. The monthly midwater and otter trawling survey (since 1980) samples at 52 channel and shoal stations from South San Francisco Bay to the lower Sacramento and San Joaquin Rivers, and tracks abundance and distribution trends of marine and estuarine fishes. Data are used to assess the status of marine and estuarine fishes in the estuary, as required by Water Right Decision 1641 (D-1641). (Note: This is part of the CDFW Bay Study.)
Bay Shrimp and Crab Abundance and Distribution Surveys	The study is designed to sample young (age-0) fishes and crabs and juvenile and adult shrimp from open water, soft bottom habitats deeper than 3 meters. For the shrimp program element, the Bay Study calculates and reports annual abundance indices and abundance trends for six common species of shrimp. The program also tracks and reports seasonal abundance patterns and annual and seasonal distributional patterns

Action	Description
	for these species. Ultimately, the abundance trends and distributional patterns are related to physical factors - primarily freshwater outflow, but also ocean and estuarine water temperature, ocean upwelling, and ocean climate indices, such as the Pacific Decadal Oscillation and North Pacific Gyre Oscillation. The goal is to determine what factors may control recruitment and distribution of the most important estuarine and marine shrimp that rear and reside in the San Francisco Estuary.
San Francisco Bay Salinity and Temperature Monitoring	This element samples salinity and water temperature in San Francisco Bay. Data are used to better understand the hydrodynamics of the estuary and calibration of multidimensional flow and transport models. Understanding how these variables are distributed around the Bay leads to a better understanding of habitat types and fish distribution in the Bay. Time series of water temperature and specific conductance samples (salinity is calculated from conductivity and water temperature) are needed (1) to improve our understanding of the hydrodynamics of the estuary (e.g., gravitational circulation), (2) for calibration of multidimensional flow and transport models of the Bay, (3) to better understand the distribution of physiochemical habitat types throughout the Bay, and (4) to provide supporting data for numerous estuarine studies of the Bay and Delta.
Delta Flows Network	The Delta Flows Network consists of 35 flow and water quality monitoring stations located throughout the Sacramento–San Joaquin Delta; 11 of these stations are supported by IEP. Data from this network of stations are used by Delta managers and scientists to make real-time decisions and plan for future events, such as climate change, water operations, restoration projects, evaluations of fish transport, and migration issues. In addition, these data are used to calibrate and validate numerical models that are used to predict water levels, flow speeds, and spatial and temporal evolution of salinity in the Delta. The data collected at these stations are critical for understanding the circulation and mixing patterns in the complex and interconnected channels that comprise the Delta region. Understanding Delta hydrodynamics is imperative to understanding the impacts of proposed major infrastructure projects and the regulatory actions being taken to protect endangered species in the Delta.
20-mm Survey Delta Smelt	This element is a fine-mesh trawl survey that monitors larval and juvenile delta smelt and longfin smelt distribution throughout its historical spring range in the Sacramento–San Joaquin Delta and San Francisco Estuary. Zooplankton sampling and water quality sampling are conducted simultaneously. Sampling is conducted every 2 weeks from mid-March through mid-July at 35 to 40 stations from eastern San Pablo Bay through the Delta. The near-real-time sample processing enables distribution data to be used by agency managers in the Smelt Working Group to assess the risk of delta smelt and longfin smelt entrainment.
Juvenile Salmon Monitoring (DJFMP)	This element will conduct weekly beach seining (year-round) within the lower Sacramento River and Delta, weekly seining in the lower San Joaquin River (January through June), and biweekly seining in San Francisco Bay and San Pablo Bay (November through June) to monitor the relative abundance and distribution of juvenile Chinook salmon in unobstructed near-shore habitats. In addition, year-round surface trawling is conducted at Chipps Island and Sacramento to monitor juvenile Chinook salmon abundance entering and exiting the Delta. Surface trawling at Mossdale is conducted from July to March to monitor the abundance and temporal distribution of juvenile Chinook salmon entering the Delta. The surface trawling at Mossdale is conducted in cooperation with CDFW, which monitors at Mossdale from April to June.

Action	Description
Coleman National Fish Hatchery Late Fall–Run Production Tagging	This element consists of coded-wire tagging of all Coleman National Fish Hatchery late fall–run production to ensure proper race identification during subsequent recovery of fish at Delta export facilities and in juvenile and adult sampling programs. Approximately 1,100,000 late fall–run Chinook salmon will be marked and tagged each year. Recovery of tagged late fall–run Chinook salmon is also part of the spring-run Chinook salmon recovery plan.
Mossdale Spring Trawl	This study is part of an overall effort to provide "near-time" information on the relative vulnerability of key fish species (primarily Chinook Salmon and steelhead) to water project operations. This supports CDFW's Region 4 field work as well as collation and reporting of data from the Mossdale trawl-sampling program from April through June. Sampling results are made available within 48 hours via the Internet.
Environmental Monitoring Program	This element monitors water quality at 22 sites in San Pablo Bay, Suisun Bay, and the Delta in compliance with D-1641. In addition to basic water quality parameters, chlorophyll, phytoplankton, benthic, and zooplankton (at a subsample of stations) samples are collected. Continuous collection of water quality data for multiple parameters, including electrical conductivity or salinity, is telemetered to the California Data Exchange Network, and the data are available on a near real-time basis for day-to-day CVP and SWP operational decisions. Identification and enumeration of phytoplankton and benthic organisms, water quality constituents, and quality control samples should be available within 2 months of collection.
San Joaquin River Dissolved Oxygen Monitoring	DWR's Bay-Delta Monitoring and Analysis Section has been monitoring DO levels in the Stockton Ship Channel during the late summer and fall since 1968. As low DO levels can have adverse impacts on fisheries and other beneficial uses of the waters within the Delta, the State Water Resources Control Board established specific water quality objectives to protect these uses. This objective is established to protect fall-run Chinook salmon and applies to the lower San Joaquin River between Stockton and Turner Cut, which includes the eastern channel. Data are used to guide water project operations and barrier placement per the baseline objectives.
Central Valley Juvenile Salmon and Steelhead Monitoring (Knights Landing)	The data collected (since 1995) provide an early warning of when juvenile salmon outmigrate toward the Delta and allows for real-time adaptive management of water operations. This sampling effort uses paired 8-foot rotary screw traps located near the town of Knights Landing. The season begins in October and continues through June of the following year. For salmonids specifically, data collection includes enumeration by life stage, race, fork lengths, and wet weight for assessing the condition factor of individual fish. A subsample of captured adipose fin-clipped (hatchery origin) Chinook salmon are held for coded-wire tag reading to assess outmigration rates of fish released from upstream hatcheries. In addition, a percentage of fall-run Chinook salmon are marked and recaptured as part of calculating passage. The daily catch is summarized and distributed by email to agency representatives and water operations managers.
Upper Estuary Zooplankton Sampling	As a means of assessing trends in fish food resources, the Zooplankton Study has estimated the abundance of zooplankton taxa in the upper San Francisco Estuary since 1972, and it is part of a D-1641 mandate to monitor water quality and related parameters. Sampling with three gear types occurs monthly at 22 stations located throughout San Pablo Bay, Suisun Marsh, Suisun Bay, and the Delta.

Action	Description
Spring Kodiak Trawl	This program element provides detection of mature and maturing delta smelt from January through May. Improved detection of delta smelt will better inform water export facility operators of the potential to entrain adult delta smelt in subsequent weeks, as well as their offspring later in the year. Monthly Kodiak trawl sampling occurs from the Napa River and Carquinez Straight through the Delta. The data collected indicate the distribution and maturity status of adult delta smelt and the occurrence of spent female delta smelt, as an indication of the onset of larval recruitment in the Delta. Data are provided shortly after sampling to the Smelt Working Group and Water Operations Management Team.
UC Davis Suisun Marsh Fish Monitoring	The study (since 1979) monitors fish populations in Suisun Marsh, especially in response to modifications being made on the way water moves through the marsh. Monthly sampling is conducted within 21 sites among nine sloughs in Suisun Marsh, using a combination of otter trawls and beach seines. The objectives of the study are to understand the entire assemblage of fishes in the marsh by examining such factors as changes in species abundance and composition through time, fish use of various habitats within the marsh, and changes in fish assemblages in association with natural and anthropogenic change. This study informs management decisions and provides the key background information needed to determine the success of marsh restoration projects.
Smelt Larva Survey	This survey provides near real-time distribution data for longfin smelt larvae in the Delta, Suisun Bay and Suisun Marsh. Data are used by agency managers to assess vulnerability of longfin smelt larvae to entrainment in south Delta export pumps. Sampling begins within the first 2 weeks in January and repeats every other week through the second week in March. The data are used to assist CDFW, USFWS, and the Smelt Working Group in assessing the risks of entrainment by the SWP and CVP and determining the Old and Middle River levels designed to minimize take of juvenile longfin smelt at these facilities.
Juvenile Salmon Emigration Real-Time Monitoring	For this element, beach seining and surface trawling are conducted 3 days/week from October 1 to January 31 near Sacramento to detect the arrival of older juvenile Chinook salmon entering the Delta. Monitoring data are used to inform Delta Cross Channel Gate closure decisions from October 1 to December 15 in order to minimize the diversion and mortality of outmigrating juvenile winter-run-sized Chinook salmon. These data also were and will continue to be used to inform biological opinions and drought operations planning decisions.
Tidal Wetland Monitoring Pilot Study	The CDFW Fish Restoration Program will collect fish and invertebrate data near existing and planned tidal wetlands. These data will provide information on how fish and invertebrate communities change pre-/post-restoration. A suite of sampling gears will be deployed to capture fish and invertebrates throughout the year to characterize their use, relative abundance, and community compositions at tidal wetlands. Over time, the Fish Restoration Program will assess the effectiveness of tidal wetland restoration as it relates to providing food sources and habitat refuge for at-risk native fishes.
Adult Striped Bass Population Estimates	This element tags and releases striped bass, monitors the fishery, monitors the tagged: untagged ratio of striped bass, and synthesizes data collected. It provides population metrics such as harvest rate, survival rate, and abundance estimates. This element makes recommendations for management of the striped bass population and fishery.
Adult Sturgeon Population Estimates	This element tags and releases white sturgeon, monitors the white sturgeon fishery, monitors the tagged: untagged ratio of white sturgeon, and synthesizes data collected. It provides population metrics such as harvest rate, survival rate, and abundance estimates. This element makes recommendations for management of the white sturgeon population and fishery, including bycatch of green sturgeon.

Action	Description
Yolo Bypass Fish Monitoring Program (YBFMP)	The objectives of this interdisciplinary monitoring effort are to collect baseline data in the Yolo Bypass on lower trophic levels (phytoplankton, zooplankton, and aquatic insects), juvenile and adult fish and water quality. Understanding the specific environmental conditions that trigger migrations and enhanced survival and growth of native fishes (especially salmon and smelt) are of critical importance for restoration efforts, and the Yolo Bypass is a critical linkage in the health of fish populations and the entire bay delta ecosystem. Furthermore, the mechanisms through which lower trophic organisms reach higher abundance in the Yolo Bypass are not well understood. The YBFMP will serve to fill in these information gaps. The Yolo Bypass has been identified as a high restoration priority by the NMFS and USFWS Biological Opinions for delta smelt, winter- and spring-run Chinook salmon. The YBFMP informs the restoration actions that are mandated or recommended in these plans, provides valuable response data for adaptively managing bypass weirs, and provides critical baseline data on floodplain ecology.
Liberty Island Fish Survey (DJFMP)	Liberty Island is a restoring wetland that provides important habitat for species of management concern, including delta smelt and Chinook salmon. This element will currently focus on summarizing data that has been previously collected under this project. This includes monthly beach seining, and larval and zooplankton trawls from February through June, which provide baseline data and serve as a reference site for future restoration efforts at Liberty Island. (Note: This is part of the US Fish and Wildlife Service Delta Juvenile Fish Monitoring Program.)
Salmon Survival Studies (DJFMP)	The objective of this task is to assess juvenile salmon survival in the south Delta and to determine the relative importance of factors influencing salmon survival as they move through the Delta. The results are used to inform several management groups (i.e., the Collaborative Adaptive Management Team's Salmonid Scoping Team workgroup).
Estimation of Pelagic Fish Populations	This element will refine design- and model-based estimates of the abundances of different life stages of delta smelt needed to assess the effectiveness of management actions on the population dynamics and the likelihood of population recovery. Previous work produced estimates for post-larvae, juveniles, sub-adults, and adults. This element will finalize and apply gear efficiency measures used to account for gear selectivity bias in catch data and consequently will standardize data across surveys, incorporate improved estimates of Delta water volumes that are needed to calculate abundances, formally compare the abundance estimates produced by two methods (design and model-based), extend our estimates to other life stages (e.g., larvae), and extend the estimates further back in time for life cycle modeling purposes (right now the model covers the period from 1990 to 2015).
Statistical Support Delta Smelt Life Cycle Model	The Delta Smelt Life Cycle Model is a state-space model designed (1) to provide a quantitative, empirically based decision support tool for assessing the effects of management actions and environmental conditions on the population dynamics of delta smelt; (2) to suggest management actions; (3) to provide guidance and recommendations for future data needs and data collection procedures; and (4) to carry out Population Viability Analysis to predict the long-term consequences of particular actions. The work this year will refine Delta Smelt Life Cycle Model(s) and assess data gaps, assess factors that may influence reproductive success and survival processes, and carry out a Population Viability Analysis to investigate the effects of potential recovery efforts.

Action	Description
Feasibility of Improving Juvenile Chinook Salmon Monitoring in the Upper San Francisco Estuary through Enhanced Delta Smelt Monitoring	This study aims to evaluate the extent to which the Enhanced Delta Smelt Monitoring (EDSM) data can complement concurrent monitoring of juvenile salmonids in the upper San Francisco Estuary. A synthesis of juvenile Chinook salmon data collected from the EDSM and other IEP long-term monitoring programs will be conducted to better understand the species' migration in the estuary and their behavioral diversity. Results from this synthesis effort will allow better understanding of juvenile salmon outmigration in the estuary and may help inform the development of future salmon monitoring program.
Status, Trends and Distribution of Cypriniform Fishes Native to the Sacramento-San Joaquin Delta, CA	Aside from the previously listed Sacramento Splittail (*Pogonichthys macrolepidotus*), little is known about the current status, trends, and distribution of the native cypriniform fish species in the Sacramento-San Joaquin Delta. The historical distributions of Sacramento Pikeminnow (*Ptychocheilus grandis*), Hitch (*Lavinia exilicauda*), and Sacramento Sucker (*Catostomus occidentalis*) cover a fairly broad geographic area in the San Francisco Estuary. However, there has been no systematic investigation of the abundance and distribution trends for these cypriniform species and there is some evidence suggesting that these native species today exist only in scattered, small populations around the Delta. This effort will address knowledge gaps associated with these species.
Flow Alteration (FLOAT) Synthesis: Update Including 2018 and 2019	In water year of 2018, there was an opportunity to study the response of delta smelt and their ecosystem to two major flow alteration actions intended to improve the status of delta smelt: Suisun Marsh Salinity Control Gate Operation in Summer and the North Delta Foodweb Action in the Summer-Fall. Also, 2019 was a wet year and wet years are hypothesized to be beneficial for the delta smelt population. There is a need to assess the data collected before, during, and after these events to assess their effects on the delta smelt population.
Synthesis of IEP Zooplankton Sample Methodologies and Variation in Zooplankton Communities across Habitats	The objective of this IEP Synthesis project is to assess and describe the variation in sampling and lab processing methodologies used for zooplankton across different IEP monitoring programs and special studies. The project is to review the various field collection, lab processing, and organism identification methodologies employed by different programs, and to devise methodologies to better integrate datasets. An integrated dataset will be produced that may be useful for performing comparative analyses that are not possible using data from single surveys. It is hoped to use the integrated dataset to explore variation in zooplankton communities across habitat types, environmental covariates, and Delta regions.
Landscape-Scale Analysis of Aquatic Vegetation Response to Treatment	Floating, submerged and emergent invasive plant species are now ubiquitous in the Delta and may have profound effects on physical habitat as well as foodweb dynamics for fish species of management concern. This study is an IEP Synthesis effort that will integrate a historical and ongoing dataset of the Delta invasive aquatic vegetation (IAV) coverage and DBW IAV treatment records for the past 14 years. It seeks to determine if treatment efficacy differs across space (e.g., different habitat types) and time. It will assess the impact of IAV control effort on the distribution, growth rate, spread and persistence, and species richness and community composition of the IAV communities.
Understanding Climate Change Tools for San Francisco Estuary Analyses and Investigation of Thermal Refugia in Warming Waters	This element will form an IEP Climate Change Project Work Team, which will conduct a synthesis of completed research relevant to climate change and an assessment of available modeling tools for future research. In a quantitative effort, a sub-team of the Project Work Team will analyze spatial and temporal patterns in water temperature using continuously collected data. The latter effort will include assessments of water temperature conditions as they relate to individual species' physiology and identify areas that may offer thermal refugia while other areas may exceed thermal thresholds for heat stress or lethal limits.

Action	Description
Estimating Abundance of Juvenile Winter-run Chinook Salmon Entering and Exiting the Delta (SAIL)	This is a continuation of a 5-year project funded by DWR and CDFW and the Central Valley Project Improvement Act in 2017. The objective of the project is to improve estimates of population abundances for juvenile fall-, winter-, and spring-run Chinook salmon at Sacramento and Chipps Island by improving trawl efficiency estimates through the use of data from releases of coded-wire tags and acoustic tags and by genetically sampling the trawl catch in 2018. The project will (1) develop statistical models for estimating trawl efficiencies from 2016–2018 data for paired acoustic tag/coded-wire tag releases of winter-run and fall-run Chinook salmon; (2) use 2018 genetic sampling of trawl catch in combination with efficiency estimates to estimate population abundances of fall-, spring-, and winter-run Chinook salmon at Sacramento and Chipps Island in 2018; (3) implement trawl efficiency studies for multiple salmon runs in 2018, which are informed by the 2016 and 2017 results and implemented in coordination with hatcheries for inclusion of acoustic tag fish with existing coded-wire tag releases; and (4) combine trawl efficiencies with genetic samples of trawl catch to provide estimates of fall-, spring-, and winter-run Chinook salmon (with estimated precision) entering and exiting the Delta in 2018.
Patterns of Biodiversity and Biotic Homogenization of the Sacramento-San Joaquin Delta	Habitat alteration and introduction of alien species have substantially changed communities and foodwebs of the Sacramento-San Joaquin Delta. This study will evaluate how fish community diversity of the Delta has changed over time and assess whether fish communities in the various regions within the Delta have become more homogeneous in recent years.
Quantitative Analysis of Stomach Contents and Body Weight for Pelagic Fishes	The Diet and Condition study has provided information on the food habits of pelagic fishes in the estuary since 2005. The study focuses on the temporal and spatial differences in diet composition and feeding success of delta smelt, striped bass, threadfin shad, longfin smelt, Mississippi silversides, and American shad.
Aquatic Habitat Sampling Platform: Platform Utility and Delta Implementation Studies	The Aquatic Habitat Sampling Platform (Sampling Platform) is a 26-foot boat, with adjustable concentrator net and smaller drift net attached to an adjustable sample chamber, containing cameras, water sampling equipment, and water quality sensors integrated with fish finder, GPS, and other data recording equipment. Depth of net opener brace can be adjusted. Images of organisms that pass through the live box are recorded via high definition, binocular video camera to facilitate enumeration, species identification and estimation of organism length. These organisms then re-enter the water column via the stern of the boat without physical handling. The Sampling Platform is an integrated aquatic species and habitat sampling system that can effectively sample fish and invertebrates and reveal habitat associations while having minimal or no "take" of sensitive species. The sampling apparatus is suspended by hydraulic arms allowing fine-scale adjustments to sampling depth during operation. Additionally, the sampling apparatus frame is attached via bolt and shear pin system to allow the frame to "break-free" if something solid is encountered. Wheels attached to the net frame bottom allow the frame to roll over obstacles, reducing impact and facilitating continued sampling across variable habitats. Deployment of this versatile sampling system expands data collection to shallow and off-channel habitat, while offering the capability to transition to deeper and open water habitats, providing for reliable estimates of sampling efficiency and "catch" per unit effort and improving our knowledge about populations, habitat associations and major stressors of key organisms.

Action	Description
Suisun Marsh Salinity Control Gate Study	The Suisun Marsh Salinity Control Gate (SMSCG) has been identified as a management tool to improve habitat conditions for delta smelt in summer-fall. The proposed effort is the scientific evaluation of the project. Much of the evaluation will be based on existing IEP surveys and instrumentation (e.g., Environmental Monitoring Program, Summer Townet Survey, Fall Midwater Trawl, Enhanced Delta Smelt Monitoring), but will include some additional evaluation tools such as the deployment of hatchery delta smelt in custom cages at strategic locations during the SMSCG action.
Using Delta Smelt Enclosures to Support Species Recovery	Very little is known about the ability of captive-born delta smelt to survive under a range of field conditions, yet there are plans to use cultured delta smelt to evaluate management actions and support species recovery through population supplementation. Therefore, it is essential to determine under what circumstances they can be held in enclosures in the field. A critical related question regarding supplementation is if, and to what extent, levels of domestication of captive-born delta smelt affect their ability to survive in the wild.
North Delta Flow Action: Role of Improved Yolo Bypass Flows on Delta Foodweb Dynamics	In a collaborative effort between DWR, Bureau of Reclamation, CDFW, USFWS, USGS, and San Francisco State University, this project monitors and evaluates the effects of augmented summer and fall flows in the Yolo Bypass and North Delta areas on lower trophic foodweb dynamics and benefits to listed fish species. Using both continuous and discrete sampling approaches, this study will relate hydrologic patterns to chlorophyll-a, nutrients and primary productivity rates, plankton densities and composition (phytoplankton and zooplankton), contaminant concentrations, as well as water quality parameters such as electrical conductivity, turbidity, and dissolved oxygen.

Source: Interagency Ecological Program 2018, 2021.

BDCP = Bay Delta Conservation Plan; BiOp = biological opinion; CDFW = California Department of Fish and Wildlife; CVP = Central Valley Project; DO = dissolved oxygen; DWR = California Department of Water Resources; FMWT = Fall Midwater Trawl; IEP = Interagency Ecological Program; NMFS = National Marine Fisheries Service; POD = pelagic organism decline; SWP = State Water Project; USFWS = U.S. Fish and Wildlife Service; USGS = U.S. Geological Survey.

Rio Vista Estuarine Research Station and Fish Technology Center

DWR is overseeing the creation of the Rio Vista Estuarine Research Station and Fish Technology Center to coordinate and consolidate research and monitoring efforts in support of delta smelt management and to create facilities to house populations of smelt as a guard against extinction. DWR is working with other resource agencies and universities to determine the best strategy for developing a conservation hatchery program for delta smelt,[3] which may lead to a future option to reintroduce cultured smelt into the wild to bolster the wild population until suitable habitat has been restored to aid in species recovery.

DWR published the final EIR along with the final EIS for the Rio Vista Estuarine Research Station in 2017. During 2018, USFWS and NMFS also released BiOps for the project, and DWR certified the project as consistent with the Delta Stewardship Council's Delta Plan. Currently, DWR is working

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[3] As part of these efforts, and as described in detail by CDFW (2021:10), the Experimental Release of Delta Smelt Project proposes to annually release up to 60,000 adult equivalents of surplus hatchery origin delta smelt each year into a portion of the current range of the species for a three-year period (2021–2024). The purpose of the Experimental Release of Delta Smelt Project is as part of an early experimental release effort to inform the feasibility of potential future supplementation efforts. The hatchery delta smelt are propagated at the University of California Davis Fish Conservation and Culture Laboratory in Byron, California. The Experimental Release of Delta Smelt Project relies on ongoing monitoring performed by the IEP and the U.S. Fish and Wildlife Service's Enhanced Delta Smelt Monitoring Program.

with USFWS and the Rio Vista Army Base to address federal funding needed for both the Rio Vista Estuarine Research Station and the Fish Technology Center. State funding has been secured for Rio Vista Estuarine Research Station.

Suisun Bay/Marsh

Aquatic Habitat

Suisun Marsh is a brackish-water marsh bordering the northern edge of Suisun Bay. The description in this section draws largely on work by Siegel et al. (2010). Most of its marsh area consists of diked wetlands managed for waterfowl, and the rest of the acreage consists of tidally influenced sloughs and emergent tidal wetlands (Suisun Ecological Workgroup 2001:20–24). The central latitudinal location of Suisun Marsh within the San Francisco Estuary makes it an important rearing area for euryhaline freshwater, estuarine, and marine fishes. Many fish species that migrate or use Delta habitats are also found in the waters of Suisun Bay. Tides reach Suisun Bay and Suisun Marsh through the Carquinez Strait, and most freshwater flows enter at the southeast border of Suisun Marsh at the confluence of the Sacramento and San Joaquin Rivers. The mixing of freshwater outflows from the Central Valley with saline tidal water in Suisun Bay and Suisun Marsh results in brackish water with strong salinity gradients, complex patterns of flow interactions, and generally the highest biomass productivity in the entire estuary (Siegel et al. 2010).

Flow, turbidity, and salinity are important factors influencing the location and abundance of zooplankton and small prey organisms used by Delta species (Kimmerer et al. 1998). The location where net current flowing inland along the bottom reverses direction and sinking particles are trapped in suspension is associated with the higher turbidity known as the estuarine turbidity maximum (Schoellhamer 2001). Zooplanktonic organisms maintain position in this region of historically high productivity in the estuary through vertical movements (Kimmerer et al. 1998).

Salinity in the Suisun Marsh and Bay system is a major water quality characteristic that strongly influences physical and ecological processes. Many fish species native to Suisun Marsh require low salinities during the spawning and rearing periods (Suisun Ecological Workgroup 2001:88; Kimmerer 2004; Feyrer et al. 2007, 2011; Nobriga et al. 2008). The Suisun Marsh and Bay usually contain both the maximum estuarine salinity gradient (i.e., greatest difference between high and low salinity) and the low-salinity zone. The overall estuarine salinity gradient trends from west (higher) to east (lower) in Suisun Bay and Suisun Marsh. The location of the low-salinity zone is influenced by outflow. Suisun Marsh also exhibits a persistent north-south salinity gradient. Despite low and seasonal flows, the surrounding watersheds have a significant water freshening effect because of the long residence times of freshwater inflows to the marsh, including discharges from the upper sloughs and wastewater effluent. The larger of these surrounding watersheds include Suisun, Green Valley, Ledgewood, Laurel, McCoy, and Union Creeks (Siegel et al. 2010:1-18).

The Suisun Bay and Suisun Marsh system contains a wide variety of habitats such as marsh plains, tidal creeks, sloughs, channels, cuts, mudflats, and bays. These features and the complex hydrodynamics and water quality of the system have historically fostered significant biodiversity within Suisun tidal aquatic habitats, but these habitats, like the Delta, have also been significantly altered and degraded by human activities over the decades.

Categories of tidal aquatic waters include bays, major sloughs, minor sloughs, and the intertidal mudflats in those areas (Engle et al. 2010). These tidal waters total approximately 26,000 acres, with the various embayments totaling about 22,350 acres. Tidal slough habitat is composed of major and minor sloughs. Major sloughs of Suisun Marsh have a combined acreage of about 2,200 acres consisting of both shallow and deep channels. Minor sloughs are made up of shallow channel habitat and have a combined acreage of about 1,100 acres. Habitats in Suisun Marsh bays and sloughs support a diverse assemblage of aquatic species that typically use open water tidal areas for breeding, foraging, rearing, or migrating. As part of the SWP long-term operations authorized by the CDFW (2020a) ITP, the Suisun Marsh Salinity Control Gates on Montezuma Slough are to be operated for up to 60 days (not necessarily consecutive) in June through October of below-normal and above-normal years, and for 30 days (not necessarily consecutive) in dry years following below-normal years. A number of tidal habitat restoration projects have been completed or are underway in Suisun Marsh (California Department of Water Resources 2019a).

Fish Entrainment

DWR and Bureau of Reclamation (Reclamation) constructed several facilities to provide lower-salinity water to managed wetlands in Suisun Marsh, including the Roaring River Distribution System, Morrow Island Distribution System, and Goodyear Slough Outfall. Other facilities constructed under the Suisun Marsh Preservation Agreement that could entrain fish include the Lower Joice Island and Cygnus Drain diversions.

The intake to the Roaring River Distribution System is screened to prevent entrainment of fish larger than approximately 1 inch (approximately 25 millimeters). DWR monitored fish entrainment from September 2004 through June 2006 at the Morrow Island Distribution System to evaluate entrainment losses at the facility. Monitoring took place over several months under various operational configurations and focused on delta smelt and salmonids. More than 20 species were identified during the sampling, but only two juvenile Chinook salmon the size of fall-run Chinook salmon were observed, at the South Intake of the Distribution System in 2006, and no delta smelt from entrained water were observed (Enos et al. 2007). The total number of longfin smelt collected in entrainment monitoring was nearly 120 in 2004/2005 and 6 in 2005/2006 (Enos et al. 2007:16). The Goodyear Slough Outfall system is open for free fish movement except near the outfall when flap gates are closed during flood tides (Bureau of Reclamation 2008:13-124). Conical fish screens have been installed on the Lower Joice Island diversion on Montezuma Slough.

Yolo Bypass

Aquatic Habitat

Aquatic habitats in the Yolo Bypass include stream and slough channels for fish migration and when flooded, seasonal spawning habitat and productive rearing habitat (Sommer et al. 2001a,b; CALFED Bay-Delta Program 2000:311; Takata et al. 2017). During years when the Yolo Bypass is flooded, it serves as an important migratory route for juvenile Chinook salmon and other native migratory and anadromous fishes moving downstream. During these times, it provides juvenile anadromous salmonids an alternative migration corridor to the lower Sacramento River (Sommer et al. 2003) and, sometimes, better rearing conditions than the adjacent Sacramento River channel (Sommer et al. 2001a,b, 2005). When the floodplain is activated, juvenile salmon can rear for weeks to months in the Yolo Bypass floodplain before migrating to the estuary (Sommer et al. 2001a,b). Research on the Yolo Bypass has found that juvenile salmon grow substantially faster in the Yolo Bypass floodplain than in the adjacent Sacramento River, primarily because of the greater availability of invertebrate prey in the floodplain (Sommer et al. 2001a,b, 2005). Increased frequency and duration of connectivity between the Sacramento River and the Yolo Bypass may increase off-channel rearing opportunities that expand the life history diversity portfolio for Central Valley Chinook salmon (Takata et al. 2017). When not flooded, the lower Yolo Bypass provides tidal habitat for young fish that enter from the lower Sacramento River via Cache Slough Complex—a network of tidal channels and flooded islands that includes Cache Slough, Lindsey Slough, Liberty Island, the Sacramento Deepwater Ship Channel, and the Yolo Bypass (McLain and Castillo 2009).

Sommer et al. (1997) found statistically significant correlations of Sacramento splittail abundance indices with Yolo Bypass inundation, reflecting floodplains providing abundant food, spawning and rearing habitat, and possibly reduced losses of eggs and larvae to aquatic predators. Because the Yolo Bypass is dry during summer and fall, nonnative species (e.g., predatory fishes) generally are not present year-round except in perennial water sources (Sommer et al. 2003). In addition to providing important fish habitat, winter and spring inundation of the Yolo Bypass supplies phytoplankton and detritus that may benefit aquatic organisms downstream in the brackish portion of the San Francisco Estuary (Sommer et al. 2004; Lehman et al. 2008b).

The benefit of seasonal inundation of the Yolo Bypass has been studied by DWR as part of the Delta Smelt Resiliency Strategy, which was developed in 2016 by DWR and other state and federal resource agencies to boost both immediate- and near-term reproduction, growth rates, and survival of delta smelt (California Natural Resources Agency 2016; Mahardja et al. 2019). The Yolo Bypass has been identified as a significant source of phytoplankton and zooplankton biomass to the Delta in the winter and spring during floodplain inundation. However, little was previously known about its contribution to the foodweb during the drier summer and fall months.

One action taken by DWR under the Delta Smelt Resiliency Strategy is the implementation of foodweb enhancement projects in the Yolo Bypass. Under this action, DWR worked with farmers as well as irrigation and reclamation districts to direct water through the Yolo Bypass in the form of flow pulses during summer and fall (Frantzich et al. 2018). The first examination of off-season flow pulses occurred in 2016 when a flow pulse of 12,700 acre-feet (AF) was released over 2 weeks in the summer. The second examination occurred during 2018 when a 19,821 AF flow occurred over 4 weeks in the fall. These flow pulses were followed in turn by a significant increase in phytoplankton biomass in the Cache Slough Complex and further downstream in the lower Sacramento River (California Natural Resources Agency 2017; California Department of Water Resources 2019b). The increase in phytoplankton biomass was also found to enhance zooplankton growth and production, thereby increasing food supplies for delta smelt and other Delta fish species. During the second year of implementing flow pulses, a managed flow pulse was generated in the fall of 2018. The 2018 Fall North Delta Flow Action generated a flow pulse of 19,821 AF over 4 weeks, which while not coinciding with a wave of phytoplankton moving through the Yolo Bypass, did result in an export of higher densities of zooplankton into downstream habitats of lower Cache Slough and the Sacramento River at Rio Vista (California Department of Water Resources 2019b).

Studies continued in 2019 on the issue of foodweb enhancement in the Yolo Bypass. Working with the Glenn-Colusa Irrigation District (GCID) and other partners, DWR tested the benefit of passing water through the Yolo Bypass to enhance delta smelt habitat in the north Delta region (Davis et al. 2019). The action was expected to generate a seasonal positive flow pulse through the Yolo Bypass Toe Drain, which was expected to benefit the foodweb in downstream areas for fishery resources. DWR altered the operation of the Knights Landing Outfall Gates and Wallace Weir to direct agricultural return flows from the Colusa Basin Drain through Ridge Cut Slough and Wallace Weir into the Yolo Bypass between late August and late September. The results of this study were reported by Twardochleb et al. (2021:3): the quantity of plankton (fish food) in the Yolo Bypass increased, but not downstream in the lower Sacramento River. In addition, more nutritious diatoms grew in the Yolo Bypass after the flow pulse than before, providing food for zooplankton. Collaborator studies provided evidence that the 2019 flow action did not negatively affect growth or survival of delta smelt or Chinook salmon. Despite these benefits to the foodweb, increased contaminant loads and low nutrient availability in the flow pulse water could have affected the magnitude of foodweb responses. Moreover, the 2019 flow action did not increase food availability downstream by as much as the 2016 flow action using diversions of Sacramento River water. Twardochleb et al. (2021:3) concluded that future studies, including repeating the 2016 flow action using Sacramento River water and an upcoming flow action synthesis comparing the results of managed flow pulses on the north Delta foodweb from 2011 to 2019, will help them assess the effects of source water (agricultural return flows vs. Sacramento River), and other mediating factors such as hydrology, to adaptively manage the flow action to maximize food availability downstream.

Potential negative effects of the north Delta foodweb enhancement action include straying of adult Chinook salmon. Twardochleb et al. (2021:32) summarized the information related to the 2019 study. They noted CDFW monitored fish straying into the Yolo Bypass using gill nets, fyke trapping and the Wallace Weir Fish Rescue Facility data during and after the 2019 managed flow pulse. Around the timing of the end of the pulse, salmonids were caught in the Rescue Facility; however, this overlapped with the normal occurrence of straying, beginning around October or November. Of 363 salmonids caught and transported, there were 11 mortalities. This suggests that the flow pulse had only minor effects on salmon and showed that the fish rescue facility can help to mitigate natural straying and mortalities. DWR and CDFW plan to continue monitoring salmon during subsequent managed flow pulses and are currently conducting a synthesis of factors influencing straying.

Bureau of Reclamation and DWR (2019) concluded that increases in Yolo Bypass floodplain inundation as a result of the notching of Fremont Weir under the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Program would result in beneficial impacts on fish, which reflect mechanisms such as increased access for juveniles (Acierto et al. 2014), faster juvenile growth (Takata et al. 2017), and survival comparable to the mainstem Sacramento River (Hance et al. 2021; Pope et al. 2021).

Fish Passage

The Fremont Weir is a major impediment to fish passage and a source of migratory delay and loss of adult Chinook salmon, steelhead, and sturgeon (National Marine Fisheries Service 2009:611; Sommer et al. 2014). The Fremont Weir creates a migration barrier for a variety of species, although fish with strong jumping capabilities (such as salmonids) may be able to pass the weir at higher flows. In 2018, DWR implemented the Fremont Weir Adult Fish Passage Modification Project. The project replaced an old, undersized, inefficient fish ladder in the center of the weir with a wider and deeper gate structure. The gate structure is equipped with two Adaptive Resolution Imaging Sonar (ARIS) cameras that aid in quantifying the structure's effectiveness. In 2019, DWR (2020b) recorded 261 hours of ARIS footage. This showed at least 70 sturgeon and more than 4,000 other adult fish volitionally passed through the structure, fish that would have most likely become stranded in the Bypass without the new fish passage structure (California Department of Water Resources 2020b:iii).

Some adult winter-run, spring-run, and fall-run Chinook salmon and white sturgeon migrate into the Yolo Bypass via the Toe Drain and Tule Canal when there is no flow into the floodplain over the

Fremont Weir. Fyke trap monitoring by DWR has shown that adult salmon and steelhead migrate up the Toe Drain in autumn and winter regardless of whether the Fremont Weir spills (Harrell and Sommer 2003; Sommer et al. 2014). The Toe Drain does not extend to the Fremont Weir because the channel is fully or partially blocked by roads or other higher ground at several locations and fish are often unable to reach upstream spawning habitat in the Sacramento River and its tributaries (Harrell and Sommer 2003; Sommer et al. 2014). Other structures in the Yolo Bypass, such as the Lisbon Weir, and irrigation dams in the northern end of the Tule Canal may also impede upstream passage of adult anadromous fish (National Marine Fisheries Service 2009:611). Modifications to some of these structures were made as part of the Fremont Weir Adult Fish Passage Modification Project, and two agricultural road crossings were altered to improve fish passage.

In addition, sturgeon and salmonids attracted by high flows into the basin become concentrated behind the Fremont Weir, where they are subject to heavy illegal fishing pressure. Passage blockage of green sturgeon at Fremont Weir could have population-level consequences (Thomas et al. 2013).

Stranding of juvenile salmonids and sturgeon has been reported in the Yolo Bypass in scoured areas behind the weir and in other areas as floodwaters recede (National Marine Fisheries Service 2009:611; Sommer et al. 2005). However, Sommer et al. (2005) found most juvenile salmon migrated off the floodplain as it drained.

DWR and Reclamation have been working on the Yolo Bypass Habitat Restoration program, which is developing and implementing several restoration actions in the Yolo Bypass. Some of these actions are complete, or nearly complete, including the Wallace Weir Adult Fish Rescue Facility Project and the Fremont Weir Adult Fish Passage Modification Project. The Agricultural Road Crossing #4 project is currently at 95% design, with construction anticipated in 2023. Preconstruction work for the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project (also known as the “Big Notch”) occurred in fall 2021, with construction beginning in May 2022.

12.1.5 San Pablo and San Francisco Bays

12.1.5.1 Description of San Pablo and San Francisco Bays

Hydrologically, the Bay may be divided into two broad subdivisions with differing ecological characteristics: a southern reach consisting of South San Francisco Bay; and a northern reach composed of Central San Francisco, San Pablo, and Suisun Bays (The Bay Institute 1998:2-77; CALFED Bay-Delta Program 2000). The southern reach receives little freshwater discharge, leading to high salinity and poor circulation (high residence time). It also has more extreme tides. The northern reach, which directly receives Delta outflow, is characterized by less extreme tides and a pronounced horizontal salinity gradient, ranging from near full marine conditions in Central Bay to near freshwater conditions in Suisun Bay. Central Bay and Suisun Bay contain large islands, features not present in San Pablo Bay and South Bay (The Bay Institute 1998; CALFED Bay-Delta Program 2000). All of the bays except Central Bay include extensive marshlands. Suisun Bay is not treated in this section because it was covered with the Delta in a previous section.

Northern Reach—Central San Francisco and San Pablo Bays

In addition to tides and large-scale influences such as warmer/cooler regimes (e.g., North Pacific Gyre Oscillation; Feyrer et al. 2015b), ecological factors having the greatest influence on fish of Central San Francisco Bay and San Pablo Bay include freshwater inflow from rivers, wetlands, riparian vegetation, and aquatic habitat diversity. Habitats in these bays are tidal perennial aquatic habitat, tidal saline emergent wetland, seasonal wetland, perennial grassland, agricultural land, and riparian habitat. These habitats support a variety of native marine, estuarine, freshwater, and anadromous fish (CALFED Bay-Delta Program 2000). San Francisco Bay is designated as a coastal estuary Habitat Area of Particular Concern and eelgrass (*Zostera marina*) is designated as seagrass Habitat Area of Particular Concern for Pacific groundfish species. Fish species that currently depend on tidal marshes and adjoining sloughs, mudflats, and embayments include delta smelt, longfin smelt, Chinook salmon, green sturgeon, white sturgeon, Pacific herring (*Clupea pallasii*), starry flounder (*Platichthys stellatus*), Sacramento splittail, American shad, and striped bass (The Bay Institute 1998:2-83–2-84; CALFED Bay-Delta Program 2000; Baxter et al. 2008:3-7). Other fish commonly found in Central Bay include northern anchovy (*Engraulis mordax*), halibut, bay goby (*Lepidogobius lepidus*), white croaker (*Genyonemus lineatus*), Pacific staghorn sculpin (*Leptocottus armatus*), and marine surfperches. English sole (*Parophrys vetulus*), shiner surfperch (*Cymatogaster aggregata*), jacksmelt (*Atherinopsis californiensis*), topsmelt (*Atherinops affinis*), diamond turbot (*Hypsopsetta guttulata*), and speckled sand dab (*Citharichthys stigmaeus*) are common in shallow waters around Central Bay. The leopard shark (*Triakis semifasciata*), sevengill shark (*Notorynchus cepedianus*), and the brown smoothhound (*Mustelus henlei*) are abundant in the intertidal mudflats of the Central Bay. The sand substrate and rock outcrops in the Central Bay support recreational fish such as the California halibut, striped bass, rockfish, and lingcod (*Ophiodon elongatus*).

Southern Reach—South San Francisco Bay

The southern reach receives far less freshwater runoff and does not generally exhibit the type of estuarine circulation that occurs in the northern reach (The Bay Institute 1998:2-78). Salinity is characteristically high, often similar to nearshore ocean levels, but is generally homogeneous. The reach is characterized by a much higher residence time of water, and on average is flushed at about one-fourth the rate of the northern reach (The Bay Institute 1998:2-78).

The South Bay supports a primarily marine fish assemblage owing to its saline water environment. Fish species include planktivorous topsmelt, jacksmelt, bay pipefish (*Syngnathus leptorhynchus*), brown rockfish (*Sebastes auriculatus*), surfperches, surf smelt (*Hypomesus pretiosus*), longfin smelt, diamond turbot, arrow goby (*Clevelandia ios*), and staghorn sculpin (The Bay Institute 1998:2-84). Evidence of longfin smelt spawning in the lower Coyote Creek watershed with successful recruitment in years of high freshwater outflow was recently found by Lewis et al. (2020). Anadromous salmonids produced in tributaries to the South Bay include steelhead and Chinook salmon, the latter of which are considered hatchery-origin strays, although recent archaeological evidence suggests Chinook salmon were historically native to the Guadalupe River watershed (Lanman et al. 2021).

12.1.5.2 Habitat Conditions and Environmental Stressors in San Pablo and San Francisco Bay Area

Environmental stressors for fish populations in San Francisco and San Pablo Bays include water and sediment quality, exposure to toxic substances, reduction in Delta outflows, legal and illegal harvest, food availability, reduction in seasonally inundated wetlands, wave and wake erosion, introduced nonnative plant and animal species, and competition for food resources with nonnative fish and macroinvertebrates (e.g., filter feeding by the nonnative mollusks) (CALFED Bay-Delta Program 2000; Armor et al. 2005; Baxter et al. 2008:8).

12.2 Applicable Laws, Regulations, and Programs

The applicable laws, regulations, and programs considered in the assessment of project impacts on fish and aquatic resources are indicated in this section, in Section 12.3.1, *Methods for Analysis*, or the impact analysis, as appropriate. Applicable laws, regulations and programs associated with state and federal agencies that have a review or potential approval responsibility have also been considered in the development CEQA impact thresholds or are otherwise considered in the assessment of environmental impacts. A listing of some of the agencies and their respective potential review and approval responsibilities, in addition to those under CEQA, is provided in Chapter 1, *Introduction*, Table 1-1. A listing of some of the federal agencies and their respective potential review, approval, and other responsibilities, in addition to those under NEPA, is provided in Chapter 1, Table 1-2.

Of particular relevance to fish and aquatic resources are the California Endangered Species Act (Fish and Game Code § 2081(b)), the federal Endangered Species Act (Section 7), the federal Magnuson-Stevens Fisheries Conservation and Management Act, the State Water Resources Control Board Water Quality Control Plan for San Francisco Bay/Sacramento San Joaquin Delta Estuary, and the State Water Resources Control Board Decision 1641 (D-1641). The impact analyses in this chapter consider potential effects to fish and aquatic resources as a result of the proposed project or project alternatives including the environmental conditions resulting from these and other regulations. A summary of regulatory assumptions used in the underlying CalSim modeling is provided in Appendix 5A, *Modeling Technical Appendix*, Section B, Attachment 2—*CalSim 3 Regulatory Assumptions and State Water Project/Central Valley Project Operational Criteria*.

12.3 Environmental Impacts

This section describes the potential impacts and compensatory mitigation associated with fish and aquatic resources that would result from project construction and maintenance of the project. It describes the methods used to determine the impacts of the project and lists the thresholds used to conclude whether an impact would be significant. Measures to mitigate (i.e., avoid, minimize, rectify, reduce, eliminate, or compensate for) significant impacts are provided. Indirect impacts are discussed in Chapter 31, *Growth Inducement*. Uncertainty in the results of such analyses is typical (e.g., Simenstad et al. 2016) and is acknowledged in the text.

12.3.1 Methods for Analysis

Quantitative and qualitative methods were used in the analysis of impacts on fish and aquatic resources for the species summarized in Table 12-1. The process and methods are outlined below.

12.3.1.1 Process and Methods of Review for Fish and Aquatic Resources

The potential for impacts on fish and aquatic resources was assessed for construction activities and for operations and maintenance activities. The potential for significant impacts was assessed based on the spatial and temporal overlap of a species' life stages with project activities, and the nature of the impact, in consideration of the conditions described below in Section 12.3.2, *Thresholds of Significance*. A summary of the main quantitative methods used in the analysis is provided in Table 12-3, which focuses on species in the Central Valley region.[4]

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[4] An initial screening of model outputs suggested detailed biological analysis was not required for the Trinity River system, as discussed in Section 12.3.3, *Impacts and Mitigation Approaches*.

Table 12-3. Methods for Analysis of Potential Effects on Fish and Aquatic Resources

		Listed or Essential Fish Habitat Species									Species of Special Concern							Economically Important Species				
Method	Region	Delta Smelt	Longfin Smelt	Sacramento River Winter-Run Chinook Salmon	Central Valley Spring-Run Chinook Salmon	Central Valley Fall-Run/Late Fall-Run Chinook Salmon	Central Valley Steelhead	North American Green Sturgeon, Southern DPS	Starry Flounder	Northern Anchovy	White Sturgeon	Pacific Lamprey	Western River Lamprey	Sacramento Hitch	Sacramento Splittail	Hardhead	Central California Roach	Striped Bass	American Shad	Threadfin Shad	Black Bass	California Bay Shrimp
Delta hydrodynamics based on DSM2 (velocity, flow reversal, junction flow)	Bay-Delta	-	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delta Passage Model	Bay-Delta	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delta smelt access restriction above north Delta intakes	Bay-Delta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delta smelt occurrence upstream of Freeport Regional Water Authority Intake	Bay-Delta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DSM2-Fingerprinting	Bay-Delta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DSM2-HYDRO [a]	Bay-Delta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DSM2-QUAL [a]	Bay-Delta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Eurytemora affinis analysis	Bay-Delta	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Impingement and Screen Contact/Passage Analysis (North Delta Intake)	Bay-Delta	X	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NDD foodweb material entrainment (delta smelt)	Bay-Delta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Delta Outflow–Abundance Index Analysis	Bay-Delta	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Noise effects of underwater construction (pile-driving spreadsheet)	Bay-Delta	X	X	X	X	X	X	X	X	-	X	X	X	X	X	X	X	X	X	X	X	-
PTM for larval entrainment	Bay-Delta	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	-
2D Modeling	Bay-Delta	X	-	X	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Riparian and wetland bench inundation [b]	Bay-Delta	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salvage based on Zeug and Cavallo (2014)	Bay-Delta	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Salvage-Density Method	Bay-Delta	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
Salvage-OMR regression (longfin smelt)	Bay-Delta	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
San Joaquin River structured decision model	Bay-Delta	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Selenium (delta smelt)	Bay-Delta	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
STARS (spreadsheet implementation)	Bay-Delta	-	-	X	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Straying Rate of Adult San Joaquin River Region Fall-Run Chinook Salmon (Marston et al. 2012)	Bay-Delta	-	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

		Listed or Essential Fish Habitat Species									Species of Special Concern							Economically Important Species				
Method	Region	Delta Smelt	Longfin Smelt	Sacramento River Winter-Run Chinook Salmon	Central Valley Spring-Run Chinook Salmon	Central Valley Fall-Run/Late Fall-Run Chinook Salmon	Central Valley Steelhead	North American Green Sturgeon, Southern DPS	Starry Flounder	Northern Anchovy	White Sturgeon	Pacific Lamprey	Western River Lamprey	Sacramento Hitch	Sacramento Splittail	Hardhead	Central California Roach	Striped Bass	American Shad	Threadfin Shad	Black Bass	California Bay Shrimp
Sturgeon year class index-outflow regression	Bay-Delta	-	-	-	-	-	-	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-
X2-abundance regression	Bay-Delta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	X	-	-	X
CalSim [a]	Bay-Delta & Upstream	X	-	X	X	X	X	X	-	-	X	X	X	X	X	X	-	X	X	-	X	-
IOS	Bay-Delta & Upstream	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OBAN	Bay-Delta & Upstream	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Winter-Run Chinook Salmon Life Cycle Model	Bay-Delta & Upstream	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Bay-Delta = San Francisco Estuary and Sacramento–San Joaquin Delta; Upstream = areas upstream of the San Francisco Estuary and Sacramento–San Joaquin Delta; PTM = particle tracking modeling.

[a] Method was used as input for other analyses in the table.

12.3.1.2 Evaluation of Construction Activities

The potential for impacts from construction activities in the Delta was assessed both qualitatively and quantitatively based on the proposed facilities under each alternative. The qualitative analysis focused on activities potentially affecting the in-water environment, in particular construction of facilities (north Delta intakes, the Southern Forebay emergency spillway, and bridge crossings), and associated activities (e.g., barge traffic transporting construction materials; withdrawal and discharge of surface water for construction purposes). The primary quantitative analysis was estimation of the potential area affected by impact pile-driving (Table 12-3), as well as the area subject to effects from construction footprint effects. Analyses were developed in consideration of information provided in Chapter 3, *Description of the Proposed Project and Alternatives*, and supporting information cited therein, as well as information as described in the following subsections.

12.3.1.3 Evaluation of Operations and Maintenance

The assessment of impacts from maintenance activities was based largely on a qualitative evaluation for the various facilities included under the alternatives. The assessment of operations effects was based on consideration of qualitative and quantitative methods (Table 12-3). Additional description of these methods and detailed results are provided in Appendix 12B, *Bay-Delta Methods and Results*. The evaluation considered various life stages and types of effects from operations under each alternative, considering the proposed facilities. For example, entrainment effects were assessed at the proposed north Delta intakes and also at the existing south Delta export facilities because of changes in operations in the north Delta resulting in changes in operations at the south Delta facilities. The focus of the detailed analysis was the Delta and Suisun Marsh/Bay. For areas upstream of the Delta, a screening-level summary of differences was undertaken to confirm minimal differences between alternatives and existing conditions. The results of this screening-level summary indicated that detailed analysis of upstream areas was not necessary because of the limited magnitude of difference between scenarios; note that while biological effects from the project alternatives are not expected to differ from existing conditions in the Sacramento River upstream of the Delta, this area was assessed as part of winter-run Chinook salmon life cycle modeling (IOS, OBAN, and Winter-Run Chinook Salmon Life Cycle Model). Export service areas were not included in the analysis because reservoirs in the export service areas receiving water as a result of operation of the project alternatives would fluctuate within typical levels that any fish assemblages present experience under existing conditions.

12.3.2 Thresholds of Significance

The proposed project would be considered to have a significant effect if it would result in any of the conditions listed below.

- Substantially reduce the habitat of a fish or aquatic species.
- Cause a fish or aquatic species' population to drop below self-sustaining levels.
- Threaten to eliminate a fish or aquatic species community.
- Substantially reduce the number or restrict the range of an endangered, rare or threatened fish or aquatic species.

- Have a significant impact, either directly or through habitat modifications, on any fish or aquatic species identified as a candidate, sensitive, or special status species in local or regional plans, policies, or regulations, or by the CDFW or U.S. Fish and Wildlife Service or by the National Marine Fisheries Service.
- Have a significant impact on any sensitive aquatic natural community identified in local or regional plans, policies, regulations, or by the CDFW or U.S. Fish and Wildlife Service.
- Interfere substantially with the movement of any native resident or migratory fish or aquatic species.

These thresholds are based primarily on the questions included in CEQA Guidelines Appendix G and on the mandatory findings of significance listed in CEQA Guidelines Section 15065. In general, the analysis assessed the potential for significant impacts by examining, where available, quantitative modeling results, such as CalSim modeling outputs (Appendix 5A, *Modeling Technical Appendix*) or quantitative biological modeling results. The threshold used for assessing potential significance of the alternatives' operations effects was a change in a modeled outcome (e.g., a measure of population abundance or survival between life stages or a habitat indicator that has been linked to population abundance) of 5% or greater relative to existing conditions. The 5% value was selected based on best professional judgment of qualified fish biologists authoring this chapter. The potential for significant impacts was considered to be progressively greater with increasingly reduced population status (e.g., a given environmental change may have greater potential to significantly affect a listed species at all-time low population numbers [e.g., delta smelt] relative to an unlisted species of concern with relatively stable numbers, albeit at lower levels than may have occurred historically; see Appendix 12A for a summary of species' status) so that differences less than 5% could be considered significant depending on species' status. The relative certainty of impacts was also considered as part of the impact conclusions (e.g., quantitative estimates based on direct population-level analyses were considered to have greater certainty than inferences based on estimated changes to habitat indicators that are hypothesized to be linked to population outcomes but for which such linkages have not been statistically demonstrated). For construction-related effects, the analysis was generally qualitative and considered the potential for species impacts given the extent of habitat affected and presence of species during construction.

12.3.2.1 Evaluation of Mitigation Impacts

CEQA also requires an evaluation of potential impacts caused by the implementation of mitigation measures. Following the CEQA conclusion for each impact, the chapter analyzes potential impacts associated with implementing both the Compensatory Mitigation Plan and the other mitigation measures required to address with potential impacts caused by the project. Mitigation impacts are considered in combination with project impacts in determining the overall significance of the project. Additional information regarding the analysis of mitigation measure impacts is provided in Chapter 4, *Framework for the Environmental Analysis*.

12.3.3 Impacts and Mitigation Approaches

12.3.3.1 No Project Alternative

As described in Chapter 3, *Description of the Proposed Project and Alternatives,* CEQA Guidelines Section 15126.6 directs that an EIR evaluate a specific alternative of "no project" along with its impact. The No Project Alternative in this Draft EIR represents the circumstances under which the proposed project (or project alternative) does not proceed and considers predictable actions, such as other projects, plans, and programs, that would be predicted to occur in the foreseeable future if the Delta Conveyance Project is not constructed and operated. This description of the environmental conditions under the No Project Alternative first considers how fish and aquatic resources could change over time and then discusses how other predictable actions could affect fish and aquatic resources.

Future Fish and Aquatic Resources Conditions

Climate change and sea level rise are key factors driving potential substantial changes future conditions for fish and aquatic resources relative to existing conditions. For example, increases in water temperature may decrease the area of suitable habitat for native fish but increase the area of suitable habitat for nonnative fish, based on current trends (Halverson et al. 2022; see also temperature trends in Table 12-47 in Impact AQUA-2 below). Increases in winter runoff as a result of increased rain-based precipitation may increase Delta inflow/outflow and associated environmental responses. For example, there may be increases in sediment loading available for resuspension to create higher suitability turbid conditions for species such as delta smelt (Stern et al. 2020; see also discussion in Impact AQUA-6 below), or greater Delta outflow potentially positively affecting species such as longfin smelt (Table 12-148 in Impact AQUA-7 below), although changes associated with sea level rise would generally move the salinity field upstream (Table 12-134 in Impact AQUA-6 below). Immediate, and potentially long-term, changes in fish and aquatic resources could occur under the No Project Alternative because of seismic events, levee failure, and the inundation of Delta lands. Moyle (2008) summarized potential general patterns of change as (1) negative effects to fish within the suction zone of levee breaks, with associated mortality from factors such as sudden changes in water quality, (2) low levels of plankton followed by blooms in the next 1 to 3 months, (3) within 1 to 5 years and beyond, changes in habitat that may increase abundance of some native fish while greatly increasing abundance of nonnative fish such as largemouth bass and common carp.

Predictable Actions by Others

A list and description of actions included as part of the No Project Alternative are provided in Appendix 3C, *Defining Existing Conditions, No Project Alternative, and Cumulative Impact Conditions*. As described in Chapter 4, *Framework for the Environmental Analysis,* the No Project Alternative analyses focus on identifying the additional water-supply related actions public water agencies may opt to follow if the Delta Conveyance Project does not occur.

Public water agencies participating in the Delta Conveyance Project have been grouped into four geographic regions. The water agencies within each geographic region would likely pursue a similar suite of water supply projects under the No Project Alternative (Appendix 3C). Construction and operation of water supply reliability projects have the potential to affect special status fish and aquatic resources. Table 12-4 provides examples of special status fish species that could be affected by the projects.

Table 12-4. Examples of Special-Status Fish Species That Could be Affected by Water Supply Reliability Projects under the No Project Alternative

Region	Special-Status Fish Species
Northern Coastal	Chinook salmon (Sacramento River winter-run ESU, Central Valley spring-run ESU, Central Valley fall-/late fall-run ESU), steelhead (Central Valley DPS and Central California Coast DPS), longfin smelt, North American green sturgeon (southern DPS), white sturgeon, Pacific lamprey, river lamprey, starry flounder, northern anchovy, striped bass, American shad, California bay shrimp, tidewater goby (*Eucyclogobius newberryi*), speckled sanddab (*Citharichthys stigmaeus*), English sole (*Parophrys vetulus*), Pacific herring (*Clupea pallasii*)
Northern Inland	Steelhead (Central California Coast DPS)
Southern Coastal	Tidewater goby, steelhead (southern California coastal DPS), California halibut (*Paralichthys californicus*), cheekspot goby (*Ilypnus gilberti*), walleye surfperch (*Hyperprosopon argenteum*), queenfish (Seriphus politus), kelp bass (*Paralabrax clathratus*), California grunion (*Leuristhes tenuis*), northern anchovy
Southern Inland	Santa Ana sucker (*Catostomus santaanae*), Santa Ana speckled dace (*Rhinichthys osculus*)

Desalination projects would most likely be pursued in the northern and southern coastal regions. The southern coastal regions would likely require larger and more desalination projects than the northern coastal region in order to replace the water yield that otherwise would have been received through the project alternatives. These projects would be sited near the coast. Groundwater recovery (brackish water desalination) would involve similar types of construction but could occur across the northern inland, southern coastal, southern inland regions and in both coastal and inland areas, such as the San Joaquin Valley. Grading and excavation at the desalination and groundwater recovery plant sites would be necessary for construction of foundations, and trenching would occur for installation of water delivery pipelines and utilities. Ground-disturbing activities in these types of units would have the potential to disturb fish and aquatic resources, because of runoff from construction activities, for example.

The northern and southern coastal regions are also most likely to explore constructing groundwater management projects. The southern coastal region would require more projects than the northern coastal region under the No Project Alternative. Groundwater management projects would occur in association with an underlying aquifer but could occur in a variety of locations. Construction activities for each project could require excavation for the construction of the recharge basins, conveyance canals, and pipelines and drilling for the construction of recovery wells (with completion intervals between approximately 200 and 900 feet below ground surface). Construction activities would include site clearing; excavation and backfill; and construction of basins, conveyance canals, pipelines, pump stations, and the turnout. Grading activities associated with the construction of recharge basins would involve earthmoving, excavation, and grading. Canals and pipelines would likely be constructed using typical open trench construction methods. In some cases where siphons would be installed, jack and bore methods could be used to tunnel under and avoid disruption of surface features. Excavation of varying depths could be required, and these construction activities have the potential to affect waterbodies containing special status fish and aquatic resources, depending on location.

Water recycling projects could be pursued in all four regions. The northern inland region would require the fewest number of wastewater treatment/water reclamation plants, followed by the northern coastal region, followed by the southern coastal region. The southern inland region would require the greatest number of water recycling projects to replace the anticipated water yield that it would receive through the Delta Conveyance Project. These projects would be located near water treatment facilities. Construction techniques for water recycling projects would vary depending on the type of project (e.g., for landscape irrigation, groundwater recharge, dust control, industrial processes) but could require earth moving activities, grading, excavation, and trenching. Because construction would involve ground-disturbing activities, such actions could negatively affect special status fish and aquatic resources, depending on location. In the southern inland region where a greater number of projects would be needed as a substitute for Delta Conveyance, the potential for impact would also be greatly increased.

Water efficiency projects could be pursued in all four regions and involve a wide variety of project types, such as flow measurement or automation in a local water delivery system, lining of canals, use of buried perforated pipes to water fields, and additional detection and repair of commercial and residential leaking pipes. These projects could occur anywhere in the regions, and most would involve little ground disturbance or would occur in previously disturbed areas, thereby limiting their potential for construction impacts to special status fish and aquatic species.

All project types across all regions would involve relatively typical construction techniques and would be required to conform with the requirements of CEQA and other regulations protecting special status fish and aquatic species. Mitigation measures would be developed to protect these species, such as described further in Impact AQUA-1 for the project alternatives. Construction activities would occur in a wide variety of locations, and impacts would not be focused on a single location sensitive for special status fish species.

Operations effects such as entrainment or impingement of fish and aquatic species during water diversions for desalination would be minimized by intake screening and would involve relatively small quantities of water in relation to source waterbodies (City of Carlsbad 2005:4.3-32). Mitigation such as provision of habitat based on established methods such as area of production foregone would likely be used to offset potential entrainment and impingement losses if found to be significant. Discharges from desalination plants would not be anticipated to result in significant increases in salinity for local fish and aquatic species but monitoring can be done to confirm that applicable thresholds (Ocean Plan criteria and U.S. Environmental Protection Agency [EPA] guidelines) are not being exceeded (City of Carlsbad 2005:4.3-54).

12.3.3.2 Impacts of the Project Alternatives on Fish and Aquatic Resources

This section discusses the impacts on fish and aquatic resources from construction and operations/maintenance of the project alternatives. In addition, each impact also includes discussion of effects of the No Project Alternative following discussion of the project alternatives using the same methods initially introduced for the project alternatives.

Impact AQUA-1: Effects of Construction of Water Conveyance Facilities on Fish and Aquatic Species

Construction—All Project Alternatives

Construction of water conveyance facilities for all alternatives has the potential to affect fish and aquatic species. Of the species described in Table 12-1, all could have the potential to occur near the main in- or near-water construction areas in the open parts of the Delta (as opposed to the construction area of the Bethany Reservoir Discharge Structure under Alternative 5), but the potential for occurrence in these open parts of the Delta near the main construction areas would be very low to almost nil for species primarily occurring downstream (starry flounder and California bay shrimp) or upstream (Central California roach) because of very limited potential for spatial overlap with construction activities relative to the species' distributions. Potential effects arising from construction activities could consist of acoustic effects; sediment disturbance leading to increased suspended sediments, turbidity and contaminants; water quality effects from accidental spills and discharge of construction water; direct physical injury or mortality from in-water work; reduced prey availability; increased predation risk; increased water temperature; and reduced habitat extent and access. These potential effects are discussed below, with the focus on the open parts of the Delta that the fish and aquatic species listed in Table 12-1 could access; additional construction effects would occur at the Bethany Reservoir Discharge Structure under Alternative 5 but would be limited to effects on a likely almost entirely nonnative and isolated fish assemblage that would not significantly add to the construction effects discussed in this section. Construction information is generally described in Chapter 3, *Description of the Proposed Project and Alternatives*, with additional details in the Engineering Project Reports for the alternatives (Delta Conveyance Design and Construction Authority 2022a, 2022b).

Acoustic Effects

Underwater noise would be generated by a variety of construction activities including pile driving, boat operations, dredging, geotechnical investigations, riprap placement, and tunnel boring machine (TBM) activities. Impact pile driving in or near aquatic habitat generates sound levels that can injure or kill fish and other aquatic organisms. Each of the project alternatives includes physical or structural components that would require vibratory and/or impact driving of temporary and permanent piles during construction. Several of these components involve pile driving activities within or adjacent to water bodies supporting fish and aquatic species, resulting in potential exposure of species to pile driving noise.

Research indicates that impact pile driving can result in significant impacts on fish because of the high level of underwater sound produced (Popper and Hastings 2009:464–480). The effects of pile driving noise on fish may include behavioral responses, physiological stress, temporary and permanent hearing loss, tissue damage (auditory and non-auditory), and direct mortality. Factors that may influence the magnitude of effects include species, life stage, and size of fish; type and size of pile and hammer; frequency and duration of pile driving; site characteristics (e.g., depth); and distance of fish from the source.

Dual interim criteria have been established to provide guidance for assessing the potential for injury of fish resulting from pile driving noise (Fisheries Hydroacoustic Working Group 2008:1) and were used in the present analysis. The dual criteria for impact pile driving are (1) 206 decibels[5] (dB) for the peak sound pressure level (SPL); and (2) 187 dB for the cumulative sound exposure level ($SEL_{cumulative}$) for fish larger than 2 grams, and 183 dB ($SEL_{cumulative}$) for fish smaller than 2 grams. The peak SPL is considered the maximum sound pressure level a fish can receive from a single strike without injury. The cumulative SEL is considered the total daily amount of acoustic energy that a

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[5] Where sound levels in decibels (dB) are referenced in this analysis, they are made relative to 1 micropascal (1 μPa, for peak and root mean square pressure) and 1 micropascal-squared-second (1 $\mu Pa^2 s$, for sound exposure level).

fish can receive from single or multiple strikes without injury. The $\text{SEL}_{\text{cumulative}}$ threshold is based on the cumulative daily exposure of a fish to noise from sources that are discontinuous (i.e., noise that occurs only for about 8 to 12 hours in a day, with 12 to 16 hours between exposure). This assumes that the fish is able to recover from such effects during this 12- to 16-hour period. These criteria relate to impact pile driving only. Vibratory pile driving is generally accepted as an effective measure for minimizing or eliminating the potential for injury of fish during in-water pile driving operations, with only impact pile driving expected to produce sound levels that could injure fish (National Marine Fisheries Service 2015:50). The potential for physical injury to fish from exposure to impact pile driving sounds was evaluated using a spreadsheet model developed by NMFS[6] to calculate the distances from the pile that sound attenuates to the peak or cumulative criteria. These distances define the area in which the criteria are expected to be exceeded as a result of impact pile driving. The NMFS spreadsheet calculates these distances based on estimates of the single-strike sound levels for each pile type (measured at 10 meters from the pile) and the rate at which sound attenuates with distance. In the following analysis, the standard sound attenuation rate of 4.5 dB per doubling of distance was used in the absence of other data.[7] To account for the exposure of fish to multiple pile driving strikes, the model computes a cumulative SEL for multiple strikes based on the single-strike SEL and the number of strikes per day or pile driving event. The NMFS spreadsheet also employs the concept of "effective quiet." This assumes that cumulative exposure of fish to pile driving sounds of less than 150 dB SEL does not result in injury or behavioral modification.

The following analysis also considers the potential for pile driving sound to adversely affect fish behavior. Potential mechanisms include startle or avoidance responses that can disrupt or alter normal activities (e.g., migration, holding, feeding) or expose individuals to increased predation risk. Insufficient data are currently available to support the establishment of a noise threshold for behavioral effects (Hastings and Popper 2005:46; Popper and Hastings 2009:464). NMFS, however, has concluded that a noise level of 150 dB root mean square (RMS) is an appropriate threshold for behavioral effects (California Department of Transportation 2020:4-30) and so this value is used in the present analysis.

The following analysis uses peak sound pressure levels (SPLs) and sound exposure levels (SELs) measured during similar pile driving operations[8] as a basis for estimating the distances at which sound levels would be expected to exceed the interim injury and behavioral thresholds (California Department of Transportation 2020:I-5–I-19). The following assessment presents the effect that is reasonably foreseeable based on the use of an impact driver with no attenuation (e.g., bubble curtains). Assumptions for the pile-driving analysis were developed based on the expected impact pile driving at each intake as described in the Conceptual Intake Cofferdam Construction Technical Memorandum (Delta Conveyance Design and Construction Authority 2022c). The assumptions reflect use of impact pile driving to the extent necessary when other methods (e.g., vibratory pile

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[6] The spreadsheet was downloaded from https://www.fisheries.noaa.gov/southeast/consultations/section-7-consultation-guidance on 2/4/2021.

[7] A sound attenuation rate of 4.5 dB per doubling of distance is equivalent to a transmission loss constant of 15, the default value in the NMFS spreadsheet; the NMFS spreadsheet indicates this value is to be used when site-specific values are unknown (as is the case in the present analysis).

[8] Specifically, the assumed sound levels used for each intake were for 24-inch AZ sheet piles in 15 meters of water. Although the intake sites are shallower than 15 meters, available sound level data for pile driving are not available for the specific depths and pile type likely to be used for construction; however, an assumption of 15 meters of depth is conservative given that attenuation with distance is greater in shallower water (California Department of Transportation 2020:4-24).

driving) are not able to complete construction requirements. An analysis of impact pile-driving noise was also conducted for the test pile program, based on three types of pile[9] being tested at a single site.

The pile driving analysis for the test pile program reflected one pile of each type on three separate days at a single site, which would occur under all the project alternatives. The analysis indicated that the distance to sound level thresholds would range from 28 feet (206 dB) to 24,135 feet (150 dB) (Table 12-5). The area of effect, accounting for attenuation of sound by river bends, ranges from 0.06 acre (206-dB threshold for sheet and steel pipe piles) to approximately 59 acres (150-dB threshold for H piles) (Table 12-5). The duration of the test pile impact driving at a single intake site would be 3 days (one day for each pile type; Table 12-5), although the actual duration of impact pile driving would be short (~2 minutes per pile; Delta Conveyance Design and Construction Authority 2022c).

Table 12-5. Assumptions and Estimates of Impact Pile Driving Distance and Area of Acoustic Effect at a Single Intake Site for the Test Pile Program

Variable	Sheet Pile Pair	Steel Pipe Pile	H Pile
Number of piles	1	1	1
Number of piles per day	1	1	1
Number of days of pile driving	1	1	1
Number of strikes per pile	19	19	19
Number of strikes per day	19	19	19
Peak single-strike sound level at 10 meters [33 feet] (dB)	205	205	208
Sound exposure level at 10 meters [33 feet] (SEL, dB)	180	180	177
Root mean square at 10 meters [33 feet] (RMS, dB)	190	190	193
Distance to 206-dB threshold (feet) [a]	28	28	45
Distance to 187-dB threshold (feet) [a]	80	80	50
Distance to 183-dB threshold (feet) [a]	147	147	93
Distance to 150-dB threshold (feet) [a]	15,228	15,228	24,135
Area of 206-dB threshold (acres)	0.06	0.06	0.15
Area of 187-dB threshold (acres)	0.46	0.46	0.18
Area of 183-dB threshold (acres)	1.28	1.28	0.60
Area of 150-dB threshold (acres)	58.41	58.41	58.64

Note: assumed testing would occur at Intake B.

dB = decibel; RMS = root mean square; SEL = sound exposure level.

[a] Note that this distance does not account for sound attenuation by site configuration (e.g., sound not going round corners at the bends in the river), which is accounted for in the area estimates given in the table.

The pile driving analysis for construction of the cofferdams and training walls indicated that the distance to sound level thresholds would range from 28 feet (206 dB) to 15,228 feet (150 dB) (Table 12-6). The area of effect, accounting for attenuation of sound by river bends, ranges from 0.06 acre (206-dB threshold) to 231 acres (150-dB threshold at Intake A) (Table 12-6). The duration of the

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[9] The assumed sound levels were for a 24-inch AZ sheet pile in 15 meters of water, a 30-inch steel pipe pile in 4–5 meters of water, and a 14-inch H pile in 6 meters of water.

impact pile driving acoustic effect at the intakes would range from 14 days (Intake A and 1,500-cfs Intake C) to 21 days (Intakes B and C) (Table 12-6).

Table 12-6. Assumptions and Estimates of Impact Pile Driving Distance and Area of Acoustic Effect at Each Intake for Construction of Cofferdams and Training Walls

Variable	Intake A	Intake B	Intake C
Alternative	2a, 4a	1, 2a, 2c, 3, 4a, 4c, 5	3,000 cfs: 1, 2a, 2b, 3, 4a, 4b, 5; 1,500 cfs: 2c, 4c
Number of piles (pairs)	269	420	3,000 cfs: 410; 1,500 cfs: 277
Number of piles per day	20	20	20
Number of days of pile driving	14	21	3,000 cfs: 21; 1,500 cfs: 14
Number of strikes per pile	20	19	10
Number of strikes per day	400	380	200
Peak single-strike sound level at 10 meters [33 feet] (dB)	205	205	205
Sound exposure level at 10 meters [33 feet] (SEL, dB)	180	180	180
Root mean square at 10 meters [33 feet] (RMS, dB)	190	190	190
Distance to 206-dB threshold (feet) [a]	28	28	28
Distance to 187-dB threshold (feet) [a]	608	588	383
Distance to 183-dB threshold (feet) [a]	1,124	1,086	708
Distance to 150-dB threshold (feet) [a]	15,228	15,228	15,228
Area of 206-dB threshold (acres)	0.06	0.06	0.06
Area of 187-dB threshold (acres)	15.20	12.30	6.72
Area of 183-dB threshold (acres)	33.44	25.06	18.47
Area of 150-dB threshold (acres)	231.35	67.69	134.10

dB = decibel; RMS = root mean square; SEL = sound exposure level.

[a] Note that this distance does not account for sound attenuation by site configuration (e.g., sound not going round corners at the bends in the river), which is accounted for in the area estimates given in the table.

Pile driving for 2 to 4 days would be required during the final year of construction in order to install steel pipe piles to support the floating log boom. Existing geotechnical information suggests that all log boom piles could be vibrated into place without the need for any impact pile driving, but a conservative estimate of impact pile driving that could be required was used for this analysis. This analysis indicated that the distance to sound level thresholds would range from 82 feet (206 dB) to 13,061 feet (150 dB) (Table 12-7). The area of effect, accounting for attenuation of sound by river bends, ranges from 0.5 acre (206-dB threshold at Intakes B and C) to 229 acres (150-dB threshold at Intake A) (Table 12-7).

Table 12-7. Assumptions and Estimates of Impact Pile Driving Distance and Area of Acoustic Effect at Each Intake for Construction of Log Booms

Variable	Intake A	Intake B	Intake C
Alternative	2a, 4a	1, 2a, 2c, 3, 4a, 4c, 5	3,000 cfs: 1, 2a, 2b, 3, 4a, 4b, 5; 1,500 cfs: 2c, 4c

Variable	Intake A	Intake B	Intake C
Number of piles	18	32	3,000 cfs: 32; 1,500 cfs: 18
Number of piles per day	10	10	10
Number of days of pile driving	2	4	3,000 cfs: 4; 1,500 cfs: 2
Number of strikes per pile	153	504	66
Number of strikes per day	1,530	5,040	660
Peak single-strike sound level at 10 meters [33 feet] (dB)	212	212	212
Sound exposure level at 10 meters [33 feet] (SEL, dB)	181	181	181
Root mean square at 10 meters [33 feet] (RMS, dB)	189	189	189
Distance to 206-dB threshold (feet) [a]	82	82	82
Distance to 187-dB threshold (feet) [a]	1,734	3,825	990
Distance to 183-dB threshold (feet) [a]	3,204	3,825	1,830
Distance to 150-dB threshold (feet) [a]	13,061	13,061	13,061
Area of 206-dB threshold (acres)	0.5	0.5	0.5
Area of 187-dB threshold (acres)	52.6	66.4	27.2
Area of 183-dB threshold (acres)	97.8	66.4	51.7
Area of 150-dB threshold (acres)	229.0	69.3	117.9

dB = decibel; RMS = root mean square; SEL = sound exposure level.

[a] Note that this distance does not account for sound attenuation by site configuration (e.g., sound not going round corners at the bends in the river), which is accounted for in the area estimates given in the table.

Pile driving would also be required at various bridge crossings associated with the project alternatives (Table 12-8). The area of effect, accounting for attenuation of sound by river bends, ranges from 0.04 acre (206-dB threshold at Snodgrass Slough) to just under 109 acres (150-dB threshold at Connection Slough) (Table 12-8). The duration of the impact pile driving acoustic effect at the bridge crossings would range from 5 days (Snodgrass Slough) to 45 days (Connection Slough) (Table 12-8).

Table 12-8. Assumptions and Estimates of Impact Pile Driving Distance and Area of Acoustic Effect at Each Bridge Crossing

Variable	Snodgrass Slough	Little Potato Slough	Connection Slough	Burns Cut
Alternative	1, 2a, 2b, 2c, 3, 4a, 4b, 4c, 5	1, 2a, 2b, 2c	1, 2a, 2b, 2c	3, 4a, 4b, 4c, 5
Pile diameter (steel pipe, inches)	16	24	72	24
Number of piles	26	42	90	50
Number of piles per day	6	6	2	6
Number of days of pile driving	5	7	45	9
Number of strikes per pile	150	150	150	150
Number of strikes per day	900	900	300	900
Peak single-strike sound level (dB)	204	212	214	212

Variable	Snodgrass Slough	Little Potato Slough	Connection Slough	Burns Cut
Sound exposure level (SEL, dB)	179	181	182	181
Root mean square (RMS, dB)	189	189	189	189
Distance to 206-dB threshold (feet) [a]	24	82	112	82
Distance to 187-dB threshold (feet) [a]	896	1,217	682	1,217
Distance to 183-dB threshold (feet) [a]	1,655	2,249	1,261	2,249
Distance to 150-dB threshold (feet) [a]	13,061	13,061	13,061	13,061
Area of 206-dB threshold (acres)	0.04	0.48	0.90	0.47
Area of 187-dB threshold (acres)	4.12	20.36	13.18	12.38
Area of 183-dB threshold (acres)	7.34	26.41	27.40	12.36
Area of 150-dB threshold (acres)	25.45	26.44	108.73	12.37

dB = decibel; RMS = root mean square; SEL = sound exposure level.

[a] Note that this distance does not account for sound attenuation by site configuration (e.g., sound not going round corners at the bends in the river), which is accounted for in the area estimates given in the table.

Boat operations during construction would result in temporary acoustic effects on fish and aquatic species. Barge/tugboat operations would be conducted to transport construction equipment and materials to each intake, for a total of 42 to 94 trips per intake (Table 12-9). There would be no more than two trips upstream and two trips downstream per day, with work assumed to be sequentially staggered by at least 1 year for each intake.

Table 12-9. Barge Round Trips (Trips in Parentheses) Associated with Construction of Each Intake

Variable	Intake A	Intake B	Intake C
Alternative	2a, 4a	1, 2a, 2c, 3, 4a, 4c, 5	3,000 cfs: 1, 2a, 2b, 3, 4a, 4b, 5; 1,500 cfs: 2c, 4c
Transport log boom and support pile installation	2 (4)	2 (4)	3,000 cfs: 2 (4); 1,500 cfs: 2 (4)
Transport clamshell excavator	1 (2)	1 (2)	3,000 cfs: 1 (2); 1,500 cfs: 1 (2)
Transport excavated/dredged material	10 (20)	28 (56)	3,000 cfs: 19 (38); 1,500 cfs: 14 (28)
Transport riprap	8 (16)	16 (32)	3,000 cfs: 12 (24); 1,500 cfs: 10 (20)
Total round trips (total trips)	21 (42)	47 (94)	3,000 cfs: 34 (68); 1,500 cfs: 27 (54)

Note: Round trips are to/from the Port of Stockton. This table does not account for barge trips associated with the test pile program (1 round trip [2 trips] at a single intake), the geotechnical investigations at the proposed intakes (1–3 round trips [2–6 trips] per alternative, based on 1 round trip per intake), and the geotechnical investigations at bridges and tunnel crossings (up to 9 round trips [18 trips] for Alternatives 1, 2a, 2b, and 2c; up to 10 round trips [20 trips] for Alternatives 3, 4a, 4b, 4c, and 5).

Each barge round trip for transport of excavated/dredged material would be associated with 1 day of mechanical (clam shell) or hydraulic dredging to excavate and prepare the subgrade at the intake for riprap placement, that is, 8 to 16 days of dredging at each intake (Table 12-9). The Reine et al.

(2014:3,292) review of potential dredging acoustic effects concluded that it is unlikely that conventional dredging operations can cause physical injury to fish species, while noting that in theory temporary hearing losses could occur if fish remained in the vicinity of a dredge for lengthy duration, although they suggested the risk of this is low. Other potential effects of dredging such as direct physical injury are discussed in subsequent sections.

Boat operations for geotechnical investigations and the test pile program would likely be conducted from a shallow-draft barge or ship, outfitted with the necessary equipment for the task, with the potential for temporary acoustic effects from boat noise being limited to behavioral effects, consistent with the above discussion for dredging effects. There would be two barge trips for the test pile program (i.e., to and from a single intake site), two to six barge trips for the geotechnical investigations at the intakes (i.e., to and from each intake site), and up to 18 (Alternatives 1, 2a, 2b, and 2c; i.e., to and from nine sites) or 20 (Alternatives 3, 4a, 4b, 4c, and 5; i.e., to and from ten sites) barge trips for the geotechnical investigations at bridges and tunnel crossings. Acoustic effects from standard geotechnical penetration tests (i.e., dropping a 140-pound automatic hammer to drive a sampler about 1.5 feet) are limited to minimal, short-duration vibrations (National Marine Fisheries Service 2017:177).

Placement of riprap has the potential to result in temporary loud noises, although the available data from analogous situations in the Delta suggest such effects would be limited: Sound data taken during the 2012 installation of rock barriers as part of DWR’s Temporary Barriers Project showed that noise levels at 100 meters from construction were below the NMFS criteria for adverse behavioral effects (150 dB),[10] any effects would be limited to 8 to 16 days of riprap placement at each intake (corresponding to the number of round trips to transport riprap shown in Table 12-9).

Tunnel boring along the central alignment (i.e., alternatives 1, 2a, 2b, and 2c) would pass beneath 7 waterbodies a total of 8 times, whereas tunnel boring along the eastern alignment (i.e., Alternatives 3, 4a, 4b, and 4c) would pass beneath 13 waterbodies a total of 16 times, and tunnel boring for the Bethany Reservoir alignment would also pass beneath 14 waterbodies a total of 17 times (Table 12-10). Tunnel boring is expected to progress at approximately 40 feet per day with work undertaken up to 20 hours per day 5 days per week and up to 10 hours on Saturdays (Delta Conveyance Design and Construction Authority 2022a,b), thereby passing under each waterbody for a number of days, depending on the width of the waterbody along the tunnel alignments. Acoustic modeling of potential effects was undertaken for the tunnel boring intersection with the San Joaquin River, which is the shallowest tunnel boring location passing beneath a waterbody (approximately 68 feet of cover between the crown of the tunnel and the bottom of the river channel). The overall sound pressure level at the bottom of the channel was estimated to be 104 dB (Delta Conveyance Design and Construction Authority 2022d), which is well below the 150-dB threshold for behavioral modification described above, for example. Therefore, it would not be expected that fish and aquatic resources would be affected by noise from boring the tunnel alignments for the alternatives.

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[10] The greatest measured peak sound pressure at 100 meters was 149 dB for a single bucket drop of rock at the Old River near Tracy barrier (Shields 2012:7).

Table 12-10. Number of Waterbody Intersections of Tunnel Boring Machine Routes by Alternative

Waterbody	Central Alignment (Alternatives 1, 2a, 2b, 2c)	Eastern Alignment (Alternatives 3, 4a, 4b, 4c)	Bethany Reservoir Alignment (Alternative 5)
Beaver Slough	0	1	1
Disappointment Slough	0	0	1
Hayes Slough	0	1	1
Hog Slough	0	1	1
Indian Slough	1	0	0
Middle River	0	1	1
Mokelumne River	1	1	1
Old River	1	2	2
Potato Slough	1	0	0
San Joaquin River	1	1	1
Snodgrass Slough	1	2	2
South Mokelumne River	2	0	0
Sycamore Slough	0	1	1
Victoria Canal	0	1	1
West Canal	0	0	1
Whiskey Slough	0	1	1
White Slough	0	2	2
Woodward Canal	0	1	0
Total	8	16	17

Source: Delta Conveyance Design and Construction Authority 2022a, 2022b.

Drilling for subsurface power transmission lines would pass once under Snodgrass Slough (all alternatives) as well as once under Little Potato Slough (Alternatives 1, 2a, 2b, and 2c). Drilling for SCADA would pass once under Little Potato Slough (Alternatives 1, 2a, 2b, and 2c) and once under Brushy Creek (all alternatives except for Alternative 5). Acoustic effects from subsurface drilling would be expected to be minimal based on noise levels measured for underwater drilling of around 130 dB (Spiga et al. 2012:56–57, 78).

Sediment Disturbance

The construction of the alternatives would result in the generation and release of suspended sediments to the water column, temporarily increasing water column turbidity above ambient levels and altering habitat conditions for fish and aquatic resource species. Turbidity-producing construction activities include bed and bank disturbance during cofferdam and log boom installation, dredging prior to riprap placement adjacent to the new intake locations, and the placement of bed and bank riprap armoring. In-water work associated with riprap would have greater relative effects on turbidity than the other activities but would be limited to one season at each intake. Propeller wash associated with boat traffic at construction sites may also produce localized turbidity pulses, depending on location.

Given the nature and scope of construction activities, and based on observations of similar in-water construction activities, increases in turbidity and suspended sediment generated during construction of the water conveyance facilities would be temporary and localized, and unlikely to reach levels causing direct injury or mortality to fish and aquatic species. NMFS (2008:95) reviewed observations of turbidity plumes during installation of riprap for bank protection projects on the Sacramento River and concluded that visible plumes are expected to be limited to only a portion of the channel width, extend no more than 1,000 feet downstream, and dissipate within hours of cessation of in-water activities. Based on these observations, NMFS (2008:95) concluded that such activities could result in turbidity levels exceeding 25–75 NTU. This level of effect is considered representative of maximum potential turbidity effects from the alternatives. The area of tidal perennial habitat that could be temporarily affected by the sediment plume from the downstream end of each intake to 1,000 feet downstream is 1.7 acres at Intake A (Alternative 2a), 1.7 acres at Intake B (all alternatives except 2b and 4b), and 2.5 acres at Intake C (all alternatives).

Sediment at construction sites could include contaminants (e.g., metals, hydrocarbons such as oil and grease, organochlorine pesticides, and polychlorinated biphenyls), so the potential exists for release and dispersal of these contaminants if these sediments are disturbed during construction. Fish and aquatic species could be directly exposed to elevated levels of contaminants if they are in immediate proximity to construction activities that disturb contaminated sediments. The greatest potential for such effects would be during dredging/excavation for riprap placement, with lesser potential during pile driving for cofferdam and log boom installation or from propeller wash by construction boat traffic. Bed disturbance could also result in indirect effects on fish and aquatic species. Toxins in river channel sediments can enter the food chain via benthic organisms. If contaminated sediments are disturbed and become suspended in the water column, they also become available directly to pelagic organisms, including fish species and planktonic food sources of fish species. Thus, construction-related disturbance of contaminated bottom sediments opens up another potential pathway to the food chain, and the potential bioaccumulation of these toxins in various fish species. The bioaccumulation of toxins can lead to lethal effects, as well as several sublethal effects (e.g., effects on behavior, digestion, and immune system; Connon et al. 2011:290). The toxins in contaminated sediments are generally adhered to the sediment and as described above for turbidity elevated suspended sediment caused by construction activity for the alternatives would be spatially limited to a portion of channel width and not extend far downstream, dissipating within hours of construction activities ceasing (see also discussion in Chapter 9 related to Impact WQ-1).

Water Quality Effects

Construction of the alternatives could result in accidental spills of contaminants, including oil, fuel, hydraulic fluids, concrete, and other construction-related materials, resulting in localized water quality degradation. This could in turn result in significant impacts on fish and aquatic species, through direct injury and mortality (e.g., damage to gill tissue causing asphyxiation) or delayed effects on growth and survival (e.g., increased stress or reduced feeding), depending on nature and extent of the spill and the contaminants involved.

The greatest potential for an adverse water quality impact is associated with an accidental spill from construction activities occurring in or near surface waters. The north Delta intakes in particular involve extensive work, albeit with much of the work occurring inside a cofferdam. There is some potential for spills during drilled shaft work, cofferdam support installation, excavation of the cofferdam, and tremie pours of concrete (although additional concrete would be poured into the concrete base, thereby minimizing the potential for concrete mixing with water within the cofferdam prior to dewatering), but once cofferdams are installed and dewatered, any spills within the cofferdam would essentially preclude movement of spill materials into the river because of river water pressure on the cofferdams. Other construction elements that occur in upland areas or are isolated from fish-bearing waters have little potential for accidental spills that could affect fish. Discharge of water from construction sites could also affect water quality for fish and aquatic species.

Direct Physical Injury

In-water construction for the alternatives may result in direct physical injury or mortality to fish and aquatic species from activities including pile-driving, barge/tugboat operations, dredging, enclosing construction areas, riprap placement, and construction water diversion from surface waters. Installation of piles or placement of riprap could involve fish being crushed, although it would be expected that risk would be very low based on the limited spatial extent of the work and the high probability of fish avoiding such activities; therefore, displacement of fish away from habitat near construction activities seems the most likely negative effect. Dredging activities may crush or entrain fish and aquatic species, although the limited spatial and temporal extent of dredging would limit the potential for negative effects. Dredging entrainment effects are most likely to occur on eggs and larvae, with mobile (juvenile and adult) fish less likely to be affected; of the latter, entrainment rates are highest for benthic species or those in high density. Fish that are entrained may survive and avoid injury, depending on site conditions (Wenger et al. 2017:978–979), although mortality rates can be large for the fish that are entrained (LFR Levine·Fricke 2004:55). Fish entrapped in construction areas enclosed by cofferdams would die without fish rescue activities, although the number of fish being trapped in such areas would be a very low proportion of individuals relative to the overall extent of species' ranges. Barge and tugboat operations could result in direct physical injury or mortality from propeller entrainment/strikes. Given the relatively limited use of barges and tugboats (i.e., approximately 42–94 trips per intake associated with intake construction [staggered by one year per intake], 2 trips for the test pile program, 2 trips per intake for geotechnical investigations, and 18–20 trips for geotechnical investigations at bridges and tunnel crossings, plus maneuvering at each site; see discussion above in *Acoustic Effects*), such effects would be expected to be limited.[11] Water for construction would primarily be provided by on-site groundwater wells. The water supply needed for construction will be satisfied through a combination of the following: import from local sources, exchanges, use of existing riparian diversions, new temporary appropriations, or existing State Water Project appropriations. Surface water rights to be diverted from existing facilities would be available at the intake locations, Lower Roberts Island at the tunnel shaft location, and Byron Tract for Southern Complex. Therefore, at most construction sites, there would be no changes to surface waters related to construction water supplies. Any use of diversions will be screened, as appropriate, and additional authorizations addressed following development of detailed construction engineering, so at the limited number of sites that could use existing surface water rights, entrainment of fish would be low based on low numbers of fish entrained at similar small intakes (e.g., Nobriga et al. 2004; Vogel 2013:82).

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[11] For example, NMFS (2017:256–263) estimated that ~23 barge trips per year to Intake A from the west Delta along the Sacramento River (a distance of 73 km [46 miles]) during June–October would result in annual propeller entrainment mortality of 0–1 juvenile winter-run Chinook salmon, 0 juvenile spring-run Chinook salmon, 104–199 juvenile fall-run Chinook salmon, 47–91 juvenile late fall–run Chinook salmon, and 1–2 juvenile steelhead. There would be 42–94 barge trips per intake plus several additional trips for geotechnical work and the test pile program, potentially resulting in somewhat greater annual propeller entrainment mortality than estimated by NMFS (2017: 256–263) but still very low in population-level terms.

Reduced Prey Availability

Construction of the project alternatives has the potential to reduce prey availability (e.g., zooplankton, benthic invertebrates, small fish) for fish and aquatic species through disturbance of aquatic habitat. Prey species may be affected by pile driving (e.g., from noise effects or direct physical contact), barge and tugboat operations (e.g., noise and sediment disturbance), dredging (e.g., direct entrainment and sediment disturbance), removal of riparian aquatic habitat (i.e., reducing habitat structures for prey in or above water), and riprap placement (e.g., direct physical contact and sediment disturbance). Isolation of construction areas with cofferdams would prevent fish and aquatic species access to prey in these areas. The potential effects would be limited in extent relative to the overall area of habitat available to fish and aquatic species in the Delta. Further discussion of habitat reduction is provided below in *Reduced Habitat Extent and Access.*

Increased Predation

In-water structures used during construction would have the potential to provide habitat for predatory species. The cofferdams to be used during construction at the north Delta intakes would include flutes (vertical grooves), which may make them suitable as predatory fish habitat (Vogel 2008b:24). In-water structures, particularly cofferdams at the north Delta intakes, may therefore result in negative effects on small fish such as downstream-migrating juvenile salmonids, or positive effects on larger predatory fish such as black bass. Overall, however, the potential effects from presence of in-water structure during construction would be limited as the overall extent would be low (Table 12-11 and Table 12-12) considering the already existing docks in the Delta (approximately 250 acres, or 0.44% of the total surface area of waterways; Lehman et al. 2019:12). The existing proportional extent of small docks in the Delta has been concluded to not be likely to have a population-level effect on species such as migrating juvenile salmonids (Lehman et al. 2019:14), so the addition of structures from construction of the alternatives would be expected to be limited in terms of additional negative effects.

In addition to in-water structure effects during construction, the various forms of in-water construction work (pile driving, barge and tugboat operations, dredging, and riprap placement) have the potential to increase predation risk for smaller fish species by increasing disturbance and susceptibility to predation (e.g., by masking the sounds of approaching predators, or causing fish to flee disturbed areas), which in turn could increase predation success of larger predatory fish such as black bass. Such effects would be temporally and spatially limited in extent. Loss of shaded riparian aquatic habitat and other shallow-water habitat because of construction would also increase susceptibility to predation.

Increased Water Temperature

Removal of trees where necessary at construction sites for the alternatives may reduce the extent of shaded riparian aquatic habitat (see discussion below in *Reduced Habitat Extent and Access* related to effects on channel margin habitat). This could potentially increase water temperature and have negative effects on fish and aquatic species, depending on species-specific temperature preferences. However, such increases would be extremely localized and would be likely only to occur in any small, semi-isolated shallow areas away from the main river channel that are shaded by trees; this type of habitat does not occur at the construction sites, particularly the north Delta intakes, which include modified riverbanks often with considerable extents of revetment. NMFS (2017:220) noted the Sacramento River and Delta are wider, faster-moving waterbodies and therefore are less likely to experience warming of water temperatures caused by limited decreases in riparian vegetation, such as would occur with construction of the alternatives. This is because as the river channels become wider, a smaller fraction of the channel is affected by shading and the narrow riparian corridor found along those riverbanks. As further described by NMFS (2017:220), the volume of water present in the river channel acts as a thermal sink, resisting temperature changes caused by shading along a narrow riparian zone. Temperature changes are more influenced by the greater surface area of exposed open water in the river channel, ambient air temperatures over those exposed areas, solar irradiation, and the influence of water layers mixing within the main river channel. The effects on fish and aquatic species from changes in water temperature would be expected to be minimal.

Reduced Habitat Extent and Access

Construction of the alternatives would result in reduced habitat extent and potentially habitat access for fish and aquatic species. The overall footprint of construction activities is approximately 1.5 to 8.9 acres of temporary impact[12] and approximately 5.6 to 17 acres of permanent impact to tidal perennial habitat (Table 12-11; see also Chapter 3, Mapbooks 3-1, 3-2, and 3-3). The footprint impact on channel margin habitat in the Sacramento River is approximately 60–570 linear feet of temporary impact and approximately 1,700–4,300 linear feet of permanent impact (Table 12-12). In addition to footprint impacts, delta smelt adult upstream migration to access shallow water for spawning upstream of the north Delta intakes may be blocked, delayed, or impeded by the presence of cofferdams isolating lower velocity, nearshore habitat (U.S. Fish and Wildlife Service 2017:317–320). This impact could impede or delay access to shallow habitat upstream of the north Delta intakes. There is uncertainty in the impact because of delta smelt adults' potential use of low velocity habitat along the opposite riverbank from the cofferdams, near the river bottom, or as created by the flutes of the cofferdams themselves. In addition, 2D modeling of the hydrodynamic effects of the cofferdams indicates that suitably low velocity habitat (i.e., no more than 0.91 feet per second per Swanson et al. 1998) would be present even at relatively high river flows. This potential impact is discussed further in Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*.

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[12] Temporary effects is the habitat extent acreage that can be returned to original basic use following completion of construction; permanent effects is the habitat acreage that cannot be returned to original basic use following completion of construction.

Table 12-11. Summary of Tidal Perennial Habitat Affected by Construction Activities (acres)

Impact Type	Feature	Waterbody	Alt. 1	Alt. 2a	Alt. 2b	Alt. 2c	Alt. 3	Alt. 4a	Alt. 4b	Alt. 4c	Alt. 5
Permanent Surface Impact	Access Railroad	Burns Cutoff	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.163
Permanent Surface Impact	Access Road	Brushy Creek	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.000
Permanent Surface Impact	Access Road	Burns Cutoff	0.000	0.000	0.000	0.000	0.094	0.094	0.094	0.094	0.090
Permanent Surface Impact	Access Road	Connection Slough	0.804	0.804	0.804	0.804	0.000	0.000	0.000	0.000	0.000
Permanent Surface Impact	Access Road	Unknown	0.130	0.130	0.130	0.130	0.140	0.140	0.140	0.140	0.061
Permanent Surface Impact	Access Road/Power – Underground New	Unknown	0.000	0.000	0.000	0.000	0.048	0.048	0.048	0.048	0.009
Permanent Surface Impact	Access Road/SCADA – Underground New	Brushy Creek	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.000
Permanent Surface Impact	Access Road/SCADA – Underground New	Burns Cutoff	0.000	0.000	0.000	0.000	0.107	0.107	0.107	0.107	0.107
Permanent Surface Impact	Access Road/SCADA – Underground New	Unknown	0.048	0.048	0.048	0.048	0.060	0.060	0.060	0.060	0.000
Permanent Surface Impact	Caltrans Road	Little Potato Slough	2.728	2.728	2.728	2.728	0.000	0.000	0.000	0.000	0.000
Permanent Surface Impact	County Road	Unknown	0.163	0.163	0.000	0.163	0.163	0.163	0.000	0.163	0.163
Permanent Surface Impact	Forebay	Italian Slough	6.807	6.807	6.807	6.807	6.807	6.807	6.807	6.807	0.000
Permanent Surface Impact	Intake	Sacramento River	4.983	6.343	2.494	4.297	4.983	6.343	2.494	4.297	4.983
Permanent Surface Impact	Levee Improvement Area	Potato Slough	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Permanent Surface Impact	Levee Improvement Area	San Joaquin River	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
Permanent Surface Impact	Shaft Site	Burns Cutoff	0.000	0.000	0.000	0.000	0.159	0.159	0.159	0.159	0.000
Permanent Surface Impact	All Combined Permanent	All Combined	15.719	17.080	13.068	15.034	12.614	13.974	9.963	11.928	5.574
Temporary Surface Impact	Access Road	Brushy Creek	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.031	0.000
Temporary Surface Impact	Access Road	Unknown	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.041	0.000
Temporary Surface Impact	Caltrans Road	Little Potato Slough	2.396	2.396	2.396	2.396	0.000	0.000	0.000	0.000	0.000
Temporary Surface Impact	County Road	Unknown	0.244	0.244	0.000	0.244	0.244	0.244	0.000	0.244	0.244
Temporary Surface Impact	Forebay Work Area	Italian Slough	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.046	0.000
Temporary Surface Impact	Intake Boundary	Sacramento River	0.834	1.157	0.381	0.779	0.834	1.157	0.381	0.779	0.834
Temporary Surface Impact	Levee Access Road	Little Potato Slough	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Temporary Surface Impact	Levee Access Road	Potato Slough	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.000	0.000
Temporary Surface Impact	Levee Access Road	San Joaquin River	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Impact Type	Feature	Waterbody	Alt. 1	Alt. 2a	Alt. 2b	Alt. 2c	Alt. 3	Alt. 4a	Alt. 4b	Alt. 4c	Alt. 5
Temporary Surface Impact	Power – Underground New	Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.010
Temporary Surface Impact	Railroad Work Area	Brushy Creek	0.266	0.266	0.266	0.266	0.266	0.266	0.266	0.266	0.000
Temporary Surface Impact	Railroad Work Area	Burns Cutoff	0.000	0.000	0.000	0.000	0.054	0.054	0.054	0.054	0.054
Temporary Surface Impact	Railroad Work Area	Unknown	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.497	0.000
Temporary Surface Impact	Road Work Area	Burns Cutoff	0.000	0.000	0.000	0.000	0.297	0.297	0.297	0.297	0.297
Temporary Surface Impact	Road Work Area	Connection Slough	4.227	4.227	4.227	4.227	0.000	0.000	0.000	0.000	0.000
Temporary Surface Impact	Road Work Area	Unknown	0.000	0.000	0.000	0.000	0.084	0.084	0.084	0.084	0.084
Temporary Surface Impact	Road Work Area/Power – Underground New	Unknown	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.025
Temporary Surface Impact	SCADA – Underground New	Unknown	0.000	0.000	0.000	0.000	0.016	0.016	0.016	0.016	0.000
Temporary Surface Impact	All Combined Temporary	All Combined	8.585	8.908	7.888	8.530	2.410	2.732	1.712	2.354	1.548

Alt. = alternative; SCADA = supervisory control and data acquisition.

Table 12-12. Summary of Channel Margin Habitat Affected by Construction Activities (linear feet)

Impact Type	Feature	Waterbody	Alt. 1	Alt. 2a	Alt. 2b	Alt. 2c	Alt. 3	Alt. 4a	Alt. 4b	Alt. 4c	Alt. 5
Permanent surface impact	Intake	Sacramento River	3,124	4,309	1,651	2,762	3,124	4,309	1,651	2,762	3,124
Temporary surface impact	Intake	Sacramento River	494	571	63	457	494	571	63	457	494

Alt. = alternative.

CEQA Conclusion—All Project Alternatives

Construction impacts on fish and aquatic species potentially would be significant because there would be the potential for spatial and temporal overlap with appreciable proportions of some of the species of management concern's populations (e.g., adult steelhead; Table 12A-9 in Appendix 12A) as well as loss of aquatic habitat. To address these impacts, the project will include Mitigation Measures AQUA-1a: *Develop and Implement an Underwater Sound Control and Abatement Plan*, AQUA-1b: *Develop and Implement a Barge Operations Plan*, AQUA-1c: *Develop and Implement a Fish Rescue and Salvage Plan*, and Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-23: *Tidal Perennial Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* and CMP-24: *Channel Margin Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* (Attachment 3F.1, *Compensatory Mitigation Design Guidelines,* Table 3F.1-3). Mitigation Measure AQUA-1a: *Develop and Implement an Underwater Sound Control and Abatement Plan* includes limiting pile-driving timing consistent with EC-14 and controlling or abating underwater noise generated during impact pile driving, for example, by starting impact pile driving at lower levels of intensity to allow fish to leave the area before the intensity is increased. Mitigation Measure AQUA-1b: *Develop and Implement a Barge Operations Plan* would include a suite of avoidance measures to minimize the potential for negative impacts from barge operations (training of tug boat operators; limiting vessel speed to minimize the effects of wake impinging on unarmored or vegetated banks and the potential for vessel wake to strand small fish; limiting the direction and/or velocity of propeller wash to prevent bottom scour and loss of aquatic vegetation; and prevention of spillage of materials and fluids from vessels), as well as assessment of effects to shoreline vegetation/river banks, with mitigation if necessary based on performance standards. Mitigation Measure AQUA-1c: *Develop and Implement a Fish Rescue and Salvage Plan* would include relocation of fish trapped in areas closed off by construction of cofferdams and training walls, thereby reducing the risk of mortality by stranding.

Several environmental commitments described in Appendix 3B, *Environmental Commitments and Best Management Practices* (Environmental Commitments EC-1: *Conduct Environmental Resources Worker Awareness Training*; EC-2: *Develop and Implement Hazardous Materials Management Plans*; EC-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans*; EC-4a: *Develop and Implement Erosion and Sediment Control Plans*; EC-4b: *Develop and Implement Stormwater Pollution Prevention Plans*; EC-14: *Construction Best Management Practices for Biological Resources*) would reduce the potential for negative impacts of construction. Environmental Commitment EC-14: *Construction Best Management Practices for Biological Resources* includes an in-water work window to limit temporal overlap of fish and aquatic resources with construction activities, particularly for listed species such as migrating salmonids. The in-water work period varies depending on location/activity but is generally from June to October, thereby avoiding or limiting temporal overlap with species such as Chinook salmon (see, for example, timing summarized in Appendix 12A, Tables 12A-3, 12A-5, and 12A-7), although as noted above, some species/life stages such as adult steelhead have the potential for appreciable overlap with construction activities and therefore the mitigation discussed above is required.

Construction impacts on fish and aquatic species would be less than significant with mitigation.

Mitigation Measure AQUA-1a: Develop and Implement an Underwater Sound Control and Abatement Plan

All Project Alternatives

DWR will implement an underwater sound control and abatement plan outlining specific measures such as changing the time of activities, best practices, and equipment that will be used to avoid and minimize the effects of underwater construction noise on fish, particularly the underwater noise effects associated with impact pile driving activities.

The underwater sound control and abatement plan will be provided to the appropriate fish and wildlife agencies for their review and approval prior to implementation of any in-water impact pile driving activities. The plan will evaluate the potential effects of underwater noise on fish using applicable and interim underwater noise thresholds established for disturbance and injury of fish (California Department of Transportation 2020:4-24–4-31). The thresholds include the following.

1. Injury threshold for fish of all sizes includes a peak sound pressure level (SPL) of 206 decibels (dB) relative to 1 micropascal.
2. Injury threshold for fish less than 2 grams is 183 dB relative to 1 micropascal cumulative sound exposure level ($\text{SEL}_{\text{sumulative}}$), and 187 dB relative to 1 micropascal $\text{SEL}_{\text{sumulative}}$ for fish greater than or equal to 2 grams.
3. Disturbance threshold for fish of all sizes is 150 dB root mean square relative to 1 micropascal.

The specific number of pilings that will be driven per day with an impact pile driver, and thus the number of pile strikes per day, will be defined as part of the design of project elements that require pilings; initial assumptions are presented in Table 12-6.

The sound control and abatement plan will restrict in-water work to the in-water work windows specified in Environmental Commitment EC-14 (Appendix 3B, *Environmental Commitments and Best Management Practices*) and approved by NMFS/USFWS/CDFW. There would be rest periods without pile driving at night.

The underwater noise generated by impact pile driving will be abated using the best available and practicable methods. Examples of such methods include the use of vibratory rather than impact pile driving equipment; use of an impact pile driver to proof piles initially placed with a vibratory pile driver; noise attenuation with pile caps (e.g., wood or micarta), bubble curtains, air-filled fabric barriers, or isolation piles; or installation of piling-specific cofferdams. Specific techniques to be used will be selected based on site-specific conditions.

In addition to primarily using vibratory pile driving methods and establishing protocols for attenuating underwater noise levels produced during in-water construction activities, DWR will develop and implement operational protocols for when impact pile driving is necessary. These operational protocols will be used to minimize the effects of impact pile driving on fish and may include the following.

4. Monitoring[13] the in-water work area for fish that may be showing signs of distress or injury as a result of pile driving activities and stopping work when distressed or injured fish are observed, for example, if injured fish are seen floating near the surface.
5. Initiating impact pile driving with a "soft-start," such that pile strikes are initiated at reduced impact and increase to full impact over several strikes to provide fish an opportunity to move out of the area.
6. Restricting impact pile driving activities to specific times of the day and for a specific duration to be determined through coordination with the fish and wildlife agencies.
7. If more than one pile driving rig is employed, ensuring pile driving activities are initiated in a way that provides an escape route and avoid "trapping" fish between pile drivers in waters exposed to underwater noise levels that could potentially cause injury.

Where impact pile driving is required, DWR will monitor underwater sound levels and require compliance with underwater noise thresholds at a distance appropriate for protection of the species (e.g., 183 dB $\text{SEL}_{\text{cumulative}}$ for fish less than 2 grams, 187 dB $\text{SEL}_{\text{cumulative}}$ for fish greater than 2 grams), based on the results from calculations to be provided in the underwater sound control and abatement plan. If such monitoring shows that noise could exceed applicable thresholds, physical or operational attenuation methods will be implemented to ensure compliance with these thresholds.

Mitigation Measure AQUA-1b: Develop and Implement a Barge Operations Plan

All Project Alternatives

DWR will require that any construction contractor proposing to use barges (to perform construction or to transport materials or equipment) develop a barge operations plan, to be approved by NMFS, USFWS, and CDFW. Each plan will be developed and submitted by the construction contractors per standard DWR contract specifications. Each barge operations plan will be part of a comprehensive traffic control plan coordinated with the U.S. Coast Guard for large channels. The barge operations plan will address the following topics.

1. Bottom scour from propeller wash.
2. Bank erosion or loss of submerged or emergent vegetation from propeller wash and/or excessive wake.
3. Accidental material spillage.
4. Sediment and benthic community disturbance from accidental or intentional barge grounding or deployment of barge spuds (extendable shafts for temporarily maintaining barge position) or anchors, including a timeline for addressing grounding to minimize risk from potential channel blockage.
5. Hazardous materials spills (e.g., fuel, oil, hydraulic fluids).

The barge operations plan will serve as a guide to barge operations and to a biological monitor who will evaluate barge operations daily during construction with respect to the stated

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[13] Monitoring will be conducted by a NMFS-/USFWS-/CDFW-approved fisheries monitor that is trained in Delta fish behavior/biology/presence and timing concerns. If distress or injury are observed, the incident will be reported to NMFS/USFWS/CDFW.

performance measures outlined in this mitigation measure (see *Performance Measures* below). This plan, when approved by the DWR and other resource agencies, will be read by barge operators and a physical copy of the plan kept aboard all vessels operating at the construction sites.

Sensitive Resources

The barge operations plan is intended to protect fish and aquatic resources in the vicinity of barge operations. The plan will be developed to avoid barge-related effects on listed species of fish; if avoidance is not possible, the plan will include provisions to minimize effects on fish and aquatic resources as described under the *Avoidance Measures*, *Environmental Training*, and *Approach and Departure Protocol* sections below. The sensitive resources potentially affected by barge maneuvering and anchoring in affected areas are listed below.

6. Sediments that could cause turbidity or changes in bathymetry if disturbed.
7. Bottom-dwelling (benthic) invertebrates that provide a prey base for fish.
8. Riparian vegetation that provides shade, cover, habitat structure, and organic nutrients to the aquatic environment.
9. Submerged aquatic vegetation that provides habitat structure and primary (plant) production.

Responsibilities

Construction contractors operating barges in the process of constructing the water conveyance facilities will be responsible for the following.

10. Operate vessels safely to prevent significant impacts on aquatic resources of the Delta.
11. Read, understand, and follow the barge operations plan.
12. Report to the project biological monitor any vessel grounding or other deviations from the barge operations plan that could have resulted in the disturbance of bottom sediments, damage to riverbanks, or loss of submerged, emergent, or riparian vegetation.
13. Immediately report material fuel or oil spills to the CDFW Office of Spill Prevention and Response, the project biological monitor, and DWR.
14. Follow all other relevant plans, including the hazardous materials management plan, stormwater pollution prevention plan (SWPPP), and spill prevention, containment, and countermeasure plan (SPCCP).
15. Observe state laws regarding monitoring and control of invasive species when introducing new watercraft to the Delta.

The biological monitor will be responsible for the following.

16. Observe barge operation activities including loading and unloading.
17. Provide same-day reports to DWR on any observed problems with barge operations.
18. Provide annual reports to DWR, summarizing monitoring observations during each construction year, including an evaluation of the plan performance measures. The annual

report will also include descriptions and representative photographs and/or videos of conditions of riverbanks and vegetation.

19. Visit each site requiring barges to determine the extent of emergent and riparian vegetation, bank conditions, and general site conditions during the growing season prior to initiation of construction, during construction, and then annually for up to 5 years after construction.
20. Monitor construction including observation of barge arrival, loading, and unloading; departure of barges at each active site and the condition of both riverbanks at each site; pile driving; and other in-water construction activity as directed by DWR.

Avoidance Measures

The following avoidance measures will be implemented to ensure that the goal of avoiding impacts on aquatic resources from tugboat and barge operations will be achieved: training of tug boat operators; limiting vessel speed to minimize the effects of wake impinging on unarmored or vegetated banks and the potential for vessel wake to strand small fish; limiting the direction and/or velocity of propeller wash to prevent bottom scour and loss of aquatic vegetation; and prevention of spillage of materials and fluids from vessels.

If deviations from these procedures are required to maintain the safety of vessels and crew, the biological monitor will be informed of the circumstances and any apparent impacts on water quality, habitats, fish, or wildlife. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.

Environmental Training

All pilots operating at intake construction and geotechnical exploration sites will be required to read and follow the barge operations plan and to keep a physical copy of the plan aboard and accessible. All pilots responsible for operating a vessel at the intake sites will read the barge operations plan and sign an affidavit as provided in the plan.

Approach and Departure Protocol

DWR will require that construction contractors develop and implement a protocol for site approach and departure to ensure the following.

21. Vessel operators will obey all federal and state navigation regulations that apply to the Delta.
22. All vessels will approach and depart from sites at dead slow in order to reduce vessel wake and propeller wash.
23. To minimize bottom disturbance, anchors and barge spuds will be used to secure vessels only when it is not possible to tie up.
24. Barge anchoring will be preplanned. Anchors will be lowered into place and not be allowed to drag across the channel bed.
25. Vessel operators will limit vessel speed as necessary to maintain wake heights of less than 2 feet at shore.
26. Vessel operators will avoid pushing stationary vessels up against fixed structures for extended periods, because this could result in excessive directed propeller wash impinging

on a single location. Barges will be tied up whenever possible to avoid the necessity of maintaining stationary position by tugboat or by the use of barge spuds.

27. Barges will not be anchored where they will ground during low tides.
28. All vessels will obey U.S. Coast Guard regulations related to the prevention, notification, and cleanup of hazardous materials spills.
29. All vessels will keep an oil spill containment kit and spill prevention and response plan onboard.
30. In the event of a fuel spill, CDFW Office of Spills Prevention and Response will be contacted immediately at 800-852-7550 or 800-OILS-911 (800-645-7911) to report the spill.
31. When transporting loose materials (e.g., sand, aggregate), barges will use deck walls or other features to prevent loose materials from blowing or washing off the deck.

Performance Measures

Performance will be assessed based on the results of the biological monitoring reports. The assessment will evaluate observations for the following indicators of impacts.

- **Emergent vegetation loss.** The extent and dominant species of emergent vegetation will be determined and mapped by a global positioning system (GPS) unit at and cross-channel from each of the intake sites during the growing seasons prior to, during, and after construction. Extent will be mapped as linear coverage along the site and opposite banks. In the event that the linear extent of emergent vegetation is found to have decreased by 20% or more following construction (or as otherwise conditioned by applicable CDFW streambed alteration agreements), the position and nature of the change will be evaluated for the probability that the loss was due to barge grounding, propeller wash, or other effects related to barge operations. Adequate performance will be achieved if the linear extent of riparian and emergent vegetation following construction is at least 80% of the preconstruction extent (or as otherwise conditioned by applicable CDFW streambed alteration agreements), not including areas that will be lost to construction activities (e.g., footprint impacts) and that will be mitigated with previously described measures (Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-23: *Tidal Perennial Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* and CMP-24: *Channel Margin Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* [Attachment 3F.1, Table 3F.1-3]). Compensatory mitigation to replace lost emergent vegetation will be undertaken should the performance standards be exceeded.
- **Bank erosion and riparian vegetation loss.** The linear extent of bank erosion will be mapped by GPS at each of the intake sites prior to, during, and after construction. Photos and written descriptions will be recorded for each area of eroded bank to describe the extent of the erosion. In the event that the linear extent of eroded bank is found to have increased by 20% or more following construction as a result of barge operations (and not other construction impacts; see above in *Emergent Vegetation Loss*), the position and nature of the change will be evaluated for the probability (low, moderate, or high) that the erosion was due to barge grounding, propeller wash, or other effects related to barge operations, and preconstruction and postconstruction photographs will be compared to determine if riparian vegetation was also lost as a result of the erosion.

- **Cargo containment.** The biological monitor will note the use of deck walls or other appropriate containment during loading and unloading of materials from a barge at each site. Adequate performance will be achieved if appropriate measures are in use during each observed loading and unloading. In the unlikely event that an accidental spill occurs despite appropriate containment measures, the barge crew will describe the type, amount, and location of the spill to the biological monitor. The biological monitor will make observations at the site of the material spill and evaluate the potential impacts of the spill on biological resources. This will help the biological monitor evaluate whether mitigation is required and will be included in the annual monitoring report. Any such impacts will be brought to the attention of the applicable fish and wildlife agency to ascertain and implement appropriate remedial measures.
- **Fuels spill prevention.** Vessels operating in accordance with the SPCCP and all applicable federal, state, and local safety and environmental laws and policies governing commercial vessel and barge operations will be considered to be performing adequately with regard to fuel spill prevention.
- **Barge grounding.** Barges are not to be grounded or anchored where falling tides are reasonably expected to cause grounding during a low tide. Barge grounding has the potential to disturb bottom sediments and benthic organisms, as well as creating a temporary obstacle to fish passage. Performance will be considered adequate if no cases of vessel grounding occur.

Contingency Measures

In the event that the performance measures are not met, DWR will coordinate with NMFS, USFWS, CDFW, and Central Valley Regional Water Quality Control Board to determine appropriate rectification or compensation for impacts on aquatic resources.

Mitigation Measure AQUA-1c: Develop and Implement a Fish Rescue and Salvage Plan

All Project Alternatives

Fish rescue operations will occur at any in-water construction site where isolation of fish may occur. Fish rescue and salvage plans will be developed by DWR or its contractors and will include detailed procedures for fish rescue and salvage to minimize the number of fish subject to stranding during placement and removal of cofferdams. The plans will be approved by NMFS, USFWS, and CDFW. The plans will identify the appropriate procedures for removing fish from construction zones and preventing fish from reentering construction zones prior to dewatering and other construction activities. A draft plan will be submitted to the fish and wildlife agencies for review and approval. An authorization letter from NMFS, USFWS, and CDFW will be required before in-water construction activities with the potential for stranding fish can proceed.

Construction activities include placement of cofferdams and training walls that isolate construction areas and minimize significant impacts on aquatic species and habitat during construction activities. However, aquatic species can become trapped within the cofferdam or behind the training walls and will need to be rescued or salvaged prior to dewatering.

All fish rescue and salvage operations will be conducted under the guidance of a qualified fish biologist[14] and in accordance with required permits. Each fish rescue plan will identify the appropriate procedures for excluding fish from the construction zones, and procedures for removing fish, should they become trapped. The primary procedure will be to herd fish out of the partially enclosed work area with seines (nets) and/or dip nets, followed by collection and removal of any remaining fish once the work area is fully enclosed; electrofishing techniques may also be authorized under certain conditions. It is critical that fish rescue and salvage operations begin as soon as possible and be completed within 48 hours after isolation of a construction area to minimize potential predation and adverse water quality impacts (high water temperature, low dissolved oxygen) associated with confinement. The cofferdam will be installed to block off the construction area before fish removal activities occur, except for a small area left open to allow fish to be herded out of the area to be enclosed. Capture, release, and relocation measures will be consistent with the general guidelines and procedures set forth in Part IX of the most recent edition of the *California Salmonid Stream Habitat Restoration Manual* (California Department of Fish and Game 2010) to minimize impacts on listed species of fish and their habitat.

All fish rescue and salvage operations will be conducted under the guidance of a fish biologist meeting the qualification requirements described under *Qualifications of Fish Rescue Personnel*. The following description includes detailed fish collection, holding, handling, and release procedures of the plan. Unless otherwise required by project permits, the construction contractor will provide the following.

1. A minimum 7-day notice to the appropriate fish and wildlife agencies, prior to an anticipated activity that could result in isolating fish, such as installation of a cofferdam.
2. Unrestricted access for the appropriate fish and wildlife agency personnel to the construction site for the duration of implementation of the fish rescue plan.
3. A work site that is accessible and safe for fish rescue workers.
4. Safety training for fish rescue workers before accessing the work site.
5. Cessation of construction activities in the vicinity of the fish rescue from the time the fish rescue begins until completion.

Qualifications of Fish Rescue Personnel

Personnel active in fish rescue efforts will include at least one person with a 4-year college degree in fisheries or biology, or a related degree. This person also must have at least 2 years of professional experience in fisheries field surveys and fish capture and handling procedures. The person will have completed an electrofishing training course such as Principles and Techniques of Electrofishing (USFWS, National Conservation Training Center), or similar course, if electrofishing is used. To avoid and minimize the risk of injury to fish, attempts to seine and/or net fish will precede the use of electrofishing equipment to the extent possible.

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[14] The qualified fish biologist will have necessary fish collection permits; will be approved by NMFS, USFWS, and CDFW; and will have experience in identifying and handling Delta fish species. The fish rescue and salvage crew overseen by the qualified fish biologist will also have experience in handling Delta fish species.

Seining and Dipnetting

Fish rescue and salvage operations will begin prior to or immediately after completing the cofferdam. As discussed above, fish will be herded from the construction area before installing the last sections of the cofferdam. Fish exclusion and/or rescue activities may need to be conducted incrementally in coordination with cofferdam placement to minimize the number of fish subjected to prolonged confinement and stressful conditions associated with crowding, capture, and handling. If the enclosed area is wadable (less than ~3 feet deep), fish can be herded out of the cofferdam enclosure by dragging a seine (net) through the enclosure, starting from the enclosed end and continuing to the cofferdam opening. It may also be possible to herd fish in deeper water with nets using divers or rafts as necessary. Depending on conditions, this process may need to be conducted several times. After completing this fish herding process, the net or an exclusion screen will be positioned at the cofferdam opening to prevent fish from reentering the enclosure while the final section of the cofferdam is installed. The net or screen mesh will be no greater than 0.125 inch, with the bottom edge of the net (lead line) securely weighted down to prevent fish from entering the area by moving under the net. Screens will be checked periodically and cleaned of debris to permit free flow of water.

After installing the last sections of the cofferdam or training wall, remaining fish in the enclosed area will be removed using seines, dip nets, electrofishing techniques, or a combination of these depending on site conditions.

Following each sweep of a seine through the enclosure, the fish rescue team will do the following.

6. Carefully bring the ends of the net together and pull in the wings, ensuring the lead line is kept as close to the substrate as possible.
7. Slowly turn the seine bag inside out to reveal captured fish, ensuring fish remain in the water as long as possible before transfer to an aerated container.
8. Follow the procedures outlined below in *Electrofishing*, and relocate fish to a predetermined release site.

Dipnetting is best suited for very small, shallow pools in which fish are concentrated and easily collected. Dip nets will be made of soft (nonabrasive) nylon material and small mesh size (0.125 inch) to collect small fish.

Electrofishing

After conducting the herding and netting operations described above, electrofishing may be necessary to remove as many fish as possible from the enclosure. Electrofishing will be conducted in accordance with NMFS electrofishing guidelines (National Marine Fisheries Service 2000) and other appropriate fish and wildlife agency guidelines. Electrofishing will be conducted by one or two 3- to 4-person teams, with each team having an electrofishing unit operator and two or three netters. At least three passes will be made through the enclosed areas to remove as many fish as possible. Fish initially will be placed in 5-gallon buckets filled with river water. Following completion of each pass, the electrofishing team will do the following.

9. Transfer fish into 5-gallon buckets filled with clean river water at ambient temperature.

10. Hold fish in 5-gallon buckets equipped with a lid and an aerator, and add fresh river water or small amounts of ice to the fish buckets if the water temperature in the buckets becomes more than 2°F warmer than ambient river waters.
11. Maintain a healthy environment for captured fish, including low densities in holding containers to avoid effects of overcrowding.
12. Use water-to-water transfers whenever possible.
13. Release fish at predetermined locations as specified in the fish rescue and salvage plans approved by NMFS, USFWS, and CDFW.
14. Segregate larger fish from smaller fish to minimize the risk of predation and physical damage to smaller fish from larger fish.
15. Limit holding time to about 10 minutes, if possible.
16. Avoid handling fish during processing unless absolutely necessary; use wet hands or dip nets if handling is needed.
17. Handle fish with hands that are free of potentially harmful products, including but not limited to sunscreen, lotion, and insect repellent.
18. Avoid anesthetizing or measuring fish.
19. Note the date, time, and location of collection; species; number of fish; approximate age (e.g., young-of-the-year, yearling, adult); fish condition (dead, visibly injured, healthy); and water temperature.
20. If positive identification of fish cannot be made without handling the fish, note this and release fish without handling.
21. In notes, indicate the level of accuracy of visual estimates to allow appropriate reporting to the appropriate fish and wildlife agencies (e.g., “Approx. 10–20 young-of-the-year steelhead”).
22. Release fish in appropriate habitat either upstream or downstream of the enclosure, noting release date, time, and location.
23. Stop efforts and immediately contact the appropriate fish and wildlife agencies if mortality or injury occurs during relocation of listed species.
24. Place dead fish of listed species in sealed plastic bags with labels indicating species, location, date, and time of collection, and store them on ice.
25. Freeze collected dead fish of listed species as soon as possible and provide the frozen specimens to the appropriate fish and wildlife agencies, as specified in the permits.
26. Release rescued fish at sites either upstream or downstream of the construction area that are similar in temperature to the area from which fish were rescued, contain ample habitat, and have a low likelihood of fish reentering the construction area or being impinged on exclusion nets/screens.

Final Inspections and Reporting

The fish rescue team will notify the contractor when the fish rescue has been completed and construction can recommence. The results of the fish rescue and salvage operations (including date, time, location, comments, method of capture, fish species, number of fish, approximate age, condition, release location, and release time) will be reported to the appropriate fish and wildlife agencies, as specified in the pertinent permits.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-23: *Tidal Perennial Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-24: *Channel Margin Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Impacts

Compensatory Mitigation

Implementation of the Compensatory Mitigation Plan could result in impacts on fish and aquatic resources. Details of compensatory mitigation are provided in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*. In summary, a total of approximately 18 to 60 acres of tidal perennial habitat and approximately 1,700 to 4,900 linear feet of channel margin habitat compensatory mitigation for construction impacts will be undertaken. Construction of aquatic habitat restoration for mitigation itself has the potential for negative effects on fish and aquatic species, with these effects generally including those previously discussed above in *Construction—All Project Alternatives* (i.e., acoustic effects, sediment disturbance, water quality effects, direct physical injury, reduced prey availability, and increased predation). Potential short-term negative effects from construction of aquatic habitat as compensatory mitigation are exemplified by effects assessed for the Lower Yolo Tidal Restoration Project (National Marine Fisheries Service 2014b). To the extent practicable, grading and excavation (e.g., of marsh plains and tidal channels) would be done prior to work allowing species to enter restored areas (e.g., excavation of notches in the perimeter of levees to facilitate tidal flows to enter and leave) to minimize negative effects on fish species. Excavation of levee perimeter notches to allow tidal exchange could result in several effects on fish species: temporary loss of aquatic and riparian habitat (e.g., increasing predation potential because of reduced cover, reduced substrate for prey, and increased water temperature); degraded water quality from contaminants liberated from soils and increased suspended sediment that could affect fish directly if in very high concentration, as well as affecting prey availability; heavy machinery noise resulting in fish being inhibited in their movements near the work areas, and possibly being startled away from work areas and, therefore, becoming more susceptible to predation; direct strikes to fish from construction equipment performing in-water work such as notch excavation in levees to restored tidal flow, leading to injury or mortality; and stranding of fish within enclosed construction areas (e.g., within cofferdams) that may be required during construction. As suggested for the Lower Yolo Tidal Restoration Project, however, such potential impacts can be minimized by construction techniques, where feasible, such as not operating heavy machinery from within the water; limiting construction to only the small areas necessary to meet restoration design (e.g., restoration of tidal connections; limiting work to low tide and daylight hours to the extent possible; and installing sheet pile exclusion barriers with vibratory hammers). Potential negative effects from compensatory mitigation construction would be expected to affect very small numbers of individuals of fish and aquatic species that may occur near sites during in-water work. Construction of compensatory mitigation will include various mitigation measures and environmental commitments as necessary and as described above for construction effects. These mitigation measures would limit the potential for negative effects by limiting work to the in-water work window and limiting the potential for water quality effects. Inclusion of selenium and methylmercury management as part of mitigation (WQ-6: *Mercury Management*; WQ-10: *Develop and Implement a Selenium Management Plan*, discussed in Chapter 9, *Water Quality*) would limit potential for negative effects from selenium or methylmercury production as a result of habitat restoration activities.

Other Mitigation Measures

Some mitigation measures would involve in-water work that would have the potential to affect fish and aquatic species. The mitigation measure with potential to result in effects on fish and aquatic species is Mitigation Measure AQUA-1a: *Develop and Implement an Underwater Sound Control and Abatement Plan*. Temporary effects on fish and aquatic species resulting from implementation of mitigation measures would be similar to construction effects of the project alternatives in certain construction areas and would contribute to fish and aquatic species impacts of the project alternatives. DWR will develop and implement an underwater sound control and abatement plan that could include installation of an attenuation device, such as a bubble curtain, or other mechanism to minimize noise, such as air-filled fabric barriers, isolation piles, or installation of piling-specific cofferdams.

Abatement measures for underwater noise generated by impact pile driving include best available and practicable methods with the potential for negative effects on fish and aquatic species by trapping them within enclosed areas: bubble curtains, air-filled fabric barriers, isolation piles, or piling-specific cofferdams. Should fish and aquatic species become trapped within the area enclosed by these methods, they would be exposed to high sound levels and may be injured, potentially fatally, by noise levels. However, the number of individuals potentially experiencing such effects would be low because of the small area affected and the likely disturbance and avoidance of the area by fish. The in-water work window for this measure also would limit the potential for temporal overlap with listed and other special-status species.

Overall, other mitigation measures implemented for the construction of the Water Conveyance Facilities, would be temporary and limited to the in-water work window during the construction phase of the project. Potential impacts would be limited to less than significant by limiting the duration of the activities to the extent possible, with Environmental Commitments EC-2: *Develop and Implement Hazardous Materials Management Plans*; EC-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans;* EC-4a: *Develop and Implement Erosion and Sediment Control Plans*; and EC-4b: *Develop and Implement Stormwater Pollution Prevention Plans*. Additionally, Environmental Commitment EC-14: *Construction Best Management Practices for Biological Resources* would minimize, but perhaps not completely avoid, the potential for injury or mortality. Mitigation Measure AQUA-1b: *Develop and Implement a Barge Operations Plan* would also minimize impacts from construction-related disturbance. Therefore, implementation of other mitigation measures is unlikely to result in impacts on fish and aquatic species, and there would be a less-than-significant impact with mitigation.

Overall, the impact on fish and aquatic species from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the overall less-than-significant with mitigation impact conclusion.

Construction—No Project Alternative

There would be no construction in the Delta under the No Project Alterative and therefore no effects to fish and aquatic resources (see discussion of construction outside of the Delta in Section 12.3.3.1, *No Project Alternative*).

Impact AQUA-2: Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon

Operations and Maintenance—All Project Alternatives

Potential effects of the project alternatives on winter-run Chinook salmon are discussed in terms of near-field effects (i.e., in the immediate proximity) of north Delta exports and south Delta exports (e.g., entrainment), in addition to far-field effects (e.g., changes to through-Delta survival and habitat suitability). Analyses were focused primarily on the San Francisco Estuary and Delta. Life cycle modeling integrates potential effects within the Bay-Delta and upstream habitat and was undertaken using three available life cycle models for winter-run Chinook salmon (IOS, OBAN, and the Sacramento River Winter-Run Chinook Salmon Life Cycle Model). Analyses were developed in consideration of habitat attributes believed to be of importance to the species based on existing conceptual models (e.g., Windell et al. 2017) and best available methods (e.g., ICF International 2016a; California Department of Water Resources 2020a). Table 12-3 in this chapter provides a summary of quantitative methods.

Near-Field Effects

North Delta Exports

The potential for negative near-field effects of the north Delta Diversion intakes on juvenile winter-run Chinook salmon (entrainment, impingement, and predation) is dependent on the occurrence of the species close to the intakes, both vertically (i.e., at similar water depth) and horizontally (i.e., on the same side of the river and near the edge of the river), as well as exposure time. At the scale of the whole downstream-migrating juvenile winter-run Chinook salmon population, only those individuals remaining in the Sacramento River (as opposed to entering Yolo Bypass) would pass the north Delta intakes. Under existing conditions, flows enter the Yolo Bypass in approximately 60%–70% of years, with the estimated percentage of the juvenile winter-run Chinook salmon population remaining in the Sacramento River averaging around 94% of the population in wet and above normal years and greater than 99% of the population in dry and critically dry years (Acierto et al. 2014).[15]

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[15] The Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project Final EIS/EIR estimated that on average 1.2% of juvenile winter-run <80-mm fork length enter Yolo Bypass under existing conditions (Bureau of Reclamation and California Department of Water Resources 2019: 8-291). Note that with notching of the Fremont Weir, as would occur prior to implementation of the project alternatives, the percentage of the juvenile winter-run Chinook salmon population remaining in the mainstem Sacramento River would be less than existing conditions (e.g., an overall mean of ~93% for juveniles <80-mm fork length; Bureau of Reclamation and California Department of Water Resources 2019: 8-291).

With respect to vertical distribution, migrating juvenile salmonids generally are in the upper portion of the water column (Smith et al. 2009). This was illustrated in a hydroacoustic study near the Delta Cross Channel, for which fish were particularly abundant between around 4 and 7 meters (13 and 23 feet) below the surface of the 13-meter-deep (43 feet) water column (Blake and Horn 2006:Figure 41), that is, fish were found at approximately 30%–50% of water column depth. Based on available design information (Table 12-13), the top of the cylindrical tee screens for the North Delta Diversion (NDD) would be located in the upper half of the water column much of the time during the main months of winter-run occurrence (i.e., November–April): generally 75%–95% or more of the time at Intakes A and B (Tables 12-14 and 12-15), and 25%–50% of the time at Intake C (Table 12-16). This suggests that exposure of juvenile migrating winter-run Chinook salmon to the screens could be frequent on the basis of their typical vertical migration distribution, if they occurred near the left river bank on which the proposed intakes would be located.

Table 12-13. Elevation of North Delta Diversion Intakes

Intake	Mean River Bottom Elevation (ft, NAVD)	Bottom of Cylindrical Tee Screen (ft, NAVD)	Top of Cylindrical Tee Screen (ft, NAVD)
A	-13	-9	-1
B	-25	-13	-5
C	-17	-13	-5

Source: Delta Conveyance Design and Construction Authority (2022e:11, 2022f:53).

ft, NAVD = feet elevation, North American Vertical Datum.

Table 12-14. Water Column Position (U = Upper 50%; L = Lower 50%) of Top of Cylindrical Tee Screens at Intake A During Various Monthly Water Surface Elevation Exceedance Percentiles

Month	1%	5%	25%	50%	75%	95%	99%
Jan	L	L	U	U	U	U	U
Feb	L	L	U	U	U	U	U
Mar	L	L	L	U	U	U	U
Apr	L	L	U	U	U	U	U
May	L	L	U	U	U	U	U
Jun	L	U	U	U	U	U	U
Jul	U	U	U	U	U	U	U
Aug	U	U	U	U	U	U	U
Sep	U	U	U	U	U	U	U
Oct	U	U	U	U	U	U	U
Nov	U	U	U	U	U	U	U
Dec	L	L	U	U	U	U	U

Source: Based on elevation data in Table 12-33 and data sources in Delta Conveyance Design and Construction Authority (2022e).

Note: Percentiles indicate water surface elevation that would be exceeded 1%, 5%, etc., of the time, so, for example, an ‘L’ in the 25% column indicates that the top of the cylindrical tee screens would be in the lower 50% of the water column 25% of the time.

Table 12-15. Water Column Position (U = Upper 50%; L = Lower 50%) of Top of Cylindrical Tee Screens at Intake B During Various Monthly Water Surface Elevation Exceedance Percentiles

Month	1%	5%	25%	50%	75%	95%	99%
Jan	L	L	U	U	U	U	U
Feb	L	L	U	U	U	U	U
Mar	L	L	U	U	U	U	U
Apr	L	L	U	U	U	U	U
May	L	U	U	U	U	U	U
Jun	U	U	U	U	U	U	U
Jul	U	U	U	U	U	U	U
Aug	U	U	U	U	U	U	U
Sep	U	U	U	U	U	U	U
Oct	U	U	U	U	U	U	U
Nov	U	U	U	U	U	U	U
Dec	L	U	U	U	U	U	U

Source: Based on elevation data in Table 12-33 and data sources in Delta Conveyance Design and Construction Authority (2022e).

Note: Percentiles indicate water surface elevation that would be exceeded 1%, 5%, etc., of the time, so, for example, an ‘L’ in the 5% column indicates that the top of the cylindrical tee screens would be in the lower 50% of the water column 5% of the time.

Table 12-16. Water Column Position (U = Upper 50%; L = Lower 50%) of Top of Cylindrical Tee Screens at Intake C During Various Monthly Water Surface Elevation Exceedance Percentiles.

Month	1%	5%	25%	50%	75%	95%	99%
Jan	L	L	L	U	U	U	U
Feb	L	L	L	U	U	U	U
Mar	L	L	L	U	U	U	U
Apr	L	L	L	U	U	U	U
May	L	L	L	U	U	U	U
Jun	L	L	U	U	U	U	U
Jul	L	L	U	U	U	U	U
Aug	L	L	U	U	U	U	U
Sep	L	U	U	U	U	U	U
Oct	U	U	U	U	U	U	U
Nov	L	U	U	U	U	U	U
Dec	L	L	L	U	U	U	U

Source: Based on elevation data in Table 12-33 and data sources in Delta Conveyance Design and Construction Authority (2022e).

Note: Percentiles indicate water surface elevation that would be exceeded 1%, 5%, etc., of the time, so, for example, an ‘L’ in the 25% column indicates that the top of the cylindrical tee screens would be in the lower 50% of the water column 25% of the time.

With respect to horizontal distribution of juvenile winter-run Chinook salmon across the river cross-section and potential exposure to the near-bank cylindrical tee screens proposed under the alternatives, several studies in the Sacramento River provide evidence for the distribution of fish being toward the outer sides of river bends, including at Clarksburg Bend (Burau et al. 2007:Figure C.17), the Delta Cross Channel (Burau et al. 2007:Figure 2.5), and near Fremont Weir (Blake et al. 2017:Figures 2 and 20). The distribution of fish toward the outside of bends is the result of centrifugal and pressure forces in bends that induce a secondary flow that lies in a plane perpendicular to the primary flow direction (Dinehart and Burau 2005) and is reflected in the bathymetry of such areas: The deeper areas, including the thalweg (i.e., the line of lowest elevation within the river channel), coincide with the areas subject to the secondary flow (Burau et al. 2007:Figure C.1). These observations agree with the general pattern of downstream-migrating juvenile salmonids in the Pacific northwest often being distributed near the thalweg, or near the shoreline (Smith et al. 2009), and the coincidence of fish occurring near the thalweg with the secondary flow results in fish being moved to the outside of bends. The three potential sites for the north Delta intakes reflected the Fish Facilities Technical Team's[16] (2011:42) earlier recommendation to locate the north Delta intakes within straight reaches of the river or mild outside bends to avoid complex flow patterns, sedimentation, and excessive scour. Locating the intakes at the outside of the river bends may lead to a greater proportion of juvenile salmonids passing close to the intakes than if the fish were occurring evenly distributed across the channel cross section. However, when holding (e.g., during the day; Plumb et al. 2016), juvenile salmonids could also occur on the inside of river bends, as illustrated at Clarksburg Bend (Burau et al. 2007:Figure C.15).

Two-dimensional modeling of the hydrodynamic effects of the north Delta intakes illustrates that the proportion of the river channel width from which water is drawn toward the intakes[17] varies depending on diversion rate and river flow (Table 12-17). Beyond this, streamlines proceed past the intakes. This indicates that any potential increase in exposure to near-field effects of the screens as a result of fish being drawn toward the intakes would be limited to this portion of the channel cross-section. Note, however, that fish being on the intake side of the critical streakline does not necessarily mean that the fish would be drawn to the intakes; as described in Chapter 3, sweeping velocity would be at least double the approach velocity (see additional discussion below), thereby limiting the potential for fish to be drawn to the intakes and minimizing the potential for negative near-field effects such as injury from contacting the screens. The CalSim modeling of the north Delta diversions provides context for the frequency of occurrence of diversions at different river flows, and therefore potential portion of the river channel flow drawn towards the north Delta intakes, by showing the percentage of months that would be within various combinations of river flows and diversions (Tables 12-18, 12-19, 12-20, 12-21, and 12-22).[18] Thus, for example, under Alternative 5 in December at Freeport flows of 18,000 cfs or less, the streakline at Intakes B and C would be around 13%–17% of the river width or less based on the results of modeling run 4F (Table 12-17) coupled with consideration of the frequency of diversion in relation to Freeport flow (Table 12-22).

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[16] The Fish Facilities Technical Team included as participating agencies the Bay Delta Conservation Plan, Reclamation, CDFW (then the California Department of Fish and Game), DWR, NMFS, and USFWS (Fish Facilities Technical Team 2011:10).

[17] This location is the critical streakline, defined as the location dividing the parcel of water that is diverted into the intake and the parcel that remains in the river channel (adapting the definition of Hance et al. [2020] for open channels), as determined by examining animated streamlines from hydrodynamic modeling.

[18] See Appendix 5A, Section B.7.1, *North Delta Diversion Operational Criteria,* and Appendix 5A, Section C.6.4, *North Delta Diversion Intakes Operation*.

Based on the operating criteria, high levels of diversion at low river flows would be very rare (see, for example, percentages for Table 12-22 corresponding to Freeport flow <=18,000 cfs and diversions >5,000–6,000 cfs). The two-dimensional modeling does not account for fish behavior or the distribution of fish in the channel (see above discussion). In addition, as described in the next section, *Entrainment and Impingement*, north Delta intake operations would meet fishery agency standards for approach and sweeping velocity in order to limit the potential for negative effects to juvenile winter-run Chinook salmon and other species.

Screen passage time is a useful measure of the duration that potential negative effects on Chinook salmon could occur, with shorter passage times limiting the potential for negative near-field effects (e.g., predation or screen contact/impingement). A fish moving downstream at the same velocity as river flow with 0.4-foot sweeping velocity would pass a single, approximately 30-foot[19] cylindrical tee screen unit in 75 seconds (i.e., 30 feet/0.4 foot per second = 75 seconds); a combined screen length of 450 feet—the approximate length of 15 screen units for Intake A under Alternatives 2a and 4a and for Intake C under Alternatives 2c and 4c—in 18.75 minutes (i.e., 450 feet/0.4 foot per second = 1,125 seconds = 18.75 minutes); and a combined screen unit length of 900 feet—the approximate screen unit length of each of Intakes B and C with 3,000-cfs capacity—in 37.5 minutes (i.e., 900 feet/0.4 foot per second = 2,250 seconds = 37.5 minutes). However, laboratory studies of juvenile Chinook salmon in close proximity to a test fish screen showed that fish may swim against the current, resulting in longer passage time than sweeping velocity alone would produce (Swanson et al. 2004).

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[19] The cylindrical fish screen units would actually be 29.33 feet long and be separated by a gap of 1 foot; each screen unit would include 7.66 feet of manifold between the two screens comprising each unit, so that there actually would be 21.67 feet length of fish screen per screen unit.

Table 12-17. Distance and Percentage of River Width of Critical Streakline at North Delta Intakes A, B, and C from Two-Dimensional Hydrodynamic Modeling

Model Run	Freeport Flow (cfs)	Diversion Flow by Intake (cfs)	Intake A River Width (ft)	Intake A Streakline (ft; % of River Width)	Intake A % of Flow Diverted	Intake B River Width (ft)	Intake B Streakline (ft; % of River Width)	Intake B % of Flow Diverted	Intake C River Width (ft)	Intake C Streakline (ft; % of River Width)	Intake C % of Flow Diverted	Notes
2D	50,000 [a]	3,000 B&C	NA	NA	0.0%	560	80 (14%)	6.0%	660	100 (15%)	6.4%	High river velocity during operation
2I	50,000 [a]	3,000 B&C/ 1,500@A	720	70 (10%)	3.0%	560	90 (16%)	6.2%	660	110 (17%)	6.6%	7,500 cfs option run
3D	30,000 [a]	3,000 B&C	NA	NA	0.0%	550	80 (15%)	10.0%	650	120 (18%)	11.1%	Moderate river velocity during operation, high diversion
3E	30,000 [a]	2,000 B&C	NA	NA	0.0%	550	70 (13%)	6.7%	650	100 (15%)	7.1%	Moderate river velocity during operation, moderate diversion
3F	30,000 [a]	1,000 B&C	NA	NA	0.0%	550	50 (9%)	3.3%	650	70 (11%)	3.4%	Moderate river velocity during operation, low diversion
3I	30,000 [a]	3,000 B&C/ 1,500@A	700	80 (11%)	5.0%	550	90 (16%)	10.5%	650	130 (20%)	11.8%	7,500 cfs option
4D	18,000 [a]	3,000 B&C	NA	NA	0.0%	540	110 (20%)	16.7%	630	180 (29%)	20.0%	Low river velocity during operation, high diversion
4E	18,000 [a]	2,000 B&C	NA	NA	0.0%	540	90 (17%)	11.1%	640	140 (22%)	12.5%	Low river velocity during operation, moderate diversion
4F	18,000 [a]	1,000 B&C	NA	NA	0.0%	540	70 (13%)	5.6%	640	110 (17%)	5.9%	Low river velocity during operation, low diversion
4I	18,000 [a]	3,000 B&C/ 1,500@A	700	100 (14%)	8.3%	540	120 (22%)	18.2%	640	220 (34%)	22.2%	7,500 cfs option
5B	Hydrograph [b]	3,000 B&C	NA	NA	0%	540	130 (24%)	14.2%	640	160 (25%)	15.3%	Low tide, 12/01/2016 02:00
5C	Hydrograph [b]	3,000 B&C	NA	NA	0%	540	150 (28%)	16.7%	640	180 (28%)	19.1%	Dropping tide, 12/01/2016 11:00
5D	Hydrograph [b]	3,000 B&C	NA	NA	0%	540	180 (33%)	23.4%	640	280 (44%)	37.1%	High tide, 12/01/2016 18:00

Source: Delta Conveyance Design and Construction Authority (2022g).

Note: The critical streakline is the location in the river channel dividing the parcel of water that is diverted into the intake and the parcel that remains in the river channel, as determined by examining animated streamlines from hydrodynamic modeling. The location of the critical streakline is measured as the distance from the left bank of the river to the flow streamline that enters the intake screens at the most downstream location; this streakline extends to a point a short distance upstream of the intake structure where the streamline is consistent with the upstream streamlines that are unaffected by the diversions.

[a] Steady-state runs (river flow constant, no tidal changes).

[b] Tidally varying flows at mean daily Freeport flow ~18,000 cfs.

Table 12-18. Percentage of Months with North Delta Diversions within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Alternatives 1 and 3, Based on CalSim Modeling

Freeport flow	Total North Delta Diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
<=18,000 cfs	0 cfs	48%	78%	52%	19%	4%	10%	13%	48%	53%	67%
<=18,000 cfs	<=1,000 cfs	9%	5%	16%	38%	28%	12%	9%	1%	7%	5%
<=18,000 cfs	>1,000–2,000 cfs	7%	5%	5%	5%	5%	2%	0%	4%	1%	3%
<=18,000 cfs	>2,000–3,000 cfs	2%	3%	4%	0%	0%	1%	2%	0%	3%	0%
<=18,000 cfs	>3,000–4,000 cfs	2%	1%	4%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>4,000–5,000 cfs	2%	0%	2%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>5,000–6,000 cfs	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
>18,000–30,000 cfs	0 cfs	23%	0%	0%	0%	0%	2%	2%	15%	5%	0%
>18,000–30,000 cfs	<=1,000 cfs	2%	2%	1%	2%	3%	5%	2%	2%	4%	1%
>18,000–30,000 cfs	>1,000–2,000 cfs	2%	3%	1%	4%	7%	5%	1%	1%	2%	2%
>18,000–30,000 cfs	>2,000–3,000 cfs	1%	1%	7%	2%	10%	6%	6%	1%	0%	6%
>18,000–30,000 cfs	>3,000–4,000 cfs	0%	0%	0%	3%	3%	6%	15%	2%	0%	0%
>18,000–30,000 cfs	>4,000–5,000 cfs	0%	0%	0%	0%	3%	2%	5%	0%	1%	3%
>18,000–30,000 cfs	>5,000–6,000 cfs	1%	0%	0%	0%	0%	0%	2%	0%	1%	2%
>30,000–50,000 cfs	0 cfs	0%	0%	1%	1%	1%	0%	3%	13%	6%	0%
>30,000–50,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	1%	0%	3%	1%
>30,000–50,000 cfs	>1,000–2,000 cfs	0%	0%	1%	1%	0%	1%	1%	0%	1%	3%
>30,000–50,000 cfs	>2,000–3,000 cfs	0%	1%	3%	2%	2%	1%	2%	1%	3%	2%
>30,000–50,000 cfs	>3,000–4,000 cfs	0%	0%	0%	3%	0%	1%	4%	1%	1%	0%
>30,000–50,000 cfs	>4,000–5,000 cfs	0%	0%	0%	4%	3%	4%	7%	0%	0%	1%
>30,000–50,000 cfs	>5,000–6,000 cfs	0%	0%	0%	3%	6%	7%	2%	0%	1%	0%
>50,000–70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	7%	6%	4%	1%
>50,000–70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	2%	1%	0%	1%	0%
>50,000–70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	0%	2%	1%	0%	0%	1%
>50,000–70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	3%	2%	2%	0%	0%	0%
>50,000–70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	2%	2%	1%	1%	0%	0%
>50,000–70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	2%	2%	4%	2%	1%	0%	0%
>50,000–70,000 cfs	>5,000–6,000 cfs	0%	0%	0%	4%	7%	4%	2%	0%	0%	0%

Freeport flow	Total North Delta Diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
>70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	4%	0%	0%	0%
>70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	1%	1%	0%	2%	0%	0%
>70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
>70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
>70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>5,000–6,000 cfs	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%

Table 12-19. Percentage of Months with North Delta Diversions Within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Alternatives 2a and 4a, Based on CalSim Modeling

Freeport flow	Total North Delta Diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
<=18,000 cfs	0 cfs	47%	77%	52%	20%	3%	10%	13%	47%	53%	67%
<=18,000 cfs	<=1,000 cfs	6%	6%	16%	35%	29%	11%	9%	2%	7%	5%
<=18,000 cfs	>1,000–2,000 cfs	10%	6%	5%	6%	4%	2%	0%	4%	1%	3%
<=18,000 cfs	>2,000–3,000 cfs	2%	3%	4%	0%	1%	1%	2%	0%	3%	0%
<=18,000 cfs	>3,000–4,000 cfs	3%	0%	2%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>4,000–5,000 cfs	1%	0%	4%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>5,000–6,000 cfs	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>6,000–7,500 cfs	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
>18,000–30,000 cfs	0 cfs	26%	0%	0%	0%	0%	3%	3%	16%	5%	0%
>18,000–30,000 cfs	<=1,000 cfs	2%	2%	1%	3%	3%	5%	1%	1%	4%	1%
>18,000–30,000 cfs	>1,000–2,000 cfs	1%	3%	1%	3%	6%	5%	1%	1%	2%	2%
>18,000–30,000 cfs	>2,000–3,000 cfs	1%	1%	7%	3%	9%	5%	6%	1%	0%	6%
>18,000–30,000 cfs	>3,000–4,000 cfs	0%	0%	0%	2%	3%	6%	14%	2%	0%	0%
>18,000–30,000 cfs	>4,000–5,000 cfs	0%	0%	0%	1%	3%	3%	6%	0%	1%	3%
>18,000–30,000 cfs	>5,000–6,000 cfs	1%	0%	0%	0%	2%	0%	1%	0%	0%	2%
>18,000–30,000 cfs	>6,000–7,500 cfs	0%	0%	0%	0%	0%	0%	1%	0%	1%	0%

Freeport flow	Total North Delta Diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
>30,000–50,000 cfs	0 cfs	0%	0%	1%	1%	1%	0%	3%	13%	6%	0%
>30,000–50,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	3%	1%
>30,000–50,000 cfs	>1,000–2,000 cfs	0%	0%	2%	1%	0%	1%	2%	0%	1%	3%
>30,000–50,000 cfs	>2,000–3,000 cfs	0%	1%	2%	0%	2%	1%	2%	1%	3%	1%
>30,000–50,000 cfs	>3,000–4,000 cfs	0%	0%	0%	4%	0%	0%	2%	1%	0%	1%
>30,000–50,000 cfs	>4,000–5,000 cfs	0%	0%	0%	4%	1%	4%	4%	0%	1%	1%
>30,000–50,000 cfs	>5,000–6,000 cfs	0%	0%	0%	2%	1%	2%	3%	0%	1%	0%
>30,000–50,000 cfs	>6,000–7,500 cfs	0%	0%	0%	2%	7%	6%	5%	0%	0%	0%
>50,000–70,000 cfs	0 cfs	0%	0%	0%	2%	1%	5%	9%	6%	4%	1%
>50,000–70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	1%	2%	0%	0%	1%	0%
>50,000–70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	0%	2%	2%	0%	0%	1%
>50,000–70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	3%	3%	1%	0%	0%	0%
>50,000–70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	2%	1%	2%	1%	0%	0%
>50,000–70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	1%	1%	3%	1%	0%	0%	0%
>50,000–70,000 cfs	>5,000–6,000 cfs	0%	0%	0%	3%	2%	2%	0%	1%	0%	0%
>50,000–70,000 cfs	>6,000–7,500 cfs	0%	0%	0%	2%	6%	3%	1%	0%	0%	0%
>70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	4%	0%	0%	0%
>70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	1%	1%	0%	2%	0%	0%
>70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
>70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
>70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>5,000–6,000 cfs	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%
>70,000 cfs	>6,000–7,500 cfs	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Table 12-20. Percentage of Months with North Delta Diversions Within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Alternatives 2b and 4b, Based on CalSim Modeling

Freeport flow	Total North Delta diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
<=18,000 cfs	0 cfs	47%	78%	52%	19%	3%	12%	13%	48%	53%	68%
<=18,000 cfs	<=1,000 cfs	10%	5%	15%	38%	29%	10%	9%	2%	7%	4%
<=18,000 cfs	>1,000–2,000 cfs	9%	7%	6%	4%	5%	3%	1%	3%	1%	3%
<=18,000 cfs	>2,000–3,000 cfs	5%	2%	12%	0%	0%	0%	1%	0%	3%	0%
>18,000–30,000 cfs	0 cfs	23%	0%	0%	0%	0%	2%	2%	18%	10%	0%
>18,000–30,000 cfs	<=1,000 cfs	3%	2%	1%	2%	4%	4%	1%	0%	1%	1%
>18,000–30,000 cfs	>1,000–2,000 cfs	2%	3%	4%	9%	14%	11%	7%	2%	1%	2%
>18,000–30,000 cfs	>2,000–3,000 cfs	1%	1%	4%	2%	9%	11%	23%	1%	2%	12%
>30,000–50,000 cfs	0 cfs	0%	0%	1%	1%	1%	0%	2%	12%	4%	0%
>30,000–50,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	1%	1%	3%	0%
>30,000–50,000 cfs	>1,000–2,000 cfs	0%	0%	2%	2%	1%	1%	1%	1%	1%	4%
>30,000–50,000 cfs	>2,000–3,000 cfs	0%	1%	2%	12%	11%	14%	18%	1%	7%	3%
>50,000–70,000 cfs	0 cfs	0%	0%	0%	2%	2%	4%	6%	5%	3%	1%
>50,000–70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	3%	2%	1%	1%	0%
>50,000–70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	0%	2%	0%	0%	1%	1%
>50,000–70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	6%	15%	13%	7%	2%	0%	0%
>70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	4%	0%	0%	0%
>70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	0%	2%	0%	0%
>70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%
>70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	2%	3%	0%	0%	0%	0%

Table 12-21. Percentage of Months with North Delta Diversions Within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Alternatives 2c and 4c, Based on CalSim Modeling

Freeport flow	Total North Delta diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
<=18,000 cfs	0 cfs	47%	78%	52%	19%	4%	11%	13%	47%	52%	68%
<=18,000 cfs	<=1,000 cfs	10%	5%	15%	37%	28%	11%	9%	2%	9%	4%
<=18,000 cfs	>1,000–2,000 cfs	7%	6%	6%	5%	5%	2%	0%	4%	1%	3%
<=18,000 cfs	>2,000–3,000 cfs	2%	2%	4%	0%	0%	1%	2%	0%	3%	0%
<=18,000 cfs	>3,000–4,000 cfs	2%	1%	6%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>4,000–5,000 cfs	2%	0%	1%	0%	0%	0%	0%	0%	0%	0%
>18,000–30,000 cfs	0 cfs	23%	0%	0%	0%	0%	2%	2%	15%	9%	0%
>18,000–30,000 cfs	<=1,000 cfs	3%	2%	1%	3%	3%	5%	1%	2%	2%	1%
>18,000–30,000 cfs	>1,000–2,000 cfs	2%	3%	1%	6%	11%	6%	2%	1%	1%	2%
>18,000–30,000 cfs	>2,000–3,000 cfs	0%	1%	7%	3%	6%	10%	11%	1%	0%	6%
>18,000–30,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	6%	4%	13%	2%	0%	0%
>18,000–30,000 cfs	>4,000–5,000 cfs	1%	0%	0%	0%	0%	0%	5%	0%	2%	5%
>30,000–50,000 cfs	0 cfs	0%	0%	1%	1%	1%	0%	2%	12%	6%	0%
>30,000–50,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	2%	1%	3%	0%
>30,000–50,000 cfs	>1,000–2,000 cfs	0%	0%	1%	1%	1%	1%	1%	0%	2%	4%
>30,000–50,000 cfs	>2,000–3,000 cfs	0%	1%	3%	2%	1%	1%	3%	2%	1%	2%
>30,000–50,000 cfs	>3,000–4,000 cfs	0%	0%	0%	7%	1%	3%	3%	0%	2%	0%
>30,000–50,000 cfs	>4,000–5,000 cfs	0%	0%	0%	3%	9%	10%	10%	0%	1%	1%
>50,000–70,000 cfs	0 cfs	0%	0%	0%	2%	2%	4%	9%	6%	4%	1%
>50,000–70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	3%	0%	0%	1%	0%
>50,000–70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	0%	1%	1%	0%	0%	1%
>50,000–70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	3%	2%	2%	0%	0%	0%
>50,000–70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	3%	2%	5%	1%	1%	0%	0%
>50,000–70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	3%	10%	6%	4%	1%	0%	0%

Freeport flow	Total North Delta diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
>70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	4%	0%	0%	0%
>70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	1%	1%	0%	2%	0%	0%
>70,000 cfs	>1,000–2,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>2,000–3,000 cfs	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
>70,000 cfs	>3,000–4,000 cfs	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%
>70,000 cfs	>4,000–5,000 cfs	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%

Table 12-22. Percentage of Months with North Delta Diversions Within 1,000-cfs Ranges, Categorized by Sacramento River at Freeport Flow, Alternative 5, Based on CalSim Modeling

Freeport flow	Total North Delta diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
<=18,000 cfs	0 cfs	48%	78%	53%	19%	4%	10%	13%	48%	53%	67%
<=18,000 cfs	<=1,000 cfs	9%	5%	16%	38%	28%	12%	9%	1%	7%	5%
<=18,000 cfs	>1,000-2,000 cfs	7%	5%	4%	5%	5%	2%	0%	4%	1%	3%
<=18,000 cfs	>2,000-3,000 cfs	2%	3%	3%	0%	0%	1%	2%	0%	3%	0%
<=18,000 cfs	>3,000-4,000 cfs	2%	1%	5%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>4,000-5,000 cfs	2%	0%	2%	0%	0%	0%	0%	0%	0%	0%
<=18,000 cfs	>5,000-6,000 cfs	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
>18,000-30,000 cfs	0 cfs	23%	1%	0%	0%	0%	2%	2%	15%	5%	0%
>18,000-30,000 cfs	<=1,000 cfs	2%	1%	1%	2%	3%	5%	2%	2%	4%	1%
>18,000-30,000 cfs	>1,000-2,000 cfs	2%	3%	1%	4%	7%	5%	1%	1%	2%	2%
>18,000-30,000 cfs	>2,000-3,000 cfs	0%	1%	1%	2%	10%	6%	6%	1%	0%	6%
>18,000-30,000 cfs	>3,000-4,000 cfs	1%	0%	6%	3%	3%	6%	15%	2%	0%	0%
>18,000-30,000 cfs	>4,000-5,000 cfs	0%	0%	0%	0%	3%	2%	5%	0%	1%	3%
>18,000-30,000 cfs	>5,000-6,000 cfs	1%	0%	0%	0%	0%	0%	2%	0%	1%	2%

Freeport flow	Total North Delta diversion	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
>30,000-50,000 cfs	0 cfs	0%	0%	1%	1%	1%	0%	3%	13%	6%	0%
>30,000-50,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	1%	1%	0%	3%	1%
>30,000-50,000 cfs	>1,000-2,000 cfs	0%	0%	1%	1%	0%	1%	1%	0%	1%	2%
>30,000-50,000 cfs	>2,000-3,000 cfs	0%	0%	1%	2%	2%	1%	2%	1%	3%	3%
>30,000-50,000 cfs	>3,000-4,000 cfs	0%	1%	2%	3%	0%	1%	4%	1%	1%	0%
>30,000-50,000 cfs	>4,000-5,000 cfs	0%	0%	0%	4%	3%	4%	7%	0%	0%	0%
>30,000-50,000 cfs	>5,000-6,000 cfs	0%	0%	0%	3%	6%	7%	2%	0%	1%	1%
>50,000-70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	7%	6%	4%	1%
>50,000-70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	0%	2%	1%	0%	1%	0%
>50,000-70,000 cfs	>1,000-2,000 cfs	0%	0%	0%	0%	0%	2%	1%	0%	0%	1%
>50,000-70,000 cfs	>2,000-3,000 cfs	0%	0%	0%	0%	3%	1%	2%	0%	0%	0%
>50,000-70,000 cfs	>3,000-4,000 cfs	0%	0%	0%	0%	2%	3%	1%	1%	0%	0%
>50,000-70,000 cfs	>4,000-5,000 cfs	0%	0%	0%	2%	2%	4%	2%	1%	0%	0%
>50,000-70,000 cfs	>5,000-6,000 cfs	0%	0%	0%	4%	7%	4%	2%	0%	0%	0%
>70,000 cfs	0 cfs	0%	0%	0%	2%	2%	5%	4%	0%	0%	0%
>70,000 cfs	<=1,000 cfs	0%	0%	0%	0%	1%	0%	0%	2%	0%	0%
>70,000 cfs	>1,000-2,000 cfs	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%
>70,000 cfs	>2,000-3,000 cfs	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
>70,000 cfs	>3,000-4,000 cfs	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
>70,000 cfs	>4,000-5,000 cfs	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%
>70,000 cfs	>5,000-6,000 cfs	0%	0%	0%	0%	1%	1%	0%	0%	0%	0%

Application of the relationships from the laboratory studies of Swanson et al. (2004) for a representative water temperature of 12°C[20] illustrated how screen passage time may differ in relation to sweeping velocity at an approach velocity of 0.2 feet per second[21] (see methods description in Appendix 12B, Section 12B.1, *Juvenile Chinook Salmon Screen Passage Duration*) (Table 12-23). It should be noted that the equations of Swanson et al. (2004) give very long screen passage times at certain sweeping velocity and approach velocity combinations, for example, almost 3,000 minutes for 7.9-centimeter fish along a 900-foot combined screen unit length at sweeping velocity of 0.4 feet per second[22] during the day, and that fish had to remain within the vicinity of the screens and were not able to swim away as they would in the wild. Such estimates are far in excess of the duration of the experimental trials (120 minutes) used to derive the swimming data and therefore should be treated with caution. Very high estimated screen passage time reflects fish that would be holding station in front of a screen for a long time. Larger fish have greater swimming ability and therefore are able to hold station for longer periods than smaller fish, so their peak screen passage time is somewhat greater than that of smaller fish, based on the results of Swanson et al. (2004). Swanson et al. (2004) found that older (smolt-size) fish acclimated to warmer temperature exhibited higher rates of negative rheotaxis (i.e., swimming with flow rather than against it), a behavior consistent with downstream migration, which would decrease passage time.

Table 12-23. Estimated Screen Passage Time (minutes) of Juvenile Chinook Salmon for Screen Lengths of 30 Feet, 450 Feet, and 900 Feet at 0.2-Feet-per-Second Approach Velocity Based on Laboratory Studies of Swanson et al. (2004)

Fish Size (centimeters)	Day/Night	Sweeping Velocity (feet per second)	Time to pass 30 Feet (minutes)	Time to pass 450 Feet (minutes)	Time to pass 900 Feet (minutes)
4.4	Day	0.4	3.1	46.9	93.8
4.4	Day	0.5	2.1	32.2	64.5
4.4	Day	0.75	1.3	19.2	38.5
4.4	Day	1	0.9	14.1	28.2
4.4	Day	1.25	0.8	11.3	22.5
4.4	Day	1.5	0.6	9.4	18.8
4.4	Day	1.75	0.5	8.1	16.2
4.4	Day	2	0.5	7.1	14.2
4.4	Night	0.4	1.3	18.9	37.8
4.4	Night	0.5	1.1	17.0	34.0
4.4	Night	0.75	0.9	14.2	28.3
4.4	Night	1	0.8	12.5	24.9
4.4	Night	1.25	0.7	11.2	22.5
4.4	Night	1.5	0.7	10.3	20.6
4.4	Night	1.75	0.6	9.5	19.0

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[20] Swanson et al. (2004) tested fish at 12°C (February–June) and 19°C (June–August), with the latter testing period including only larger fish by day. Based on the available relationships, greater temperatures increased negative rheotaxis, i.e., the tendency to orient more with flow (rather than against it) and swim downstream more quickly.

[21] Note that approach velocity may be less than 0.2 feet per second at lower rates of diversion.

[22] Note that north Delta diversion operators would be likely to employ a safety margin for sweeping velocity, so diversions would be likely to occur at sweeping velocity greater than 0.4 ft/s.

Fish Size (centimeters)	Day/Night	Sweeping Velocity (feet per second)	Time to pass 30 Feet (minutes)	Time to pass 450 Feet (minutes)	Time to pass 900 Feet (minutes)
4.4	Night	2	0.6	8.8	17.7
7.9	Day	0.4	99.4	>120 [a]	>120 [a]
7.9	Day	0.5	7.4	110.7	>120 [a]
7.9	Day	0.75	2.2	33.3	66.6
7.9	Day	1	1.4	20.5	40.9
7.9	Day	1.25	1.0	15.0	29.9
7.9	Day	1.5	0.8	11.8	23.7
7.9	Day	1.75	0.7	9.8	19.7
7.9	Day	2	0.6	8.4	16.8
7.9	Night	0.4	2.2	32.4	64.7
7.9	Night	0.5	1.8	27.1	54.2
7.9	Night	0.75	1.4	20.6	41.1
7.9	Night	1	1.1	17.2	34.3
7.9	Night	1.25	1.0	14.9	29.8
7.9	Night	1.5	0.9	13.3	26.6
7.9	Night	1.75	0.8	12.0	24.0
7.9	Night	2	0.7	11.0	21.9

Note: Estimates for 7.9-cm fish at night involve extrapolation beyond range of experimental data.

[a] Values greater than 120 minutes are beyond the length of time of experimental trials from which the statistical relationships were developed.

The laboratory studies of Swanson et al. (2004) showed that swimming velocity is lower at night than during the day for a given set of flow conditions; this generally results in screen passage time decreasing as sweeping velocity increases over the full range of sweeping flows examined here, because screen passage velocity becomes more negative (i.e., fish move downstream more quickly). As noted above, most migration occurs at night (Plumb et al. 2016) and so the estimates for night may be more representative of conditions that migrating juvenile fish could experience at the north Delta intake screens.[23] Longer screen lengths increase screen passage time: For example, at a sweeping velocity of 0.4 feet per second during the night, a 4.4-centimeter juvenile encountering a single 30-foot cylindrical tee screen may pass in 3.1 minutes, compared to nearly 94 minutes for the combined length of thirty 30-foot screens. For all alternatives except 2b and 4b (which only have a single intake), juvenile winter-run Chinook salmon migrating downstream close to shore could encounter more than one of the north Delta intakes within a few hours and be susceptible to potential near-field effects, depending on travel time. For example, based on mean migration rates of acoustic tagged winter-run Chinook salmon discussed further below (Table 12-24), a winter-run

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[23] Note, however, that as described in Appendix 5A, Section C.6.5.1, to avoid nocturnal pumping during the main juvenile salmonid outmigration season, DSM2 modeling assumed the north Delta intakes generally operated during daytime hours (6 am–6 pm) to the extent possible (except during the months of July–September). As described in Chapter 3, operators will operate the facility within the constraints at each intake, including minimum sweeping requirements and allowable approach velocities. To the extent possible, the SWP will prioritize north Delta diversion sub-daily diversions during daylight hours. As noted in Chapter 3, the diel behavior in the intake reaches will be further studied.

juvenile could move from Intake A to Intake B (1.5 river miles) in approximately 1.2 to 2.6 hours; and from Intake B to Intake C (2.5 river miles) in 2.0–4.3 hours. There is uncertainty in the applicability of the laboratory results to cylindrical tee screens given that the laboratory studies were more suited to vertical flat plate screens that fish would be passing horizontally next to, as opposed to potentially immediately above or under as well as horizontally next to as in the case of cylindrical tee screens, and the fish in the laboratory had to remain within relatively close proximity (< 5 feet) to the fish screen as opposed to the proposed cylindrical screen locations within the several-hundred-foot-wide Sacramento River channel.

Table 12-24. Mean, Minimum, and Maximum Estimated Time (Minutes) for Juvenile Salmon Acoustic Telemetry System (JSATS)-Tagged Winter-Run Chinook Salmon to Travel Distances of 30 Feet, 450 Feet, and 900 Feet in 2013–2019.

Year	Number of Fish	30 Feet Mean	30 Feet Minimum	30 Feet Maximum	450 Feet Mean	450 Feet Minimum	450 Feet Maximum	900 Feet Mean	900 Feet Minimum	900 Feet Maximum
2013	7	0.58	0.37	0.76	8.74	5.52	11.34	17.48	11.05	22.68
2014	116	0.27	0.15	2.33	4.00	2.25	34.95	8.01	4.51	69.89
2015	184	0.31	0.14	2.68	4.67	2.07	40.15	9.33	4.13	80.30
2016	257	0.26	0.09	–[a]	3.89	1.38	–[a]	7.78	2.77	–[a]
2017	223	0.30	0.11	2.94	4.45	1.58	44.09	8.90	3.15	88.18
2018	145	0.28	0.11	1.20	4.14	1.61	18.03	8.28	3.21	36.07
2019	199	0.30	0.11	3.28	4.45	1.71	49.17	8.90	3.42	98.35
Mean	-	0.33	0.15	2.20	4.91	2.30	32.96	9.81	4.61	65.91

Source: Ammann pers. comm.

[a] Maximum could not be calculated because slowest migration was upstream movement. Mean fish size was generally 90–100-mm fork length. Migration speed was based on detections between Freeport and Hood.

The estimates of screen passage time based on laboratory swimming trials can be compared to migration speed estimates from acoustically tagged juvenile winter-run Chinook salmon in the Sacramento River between Freeport and Hood. Based on data from 2013–2019, the time to travel 30 feet (i.e., equivalent to one cylindrical tee screen unit) ranged from 0.09 minute to 3.3 minutes; the time to travel 450 feet (i.e., the equivalent of 15 cylindrical tee screen units) ranged from 1.4 minutes to just under 50 minutes; and the time to travel 900 feet (i.e., the equivalent of 30 cylindrical tee screen units) ranged from 2.8 minutes to nearly 100 minutes (Table 12-24). In general, these estimates are comparable to or lower than the screen passage estimates based on swimming behavior in the laboratory (Table 12-23).

Fisheries studies would be undertaken to provide information on the near-field effects of the north Delta intakes on juvenile salmonids once they are operational, to inform the refinement of future operations and adaptive management (see Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

ENTRAINMENT AND IMPINGEMENT

North Delta intake operations would meet fishery agency standards for approach velocity (0.2 foot per second per USFWS criteria for delta smelt) and a minimum sweeping velocity of 0.4 feet per second to limit the potential for negative effects to juvenile winter-run Chinook salmon and other species. As noted in Chapter 3, refinements to these criteria will be considered through ongoing fish agency coordination as well through real time operations and adaptive management.

Calculations suggest that a 1.75-mm screen opening size, as proposed for the north Delta intakes to meet fishery agency criteria (National Marine Fisheries Service 1997; California Department of Fish and Game 2000), would be effective at excluding juvenile salmonids of 22-mm standard length and greater (ICF International 2016a:5-103), which is the equivalent of around 25-mm fork length. This would be expected to exclude all juvenile winter-run Chinook salmon occurring in the vicinity of the north Delta intakes (see summary of fish sizes in the north Delta by National Marine Fisheries Service 2017:579). Cylindrical tee screens installed in the Columbia River have a hydraulic bypass effect created by moving water encountering the nose cone at the upstream end of the screens and forming a "bow wave," which physically keeps organisms away from the screens and also allows organisms to detect and avoid it (Coutant 2021). The upstream end of the most upstream screen of each of the north Delta intakes would also have a nose cone, so a bow wave effect could, in addition to screen characteristics meeting protective velocity criteria, limit the potential for entrainment, as well as impingement, over the extent of the intakes experiencing the bow wave effect. The extent to which the bow wave effect would extend over the length of the multiple-screen array (i.e., 15 or 30 screens) and other hydrodynamics along the screen face is not known, and it is uncertain how observations made in the Columbia River (Coutant 2021) with a different screen configuration and generally greater flow may translate to the Delta. During design of the intakes, computational modeling would be undertaken, and field measurements/baffle adjustments would be done during commissioning/operations, both to demonstrate compliance with velocity criteria (Delta Conveyance Design and Construction Authority 2022h).

The potential for juvenile salmonids to contact and be impinged on the screens of the north Delta intakes would be very limited. Experimental studies at the UC Davis Fish Treadmill facility found that Chinook salmon experienced frequent contact with the simulated fish screen but were rarely impinged (defined as prolonged screen contacts >2.5 minutes) and impingement was not related to any of the experimental variables examined (Swanson et al. 2004). Of the experiments they conducted, Swanson et al. (2004:274) noted:

> The injury rates of both preexperiment and experimental fish were generally high but most injuries consisted of minor damage to fins and scales. Among the four treatments, significant differences in injury indices were apparently related to the duration of laboratory holding, with larger, older fish exhibiting more damage. Within treatments, the injury index was not significantly affected by either flow regime or screen contact rate (regression and correlation, $P > 0.3$, all tests) and, in general, preexperimental indices were similar to those measured for fish after exposure in the Fish Treadmill.
>
> Survival in all experiments was high. Of the more than 3,200 fish tested, only five fish from four experiments died during the experiment and one fish, from a fifth experiment, during the 48-h postexperiment period. Two of the mortalities were from daytime experiments and four were from nighttime experiments. All mortalities were from flow treatments with a sweeping flow component, but the small number precluded the detection of significant flow effects on survival. The death of these fish did not appear to be related to observed impingements.

The laboratory environment described above does not fully represent Sacramento River conditions for factors such as water quality conditions and only provides information on the subset of all fish that would be in relatively close proximity to the screens. The proposed north Delta intake cylindrical tee screens would have a smooth screen surface and would be frequently—several times a day, with capability of once every 5 minutes if necessary—cleaned by internal and external brushes, which would provide additional protection to minimize screen surface impingement of juvenile winter-run Chinook salmon. The smooth surface also would serve to reduce the risk of abrasion and scale loss for any fish that does come into contact with the screens (Swanson et al. 2004). As noted above, the hydraulic bypass effect of cylindrical tee screens may also limit potential negative effects from screen contact. Overall, the observed experimental results and the design of the fish screens indicate that minimal risk would be expected from entrainment or impingement for juvenile winter-run Chinook salmon.

Diversions by the north Delta intakes are likely to entrain foodweb organisms for juvenile winter-run Chinook salmon. As described further for delta smelt in Impact AQUA-6 below, the potential for entrainment of phytoplankton carbon at the north Delta intakes to affect the Delta foodweb is limited, particularly considering the in situ production within the Delta. Juvenile Chinook salmon diet in the north Delta/lower Sacramento River mostly includes zooplankton and insects (Kjelson et al. 1982; Sommer et al. 2001b). Although some entrainment of zooplankton is likely to occur, effects on juvenile Chinook salmon prey availability are likely to be limited given relatively high in situ production within the Delta compared to inputs from freshwater flow (Jassby et al. 2002; Sobczak et al. 2002). For additional information, refer to the analysis of *Food Availability* in Impact AQUA-6: *Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt*.

PREDATION

Increased predation of juvenile winter-run Chinook salmon at the north Delta intakes could occur if predatory fish aggregate along the north Delta intake cylindrical tee screens or associated in-water structures (i.e., the floating log boom and its support pilings, including accumulated debris) at greater density than existing conditions. Studies in the Delta have shown greater abundance of predatory fish at manmade structures (Sabal et al. 2016) but as discussed under Impact AQUA-1, the relatively limited extent of in-water manmade structures in the Delta suggests that these are unlikely to have a population-level effect on species such as migrating juvenile salmonids (Lehman et al. 2019). Two Central Valley studies provide an assessment of predation in the vicinity of cylindrical screens (Demetras et al. 2013) or intakes projecting into the river (Michel et al. 2014). Demetras et al. (2013) found very few potential juvenile salmonid predators and no predator aggregations near cylindrical fish screens in the Sacramento River at Redding (Bella Vista Water District's Wintu Pumping Plant). There was no evidence of predation upon juvenile salmonids that might be attributed to or influenced by the design of the diversion facility (Demetras et al. 2013)[24]. In the Delta, Michel et al. (2014) found predation rate at the City of Sacramento Water Treatment Plant diversion—which includes an intake with flat plate fish screens on both sides of an in-river intake structure located approximately 240 feet from the left bank of the approximately 720-foot-wide river channel—was similar to other non-diversion bank locations in the vicinity.

Aggregation of predatory fish has been previously observed at the Hamilton City intake (Vogel 2008b), which is the only completed study of predation at long fish screens in the Central Valley, and which involved calculation of survival along the fish screen based on recapture of marked juvenile Chinook salmon released from several locations. Vogel's (2008b) study found that mean survival of tagged juvenile Chinook salmon at the Hamilton City intake in 2007—the only year of the study in which flow-control blocks at the weir at the downstream end of the fish screen were removed to reduce predatory fish concentration—was approximately 95% along the fish screen. However, the

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[24] Note that the study by Demetras et al. (2013) was based on two 70–100-cfs diversion facilities in the upper Sacramento River at 6–10-foot depth where the main predatory species were rainbow trout. Water temperature at these sites is lower than at the proposed north Delta intakes.

percentage of tagged juvenile Chinook salmon released at the upstream end of the fish screen that were recaptured at a downstream sampling location was similar to or slightly greater than for fish released at the downstream end of the fish screen, when standardized for the distance that the fish had to travel to the recapture site. These data suggest that survival along the screen was at least similar to survival in the portion of the channel without the screen (i.e., screen survival was similar to baseline survival, if the latter is assumed to be represented by the channel downstream of the screen). Note that sweeping velocity at the Hamilton City intake is higher than at the proposed north Delta intakes, which could give lower predation risk based on available flow-survival studies (e.g., Perry et al. 2018). However, test fish providing the estimate of survival in the channel downstream of the screen were released prior to the fish that were released at the upstream end of the fish screen, which could have confounded comparisons of relative survival between these groups if predatory fishes became partly satiated prior to the arrival of the fish released at the upstream end of the screen (thus potentially making their survival relatively higher than otherwise would have occurred) (Vogel 2008b:12). In addition, batch releases of relatively high numbers of test fish could have given greater survival than if smaller numbers of fish had passed along the fish screen (Vogel 2008b:20).

A recent study of acoustically tagged juvenile late fall–run Chinook salmon survival by Henderson et al. (2019) primarily provides information regarding far-field effects of flow but also has value in allowing inference regarding near-field effects of diversions. Henderson et al. (2019:Table 1) hypothesized that the density of diversions (number per kilometer) would be negatively related to survival because of higher predator densities near the diversions. In fact, they found the opposite, and speculated that greater survival with higher diversion density may be more a function of habitat conditions where diversions are more abundant, for example, armored banks resulting in reduced predator density and predation mortality (Henderson et al. 2019:1558). Reach-specific survival estimates by Henderson et al. (2019) provide context for the near-field effects provided by the physical structure of the existing long Red Bluff Diversion Dam and Glenn Colusa Irrigation District Hamilton City intakes. During the 2007–2011 study years, survival in the reach including the Red Bluff intake ranged in rank from highest survival (2007, 2011) to second lowest survival of 19 reaches in 2008. Survival in the Hamilton City reach ranged from highest survival (2010, 2011) to 12th highest survival of 19 reaches in 2008. The studies by Henderson et al. (2019) and Vogel (2008b) are not inconsistent in suggesting that near-field survival at large fish screens does not appear to be greatly different from reaches without intakes. (These studies do not quantify predation directly. It is assumed that predation is the main reason for survival differences, although it is possible that factors such as injury from screen contact and subsequent mortality could occur, although this appears less likely based on the laboratory studies of Swanson et al. [2004] discussed above.)

Overall, the weight of available information suggests that near-field predation effects of the north Delta intakes on juvenile winter-run Chinook salmon would be limited, albeit with some uncertainty given that the studies were not of long cylindrical tee screen structures in the north Delta. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the refinement of future operations and adaptive management (see Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

South Delta Exports

JUVENILE ENTRAINMENT

As described in Chapter 3, the existing facilities in the south Delta would be governed by the applicable regulatory requirements such as the SWRCB Bay-Delta Water Quality Control Plan, federal BiOps (National Marine Fisheries Service 2019; U.S. Fish and Wildlife Service 2019), CESA Incidental Take Permit for SWP (California Department of Fish and Wildlife 2020a), and USACE Clifton Court diversion limits.

The CalSim modeling for existing conditions and the project alternatives includes representation of regulatory requirements, although not all real-time requirements, such as those based on monitoring of fish presence, are able to be fully represented by the modeling (Appendix 5A, *Modeling Technical Appendix*). The risk of winter-run Chinook salmon entrainment under existing conditions and all alternatives would be minimized by the inclusion of the various regulatory requirements from the existing permits noted above (e.g., take limits for number of winter-run Chinook salmon lost to entrainment at the south Delta export facilities).

Two analyses assess the potential for changes to south Delta entrainment risk for juvenile winter-run Chinook salmon. As described in Appendix 12B (Section 12B.2, *Salvage-Density Method*), the salvage-density method weights CalSim-modeled south Delta exports by historical patterns of juvenile winter-run Chinook salmon entrainment loss density (fish per acre-foot of water exported). Note that although this method provides an index of entrainment loss, it functions primarily to illustrate south Delta export rate differences between modeling scenarios. The method does not account for differences in salvage and entrainment loss that could occur because of other operational effects (e.g., changes in juvenile salmonid routing because of the north Delta intakes[25]). The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the alternatives relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the December through April time period when winter-run are generally salvaged (Table 12-25 and Table 12-26).[26] As noted above, various regulatory requirements would be implemented under existing conditions and therefore are part of the baseline and also part of the No Project Alternative and are incorporated into all project alternatives to minimize entrainment effects on winter-run Chinook salmon.

Table 12-25. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	2,217	1,992 (-10%)	2,021 (-9%)	2,083 (-6%)	2,031 (-8%)	1,987 (-10%)
Above normal	N/A	(-6%)	(-1%)	(0%)	(-2%)	(-6%)
Below normal	1,519	1,380 (-9%)	1,457 (-4%)	1,499 (-1%)	1,438 (-5%)	1,380 (-9%)
Dry	1,011	939 (-7%)	932 (-8%)	980 (-3%)	933 (-8%)	939 (-7%)
Critically dry	890	827 (-7%)	874 (-2%)	820 (-8%)	794 (-11%)	824 (-7%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

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[25] Such changes are analyzed below in the *Hydrodynamic Effects* section and are considered as part of the Delta Passage Model in the *Through-Delta Survival* section below, which also includes south Delta export effects.

[26] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-1 and 12B-2).

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-26. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	228	233 (2%)	227 (0%)	228 (0%)	230 (1%)	233 (2%)
Above normal	N/A	(4%)	(-1%)	(0%)	(1%)	(3%)
Below normal	526	552 (5%)	554 (5%)	541 (3%)	551 (5%)	552 (5%)
Dry	304	317 (4%)	318 (4%)	312 (2%)	317 (4%)	317 (4%)
Critically dry	82	82 (0%)	80 (-3%)	82 (0%)	84 (2%)	83 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions; N/A = not applicable.

As described above, the salvage-density method is essentially a means of examining changes in south Delta exports weighted by historical salvage density to account for species timing between months; the method does not account for potential nonlinear relationships between salvage (entrainment) and south Delta exports, nor does it account for other factors that may influence salvage, such as Delta channel flows that could influence the survival or migration routes that juvenile salmonids may take. Zeug and Cavallo (2014) demonstrated that these other factors could be linked statistically to salvage of marked hatchery-reared juvenile Chinook salmon. The methods employed by Zeug and Cavallo (2014) were used to assess potential differences in juvenile winter-run Chinook salmon entrainment risk between existing conditions and the alternatives (see detailed methods description in Appendix 12B, Section 12B.3, *Juvenile Winter-Run Chinook Salmon Salvage Based on Zeug and Cavallo (2014)*). The results of this method were consistent with the salvage-density method in suggesting that salvage of juvenile winter-run Chinook salmon would be similar or somewhat lower under the alternatives relative to existing conditions (Table 12-27; summary plots of the results are also provided in Appendix 12B, Section 12B.3.2, *Results*).

Table 12-27. Proportion of Juvenile Winter-Run Chinook Salmon Entering the Delta Salvaged at the South Delta Export Facilities, Averaged by Water Year Type, Based on Zeug and Cavallo (2014)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.0037	0.0031 (-17%)	0.0031 (-18%)	0.0032 (-13%)	0.0032 (-15%)	0.0031 (-18%)
Above normal	0.0022	0.0022 (-2%)	0.0022 (-2%)	0.0023 (1%)	0.0022 (-2%)	0.0022 (-2%)
Below normal	0.0022	0.0022 (-1%)	0.0022 (0%)	0.0022 (0%)	0.0022 (0%)	0.0022 (-1%)
Dry	0.0018	0.0018 (-2%)	0.0018 (-1%)	0.0018 (-2%)	0.0018 (-2%)	0.0018 (-2%)
Critically dry	0.0017	0.0016 (-1%)	0.0016 (-1%)	0.0016 (-1%)	0.0017 (-1%)	0.0016 (-2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

ADULT ENTRAINMENT

In addition to juvenile winter-run Chinook salmon, adult winter-run Chinook salmon are also subject to entrainment at the south Delta export facilities (California Department of Fish and Wildlife 2020a, Attachment 8:60–63). It is estimated that 466 adult Chinook salmon were salvaged during 1993–2018 (i.e., an annual mean of ~18 fish), all during the months of September through May, with highest salvage in November, December, and March, which overlaps with adult winter-run Chinook salmon occurrence in the Delta (California Department of Fish and Wildlife 2020a, Attachment 8:60–63; Table 12A-3 in Appendix 12A shows January–March as the main period of occurrence). South Delta exports under the project alternatives generally would be similar or slightly less than under existing conditions (Appendix 5A, Figure B.5.3.1 and Tables B.5.3.1, B.5.3.2, B.5.3.3., B.5.3.4, B.5.3.5, and B.5.3.6), indicating entrainment risk for adult winter-run Chinook salmon generally would be similar or slightly less than existing conditions.

Far-Field Effects

Indirect Mortality Within the Delta

In addition to potential near-field, direct effects on winter-run Chinook salmon as discussed in the previous sections, the project alternatives have the potential to indirectly result in changes to mortality of juvenile winter-run Chinook salmon in the Delta as a result of changes in flow patterns and resulting survival or routing of fish into migration pathways with differing survival probabilities. This section includes a summary of hydrodynamic effects based on potential indicators of indirect mortality risk (e.g., channel velocity and flow routing into junctions) as well as an assessment of through-Delta survival using available models.

As described in more detail in Chapter 3, *Description of the Proposed Project and Alternatives*, the project alternatives include new operations criteria for the proposed north Delta intakes to minimize potential negative effects to fish, in particular juvenile winter-run Chinook salmon. In addition to the previously discussed velocity criteria to minimize potential for near-field effects (see discussion of *Entrainment and Impingement* above), the new operations criteria would include bypass flow criteria and pulse protection and low-level pumping. As described in Chapter 3, the proposed operations criteria and tidal restoration[27] are intended to minimize and fully mitigate the potential impacts of the NDD operations. The real time decision-making specific to the NDD operations would be mainly associated with reviewing real-time abiotic and fish monitoring data and ensuring proposed weekly, daily, and sub-daily operations are consistent with the permitted criteria and within the effects analyzed in the permits. See Chapter 3, Section 3.17, *Real-Time Operational Decision-Making Process* for additional details. Tables 3.14 and 3.15 in Chapter 3 provide proposed operations criteria and north Delta intake bypass flow and pulse protection requirements.

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[27] See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

HYDRODYNAMIC EFFECTS

Diversion of flow by the NDD would result in less Sacramento River flow moving downstream. Less Sacramento River flow would increase the effect of tides, would increase juvenile Chinook salmon travel time and therefore potential exposure to predatory fish, and would increase the potential for flow to be diverted into the interior Delta at Georgiana Slough/DCC,[28] where juvenile Chinook salmon survival is lower than on the mainstem Sacramento River (Perry et al. 2018; Hance et al. 2021). As described in Appendix 12B, Section 12B.4, *Hydrodynamic Effects Based on DSM2-HYDRO Data*, an assessment of potential hydrodynamic changes was undertaken using DSM2-HYDRO outputs. This illustrated the reduced overlap in north Delta velocity of the alternatives compared to existing conditions, including during key portions of the juvenile winter-run Chinook salmon downstream migration period (see, for example, Figures 12B-13, 12B-14, 12B-15, 12B-16, and 12B-17 in Appendix 12B), with very little difference in interior/south Delta hydrodynamics (e.g., Figures 12B-18, 12B-19, 12B-20, 12B-21, and 12B-22 in Appendix 12B). The reduced overlap in velocity between the alternatives and existing conditions generally reflected the somewhat lower velocity under the alternatives, as illustrated for the Sacramento River just downstream of Intake C (Table 12-28). The DSM2 modeling also indicated that a somewhat greater proportion of flow would enter the interior Delta at Georgiana Slough in some months with relatively high occurrence of juvenile winter-run Chinook salmon, in particular January–March (Figure 12B-47 in Appendix 12B), which generally indicates a greater proportion of juvenile Chinook salmon would enter Georgiana Slough based on available studies (e.g., Cavallo et al. 2015), and that there generally would be greater incidence of reversing flow in the Sacramento River just downstream of Georgiana Slough (Table 12-29). Months with smaller differences in these hydrodynamic indicators (e.g., April) reflect other operational constraints on overall Delta water operations, such as meeting the longfin smelt spring outflow requirements from the CDFW (2020a) ITP. Reduced velocity, increased reversing flow just downstream of Georgiana Slough, and increased flow into the interior Delta at Georgiana Slough would tend to reduce juvenile winter-run Chinook salmon through-Delta survival, as analyzed further below in *Through-Delta Survival.*

Table 12-28. Mean Channel Velocity (feet per second) in the Sacramento River Downstream of Intake C

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
September						
Wet	1.51	1.49 (-1%)	1.49 (-1%)	1.50 (-1%)	1.50 (-1%)	1.49 (-2%)
Above normal	1.46	1.44 (-1%)	1.45 (-1%)	1.45 (-1%)	1.44 (-2%)	1.44 (-1%)
Below normal	1.14	0.98 (-14%)	0.99 (-13%)	1.00 (-12%)	0.99 (-13%)	0.98 (-14%)
Dry	0.80	0.76 (-5%)	0.76 (-5%)	0.76 (-5%)	0.77 (-5%)	0.76 (-5%)
Critically dry	0.69	0.69 (0%)	0.69 (0%)	0.69 (0%)	0.69 (0%)	0.69 (0%)
October						
Wet	1.10	1.07 (-3%)	1.07 (-3%)	1.07 (-3%)	1.07 (-3%)	1.07 (-3%)
Above normal	0.94	0.93 (-1%)	0.94 (-1%)	0.95 (0%)	0.94 (-1%)	0.93 (-1%)
Below normal	0.93	0.91 (-2%)	0.91 (-2%)	0.90 (-3%)	0.90 (-2%)	0.90 (-2%)
Dry	0.88	0.90 (1%)	0.90 (2%)	0.90 (1%)	0.90 (1%)	0.90 (1%)

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[28] Perry et al. (2016:16–17) illustrated the concept of the *critical streakline* (i.e., the spatial divide between parcels of water that enter a side channel or remain in the main channel) and how this is affected by the riverine/tidal hydrodynamics at channel junctions.

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Critically dry	0.72	0.71 (-1%)	0.71 (-1%)	0.70 (-3%)	0.71 (-2%)	0.70 (-3%)
November						
Wet	1.40	1.33 (-5%)	1.33 (-6%)	1.34 (-4%)	1.34 (-5%)	1.33 (-5%)
Above normal	1.05	0.99 (-6%)	0.98 (-6%)	0.99 (-6%)	0.98 (-7%)	0.98 (-7%)
Below normal	1.07	0.99 (-8%)	0.98 (-9%)	1.01 (-6%)	1.00 (-7%)	0.98 (-8%)
Dry	0.93	0.89 (-4%)	0.89 (-4%)	0.90 (-4%)	0.89 (-4%)	0.89 (-5%)
Critically dry	0.71	0.68 (-4%)	0.68 (-3%)	0.68 (-3%)	0.68 (-4%)	0.68 (-4%)
December						
Wet	2.51	2.43 (-3%)	2.41 (-4%)	2.48 (-1%)	2.45 (-2%)	2.43 (-3%)
Above normal	1.59	1.49 (-6%)	1.49 (-6%)	1.52 (-4%)	1.50 (-5%)	1.49 (-6%)
Below normal	1.36	1.29 (-5%)	1.29 (-5%)	1.31 (-4%)	1.30 (-5%)	1.29 (-5%)
Dry	1.02	0.97 (-5%)	0.97 (-5%)	0.97 (-5%)	0.97 (-4%)	0.97 (-5%)
Critically dry	1.03	1.00 (-3%)	1.00 (-4%)	1.00 (-3%)	1.00 (-3%)	1.00 (-3%)
January						
Wet	3.18	3.11 (-2%)	3.09 (-3%)	3.16 (0%)	3.13 (-1%)	3.11 (-2%)
Above normal	2.70	2.54 (-6%)	2.51 (-7%)	2.62 (-3%)	2.58 (-4%)	2.54 (-6%)
Below normal	1.59	1.48 (-7%)	1.46 (-8%)	1.51 (-5%)	1.49 (-7%)	1.48 (-7%)
Dry	1.17	1.09 (-6%)	1.09 (-7%)	1.12 (-4%)	1.10 (-6%)	1.10 (-6%)
Critically dry	1.09	1.01 (-7%)	1.00 (-8%)	1.03 (-6%)	1.02 (-7%)	1.01 (-7%)
February						
Wet	3.59	3.60 (0%)	3.60 (0%)	3.63 (1%)	3.61 (1%)	3.60 (0%)
Above normal	2.93	2.80 (-4%)	2.80 (-5%)	2.87 (-2%)	2.82 (-4%)	2.80 (-4%)
Below normal	1.94	1.81 (-7%)	1.81 (-6%)	1.87 (-4%)	1.83 (-5%)	1.81 (-7%)
Dry	1.77	1.65 (-7%)	1.64 (-7%)	1.70 (-4%)	1.67 (-6%)	1.65 (-7%)
Critically dry	1.22	1.17 (-3%)	1.18 (-3%)	1.18 (-3%)	1.17 (-3%)	1.17 (-4%)
March						
Wet	3.24	3.24 (0%)	3.23 (0%)	3.25 (0%)	3.24 (0%)	3.24 (0%)
Above normal	2.76	2.62 (-5%)	2.60 (-6%)	2.67 (-3%)	2.62 (-5%)	2.62 (-5%)
Below normal	1.82	1.63 (-11%)	1.61 (-11%)	1.69 (-7%)	1.65 (-10%)	1.63 (-11%)
Dry	1.55	1.44 (-7%)	1.42 (-9%)	1.48 (-4%)	1.46 (-6%)	1.44 (-7%)
Critically dry	1.11	1.06 (-4%)	1.05 (-5%)	1.07 (-3%)	1.07 (-4%)	1.06 (-4%)
April						
Wet	2.65	2.66 (0%)	2.66 (0%)	2.68 (1%)	2.66 (0%)	2.66 (0%)
Above normal	1.76	1.72 (-3%)	1.72 (-2%)	1.73 (-2%)	1.72 (-3%)	1.72 (-3%)
Below normal	1.27	1.28 (1%)	1.28 (1%)	1.28 (1%)	1.28 (1%)	1.28 (1%)
Dry	1.04	1.04 (0%)	1.04 (1%)	1.03 (0%)	1.04 (0%)	1.04 (0%)
Critically dry	0.81	0.81 (1%)	0.81 (0%)	0.81 (1%)	0.81 (1%)	0.81 (1%)
May						
Wet	2.31	2.28 (-1%)	2.28 (-1%)	2.29 (-1%)	2.29 (-1%)	2.28 (-1%)
Above normal	1.78	1.71 (-4%)	1.70 (-4%)	1.73 (-3%)	1.72 (-4%)	1.71 (-4%)
Below normal	1.24	1.23 (-1%)	1.22 (-1%)	1.23 (-1%)	1.23 (-1%)	1.23 (-1%)
Dry	0.98	0.98 (0%)	0.98 (0%)	0.97 (-1%)	0.97 (-1%)	0.98 (0%)
Critically dry	0.76	0.75 (-1%)	0.75 (-1%)	0.75 (-1%)	0.75 (-1%)	0.75 (-1%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
June						
Wet	1.75	1.68 (-4%)	1.68 (-4%)	1.68 (-4%)	1.68 (-4%)	1.68 (-4%)
Above normal	1.42	1.32 (-8%)	1.32 (-8%)	1.35 (-5%)	1.32 (-7%)	1.32 (-8%)
Below normal	1.13	1.11 (-1%)	1.11 (-1%)	1.11 (-1%)	1.11 (-1%)	1.11 (-1%)
Dry	1.12	1.12 (0%)	1.11 (-1%)	1.12 (0%)	1.11 (0%)	1.12 (0%)
Critically dry	0.86	0.86 (0%)	0.86 (-1%)	0.86 (0%)	0.87 (0%)	0.86 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-29. Number of Hours within Each Month with Reversing Flow in the Sacramento River Downstream of Georgiana Slough (DSM2 Channel 423)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
September						
Wet (720)	7.3	10.1 (2.8/38%)	10.5 (3.2/44%)	9.1 (1.8/25%)	9.7 (2.4/33%)	10.1 (2.8/38%)
Above Normal (720)	12.8	18.4 (5.6/43%)	19.0 (6.2/48%)	17.4 (4.6/36%)	17.2 (4.4/34%)	18.3 (5.5/43%)
Below Normal (720)	44.3	53.7 (9.3/21%)	55.6 (11.2/25%)	51.9 (7.5/17%)	53.7 (9.3/21%)	53.7 (9.3/21%)
Dry (720)	93.2	113.6 (20.4/22%)	114.5 (21.3/23%)	106.2 (12.9/14%)	111.9 (18.7/20%)	113.2 (20.0/21%)
Critically Dry (720)	129.0	141.3 (12.3/10%)	144.5 (15.5/12%)	139.9 (10.9/8%)	140.6 (11.5/9%)	141.4 (12.3/10%)
October						
Wet (744)	180.4	180.1 (-0.3/0%)	178.2 (-2.2/-1%)	179.4 (-1.0/-1%)	179.4 (-1.0/-1%)	180.0 (-0.4/0%)
Above Normal (744)	236.3	235.7 (-0.6/0%)	236.1 (-0.2/0%)	232.4 (-3.8/-2%)	234.3 (-1.9/-1%)	235.7 (-0.6/0%)
Below Normal (744)	227.3	220.8 (-6.4/-3%)	220.1 (-7.2/-3%)	223.6 (-3.7/-2%)	220.7 (-6.6/-3%)	220.8 (-6.4/-3%)
Dry (744)	241.9	242.4 (0.6/0%)	244.0 (2.2/1%)	242.4 (0.6/0%)	242.7 (0.9/0%)	242.0 (0.1/0%)
Critically Dry (744)	252.1	254.1 (2.1/1%)	254.0 (1.9/1%)	255.7 (3.6/1%)	254.5 (2.5/1%)	254.7 (2.7/1%)
November						
Wet (720)	144.9	154.4 (9.4/7%)	154.6 (9.6/7%)	152.7 (7.8/5%)	154.4 (9.5/7%)	155.2 (10.3/7%)
Above Normal (720)	172.3	180.9 (8.7/5%)	182.4 (10.2/6%)	181.6 (9.3/5%)	178.4 (6.2/4%)	182.2 (9.9/6%)
Below Normal (720)	202.5	207.9 (5.4/3%)	207.2 (4.7/2%)	203.5 (1.0/0%)	206.2 (3.7/2%)	208.2 (5.7/3%)
Dry (720)	210.3	215.0 (4.7/2%)	215.1 (4.8/2%)	215.4 (5.1/2%)	214.3 (4.0/2%)	214.9 (4.6/2%)
Critically Dry (720)	252.2	251.5 (-0.7/0%)	250.4 (-1.8/-1%)	249.7 (-2.5/-1%)	250.6 (-1.6/-1%)	251.4 (-0.8/0%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
December						
Wet (744)	16.8	20.4 (3.6/22%)	20.1 (3.3/20%)	20.1 (3.3/20%)	20.6 (3.9/23%)	20.4 (3.6/22%)
Above Normal (744)	25.9	29.6 (3.7/14%)	29.7 (3.8/14%)	30.3 (4.3/17%)	30.5 (4.6/18%)	29.6 (3.7/14%)
Below Normal (744)	79.7	85.3 (5.5/7%)	86.2 (6.4/8%)	85.5 (5.8/7%)	84.9 (5.2/7%)	85.3 (5.5/7%)
Dry (744)	142.7	143.4 (0.8/1%)	143.6 (1.0/1%)	144.0 (1.3/1%)	144.5 (1.8/1%)	143.4 (0.8/1%)
Critically Dry (744)	221.3	221.5 (0.3/0%)	221.5 (0.2/0%)	220.7 (-0.6/0%)	221.0 (-0.3/0%)	221.5 (0.3/0%)
January						
Wet (744)	0.0	0.1 (0.1)	0.4 (0.4)	0.0 (0.0)	0.0 (0.0)	0.1 (0.1)
Above Normal (744)	0.4	5.2 (4.7/1056%)	6.2 (5.8/1301%)	1.6 (1.2/261%)	4.0 (3.5/789%)	5.2 (4.8/1076%)
Below Normal (744)	19.6	23.7 (4.1/21%)	24.1 (4.5/23%)	22.7 (3.1/16%)	23.4 (3.8/19%)	23.7 (4.1/21%)
Dry (744)	35.7	48.6 (13.0/36%)	44.4 (8.8/25%)	46.1 (10.5/29%)	48.2 (12.5/35%)	48.6 (13.0/36%)
Critically Dry (744)	91.5	102.1 (10.6/12%)	102.0 (10.5/11%)	101.7 (10.2/11%)	102.4 (10.9/12%)	104.0 (12.4/14%)
February						
Wet (675)	0.0	2.2 (2.2/6700%)	2.5 (2.4/7500%)	1.8 (1.8/5600%)	2.3 (2.3/7000%)	2.2 (2.2/6700%)
Above Normal (680)	0.0	1.2 (1.2)	1.7 (1.7)	0.0 (0.0)	0.3 (0.3)	1.2 (1.2)
Below Normal (680)	9.1	24.1 (15.0/164%)	24.6 (15.4/169%)	16.7 (7.5/82%)	21.7 (12.5/137%)	24.1 (15.0/164%)
Dry (677)	39.3	53.0 (13.7/35%)	54.7 (15.4/39%)	47.7 (8.3/21%)	49.1 (9.8/25%)	53.0 (13.7/35%)
Critically Dry (680)	115.1	117.9 (2.8/2%)	119.5 (4.4/4%)	116.4 (1.3/1%)	117.4 (2.3/2%)	117.7 (2.6/2%)
March						
Wet (744)	173.3	175.8 (2.5/1%)	175.8 (2.5/1%)	176.0 (2.7/2%)	175.3 (2.0/1%)	176.1 (2.8/2%)
Above Normal (744)	198.1	204.9 (6.7/3%)	205.8 (7.7/4%)	200.4 (2.2/1%)	204.4 (6.3/3%)	204.9 (6.7/3%)
Below Normal (744)	232.5	252.3 (19.8/9%)	250.1 (17.6/8%)	250.4 (17.9/8%)	252.6 (20.1/9%)	252.4 (19.9/9%)
Dry (744)	279.8	286.1 (6.3/2%)	285.6 (5.8/2%)	285.0 (5.2/2%)	285.4 (5.6/2%)	286.1 (6.3/2%)
Critically Dry (744)	294.8	297.7 (3.0/1%)	297.9 (3.1/1%)	297.9 (3.1/1%)	297.8 (3.0/1%)	297.7 (3.0/1%)
April						
Wet (720)	197.5	202.0 (4.5/2%)	201.7 (4.3/2%)	202.6 (5.1/3%)	201.8 (4.4/2%)	202.0 (4.5/2%)
Above Normal (720)	190.4	198.6 (8.2/4%)	198.1 (7.7/4%)	198.6 (8.2/4%)	199.6 (9.2/5%)	198.6 (8.2/4%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below Normal (720)	206.2	210.6 (4.4/2%)	209.4 (3.1/2%)	208.2 (2.0/1%)	210.2 (4.0/2%)	210.4 (4.2/2%)
Dry (720)	244.4	242.7 (-1.7/-1%)	243.3 (-1.2/0%)	242.5 (-1.9/-1%)	242.6 (-1.8/-1%)	242.3 (-2.1/-1%)
Critically Dry (720)	291.0	290.6 (-0.4/0%)	291.0 (0.0/0%)	290.9 (-0.1/0%)	290.4 (-0.6/0%)	290.6 (-0.4/0%)
May						
Wet (744)	11.4	14.7 (3.3/29%)	14.7 (3.3/29%)	13.7 (2.3/20%)	14.7 (3.3/29%)	14.7 (3.3/29%)
Above Normal (744)	22.5	27.9 (5.4/24%)	28.2 (5.7/25%)	27.6 (5.1/23%)	28.4 (5.9/26%)	27.9 (5.4/24%)
Below Normal (744)	71.5	71.5 (0.0/0%)	70.3 (-1.2/-2%)	71.2 (-0.3/0%)	72.0 (0.5/1%)	71.5 (0.1/0%)
Dry (744)	144.9	140.9 (-4.0/-3%)	140.3 (-4.5/-3%)	143.0 (-1.8/-1%)	141.7 (-3.1/-2%)	140.9 (-4.0/-3%)
Critically Dry (744)	209.6	206.5 (-3.1/-1%)	207.1 (-2.4/-1%)	205.9 (-3.7/-2%)	206.1 (-3.4/-2%)	206.5 (-3.1/-1%)
June						
Wet (720)	98.2	121.1 (22.9/23%)	120.5 (22.3/23%)	116.8 (18.5/19%)	119.6 (21.4/22%)	121.1 (22.9/23%)
Above Normal (720)	191.1	205.6 (14.5/8%)	205.9 (14.8/8%)	202.8 (11.7/6%)	204.3 (13.2/7%)	205.6 (14.5/8%)
Below Normal (720)	210.6	212.9 (2.2/1%)	213.2 (2.6/1%)	213.7 (3.1/1%)	213.2 (2.6/1%)	212.8 (2.2/1%)
Dry (720)	220.9	221.2 (0.4/0%)	221.8 (0.9/0%)	221.2 (0.4/0%)	221.3 (0.5/0%)	221.2 (0.3/0%)
Critically Dry (720)	256.7	255.7 (-1.0/0%)	256.4 (-0.3/0%)	255.0 (-1.7/-1%)	254.9 (-1.9/-1%)	255.7 (-1.0/0%)

Note: Numbers in parentheses after water year type indicate total number of hours by month. Absolute and percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Absolute differences are shown in parentheses when existing conditions percentage is zero.

Alt = alternative; EC = existing conditions.

THROUGH-DELTA SURVIVAL

Operations of the project alternatives could affect juvenile winter-run Chinook salmon migrating through the Delta by reducing Sacramento River flow downstream of the north Delta intakes, which could influence through-Delta survival based on flow-survival relationships. The potential for such effects was assessed using a spreadsheet version of the through-Delta survival function formulated by Perry et al. (2018),[29] which estimates through-Delta survival as a function of daily Sacramento

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[29] The spreadsheet model was provided by Perry (pers. comm.) and reproduces the mean response of the STARS (Survival, Travel time, And Routing Simulation) model (Perry et al. 2020). There is some uncertainty in the extent to which the relationships in the model are representative of wild-origin winter-run Chinook salmon juveniles, given that the model was based on results from larger hatchery-origin late fall–run Chinook salmon juveniles; however, the results of the Delta Passage Model, described below, are based on hatchery-origin winter-run Chinook salmon juveniles.

River flow at Freeport as well as Delta Cross Channel gate position. The results of this analysis showed that during the main period of juvenile winter-run Chinook salmon occurrence in the Delta (i.e., December–April; Table 12A-3 in Appendix 12A), mean through-Delta survival under the project alternatives was 0% to 4% less than existing conditions (Table 12-30). Larger differences in through-Delta survival occurred in September (up to 5%–6% less than existing conditions in below normal years), which is a period that is generally prior to the first juvenile winter-run occurrence in trawls or beach seines at Sacramento except in some years (Attachment 12A.1, *Juvenile Salmonid Monitoring, Sampling, and Salvage Timing Summary from SacPAS*). Relatively large differences in survival (8%–10% less under the project alternatives) also occurred in June of above normal years, although this is after the period of nearly all juvenile winter-run occurrence and has more relevance to juvenile spring-run and fall-run Chinook salmon (discussed further under in Impact AQUA-3: *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon*, and Impact AQUA-4: *Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon*).

Table 12-30. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
September						
Wet	0.37	0.37 (-1%)	0.37 (-1%)	0.37 (0%)	0.37 (-1%)	0.37 (-1%)
Above normal	0.36	0.36 (-1%)	0.36 (0%)	0.36 (0%)	0.35 (-1%)	0.36 (-1%)
Below normal	0.31	0.29 (-6%)	0.30 (-6%)	0.30 (-5%)	0.30 (-6%)	0.29 (-6%)
Dry	0.27	0.26 (-2%)	0.26 (-2%)	0.26 (-2%)	0.27 (-2%)	0.26 (-2%)
Critically dry	0.26	0.25 (-3%)	0.25 (-3%)	0.25 (-3%)	0.25 (-3%)	0.25 (-3%)
October						
Wet	0.37	0.37 (0%)	0.37 (0%)	0.37 (0%)	0.37 (0%)	0.37 (0%)
Above normal	0.34	0.34 (1%)	0.34 (1%)	0.34 (0%)	0.34 (1%)	0.34 (1%)
Below normal	0.31	0.32 (3%)	0.32 (3%)	0.32 (3%)	0.32 (3%)	0.32 (2%)
Dry	0.34	0.34 (0%)	0.34 (0%)	0.34 (0%)	0.34 (0%)	0.34 (0%)
Critically dry	0.32	0.31 (-2%)	0.31 (-2%)	0.31 (-3%)	0.31 (-2%)	0.31 (-2%)
November						
Wet	0.40	0.39 (-1%)	0.39 (-1%)	0.39 (-1%)	0.39 (-1%)	0.39 (-2%)
Above normal	0.38	0.38 (0%)	0.38 (0%)	0.37 (0%)	0.37 (0%)	0.37 (0%)
Below normal	0.37	0.37 (2%)	0.37 (2%)	0.36 (0%)	0.37 (2%)	0.37 (1%)
Dry	0.33	0.33 (0%)	0.33 (0%)	0.34 (3%)	0.33 (2%)	0.33 (0%)
Critically dry	0.31	0.31 (0%)	0.31 (0%)	0.31 (1%)	0.31 (0%)	0.31 (0%)
December						
Wet	0.47	0.46 (-2%)	0.46 (-2%)	0.46 (-1%)	0.46 (-1%)	0.46 (-2%)
Above normal	0.46	0.45 (-2%)	0.45 (-2%)	0.45 (-1%)	0.45 (-2%)	0.45 (-2%)
Below normal	0.48	0.47 (-2%)	0.47 (-2%)	0.48 (-1%)	0.47 (-1%)	0.47 (-2%)
Dry	0.42	0.41 (-3%)	0.41 (-3%)	0.41 (-2%)	0.41 (-3%)	0.41 (-3%)
Critically dry	0.38	0.38 (-1%)	0.37 (-1%)	0.38 (-1%)	0.38 (-1%)	0.38 (-1%)
January						
Wet	0.61	0.60 (-2%)	0.60 (-2%)	0.61 (-1%)	0.60 (-1%)	0.60 (-2%)
Above normal	0.58	0.56 (-3%)	0.56 (-3%)	0.57 (-2%)	0.56 (-2%)	0.56 (-3%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below normal	0.48	0.47 (-3%)	0.46 (-3%)	0.47 (-2%)	0.47 (-3%)	0.47 (-3%)
Dry	0.43	0.42 (-2%)	0.42 (-2%)	0.42 (-1%)	0.42 (-2%)	0.42 (-2%)
Critically dry	0.42	0.41 (-2%)	0.41 (-3%)	0.41 (-2%)	0.41 (-2%)	0.41 (-2%)
February						
Wet	0.64	0.63 (-1%)	0.63 (-1%)	0.64 (-1%)	0.63 (-1%)	0.63 (-1%)
Above normal	0.60	0.58 (-2%)	0.58 (-3%)	0.59 (-2%)	0.58 (-2%)	0.58 (-2%)
Below normal	0.51	0.50 (-3%)	0.50 (-2%)	0.51 (-2%)	0.50 (-2%)	0.50 (-3%)
Dry	0.50	0.49 (-3%)	0.48 (-3%)	0.49 (-2%)	0.49 (-2%)	0.49 (-3%)
Critically dry	0.44	0.43 (-1%)	0.43 (-1%)	0.43 (-1%)	0.43 (-1%)	0.43 (-1%)
March						
Wet	0.62	0.61 (-1%)	0.61 (-1%)	0.61 (-1%)	0.61 (-1%)	0.61 (-1%)
Above normal	0.59	0.57 (-3%)	0.57 (-3%)	0.58 (-2%)	0.57 (-3%)	0.57 (-3%)
Below normal	0.50	0.48 (-4%)	0.48 (-5%)	0.49 (-3%)	0.48 (-4%)	0.48 (-4%)
Dry	0.48	0.46 (-3%)	0.46 (-3%)	0.47 (-2%)	0.47 (-2%)	0.46 (-3%)
Critically dry	0.42	0.42 (-1%)	0.41 (-1%)	0.42 (-1%)	0.42 (-1%)	0.42 (-1%)
April						
Wet	0.57	0.57 (-1%)	0.57 (-1%)	0.57 (0%)	0.57 (-1%)	0.57 (-1%)
Above normal	0.50	0.49 (-1%)	0.49 (-1%)	0.49 (-1%)	0.49 (-1%)	0.49 (-1%)
Below normal	0.44	0.44 (0%)	0.44 (0%)	0.44 (0%)	0.44 (0%)	0.44 (0%)
Dry	0.41	0.41 (0%)	0.41 (0%)	0.41 (0%)	0.41 (0%)	0.41 (0%)
Critically dry	0.38	0.38 (0%)	0.38 (0%)	0.38 (0%)	0.38 (0%)	0.38 (0%)
May						
Wet	0.55	0.54 (-1%)	0.54 (-1%)	0.54 (-1%)	0.54 (-1%)	0.54 (-1%)
Above normal	0.50	0.49 (-2%)	0.49 (-2%)	0.49 (-1%)	0.49 (-2%)	0.49 (-2%)
Below normal	0.44	0.44 (0%)	0.44 (0%)	0.44 (0%)	0.44 (0%)	0.44 (0%)
Dry	0.41	0.41 (0%)	0.41 (0%)	0.41 (0%)	0.41 (0%)	0.41 (0%)
Critically dry	0.37	0.37 (0%)	0.37 (0%)	0.37 (0%)	0.37 (0%)	0.37 (0%)
June						
Wet	0.43	0.41 (-4%)	0.41 (-4%)	0.41 (-4%)	0.41 (-4%)	0.41 (-4%)
Above normal	0.39	0.35 (-10%)	0.35 (-10%)	0.36 (-8%)	0.36 (-9%)	0.35 (-10%)
Below normal	0.33	0.33 (0%)	0.33 (0%)	0.33 (0%)	0.33 (0%)	0.33 (0%)
Dry	0.33	0.33 (0%)	0.33 (0%)	0.33 (0%)	0.33 (0%)	0.33 (0%)
Critically dry	0.29	0.29 (0%)	0.29 (0%)	0.29 (0%)	0.29 (0%)	0.29 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Note that the spreadsheet version of the Perry et al. (2018) model does not account for the variability in coefficient estimates (Perry et al. 2018:Figure 6), which would likely give appreciable overlap of estimates in through-Delta survival between existing conditions and the project alternatives, particularly in relation to the relatively small differences between alternatives. Note also that the CDFW (2020a) SWP ITP requires a Georgiana Slough Migratory Barrier to be installed to reduce juvenile winter- and spring-run Chinook salmon entry into Georgiana Slough by means of acoustic and light stimuli deterring the juveniles from entering Georgiana Slough (California Department of Water Resources 2015:2-23;2-24). The analysis with the spreadsheet version of the Perry et al. (2018) model did not include a representation of the barrier because the specific operating criteria (e.g., months for installation) are not yet known. However, to illustrate the potential effects of the barrier on relative survival differences between existing conditions and the project alternatives, a sensitivity analysis was undertaken assuming the barrier was installed and reduced proportional entry into Georgiana Slough by 50%[30] compared to no barrier, during September through June. Although the sensitivity analysis gave higher absolute estimates of through-Delta survival, as expected, there was no change in the relative pattern of percentage differences between existing conditions and the project alternatives (compare corresponding cells in Table 12-31 with Table 12-30).

Table 12-31. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018), Including Assumption that Georgiana Slough Migratory Barrier Reduces Entry in Georgiana Slough by 50%

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
September						
Wet	0.39	0.39 (-1%)	0.39 (-1%)	0.39 (0%)	0.39 (-1%)	0.39 (-1%)
Above normal	0.38	0.38 (-1%)	0.38 (0%)	0.38 (0%)	0.38 (-1%)	0.38 (-1%)
Below normal	0.34	0.31 (-6%)	0.32 (-6%)	0.32 (-5%)	0.32 (-6%)	0.31 (-6%)
Dry	0.29	0.28 (-2%)	0.28 (-2%)	0.28 (-2%)	0.28 (-2%)	0.28 (-2%)
Critically dry	0.28	0.27 (-3%)	0.27 (-3%)	0.27 (-3%)	0.27 (-3%)	0.27 (-3%)
October						
Wet	0.40	0.40 (0%)	0.40 (0%)	0.40 (0%)	0.40 (0%)	0.40 (1%)
Above normal	0.36	0.37 (1%)	0.37 (1%)	0.36 (0%)	0.37 (1%)	0.37 (1%)
Below normal	0.34	0.35 (3%)	0.35 (4%)	0.35 (4%)	0.35 (4%)	0.35 (3%)
Dry	0.38	0.38 (0%)	0.38 (0%)	0.38 (0%)	0.38 (0%)	0.38 (0%)
Critically dry	0.36	0.35 (-3%)	0.35 (-3%)	0.35 (-3%)	0.35 (-3%)	0.35 (-3%)
November						
Wet	0.43	0.42 (-1%)	0.42 (-1%)	0.42 (-1%)	0.42 (-1%)	0.42 (-1%)
Above normal	0.41	0.40 (0%)	0.41 (0%)	0.40 (0%)	0.40 (0%)	0.40 (0%)
Below normal	0.40	0.41 (2%)	0.41 (3%)	0.40 (0%)	0.41 (3%)	0.41 (2%)
Dry	0.36	0.37 (1%)	0.36 (1%)	0.37 (4%)	0.37 (3%)	0.37 (1%)
Critically dry	0.34	0.34 (0%)	0.34 (0%)	0.35 (1%)	0.34 (1%)	0.34 (0%)
December						
Wet	0.50	0.50 (-1%)	0.50 (-2%)	0.50 (-1%)	0.50 (-1%)	0.50 (-1%)
Above normal	0.49	0.48 (-2%)	0.48 (-2%)	0.49 (-1%)	0.48 (-2%)	0.48 (-2%)
Below normal	0.51	0.51 (-1%)	0.51 (-2%)	0.51 (-1%)	0.51 (-1%)	0.51 (-1%)
Dry	0.45	0.44 (-2%)	0.44 (-2%)	0.44 (-2%)	0.44 (-2%)	0.44 (-2%)

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[30] A 50% reduction in entry to Georgiana Slough was observed during the 2012 pilot testing of the barrier (California Department of Water Resources 2015).

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Critically dry	0.41	0.41 (-1%)	0.41 (-1%)	0.41 (-1%)	0.41 (-1%)	0.41 (-1%)
January						
Wet	0.64	0.63 (-2%)	0.63 (-2%)	0.64 (-1%)	0.64 (-1%)	0.63 (-2%)
Above normal	0.61	0.60 (-2%)	0.59 (-3%)	0.60 (-1%)	0.60 (-2%)	0.60 (-2%)
Below normal	0.52	0.51 (-2%)	0.50 (-3%)	0.51 (-2%)	0.51 (-2%)	0.51 (-2%)
Dry	0.47	0.46 (-2%)	0.46 (-2%)	0.47 (-1%)	0.46 (-2%)	0.46 (-2%)
Critically dry	0.46	0.45 (-2%)	0.45 (-2%)	0.45 (-2%)	0.45 (-2%)	0.45 (-2%)
February						
Wet	0.67	0.66 (-1%)	0.66 (-1%)	0.67 (0%)	0.66 (-1%)	0.66 (-1%)
Above normal	0.63	0.62 (-2%)	0.62 (-2%)	0.62 (-2%)	0.62 (-2%)	0.62 (-2%)
Below normal	0.55	0.54 (-2%)	0.54 (-2%)	0.54 (-1%)	0.54 (-2%)	0.54 (-2%)
Dry	0.54	0.53 (-2%)	0.52 (-2%)	0.53 (-2%)	0.53 (-2%)	0.53 (-2%)
Critically dry	0.48	0.47 (-1%)	0.47 (-1%)	0.47 (-1%)	0.47 (-1%)	0.47 (-1%)
March						
Wet	0.65	0.64 (-1%)	0.64 (-1%)	0.64 (-1%)	0.64 (-1%)	0.64 (-1%)
Above normal	0.62	0.61 (-2%)	0.61 (-3%)	0.61 (-2%)	0.61 (-2%)	0.61 (-2%)
Below normal	0.54	0.52 (-4%)	0.52 (-4%)	0.53 (-3%)	0.52 (-4%)	0.52 (-4%)
Dry	0.52	0.50 (-2%)	0.50 (-3%)	0.51 (-1%)	0.51 (-2%)	0.50 (-2%)
Critically dry	0.46	0.46 (-1%)	0.46 (-1%)	0.46 (-1%)	0.46 (-1%)	0.46 (-1%)
April						
Wet	0.61	0.60 (-1%)	0.60 (-1%)	0.60 (0%)	0.60 (-1%)	0.60 (-1%)
Above normal	0.54	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)
Below normal	0.48	0.48 (0%)	0.48 (0%)	0.48 (0%)	0.48 (0%)	0.48 (0%)
Dry	0.45	0.46 (0%)	0.46 (0%)	0.45 (0%)	0.46 (0%)	0.46 (0%)
Critically dry	0.43	0.43 (0%)	0.43 (0%)	0.43 (0%)	0.43 (0%)	0.43 (0%)
May						
Wet	0.58	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)
Above normal	0.54	0.53 (-1%)	0.53 (-2%)	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)
Below normal	0.48	0.48 (0%)	0.48 (0%)	0.48 (0%)	0.48 (0%)	0.48 (0%)
Dry	0.45	0.45 (0%)	0.45 (0%)	0.45 (0%)	0.45 (0%)	0.45 (0%)
Critically dry	0.42	0.42 (0%)	0.42 (0%)	0.42 (0%)	0.42 (0%)	0.42 (0%)
June						
Wet	0.46	0.44 (-4%)	0.44 (-4%)	0.44 (-3%)	0.44 (-4%)	0.44 (-4%)
Above normal	0.42	0.38 (-10%)	0.38 (-10%)	0.38 (-9%)	0.38 (-9%)	0.38 (-10%)
Below normal	0.35	0.35 (0%)	0.35 (0%)	0.35 (0%)	0.35 (0%)	0.35 (0%)
Dry	0.35	0.35 (0%)	0.35 (0%)	0.35 (0%)	0.35 (0%)	0.35 (0%)
Critically dry	0.32	0.32 (0%)	0.31 (0%)	0.32 (0%)	0.32 (0%)	0.32 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

The results of the Delta Passage Model (see description of method in Appendix 12B, Section 12B.5, *Delta Passage Model*) were similar to those of the analysis based on the Perry et al. (2018) through-Delta survival function, with mean estimated through-Delta survival of juvenile winter-run Chinook salmon under the project alternatives ranging from 1% to 3% less than existing conditions (Table 12-32; compare in particular to the December through April results in Table 12-30, which as previously described represents the main period of juvenile winter-run occurrence in the Delta and is reflected in the Delta Passage Model entry distribution; see Figure 12B-57 in Appendix 12B).[31] Additional plots of results from the Delta Passage Model analysis are presented in Appendix 12B, Section 12B.5.2, *Results*, and illustrate the broad variability in results by alternative for a given year, when incorporating randomization of uncertainty in model coefficients (see, for example, Figure 12B-70 in Appendix 12B).

Table 12-32. Through-Delta Survival of Juvenile Winter-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.31	0.31 (-2%)	0.31 (-2%)	0.31 (-1%)	0.31 (-1%)	0.31 (-2%)
Above normal	0.25	0.24 (-2%)	0.24 (-3%)	0.24 (-2%)	0.24 (-2%)	0.24 (-2%)
Below normal	0.19	0.18 (-3%)	0.18 (-3%)	0.18 (-2%)	0.18 (-3%)	0.18 (-3%)
Dry	0.16	0.16 (-3%)	0.16 (-3%)	0.16 (-2%)	0.16 (-2%)	0.16 (-3%)
Critically dry	0.14	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

The two through-Delta survival analyses (spreadsheet implementation of the Perry et al. (2018) survival function and the Delta Passage Model) suggested the potential for through-Delta survival under the project alternatives to be somewhat less than existing conditions. As previously described, these modeling results reflect flow-based criteria and requirements but do not account for adjustments to operations. These adjustments may be in response to real-time monitoring of fish to further limit potential negative effects. Fisheries studies would be undertaken to provide information on the far-field effects of the north Delta intakes on juvenile salmonids once they are operational, to inform the refinement of future operations and adaptive management, as needed (Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

Habitat Suitability

Several aspects of habitat suitability for winter-run Chinook salmon and the potential far-field effects of the project alternatives were examined: riparian and wetland bench inundation (juvenile rearing habitat); water temperature; *Microcystis* harmful algae blooms; and metals (selenium and mercury).

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[31] Note that the Delta Passage Model is based on results from juvenile Chinook salmon ≥80 mm in length.

RIPARIAN AND WETLAND BENCH INUNDATION

Channel margin habitat in the Delta, and in much of the Sacramento and San Joaquin Rivers in general, has been considerably reduced in relation to historical extent because of the construction of levees and the armoring of their banks with riprap (Williams 2006). These practices have reduced the extent of high-value rearing or holding habitat for Chinook salmon juveniles. Whereas previous riverbank protection of levees focused on solely riprap installation, more recent protection incorporates riparian and wetland benches, as well as other habitat features, to restore habitat function (H. T. Harvey and Associates and PRBO Conservation Science 2010; Hellmair et al. 2018). The riparian and wetland benches are shallow, restored areas along the channel margins that have relatively gentle slopes (e.g., 10:1 instead of the customary 3:1; Casas et al. 2012) and are designed to be wetted or flooded during certain parts of the year to provide habitat for listed species of fish, including juvenile Chinook salmon, and other species. Wetland benches are at lower elevations where more frequent wetting and inundation may be expected, and riparian benches occupy higher portions of the slope where inundation is restricted to high-flow events. These benches are planted and often secured with riprap or other materials.

Several levee improvement projects in the north Delta have been implemented and included the restoration of benches intended to be inundated under specific flows during certain months to provide suitable habitat for listed species of fish; the total length is approximately 47,000 linear feet (~8.9 miles)[32]. Restored benches in the north Delta could potentially be affected by the water operations of the project alternatives because of changes in water level; for example, less water in the Sacramento River below the north Delta intakes could result in riparian benches being inundated less frequently. This possibility was examined by calculating bench inundation indices for juvenile Chinook salmon (see detailed method description in Appendix 12B, Section 12B.6, *Riparian and Wetland Bench Inundation*). These indices range from 0 (no availability of bench habitat) to 1 (water depth on the bench is optimal for juvenile Chinook salmon all of the time)[33]. The analysis was undertaken for riparian and wetland benches in five geographic locations within the north Delta, by linking bench elevation data to DSM2-HYDRO-simulated water surface elevation for three seasonal periods (fall: October–November; winter: December–February; spring: March–June).

The analysis of bench inundation suggested the potential for changes in inundation under the project alternatives relative to existing conditions, ranging from little difference to just over 20% (relative difference) less bench inundation under the project alternatives (Table 12-33). The largest differences were for riparian benches in the Sacramento River downstream of the NDD in winter/spring, with little difference in areas well downstream (e.g., Cache Slough). There was also little difference for wetland benches, which are intended to be inundated at lower water surface elevations that would be available at much lower flows. The project alternatives would result in less availability of inundated bench habitat for juvenile winter-run Chinook salmon under the project alternatives compared to existing conditions. Multiplying the proportional difference in inundation

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[32] By way of comparison, the total length of riverbank (including both banks) along the main migratory pathways in the north Delta upstream of Rio Vista is ~90 miles (mainstem Sacramento River), ~12 miles (Sutter Slough), ~18 miles (Steamboat Slough), and ~14 miles (Miner Slough).

[33] For example, a bench inundation index of 0.20 equates to optimal depth (suitability = 1) 20% of the time within a season (with no other inundation occurring); or equates to relatively poor depth (suitability = 0.20) 100% of the time within a season. Note that depending on water depth under existing conditions, bench inundation indices could be greater, the same, or less under the project alternative, as a result of differences in suitability with differences in water depth (see Figure 12B-2), although the modeling indicated mostly lower inundation indices under the project alternatives because of the north Delta diversions.

indices between the project alternatives and existing conditions (Table 12-33) by the length of bench in each area allows the largest differences as a result of the project alternatives to be expressed in linear feet, which is subsequently used for mitigation calculations; the overall differences relative to existing conditions ranged from approximately 1,600 feet (~3.5%) less under Alternatives 2b/4b to approximately 2,800 feet (6%) less under Alternatives 2a/4a (Table 12-34).

Table 12-33. Mean Riparian and Wetland Bench Inundation Index by Geographic Group, Season, and Water Year Type

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Cache Slough	Riparian	W	Winter	0.23	0.23 (-2%)	0.23 (-2%)	0.23 (-1%)	0.23 (-2%)	0.23 (-2%)
Cache Slough	Riparian	AN	Winter	0.16	0.15 (-3%)	0.15 (-3%)	0.15 (-2%)	0.15 (-3%)	0.15 (-3%)
Cache Slough	Riparian	BN	Winter	0.10	0.09 (-3%)	0.09 (-3%)	0.09 (-2%)	0.09 (-3%)	0.09 (-3%)
Cache Slough	Riparian	D	Winter	0.08	0.08 (-2%)	0.08 (-2%)	0.08 (-2%)	0.08 (-2%)	0.08 (-2%)
Cache Slough	Riparian	C	Winter	0.08	0.08 (-2%)	0.08 (-2%)	0.08 (-1%)	0.08 (-1%)	0.08 (-2%)
Cache Slough	Wetland	W	Winter	0.64	0.63 (0%)	0.63 (0%)	0.64 (0%)	0.63 (0%)	0.63 (0%)
Cache Slough	Wetland	AN	Winter	0.61	0.60 (-1%)	0.60 (-1%)	0.60 (0%)	0.60 (-1%)	0.60 (-1%)
Cache Slough	Wetland	BN	Winter	0.55	0.54 (0%)	0.54 (0%)	0.55 (0%)	0.54 (0%)	0.54 (0%)
Cache Slough	Wetland	D	Winter	0.53	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)
Cache Slough	Wetland	C	Winter	0.53	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)
Sacramento River above north Delta intakes	Riparian	W	Winter	0.22	0.23 (4%)	0.23 (4%)	0.22 (2%)	0.23 (3%)	0.23 (4%)
Sacramento River above north Delta intakes	Riparian	AN	Winter	0.26	0.26 (1%)	0.26 (1%)	0.26 (0%)	0.26 (0%)	0.26 (1%)
Sacramento River above north Delta intakes	Riparian	BN	Winter	0.24	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)
Sacramento River above north Delta intakes	Riparian	D	Winter	0.16	0.15 (-6%)	0.15 (-7%)	0.16 (-4%)	0.15 (-5%)	0.15 (-6%)
Sacramento River above north Delta intakes	Riparian	C	Winter	0.12	0.12 (-5%)	0.12 (-5%)	0.12 (-4%)	0.12 (-4%)	0.12 (-5%)
Sacramento River above north Delta intakes	Wetland	W	Winter	0.14	0.15 (4%)	0.15 (5%)	0.14 (2%)	0.14 (3%)	0.15 (4%)
Sacramento River above north Delta intakes	Wetland	AN	Winter	0.27	0.28 (6%)	0.28 (6%)	0.28 (4%)	0.28 (5%)	0.28 (6%)
Sacramento River above north Delta intakes	Wetland	BN	Winter	0.49	0.50 (3%)	0.50 (4%)	0.50 (3%)	0.50 (3%)	0.50 (3%)
Sacramento River above north Delta intakes	Wetland	D	Winter	0.61	0.63 (2%)	0.63 (2%)	0.62 (1%)	0.63 (2%)	0.63 (2%)
Sacramento River above north Delta intakes	Wetland	C	Winter	0.69	0.70 (2%)	0.70 (2%)	0.69 (1%)	0.70 (1%)	0.70 (2%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	W	Winter	0.42	0.42 (0%)	0.42 (0%)	0.43 (1%)	0.43 (1%)	0.42 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	AN	Winter	0.35	0.34 (-3%)	0.34 (-4%)	0.35 (-2%)	0.35 (-1%)	0.34 (-3%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	BN	Winter	0.18	0.15 (-16%)	0.15 (-18%)	0.16 (-9%)	0.16 (-13%)	0.15 (-16%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	D	Winter	0.07	0.06 (-22%)	0.06 (-23%)	0.06 (-14%)	0.06 (-18%)	0.06 (-22%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	C	Winter	0.05	0.04 (-19%)	0.04 (-21%)	0.04 (-13%)	0.04 (-16%)	0.04 (-19%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	W	Winter	0.32	0.35 (9%)	0.35 (10%)	0.33 (5%)	0.34 (8%)	0.35 (9%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	AN	Winter	0.46	0.49 (7%)	0.49 (7%)	0.48 (4%)	0.48 (5%)	0.49 (7%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	BN	Winter	0.57	0.58 (1%)	0.58 (2%)	0.57 (0%)	0.58 (1%)	0.58 (1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	D	Winter	0.58	0.57 (-1%)	0.57 (-1%)	0.57 (-1%)	0.57 (-1%)	0.57 (-1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	C	Winter	0.56	0.55 (-1%)	0.55 (-1%)	0.55 (-1%)	0.55 (-1%)	0.55 (-1%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	W	Winter	0.56	0.55 (-2%)	0.55 (-3%)	0.55 (-1%)	0.55 (-2%)	0.55 (-2%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	AN	Winter	0.44	0.41 (-7%)	0.41 (-8%)	0.43 (-4%)	0.42 (-5%)	0.41 (-7%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	BN	Winter	0.21	0.18 (-14%)	0.18 (-16%)	0.19 (-9%)	0.19 (-12%)	0.18 (-14%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	D	Winter	0.11	0.10 (-13%)	0.10 (-14%)	0.11 (-8%)	0.10 (-11%)	0.10 (-13%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	C	Winter	0.09	0.08 (-9%)	0.08 (-10%)	0.08 (-7%)	0.08 (-8%)	0.08 (-9%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	W	Winter	0.43	0.45 (6%)	0.46 (6%)	0.44 (4%)	0.45 (5%)	0.45 (6%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	AN	Winter	0.55	0.58 (5%)	0.58 (5%)	0.57 (3%)	0.57 (4%)	0.58 (5%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	BN	Winter	0.64	0.64 (1%)	0.64 (1%)	0.64 (0%)	0.64 (0%)	0.64 (1%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	D	Winter	0.63	0.63 (-1%)	0.63 (-1%)	0.63 (-1%)	0.63 (-1%)	0.63 (-1%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	C	Winter	0.63	0.62 (0%)	0.62 (0%)	0.62 (-1%)	0.62 (0%)	0.62 (-1%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sutter/Steamboat Sloughs	Riparian	W	Winter	0.54	0.54 (-1%)	0.54 (-1%)	0.54 (0%)	0.54 (-1%)	0.54 (-1%)
Sutter/Steamboat Sloughs	Riparian	AN	Winter	0.48	0.46 (-4%)	0.45 (-5%)	0.46 (-2%)	0.46 (-3%)	0.46 (-4%)
Sutter/Steamboat Sloughs	Riparian	BN	Winter	0.31	0.29 (-7%)	0.29 (-8%)	0.30 (-4%)	0.29 (-6%)	0.29 (-7%)
Sutter/Steamboat Sloughs	Riparian	D	Winter	0.24	0.22 (-5%)	0.22 (-6%)	0.23 (-4%)	0.23 (-5%)	0.22 (-5%)
Sutter/Steamboat Sloughs	Riparian	C	Winter	0.21	0.21 (-3%)	0.21 (-4%)	0.21 (-3%)	0.21 (-3%)	0.21 (-3%)
Sutter/Steamboat Sloughs	Wetland	W	Winter	0.44	0.47 (6%)	0.47 (6%)	0.46 (4%)	0.46 (5%)	0.47 (6%)
Sutter/Steamboat Sloughs	Wetland	AN	Winter	0.59	0.62 (5%)	0.62 (6%)	0.61 (3%)	0.62 (4%)	0.62 (5%)
Sutter/Steamboat Sloughs	Wetland	BN	Winter	0.74	0.76 (2%)	0.76 (2%)	0.75 (1%)	0.75 (2%)	0.76 (2%)
Sutter/Steamboat Sloughs	Wetland	D	Winter	0.78	0.78 (1%)	0.78 (1%)	0.78 (0%)	0.78 (1%)	0.78 (1%)
Sutter/Steamboat Sloughs	Wetland	C	Winter	0.79	0.79 (0%)	0.79 (0%)	0.79 (0%)	0.79 (0%)	0.79 (0%)
Cache Slough	Riparian	W	Spring	0.14	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)
Cache Slough	Riparian	AN	Spring	0.09	0.09 (-3%)	0.09 (-3%)	0.09 (-2%)	0.09 (-3%)	0.09 (-3%)
Cache Slough	Riparian	BN	Spring	0.07	0.07 (-2%)	0.07 (-2%)	0.07 (-1%)	0.07 (-1%)	0.07 (-2%)
Cache Slough	Riparian	D	Spring	0.07	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)
Cache Slough	Riparian	C	Spring	0.07	0.07 (0%)	0.07 (-1%)	0.07 (0%)	0.07 (0%)	0.07 (0%)
Cache Slough	Wetland	W	Spring	0.60	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)
Cache Slough	Wetland	AN	Spring	0.56	0.56 (-1%)	0.56 (-1%)	0.56 (0%)	0.56 (-1%)	0.56 (-1%)
Cache Slough	Wetland	BN	Spring	0.53	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)	0.53 (0%)
Cache Slough	Wetland	D	Spring	0.52	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)
Cache Slough	Wetland	C	Spring	0.52	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)
Sacramento River above north Delta intakes	Riparian	W	Spring	0.27	0.27 (0%)	0.27 (0%)	0.27 (0%)	0.27 (0%)	0.27 (0%)
Sacramento River above north Delta intakes	Riparian	AN	Spring	0.31	0.29 (-5%)	0.29 (-5%)	0.30 (-3%)	0.29 (-4%)	0.29 (-5%)
Sacramento River above north Delta intakes	Riparian	BN	Spring	0.17	0.17 (-4%)	0.17 (-4%)	0.17 (-3%)	0.17 (-4%)	0.17 (-4%)
Sacramento River above north Delta intakes	Riparian	D	Spring	0.12	0.11 (-5%)	0.11 (-6%)	0.11 (-4%)	0.11 (-5%)	0.11 (-5%)
Sacramento River above north Delta intakes	Riparian	C	Spring	0.07	0.07 (-3%)	0.07 (-4%)	0.07 (-2%)	0.07 (-2%)	0.07 (-3%)
Sacramento River above north Delta intakes	Wetland	W	Spring	0.25	0.26 (5%)	0.26 (5%)	0.26 (3%)	0.26 (4%)	0.26 (5%)
Sacramento River above north Delta intakes	Wetland	AN	Spring	0.37	0.39 (6%)	0.39 (6%)	0.38 (4%)	0.39 (5%)	0.39 (6%)
Sacramento River above north Delta intakes	Wetland	BN	Spring	0.61	0.62 (2%)	0.62 (2%)	0.62 (2%)	0.62 (2%)	0.62 (2%)
Sacramento River above north Delta intakes	Wetland	D	Spring	0.69	0.70 (1%)	0.70 (1%)	0.70 (1%)	0.70 (1%)	0.70 (1%)
Sacramento River above north Delta intakes	Wetland	C	Spring	0.77	0.77 (0%)	0.77 (1%)	0.77 (0%)	0.77 (0%)	0.77 (0%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	W	Spring	0.38	0.36 (-5%)	0.36 (-5%)	0.36 (-4%)	0.36 (-5%)	0.36 (-5%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	AN	Spring	0.24	0.22 (-10%)	0.21 (-11%)	0.22 (-8%)	0.22 (-10%)	0.21 (-10%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	BN	Spring	0.07	0.06 (-17%)	0.06 (-19%)	0.07 (-11%)	0.06 (-15%)	0.06 (-17%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	D	Spring	0.04	0.03 (-19%)	0.03 (-22%)	0.03 (-11%)	0.03 (-15%)	0.03 (-19%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	C	Spring	0.02	0.02 (-16%)	0.02 (-18%)	0.02 (-11%)	0.02 (-13%)	0.02 (-16%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	W	Spring	0.46	0.46 (1%)	0.46 (1%)	0.46 (1%)	0.46 (1%)	0.46 (1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	AN	Spring	0.59	0.58 (0%)	0.59 (0%)	0.59 (0%)	0.59 (0%)	0.58 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	BN	Spring	0.58	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)	0.58 (-1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	D	Spring	0.55	0.55 (0%)	0.55 (0%)	0.55 (0%)	0.55 (0%)	0.55 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	C	Spring	0.50	0.50 (0%)	0.50 (0%)	0.50 (0%)	0.50 (0%)	0.50 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	W	Spring	0.44	0.43 (-4%)	0.42 (-4%)	0.43 (-4%)	0.43 (-4%)	0.42 (-4%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	AN	Spring	0.27	0.24 (-10%)	0.24 (-11%)	0.25 (-8%)	0.24 (-10%)	0.24 (-10%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	BN	Spring	0.11	0.09 (-12%)	0.09 (-13%)	0.10 (-7%)	0.10 (-10%)	0.09 (-12%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	D	Spring	0.07	0.07 (-9%)	0.06 (-11%)	0.07 (-5%)	0.07 (-7%)	0.07 (-9%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	C	Spring	0.05	0.05 (-5%)	0.05 (-5%)	0.05 (-3%)	0.05 (-4%)	0.05 (-5%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	W	Spring	0.55	0.56 (0%)	0.56 (0%)	0.56 (1%)	0.56 (0%)	0.56 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	AN	Spring	0.65	0.64 (0%)	0.64 (0%)	0.64 (0%)	0.64 (0%)	0.64 (0%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	BN	Spring	0.64	0.64 (0%)	0.64 (0%)	0.64 (0%)	0.64 (0%)	0.64 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	D	Spring	0.62	0.62 (0%)	0.62 (0%)	0.62 (0%)	0.62 (0%)	0.62 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	C	Spring	0.60	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)
Sutter/Steamboat Sloughs	Riparian	W	Spring	0.47	0.46 (-3%)	0.46 (-3%)	0.46 (-2%)	0.46 (-3%)	0.46 (-3%)
Sutter/Steamboat Sloughs	Riparian	AN	Spring	0.36	0.34 (-6%)	0.34 (-6%)	0.34 (-4%)	0.34 (-6%)	0.34 (-6%)
Sutter/Steamboat Sloughs	Riparian	BN	Spring	0.23	0.22 (-4%)	0.22 (-5%)	0.23 (-3%)	0.22 (-4%)	0.22 (-4%)
Sutter/Steamboat Sloughs	Riparian	D	Spring	0.20	0.19 (-3%)	0.19 (-3%)	0.20 (-2%)	0.20 (-2%)	0.19 (-3%)
Sutter/Steamboat Sloughs	Riparian	C	Spring	0.18	0.17 (-1%)	0.17 (-1%)	0.17 (-1%)	0.17 (-1%)	0.17 (-1%)
Sutter/Steamboat Sloughs	Wetland	W	Spring	0.60	0.61 (1%)	0.61 (1%)	0.61 (1%)	0.61 (1%)	0.61 (1%)
Sutter/Steamboat Sloughs	Wetland	AN	Spring	0.72	0.74 (2%)	0.74 (2%)	0.73 (1%)	0.74 (2%)	0.74 (2%)
Sutter/Steamboat Sloughs	Wetland	BN	Spring	0.79	0.79 (0%)	0.79 (1%)	0.79 (0%)	0.79 (0%)	0.79 (0%)
Sutter/Steamboat Sloughs	Wetland	D	Spring	0.79	0.79 (0%)	0.80 (0%)	0.79 (0%)	0.79 (0%)	0.79 (0%)
Sutter/Steamboat Sloughs	Wetland	C	Spring	0.79	0.79 (0%)	0.79 (0%)	0.79 (0%)	0.79 (0%)	0.79 (0%)
Cache Slough	Riparian	W	Fall	0.07	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)
Cache Slough	Riparian	AN	Fall	0.07	0.07 (-1%)	0.07 (-1%)	0.07 (-1%)	0.07 (0%)	0.07 (-1%)
Cache Slough	Riparian	BN	Fall	0.06	0.06 (-1%)	0.06 (-1%)	0.06 (-1%)	0.06 (-1%)	0.06 (-1%)
Cache Slough	Riparian	D	Fall	0.05	0.05 (-1%)	0.05 (-1%)	0.05 (-1%)	0.05 (-1%)	0.05 (-1%)
Cache Slough	Riparian	C	Fall	0.06	0.06 (0%)	0.06 (0%)	0.06 (0%)	0.06 (0%)	0.06 (0%)
Cache Slough	Wetland	W	Fall	0.54	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)
Cache Slough	Wetland	AN	Fall	0.54	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)
Cache Slough	Wetland	BN	Fall	0.53	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)
Cache Slough	Wetland	D	Fall	0.52	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)
Cache Slough	Wetland	C	Fall	0.52	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)	0.52 (0%)
Sacramento River above north Delta intakes	Riparian	W	Fall	0.15	0.15 (-1%)	0.15 (-1%)	0.15 (0%)	0.15 (0%)	0.15 (0%)
Sacramento River above north Delta intakes	Riparian	AN	Fall	0.07	0.07 (2%)	0.07 (1%)	0.07 (0%)	0.07 (1%)	0.07 (1%)
Sacramento River above north Delta intakes	Riparian	BN	Fall	0.08	0.08 (-3%)	0.08 (-3%)	0.08 (-2%)	0.08 (-3%)	0.08 (-4%)
Sacramento River above north Delta intakes	Riparian	D	Fall	0.07	0.06 (-2%)	0.06 (-2%)	0.07 (-1%)	0.06 (-2%)	0.06 (-3%)
Sacramento River above north Delta intakes	Riparian	C	Fall	0.04	0.04 (-1%)	0.04 (-1%)	0.04 (-2%)	0.04 (-2%)	0.04 (-2%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sacramento River above north Delta intakes	Wetland	W	Fall	0.64	0.64 (1%)	0.65 (1%)	0.64 (1%)	0.64 (1%)	0.64 (1%)
Sacramento River above north Delta intakes	Wetland	AN	Fall	0.76	0.75 (0%)	0.76 (0%)	0.76 (0%)	0.76 (0%)	0.76 (0%)
Sacramento River above north Delta intakes	Wetland	BN	Fall	0.75	0.75 (0%)	0.75 (0%)	0.75 (0%)	0.75 (0%)	0.75 (0%)
Sacramento River above north Delta intakes	Wetland	D	Fall	0.77	0.77 (0%)	0.77 (0%)	0.77 (0%)	0.77 (0%)	0.77 (0%)
Sacramento River above north Delta intakes	Wetland	C	Fall	0.78	0.78 (0%)	0.78 (0%)	0.78 (0%)	0.78 (0%)	0.78 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	W	Fall	0.09	0.08 (-7%)	0.08 (-8%)	0.08 (-8%)	0.08 (-8%)	0.08 (-8%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	AN	Fall	0.02	0.02 (-4%)	0.02 (-4%)	0.02 (-5%)	0.02 (-4%)	0.02 (-4%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	BN	Fall	0.02	0.02 (-14%)	0.02 (-13%)	0.02 (-10%)	0.02 (-13%)	0.02 (-15%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	D	Fall	0.01	0.01 (-12%)	0.01 (-11%)	0.01 (-8%)	0.01 (-12%)	0.01 (-13%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Riparian	C	Fall	0.01	0.01 (-2%)	0.01 (-2%)	0.01 (-3%)	0.01 (-3%)	0.01 (-3%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	W	Fall	0.54	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)	0.54 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	AN	Fall	0.53	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)	0.53 (-1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	BN	Fall	0.51	0.51 (-1%)	0.51 (-1%)	0.51 (-1%)	0.51 (-1%)	0.51 (-1%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	D	Fall	0.49	0.49 (0%)	0.49 (0%)	0.49 (0%)	0.49 (0%)	0.49 (0%)
Sacramento River below north Delta intakes to Sutter/Steamboat Slough	Wetland	C	Fall	0.47	0.47 (0%)	0.47 (0%)	0.47 (-1%)	0.47 (0%)	0.47 (-1%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	W	Fall	0.12	0.11 (-6%)	0.11 (-6%)	0.11 (-6%)	0.11 (-6%)	0.11 (-6%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	AN	Fall	0.05	0.05 (-2%)	0.05 (-3%)	0.05 (-2%)	0.05 (-2%)	0.05 (-2%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	BN	Fall	0.05	0.05 (-6%)	0.05 (-6%)	0.05 (-4%)	0.05 (-5%)	0.04 (-6%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	D	Fall	0.04	0.04 (-4%)	0.04 (-4%)	0.04 (-2%)	0.04 (-4%)	0.04 (-4%)

Geographic Group	Bench Type	WYT	Season	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Riparian	C	Fall	0.03	0.03 (-1%)	0.03 (-1%)	0.03 (-1%)	0.03 (-1%)	0.03 (-1%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	W	Fall	0.62	0.62 (0%)	0.62 (0%)	0.62 (0%)	0.62 (0%)	0.62 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	AN	Fall	0.61	0.61 (0%)	0.61 (0%)	0.61 (0%)	0.61 (0%)	0.61 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	BN	Fall	0.60	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)	0.60 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	D	Fall	0.59	0.59 (0%)	0.59 (0%)	0.59 (0%)	0.59 (0%)	0.59 (0%)
Sacramento River from Sutter/Steamboat Slough to Rio Vista	Wetland	C	Fall	0.58	0.58 (0%)	0.58 (0%)	0.58 (0%)	0.58 (0%)	0.58 (0%)
Sutter/Steamboat Sloughs	Riparian	W	Fall	0.24	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)	0.23 (-2%)
Sutter/Steamboat Sloughs	Riparian	AN	Fall	0.19	0.19 (-1%)	0.19 (-1%)	0.19 (-1%)	0.19 (-1%)	0.19 (-1%)
Sutter/Steamboat Sloughs	Riparian	BN	Fall	0.18	0.17 (-2%)	0.17 (-2%)	0.18 (-1%)	0.17 (-2%)	0.17 (-2%)
Sutter/Steamboat Sloughs	Riparian	D	Fall	0.17	0.16 (-1%)	0.16 (-1%)	0.16 (-1%)	0.16 (-1%)	0.16 (-1%)
Sutter/Steamboat Sloughs	Riparian	C	Fall	0.16	0.16 (0%)	0.16 (0%)	0.16 (-1%)	0.16 (0%)	0.16 (-1%)
Sutter/Steamboat Sloughs	Wetland	W	Fall	0.78	0.78 (0%)	0.78 (0%)	0.78 (0%)	0.78 (0%)	0.78 (0%)
Sutter/Steamboat Sloughs	Wetland	AN	Fall	0.80	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)
Sutter/Steamboat Sloughs	Wetland	BN	Fall	0.80	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)
Sutter/Steamboat Sloughs	Wetland	D	Fall	0.80	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)
Sutter/Steamboat Sloughs	Wetland	C	Fall	0.80	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)	0.80 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions; WYT = water year type (W = wet, AN = above normal, BN = below normal, D = dry, C = critically dry).

Table 12-34. Riparian Bench Length and Total Deficit Compared to Existing Conditions (linear feet)

Geographic Location	Bench Type	Length	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Cache Slough	Riparian	2,950	-90	-95	-71	-88	-91
Cache Slough	Wetland	3,992	-27	-28	-19	-24	-27
Sacramento River above north Delta intakes	Riparian	18,251	-1,075	-1,306	-660	-952	-1,089
Sacramento River above north Delta intakes	Wetland	3,766	-18	-13	-7	-14	-14
Sacramento River below north Delta intakes to Sutter/ Steamboat Sl.	Riparian	3,037	-662	-688	-426	-561	-669
Sacramento River below north Delta intakes to Sutter/ Steamboat Sl.	Wetland	3,115	-37	-39	-38	-37	-41
Sacramento River from Sutter/ Steamboat Sl. To Rio Vista	Riparian	1,685	-237	-266	-146	-201	-236
Sacramento River from Sutter/ Steamboat Sl. To Rio Vista	Wetland	2,430	-14	-15	-12	-13	-14
Sutter/Steamboat Sloughs	Riparian	5,235	-360	-397	-233	-309	-358
Sutter/Steamboat Sloughs	Wetland	2,670	0	0	-1	0	0
Total	Both	47,131	-2,519	-2,847	-1,613	-2,198	-2,540

Note: Results are not future predictions and are intended only to compare alternatives.
Alt = alternative.

WATER TEMPERATURE

The project alternatives would have minimal effects on water temperature relative to existing conditions. Kimmerer (2004:19–20) noted that the water temperature in the San Francisco Estuary depends mainly on air temperature, and that even in the Delta the relationship between air and water temperature is only slightly affected by freshwater inflow. Kimmerer (2004) further noted that at Freeport high inflow reduces water temperature on cool days, presumably because water reaches the Delta before its temperature equilibrates with air temperature; at Antioch low inflow increases water temperature on cool days, probably because of the moderating effect of warmer estuarine water moving farther upstream. USFWS (2008:194) suggested, based on Kimmerer (2004), that water temperatures at Freeport can be cooled up to about 3°C by high Sacramento River flows, but only by very high river flows that cannot be sustained by CVP/SWP (reservoir) operations. Operations-based flow-related effects on Delta water temperature are expected to be minor (Wagner et al. 2011). This was illustrated by DSM2-QUAL modeling for representative locations on the Sacramento River (downstream of Intake C and at Rio Vista; Table 12-35 and Table 12-36) and San Joaquin River (at Jersey Point; Table 12-37).

Table 12-35. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, Sacramento River Immediately Downstream of Intake C

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	Jan	9.4	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)
Wet	Feb	10.8	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	Mar	12.6	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)
Wet	Apr	14.7	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)
Wet	May	17.7	17.7 (0.0)	17.7 (0.0)	17.7 (0.0)	17.7 (0.0)	17.7 (0.0)
Wet	Jun	19.5	19.5 (0.0)	19.5 (0.0)	19.5 (0.0)	19.5 (0.0)	19.5 (0.0)
Wet	Jul	20.9	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)
Wet	Aug	20.7	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)
Wet	Sep	19.6	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)
Wet	Oct	16.5	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)
Wet	Nov	12.7	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)
Wet	Dec	10.0	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)	10.0 (0.0)
Above normal	Jan	9.4	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)
Above normal	Feb	10.6	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)
Above normal	Mar	12.8	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)
Above normal	Apr	15.0	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)
Above normal	May	17.8	17.8 (0.0)	17.8 (0.0)	17.8 (0.0)	17.8 (0.0)	17.8 (0.0)
Above normal	Jun	19.6	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)
Above normal	Jul	21.2	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)
Above normal	Aug	20.7	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)
Above normal	Sep	19.6	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)	19.6 (0.0)
Above normal	Oct	16.8	16.8 (0.0)	16.8 (0.0)	16.8 (0.0)	16.8 (0.0)	16.8 (0.0)
Above normal	Nov	12.1	12.1 (0.0)	12.1 (0.0)	12.1 (0.0)	12.1 (0.0)	12.1 (0.0)
Above normal	Dec	9.4	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)	9.4 (0.0)
Below normal	Jan	8.7	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)
Below normal	Feb	10.3	10.3 (0.0)	10.3 (0.0)	10.3 (0.0)	10.3 (0.0)	10.3 (0.0)
Below normal	Mar	12.5	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)	12.5 (0.0)
Below normal	Apr	15.1	15.1 (0.0)	15.1 (0.0)	15.1 (0.0)	15.1 (0.0)	15.1 (0.0)
Below normal	May	17.3	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)
Below normal	Jun	19.7	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)
Below normal	Jul	21.0	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)
Below normal	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Below normal	Sep	19.3	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)
Below normal	Oct	16.6	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)
Below normal	Nov	12.4	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)
Below normal	Dec	9.2	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)
Dry	Jan	8.4	8.4 (0.0)	8.4 (0.0)	8.4 (0.0)	8.4 (0.0)	8.4 (0.0)
Dry	Feb	10.4	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)
Dry	Mar	12.7	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)
Dry	Apr	15.0	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)	15.0 (0.0)
Dry	May	17.3	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)	17.3 (0.0)
Dry	Jun	19.7	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)	19.7 (0.0)
Dry	Jul	20.7	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)	20.7 (0.0)
Dry	Aug	20.3	20.3 (0.0)	20.2 (0.0)	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)
Dry	Sep	19.1	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Dry	Oct	16.2	16.2 (0.0)	16.2 (0.0)	16.2 (0.0)	16.2 (0.0)	16.2 (0.0)
Dry	Nov	12.2	12.2 (0.0)	12.2 (0.0)	12.2 (0.0)	12.2 (0.0)	12.2 (0.0)
Dry	Dec	9.2	9.1 (0.0)	9.1 (0.0)	9.2 (0.0)	9.2 (0.0)	9.1 (0.0)
Critically dry	Jan	8.7	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)
Critically dry	Feb	10.8	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)	10.8 (0.0)
Critically dry	Mar	13.1	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)
Critically dry	Apr	14.9	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)
Critically dry	May	17.1	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)
Critically dry	Jun	19.3	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)	19.3 (0.0)
Critically dry	Jul	21.0	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)
Critically dry	Aug	20.3	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)
Critically dry	Sep	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)
Critically dry	Oct	16.7	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)
Critically dry	Nov	12.6	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)
Critically dry	Dec	9.0	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)

Note: Values in parentheses indicate absolute differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Table 12-36. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, Sacramento River at Rio Vista

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	Jan	9.3	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)	9.2 (0.0)
Wet	Feb	10.9	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)
Wet	Mar	12.8	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)
Wet	Apr	14.7	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)	14.7 (0.0)
Wet	May	17.4	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)
Wet	Jun	19.1	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)
Wet	Jul	20.8	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)
Wet	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Wet	Sep	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)
Wet	Oct	16.1	16.1 (0.0)	16.1 (0.0)	16.1 (0.0)	16.1 (0.0)	16.1 (0.0)
Wet	Nov	12.8	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)
Wet	Dec	9.8	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)
Above normal	Jan	9.1	9.1 (0.0)	9.1 (0.0)	9.1 (0.0)	9.1 (0.0)	9.1 (0.0)
Above normal	Feb	10.6	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)	10.6 (0.0)
Above normal	Mar	13.1	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)
Above normal	Apr	14.9	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)	14.9 (0.0)
Above normal	May	17.4	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)	17.4 (0.0)
Above normal	Jun	19.1	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)
Above normal	Jul	21.2	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)
Above normal	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Above normal	Sep	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Above normal	Oct	16.6	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)
Above normal	Nov	12.3	12.3 (0.0)	12.3 (0.0)	12.3 (0.0)	12.3 (0.0)	12.3 (0.0)
Above normal	Dec	9.0	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)	9.0 (0.0)
Below normal	Jan	8.1	8.1 (0.0)	8.1 (0.0)	8.1 (0.0)	8.1 (0.0)	8.1 (0.0)
Below normal	Feb	10.2	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)
Below normal	Mar	12.7	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)
Below normal	Apr	14.8	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)
Below normal	May	16.6	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)
Below normal	Jun	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)
Below normal	Jul	20.9	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)	20.9 (0.0)
Below normal	Aug	20.3	20.2 (0.0)	20.2 (0.0)	20.2 (0.0)	20.2 (0.0)	20.2 (0.0)
Below normal	Sep	19.0	18.9 (0.0)	19.0 (0.0)	19.0 (0.0)	19.0 (0.0)	18.9 (0.0)
Below normal	Oct	16.3	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)
Below normal	Nov	12.6	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)	12.6 (0.0)
Below normal	Dec	8.9	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)
Dry	Jan	7.6	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)
Dry	Feb	10.2	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)
Dry	Mar	12.9	12.9 (0.0)	13.0 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)
Dry	Apr	14.8	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)
Dry	May	16.6	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)
Dry	Jun	19.1	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)	19.1 (0.0)
Dry	Jul	20.4	20.4 (0.0)	20.4 (0.0)	20.4 (0.0)	20.4 (0.0)	20.4 (0.0)
Dry	Aug	19.9	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)
Dry	Sep	18.7	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)	18.7 (0.0)	18.6 (0.0)
Dry	Oct	15.8	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)
Dry	Nov	12.4	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)	12.4 (0.0)
Dry	Dec	8.8	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)	8.8 (0.0)
Critically dry	Jan	8.1	8.0 (0.0)	8.0 (0.0)	8.0 (0.0)	8.0 (0.0)	8.0 (0.0)
Critically dry	Feb	10.7	10.7 (0.0)	10.7 (0.0)	10.7 (0.0)	10.7 (0.0)	10.7 (0.0)
Critically dry	Mar	13.5	13.5 (0.0)	13.5 (0.0)	13.5 (0.0)	13.5 (0.0)	13.5 (0.0)
Critically dry	Apr	14.5	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)
Critically dry	May	16.5	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)	16.5 (0.0)
Critically dry	Jun	18.8	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)
Critically dry	Jul	21.2	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)
Critically dry	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Critically dry	Sep	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)
Critically dry	Oct	16.6	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)
Critically dry	Nov	12.9	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)
Critically dry	Dec	8.6	8.6 (0.0)	8.6 (0.0)	8.6 (0.0)	8.6 (0.0)	8.6 (0.0)

Note: Values in parentheses indicate absolute differences of alternatives compared to existing conditions.

Alt = alternative; EC = existing conditions.

Table 12-37. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, San Joaquin River at Jersey Point

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	Jan	8.9	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)
Wet	Feb	10.9	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)	10.9 (0.0)
Wet	Mar	13.1	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)
Wet	Apr	14.8	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)
Wet	May	17.2	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)	17.1 (0.0)
Wet	Jun	18.9	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)
Wet	Jul	20.6	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)
Wet	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Wet	Sep	19.0	19.0 (0.0)	19.0 (0.0)	19.0 (0.0)	19.0 (0.0)	19.0 (0.0)
Wet	Oct	16.0	16.0 (0.0)	16.0 (0.0)	16.0 (0.0)	16.0 (0.0)	16.0 (0.0)
Wet	Nov	13.1	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)	13.1 (0.0)
Wet	Dec	9.8	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)
Above normal	Jan	8.7	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)
Above normal	Feb	10.5	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)	10.4 (0.0)
Above normal	Mar	13.4	13.5 (0.0)	13.5 (0.0)	13.4 (0.0)	13.5 (0.0)	13.5 (0.0)
Above normal	Apr	14.8	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)
Above normal	May	17.0	17.0 (0.0)	17.0 (0.0)	17.0 (0.0)	17.0 (0.0)	17.0 (0.0)
Above normal	Jun	18.8	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)	18.8 (0.0)
Above normal	Jul	21.0	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)	21.0 (0.0)
Above normal	Aug	20.5	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)	20.5 (0.0)
Above normal	Sep	18.9	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)
Above normal	Oct	16.7	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)	16.7 (0.0)
Above normal	Nov	12.7	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)	12.7 (0.0)
Above normal	Dec	8.9	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)
Below normal	Jan	7.6	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)	7.6 (0.0)
Below normal	Feb	9.7	9.7 (0.0)	9.7 (0.0)	9.7 (0.0)	9.7 (0.0)	9.7 (0.0)
Below normal	Mar	12.8	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)
Below normal	Apr	14.6	14.6 (0.0)	14.6 (0.0)	14.6 (0.0)	14.6 (0.0)	14.6 (0.0)
Below normal	May	16.3	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)
Below normal	Jun	18.9	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)
Below normal	Jul	20.8	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)	20.8 (0.0)
Below normal	Aug	20.1	20.1 (0.0)	20.1 (0.0)	20.1 (0.0)	20.1 (0.0)	20.1 (0.0)
Below normal	Sep	18.9	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)
Below normal	Oct	16.3	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)
Below normal	Nov	12.9	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)	12.9 (0.0)
Below normal	Dec	8.9	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)
Dry	Jan	7.0	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)	7.0 (0.0)
Dry	Feb	9.8	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)	9.8 (0.0)
Dry	Mar	13.0	13.0 (0.0)	13.0 (0.0)	13.0 (0.0)	13.0 (0.0)	13.0 (0.0)
Dry	Apr	14.8	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)	14.8 (0.0)
Dry	May	16.3	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)

Water Year Type	Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Dry	Jun	18.9	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)	18.9 (0.0)
Dry	Jul	20.3	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)	20.3 (0.0)
Dry	Aug	19.9	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)	19.9 (0.0)
Dry	Sep	18.6	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)
Dry	Oct	15.8	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)	15.8 (0.0)
Dry	Nov	12.8	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)	12.8 (0.0)
Dry	Dec	8.9	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)	8.9 (0.0)
Critically dry	Jan	7.5	7.4 (0.0)	7.4 (0.0)	7.4 (0.0)	7.4 (0.0)	7.4 (0.0)
Critically dry	Feb	10.2	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)	10.2 (0.0)
Critically dry	Mar	13.6	13.6 (0.0)	13.6 (0.0)	13.6 (0.0)	13.6 (0.0)	13.6 (0.0)
Critically dry	Apr	14.5	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)	14.5 (0.0)
Critically dry	May	16.3	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)	16.3 (0.0)
Critically dry	Jun	18.6	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)	18.6 (0.0)
Critically dry	Jul	21.2	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)	21.2 (0.0)
Critically dry	Aug	20.6	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)	20.6 (0.0)
Critically dry	Sep	19.2	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)	19.2 (0.0)
Critically dry	Oct	16.6	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)	16.6 (0.0)
Critically dry	Nov	13.2	13.2 (0.0)	13.2 (0.0)	13.2 (0.0)	13.2 (0.0)	13.2 (0.0)
Critically dry	Dec	8.7	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)	8.7 (0.0)

Note: Values in parentheses indicate absolute differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

CYANOBACTERIA HARMFUL ALGAL BLOOMS

Early migrating juvenile winter-run Chinook salmon entering the Delta could have the potential to encounter cyanobacteria harmful algal blooms (CHABs) including *Microcystis*, which occur during the warmer part of the year with temperature above 19°C (66.2°F; see discussion in Impact WQ-14 in Chapter 9). However, as discussed in Impact WQ-14 in Chapter 9, changes in CHABs are concluded to be less than significant and therefore would not significantly affect any early migrating winter-run in the Delta.

METALS

Methylmercury and selenium have the potential to negatively affect habitat suitability for winter-run Chinook salmon in the Delta. As discussed in detail in Chapter 9, *Water Quality*, changes in water operations under the project alternatives would have very little effect on Delta fish tissue concentrations of methylmercury and selenium, relative to existing conditions.

ADULT STRAYING

There is little information from which to infer the potential for adult winter-run Chinook salmon migratory delay because of reductions in Delta inflow as a result of north Delta exports, although the available information for hatchery fall-run Chinook salmon indicates straying rates of fish returning to the Sacramento River are always low (Marston et al. 2012). This suggests relatively little influence of flows and therefore no likely difference between the project alternatives and existing conditions for potential straying of adult winter-run Chinook salmon.

Life Cycle Modeling

Three life cycle models were run to provide population-level assessment of operations impacts of the project alternatives: IOS, OBAN, and the Winter-Run Chinook Salmon Life Cycle Model (Hendrix et al. 2014, 2019). The methods for IOS and OBAN are described in Section 12.B.7, *Interactive Object-Oriented Simulation* (IOS), and in Section 12B.8, *Oncorhynchus Bayesian Analysis* (OBAN), in Appendix 12B.

The results of the IOS modeling gave overall (all-year) mean adult female winter-run Chinook salmon escapement under the alternatives of 7% to 13% less than existing conditions (Table 12-38). This reflected lower juvenile through-Delta survival under the project alternatives as compared to existing conditions because survival was similar between the alternatives and existing conditions for egg, fry, and riverine life stages (Tables 12-40, 12-41, 12-42). (Graphical summaries are also provided in Appendix 12B, Section 12B.7.3, *Results*.) General reasons for minor upstream differences in fry and egg survival are discussed further below in the description of OBAN modeling results.

Table 12-38. Mean Adult Female Winter-Run Chinook Salmon Escapement (Number of Fish) Based on the IOS Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	3,769	3,475 (-8%)	3,322 (-12%)	3,535 (-6%)	3,420 (-9%)	3,448 (-9%)
Above normal	3,498	3,185 (-9%)	3,163 (-10%)	3,296 (-6%)	3,243 (-7%)	3,210 (-8%)
Below normal	3,319	2,968 (-11%)	2,903 (-13%)	3,078 (-7%)	3,005 (-9%)	2,945 (-11%)
Dry	3,468	3,158 (-9%)	3,064 (-12%)	3,182 (-8%)	3,143 (-9%)	3,157 (-9%)
Critically dry	2,128	1,943 (-9%)	1,890 (-11%)	1,989 (-6%)	1,926 (-9%)	1,931 (-9%)
All	3,301	3,004 (-9%)	2,912 (-12%)	3,070 (-7%)	2,996 (-9%)	2,993 (-9%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Table 12-39. Mean Juvenile Winter-Run Chinook Salmon Through-Delta Proportional Survival Based on the IOS Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.35	0.34 (-1%)	0.34 (-1%)	0.35 (-1%)	0.35 (-1%)	0.34 (-1%)
Above normal	0.31	0.30 (-3%)	0.30 (-3%)	0.31 (-2%)	0.30 (-2%)	0.30 (-3%)
Below normal	0.26	0.25 (-4%)	0.24 (-5%)	0.25 (-3%)	0.25 (-4%)	0.25 (-4%)
Dry	0.20	0.19 (-5%)	0.19 (-5%)	0.20 (-3%)	0.19 (-4%)	0.19 (-5%)
Critically dry	0.17	0.16 (-4%)	0.16 (-4%)	0.16 (-3%)	0.16 (-4%)	0.16 (-4%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Table 12-40. Mean Winter-Run Chinook Salmon Egg Proportional Survival Based on the IOS Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	1.00	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)
Above normal	1.00	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)
Below normal	1.00	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)
Dry	1.00	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)	1.00 (0%)
Critically dry	0.86	0.89 (3%)	0.90 (4%)	0.90 (4%)	0.90 (4%)	0.89 (3%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Table 12-41. Mean Winter-Run Chinook Salmon Fry Proportional Survival Based on the IOS Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.95	0.95 (0%)	0.95 (0%)	0.95 (0%)	0.95 (0%)	0.95 (0%)
Above normal	0.96	0.96 (0%)	0.96 (0%)	0.96 (0%)	0.96 (0%)	0.96 (0%)
Below normal	0.96	0.96 (0%)	0.96 (0%)	0.96 (0%)	0.96 (0%)	0.96 (0%)
Dry	0.95	0.95 (0%)	0.95 (0%)	0.95 (0%)	0.95 (0%)	0.95 (0%)
Critically dry	0.81	0.83 (2%)	0.84 (3%)	0.83 (3%)	0.83 (3%)	0.83 (2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Table 12-42. Mean Juvenile Winter-Run Chinook Salmon Riverine Proportional Survival Based on the IOS Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.29	0.29 (0%)	0.29 (0%)	0.29 (0%)	0.29 (0%)	0.29 (0%)
Above normal	0.26	0.26 (0%)	0.26 (0%)	0.26 (0%)	0.26 (0%)	0.26 (0%)
Below normal	0.25	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)
Dry	0.25	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)
Critically dry	0.25	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)	0.25 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

The methods and results of the OBAN model are discussed in detail in Appendix 12B, Attachment 12B.1, *Draft results of OBAN analysis of Delta Conveyance Project Alternatives 2020.* The modeled median abundances were highest under Alternatives 2a/4a relative to existing conditions and all other alternatives (Table 12-43). Alternatives 2a/4a had median abundances greater than the existing conditions when averaged across the timeseries, whereas all other alternatives had median abundances less than existing conditions. The mean relative difference (%) followed a similar pattern, although Alternatives 2a/4a were marginally lower than existing conditions (Table 12-43). These results were due in large part to the initial ten years of the modeling time period, and comparisons among the remaining years indicated median abundances below existing conditions for all alternatives. Differences in the performance of the alternatives were due mostly to the egg through fry survival stage of the OBAN model, which uses temperature at Bend Bridge and minimum flow at Bend Bridge as physical drivers. Temperatures and minimum flows were similar among alternatives, but temperatures were slightly lower on average under Alternatives 2a/4a, and flows were slightly higher relative to the other alternatives. Reasons for small upstream differences in flows are generally discussed in Chapter 5, *Surface Water* (see discussion of *Changes to Sacramento River Basin Flows* in Section 5.3.2.2, *Project Alternatives*), and include differences in carriage water needs between existing conditions and the project alternatives, with minor differences in Shasta Reservoir storage (see discussion of *Changes to SWP and CVP Reservoir Storage* in Section 5.3.2.2, *Project Alternatives*) likely affecting downstream temperature (e.g., slightly lower temperature because of slightly greater reservoir storage). In addition to the main model runs, the OBAN model was run with two mortality assumptions (5% and 10%) to evaluate the sensitivity of model results to additional potential mortality associated with the north Delta diversions, as generally informed by the mid- and upper-level differences from the through-Delta survival modeling (Table 12-30), for example. All of the alternatives, including Alternatives 2a/4a, had median abundance less than the existing conditions under a mortality assumption of 5% and 10% over the full time period of the model (Table 12-43).

Table 12-43. OBAN Winter-Run Chinook Salmon Escapement Results: Mean Difference (Project Alternatives Minus Existing Conditions, Based on Annual Median) and Mean Probability of Greater Escapement under Project Alternatives Compared to Existing Conditions.

Alternative	Mean Escapement Absolute Difference	Mean Escapement % Difference	Mean Probability > EC
Alts 1, 3	-1.1	-13	0.40
Alts 1, 3 5%	-3.0	-25	0.31
Alts 1, 3 10%	-5.1	-37	0.23
Alts 2a, 4a	1.6	-3	0.48
Alts 2a, 4a 5%	-0.3	-16	0.38
Alts 2a, 4a 10%	-2.4	-29	0.29
Alts 2b, 4b	-1.3	-6	0.45
Alts 2b, 4b 5%	-3.3	-20	0.35
Alts 2b, 4b 10%	-5.1	-32	0.26
Alts 2c, 4c	-1.2	-7	0.44
Alts 2c, 4c 5%	-3.0	-21	0.34
Alts 2c, 4c 10%	-4.9	-33	0.26
Alt 5	-1.5	-12	0.41
Alt 5 5%	-3.4	-25	0.31
Alt 5 10%	-5.2	-36	0.24

Note: Table only includes mean responses and does not consider model uncertainty. '5%', and '10%' after each alternative number indicates sensitivity analyses for additional through-Delta mortality of 5% and 10% representing additional near- or far-field mortality not captured by the OBAN model—that was added to the through-Delta survival calculated by the OBAN model. The 5% and 10% values were chosen on the basis of other analyses such as through-Delta survival analyses suggesting potential decreases of this general magnitude.

Alt = alternative; EC = existing conditions.

In contrast to the IOS and OBAN models, the Winter-Run Chinook Salmon Life Cycle Model results suggested spawner abundance, freshwater productivity, and cohort replacement rate may be slightly greater under the alternatives than existing conditions (Table 12-43a). The mechanisms and explanation for these results will be fully investigated and reported during the project permitting process.

Table 12-43a. Summary of Winter-Run Chinook Salmon Life Cycle Model Results.

Output	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Spawner abundance (mean % difference relative to EC)	4.96%	5.88%	5.74%	5.88%	5.19%
Probability of spawner abundance > EC	1.00	1.00	1.00	1.00	1.00
Freshwater productivity (mean % difference in gulf smolts per spawner relative to EC)	0.54%	0.40%	0.50%	0.53%	0.52%
Cohort replacement rate (mean % difference relative to EC)	0.65%	0.60%	0.65%	0.67%	0.62%
Probability of cohort replacement rate > EC	0.98	0.95	0.96	0.97	0.98

Alt = alternative; EC = existing conditions.

Maintenance Effects

Maintenance of the north Delta intake facilities for each project alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on winter-run Chinook salmon. The cylindrical tee screens at each intake would be lifted out of the water with the intake's gantry crane for cleaning purposes and may be fixed at the top of the guide rail before being washed with a high-pressure mobile power washer approximately every 6 months (Delta Conveyance Design and Construction Authority 2022i:11), with approximately half a day of associated work (including 1 hour of actual washing) for each screen at each intake (i.e., a total of 15 days of washing for each 3,000-cfs intake and 8 days for each 1,500-cfs intake). This washing process may cause removed sediment and aquatic growth or vegetation to reenter the river, resulting in its redistribution by river currents and minimal effects to the river and species such as winter-run Chinook salmon because of the very small amount of material compared to the size of the receiving waterbody. The velocity of diverted water through the cylindrical tee screen system and piping generally is expected to be sufficient to keep sediment moving until it reaches the settling basins (Delta Conveyance Design and Construction Authority 2022i:13). Sediment jetting would only be required at the base of the screen structure to help keep sediment from accumulating beneath the screens; this jetting would be done frequently (hourly to daily, depending on needs), thereby resulting in minimal changes to suspended sediment/turbidity, with sediment jetted from the screen rapidly dispersing within the river channel and, therefore, having very limited or no effects on any winter-run Chinook salmon occurring in the vicinity. When the screen units are lifted up to the deck for cleaning, solid panels would be installed behind the screen in the back guide rail for the unit being cleaned. These panels would seal off that unit's intake area from diversions, so there would be no potential to divert water through an unscreened area while the screen is being cleaned and therefore no risk of fish entrainment. Periodic removal of debris from the log booms at each intake (e.g., accumulations following storms) would involve hand and power tools (Delta Conveyance Design and Construction Authority 2022j) but would not be likely to negatively affect juvenile winter-run Chinook salmon, which if in the vicinity would be startled and swim away. Removal of accumulated debris would limit increases in potential predatory fish holding habitat.

CEQA Conclusion—All Project Alternatives

The above analyses demonstrate that the near-field effects of the north Delta intakes would be limited but acknowledge some uncertainty and noted that fishery studies of juvenile Chinook salmon distribution and survival as well as predatory fish and predation would be undertaken to inform the adaptive management process. Near-field effects of south Delta exports (entrainment) under the project alternatives would be similar to or potentially somewhat less than existing conditions because of some diversions occurring at the north Delta intakes instead of the south Delta facilities. Analyses of habitat suitability suggested limited potential for negative effects of the project alternatives relative to existing conditions on water quality (water temperature, CHABs, and metals). Therefore near-field and water quality impacts of the project alternatives would be less than significant.

The project alternatives would have negative hydrodynamic impacts on designated juvenile winter-run Chinook salmon critical habitat and other habitat in the north Delta, including increases in flow reversals in the Sacramento River below Georgiana Slough and increases in the proportion of flow entering the interior Delta through Georgiana Slough, which is a relatively low-survival migration pathway compared to other north Delta pathways (mainstem Sacramento River and Sutter/Steamboat Sloughs; Perry et al. 2018). In addition, exports by the north Delta intakes would reduce the inundation of riparian and wetland bench habitat by 4-6% depending on alternative. Analyses of indirect mortality effects within the Delta reflecting these hydrodynamic impacts suggested that through-Delta survival of juvenile winter-run Chinook salmon under the project alternatives could be 0% to 4% less than existing conditions, with appreciable variability around the estimates for individual years when accounting for uncertainty in model estimates (as illustrated for the Delta Passage Model in Appendix 12B). Results from the winter-run life cycle modeling showed that through-Delta survival impacts could have population-level impacts based on 7% to 13% lower mean adult female escapement from the IOS model under the alternatives relative to existing conditions, and the OBAN life cycle model with 5% and 10% additional mortality in juvenile Delta survival to account for potential north Delta intakes effects also suggested the potential for lower escapement under the alternatives than existing conditions. Modeling results reflect flow-based criteria and requirements but do not account for adjustments to operations in response to real-time monitoring of fish to further limit potential negative effects. In contrast, the Winter-Run Chinook Salmon Life Cycle Model suggested spawner abundance, freshwater productivity, and cohort replacement rate may be slightly greater under the alternatives than existing conditions. As described in Chapter 3, the proposed operations criteria and tidal restoration[34] are intended to minimize and fully mitigate the potential impacts of the NDD operations. The real time decision-making specific to the NDD operations would be mainly associated with reviewing real-time abiotic

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[34] See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

and fish monitoring data and ensuring proposed weekly, daily, and sub-daily operations are consistent with the permitted criteria and within the effects analyzed in the permits. See Chapter 3, Section 3.17, *Real-Time Operational Decision-Making Process*, for additional details. Tables 3.14 and 3.15 in Chapter 3 provide proposed operations criteria and north Delta intake bypass flow and pulse protection requirements.

The available information generally indicates that diversion at the NDD would negatively affect winter-run Chinook salmon through flow-survival and habitat impacts. The Sacramento River is the main migration pathway through the Delta for juvenile winter-run and therefore a large proportion of the population would potentially be exposed to negative impacts. Although there is uncertainty in the biological impacts given the variability in statistical relationships (see, for example, the range of the credible intervals shown in Figure 5 of Perry et al. 2018) and the extent to which the impacts may be limited by operations, the negative impacts on habitat-based indicators (flow reversals and flow entering Georgiana Slough) have greater certainty. The operations-related impact would be significant. To address the significance of the impacts, Mitigation Measure CMP: *Compensatory Mitigation Plan* would be implemented, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* and CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles* (Attachment 3F.1, Table 3F.1-3). This mitigation would reduce negative hydrodynamic effects such as flow reversals in the Sacramento River at Georgiana Slough (CMP-25)[35] and reduced effects from reduced inundation of riparian/wetland benches as a result of NDD operations (CMP-26). The mitigation thereby would reduce potential for negative effects on winter-run Chinook salmon through-Delta survival as a result of factors such as flow-related changes in migration speed and probability of entering the low-survival interior Delta migration pathway and restoring new bench habitat at elevations that would be inundated under reduced flows downstream of the north Delta intakes. The impact of operations and maintenance of the project alternatives would be less than significant with mitigation.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Impacts

<u>Compensatory Mitigation</u>

Implementation of the Compensatory Mitigation Plan could result in impacts on winter-run Chinook salmon. Following completion of compensatory mitigation construction (tidal perennial habitat and

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[35] The mitigation would reduce negative hydrodynamic effects of the north Delta intakes by redirecting tidal energy away from the mainstem Sacramento River; see Resource Management Associates (2020) for modeling efforts discussing how changes in Delta geometry affect hydrodynamics.

channel margin habitat for operations impacts; see Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*), restored tidal habitat areas would have the potential for positive effects on winter-run Chinook salmon, for example by providing foraging habitat along marsh edges (Brown 2003) or a greater extent of inundated vegetated habitat for occupancy (Hellmair et al. 2018). Efficacy monitoring of performance standards would assess the degree to which positive effects are occurring and inform adjustment to sites as necessary to increase positive effects (Appendix 3F). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have less-than-significant impacts on CHABs.

<u>Other Mitigation Measures</u>

Other mitigation measures proposed would have no impacts on winter-run Chinook Salmon during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact winter-run Chinook salmon during operations and maintenance, and there would be no impact.

Overall, the impact on winter-run Chinook salmon during operations and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less than significant with mitigation impact conclusion.

No Project Alternative

Under 2020 climate assumptions, there would be no difference in operational effects between the No Project Alternative and existing conditions. Climate change-related shifts would generally increase winter/early spring Sacramento River flows into the Delta under the No Project Alternative under 2040 climate assumptions relative to existing conditions during December–April, as indicated by CalSim modeling (Appendix 5A, Attachment 3, *CalSim 3 Model Results*, Figure B.3.5.1 and Table B.3.5.1). These differences could result in higher through-Delta survival (Table 12-44) and generally greater inundation of riparian benches based on the mechanisms discussed above for the project alternatives, although for riparian bench inundation the largest driver of the overall positive difference is greater riparian bench indices in the Cache Slough region possibly as a result of greater sea level under the No Project Alternative. The IOS life cycle model suggested the potential for appreciably greater (21%) winter-run Chinook salmon female escapement under the No Project Alternative relative to existing conditions, reflecting generally greater through-Delta survival under the No Project Alternative. Application of the salvage-density method suggested that entrainment loss under the No Project Alternative generally would be similar to, slightly higher than, or slightly lower than existing conditions (Tables 12-45 and 12-46); as discussed for the project alternatives, existing conditions and the No Project Alternative would have the same regulations (e.g., California Department of Fish and Wildlife [2020a] ITP) limiting entrainment loss of winter-run Chinook salmon. DSM2 simulations suggest mean September–June water temperature under the No Project Alternative would be 0.2–1.5°C greater than existing conditions (Table 12-47), although mean temperature during the main winter-spring juvenile outmigration months (December–April) would remain below the high-mortality threshold of 20°C found by Nobriga et al. (2021). These differences reflect differences in climate assumptions for 2040 (No Project Alternative) compared to 2020 (existing conditions), as described in more detail in Appendix 5A, Section B, Attachment 4, *Climate Change Development for Delta Conveyance Project*.

Table 12-44. Probability of Juvenile Chinook Salmon Through-Delta Survival, Averaged by Month and Water Year Type, Based on Perry et al. (2018), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
September		
Wet	0.37	0.34 (-7%)
Above normal	0.36	0.33 (-9%)
Below normal	0.31	0.28 (-10%)
Dry	0.27	0.26 (-3%)
Critically dry	0.26	0.25 (-4%)
October		
Wet	0.37	0.32 (-13%)
Above normal	0.34	0.30 (-11%)
Below normal	0.31	0.33 (4%)
Dry	0.34	0.33 (-2%)
Critically dry	0.32	0.32 (0%)
November		
Wet	0.40	0.38 (-4%)
Above normal	0.38	0.36 (-3%)
Below normal	0.37	0.38 (3%)
Dry	0.33	0.33 (0%)
Critically dry	0.31	0.30 (-3%)
December		
Wet	0.47	0.47 (0%)
Above normal	0.46	0.47 (2%)
Below normal	0.48	0.49 (2%)
Dry	0.42	0.42 (1%)
Critically dry	0.38	0.40 (5%)
January		
Wet	0.61	0.62 (1%)
Above normal	0.58	0.59 (2%)
Below normal	0.48	0.49 (2%)
Dry	0.43	0.44 (2%)
Critically dry	0.42	0.43 (2%)
February		
Wet	0.64	0.64 (1%)
Above normal	0.60	0.60 (0%)
Below normal	0.51	0.52 (2%)
Dry	0.50	0.51 (2%)
Critically dry	0.44	0.45 (3%)

Water Year Type	EC	NPA
March		
Wet	0.62	0.62 (1%)
Above normal	0.59	0.59 (1%)
Below normal	0.50	0.51 (1%)
Dry	0.48	0.49 (3%)
Critically dry	0.42	0.43 (2%)
April		
Wet	0.57	0.56 (-2%)
Above normal	0.50	0.50 (0%)
Below normal	0.44	0.46 (5%)
Dry	0.41	0.44 (6%)
Critically dry	0.38	0.40 (4%)
May		
Wet	0.55	0.49 (-10%)
Above normal	0.50	0.46 (-7%)
Below normal	0.44	0.43 (-2%)
Dry	0.41	0.40 (-2%)
Critically dry	0.37	0.37 (-1%)
June		
Wet	0.43	0.34 (-20%)
Above normal	0.39	0.34 (-13%)
Below normal	0.33	0.33 (0%)
Dry	0.33	0.32 (-2%)
Critically dry	0.29	0.30 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The main period of juvenile winter-run Chinook salmon occurrence in the Delta is December–April. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions.

Table 12-45. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	2,217	2,377 (7%)
Above normal	N/A	(11%)
Below normal	1,519	1,623 (7%)
Dry	1,011	961 (-5%)
Critically dry	890	861 (-3%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-46. Entrainment Loss of Juvenile Winter-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	228	219 (-4%)
Above normal	N/A	(-6%)
Below normal	526	464 (-12%)
Dry	304	269 (-12%)
Critically dry	82	73 (-12%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-47. Mean Water Temperature (degrees Celsius) by Water Year Type and Month from DSM2-QUAL Modeling, Comparing No Project Alternative to Existing Conditions

		Immediately Downstream of Intake C		Sacramento River at Rio Vista		San Joaquin River at Jersey Point	
Water Year Type	Month	EC	NPA	EC	NPA	EC	NPA
Wet	Jan	9.4	10.1 (0.7)	9.3	10.1 (0.8)	8.9	9.9 (1.0)
Wet	Feb	10.8	11.5 (0.7)	10.9	11.6 (0.8)	10.9	11.9 (0.9)
Wet	Mar	12.6	13.1 (0.6)	12.8	13.4 (0.6)	13.1	13.9 (0.8)
Wet	Apr	14.7	15.2 (0.4)	14.7	15.3 (0.6)	14.8	15.6 (0.8)
Wet	May	17.7	18.0 (0.3)	17.4	18.0 (0.5)	17.2	18.0 (0.8)
Wet	Jun	19.5	19.7 (0.2)	19.1	19.7 (0.6)	18.9	19.8 (0.9)
Wet	Jul	20.9	21.1 (0.2)	20.8	21.4 (0.7)	20.6	21.5 (0.9)
Wet	Aug	20.7	21.1 (0.4)	20.5	21.6 (1.1)	20.5	21.9 (1.4)
Wet	Sep	19.6	20.1 (0.5)	19.2	20.3 (1.1)	19.0	20.4 (1.5)
Wet	Oct	16.5	17.1 (0.6)	16.1	17.2 (1.1)	16.0	17.3 (1.3)
Wet	Nov	12.7	13.3 (0.7)	12.8	13.8 (1.0)	13.1	14.3 (1.2)
Wet	Dec	10.0	10.8 (0.8)	9.8	10.8 (1.0)	9.8	11.0 (1.2)
Above normal	Jan	9.4	10.1 (0.7)	9.1	10.0 (0.8)	8.7	9.8 (1.1)
Above normal	Feb	10.6	11.3 (0.8)	10.6	11.5 (0.9)	10.5	11.5 (1.0)
Above normal	Mar	12.8	13.4 (0.6)	13.1	13.8 (0.7)	13.4	14.2 (0.8)
Above normal	Apr	15.0	15.4 (0.4)	14.9	15.5 (0.6)	14.8	15.6 (0.8)
Above normal	May	17.8	18.0 (0.2)	17.4	17.9 (0.6)	17.0	17.9 (0.8)
Above normal	Jun	19.6	19.8 (0.2)	19.1	19.7 (0.6)	18.8	19.7 (0.9)

		Immediately Downstream of Intake C		Sacramento River at Rio Vista		San Joaquin River at Jersey Point	
Water Year Type	Month	EC	NPA	EC	NPA	EC	NPA
Above normal	Jul	21.2	21.4 (0.2)	21.2	21.9 (0.7)	21.0	22.0 (0.9)
Above normal	Aug	20.7	21.0 (0.3)	20.5	21.6 (1.1)	20.5	21.9 (1.4)
Above normal	Sep	19.6	20.0 (0.4)	19.2	20.2 (1.0)	18.9	20.3 (1.4)
Above normal	Oct	16.8	17.3 (0.5)	16.6	17.8 (1.2)	16.7	18.0 (1.4)
Above normal	Nov	12.1	12.8 (0.7)	12.3	13.4 (1.1)	12.7	14.0 (1.3)
Above normal	Dec	9.4	10.1 (0.8)	9.0	10.0 (1.0)	8.9	10.2 (1.3)
Below normal	Jan	8.7	9.2 (0.6)	8.1	9.0 (0.8)	7.6	8.7 (1.1)
Below normal	Feb	10.3	10.9 (0.6)	10.2	10.9 (0.8)	9.7	10.7 (1.0)
Below normal	Mar	12.5	13.0 (0.5)	12.7	13.3 (0.7)	12.8	13.6 (0.8)
Below normal	Apr	15.1	15.5 (0.4)	14.8	15.5 (0.7)	14.6	15.5 (0.8)
Below normal	May	17.3	17.6 (0.3)	16.6	17.3 (0.7)	16.3	17.2 (0.9)
Below normal	Jun	19.7	20.0 (0.3)	19.2	20.0 (0.8)	18.9	19.9 (1.0)
Below normal	Jul	21.0	21.1 (0.1)	20.9	21.7 (0.8)	20.8	21.8 (1.0)
Below normal	Aug	20.5	20.8 (0.2)	20.3	21.3 (1.1)	20.1	21.5 (1.4)
Below normal	Sep	19.3	19.7 (0.3)	19.0	20.2 (1.2)	18.9	20.3 (1.5)
Below normal	Oct	16.6	17.2 (0.6)	16.3	17.5 (1.2)	16.3	17.7 (1.4)
Below normal	Nov	12.4	13.0 (0.6)	12.6	13.6 (1.0)	12.9	14.1 (1.2)
Below normal	Dec	9.2	9.9 (0.7)	8.9	9.9 (1.0)	8.9	10.1 (1.2)
Dry	Jan	8.4	9.0 (0.6)	7.6	8.5 (0.9)	7.0	8.2 (1.2)
Dry	Feb	10.4	11.0 (0.6)	10.2	11.0 (0.8)	9.8	10.8 (1.0)
Dry	Mar	12.7	13.2 (0.6)	12.9	13.6 (0.7)	13.0	13.8 (0.8)
Dry	Apr	15.0	15.4 (0.4)	14.8	15.5 (0.7)	14.8	15.7 (0.9)
Dry	May	17.3	17.6 (0.3)	16.6	17.3 (0.7)	16.3	17.2 (0.9)
Dry	Jun	19.7	19.9 (0.2)	19.1	19.9 (0.7)	18.9	19.8 (0.9)
Dry	Jul	20.7	20.7 (0.0)	20.4	21.1 (0.7)	20.3	21.2 (1.0)
Dry	Aug	20.3	20.5 (0.3)	19.9	21.2 (1.2)	19.9	21.3 (1.4)
Dry	Sep	19.1	19.4 (0.4)	18.7	19.9 (1.3)	18.6	20.1 (1.5)
Dry	Oct	16.2	16.7 (0.5)	15.8	16.9 (1.1)	15.8	17.1 (1.3)
Dry	Nov	12.2	12.8 (0.6)	12.4	13.5 (1.0)	12.8	14.0 (1.2)
Dry	Dec	9.2	9.9 (0.7)	8.8	9.9 (1.1)	8.9	10.2 (1.3)
Critically dry	Jan	8.7	9.3 (0.6)	8.1	8.9 (0.9)	7.5	8.6 (1.2)
Critically dry	Feb	10.8	11.3 (0.5)	10.7	11.4 (0.8)	10.2	11.2 (1.0)
Critically dry	Mar	13.1	13.5 (0.4)	13.5	14.1 (0.7)	13.6	14.4 (0.8)
Critically dry	Apr	14.9	15.3 (0.4)	14.5	15.3 (0.7)	14.5	15.4 (0.9)
Critically dry	May	17.1	17.4 (0.2)	16.5	17.3 (0.8)	16.3	17.2 (1.0)
Critically dry	Jun	19.3	19.6 (0.3)	18.8	19.6 (0.8)	18.6	19.6 (1.0)
Critically dry	Jul	21.0	21.2 (0.2)	21.2	22.2 (1.0)	21.2	22.2 (1.1)
Critically dry	Aug	20.3	20.8 (0.4)	20.5	21.9 (1.4)	20.6	22.0 (1.5)
Critically dry	Sep	19.2	19.6 (0.4)	19.2	20.5 (1.4)	19.2	20.7 (1.5)
Critically dry	Oct	16.7	17.0 (0.3)	16.6	17.7 (1.2)	16.6	18.0 (1.4)
Critically dry	Nov	12.6	13.2 (0.5)	12.9	14.0 (1.1)	13.2	14.4 (1.2)

		Immediately Downstream of Intake C		Sacramento River at Rio Vista		San Joaquin River at Jersey Point	
Water Year Type	Month	EC	NPA	EC	NPA	EC	NPA
Critically dry	Dec	9.0	9.6 (0.7)	8.6	9.7 (1.1)	8.7	10.1 (1.3)

Note: Values in parentheses indicate absolute differences of No Project Alternative compared to existing conditions.
NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-3: Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Spring-Run Chinook Salmon

Operations and Maintenance—All Project Alternatives

Impacts of the project alternatives on spring-run Chinook salmon generally would be similar to those previously discussed in Impact AQUA-2: *Effects of Operations and Maintenance of Water Conveyance Facilities on Sacramento River Winter-Run Chinook Salmon*, for winter-run Chinook salmon, with some differences caused by spring-run biology and ecology. Similar to winter-run Chinook salmon, there would be no risk of juvenile entrainment at the north Delta intakes based on spring-run size distribution (see National Marine Fisheries Service 2017:579). The timing of juvenile spring-run occurrence in the Delta is generally December–May (Table 12A-5 in Appendix 12A), with very few individuals occurring following May; however, yearlings may begin to occur in fall months (Attachment 12A.1) beginning October. As previously discussed for winter-run, operations of the NDD would result in periods of lower channel velocity (Table 12-28), increased flow reversals in the Sacramento River below Georgiana Slough (Table 12-29), and increased proportion of flow entering the interior Delta (Figure 12B-47 in Appendix 12B) compared to existing conditions. These hydrodynamic indicators of through-Delta survival impacts are reflected in the results of the Delta Passage Model (Table 12-48) and the modeling based on Perry et al. (2018; Table 12-30), which generally show mean survival up to 3%–4% lower under the project alternatives compared to existing conditions during the main migration period; differences during the fall (October/November) yearling migration period range from 6% less than existing conditions to 5% more than existing conditions (October in dry years under Alternatives 2a/4a; Table 12-30). Riparian bench rearing/holding habitat in the Sacramento River downstream of the NDD under the project alternatives would be around 5%–10% or more less than existing conditions during March–May in wetter water year types (Table 12-33).

Table 12-48. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.33	0.32 (-2%)	0.32 (-2%)	0.33 (-1%)	0.32 (-2%)	0.32 (-2%)
Above normal	0.26	0.26 (-2%)	0.26 (-2%)	0.26 (-2%)	0.26 (-2%)	0.26 (-2%)
Below normal	0.19	0.19 (-3%)	0.19 (-3%)	0.19 (-2%)	0.19 (-3%)	0.19 (-3%)
Dry	0.17	0.17 (-2%)	0.17 (-2%)	0.17 (-1%)	0.17 (-2%)	0.17 (-2%)
Critically dry	0.14	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)	0.14 (-1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.
Table only includes mean responses and does not consider model uncertainty.
Alt = alternative; EC = existing conditions.

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the project alternatives relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that spring-run are generally salvaged (Table 12-49 and Table 12-50).[36] As noted for winter-run, various regulatory requirements that are required under existing conditions would also apply to the alternatives; therefore, they are part of the baseline and also part of the No Project Alternative and are incorporated into all project alternatives to minimize south Delta entrainment effects on spring-run Chinook salmon.

Table 12-49. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	43,712	39,716 (-9%)	40,508 (-7%)	42,373 (-3%)	40,835 (-7%)	39,676 (-9%)
Above normal	N/A	(-12%)	(-6%)	(3%)	(-9%)	(-12%)
Below normal	3,256	3,080 (-5%)	3,085 (-5%)	3,212 (-1%)	3,115 (-4%)	3,079 (-5%)
Dry	3,120	3,121 (0%)	3,127 (0%)	3,079 (-1%)	3,090 (-1%)	3,121 (0%)
Critically dry	3,043	3,038 (0%)	3,005 (-1%)	3,031 (0%)	3,022 (-1%)	3,038 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-50. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	8,259	8,776 (6%)	8,649 (5%)	8,564 (4%)	8,656 (5%)	8,776 (6%)
Above normal	N/A	(8%)	(7%)	(4%)	(6%)	(8%)
Below normal	3,401	3,419 (1%)	3,414 (0%)	3,426 (1%)	3,448 (1%)	3,419 (1%)
Dry	3,152	3,156 (0%)	3,142 (0%)	3,179 (1%)	3,179 (1%)	3,156 (0%)
Critically dry	156	157 (1%)	152 (-2%)	161 (3%)	162 (4%)	157 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Spring-run Chinook salmon have been reintroduced to the San Joaquin River Basin, and there is evidence for through-Delta flow-survival effects on juvenile Chinook salmon following entry from the San Joaquin River basin (e.g., Buchanan and Skalski 2020), so through-Delta survival impacts on juveniles were analyzed with the Structured Decision Model San Joaquin River routing application

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[36] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-3 and 12B-4).

(Appendix 12B, Section 12B.9, *San Joaquin River Juvenile Chinook Salmon Through-Delta Survival (Structured Decision Model Routing Application)*). The results of this analysis indicated that changes in south Delta operations as a result of the project alternatives generally would not result in lower through-Delta survival relative to existing conditions, although there may be somewhat lower survival in dry years, but survival would be low under all scenarios (Table 12-51).

Table 12-51. Through-Delta Survival of Juvenile Spring-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.033	0.032 (0%)	0.032 (0%)	0.033 (0%)	0.033 (0%)	0.032 (0%)
Above normal	0.033	0.033 (0%)	0.033 (-1%)	0.033 (0%)	0.033 (0%)	0.033 (0%)
Below normal	0.028	0.028 (2%)	0.028 (2%)	0.028 (2%)	0.028 (2%)	0.028 (2%)
Dry	0.026	0.024 (-4%)	0.025 (-3%)	0.025 (0%)	0.024 (-4%)	0.024 (-5%)
Critically dry	0.017	0.017 (0%)	0.016 (-3%)	0.016 (-4%)	0.017 (0%)	0.017 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on spring-run Chinook salmon. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The operations of the north Delta intakes would have negative effects on spring-run Chinook in a generally similar manner to what was discussed for winter-run Chinook salmon. However, the main period of potential effects on young-of-the-year juvenile spring-run Chinook salmon is later in the winter-spring than for winter-run Chinook salmon, with the result that potential effects on spring-run young-of-the-year juveniles are somewhat less than for winter-run because of less use of the north Delta intakes in the spring (compare, for example, the results of the DPM; Tables 12-48 and 12-32) because the north Delta diversions are more limited in the spring. Recent research for two spring-run Chinook salmon populations in the Central Valley indicates that the majority of returning adults emigrated as yearlings (Cordoleani et al. 2021), which migrate beginning in fall and therefore have the potential to overlap periods of greater north Delta diversions with greater potential effects on through-Delta survival as shown by the Perry et al. (2018) modeling results. As a result, and although there is uncertainty in biological impacts because of the variability in flow-survival statistical relationships (see discussion for winter-run Chinook salmon), it is concluded that the operations and maintenance impact of the project alternatives would be significant for spring-run Chinook salmon. Compensatory mitigation to be implemented for the winter-run Chinook salmon significant impact discussed above in Impact AQUA-2 (i.e., Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* and CMP-26: *Channel Margin Habitat Restoration for Operations*

Impacts on Chinook Salmon Juveniles [Attachment 3F.1, Table 3F.1-3]) would also be applied to spring-run Chinook salmon to mitigate hydrodynamic effects such as flow reversals in the Sacramento River at Georgiana Slough (CMP-25) and effects from reduced inundation of riparian/wetland benches as a result of NDD operations (CMP-26). The impact would be less than significant with mitigation.

Mitigation Impacts

Compensatory Mitigation

Implementation of the Compensatory Mitigation Plan could result in impacts on spring-run Chinook salmon as analyzed in this chapter. As discussed for winter-run Chinook salmon, following completion of compensatory mitigation construction (tidal perennial habitat and channel margin habitat for operations impacts; see Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*), restored tidal habitat areas would have the potential for positive effects on spring-run Chinook salmon, for example by providing foraging habitat along marsh edges (Brown 2003) or a greater extent of inundated vegetated habitat for occupancy (Hellmair et al. 2018). Efficacy monitoring of performance standards would assess the degree to which positive effects are occurring and inform adjustment to sites as necessary to increase positive effects (Appendix 3F).

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on spring-run Chinook salmon during operation and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact spring-run Chinook salmon during operation and maintenance, and there would be no impact.

Overall, the impact on spring-run Chinook salmon during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less than significant with mitigation impact conclusion.

No Project Alternative

At 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. As discussed for winter-run Chinook salmon, climate change-related shifts would generally increase Sacramento River flows into the Delta under the No Project Alternative at 2040 relative to existing conditions during December–April, as indicated by CalSim modeling (Appendix 5A: Attachment 3, Figure B.3.5.1 and Table B.3.5.1). These differences could result in higher through-Delta survival (Table 12-44) and inundation of riparian benches under the No Project Alternative based on the mechanisms discussed above for the project alternatives and in the No Project Alternative analysis for winter-run Chinook salmon. As previously discussed for the project alternatives, spring-run also occur into May, when Sacramento River flows generally would be lower under the No Project Alternative compared to existing conditions as a result of climate change, thereby giving potentially lower through-Delta survival (Table 12-44) and bench inundation compared to existing conditions. Overall, however, the results of the Delta Passage Model gave water-year-type mean through-Delta survival of Chinook salmon smolts that were 1% to 11%

greater under the No Project Alternative than existing conditions. Application of the salvage-density method suggested that entrainment loss under the No Project Alternative could be similar, greater (SWP in above normal and below normal years), or lower (CVP) than existing conditions (Tables 12-52 and 12-53); as discussed for the project alternatives, existing conditions and the No Project Alternative would have the same regulations (e.g., California Department of Fish and Wildlife [2020a] ITP) limiting entrainment loss of spring-run Chinook salmon. As described for winter-run Chinook salmon, DSM2 simulations suggest mean September–June water temperature under the No Project Alternative would be 0.2–1.5°C greater than existing conditions (Table 12-47), although mean temperature during the main winter-spring juvenile outmigration months (December–April) would remain below the high-mortality threshold of 20°C found by Nobriga et al. (2021). These differences reflect differences in climate assumptions for 2040 (No Project Alternative) compared to 2020 (existing conditions), as described in more detail in Appendix 5A, Section B, Attachment 4, *Climate Change Development for Delta Conveyance Project*.

Table 12-52. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	43,712	42,266 (-3%)
Above normal	N/A	(23%)
Below normal	3,256	4,006 (23%)
Dry	3,120	3,047 (-2%)
Critically dry	3,043	2,815 (-7%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-53. Entrainment Loss of Juvenile Spring-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	8,259	6,720 (-19%)
Above normal	N/A	(-25%)
Below normal	3,401	2,170 (-36%)
Dry	3,152	2,068 (-34%)
Critically dry	156	112 (-28%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-4: Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Fall-Run/Late Fall–Run Chinook Salmon

Operations and Maintenance—All Project Alternatives

Impacts of the project alternatives on fall-run and late fall–run Chinook salmon generally would be similar in nature to those previously discussed in Impacts AQUA-2 for winter-run Chinook salmon and AQUA-3 for spring-run Chinook salmon, with some differences caused by fall-run and late fall–run biology and ecology. There may be a small risk of juvenile entrainment at the north Delta intake cylindrical fish screens based on fall-run and late fall–run size distribution (see National Marine Fisheries Service 2017:579), although cylindrical tee screens in the Columbia River have been shown to virtually eliminate entrainment risk (Coutant 20211), albeit under different configuration and generally greater flow than in the Delta (see also discussion for winter-run Chinook salmon). The timing of juvenile fall-run and late fall–run occurrence in the Delta is primarily November/December–June (Tables 12A-6 and 12A-7 in Appendix 12A). As previously discussed for winter- and spring-run, operations of the NDD would result in periods of lower channel velocity (Table 12-28), increased flow reversals in the Sacramento River below Georgiana Slough (Table 12-29), and increased proportion of flow entering the interior Delta (Figure 12B-47 in Appendix 12B) compared to existing conditions. These hydrodynamic indicators of through-Delta survival impacts are reflected in the results of the Delta Passage Model (Tables 12-54 and 12-55) and the modeling based on Perry et al. (2018; Table 12-30), which generally showed mean survival up to 3%–4% lower under the project alternatives compared to existing conditions, with the Perry et al. (2018) model also showing 8%–10% less through-Delta survival in June of above normal years (Table 12-30). Riparian bench rearing/holding habitat in the Sacramento River downstream of the NDD under the project alternatives would be less by around 5%–10% or more than existing conditions during December–February and March–May in wetter water year types (Table 12-33).

Table 12-54. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.28	0.27 (-2%)	0.27 (-2%)	0.27 (-2%)	0.27 (-2%)	0.27 (-2%)
Above normal	0.21	0.20 (-2%)	0.20 (-2%)	0.20 (-2%)	0.20 (-2%)	0.20 (-2%)
Below normal	0.17	0.17 (-1%)	0.17 (-2%)	0.17 (-1%)	0.17 (-1%)	0.17 (-1%)
Dry	0.15	0.15 (0%)	0.15 (0%)	0.15 (0%)	0.15 (0%)	0.15 (0%)
Critically dry	0.13	0.13 (0%)	0.13 (0%)	0.13 (0%)	0.13 (0%)	0.13 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-55. Through-Delta Survival of Juvenile Late Fall–Run Chinook Salmon, Averaged by Water Year Type, Based on the Delta Passage Model

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.25	0.25 (-1%)	0.24 (-2%)	0.25 (-1%)	0.25 (-1%)	0.25 (-1%)
Above normal	0.20	0.20 (-2%)	0.20 (-3%)	0.20 (-2%)	0.20 (-2%)	0.20 (-3%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below normal	0.16	0.16 (-3%)	0.16 (-3%)	0.16 (-2%)	0.16 (-3%)	0.16 (-3%)
Dry	0.14	0.14 (-2%)	0.14 (-2%)	0.14 (-2%)	0.14 (-2%)	0.14 (-2%)
Critically dry	0.13	0.13 (-1%)	0.13 (-2%)	0.13 (-1%)	0.13 (-1%)	0.13 (-1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the project alternatives relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that fall- and late fall–run are generally salvaged (Tables 12-56, 12-57, 12-58, and 12-59),[37] indicating that entrainment risk would not be greater under the project alternatives compared to existing conditions. As noted for winter-run and spring-run, various regulatory requirements would be implemented under existing conditions and therefore are part of the baseline and also part of the No Project Alternative and are incorporated into all project alternatives to minimize south Delta entrainment effects on listed Chinook salmon. Although focused on listed Chinook salmon, the temporal overlap with fall- and late fall–run Chinook would result in ancillary protection for the unlisted Chinook salmon.

Table 12-56. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	21,628	20,478 (-5%)	21,224 (-2%)	21,382 (-1%)	20,857 (-4%)	20,462 (-5%)
Above normal	N/A	(-8%)	(0%)	(3%)	(-3%)	(-8%)
Below normal	2,933	2,757 (-6%)	2,768 (-6%)	2,847 (-3%)	2,763 (-6%)	2,757 (-6%)
Dry	3,952	3,910 (-1%)	3,940 (0%)	3,771 (-5%)	3,775 (-4%)	3,910 (-1%)
Critically dry	3,747	3,669 (-2%)	3,670 (-2%)	3,681 (-2%)	3,668 (-2%)	3,671 (-2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-57. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	9,143	9,616 (5%)	9,359 (2%)	9,398 (3%)	9,504 (4%)	9,614 (5%)
Above normal	N/A	(7%)	(3%)	(2%)	(4%)	(7%)

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[37] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-5, 12B-6, 12B-7, and 12B-8).

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below normal	2,884	2,878 (0%)	2,871 (0%)	2,901 (1%)	2,920 (1%)	2,878 (0%)
Dry	4,160	4,147 (0%)	4,133 (-1%)	4,190 (1%)	4,200 (1%)	4,147 (0%)
Critically dry	178	179 (0%)	176 (-1%)	182 (2%)	181 (2%)	179 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-58. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	1,361	1,319 (-3%)	1,312 (-4%)	1,322 (-3%)	1,319 (-3%)	1,316 (-3%)
Above normal	N/A	(-6%)	(-6%)	(-6%)	(-7%)	(-6%)
Below normal	387	376 (-3%)	380 (-2%)	378 (-2%)	378 (-2%)	376 (-3%)
Dry	1,053	953 (-10%)	997 (-5%)	935 (-11%)	928 (-12%)	953 (-10%)
Critically dry	708	663 (-6%)	694 (-2%)	696 (-2%)	670 (-5%)	667 (-6%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-59. Entrainment Loss of Juvenile Late Fall–Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	262	261 (0%)	262 (0%)	260 (-1%)	262 (0%)	261 (0%)
Above normal	N/A	(0%)	(-1%)	(-1%)	(-1%)	(0%)
Below normal	67	69 (3%)	69 (2%)	70 (4%)	69 (3%)	69 (3%)
Dry	93	87 (-7%)	84 (-10%)	90 (-3%)	90 (-4%)	86 (-7%)
Critically dry	30	30 (1%)	29 (-2%)	28 (-5%)	29 (-2%)	30 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Fall-run Chinook salmon occur in the San Joaquin River Basin, with evidence for flow-survival effects when passing through the Delta (e.g., Buchanan and Skalski 2020), so through-Delta survival impacts on juveniles were analyzed with the Structured Decision Model San Joaquin River routing application (Appendix 12B, Section 12B.9). The results of this analysis indicated that south Delta operations under the project alternatives generally would give similar through-Delta survival as existing conditions (Table 12-60).

Table 12-60. Through-Delta Survival of Juvenile Fall-Run Chinook Salmon from the San Joaquin River Basin, Averaged by Water Year Type, Based on the Structured Decision Model Routing Application

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.033	0.033 (0%)	0.033 (0%)	0.033 (0%)	0.033 (0%)	0.033 (0%)
Above normal	0.033	0.033 (0%)	0.033 (0%)	0.033 (0%)	0.033 (0%)	0.033 (0%)
Below normal	0.029	0.030 (1%)	0.030 (1%)	0.030 (1%)	0.030 (1%)	0.030 (1%)
Dry	0.027	0.026 (-4%)	0.027 (-3%)	0.027 (-2%)	0.026 (-4%)	0.026 (-4%)
Critically dry	0.017	0.017 (0%)	0.016 (-1%)	0.016 (-1%)	0.017 (0%)	0.017 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

The straying rate of adult fall-run Chinook salmon to the San Joaquin River Basin could be affected by changes in south Delta water operations under the project alternatives relative to existing conditions. As described further in Appendix 12B, Section 12B.10, *San Joaquin River Adult Fall-Run Chinook Salmon Straying Analysis Based on Marston et al. (2012)*, statistical equations developed by Marston et al. (2012) were used to estimate straying rate as a function of October/November San Joaquin River flows and south Delta exports. This analysis suggested that there is the potential for mean straying rate to be around 0% to approximately 13% less under the project alternatives compared to existing conditions (Table 12-61), albeit with appreciable uncertainty because it is unclear whether San Joaquin River pulse flows, south Delta exports, or both are the main driver of straying (Marston et al. 2012).

Table 12-61. Straying Rate (percent) of San Joaquin River Basin Fall-Run Chinook Salmon to the Sacramento River Basin, Averaged by Water Year Type, Based on Marston et al. (2012)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	22%	20% (-11%)	19% (-13%)	21% (-5%)	21% (-7%)	20% (-11%)
Above normal	23%	22% (-5%)	22% (-5%)	22% (-3%)	22% (-4%)	22% (-5%)
Below normal	17%	16% (-9%)	15% (-12%)	16% (-10%)	16% (-8%)	16% (-9%)
Dry	19%	19% (-1%)	19% (0%)	19% (-1%)	19% (-1%)	19% (-1%)
Critically dry	11%	11% (-5%)	11% (-4%)	11% (-8%)	11% (-6%)	11% (-6%)

Notes: Percentage values in parentheses indicate relative differences of alternatives compared to existing conditions (relative differences are larger than absolute differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

In addition to fall-run Chinook salmon from the Sacramento River and San Joaquin River Basins, the project alternatives would have the potential to affect fall-run from the Mokelumne River Basin. For juvenile outmigration, the main effect of concern is related to entrainment risk caused by March–

June south Delta exports (Workman 2018:14), although historical population-level losses were estimated to be small by DWR (2020a:4-229–4-230). During March–June, the project alternatives generally would have similar or somewhat less south Delta exports relative to existing conditions (Tables 12-62, 12-63, 12-64, 12-65) and therefore south Delta entrainment risk would not be noticeably different under the project alternatives than existing conditions. Indicators of broader hydrodynamic effects of water operations relevant to Mokelumne River fall-run juveniles also indicated limited differences between the project alternatives, including the proportion of flow entering the south Delta from the mainstem San Joaquin River at mouth of Old River (Appendix 12B, Figure 12B-52), Fisherman's Cut (Appendix 12B, Figure 12B-53), False River (Appendix 12B, Figure 12B-54), and Jersey Point (Appendix 12B, Figure 12B-55).

Table 12-62. Mean South Delta Exports (cubic feet per second) by Water Year Type, March

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7,664	7,204 (-6%)	7,145 (-7%)	7,398 (-3%)	7,266 (-5%)	7,187 (-6%)
Above normal	6,203	6,192 (0%)	6,195 (0%)	6,204 (0%)	6,198 (0%)	6,192 (0%)
Below normal	5,433	5,427 (0%)	5,431 (0%)	5,431 (0%)	5,429 (0%)	5,427 (0%)
Dry	4,713	4,716 (0%)	4,718 (0%)	4,714 (0%)	4,715 (0%)	4,715 (0%)
Critically dry	4,294	4,175 (-3%)	4,155 (-3%)	4,216 (-2%)	4,207 (-2%)	4,183 (-3%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-63. Mean South Delta Exports (cubic feet per second) by Water Year Type, April

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7,004	6,545 (-7%)	6,516 (-7%)	6,676 (-5%)	6,583 (-6%)	6,544 (-7%)
Above normal	4,675	4,528 (-3%)	4,583 (-2%)	4,625 (-1%)	4,526 (-3%)	4,528 (-3%)
Below normal	3,608	3,615 (0%)	3,632 (1%)	3,614 (0%)	3,616 (0%)	3,615 (0%)
Dry	3,053	3,070 (1%)	3,063 (0%)	3,062 (0%)	3,070 (1%)	3,070 (1%)
Critically dry	2,125	2,162 (2%)	2,131 (0%)	2,197 (3%)	2,192 (3%)	2,162 (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-64. Mean South Delta Exports (cubic feet per second) by Water Year Type, May

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	6,643	6,765 (2%)	6,759 (2%)	6,848 (3%)	6,777 (2%)	6,762 (2%)
Above normal	5,049	5,110 (1%)	5,164 (2%)	5,148 (2%)	5,025 (0%)	5,110 (1%)
Below normal	3,646	3,781 (4%)	3,809 (4%)	3,750 (3%)	3,782 (4%)	3,781 (4%)
Dry	3,254	3,240 (0%)	3,247 (0%)	3,228 (-1%)	3,257 (0%)	3,240 (0%)
Critically dry	2,653	2,615 (-1%)	2,616 (-1%)	2,622 (-1%)	2,613 (-2%)	2,614 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-65. Mean South Delta Exports (cubic feet per second) by Water Year Type, June

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	8,095	8,095 (0%)	8,101 (0%)	8,089 (0%)	8,095 (0%)	8,095 (0%)
Above normal	6,783	6,779 (0%)	6,784 (0%)	6,785 (0%)	6,790 (0%)	6,779 (0%)
Below normal	5,683	5,711 (0%)	5,688 (0%)	5,700 (0%)	5,707 (0%)	5,711 (0%)
Dry	5,257	5,238 (0%)	5,204 (-1%)	5,265 (0%)	5,240 (0%)	5,238 (0%)
Critically dry	2,091	2,113 (1%)	2,067 (-1%)	2,145 (3%)	2,205 (5%)	2,114 (1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Potential effects related to straying of adult Mokelumne River fall-run Chinook salmon to the Sacramento River when the DCC is open during October and November (Setka 2018) were also evaluated. As described in Chapter 3, the DCC, as with all CVP facilities, would continue to be operated consistent with applicable laws and contractual obligations. The CalSim modeling results for the number of days that the DCC is open showed that the project alternatives had similar or lower mean number of days of DCC open compared to existing conditions for wet, above normal, and below normal years, with 2–6 more days of DCC opening under the project alternatives in October (Tables 12-66 and 12-67). These results reflect modeling assumptions related to changes in the frequency of closure of the DCC gates to conserve storage in Shasta Reservoir when the D-1641 flow standard at Rio Vista is controlling operations. The frequency of Rio Vista controlling is influenced by NDD operations and also by changes in storage releases for SWP exports in the fall. In general, under the project alternatives, the DCC is open less than under existing conditions because diversions at the NDD reduce Delta inflow and hence cause the Rio Vista standard to control more frequently, which leads to more DCC gate closures to increase flow in the Sacramento River. The exception to this is in October of dry and critically dry years, when greater releases for exports by the SWP sometimes cause higher flow at Rio Vista, and hence Rio Vista controls less frequently, which in turn reduces the frequency of DCC gate closures. These increased releases for exports are generally due to limitations in the operations logic in CalSim 3, which lead to increased SWP water supply allocations in the project alternatives that are sometimes higher than necessary. Therefore, the increases in DCC days open in October of dry and critically dry years are unlikely to occur in a real operation. The modeling results do not account for DCC closure in association with Mokelumne River pulse flows, as required under the ROC LTO proposed action (Bureau of Reclamation 2019:3-37), and which is part of existing conditions and the project alternatives, with implementation as illustrated in October 2021 (Salmon Monitoring Team 2021).

Table 12-66. Mean Number of Days with Delta Cross Channel Open by Water Year Type, October

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	16	13 (-20%)	12 (-27%)	13 (-20%)	13 (-20%)	13 (-20%)
Above normal	25	23 (-10%)	23 (-10%)	23 (-10%)	23 (-10%)	23 (-10%)
Below normal	17	15 (-10%)	15 (-11%)	15 (-10%)	15 (-10%)	15 (-9%)
Dry	18	22 (19%)	24 (31%)	22 (18%)	22 (18%)	22 (18%)
Critically dry	9	11 (25%)	11 (25%)	11 (25%)	11 (25%)	11 (25%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-67. Mean Number of Days with Delta Cross Channel Open by Water Year Type, November

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	13	11 (-12%)	11 (-13%)	11 (-12%)	11 (-12%)	11 (-12%)
Above normal	15	12 (-20%)	12 (-18%)	14 (-5%)	10 (-30%)	12 (-20%)
Below normal	17	16 (-5%)	15 (-11%)	16 (-5%)	16 (-5%)	16 (-5%)
Dry	16	12 (-24%)	12 (-24%)	14 (-15%)	12 (-24%)	12 (-24%)
Critically dry	14	13 (-12%)	13 (-12%)	11 (-22%)	11 (-20%)	13 (-12%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on fall-run/late fall–run Chinook salmon. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The operations of the north Delta intakes would have negative effects on fall- and late fall-run Chinook in a generally similar manner to what was discussed for winter- and spring-run Chinook salmon. The main period of potential effects on the numerically dominant Sacramento River basin fall-run Chinook salmon is later in the winter-spring than for winter-run and spring-run Chinook salmon, when north Delta diversions are more limited and therefore potential effects are more limited (compare, for example, the results of the DPM; Tables 12-32, 12-48, and 12-54). Through-Delta migration survival effects on late fall-run Chinook salmon are more similar in magnitude to winter-run (e.g., compare Table 12-55 to Table 12-32). Effects on San Joaquin and Mokelumne fall-run would not be negative relative to existing conditions. As a result, although there is uncertainty in biological impacts because of the variability in flow-survival statistical relationships (see discussion for winter-run Chinook salmon), it is concluded that the impact of the project alternatives on fall-run Chinook salmon would be less than significant. Compensatory mitigation to be implemented for the winter-run Chinook salmon significant impact discussed above in Impact AQUA-2 (i.e., Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles* and CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles* [Attachment 3F.1, Table 3F.1-3]) would further reduce the already less-than-significant negative hydrodynamic effects such as flow reversals in the Sacramento River at Georgiana Slough (CMP-25) and effects from reduced inundation of riparian/wetland benches as a result of NDD operations (CMP-26).

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on fall-/late fall-run Chinook salmon as analyzed in this chapter. As discussed for winter- and spring-run Chinook salmon, following completion of compensatory mitigation construction (tidal perennial habitat and channel margin habitat for operations impacts; see Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*), restored tidal habitat areas would have the potential for positive effects on fall- and late fall–run Chinook salmon, for example by providing foraging habitat along marsh edges (Brown 2003) or more inundated vegetated habitat for occupancy (Hellmair et al. 2018). Efficacy monitoring of performance standards would assess the degree to which positive effects are occurring and inform adjustment to sites as necessary to increase positive effects (Appendix 3F).

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on fall-run/late fall–run Chinook salmon during operation and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact fall-run/late fall–run Chinook salmon during operation and maintenance, and there would be no impact.

Overall, the impact on fall-run/late fall–run Chinook salmon during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion. Any mitigation measures applied to fall-run/late fall–run Chinook salmon will be used to further reduce the already less-than-significant impacts.

No Project Alternative

At 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. As discussed for winter-run (Impact AQUA-2) and spring-run (Impact AQUA-3) Chinook salmon, climate change-related shifts would generally increase Sacramento River flows into the Delta under the No Project Alternative at 2040 relative to existing conditions during December–April, as indicated by CalSim modeling (Appendix 5A, Attachment 3, Figure B.3.5.1 and Table B.3.5.1). These differences could result in higher through-Delta survival (Table 12-44) and inundation of riparian benches under the No Project Alternative for fall- and late-fall run Chinook salmon, based on the mechanisms discussed above for the project alternatives. As previously discussed for the project alternatives, fall-/late fall-run also occur in November and May/June, when Sacramento River flows would be lower under the No Project Alternative compared to existing conditions, thereby giving potentially lower through-Delta survival (Table 12-44) and bench inundation compared to existing conditions. Application of the salvage-density method suggested that entrainment loss under the No Project Alternative could be similar, lower (CVP), or greater (SWP in above normal and below normal years) than existing conditions (Tables 12-68, 12-69, 12-70, and 12-71); as discussed for the project alternatives, existing conditions and the No Project Alternative would have the same regulations (e.g., California Department of Fish and Wildlife [2020a] ITP) limiting entrainment loss of listed Chinook salmon, which would provide ancillary protection for fall- and late-fall run Chinook salmon. As described for winter- and spring-run Chinook salmon, DSM2 simulations suggest mean September–June water temperature under the No Project Alternative would be 0.2–1.5°C greater than existing conditions (Table 12-47). Mean temperature in June, at the end of the outmigration season, would be closer to the high-mortality threshold of 20°C found by Nobriga et al. (2021) under the No Project Alternative compared to existing conditions. These differences reflect differences in climate assumptions for 2040 (No Project Alternative) compared to 2020 (existing conditions), as described in more detail in Appendix 5A, Section B, Attachment 4, *Climate Change Development for Delta Conveyance Project*.

Table 12-68. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	21,628	22,874 (6%)
Above normal	N/A	(40%)
Below normal	2,933	3,856 (31%)
Dry	3,952	3,799 (-4%)
Critically dry	3,747	3,328 (-11%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-69. Entrainment Loss of Juvenile Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	9,143	7,183 (-21%)
Above normal	N/A	(-34%)
Below normal	2,884	1,461 (-49%)
Dry	4,160	2,341 (-44%)
Critically dry	178	121 (-32%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-70. Entrainment Loss of Juvenile Late Fall-Run Chinook Salmon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	1,361	1,474 (8%)
Above normal	N/A	(-6%)
Below normal	387	384 (-1%)
Dry	1,053	1,062 (1%)
Critically dry	708	681 (-4%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-71. Entrainment Loss of Juvenile Late Fall-Run Chinook Salmon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	262	266 (1%)
Above normal	N/A	(0%)
Below normal	67	67 (0%)
Dry	93	87 (-7%)
Critically dry	30	28 (-4%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Differences in south Delta operations under the No Project Alternative could give less straying of San Joaquin River basin fall-run Chinook salmon adults compared to existing conditions, based on application of the method based on Marston et al. (2012; Table 12-72). Generally similar or higher spring San Joaquin River at Vernalis flows under the No Project Alternative (as indicated by CalSim modeling; Appendix 5A, Attachment 3, Figure B.3.16.1 and Table B.3.16.1) indicate that through-Delta survival of juvenile fall-run from the San Joaquin River basin would not be lower than existing conditions. Relevant to Mokelumne River fall-run Chinook salmon juveniles, the CalSim modeling indicated that south Delta exports during March–June would be similar or would not be greater under the No Project Alternative compared to existing conditions (Tables 12-73, 12-74, 12-75, 12-76), therefore entrainment risk would not be greater. For Mokelumne River adult Chinook salmon and as noted for the analysis of the project alternatives, the DCC would continue to be operated consistent with applicable laws and contractual obligations. CalSim modeling of the No Project Alternative suggested that in general the number of days with DCC open would be similar, although there were larger modeled differences between mean number of days open in above normal and below normal years in October (Tables 12-77 and 12-78).

Table 12-72. Straying Rate (Percent) of San Joaquin River Basin Fall-Run Chinook Salmon to the Sacramento River Basin, Averaged by Water Year Type, Based on Marston et al. (2012), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	22%	19% (-13%)
Above normal	23%	18% (-19%)
Below normal	17%	16% (-9%)
Dry	19%	15% (-23%)
Critically dry	11%	8% (-26%)

Notes: Percentage values in parentheses indicate relative differences of No Project Alternative compared to existing conditions (relative differences are larger than absolute differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-73. Mean South Delta Exports (cubic feet per second) by Water Year Type, March, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7,664	7,869 (3%)
Above normal	6,203	6,355 (2%)
Below normal	5,433	5,233 (-4%)
Dry	4,713	3,839 (-19%)
Critically dry	4,294	3,817 (-11%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-74. Mean South Delta Exports (cubic feet per second) by Water Year Type, April, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7,004	6,512 (-7%)
Above normal	4,675	4,596 (-2%)
Below normal	3,608	3,429 (-5%)
Dry	3,053	2,587 (-15%)
Critically dry	2,125	1,656 (-22%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-75. Mean South Delta Exports (cubic feet per second) by Water Year Type, May, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	6,643	5,748 (-13%)
Above normal	5,049	4,456 (-12%)
Below normal	3,646	2,761 (-24%)
Dry	3,254	1,690 (-48%)
Critically dry	2,653	1,845 (-30%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-76. Mean South Delta Exports (cubic feet per second) by Water Year Type, June, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	8,095	7,244 (-11%)
Above normal	6,783	6,100 (-10%)
Below normal	5,683	5,496 (-3%)
Dry	5,257	4,298 (-18%)
Critically dry	2,091	1,771 (-15%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-77. Mean Number of Days with Delta Cross Channel Open by Water Year Type, October, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	16	18 (11%)
Above normal	25	21 (-16%)
Below normal	17	22 (31%)
Dry	18	19 (2%)
Critically dry	9	8 (-6%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-78. Mean Number of Days with Delta Cross Channel Open by Water Year Type, November, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	13	13 (4%)

Water Year Type	EC	NPA
Above normal	15	17 (13%)
Below normal	17	18 (3%)
Dry	16	18 (10%)
Critically dry	14	13 (-12%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-5: Effects of Operations and Maintenance of Water Conveyance Facilities on Central Valley Steelhead

Operations and Maintenance—All Project Alternatives

Impacts of the project alternatives on steelhead generally would be similar in nature to those previously discussed in Impacts AQUA-2, AQUA-3, and AQUA-4 for winter-, spring-, and fall-/late fall–run Chinook salmon. There would be no risk of juvenile entrainment at the north Delta intakes based on steelhead size distribution (see National Marine Fisheries Service 2017:579), although cylindrical tee screens similar to those proposed for the north Delta intakes have been shown to virtually eliminate entrainment risk (Coutant 20211), albeit with the caveats previously described for winter-run Chinook salmon.

As described in Appendix 12A, the main juvenile steelhead migration period in the Delta is February–May. Through-Delta flow-survival relationships analogous to those for juvenile Chinook salmon (e.g., Perry et al. 2018; see also discussion for winter-run Chinook salmon) have not been established for migrating juvenile steelhead from the Sacramento River Basin, although the species does show analogous route-specific survival differences (Singer et al. 2013) and there are flow-survival relationships for steelhead from the San Joaquin River Basin emigrating through the Delta (Buchanan et al. 2021). Assuming that flow may affect survival in a somewhat similar manner to juvenile Chinook salmon, which is uncertain, the modeling based on the through-Delta survival function formulated by Perry et al. (2018) suggests that mean through-Delta survival of juvenile steelhead under the project alternatives may be similar or somewhat less (up to 4%) (Table 12-30). This reflects hydrodynamic changes such as channel velocity (Table 12-28) and the proportion of time with reversing flow in the Sacramento River below Georgiana Slough (Table 12-29).

The results from application of the salvage-density method illustrated that south Delta exports generally would be similar or slightly lower under the project alternatives relative to existing conditions at the SWP Banks and CVP Jones south Delta export facilities during the time period that steelhead are generally salvaged (Tables 12-79 and 12-80).[38] As noted for winter-run and spring-run, various regulatory requirements under existing conditions would also apply to the project alternatives, and therefore are part of the baseline and also part of the No Project Alternative and are incorporated into all project alternatives to minimize south Delta entrainment effects on steelhead.

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[38] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-9 and 12B-10).

Table 12-79. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	5,216	4,670 (-10%)	4,739 (-9%)	4,872 (-7%)	4,752 (-9%)	4,664 (-11%)
Above normal	N/A	(-6%)	(0%)	(3%)	(-3%)	(-6%)
Below normal	3,251	2,986 (-8%)	3,120 (-4%)	3,209 (-1%)	3,096 (-5%)	2,986 (-8%)
Dry	2,327	2,220 (-5%)	2,211 (-5%)	2,288 (-2%)	2,215 (-5%)	2,221 (-5%)
Critically dry	2,130	2,021 (-5%)	2,091 (-2%)	2,009 (-6%)	1,978 (-7%)	2,018 (-5%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-80. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	295	304 (3%)	297 (1%)	297 (1%)	301 (2%)	304 (3%)
Above normal	N/A	(4%)	(0%)	(1%)	(3%)	(4%)
Below normal	945	997 (6%)	996 (5%)	974 (3%)	992 (5%)	997 (6%)
Dry	677	702 (4%)	704 (4%)	688 (2%)	703 (4%)	702 (4%)
Critically dry	200	204 (2%)	198 (-1%)	206 (3%)	208 (4%)	202 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Studies of acoustically tagged juvenile steelhead found San Joaquin River flow at Vernalis, presence of a rock barrier at Head of Old River, fish size, and year to be significant predictors of through-Delta survival, whereas south Delta exports were not supported as significant predictors of survival (Buchanan et al. 2021). Given the absence of a Head of Old River rock barrier under existing conditions and all project alternatives, as well as essentially identical Vernalis flows (Tables 12-81, 12-82, 12-83, and 12-84), there would be no difference in juvenile steelhead through-Delta survival from the San Joaquin River Basin between the project alternatives and existing conditions.

Table 12-81. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, February

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	9,589	9,598 (0%)	9,609 (0%)	9,596 (0%)	9,600 (0%)	9,598 (0%)
Above normal	4,972	4,981 (0%)	4,994 (0%)	4,975 (0%)	4,970 (0%)	4,980 (0%)
Below normal	3,218	3,225 (0%)	3,232 (0%)	3,221 (0%)	3,224 (0%)	3,224 (0%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Dry	1,962	1,969 (0%)	1,975 (1%)	1,966 (0%)	1,968 (0%)	1,969 (0%)
Critically dry	1,912	1,918 (0%)	1,923 (1%)	1,915 (0%)	1,917 (0%)	1,917 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-82. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, March

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	11,043	11,054 (0%)	11,089 (0%)	11,049 (0%)	11,053 (0%)	11,054 (0%)
Above normal	5,487	5,496 (0%)	5,506 (0%)	5,492 (0%)	5,494 (0%)	5,496 (0%)
Below normal	3,065	3,073 (0%)	3,079 (0%)	3,069 (0%)	3,072 (0%)	3,072 (0%)
Dry	1,963	1,968 (0%)	1,974 (1%)	1,966 (0%)	1,968 (0%)	1,968 (0%)
Critically dry	1,799	1,804 (0%)	1,809 (1%)	1,802 (0%)	1,804 (0%)	1,804 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-83. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, April

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	11,459	11,472 (0%)	11,485 (0%)	11,466 (0%)	11,471 (0%)	11,471 (0%)
Above normal	6,128	6,139 (0%)	6,151 (0%)	6,133 (0%)	6,136 (0%)	6,138 (0%)
Below normal	3,804	3,813 (0%)	3,822 (0%)	3,809 (0%)	3,812 (0%)	3,813 (0%)
Dry	2,434	2,440 (0%)	2,448 (1%)	2,438 (0%)	2,439 (0%)	2,439 (0%)
Critically dry	1,987	1,991 (0%)	1,995 (0%)	1,990 (0%)	1,991 (0%)	1,991 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-84. Mean San Joaquin River Flow at Vernalis (cubic feet per second) by Water Year Type, May

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	9,893	9,909 (0%)	9,924 (0%)	9,902 (0%)	9,908 (0%)	9,909 (0%)
Above normal	5,531	5,548 (0%)	5,562 (1%)	5,536 (0%)	5,541 (0%)	5,548 (0%)
Below normal	3,858	3,869 (0%)	3,880 (1%)	3,864 (0%)	3,867 (0%)	3,868 (0%)
Dry	2,712	2,718 (0%)	2,727 (1%)	2,717 (0%)	2,718 (0%)	2,717 (0%)
Critically dry	2,059	2,066 (0%)	2,070 (1%)	2,064 (0%)	2,066 (0%)	2,065 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

As discussed for fall-run Chinook salmon in Impact AQUA-4, there would not be an increase in south Delta entrainment risk for juvenile steelhead emigrating from the Mokelumne River based on south Delta exports (Tables 12-62, 12-63, 12-64, and 12-65) and hydrodynamic indicators (Appendix 12B, Figures 12B-52, 12B-53, 12B-54, and 12B-55).

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on steelhead. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

As discussed for juvenile Chinook salmon, the operations of the north Delta intakes would have negative effects on juvenile steelhead emigrating from the Sacramento River basin. As described above in the analysis of potential operations effects, specific flow-survival relationships have not been developed, so the magnitude of the effect is uncertain, but could be similar to juvenile Chinook salmon. Effects on steelhead from the San Joaquin and Mokelumne River basins would not be negative under the project alternatives, relative to existing conditions. As discussed by National Marine Fisheries Service (2016:19), Central Valley steelhead is in danger of extinction, with very low levels of natural production. Available data and studies for steelhead are limited relative to Chinook salmon and so there is some uncertainty in potential effects. As previously noted for winter-run Chinook salmon, there is uncertainty in the biological impacts because of the variability in flow-survival statistical relationships. However, per the significance criteria (Section 12.3.2, *Thresholds of Significance*), the potential for negative effects of the north Delta intakes (e.g., up to 4% less through-Delta migration survival per the Perry et al. model implemented for juvenile Chinook salmon) and the population status leads to the conclusion that the impact would be significant. Compensatory mitigation (tidal perennial habitat restoration and channel margin restoration) described in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources,* and as previously discussed for winter-run Chinook salmon would be implemented to reduce the impact to less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on Central Valley steelhead as analyzed in this chapter. As discussed for Chinook salmon in Impacts AQUA-2, AQUA-3, and AQUA-4, following completion of compensatory mitigation construction (tidal perennial habitat and channel margin habitat for operations impacts; see Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*), restored tidal habitat areas would have the potential for positive effects on steelhead, for example by providing foraging habitat along marsh edges (Brown 2003) or a greater extent of inundated vegetated habitat for occupancy (Hellmair et al. 2018). However, juvenile steelhead's association with habitat variables is weaker than juvenile Chinook salmon (Zajanc et al. 2013). Efficacy monitoring of performance standards would assess the degree to which positive effects are occurring and inform adjustment to sites as necessary to increase positive effects (Appendix 3F).

<u>*Other Mitigation Measures*</u>

Other mitigation measures proposed would have no impacts on steelhead during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact steelhead during operation and maintenance, and there would be no impact.

Overall, the impact on steelhead during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less than significant with mitigation impact conclusion.

No Project Alternative

At 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. As discussed for other salmonids (Impacts AQUA-2, AQUA-3, and AQUA-4), climate change–related shifts would generally increase Sacramento River flows into the Delta under the No Project Alternative at 2040 relative to existing conditions during December–April, as indicated by CalSim modeling (Appendix 5A: Attachment 3, Figure B.3.5.1 and Table B.3.5.1). These differences could result in higher through-Delta survival under the No Project Alternative, based on the mechanisms discussed above for the project alternatives, which could increase through-Delta survival of juvenile steelhead during the February–April main migration period (see Table 12-44 for context provided by juvenile Chinook salmon through-Delta survival analysis). As described for Chinook salmon, DSM2 simulations suggest mean September–June water temperature under the No Project Alternative would be 0.2–1.5°C greater than existing conditions (Table 12-47). During the main February–April through-Delta migration period, modeled differences were 0.4–1.0°C. These differences reflect differences in climate assumptions for 2040 (No Project Alternative) compared to 2020 (existing conditions), as described in more detail in Appendix 5A, Section B, Attachment 4, *Climate Change Development for Delta Conveyance Project*.

Lower through-Delta survival could occur for steelhead migrating during May, when Sacramento River flows to the Delta would be lower under the No Project Alternative compared to existing conditions (Table 12-44). Application of the salvage-density method suggested that steelhead entrainment loss under the No Project Alternative generally would be similar to existing conditions (Tables 12-85 and 12-86), with somewhat less south Delta exports at CVP resulting from prioritization of CVP reservoir storage at 2040 relative to 2020; as discussed for the project alternatives, existing conditions and the No Project Alternative would have the same regulations (i.e., NMFS [2019] BiOp) limiting entrainment loss of juvenile steelhead. Generally similar or higher spring San Joaquin River at Vernalis flows under the No Project Alternative (as indicated by CalSim modeling; Appendix 5A, Attachment 3, Figure B.3.16.1 and Table B.3.16.1) indicate that through-Delta survival of juvenile steelhead from the San Joaquin River basin would not be lower than existing conditions. As discussed for fall-run Chinook salmon, the modeled springtime south Delta exports do not indicate greater south Delta entrainment risk for juvenile steelhead from the Mokelumne River.

Table 12-85. Entrainment Loss of Juvenile Steelhead at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	5,216	5,476 (5%)
Above normal	N/A	(24%)
Below normal	3,251	3,597 (11%)
Dry	2,327	2,265 (-3%)
Critically dry	2,130	1,996 (-6%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-86. Entrainment Loss of Juvenile Steelhead at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	295	264 (-10%)
Above normal	N/A	(-17%)
Below normal	945	814 (-14%)
Dry	677	524 (-23%)
Critically dry	200	157 (-21%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-6: Effects of Operations and Maintenance of Water Conveyance Facilities on Delta Smelt

Operations and Maintenance—All Project Alternatives

Potential effects of the project alternatives on delta smelt are discussed in terms of near-field effects (i.e., in the immediate proximity) of north Delta exports and south Delta exports (e.g., entrainment), in addition to far-field habitat effects (e.g., changes to food availability and other factors potentially linked to changes in water operations). Analyses were developed in consideration of habitat attributes believed to be of importance to the species based on existing conceptual models (e.g., Interagency Ecological Program Management, Analysis, and Synthesis Team 2015; see summary by California Department of Water Resources 2020a:4-119) and best available methods (e.g., ICF International 2016a; U.S. Fish and Wildlife Service 2017; California Department of Water Resources 2020a). A summary of quantitative methods is provided in Table 12-3.

North Delta Exports

The low population abundance of delta smelt (Appendix 12A) in recent years suggests that few delta smelt would be exposed to potential near-field effects of the north Delta diversion intakes, including entrainment, impingement, predation, and upstream passage restriction. Beach seine data constitute the best available information to assess potential delta smelt occurrence in the vicinity of the north Delta intakes because the sampling is undertaken year-round at multiple locations. There have been no delta smelt collected at any of 12 stations in or near the mainstem Sacramento River between River Miles 12 and 80 since 2017 (Table 12-87). In addition to absolute numbers being low, the proportion of the delta smelt population that would be exposed to the north Delta intakes would also be very low, as summarized in analyses of historical data from various sampling programs by ICF International (2016b:4-64–4-90). Although absolute population abundance could increase because of hatchery supplementation (USFWS 2019:153), for example, the proportion of the delta smelt population exposed to the north Delta intakes would be low.

Upstream Migration Effects and Predation

The north Delta intakes could reduce the potential for migrating adult delta smelt to migrate upstream to spawning areas in the northern Delta based on replacement of low velocity nearshore habitat at the north Delta intake locations with fish screens and associated structures. Previous analyses demonstrated that the tidal surfing behavior typically employed by adult delta smelt elsewhere in the Delta (Bennett and Burau 2015) would not allow passage upstream of the north Delta intakes because of the primarily downstream flow in the intake reach (ICF International 2016a:6-75) and more recent analyses exploring a variety of tidal migration and other behaviors also found that all investigated behaviors would result in minimum numbers of fish entering the Sacramento River above Rio Vista (Gross et al. 2021); therefore active swimming is required. As described by USFWS (2017:318), for a delta smelt to swim upstream at all, river velocity has to be less than its sustainable swimming speed. Assuming that river velocity at Freeport is representative of river velocity near the north Delta intakes (which would be designed to have adequate sweeping velocity to meet downstream juvenile salmon migration requirements), the distance that a delta smelt can swim over a sustainable swimming period of 1 hour can be calculated based on maximum sustainable swimming speed (0.91 ft/s; Swanson et al. 1998). Methods for the upstream migration analysis are described in more detail in Appendix 12B, *Bay-Delta Methods and Results*, Section 12B.11, *Delta Smelt Upstream Migration Past North Delta Diversions*. Note that the method is applicable to fish in close proximity to the screens under the assumption that fish are swimming along the screens; as discussed further below, areas of low velocity that occur near the river bottom or channel margins could also be used for migration.

Based on the methods described in Appendix 12B, Section 12B.11, historical water velocity data during the main upstream migration period (December–March) indicate that downstream velocity would be sufficiently low for adult delta smelt to successfully migrate upstream within an hour past a single, approximately 30-foot cylindrical tee screen unit at Intakes A, B, and C just under 15% of the time, compared to 12% of the time for a combined screen length of 450 feet (i.e., the approximate length of 15 screen units for Intake A under Alternatives 2a and 4a and for Intake C under Alternatives 2c and 4c), and just under 10% of the time for a combined screen unit length of 900 feet (i.e., the approximate screen unit length of each of Intakes B and C with 3,000-cfs capacity).[39] The results for 450-foot and 900-foot screen unit lengths may also be representative of conditions along the vertical wall behind the cylindrical tee fish screens, should delta smelt occur in that area rather than along the fish screens.

Application of the results of laboratory investigations to velocity data from a relatively low-flow historical migration period (February 1991; see description in Appendix 12B, Section 12B.11) suggest that adult delta smelt passing close to the north Delta intake screens when velocity is sufficiently low for upstream migration could contact the fish screens and result in somewhat reduced survival (92%–93% survival for screen lengths of 30–900 feet; see Appendix 12B). Combined with screen length that could be passed within a 1-hour sustainable swimming period, the analysis suggests that adult delta smelt passing close to the intakes would have a passage probability of 9% for a single 30-foot screen, 7% for a combined screen length of 450 feet, and 5% for a combined screen length of 900 feet. These results are primarily the result of the downstream river velocity combined with the screen length, as opposed to survival effects of screen contact, and have uncertain application to the proposed cylindrical fish screens because the foundational studies were based on flat plate screens that fish were required to be in close proximity to at all times. The potential for reduction of upstream passage by the north Delta intakes may be proportional to the overall screen length and, therefore, the overall capacity of each alternative. As such, the potential reduction in upstream passage may be greatest under Alternatives 2a and 4a (7,500-cfs capacity); less under Alternatives 1, 3, and 5 (6,000-cfs capacity); second lowest under Alternatives 2c and 4c (4,500-cfs capacity); and least under Alternatives 2b and 4b (3,000-cfs capacity).

It is uncertain what proportion of upstream-migrating adult delta smelt occurring in the Sacramento River would experience the potential reduction in upstream passage by the north Delta intakes suggested by the above analysis. Although suitably low velocity for upstream migration based on Freeport channel velocity may occur during a relatively low proportion of time, it is possible that upstream migration would be concentrated during these limited periods. In addition, 2D hydraulic modeling conducted to illustrate potential north Delta intake effects on river hydrodynamics shows that there is a considerable extent of sufficiently low-velocity habitat on the opposite (west/right) bank of the Sacramento River from the north Delta intakes, although the greatest extent is on the east/left bank (the same side as the proposed intakes), particularly during higher flows (Delta Conveyance Design and Construction Authority 2022g). USFWS (2017:318) considered that it is unlikely that delta smelt could exclusively use the west bank to migrate past the north Delta intakes because the Sacramento River makes six major bends between Isleton and Freeport. This would shunt the highest velocity parts of the river cross section back and forth across the channel, requiring fish to change banks to avoid being swept downstream. In addition, USFWS (2017:318) considered that it seems unlikely that delta smelt could keep swimming up one bank of the river to areas upstream because they would eventually need to avoid a predator or be displaced off the shoreline at night when they lose visual reference and become less active. While these factors may increase the risk of passage delay by the north Delta intakes, the cylindrical tee fish screens and their associated manifolds, as well as the support piles for the log boom structure may provide

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[39] Calculations for a single fish screen were included to illustrate potential effects if fish only encountered one of the screens and not any others while swimming upstream (e.g., if they otherwise had occupied a different portion of the water column away from the fish screens). In combination with the full length of fish screens, this illustrates the range of potential effects for fish in close proximity to the screens. As noted for Impact AQUA-2, the cylindrical fish screen units would actually be 29.33 feet long and be separated by a gap of 1 foot; each screen unit would include 7.66 feet of manifold between the two screens comprising each unit, so that there actually would be 21.67 feet length of screen per screen unit.

velocity refuge for upstream migrating adult delta smelt occurring near the intakes, thereby reducing the extent of the potential negative effect. Low-velocity habitat for migration may also occur near the riverbed and field studies have shown delta smelt use of the bottom half of the water column, such as on ebb tides (Feyrer et al. 2013). In addition, if encountering high-velocity habitat at the NDD intakes, delta smelt could also switch banks to seek low-velocity habitat, thereby avoiding complete passage blockage and only perhaps resulting in some migration delay. Historical beach seine data at Clarksburg illustrate use of the opposite bank from Intake B (Table 12-87).

Statistical analysis of the Freeport Regional Water Authority intake in the north Delta did not find evidence that the intake reduced upstream occurrence of delta smelt during and following construction, in comparison to the pre-construction period (Appendix 12B, Section 12B.22, *Delta Smelt Occurrence Upstream of Freeport Regional Water Authority Intake*). Although the Freeport intake is shorter and has a different (flat plate) screen design than the proposed north Delta intakes, the analysis suggests that delta smelt are able to pass this intake to migrate upstream. In addition, the statistical analysis of delta smelt occurrence upstream of Freeport did not find a significant relationship between mean December–March Sacramento River at Freeport flow and delta smelt probability of occurrence upstream of Freeport (Appendix 12B, Section 12B.22, *Delta Smelt Occurrence Upstream of Freeport Regional Water Authority Intake*). In their paper describing the occurrence of a single delta smelt in the rotary screw trap at Knights Landing in March 2010, Vincik and Julienne (2012) suggested that the hydrologically dry water year could have driven delta smelt farther upstream in the system but acknowledged that they could not ascertain exactly what conditions led to migration so far upstream. Thus, while in theory diversions at the north Delta intakes could enhance the far-field, riverscape scale potential for upstream migration by adult delta smelt occurring in the north Delta riverine reaches based on lower velocity, and decrease potential migration based on near-field effects from the fish screens, there is uncertainty in the extent to which either effect would occur. Uncertainty in the potential effects on upstream passage of adult delta smelt would be addressed by field studies involving methods such as beach seining or environmental DNA.

Table 12-87. Number of Delta Smelt Collected by Beach Seining in the Sacramento River Between River Miles 12 and 80, January–June 2012–2021, With Frequency of Years with Collection of At Least One Individual Compared to 1994–2014

Station	Location Relative to North Delta Intakes	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Frequency (2012–2021)	Frequency (1994–2014)
SR012W (Sandy Beach)	Downstream	5	4	46	29	2	4	0	0	0	0	0.60	0.86
SR014W (Rio Vista)	Downstream	2	0	2	0	0	0	0	0	0	0	0.20	0.90
SR017E (Isleton)	Downstream	0	0	0	0	0	0	0	0	0	0	0.00	0.38
SR024E (Koket)	Downstream	3	0	0	0	0	0	0	0	0	0	0.10	0.62
XC001N (Delta Cross Channel)	Downstream	0	0	0	0	0	0	0	0	0	0	0.00	0.05
GS010E (Georgiana Slough)	Downstream	2	0	0	0	0	0	0	0	0	0	0.10	0.19
SS011N (Steamboat Slough (mouth)	Downstream	9	0	0	0	0	0	0	0	0	0	0.10	0.43
SR043W (Clarksburg)	Across river from Intake B	9	0	11	0	0	0	0	0	0	0	0.20	0.71
SR049E (Garcia Bend)	Upstream	33	0	6	0	0	0	0	0	0	0	0.20	0.76
SR055E (Sherwood Harbor)	Upstream	0	0	0	0	0	0	0	0	0	0	0.00	0.00
SR057E (Miller Park)	Upstream	0	0	0	0	0	0	0	0	0	0	0.00	0.10
SR060E (Discovery Park)	Upstream	0	0	5	0	0	0	0	0	0	0	0.10	0.19
AM001S (American River)	Upstream	0	0	0	0	0	0	0	0	0	0	0.00	0.05
SR062E (Sand Cove)	Upstream	0	0	3	0	0	0	0	0	0	0	0.10	0.10
SR071E (Elkhorn)	Upstream	0	0	0	0	0	0	0	0	0	0	0.00	0.10
SR080E (Verona)	Upstream	0	0	0	0	0	0	0	0	0	0	0.00	0.10

Sources: 2012–2021 data from U.S. Fish and Wildlife Service (2021);1994–2014 frequency summary from U.S. Fish and Wildlife Service (2017:153).

Note: Station codes on the Sacramento River (SR) indicate river miles upstream of the confluence the Sacramento and San Joaquin Rivers; the north Delta intakes are at approximately river mile 37–41.

The north Delta intakes may provide predatory fish with low-velocity ambush locations, given the association of some species with anthropogenic features (e.g., Sabal et al. 2016). This could increase exposure of delta smelt to predation risk, although the increase in in-water structure would be small and a relatively minor increase to the limited extent of in-water structures within the Delta (Lehman et al. 2019). Although not specific to delta smelt and not within the Delta, studies in the Sacramento River have not provided evidence for statistically significant effects of either cylindrical tee fish screens (Demetras et al. 2013) or intake structures generally (Henderson et al. 2019) on survival of migrating small fish. Field studies would be undertaken to assess predator association with the north Delta intakes and to inform the need for adaptive management (Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

Entrainment and Impingement

The north Delta intakes would be screened to fishery agency standards, including 0.2-ft/s approach velocity for delta smelt protection and 1.75-mm opening, to limit the potential for entrainment or impingement. Delta smelt eggs and embryos are demersal and adhesive, attaching to substrates with an adhesive stalk formed by the outer layer of the egg (Bennett 2005:17), and therefore are not believed to be highly mobile following spawning (USFWS 2019:100) and so generally would not be susceptible to entrainment or impingement.[40] Based on delta smelt body depth to body length ratios and using the screening effectiveness analysis described in Appendix 12B, the proposed north Delta intake screen opening of 1.75 mm would prevent delta smelt greater than standard length of around 20–21 mm (approximately 90 days old; Hobbs et al. 2007) from being entrained through the fish screens. Therefore, only delta smelt smaller than 20–21 mm (i.e., larvae/early juveniles) would be vulnerable to entrainment.

The proportion of water diverted by the north Delta intakes during the months of young delta smelt vulnerability (i.e., March–June, especially April–May) provides a coarse indicator of entrainment/impingement risk of the small proportion of delta smelt occurring near the north Delta intakes, assuming that the proportion of water diverted is proportional to intake exposure for young life stages moving downstream. CalSim modeling suggests that the median percentage of flow diverted would be 6%–7% in March (range: 0%–22%), 0% in April (range: 0%–16%), 0% in May (range: 0%–22%), and 0% in June (range: 0%–19%) (Table 12-88). The percentage of young delta smelt being entrained or impinged on the north Delta intake screens would likely be less than these percentages. This is because field studies in the Delta have shown that cylindrical tee fish screens may exclude a considerably greater proportion of delta smelt than would be expected based solely on theoretical calculations (Nobriga et al. 2004). Mechanisms contributing to these observations may include the hydraulic bypass effect created by moving water encountering the end of the cylindrical tee fish screens and forming a "bow wave," which physically keeps organisms away from the screens, as well as detection and avoidance of the bow wave, as suggested for cylindrical screens in the Columbia River (Coutant 2021; albeit with the caveats previously described for winter-run Chinook salmon). The small, early life stages of delta smelt tend to be distributed off the bottom and

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[40] To the extent that delta smelt eggs attached to sand are resuspended by water flow, the assessment of percentage of flow diverted by the north Delta intakes for larvae provides some context for entrainment risk. Note, however, that there is no information on the probability of resuspended eggs surviving resuspension, which based on inferences made for other smelt species may be low because of displacement to areas of less suitable habitat than those selected by spawning adults (Brown and Taylor 1995). Note also that the proportion of the total delta smelt population's eggs that may be subject to entrainment risk would be low based on the species' distribution information provided earlier in this section.

are pelagic, mostly near the surface of the water column prior to swim bladder development (Bennett 2005:18; Wang 2007:7), whereas following swim bladder development, there is evidence for changes in distribution from the upper to lower water column depending on the time of the day (see summary by Bennett 2005:20, which notes that different studies have found different times of the day for occurrence in the upper water column). Occurrence in the upper half of the water column would result in potential exposure to the north Delta intakes much of the time for these individuals occurring near the intakes, based on the proportion of time that the tops of the screens would be in the upper half of the water column (see Tables 12-14, 12-15, and 12-16 in Impact AQUA-2 for winter-run Chinook salmon). The overall proportion of the delta smelt population that could be exposed to such effects would be small, given that the main distribution of the species is farther downstream in the Delta and elsewhere (e.g., Suisun Marsh; Appendix 12A).

Table 12-88. Percentage of Sacramento River Flow Diverted by the North Delta Diversions, March–June

Percentile	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
March					
Minimum	0%	0%	0%	0%	0%
10%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%
30%	1%	0%	1%	1%	1%
40%	3%	3%	4%	4%	3%
50%	7%	7%	6%	7%	7%
60%	11%	11%	7%	9%	11%
70%	13%	14%	8%	11%	13%
80%	15%	15%	10%	14%	15%
90%	17%	17%	13%	16%	17%
Maximum	21%	22%	16%	19%	21%
April					
Minimum	0%	0%	0%	0%	0%
10%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%
30%	0%	0%	0%	0%	0%
40%	0%	0%	0%	0%	0%
50%	0%	0%	0%	0%	0%
60%	0%	0%	0%	0%	0%
70%	0%	0%	0%	0%	0%
80%	0%	0%	0%	0%	0%
90%	7%	7%	4%	7%	7%
Maximum	16%	16%	15%	16%	16%

Percentile	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
May					
Minimum	0%	0%	0%	0%	0%
10%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%
30%	0%	0%	0%	0%	0%
40%	0%	0%	0%	0%	0%
50%	0%	0%	0%	0%	0%
60%	0%	0%	0%	0%	0%
70%	1%	1%	0%	0%	1%
80%	3%	3%	4%	3%	3%
90%	7%	7%	7%	7%	7%
Maximum	20%	22%	15%	20%	20%
June					
Minimum	0%	0%	0%	0%	0%
10%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%
30%	0%	0%	0%	0%	0%
40%	0%	0%	0%	0%	0%
50%	0%	0%	0%	0%	0%
60%	0%	0%	0%	0%	0%
70%	2%	2%	1%	1%	2%
80%	5%	5%	5%	5%	6%
90%	12%	12%	11%	12%	12%
Maximum	19%	19%	14%	18%	19%

Alt = alternative.

South Delta Exports

Old and Middle River (OMR) flows are an important indicator of adult (December–March) and larval/early juvenile (March–June) delta smelt entrainment risk at the south Delta export facilities (Grimaldo et al. 2009; U.S. Fish and Wildlife Service 2019:Appendix 2; Grimaldo et al. 2021; Smith et al. 2021). As described in Chapter 3, the existing facilities in the south Delta will be governed by applicable regulatory requirements, such as those specified under the SWRCB Bay-Delta Water Quality Control Plan, federal BiOps (National Marine Fisheries Service 2019; U.S. Fish and Wildlife Service 2019), CESA Incidental Take Permit for SWP (California Department of Fish and Wildlife 2020a), and USACE Clifton Court diversion limits. The CalSim modeling for existing conditions and the project alternatives includes representation of these requirements, although not all real-time requirements, such as those based on monitoring of fish presence, are represented (Appendix 5A). The risk of delta smelt entrainment under existing conditions and all alternatives would be minimized by the inclusion of the various existing regulatory requirements. Although there are some differences in modeled OMR flows greater than 5%–10% between existing conditions and the alternatives, generally reflecting less south Delta exports under the project alternatives because of north Delta exports, the magnitude and signs of the absolute estimates are sufficiently similar to suggest that there would be similar levels of delta smelt entrainment risk under the project alternatives and existing conditions (Tables 12-89, 12-90, 12-91, 12-92, 12-93, 12-94, and 12-95).

Table 12-89. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, December

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-5,229	-5,046 (3%)	-5,013 (4%)	-5,057 (3%)	-5,052 (3%)	-5,035 (4%)
Above normal	-6,900	-6,523 (5%)	-6,439 (7%)	-6,444 (7%)	-6,364 (8%)	-6,527 (5%)
Below normal	-6,249	-6,065 (3%)	-6,115 (2%)	-6,137 (2%)	-6,105 (2%)	-6,064 (3%)
Dry	-5,666	-5,117 (10%)	-5,166 (9%)	-5,201 (8%)	-5,163 (9%)	-5,115 (10%)
Critically dry	-4,281	-4,173 (3%)	-4,178 (2%)	-4,085 (5%)	-4,081 (5%)	-4,182 (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-90. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, January

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-2,972	-2,925 (2%)	-2,925 (2%)	-2,800 (6%)	-2,911 (2%)	-2,902 (2%)
Above normal	-4,274	-4,274 (0%)	-4,274 (0%)	-4,274 (0%)	-4,274 (0%)	-4,274 (0%)
Below normal	-4,393	-4,374 (0%)	-4,350 (1%)	-4,322 (2%)	-4,330 (1%)	-4,374 (0%)
Dry	-4,812	-4,680 (3%)	-4,680 (3%)	-4,693 (2%)	-4,680 (3%)	-4,680 (3%)
Critically dry	-4,303	-4,208 (2%)	-4,136 (4%)	-4,163 (3%)	-4,219 (2%)	-4,209 (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-91. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, February

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-3,029	-2,656 (12%)	-2,636 (13%)	-2,728 (10%)	-2,674 (12%)	-2,652 (12%)
Above normal	-3,712	-3,725 (0%)	-3,763 (-1%)	-3,967 (-7%)	-3,855 (-4%)	-3,725 (0%)
Below normal	-4,460	-4,374 (2%)	-4,416 (1%)	-4,514 (-1%)	-4,411 (1%)	-4,374 (2%)
Dry	-4,516	-4,658 (-3%)	-4,658 (-3%)	-4,654 (-3%)	-4,654 (-3%)	-4,658 (-3%)
Critically dry	-4,350	-4,335 (0%)	-4,378 (-1%)	-4,316 (1%)	-4,339 (0%)	-4,266 (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-92. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, March

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-1,289	-856 (34%)	-783 (39%)	-1,041 (19%)	-915 (29%)	-840 (35%)
Above normal	-2,916	-2,902 (0%)	-2,900 (1%)	-2,915 (0%)	-2,909 (0%)	-2,902 (0%)
Below normal	-3,383	-3,375 (0%)	-3,375 (0%)	-3,379 (0%)	-3,377 (0%)	-3,375 (0%)
Dry	-3,292	-3,293 (0%)	-3,292 (0%)	-3,292 (0%)	-3,292 (0%)	-3,293 (0%)
Critically dry	-3,001	-2,890 (4%)	-2,870 (4%)	-2,929 (2%)	-2,919 (3%)	-2,898 (3%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-93. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, April

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-951	-523 (45%)	-489 (49%)	-646 (32%)	-558 (41%)	-522 (45%)
Above normal	-1,531	-1,393 (9%)	-1,437 (6%)	-1,484 (3%)	-1,391 (9%)	-1,393 (9%)
Below normal	-1,715	-1,717 (0%)	-1,728 (-1%)	-1,718 (0%)	-1,719 (0%)	-1,717 (0%)
Dry	-1,813	-1,826 (-1%)	-1,816 (0%)	-1,820 (0%)	-1,827 (-1%)	-1,826 (-1%)
Critically dry	-1,181	-1,213 (-3%)	-1,182 (0%)	-1,245 (-5%)	-1,240 (-5%)	-1,212 (-3%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-94. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, May

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-1,555	-1,658 (-7%)	-1,644 (-6%)	-1,739 (-12%)	-1,671 (-7%)	-1,656 (-7%)
Above normal	-2,397	-2,445 (-2%)	-2,487 (-4%)	-2,485 (-4%)	-2,370 (1%)	-2,445 (-2%)
Below normal	-1,882	-2,000 (-6%)	-2,020 (-7%)	-1,974 (-5%)	-2,001 (-6%)	-2,000 (-6%)
Dry	-2,028	-2,005 (1%)	-2,007 (1%)	-1,995 (2%)	-2,021 (0%)	-2,005 (1%)
Critically dry	-1,710	-1,672 (2%)	-1,671 (2%)	-1,680 (2%)	-1,670 (2%)	-1,672 (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-95. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, June

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-4,411	-4,404 (0%)	-4,403 (0%)	-4,401 (0%)	-4,405 (0%)	-4,404 (0%)
Above normal	-4,953	-4,942 (0%)	-4,940 (0%)	-4,953 (0%)	-4,954 (0%)	-4,942 (0%)
Below normal	-4,899	-4,920 (0%)	-4,894 (0%)	-4,913 (0%)	-4,918 (0%)	-4,920 (0%)
Dry	-4,750	-4,730 (0%)	-4,693 (1%)	-4,756 (0%)	-4,731 (0%)	-4,730 (0%)
Critically dry	-2,084	-2,101 (-1%)	-2,056 (1%)	-2,132 (-2%)	-2,187 (-5%)	-2,102 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Particle tracking modeling was used to provide additional assessment of potential delta smelt entrainment effects (for method, see Appendix 12B, Section 12B.12, *Delta Smelt Larval Entrainment (DSM2 Particle Tracking Model)*). The results of this modeling generally gave little difference between the project alternatives and existing conditions (Table 12-96), in agreement with the examination of Old and Middle River flows discussed above.

Table 12-96. Entrainment of Particles at the South Delta Export Facilities and North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Delta Smelt Larval/Early Juvenile Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
March						
Wet	4.22	4.27 (1%)	4.28 (1%)	4.26 (1%)	4.27 (1%)	4.27 (1%)
Above normal	6.90	6.97 (1%)	6.94 (1%)	6.94 (1%)	6.94 (1%)	6.97 (1%)
Below normal	18.21	18.45 (1%)	18.44 (1%)	18.37 (1%)	18.40 (1%)	18.43 (1%)
Dry	16.90	16.98 (1%)	17.01 (1%)	16.96 (0%)	16.98 (1%)	16.98 (1%)
Critically dry	18.44	18.05 (-2%)	17.94 (-3%)	18.28 (-1%)	18.27 (-1%)	18.10 (-2%)
April						
Wet	3.82	3.57 (-7%)	3.53 (-8%)	3.65 (-4%)	3.66 (-4%)	3.55 (-7%)
Above normal	6.44	6.58 (2%)	6.57 (2%)	6.58 (2%)	6.59 (2%)	6.58 (2%)
Below normal	9.55	9.45 (-1%)	9.72 (2%)	9.58 (0%)	9.61 (1%)	9.45 (-1%)
Dry	9.19	9.26 (1%)	9.12 (-1%)	9.32 (1%)	9.27 (1%)	9.23 (0%)
Critically dry	8.13	8.32 (2%)	8.08 (-1%)	8.49 (4%)	8.47 (4%)	8.33 (2%)
May						
Wet	7.82	8.52 (9%)	8.52 (9%)	8.51 (9%)	8.47 (8%)	8.52 (9%)
Above normal	13.03	14.13 (8%)	14.13 (8%)	13.83 (6%)	13.95 (7%)	14.12 (8%)
Below normal	10.26	10.83 (6%)	10.92 (6%)	10.71 (4%)	10.86 (6%)	10.80 (5%)
Dry	11.91	11.92 (0%)	11.94 (0%)	11.72 (-2%)	11.99 (1%)	11.92 (0%)
Critically dry	12.73	12.48 (-2%)	12.47 (-2%)	12.53 (-2%)	12.50 (-2%)	12.50 (-2%)
June						
Wet	16.40	16.54 (1%)	16.55 (1%)	16.54 (1%)	16.54 (1%)	16.54 (1%)
Above normal	27.00	26.72 (-1%)	26.76 (-1%)	26.71 (-1%)	26.74 (-1%)	26.80 (-1%)
Below normal	27.61	27.71 (0%)	27.58 (0%)	27.68 (0%)	27.69 (0%)	27.71 (0%)
Dry	27.91	27.85 (0%)	27.55 (-1%)	28.00 (0%)	27.89 (0%)	27.87 (0%)
Critically dry	13.13	13.34 (2%)	13.10 (0%)	13.51 (3%)	13.85 (5%)	13.29 (1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Habitat Effects

Sediment Entrainment

The Interagency Ecological Program Management, Analysis, and Synthesis Team (IEP MAST) (2015:87–89) conceptual model identifies predation risk as a habitat attribute affecting delta smelt survival; flows interact with erodible sediment supply to affect turbidity and, in general, greater turbidity is thought to lower the risk of predation on delta smelt (Bennett 2005; Moyle et al. 2016). Sandy sediment is also an important substrate for spawning (Lindberg et al. 2020). Large amounts of sediment enter the Delta from winter and spring storm runoff, with resuspension caused by tidal and wind action (Schoellhamer et al. 2014; Bever et al. 2018). Wright and Schoellhamer (2005) found that approximately 66% of the sediment entered the Delta from the Sacramento River. The north Delta intakes would entrain sediment, with annual mean entrainment estimates of this suspended sediment otherwise destined to move downstream in the Sacramento River ranging from 2% to 8% and an overall total during the 1922–2015 CalSim modeling period of 4%–5% (Table 12-97).[41] A recent analysis examining future climate scenarios predicts significant increases in large flow events and sediment loading to the Delta from the Sacramento River over the next century for two representative greenhouse gas concentration pathways, which may increase turbidity (Stern et al. 2020). The magnitude of the projected increases in sediment loading relative to existing conditions (+33%–38% by 2040–2069; +39%–69% by 2070–2099) is appreciably greater than the estimated reduction in sediment loading as a result of north Delta intake entrainment. In addition, the increase in sediment would have the potential to largely reverse the approximately 50% reduction in sediment loading from the Sacramento River estimated to have occurred during the second half of the twentieth century (Wright and Schoellhamer 2004). The relatively small percentage of sediment entrained by the north Delta intakes indicates that the project alternatives would likely have limited impacts on suspended sediment and turbidity for delta smelt. It is unlikely that water, and sediment, diversion would produce any immediate change in turbidity (or the concentration of suspended sediment) at or downstream of the intakes. Rather, the potential for an effect would be tied to the decrease in sediment load, which could be deposited and resuspended in areas delta smelt inhabit downstream of the intakes. Uncertainty in the potential for impacts, particularly in light of projected future trends in suspended sediment (Stern et al. 2020), would be addressed through an adaptive management program (see discussion in *CEQA Conclusion—All Project Alternatives*).

Table 12-97. Mean Annual Percentage of Suspended Sediment in the Sacramento River at Freeport Entrained by the North Delta Diversions by Water Year Type and Total Percentage Entrained Over Full CalSim Modeling Period (Water Years 1922–2015)

Water Year Type	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	4%	4%	3%	4%	4%
Above normal	7%	8%	5%	7%	7%
Below normal	7%	8%	5%	7%	7%
Dry	5%	6%	4%	5%	5%

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[41] Estimates of suspended sediment entrainment by the north Delta intakes were made by multiplying historical median monthly suspended sediment concentration in the Sacramento River at Freeport (Delta Conveyance Design and Construction Authority 2022k: Figure 3) by the CalSim-modeled monthly mean Sacramento River flow and north Delta intake diversions.

Water Year Type	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Critically dry	3%	3%	2%	3%	3%
Total	5%	5%	4%	5%	5%

Alt = alternative.

Food Availability

The IEP MAST (2015:88) conceptual model suggests that Delta exports of water could affect food availability for larval delta smelt. The mechanism for the impacts of Delta exports on food availability could be related to the hydrodynamic impacts of Delta outflow because a positive correlation exists between the density of the important delta smelt larval and juvenile zooplankton prey *Eurytemora affinis* in the low salinity zone and Delta outflow (as indexed by X2) during the spring (March–May; Kimmerer 2002b; Greenwood 2018). Other analyses have also found positive correlations between outflow and delta smelt calanoid copepod prey in spring (Hamilton et al. 2020), whereas some other analyses have not found statistically significant relationships between spring outflow and biomass per unit of sampling effort for other delta smelt prey (*Limnoithona tetraspina* and *Pseudodiaptomus forbesi*; California Department of Water Resources and Bureau of Reclamation 2021:2-11). To assess the magnitude of potential differences in *E. affinis* availability for larval/juvenile delta smelt, a regression of March–May X2 versus *E. affinis* density in the low salinity zone was used to compare existing conditions and the alternatives (see the methods description provided in Appendix 12B, Section 12B.13, *Eurytemora affinis*–X2 Analysis). This analysis suggested that the difference in *E. affinis* density in the low salinity zone between the alternatives and existing conditions would be small (0%–3%). Such differences are much less than the range of the prediction intervals from this statistical model, which span several orders of magnitude (see Table 12B-43 in Appendix 12B for results by individual year, including prediction intervals). This indicates very little potential for negative effects on delta smelt from the alternatives relative to existing conditions with respect to *E. affinis* food availability.

Table 12-98. Mean *Eurytemora affinis* Density (adults per cubic meter) in the Low Salinity Zone by Water Year Type

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	185	183 (-1%)	182 (-1%)	183 (-1%)	183 (-1%)	183 (-1%)
Above normal	159	155 (-3%)	155 (-3%)	156 (-2%)	155 (-3%)	155 (-3%)
Below normal	121	118 (-3%)	118 (-3%)	119 (-2%)	118 (-3%)	118 (-3%)
Dry	102	100 (-2%)	99 (-3%)	100 (-2%)	100 (-2%)	100 (-2%)
Critically dry	79	78 (-1%)	78 (-1%)	78 (-1%)	78 (-1%)	78 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty (see Table 12B-43 in Appendix 12B for results by individual year, including prediction intervals). Results are not predictions of actual values and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

In addition to the importance of food availability in spring as discussed above, the IEP MAST (2015:88–89) conceptual model describes food availability and quality as key components of the transition probability of juvenile and subadult delta smelt to subsequent life stages through growth and survival of individuals. Analyses have shown that summer and fall (July–September) Delta outflow is positively correlated with the subsidy of the delta smelt zooplankton prey *Pseudodiaptomus forbesi* to the low salinity zone from the freshwater Delta (Kimmerer et al. 2018a). Other analyses have found largely nonlinear relationships between outflow and calanoid copepod biomass in the Delta and Suisun Marsh/Bay, with potential for negative effects of greater September/October outflow on delta smelt prey at several locations (Hamilton et al. 2020). Polansky et al. (2021) found that delta smelt postlarval survival during June–August was positively correlated with prey abundance[42] and that prey abundance was highly positively correlated with Delta outflow during these months. Detailed examination of a fall flow action in 2017 did not provide evidence for an increase in delta smelt prey with increased outflow resulting in X2 farther downstream (Schultz et al. 2019:242–249). The modeling results generally show similar or less Delta outflow under the project alternatives than existing conditions during June–October (Tables 12-99, 12-100, 12-101, 12-102, and 12-103) as a result of less outflow needed for meeting Delta salinity requirements under the project alternatives. Given the range of relationships suggested by the available studies discussed above (Kimmerer et al. 2018a; Schultz et al. 2019:242–249; Hamilton et al. 2020), the extent to which differences in Delta outflow would result in changes in delta smelt prey is uncertain but may be small relative to other factors such as the high rate of foodweb material grazing by clams in the low salinity zone (Kayfetz and Kimmerer 2017; Kimmerer et al. 2019b). In addition, an appreciable portion of delta smelt occur upstream of the low salinity zone (i.e., an average of 23% [range 2% to 47%] during the 2005–2014 period [Bush 2017]) and would not experience any effects on prey availability in the low salinity zone. Recent analyses by DWR (2020a:4-149–4-151) suggest lower San Joaquin River flow (QWEST) may be an indicator of *P. forbesi* spatial subsidy potential, given entrainment of *P. forbesi* (Kimmerer et al. 2019b). QWEST flow, particularly the frequency of positive QWEST flow, generally is similar between existing conditions and the alternatives (Table 12-104, 12-105, 12-106, 12-107, 12-108), indicating that *P. forbesi* prey availability based on this hypothesized mechanism would be similar between existing conditions and the project alternatives.

Table 12-99. Mean Delta Outflow (cubic feet per second) by Water Year Type, June

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	22,071	20,780 (-6%)	20,787 (-6%)	20,838 (-6%)	20,758 (-6%)	20,750 (-6%)
Above normal	14,252	12,385 (-13%)	12,391 (-13%)	12,967 (-9%)	12,484 (-12%)	12,245 (-14%)
Below normal	6,679	6,527 (-2%)	6,525 (-2%)	6,518 (-2%)	6,513 (-2%)	6,527 (-2%)
Dry	6,112	6,165 (1%)	6,162 (1%)	6,135 (0%)	6,135 (0%)	6,166 (1%)
Critically dry	5,462	5,462 (0%)	5,462 (0%)	5,462 (0%)	5,462 (0%)	5,462 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-100. Mean Delta Outflow (cubic feet per second) by Water Year Type, July

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	9,821	9,412 (-4%)	9,408 (-4%)	9,416 (-4%)	9,413 (-4%)	9,423 (-4%)

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[42] As illustrated by plots of the predicted relationship with associated credible intervals from statistical modeling (Polansky et al. 2021: Figure C.1), there is appreciable statistical uncertainty in the relationship, which is based on annual mean values across water years.

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Above normal	8,038	7,229 (-10%)	7,232 (-10%)	7,350 (-9%)	7,231 (-10%)	7,230 (-10%)
Below normal	6,397	5,520 (-14%)	5,527 (-14%)	5,686 (-11%)	5,541 (-13%)	5,520 (-14%)
Dry	4,273	4,218 (-1%)	4,220 (-1%)	4,213 (-1%)	4,219 (-1%)	4,218 (-1%)
Critically dry	3,566	3,544 (-1%)	3,545 (-1%)	3,530 (-1%)	3,544 (-1%)	3,544 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-101. Mean Delta Outflow (cubic feet per second) by Water Year Type, August

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	5,696	5,546 (-3%)	5,550 (-3%)	5,496 (-4%)	5,502 (-3%)	5,546 (-3%)
Above normal	5,246	5,269 (0%)	5,269 (0%)	5,245 (0%)	5,268 (0%)	5,268 (0%)
Below normal	3,391	3,395 (0%)	3,438 (1%)	3,394 (0%)	3,386 (0%)	3,402 (0%)
Dry	3,139	3,136 (0%)	3,093 (-1%)	3,163 (1%)	3,162 (1%)	3,144 (0%)
Critically dry	2,573	2,573 (0%)	2,573 (0%)	2,573 (0%)	2,573 (0%)	2,573 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-102. Mean Delta Outflow (cubic feet per second) by Water Year Type, September

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	10,347	10,207 (-1%)	10,214 (-1%)	10,273 (-1%)	10,265 (-1%)	10,181 (-2%)
Above normal	9,682	9,740 (1%)	9,740 (1%)	9,728 (0%)	9,741 (1%)	9,740 (1%)
Below normal	3,515	3,037 (-14%)	3,060 (-13%)	3,113 (-11%)	3,065 (-13%)	3,032 (-14%)
Dry	2,641	2,476 (-6%)	2,484 (-6%)	2,476 (-6%)	2,490 (-6%)	2,477 (-6%)
Critically dry	2,608	2,609 (0%)	2,609 (0%)	2,609 (0%)	2,609 (0%)	2,609 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-103. Mean Delta Outflow (cubic feet per second) by Water Year Type, October

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	8,004	8,049 (1%)	8,175 (2%)	7,717 (-4%)	7,707 (-4%)	8,034 (0%)
Above normal	6,084	6,167 (1%)	6,166 (1%)	6,188 (2%)	6,165 (1%)	6,167 (1%)
Below normal	5,981	5,848 (-2%)	5,847 (-2%)	5,836 (-2%)	5,850 (-2%)	5,849 (-2%)
Dry	5,168	5,210 (1%)	5,217 (1%)	5,173 (0%)	5,210 (1%)	5,209 (1%)
Critically dry	4,068	4,004 (-2%)	3,997 (-2%)	3,979 (-2%)	3,998 (-2%)	3,974 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-104. Percentage of Years with Positive QWEST Flow, July–October

Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
July	28%	31% (12%)	30% (8%)	31% (12%)	30% (8%)	31% (12%)
August	29%	26% (-11%)	26% (-11%)	24% (-15%)	24% (-15%)	26% (-11%)
September	45%	49% (10%)	49% (10%)	48% (7%)	49% (10%)	49% (10%)
October	47%	48% (2%)	48% (2%)	47% (0%)	48% (2%)	48% (2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-105. Mean QWEST (cubic feet per second) by Water Year Type, July

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	227	488 (115%)	488 (115%)	430 (90%)	461 (103%)	491 (116%)
Above normal	-1,903	-937 (51%)	-905 (52%)	-967 (49%)	-949 (50%)	-919 (52%)
Below normal	-2,779	-2,090 (25%)	-2,124 (24%)	-2,199 (21%)	-2,106 (24%)	-2,090 (25%)
Dry	-2,660	-2,576 (3%)	-2,450 (8%)	-2,522 (5%)	-2,595 (2%)	-2,579 (3%)
Critically dry	1,240	1,220 (-2%)	1,252 (1%)	1,264 (2%)	1,241 (0%)	1,222 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-106. Mean QWEST (cubic feet per second) by Water Year Type, August

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-1,656	-1,568 (5%)	-1,577 (5%)	-1,586 (4%)	-1,630 (2%)	-1,568 (5%)
Above normal	-2,926	-2,516 (14%)	-2,615 (11%)	-2,610 (11%)	-2,531 (13%)	-2,516 (14%)
Below normal	-3,568	-3,200 (10%)	-3,242 (9%)	-3,359 (6%)	-3,216 (10%)	-3,206 (10%)
Dry	-408	-536 (-31%)	-444 (-9%)	-554 (-36%)	-562 (-38%)	-549 (-34%)
Critically dry	1,378	1,276 (-7%)	1,277 (-7%)	1,331 (-3%)	1,291 (-6%)	1,278 (-7%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-107. Mean QWEST (cubic feet per second) by Water Year Type, September

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	729	792 (9%)	790 (8%)	775 (6%)	807 (11%)	784 (8%)
Above normal	972	1,204 (24%)	1,145 (18%)	1,083 (11%)	1,285 (32%)	1,155 (19%)
Below normal	-2,511	-1,669 (34%)	-1,741 (31%)	-1,781 (29%)	-1,701 (32%)	-1,670 (33%)
Dry	-372	-208 (44%)	-203 (46%)	-248 (33%)	-249 (33%)	-209 (44%)
Critically dry	447	541 (21%)	543 (21%)	540 (21%)	543 (21%)	542 (21%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-108. Mean QWEST (cubic feet per second) by Water Year Type, October

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	-148	-247 (-67%)	-276 (-86%)	-213 (-44%)	-261 (-76%)	-255 (-72%)
Above normal	814	585 (-28%)	569 (-30%)	680 (-16%)	609 (-25%)	626 (-23%)
Below normal	-815	-397 (51%)	-409 (50%)	-894 (-10%)	-840 (-3%)	-377 (54%)
Dry	-88	-69 (22%)	-56 (36%)	-37 (58%)	-77 (12%)	-75 (14%)
Critically dry	-39	43 (212%)	37 (195%)	71 (283%)	49 (227%)	43 (211%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

In situ production of phytoplankton carbon within the Delta is several times greater than inputs from freshwater inflow (Jassby et al. 2002) and is the dominant supply to the planktonic foodweb that includes delta smelt (Sobczak et al. 2002). Phytoplankton and zooplankton are the base of the foodweb supporting delta smelt. As highlighted by Arthur et al. (1996), Jassby and Cloern (2000), Jassby et al. (2002), and USFWS (2008:228), SWP/CVP water exports directly entrain phytoplankton and zooplankton. Recent analyses suggest that the combination of clam grazing and south Delta exports have negatively affected pelagic productivity in the San Francisco Estuary (Hammock et al. 2019a).[43] Entrainment of phytoplankton and zooplankton by the south Delta export facilities generally would be somewhat less under the alternatives, but the north Delta intakes would add a new source of loss along the Sacramento River under the project alternatives. The impact of this was examined using an assessment of phytoplankton carbon entrained, based on chlorophyll a concentration data for Hood (representing the load of entrained phytoplankton), in relation to the biomass of phytoplankton in the Delta (taken from Antioch chlorophyll a data, multiplied up to the volume of the Delta). The methods for this analysis are presented in Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*. This analysis is essentially an approximation of potential entrainment of phytoplankton carbon load that could be entrained by the north Delta intakes. Factors that could offset any potential effects to delta smelt include the in situ productivity of phytoplankton carbon within the Delta, which could be relatively large, and reduced entrainment of phytoplankton carbon by the south Delta export facilities under the project alternatives. In addition, per the analysis by Hammock et al. (2019a), increases in hydraulic residence time could affect phytoplankton production. These factors are discussed qualitatively below.

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[43] Note that Hammock et al.'s (2019a) analysis simulated a scenario of historical water operations including south Delta exports compared to scenarios of historical water operations excluding south Delta exports or limiting south Delta exports to very low levels observed during the 1977 drought; however, the analysis did not account for other changes in water operations that would be associated with cessation or limitation of south Delta exports, in particular reductions in Delta inflow given ceased or limited demand for south Delta exports. Note also that Hammock et al. (2019a) focused more residence time effects as opposed to direct entrainment.

The analysis of potential north Delta intake entrainment of phytoplankton carbon estimated that the NDD could entrain between 0% and just over 8% of the Delta standing stock of phytoplankton carbon; the upper estimates are for Alternatives 2a and 4a during December under the assumption of a minimum Delta phytoplankton carbon stock size (Tables 12-109, 12-110, 12-111, 12-112, and 12-113). Overall, the estimates of potential phytoplankton carbon entrained were low, and on the basis of the 95th percentiles, entrainment would rarely be more than 5% of the standing stock under any project alternative. This low level of entrainment of phytoplankton carbon entering the Delta, coupled with observations that in situ production of phytoplankton carbon within the Delta is several times greater than inputs from freshwater inflow (Jassby et al. 2002) and is the dominant supply to the planktonic foodweb that includes delta smelt (Sobczak et al. 2002), suggests that the potential for effects on delta smelt would be very limited, particularly given the larger scale of losses to the foodweb including clams (Jassby et al. 2002). In addition, less south Delta exports under the alternatives would allow a greater proportion of San Joaquin River water to reach the western Delta and Suisun Bay, which could result in an increase in productivity because San Joaquin River water entering the Delta has a much higher load of organic matter than the Sacramento River (Jassby and Cloern 2000), but this contribution would likely be small because San Joaquin River water generally makes up a very small proportion of the water in the portions of the Delta where delta smelt are more likely to occur.[44] Jassby et al. (2002) estimated that on average during spring through fall, the Delta produces 44 metric tons per day of phytoplankton carbon and another 12 metric tons per day flows into the Delta from its tributaries. Of that 56 tons per day, the south Delta export facilities remove approximately 8 metric tons per day, or about 14% (Jassby et al. 2002). However, as noted above in relation to QWEST flows, differences between the project alternatives and existing conditions would be small.

Table 12-109. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size, Alternatives 1 and 3

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
January	0.0%	0.7%	3.8%	0.0%	0.3%	1.7%
February	0.0%	0.5%	3.3%	0.0%	0.3%	1.8%
March	0.0%	0.4%	2.3%	0.0%	0.2%	1.1%
April	0.0%	0.0%	1.6%	0.0%	0.0%	0.5%
May	0.0%	0.0%	1.9%	0.0%	0.0%	0.4%
June	0.0%	0.0%	1.7%	0.0%	0.0%	0.8%
July	0.0%	0.0%	1.6%	0.0%	0.0%	0.7%
August	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%
September	0.0%	0.0%	1.3%	0.0%	0.0%	0.4%
October	0.0%	0.0%	0.9%	0.0%	0.0%	0.2%
November	0.0%	0.0%	1.8%	0.0%	0.0%	0.6%

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[44] For example, the DSM2 fingerprinting analysis used in the *Selenium* analysis described below had water year-type means of San Joaquin River percentage of water at Chipps Island ranging from a minimum of 0.02% to a maximum of 7.5% for existing conditions; the alternatives had minima of 0.03% and maxima of 7.8% during these periods, indicating that San Joaquin River water would be limited under existing conditions and the alternatives.

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
December	0.0%	0.9%	7.4%	0.0%	0.2%	1.4%

Note: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

Table 12-110. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size, Alternatives 2a and 4a

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
January	0.0%	0.8%	4.2%	0.0%	0.4%	1.9%
February	0.0%	0.5%	3.5%	0.0%	0.3%	2.0%
March	0.0%	0.5%	2.6%	0.0%	0.2%	1.2%
April	0.0%	0.0%	1.7%	0.0%	0.0%	0.5%
May	0.0%	0.0%	1.9%	0.0%	0.0%	0.4%
June	0.0%	0.0%	1.7%	0.0%	0.0%	0.8%
July	0.0%	0.0%	1.5%	0.0%	0.0%	0.7%
August	0.0%	0.0%	0.3%	0.0%	0.0%	0.2%
September	0.0%	0.0%	1.3%	0.0%	0.0%	0.4%
October	0.0%	0.0%	0.8%	0.0%	0.0%	0.2%
November	0.0%	0.0%	1.9%	0.0%	0.0%	0.7%
December	0.0%	0.9%	8.2%	0.0%	0.2%	1.5%

Note: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

Table 12-111. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size, Alternatives 2b and 4b

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
January	0.0%	0.6%	2.3%	0.0%	0.3%	1.0%
February	0.0%	0.5%	2.0%	0.0%	0.3%	1.1%
March	0.0%	0.4%	1.5%	0.0%	0.2%	0.7%
April	0.0%	0.0%	1.1%	0.0%	0.0%	0.3%
May	0.0%	0.0%	1.8%	0.0%	0.0%	0.4%
June	0.0%	0.0%	1.4%	0.0%	0.0%	0.6%
July	0.0%	0.0%	1.2%	0.0%	0.0%	0.5%

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
August	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%
September	0.0%	0.0%	1.1%	0.0%	0.0%	0.3%
October	0.0%	0.0%	0.8%	0.0%	0.0%	0.2%
November	0.0%	0.0%	1.3%	0.0%	0.0%	0.5%
December	0.0%	0.9%	4.4%	0.0%	0.2%	0.8%

Note: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

Table 12-112. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size, Alternatives 2c and 4c

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
January	0.0%	0.7%	3.2%	0.0%	0.3%	1.4%
February	0.0%	0.6%	2.8%	0.0%	0.3%	1.6%
March	0.0%	0.4%	2.1%	0.0%	0.2%	1.0%
April	0.0%	0.0%	1.6%	0.0%	0.0%	0.5%
May	0.0%	0.0%	1.8%	0.0%	0.0%	0.4%
June	0.0%	0.0%	1.6%	0.0%	0.0%	0.7%
July	0.0%	0.0%	1.6%	0.0%	0.0%	0.7%
August	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%
September	0.0%	0.0%	1.2%	0.0%	0.0%	0.4%
October	0.0%	0.0%	0.8%	0.0%	0.0%	0.2%
November	0.0%	0.0%	1.6%	0.0%	0.0%	0.6%
December	0.0%	0.9%	6.0%	0.0%	0.2%	1.1%

Note: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

Table 12-113. Estimated 5th, 50th, and 95th Percentile Entrainment of Phytoplankton Carbon at the North Delta Diversions Based on Minimum and Maximum Delta Phytoplankton Carbon Stock Size, Alternative 5

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
January	0.0%	0.7%	3.9%	0.0%	0.3%	1.7%
February	0.0%	0.6%	3.3%	0.0%	0.3%	1.9%
March	0.0%	0.5%	2.4%	0.0%	0.2%	1.1%

Month	Min. Stock Size: 5th Percentile Entrainment	Min. Stock Size: 50th Percentile Entrainment	Min. Stock Size: 95th Percentile Entrainment	Max. Stock Size: 5th Percentile Entrainment	Max. Stock Size: 50th Percentile Entrainment	Max. Stock Size: 95th Percentile Entrainment
April	0.0%	0.0%	1.6%	0.0%	0.0%	0.5%
May	0.0%	0.0%	1.9%	0.0%	0.0%	0.4%
June	0.0%	0.0%	1.8%	0.0%	0.0%	0.8%
July	0.0%	0.0%	1.6%	0.0%	0.0%	0.7%
August	0.0%	0.0%	0.4%	0.0%	0.0%	0.2%
September	0.0%	0.0%	1.3%	0.0%	0.0%	0.4%
October	0.0%	0.0%	0.9%	0.0%	0.0%	0.2%
November	0.0%	0.0%	1.8%	0.0%	0.0%	0.7%
December	0.0%	0.9%	7.4%	0.0%	0.2%	1.4%

Note: Max. and min. stock size = maximum and minimum stock size based on multiplying observed maximum and minimum phytoplankton carbon density at Antioch by the volume of the Delta. Entrainment percentiles represent the range of entrainment based on modeled north Delta intake diversion rates (Appendix 12B, Section 12B.14, *Phytoplankton Carbon Entrainment by North Delta Diversions*).

As previously noted, increases in residence time have been correlated with increases in phytoplankton, although this relationship may vary depending on the amount of Sacramento River flow (Hammock et al. 2019a). Lower Sacramento River flow downstream of the north Delta intakes under the alternatives would be expected to increase residence time relative to existing conditions, although it is uncertain the extent to which this might translate to increases in phytoplankton. As shown in Chapter 9, *Water Quality*, modeled increases in residence time (Table 9-19 in Chapter 9) were not determined to result in significant increases in CHABs, albeit with considerable uncertainty.

Summer-Fall Low Salinity Habitat Extent and Related Factors

The IEP MAST (2015) conceptual model posits that delta smelt abundance, survival, and growth are affected by the size and location of the low salinity zone during fall, with IEP MAST (2015:142) concluding: “The limited amount of available data provides some evidence in support of this hypothesis, but additional years of data and investigations are needed.” Others have found that low salinity zone habitat may not be a good predictor of delta smelt survival (ICF 2017:128), with the recent life cycle modeling effort by Polansky et al. (2021) finding that the area of low-salinity habitat was not among the predictors with highest evidence for relationships to trends in delta smelt population abundance indices. As described by DWR (2020a:4-156), an additional argument in support of summer-fall habitat actions potentially being of importance to delta smelt is that having a broader distribution provides “bet-hedging” against the effects of environmental stressors. For example, if a species’ distribution is too constrained, the risk of a population not being able to persist is elevated as compared to a broader distribution (Thorson et al. 2014). Hence, habitat actions that help support a broad distribution can have long-term population benefits. This logic is somewhat different than the goal of maximizing physical habitat area. The issue of the area of low-salinity habitat extent or related parameters such as Delta outflow and X2 and their relationship to delta smelt population dynamics is controversial and has been investigated by a number of authors (e.g., Feyrer et al. 2011; Miller et al. 2012; Manly et al. 2015; Feyrer et al. 2015a; Murphy and Weiland 2019). Hamilton and Murphy’s (2018) review of prior studies noted that freshwater flow had not been found to have a direct association with delta smelt abundance. However, the recent state-space nonlinear modeling investigation by Polansky et al. (2021) found relatively strong statistical support for June–August Delta outflow being positively correlated to June–August survival (further shown by Smith et al. 2021), and September–November X2 being negatively correlated to the subsequent year's recruitment (adult to larval survival).[45]

Existing conditions and all project alternatives include structured decision-making to implement the Delta Smelt Summer-Fall Habitat Action (i.e., an assumed continuation of the existing program), which is intended to improve delta smelt food supply and habitat, thereby contributing to the recruitment, growth, and survival of the species. The potential effects of the Delta Smelt Summer-Fall Habitat Action on delta smelt were recently analyzed by DWR (2020a:5-123–5-125), which found that the extent of low-salinity habitat for delta smelt would not be lower under the adopted project than under the then existing condition (i.e., management to the 2008 USFWS biological opinion). Continuation of the Delta Smelt Summer-Fall Habitat Action under the project alternatives would continue the provision of low salinity habitat to a similar extent as existing conditions. An additional indicator of delta smelt summer-fall habitat is provided by the frequency of occurrence of X2 less than 85 kilometers, indicating that low-salinity water (i.e., 0.5 to 6 parts per thousand salinity; Delta Modeling Associates 2014:1) would be overlapping physically larger habitat areas in Honker Bay (U.S. Fish and Wildlife Service 2017:307–317). CalSim modeling indicates that the frequency of occurrence of low salinity water in Honker Bay under the alternatives generally would be similar to existing conditions, with minor (2%–8%) reductions in October–December (Table 12-114) caused by less outflow needed for meeting Delta salinity requirements under the project alternatives.

Table 12-114. Percentage of Years with X2 Less than 85 km (Low Salinity Zone within Honker Bay), June–December

Month	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
June	94%	94% (0%)	94% (0%)	94% (0%)	94% (0%)	94% (0%)
July	77%	76% (-1%)	76% (-1%)	76% (-1%)	76% (-1%)	76% (-1%)
August	45%	45% (0%)	45% (0%)	45% (0%)	45% (0%)	45% (0%)
September	45%	45% (0%)	45% (0%)	45% (0%)	45% (0%)	45% (0%)
October	49%	48% (-2%)	48% (-2%)	48% (-2%)	47% (-4%)	48% (-2%)
November	41%	39% (-5%)	40% (-3%)	39% (-5%)	38% (-8%)	39% (-5%)
December	50%	49% (-2%)	49% (-2%)	49% (-2%)	49% (-2%)	49% (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions; km = kilometers.

As previously described above, the recent investigation by Polansky et al. (2021) found relatively strong statistical support for June–August Delta outflow being positively correlated to June–August survival, and for September–November X2 being negatively correlated to the subsequent year's

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[45] As illustrated by plots of the predicted relationship with associated credible intervals from statistical modeling (Polansky et al. 2021: Figures 1 and C.1), there is appreciable statistical uncertainty in the relationships, which are based on annual mean values across water years. September–November X2 thus was not included in the modeling effort by Smith et al. (2021), which focused only on the relationships found by Polansky et al. (2021) to have the most evidence of having an effect in the hypothesized direction.

recruitment (adult to larval survival).[46] As previously described in the analysis of food availability effects, Delta outflow tends to be similar or lower under the project alternatives compared to existing conditions (Tables 12-99, 12-100, and 12-101) as a result of less outflow needed for meeting Delta salinity requirements under the project alternatives. Mean September–November X2 under the project alternatives is similar to or up to 0.6 mile (0.9 km) upstream under the project alternatives relative to existing conditions (Table 12-115), again as a result of less outflow needed for meeting Delta salinity requirements under the project alternatives.

Table 12-115. Mean September–November X2 By Water Year Type

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	79.0	79.3 (0.3)	79.3 (0.3)	79.2 (0.3)	79.3 (0.3)	79.3 (0.4)
Above normal	80.5	80.6 (0.1)	80.6 (0.1)	80.6 (0.1)	80.6 (0.1)	80.6 (0.1)
Below normal	87.6	88.3 (0.8)	88.3 (0.7)	88.4 (0.9)	88.5 (1.0)	88.3 (0.8)
Dry	91.1	91.4 (0.3)	91.4 (0.3)	91.4 (0.3)	91.3 (0.3)	91.4 (0.3)
Critically dry	93.1	93.2 (0.1)	93.2 (0.1)	93.2 (0.0)	93.2 (0.1)	93.2 (0.1)

Note: Values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions; km = kilometers.

Predation

As previously noted above in the discussion of sediment entrainment, the IEP MAST conceptual model (2015:87–89) suggests that the probability of delta smelt surviving to subsequent life stages is influenced by predation risk, which may involve different factors such as turbidity, water temperature, and predators. With respect to turbidity, as discussed above, although the north Delta intakes would entrain sediment, effects may be limited by future increases in sediment entering the Delta relative to existing conditions. Water operations such as reservoir releases or diversions have limited potential to affect water temperature in the Delta (Kimmerer 2004; Wagner et al. 2011; see Tables 12-16, 12-36, and 12-37 in Impact AQUA-2), thereby resulting in differences in water operations between existing conditions and water temperature having limited potential to affect predation risk as a result of temperature effects.

Detection of predation on delta smelt embryos and larvae is rare, which reduces the certainty of any conclusions of analyses of predation, although Mississippi silversides have been found with delta smelt DNA in their guts during the delta smelt larval period (Schreier et al. 2016). Two recent statistical examinations found support for silverside abundance negatively affecting delta smelt survival and abundance (Hamilton and Murphy 2018; Polansky et al. 2021). For this impact assessment, inference of potential effects from the alternatives on silversides is made using multivariate relationships identified by Mahardja et al. (2016), which showed summer (June–September) Delta inflow and spring (March–May) south Delta exports had the strongest correlations with silverside cohort strength. Both relationships were negative. Mahardja et al. (2016:12) cautioned that the relationships are not meant to imply causality, given that the mechanisms could not be identified, and that further investigation is merited. Nonetheless, March–May south Delta exports under the project alternatives generally would be similar or slightly lower (in wet years)

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[46] As previously noted, and as illustrated by plots of the predicted relationship with associated credible intervals from statistical modeling (Polansky et al. 2021: Figures 1 and C.1), there is appreciable statistical uncertainty in the relationships, which are based on annual mean values across water years.

than under existing conditions (Table 12-116), which could result in similar or slightly higher silverside cohort strength than existing conditions based on the results of Mahardja et al. (2016). June–September Delta inflow under the alternatives is similar to existing conditions (Table 12-117). Differences in south Delta exports may have the potential to increase silverside cohort strength under the project alternatives relative to existing conditions in wet years, although, as noted above, there is appreciable uncertainty given that the relationship is correlative rather than causal and the differences in outflow are not very large; higher flow conditions during sampling could have caused lower capture efficiency or a shift of the species downstream out of the sampling area rather than lower population abundance, for example (Mahardja et al. 2016:12–13). If there were increases in silversides as a result of changes in south Delta exports under the alternatives, this could also affect prey for delta smelt given the overlap in prey between delta smelt and silversides (e.g., *E. affinis*; Cohen and Bollens 2008).

Table 12-116. Mean South Delta Exports (cubic feet per second) by Water Year Type, March–May

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7,104	6,838 (-4%)	6,806 (-4%)	6,974 (-2%)	6,875 (-3%)	6,831 (-4%)
Above normal	5,309	5,277 (-1%)	5,314 (0%)	5,326 (0%)	5,250 (-1%)	5,277 (-1%)
Below normal	4,229	4,274 (1%)	4,290 (1%)	4,265 (1%)	4,276 (1%)	4,274 (1%)
Dry	3,673	3,675 (0%)	3,676 (0%)	3,668 (0%)	3,681 (0%)	3,675 (0%)
Critically dry	3,024	2,984 (-1%)	2,967 (-2%)	3,012 (0%)	3,004 (-1%)	2,986 (-1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-117. Mean Delta Inflow (cubic feet per second) by Water Year Type, June–September

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	25,915	25,809 (0%)	25,814 (0%)	25,820 (0%)	25,825 (0%)	25,809 (0%)
Above normal	22,444	22,171 (-1%)	22,200 (-1%)	22,184 (-1%)	22,139 (-1%)	22,182 (-1%)
Below normal	18,053	17,788 (-1%)	17,805 (-1%)	17,852 (-1%)	17,804 (-1%)	17,806 (-1%)
Dry	14,306	14,362 (0%)	14,269 (0%)	14,363 (0%)	14,403 (1%)	14,372 (0%)
Critically dry	10,061	10,113 (1%)	10,093 (0%)	10,077 (0%)	10,122 (1%)	10,112 (1%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The Sacramento River flow term in the Delta inflow calculation is downstream of the NDD.

Alt = alternative; EC = existing conditions.

There is statistical evidence for striped bass abundance being negatively related to delta smelt survival (Polansky et al. 2021; see also Nobriga and Smith 2020), but as discussed further below in Impact AQUA-14: *Effects of Operations and Maintenance of Water Conveyance Facilities on Striped Bass*, the project alternatives would not result in increases in striped bass abundance and therefore would not increase predation risk for delta smelt.

Cyanobacteria Harmful Algal Blooms

The IEP MAST (2015:88–89) conceptual model posits a linkage between various factors (nutrients, summer hydrology, and air temperature) and toxicity from harmful algal blooms to delta smelt and their prey. Analyses conducted for Impact WQ-14 in Chapter 9 showed that operational changes in CHABs are concluded to be less than significant and therefore would not significantly affect delta smelt or their prey.

Selenium

The increase in the proportion of San Joaquin River water entering the Delta because of less south Delta exports under the project alternatives relative to existing conditions would be expected to increase the selenium concentration in Delta water because the San Joaquin River is relatively high in selenium. (See additional discussion of selenium in Chapter 9, *Water Quality*.) The potential for this change to affect delta smelt through body deformities resulting from feeding on contaminated prey was investigated using the results of DSM2 volumetric fingerprinting estimates, Delta water source selenium input concentrations, conversions of water selenium concentration to particulate selenium concentration, and trophic transfer factors to estimate the concentration of selenium from delta smelt copepod prey to delta smelt tissue (see method description in Appendix 12B, Section 12B.15, *Delta Smelt Selenium Bioaccumulation*). As described in Appendix 12B, this analysis has a number of assumptions leading to uncertainty in the results, including that the selenium toxicity threshold for Sacramento splittail (7.2 micrograms per gram [µg/g] selenium whole-body tissue concentration; Rigby et al. 2010) is representative of delta smelt, and the uncertainty around the concentration of selenium in the diet that results in toxic effects.

The results of the analysis indicated that although there could be very minor increases in selenium body tissue concentration as a result of the project alternatives (e.g., differences in mean tissue concentration of less than 0.01 µg/g), there would be no exceedances of the 7.2–µg/g selenium whole-body tissue concentration used to assess the potential for deformities. The maximum estimated selenium concentration at the conservatively high selenium particulate to water ratio (K_d) of 6,000 resulted in maximum whole body selenium concentration for existing conditions and all alternatives ranging from 1.5 µg/g in the San Joaquin River at Antioch to 2.0 µg/g at Cache Slough at Ryer Island, indicating that even maximum selenium tissue estimates were several times lower than the threshold for potential deformities to occur. This indicates very little potential for negative effects on delta smelt.

Maintenance Effects

Maintenance of the north Delta intake facilities for each project alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on delta smelt. According to the Intakes Operations and Maintenance Equipment and Facility Needs Technical Memorandum (Delta Conveyance Design and Construction Authority 2022i:11), for cleaning purposes, the cylindrical tee screens would be lifted out of the water with the intake's gantry crane and may be fixed at the top of the guide rail before being washed with high-pressure mobile power washer. This process would occur approximately every 6 months and last approximately 15 days at each 3,000-cfs intake and 8 days at each 1,500-cfs intake, with approximately one hour of washing for each screen at each intake. This washing process may cause removed sediment and aquatic growth or vegetation to reenter the river, resulting in redistribution by river currents, and minimal effects to the river and species such as delta smelt because of the very small amount of material compared to the size of the receiving waterbody. In general, the velocity through the cylindrical tee screen system and piping should be sufficient to keep sediment moving until it reaches the settling basins (Delta Conveyance Design and Construction Authority 2022i:13). Sediment jetting would only be required at the base of the screen structure to help keep sediment from accumulating beneath the screens; this jetting would be done frequently (hourly to daily, depending on needs), thereby resulting in minimal changes to suspended sediment/turbidity, with sediment jetted from the screen rapidly dispersing within the river channel and, therefore, having very limited or no effects on any delta smelt occurring in the vicinity. Before the screen units are lifted up to the deck for cleaning, solid panels would be installed behind the screen in the back guide rail for the unit being cleaned. These panels would seal off that unit's intake area from diversions, so there would be no potential to divert water through an unscreened area while the screen is being cleaned and therefore no risk of fish entrainment.

CEQA Conclusion—All Project Alternatives

The analyses above suggested potential negative effects to a very small proportion of the delta smelt population from near-field effects of the north Delta intakes, including possible limitation of access to critical and other habitat within the species' range upstream of the north Delta intakes caused by the presence of the fish screen structures. However, as discussed above and illustrated by 2D modeling, there appears to be a large amount of nearshore habitat with suitable velocity for adult upstream migrating delta smelt, and delta smelt could also seek lower velocity habitat near the river bottom. The screen structures themselves also could provide velocity refuge. Delta smelt upstream migration could also be focused during periods with lower velocity suitable for migration. There is no evidence that delta smelt upstream migration was reduced by construction and operation of the Freeport Regional Water Authority Intake, a flat screen albeit shorter facility than the proposed north Delta intakes. As previously noted, the field study program would inform the extent to which access was affected. Other near-field effects such as entrainment of delta smelt larvae would be very limited, firstly by the low proportion of the population occurring in the area, and secondly because the north Delta intake operations in the key spring months with greatest larval entrainment risk would be relatively limited (e.g., median percentage diversion in April and May = 0%). South Delta entrainment risk would be similar between the project alternatives and existing conditions, with the project alternatives and existing conditions all including the current operational criteria under federal and state water project permits.

The effects analysis estimated long-term sediment entrainment by the north Delta intakes of 4%–5% of load entering the Delta from the Sacramento River. Sediment from the Sacramento River contributes approximately 66% of the total load entering the Delta (Wright and Schoellhamer 2005), suggesting that the north Delta intakes could reduce the load entering the Delta by approximately 2.7%–4%. This relatively low percentage is not concluded to be a significant impact through reduction in available sediment for resuspension to create turbid delta smelt habitat. As discussed above in the impact analysis, the projected increase in sediment entering the Delta over time from future climate change has the potential to result in more sediment entering the Delta than existing conditions. Given the importance of sediment as a component of delta smelt habitat (particularly when resuspended to create greater turbidity), Environmental Commitment EC-15 *Sediment Monitoring, Modeling, and Reintroduction Adaptive Management* would include study and adaptive management related to entrainment of sediment by the north Delta intakes.

The extent of summer-fall low salinity rearing habitat for delta smelt would be similar under the project alternatives and existing conditions because the project alternatives and existing conditions include the Delta Smelt Summer-Fall Habitat Action and generally have a similar percentage of years with the low salinity zone within Honker Bay. The impact thus would be less than significant on low salinity rearing habitat. The analysis of selenium bioaccumulation as a result of operations indicated that there would be a less-than-significant impact because any increase under the project alternatives relative to existing conditions would be well below potentially harmful thresholds, albeit with some uncertainty given the use of a proxy species' (Sacramento splittail) threshold. Analyses conducted for Impact WQ-14 in Chapter 9 showed that operational changes in CHABs are concluded to be less than significant and therefore would not significantly affect delta smelt or their prey. Maintenance of the north Delta intakes (e.g., screen washing; sediment jetting) also would have less-than-significant effects on delta smelt.

There is generally somewhat less Delta outflow under the project alternatives than existing conditions during spring–fall as a result of less outflow being needed for meeting Delta salinity requirements. There is considerable uncertainty in the potential for negative effects to delta smelt food availability, predation, and recruitment as a result of these changes in Delta outflow, which are within the existing parameters of current regulations (e.g., D-1641; federal and state water project permits). Given the existing all-time low abundance indices of delta smelt, the impacts are concluded to be significant. Tidal habitat restoration of approximately 1,100-1,400 acres under Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-27 (Attachment 3F-1, Table 3F.1-3), would mitigate these impacts. Restoration would increase the extent of suitable delta smelt habitat (e.g., intertidal and subtidal habitat; California Department of Fish and Game 2011) with appropriate parameters (e.g., turbidity) providing habitat for occupancy (e.g., Sommer and Mejia 2013) or higher food availability in the vicinity (e.g., Hammock et al. 2019b). The impact would be less than significant with mitigation (see also the *Compensatory Mitigation* discussion of the *Mitigation Impacts* section below).

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-27: *Tidal Habitat Restoration for Operations Impacts on Delta Smelt* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Impacts

<u>*Compensatory Mitigation*</u>

Implementation of the Compensatory Mitigation Plan could result in impacts on delta smelt as analyzed in this chapter. Restoration of tidal perennial habitat, shallow water habitat, or channel margin habitat as compensatory mitigation has the potential to affect delta smelt.

Following completion of compensatory mitigation, restored tidal habitat areas would have positive effects on delta smelt. Such effects include greater habitat extent (e.g., as shown for Liberty Island in the north Delta; Sommer and Mejia 2013) and greater food availability on-site or in nearby areas (Hammock et al. 2019b) but not at larger spatial scales such as in other regions of the Delta (Herbold et al. 2014; Hartman et al. 2017; Kimmerer et al. 2018b). Efficacy monitoring would assess the degree to which positive effects are occurring and inform adjustment to sites as necessary to increase positive effects. Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs. The effects of compensatory mitigation on delta smelt would be less than significant.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on delta smelt during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact delta smelt during operation and maintenance, and there would be no impact.

Overall, the impact on delta smelt during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less than significant with mitigation impact conclusion.

No Project Alternative

At 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. At 2040 climate, Old and Middle River flows during December–June, an indicator of adult/larval/early juvenile delta smelt south Delta entrainment risk, generally would be similar or greater under the No Project Alternative compared to existing conditions (Tables 12-119, 12-120, 12-121, 12-122, 12-123, 12-124, and 12-125). The results of larval/early juvenile entrainment analysis with DSM2-PTM gave similar or lower entrainment under the No Project Alternative relative to existing conditions. This, coupled with the same regulations to limit delta smelt entrainment loss (e.g., the California Department of Fish and Wildlife [2020a] ITP) indicate that delta smelt south Delta entrainment risk would not be greater under the No Project Alternative compared to existing conditions. As noted in the analysis of the project alternatives, there is considerable uncertainty in estimates of flow-related changes on factors such as delta smelt food availability or predation. Nevertheless, climate change-related reductions in spring Delta outflow and sea level rise result in predictions of lower smelt zooplankton prey *E. affinis* than existing conditions (Table 12-126). Other indicators of delta smelt prey availability suggested potential for mixed effects, e.g., less Delta outflow in June and July of wetter years (Tables 12-127 and 12-128), with other summer/fall months/water year types having lower, similar, or greater Delta outflow (Tables 12-129, 12-130, and 12-131); whereas the incidence of positive QWEST flow under the No Project Alternative was considerably greater than existing conditions (Table 12-132), suggesting greater potential for *P. forbesi* subsidy from the lower San Joaquin River. As discussed for project alternatives, the recent investigation by Polansky et al. (2021) found relatively strong statistical support for June–August Delta outflow being positively correlated to June–August survival, and for September–November X2 being negatively correlated to the subsequent year's recruitment (adult to larval survival). During June–December, the No Project Alternative generally would have less overlap of the low salinity zone with Honker Bay compared to existing conditions (Table 12-133). The CalSim modeling generally indicated the potential for lower June–August survival and subsequent recruitment based on lower Delta outflow and greater X2 under the No Project Alternative compared to existing conditions (Tables 12-127, 12-128, 12-129, and 12-134). As described for the project alternatives, March–May south Delta exports and June–September Delta inflow are statistically related to predatory silverside abundance. Under the No Project Alternative, both March–May south Delta exports (Table 12-135) and June–September inflow (Table 12-136) would be less than existing conditions, which would suggest the potential for greater silverside abundance under the No Project Alternative. As previously noted, there is considerable uncertainty in the potential flow-related effects on food, survival/recruitment, and predators of delta smelt, as described for the analysis of the project alternatives. Water temperature would be higher under the

No Project Alternative than existing conditions (Table 12-47 in Impact AQUA-2), reflecting climate change assumptions (Appendix 5A, Section B, Attachment 4, *Climate Change Development for Delta Conveyance Project*), and would decrease habitat suitability for delta smelt (e.g., mean July temperature at Rio Vista under the No Project Alternative would be more often above the 21.9-°C threshold dividing adequate and unsuitable habitat per the affinity analysis of Hamilton and Murphy [2020]). Analyses in Appendix 9L found that CHABs would be expected to occur with similar or greater frequency throughout the study area for the No Project Alternative, relative to existing conditions, as a result of climate change. The results of the selenium analyses presented above and in Appendix 12C found no exceedance in the threshold for physical deformities for either existing conditions or the No Project Alternative.

Table 12-119. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, December, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-5,229	-4,529 (13%)
Above normal	-6,900	-6,035 (13%)
Below normal	-6,249	-5,626 (10%)
Dry	-5,666	-5,493 (3%)
Critically dry	-4,281	-3,992 (7%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-120. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, January, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-2,972	-2,552 (14%)
Above normal	-4,274	-4,211 (1%)
Below normal	-4,393	-4,358 (1%)
Dry	-4,812	-4,765 (1%)
Critically dry	-4,303	-3,861 (10%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-121. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, February, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-3,029	-2,224 (27%)
Above normal	-3,712	-3,214 (13%)
Below normal	-4,460	-3,769 (15%)
Dry	-4,516	-4,496 (0%)

Water Year Type	EC	NPA
Critically dry	-4,350	-3,410 (22%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-122. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, March, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-1,289	-559 (57%)
Above normal	-2,916	-2,780 (5%)
Below normal	-3,383	-3,185 (6%)
Dry	-3,292	-2,529 (23%)
Critically dry	-3,001	-2,529 (16%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-123. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, April, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-951	-323 (66%)
Above normal	-1,531	-1,502 (2%)
Below normal	-1,715	-1,477 (14%)
Dry	-1,813	-1,353 (25%)
Critically dry	-1,181	-721 (39%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-124. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, May, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-1,555	-588 (62%)
Above normal	-2,397	-1,668 (30%)
Below normal	-1,882	-998 (47%)
Dry	-2,028	-555 (73%)
Critically dry	-1,710	-986 (42%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-125. Mean Old and Middle River Flow (cubic feet per second) by Water Year Type, June, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	-4,411	-4,221 (4%)
Above normal	-4,953	-4,590 (7%)
Below normal	-4,899	-4,803 (2%)
Dry	-4,750	-3,909 (18%)
Critically dry	-2,084	-1,801 (14%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-126. Mean *Eurytemora affinis* Density (adults per cubic meter) in the Low Salinity Zone by Water Year Type, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	185	155 (-16%)
Above normal	159	140 (-12%)
Below normal	121	115 (-6%)
Dry	102	102 (0%)
Critically dry	79	79 (0%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not predictions of actual values and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions.

Table 12-127. Mean Delta Outflow (cubic feet per second) by Water Year Type, June, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	22,071	11,896 (-46%)
Above normal	14,252	9,609 (-33%)
Below normal	6,679	6,475 (-3%)
Dry	6,112	6,052 (-1%)
Critically dry	5,462	5,905 (8%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-128. Mean Delta Outflow (cubic feet per second) by Water Year Type, July, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	9,821	7,839 (-20%)
Above normal	8,038	7,297 (-9%)
Below normal	6,397	5,399 (-16%)
Dry	4,273	4,589 (7%)
Critically dry	3,566	3,442 (-3%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-129. Mean Delta Outflow (cubic feet per second) by Water Year Type, August, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	5,696	5,046 (-11%)
Above normal	5,246	5,129 (-2%)
Below normal	3,391	3,362 (-1%)
Dry	3,139	3,593 (14%)
Critically dry	2,573	3,024 (18%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-130. Mean Delta Outflow (cubic feet per second) by Water Year Type, September, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	10,347	11,525 (11%)
Above normal	9,682	10,874 (12%)
Below normal	3,515	3,197 (-9%)
Dry	2,641	2,215 (-16%)
Critically dry	2,608	2,335 (-10%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-131. Mean Delta Outflow (cubic feet per second) by Water Year Type, October, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	8,004	7,656 (-4%)

Water Year Type	EC	NPA
Above normal	6,084	6,795 (12%)
Below normal	5,981	5,997 (0%)
Dry	5,168	5,723 (11%)
Critically dry	4,068	3,961 (-3%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-132. Percentage of Years with Positive QWEST Flow, July–October, Comparing No Project Alternative to Exiting Conditions

Month	EC	NPA
July	28%	55% (100%)
August	29%	51% (78%)
September	45%	64% (43%)
October	47%	78% (66%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-133. Percentage of Years with X2 Less than 85 km (Low Salinity Zone within Honker Bay), June–December, Comparing No Project Alternative to Existing Conditions

Month	EC	NPA
June	94%	90% (-3%)
July	77%	49% (-36%)
August	45%	37% (-17%)
September	45%	45% (0%)
October	49%	48% (-2%)
November	41%	22% (-46%)
December	50%	54% (9%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions (these are percentage point differences as opposed to absolute percentage differences). Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions; km = kilometers.

Table 12-134. Mean September–November X2 By Water Year Type, Comparing No Project Alternative to Existing Conditions

Month	EC	NPA
Wet	79.0	80.6 (1.6)
Above normal	80.5	82.0 (1.5)

Month	EC	NPA
Below normal	87.6	89.8 (2.2)
Dry	91.1	92.7 (1.6)
Critically dry	93.1	93.5 (0.4)

Note: Values in parentheses indicate differences of No Project Alternative compared to existing conditions (kilometers).

NPA = No Project Alternative; EC = existing conditions; km = kilometers.

Table 12-135. Mean South Delta Exports (cubic feet per second) by Water Year Type, March–May, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7,104	6,710 (-6%)
Above normal	5,309	5,136 (-3%)
Below normal	4,229	3,808 (-10%)
Dry	3,673	2,705 (-26%)
Critically dry	3,024	2,440 (-19%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

NPA = No Project Alternative; EC = existing conditions.

Table 12-136. Mean Delta Inflow (cubic feet per second) by Water Year Type, June–September, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	25,915	20,865 (-19%)
Above normal	22,444	18,370 (-18%)
Below normal	18,053	14,700 (-19%)
Dry	14,306	11,846 (-17%)
Critically dry	10,061	9,892 (-2%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. The Sacramento River flow term in the Delta inflow calculation is downstream of the NDD.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-7: Effects of Operations and Maintenance of Water Conveyance Facilities on Longfin Smelt

Operations and Maintenance—All Project Alternatives

As with delta smelt, potential effects are discussed in terms of near-field effects of north Delta exports and south Delta exports (e.g., entrainment), in addition to far-field habitat effects (changes to food availability and Delta outflow-abundance effects). Analyses were developed in consideration of factors assessed to be of importance to the species based on available literature, including conceptual models (e.g., Baxter et al. 2010) and best available methods (e.g., ICF International

2016b; California Department of Water Resources 2020a). A summary of methods is provided in Table 12-3.

North Delta Exports

Longfin smelt could experience somewhat similar effects from the north Delta intakes as previously discussed for delta smelt, that is, reduction in potential to migrate upstream, predation, entrainment, and impingement leading to death or injury. (Longfin smelt adults are larger than delta smelt adults, however, and therefore probably would be less susceptible to reduction in upstream migration potential because of greater swimming ability.) However, should such effects occur, they would affect an even smaller proportion of the longfin smelt population than delta smelt because the species occurs farther downstream than delta smelt. The beach seine sampling discussed previously for delta smelt (see Table 12-87) collected only two longfin smelt during December–June 2012–2021, both at the most downstream station (SR012W (Sandy Beach)). This is consistent with previous analyses showing that longfin smelt have never been frequently collected in the vicinity of the north Delta intakes based on available sampling (ICF International 2016b:4-269–4-272).

South Delta Exports

There is the potential for adult longfin smelt entrainment to occur at the south Delta export facilities under existing conditions and the project alternatives, although take of adults is very limited relative to other life stages. Grimaldo et al. (2009) found that adult longfin smelt salvage at the South Delta export facilities was significantly negatively related to mean December–February OMR flows, but not to X2 (or other variables that were examined). As previously noted for delta smelt, modeled OMR flows are generally similar between existing conditions and the project alternatives, suggesting generally similar longfin smelt entrainment risk (Tables 12-89, 12-90, 12-91). Existing conditions and all project alternatives include OMR management from December 1 through February 28, during which time additional real-time consideration of adult longfin smelt entrainment risk is undertaken by DWR in association with CDFW and the Water Operations Management Team to provide entrainment protection for adult longfin smelt under the CDFW (2020a) ITP for the SWP.

Larval longfin smelt entrainment by the south Delta export facilities and other diversions could occur under existing conditions and the project alternatives, and winter (January–March) is of particular concern. A DSM2-PTM (particle tracking model) analysis was undertaken using the methods provided in Appendix 12B, Section 12B.16, *Longfin Smelt Larval Entrainment (DSM2 Particle Tracking Model)*. Staff observations from preliminary longfin smelt culture efforts at the UC Davis Fish Conservation and Culture Laboratory have suggested that larvae may not be buoyant in freshwater, but field studies found that they are buoyant in brackish water (California Department of Water Resources 2020a:4-181), which may add some uncertainty to the results from PTM analysis. Analysis of surface and neutrally buoyant particles provides information on two plausible behaviors, recognizing that the estimates are only order-of-magnitude comparisons that are best used in a relative fashion to compare different operational scenarios.

The DSM2-PTM results suggested that there would be relatively minor differences in the potential for entrainment of longfin smelt larvae between existing conditions and the project alternatives (Tables 12-137 and 12-138). Flux of particles into the south Delta was also generally similar, with somewhat larger relative differences arising because of the overall low absolute number of particles entering the south Delta (Tables 12-139 and 12-140). Such differences in particle entrainment primarily reflect hydrodynamic differences between the project alternatives and existing conditions in south Delta exports and Sacramento River inflow. Passage of particles past Chipps Island was also similar between the project alternatives and existing conditions (Table 12-141 and 12-142). Real-time operational measures required under the CDFW (2020a:81–84) ITP for the SWP are included in the existing conditions and the alternatives that manage OMR flows for the protection of longfin smelt. Although the estimates of entrainment are primarily intended to be used comparatively, the weightings applied in the modeling are intended to represent a realistic distribution of larvae in the Delta and downstream and therefore may provide some perspective on the magnitude of larval population loss, which is generally a low single-digit percentage (Tables 12-137 and 12-138). Note that these estimates may overestimate entrainment loss in very wet years because the Smelt Larval Survey weighting for particle starting distributions does not sample the full extent of downstream areas where the species is occurring (see Appendix 12B, Section 12B.16.3, *Note on Proportion of Larval Population outside the Delta and Suisun Marsh and Bay*).

Table 12-137. Entrainment of Neutrally Buoyant Particles at the South Delta Export Facilities and North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	1.76	1.86 (6%)	1.85 (6%)	1.81 (3%)	1.83 (4%)	1.85 (6%)
Above normal	3.17	3.32 (5%)	3.36 (6%)	3.26 (3%)	3.29 (4%)	3.33 (5%)
Below normal	5.97	6.23 (4%)	6.24 (5%)	6.16 (3%)	6.16 (3%)	6.22 (4%)
Dry	8.72	8.92 (2%)	8.95 (3%)	8.82 (1%)	8.88 (2%)	8.90 (2%)
Critically dry	8.47	8.67 (2%)	8.51 (0%)	8.47 (0%)	8.67 (2%)	8.61 (2%)
February						
Wet	1.23	1.25 (1%)	1.25 (2%)	1.24 (1%)	1.24 (1%)	1.25 (1%)
Above normal	2.14	2.31 (8%)	2.32 (8%)	2.26 (6%)	2.31 (8%)	2.31 (8%)
Below normal	3.73	3.81 (2%)	3.85 (3%)	3.98 (7%)	3.86 (4%)	3.81 (2%)
Dry	4.28	4.74 (11%)	4.76 (11%)	4.67 (9%)	4.70 (10%)	4.74 (11%)
Critically dry	5.25	5.29 (1%)	5.38 (3%)	5.35 (2%)	5.36 (2%)	5.20 (-1%)
March						
Wet	0.82	0.83 (1%)	0.83 (0%)	0.83 (1%)	0.82 (0%)	0.82 (0%)
Above normal	1.25	1.36 (9%)	1.37 (10%)	1.34 (7%)	1.35 (8%)	1.37 (10%)
Below normal	2.32	2.50 (8%)	2.51 (8%)	2.45 (6%)	2.48 (7%)	2.49 (8%)
Dry	2.97	3.06 (3%)	3.09 (4%)	3.03 (2%)	3.04 (2%)	3.08 (4%)
Critically dry	3.22	3.14 (-2%)	3.11 (-3%)	3.22 (0%)	3.21 (0%)	3.16 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

Alt = alternative; EC = existing conditions.

Table 12-138. Entrainment of Surface-Oriented Particles at the South Delta Export Facilities and North Bay Aqueduct from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	1.86	1.98 (7%)	1.98 (7%)	1.95 (5%)	1.97 (6%)	1.99 (7%)
Above normal	3.35	3.66 (9%)	3.68 (10%)	3.55 (6%)	3.60 (7%)	3.67 (9%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below normal	6.58	6.90 (5%)	6.91 (5%)	6.81 (4%)	6.83 (4%)	6.90 (5%)
Dry	9.53	9.90 (4%)	9.90 (4%)	9.79 (3%)	9.84 (3%)	9.90 (4%)
Critically dry	9.71	9.63 (-1%)	9.46 (-3%)	9.45 (-3%)	9.65 (-1%)	9.58 (-1%)
February						
Wet	1.27	1.30 (2%)	1.32 (4%)	1.30 (3%)	1.31 (3%)	1.31 (3%)
Above normal	2.26	2.51 (11%)	2.52 (11%)	2.44 (8%)	2.52 (11%)	2.51 (11%)
Below normal	4.01	4.24 (6%)	4.28 (7%)	4.42 (10%)	4.27 (6%)	4.25 (6%)
Dry	4.68	5.28 (13%)	5.30 (13%)	5.18 (11%)	5.24 (12%)	5.29 (13%)
Critically dry	5.83	6.00 (3%)	6.08 (4%)	6.05 (4%)	6.09 (4%)	5.90 (1%)
March						
Wet	0.87	0.88 (2%)	0.88 (2%)	0.89 (2%)	0.88 (1%)	0.89 (2%)
Above normal	1.32	1.48 (12%)	1.48 (12%)	1.43 (8%)	1.46 (11%)	1.47 (12%)
Below normal	2.50	2.81 (13%)	2.82 (13%)	2.75 (10%)	2.78 (11%)	2.81 (13%)
Dry	3.28	3.50 (7%)	3.54 (8%)	3.45 (5%)	3.47 (6%)	3.50 (7%)
Critically dry	3.51	3.68 (5%)	3.64 (4%)	3.75 (7%)	3.73 (6%)	3.68 (5%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Table 12-139. South Delta Flux of Neutrally Buoyant Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	-0.43	-0.33 (23%)	-0.33 (23%)	-0.38 (11%)	-0.36 (16%)	-0.33 (23%)
Above normal	0.96	1.11 (16%)	1.15 (20%)	1.06 (11%)	1.09 (14%)	1.13 (18%)
Below normal	3.89	4.15 (7%)	4.16 (7%)	4.09 (5%)	4.07 (5%)	4.13 (6%)
Dry	6.57	6.79 (3%)	6.82 (4%)	6.68 (2%)	6.74 (3%)	6.78 (3%)
Critically dry	7.00	7.21 (3%)	7.04 (1%)	7.02 (0%)	7.21 (3%)	7.14 (2%)
February						
Wet	-0.97	-0.95 (2%)	-0.95 (2%)	-0.96 (1%)	-0.96 (1%)	-0.95 (2%)
Above normal	-0.07	0.10 (257%)	0.12 (275%)	0.07 (199%)	0.10 (251%)	0.12 (279%)
Below normal	1.67	1.77 (6%)	1.81 (8%)	1.94 (16%)	1.82 (9%)	1.77 (5%)
Dry	2.35	2.83 (20%)	2.85 (21%)	2.75 (17%)	2.79 (19%)	2.83 (20%)
Critically dry	3.84	3.91 (2%)	3.99 (4%)	3.97 (3%)	3.98 (4%)	3.80 (-1%)
March						
Wet	-1.24	-1.23 (0%)	-1.23 (0%)	-1.23 (1%)	-1.23 (0%)	-1.23 (0%)
Above normal	-0.79	-0.68 (14%)	-0.68 (14%)	-0.70 (11%)	-0.69 (13%)	-0.67 (15%)
Below normal	0.34	0.54 (59%)	0.55 (63%)	0.49 (45%)	0.52 (55%)	0.54 (60%)
Dry	1.18	1.30 (10%)	1.30 (10%)	1.25 (6%)	1.26 (7%)	1.30 (10%)
Critically dry	1.97	1.90 (-4%)	1.86 (-5%)	1.97 (0%)	1.97 (0%)	1.91 (-3%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Table 12-140. South Delta Flux of Surface-Oriented Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	-0.32	-0.20 (37%)	-0.19 (40%)	-0.23 (28%)	-0.22 (32%)	-0.19 (41%)
Above normal	1.15	1.46 (27%)	1.49 (30%)	1.36 (19%)	1.41 (23%)	1.47 (28%)
Below normal	4.49	4.80 (7%)	4.81 (7%)	4.73 (5%)	4.73 (5%)	4.81 (7%)
Dry	7.36	7.75 (5%)	7.75 (5%)	7.63 (4%)	7.69 (5%)	7.75 (5%)
Critically dry	8.19	8.17 (0%)	7.99 (-2%)	7.99 (-2%)	8.18 (0%)	8.11 (-1%)
February						
Wet	-0.92	-0.88 (4%)	-0.88 (5%)	-0.89 (4%)	-0.89 (4%)	-0.88 (5%)
Above normal	0.07	0.32 (383%)	0.32 (389%)	0.25 (282%)	0.32 (390%)	0.32 (393%)
Below normal	1.96	2.21 (12%)	2.24 (14%)	2.39 (22%)	2.24 (14%)	2.21 (13%)
Dry	2.76	3.37 (22%)	3.39 (23%)	3.28 (19%)	3.33 (21%)	3.38 (22%)
Critically dry	4.41	4.63 (5%)	4.71 (7%)	4.67 (6%)	4.72 (7%)	4.52 (2%)
March						
Wet	-1.18	-1.17 (1%)	-1.17 (1%)	-1.16 (2%)	-1.17 (1%)	-1.16 (1%)
Above normal	-0.71	-0.55 (23%)	-0.55 (23%)	-0.60 (16%)	-0.57 (20%)	-0.56 (22%)
Below normal	0.53	0.87 (63%)	0.88 (65%)	0.81 (52%)	0.85 (59%)	0.87 (64%)
Dry	1.52	1.75 (15%)	1.78 (17%)	1.70 (11%)	1.71 (12%)	1.74 (15%)
Critically dry	2.28	2.51 (10%)	2.46 (8%)	2.57 (12%)	2.55 (11%)	2.51 (10%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Table 12-141. Passage Past Chipps Island of Neutrally Buoyant Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	47.25	47.07 (0%)	47.06 (0%)	47.14 (0%)	47.11 (0%)	47.09 (0%)
Above normal	44.60	44.39 (0%)	44.37 (-1%)	44.47 (0%)	43.91 (-2%)	43.83 (-2%)
Below normal	39.03	38.42 (-2%)	38.44 (-2%)	38.58 (-1%)	38.52 (-1%)	38.45 (-1%)
Dry	33.90	33.11 (-2%)	33.07 (-2%)	32.86 (-3%)	33.22 (-2%)	33.15 (-2%)
Critically dry	32.84	32.22 (-2%)	32.31 (-2%)	31.82 (-3%)	32.19 (-2%)	31.69 (-4%)
February						
Wet	47.97	47.93 (0%)	47.94 (0%)	47.94 (0%)	47.95 (0%)	47.94 (0%)
Above normal	46.95	46.73 (0%)	47.93 (0%)	46.77 (0%)	46.73 (0%)	46.72 (0%)
Below normal	43.27	42.75 (-1%)	46.74 (0%)	42.67 (-1%)	42.69 (-1%)	42.76 (-1%)
Dry	41.06	40.18 (-2%)	42.81 (-1%)	40.71 (-1%)	40.39 (-2%)	40.22 (-2%)
Critically dry	37.06	36.19 (-2%)	40.18 (-2%)	36.17 (-2%)	36.14 (-2%)	36.23 (-2%)
March						
Wet	47.70	47.67 (0%)	47.69 (0%)	47.68 (0%)	47.69 (0%)	47.68 (0%)
Above normal	47.08	46.94 (0%)	46.93 (0%)	46.94 (0%)	46.94 (0%)	46.95 (0%)
Below normal	45.35	45.20 (0%)	45.28 (0%)	45.27 (0%)	45.25 (0%)	45.22 (0%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Dry	43.86	43.57 (-1%)	43.54 (-1%)	43.64 (0%)	43.60 (-1%)	43.55 (-1%)
Critically dry	39.70	39.09 (-2%)	39.12 (-1%)	39.02 (-2%)	39.04 (-2%)	39.08 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Table 12-142. Passage Past Chipps Island of Surface-Oriented Particles from DSM2 Particle Tracking Modeling, Weighted by Longfin Smelt Larval Distribution

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
January						
Wet	47.74	47.74 (0%)	47.72 (0%)	47.79 (0%)	47.76 (0%)	47.72 (0%)
Above normal	44.90	44.68 (0%)	44.65 (-1%)	44.79 (0%)	44.20 (-2%)	44.09 (-2%)
Below normal	38.94	38.35 (-2%)	38.38 (-1%)	38.50 (-1%)	38.45 (-1%)	38.37 (-1%)
Dry	33.59	32.65 (-3%)	32.65 (-3%)	32.44 (-3%)	32.75 (-2%)	32.63 (-3%)
Critically dry	32.77	31.91 (-3%)	32.04 (-2%)	31.52 (-4%)	31.95 (-3%)	31.41 (-4%)
February						
Wet	48.58	48.78 (0%)	48.76 (0%)	48.78 (0%)	48.77 (0%)	48.78 (0%)
Above normal	47.32	47.27 (0%)	47.27 (0%)	47.36 (0%)	47.28 (0%)	47.28 (0%)
Below normal	43.57	42.98 (-1%)	43.03 (-1%)	42.86 (-2%)	42.95 (-1%)	42.96 (-1%)
Dry	41.22	40.28 (-2%)	40.24 (-2%)	40.80 (-1%)	40.52 (-2%)	40.28 (-2%)
Critically dry	36.96	36.10 (-2%)	35.98 (-3%)	36.09 (-2%)	36.01 (-3%)	36.16 (-2%)
March						
Wet	48.33	48.55 (0%)	48.54 (0%)	48.55 (0%)	48.55 (0%)	48.54 (0%)
Above normal	47.57	47.63 (0%)	47.62 (0%)	47.65 (0%)	47.65 (0%)	47.64 (0%)
Below normal	45.81	45.57 (-1%)	45.66 (0%)	45.64 (0%)	45.63 (0%)	45.57 (-1%)
Dry	44.12	43.84 (-1%)	43.79 (-1%)	43.92 (0%)	43.88 (-1%)	43.84 (-1%)
Critically dry	39.92	39.16 (-2%)	39.18 (-2%)	39.13 (-2%)	39.14 (-2%)	39.13 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions.
Alt = alternative; EC = existing conditions.

Grimaldo et al. (2009) found that juvenile longfin smelt salvage principally occurred in the months of April and May and was significantly negatively related to mean April–May OMR flow (and was not related to other factors such as X2). For this impacts analysis, an evaluation of potential differences in entrainment between the alternatives and existing conditions was evaluated by recreating and applying the Grimaldo et al. (2009) relationship between salvage and OMR flows (see Appendix 12B). This analysis suggested that entrainment under the alternatives generally could be similar to or less than under existing conditions (Table 12-143) as a result of less south Delta exports under the alternatives. As previously noted above, real-time operational measures required under the CDFW (2020a:81–84) ITP for the SWP are included in the existing conditions and the project alternatives; these operational measures manage OMR flows for the protection of longfin smelt. Entrainment of juvenile longfin smelt is likely to represent a low percentage of the overall juvenile longfin smelt population because a very small percentage of the juvenile population was estimated to have been entrained in recent years (2009 onward) (California Department of Water Resources 2020a:4-187). Juvenile longfin smelt entrainment loss under existing conditions and the project alternatives likely represents a low percentage of the overall juvenile longfin smelt population because the species is widely distributed in the San Francisco Bay and its tributaries, including the Napa and Petaluma rivers, and South Bay tributaries (California Department of Water Resources 2020a:5-144).

Table 12-143. Mean Juvenile Longfin Smelt April–May Salvage at the South Delta Export Facilities by Water Year Type, as Estimated by the Regression Including Mean Old and Middle River Flows

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	2,712	2,499 (-8%)	2,472 (-9%)	2,581 (-5%)	2,510 (-7%)	2,494 (-8%)
Above normal	3,252	3,208 (-1%)	3,244 (0%)	3,291 (1%)	3,194 (-2%)	3,209 (-1%)
Below normal	3,403	3,415 (0%)	3,423 (1%)	3,443 (1%)	3,416 (0%)	3,415 (0%)
Dry	3,567	3,566 (0%)	3,550 (0%)	3,575 (0%)	3,571 (0%)	3,566 (0%)
Critically dry	2,220	2,168 (-2%)	2,135 (-4%)	2,182 (-2%)	2,215 (0%)	2,158 (-3%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty (see Table 12B-77 in Appendix 12B for results by individual year, including prediction intervals). Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Habitat Effects

Food Availability

As described in Appendix 12A, during the first few months of life (January–May), longfin smelt prey on calanoid copepods including *E. affinis* and *P. forbesi*, before switching to mysid prey when they are large enough (see also Jungbluth et al. 2021; Barros et al. 2022). As discussed for delta smelt above, a regression of March–May X2 versus *E. affinis* density in the low salinity zone was used to compare the existing conditions and alternatives (see the methods description provided in Appendix 12B). This analysis suggested that the difference in *E. affinis* density in the low salinity zone between the alternatives and existing conditions would be small (0%–3%). Such differences are much less than the range of the prediction intervals from this statistical model, which span several orders of magnitude (see Table 12B-43 in Appendix 12B). As noted in Appendix 12A, mysid density is positively correlated with spring Delta outflow and negatively correlated with spring X2 (Mac Nally et al. 2010), although with a changing relationship to May–October X2 for the mysid *Neomysis mercedis* (negative prior to 1987, positive following 1987; Kimmerer 2002b). Collectively, this information suggests that there is very little potential for negative effects on longfin smelt from the project alternatives relative to existing conditions with respect to food availability.

Delta Outflow-Abundance

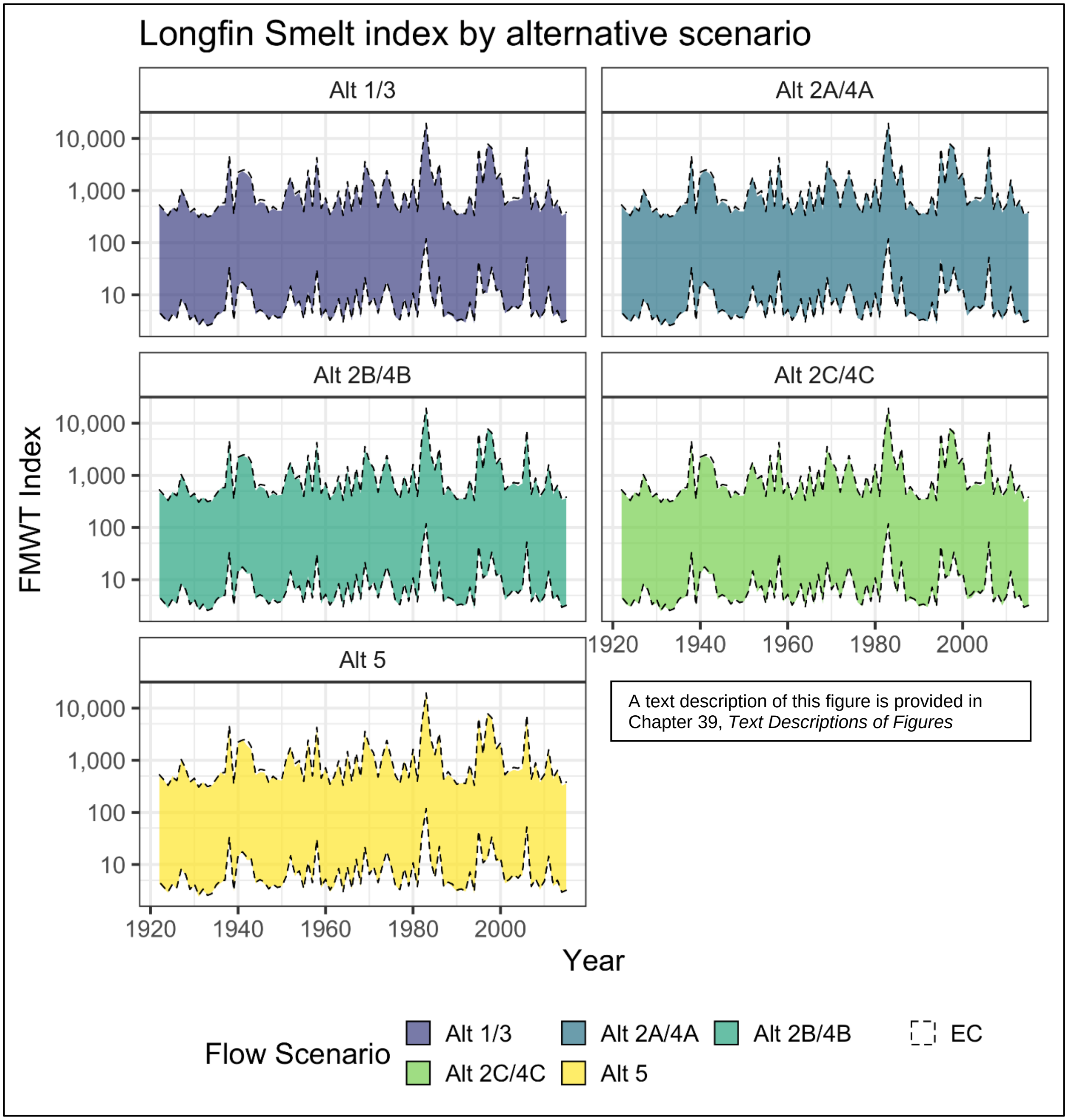
For longfin smelt, focus on estuarine flow has centered on the positive relationship found between winter and spring outflow and juvenile abundance during the fall (Rosenfield and Baxter 2007; Kimmerer et al. 2009). Specifically, as X2 shifts downstream during the winter and spring, the abundance index of longfin smelt in the following Fall Midwater Trawl Survey increases (Kimmerer 2002a; Kimmerer et al. 2009). The potential mechanisms underlying this relationship have been hypothesized but their relative importance is poorly understood; however, the significant X2-abundance relationship suggests that higher outflow (lower X2) or wetter hydrology produce conditions that enhance recruitment to juvenile life stages. Hypotheses about underlying mechanisms to this X2-abundance relationship include transport of larval longfin smelt out of the Delta to downstream rearing habitats (Moyle 2002:32; Rosenfield and Baxter 2007); increased extent of rearing habitat as X2 moves seaward (Kimmerer et al. 2009); retention of larvae in suitable rearing habitats (Kimmerer et al. 2009); increased food abundance under higher flows (Kimmerer 2002a); and tributary flows leading to greater spawning/recruitment in wetter years (Lewis et al. 2020; Grimaldo et al. 2020). Note that analyses relying on surveys such as the Fall Midwater Trawl index do not fully encompass the range of longfin smelt and do not reflect potential changes in catchability over time because of factors such as increased water clarity and gear avoidance (Latour 2016; Peterson and Barajas 2018) that are the subject of ongoing investigations.

With respect to habitat size for early life stages, new information indicates that the distribution of spawning and early life stages may be broader than previously thought, including areas with salinity ranging from 2 to 12 parts per thousand (Grimaldo et al. 2017). It has also been recognized that abundance of adults (spawners) is an important factor driving longfin smelt population dynamics (Baxter et al. 2010), with recent studies examining this link in detail (Maunder et al. 2015; Nobriga and Rosenfield 2016). A state-space modeling study by Maunder et al. (2015) found that multiple factors (i.e., flow, ammonium concentration, and water temperature) and density dependence were correlated to the survival of longfin smelt (represented by Bay Study abundance indices during 1980–2009). The flow factors included in their best models (i.e., Sacramento River October–July unimpaired runoff and Napa River runoff), however, cannot be affected by Delta water operations because of their geographic position in the watersheds. Nobriga and Rosenfield (2016) found that December–May Delta outflow had a positive association with recruits per spawner and that juvenile recruitment from age 0 to age 2 was density-dependent (lower survival with greater numbers of juveniles), but cautioned that the density-dependence in the model may be too strong; both recruits per spawner and juvenile recruitment were based on Bay Study sampling.

To assess potential effects of the project alternatives, a population dynamics model estimating Fall Midwater Trawl index as a function of December–May Delta outflow (accounting for changes in this relationship because of the *Potamocorbula* clam invasion and the Pelagic Organism Decline) and parental stock size (the Fall Midwater Trawl index 2 years earlier) was developed. The model was used to compare the project alternatives to existing conditions, using Delta outflow outputs from CalSim; additional detail on the method is provided in Appendix 12B, Section 12B.18, *Longfin Smelt Delta Outflow–Abundance Index Analysis*.

Existing conditions and the project alternatives include export curtailments for spring (April 1–May 31) outflow per the requirements from the CDFW SWP ITP (2020a:102–106), which limit Delta outflow differences in spring. There is generally less Delta outflow under the project alternatives than existing conditions during December–March (see, for example, Tables B.4.1.2 through B.4.1.6 in Appendix 5A, Attachment 3), which is reflected in the results of the Delta outflow–abundance index. The results of the Delta outflow–abundance index analysis showed that differences in predicted Fall Midwater Trawl abundance index between existing conditions and the project alternatives were very small relative to the variability in the predicted values, which spans several orders of magnitude (Figure 12-1). Differences in mean estimates of Fall Midwater Trawl abundance index by water year type ranged from 2% to 10% less under the project alternatives compared to existing conditions (Table 12-144). The modeling results showed that the variability in Fall Midwater Trawl index predictions within each scenario was considerably greater than the differences between the scenarios. The mean probability of the Fall Midwater Trawl index being less under the alternatives than existing conditions ranged from 0.517 (Alternatives 2a and 4a in critically dry years) to 0.594

(Alternative 1 in above normal years), where 0.500 indicates an equal probability of the index being smaller or larger than existing conditions (Table 12-145). The variability in abundance index predictions reflects the uncertainty in parameter estimates, which in turn results in uncertainty in the extent to which operations-related differences in Delta outflow could affect longfin smelt. Specifically, variability in Delta outflow associated with overall hydrologic conditions (i.e., different water year types) is substantially larger than the relatively minor differences in Delta outflow associated with changes in water operations resulting from the project alternatives. As described previously, Maunder et al. (2015) found that general hydrological conditions in the Sacramento River watershed and Napa River were a better explanation of population dynamics than Delta outflow, which likely explains some of the uncertainty regarding the potential operations-related effects of differences in Delta outflow.



A text description of this figure is provided in Chapter 39, *Text Descriptions of Figures*

1
2 Note: Alt = alternative; EC = existing conditions.

3 **Figure 12-1. Time Series Plots of Predicted Longfin Smelt Fall Midwater Trawl Index from Application**
4 **of the Delta Outflow-Abundance Index Method**

Table 12-144. Predicted Mean Longfin Smelt Fall Midwater Trawl Index Averaged by Water Year Type, Based on Delta Outflow-Abundance Index Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	383	358 (-7%)	356 (-7%)	366 (-4%)	360 (-6%)	359 (-6%)
Above normal	105	95 (-10%)	94 (-10%)	97 (-7%)	95 (-9%)	95 (-10%)
Below normal	61	57 (-6%)	57 (-6%)	58 (-4%)	57 (-6%)	57 (-6%)
Dry	57	53 (-6%)	53 (-6%)	55 (-4%)	54 (-5%)	53 (-6%)
Critically dry	44	43 (-3%)	43 (-3%)	44 (-2%)	43 (-3%)	43 (-4%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Results are not future predictions and are intended only to compare alternatives.

Alt = alternative; EC = existing conditions.

Table 12-145. Probability of Longfin Smelt Fall Midwater Trawl Index Smaller than Existing Conditions Averaged by Water Year Type, Based on Delta Outflow–Abundance Index Method

Water Year Type	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0.565	0.555	0.548	0.554	0.557
Above normal	0.594	0.589	0.570	0.579	0.584
Below normal	0.559	0.551	0.541	0.547	0.550
Dry	0.540	0.532	0.529	0.529	0.535
Critically dry	0.526	0.517	0.519	0.518	0.519

Note: Probability of 0.500 indicates equal probability of Fall Midwater Trawl index being smaller or larger than existing conditions.

Alt = alternative.

Maintenance Effects

As described in more detail above for delta smelt, maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on longfin smelt. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

In general, the analyses of the operations and maintenance impacts of the project alternatives suggested minor impacts on longfin smelt, relative to existing conditions, including near-field effects of the north Delta intakes, south Delta entrainment, and very little potential for negative effects on food availability as a result of differences in spring Delta outflow. Any such impacts would not be significant because they are minor and would affect only a very small proportion of the longfin smelt population. The analyses of flow-related effects (differences in Delta outflow) on longfin smelt abundance suggested more potential for negative effects under the project alternatives (i.e., mean difference of 2%–10% less depending on water year type) and a potentially significant impact given that they represent a population-level impact. There is uncertainty in the impact, however, given the appreciably greater variability of longfin smelt abundance index estimates for a given alternative relative to the difference from existing conditions. Operations of the project alternatives would be consistent with all applicable regulations to limit the potential for negative effects on fish and aquatic resources, including the existing spring outflow measures required by the CDFW (2020a) ITP. Nevertheless, the uncertain negative outflow-related effect is considered significant in light of the species' CESA-listed status and low population abundance indices. As such, the project alternatives would implement approximately 110 to 140 acres of compensatory mitigation (Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-28: *Tidal Habitat Restoration for Operations Impacts on Longfin Smelt* [Attachment 3F.1, Table 3F.1-3]). Tidal habitat would expand the diversity, quantity, and quality of longfin smelt rearing and refuge habitat consistent with recent tidal habitat mitigation required for outflow impacts to the species (California Department of Fish and Wildlife 2020a:112) and would therefore reduce the potential effects caused by reduced outflow. As shown by multiple recent tidal habitat restoration projects in the Delta (e.g., California Department of Water Resources 2019a), there are potential feasible opportunities for tidal habitat restoration directly applicable to longfin smelt, with demonstrated presence of longfin smelt (Environmental Science Associates 2021:5-2). This tidal habitat restoration mitigation would reduce the impact to a less-than-significant level; therefore, the impact would be less than significant with mitigation.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-28: *Tidal Habitat Restoration for Operations Impacts on Longfin Smelt* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on longfin smelt as analyzed in this chapter. Following completion of compensatory mitigation, restored tidal habitat areas would have positive effects on longfin smelt such as increased habitat extent or greater food availability; relatively high abundance of longfin smelt has been observed in various restored habitats in the lower San Francisco Estuary (Lewis et al. 2020).

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on longfin smelt during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact longfin smelt during operation and maintenance, and there would be no impact.

Overall, the impact on longfin smelt during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less than significant with mitigation impact conclusion.

No Project Alternative

At 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. At 2040 climate, Old and Middle River flows during December–March, an indicator of adult/larval longfin smelt south Delta entrainment risk, generally would be similar or greater under the No Project Alternative compared to existing conditions (see Tables 12-119, 12-120, 12-121, and 12-122 in the delta smelt No Project Alternative analysis above). This is consistent with DSM2-PTM results for existing conditions and the No Project Alternative. The April through May salvage regression also indicated less juvenile entrainment risk under the No Project Alternative (Table 12-147)[47]. These factors, coupled with the same regulations to limit longfin smelt entrainment loss (i.e., the California Department of Fish and Wildlife [2020a] ITP) indicate that entrainment risk would not be greater under the No Project Alternative compared to existing conditions. Climate change-related shifts would generally increase winter/early spring Delta outflow under the No Project Alternative relative to existing conditions, resulting in appreciably greater predictions of longfin smelt Fall Midwater Trawl abundance index under the No Project Alternative than existing conditions (Table 148), albeit with uncertainty as discussed for the project alternatives. The probability of the No Project Alternative having lower Fall Midwater Trawl abundance index than existing conditions ranged from 0.32 in wet years to 0.41 in critically dry years (Table 12-149). As discussed for delta smelt, climate change-related reductions in spring Delta outflow and sea level rise result in predictions of lower smelt zooplankton prey *E. affinis* than existing conditions (Table 12-126).

Table 12-147. Mean Juvenile Longfin Smelt April–May Salvage at the South Delta Export Facilities by Water Year Type, as Estimated by the Regression Including Mean Old and Middle River Flows, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	2,712	2,041 (-25%)
Above normal	3,252	2,876 (-12%)
Below normal	3,403	2,734 (-20%)
Dry	3,567	2,468 (-31%)
Critically dry	2,220	1,531 (-31%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions.

Table 12-148. Predicted Mean Longfin Smelt Fall Midwater Trawl Index Averaged by Water Year Type, Based on Delta Outflow-Abundance Index Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	383	559 (46%)
Above normal	105	161 (53%)
Below normal	61	72 (18%)

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[47] Table number 12-146 was not used in this chapter.

Water Year Type	EC	NPA
Dry	57	72 (26%)
Critically dry	44	46 (5%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions.

Table 12-149. Probability of No Project Alternative Longfin Smelt Fall Midwater Trawl Index Being Smaller than Existing Conditions Averaged by Water Year Type, Based on Delta Outflow-Abundance Index Method

Water Year Type	Probability
Wet	0.320
Above normal	0.342
Below normal	0.378
Dry	0.389
Critically dry	0.406

Note: Probability of 0.500 indicates equal probability of Fall Midwater Trawl index being smaller or larger than existing conditions.

Impact AQUA-8: Effects of Operations and Maintenance of Water Conveyance Facilities on Southern DPS Green Sturgeon

Operations and Maintenance—All Project Alternatives

Analyses of potential effects of the project alternatives on green sturgeon were developed in consideration of habitat attributes believed to be of importance to the species based on existing conceptual models (Heublein et al. 2017a, 2017b) and best available methods (e.g., ICF International 2016a; California Department of Water Resources 2020a).

Relative to juvenile salmonids, there are no field-based investigations informing the risk from near-field effects of the project alternatives at the north Delta intakes for green sturgeon. Laboratory investigations are available from which risk can be inferred, however. Larval green sturgeon occur well upstream of the Delta (Heublein et al. 2017a) and so there would be no risk of entrainment at the north Delta intakes. Although screen velocity criteria for green sturgeon have not been developed by NMFS or CDFW, the laboratory studies of Verhille et al. (2014) provided recommendations for intake approach velocity based on flow-tolerance criteria (Figure 12-2). The proposed north Delta intake approach velocity of 0.2 foot per second would be well below the criteria described by Verhille et al. (2014; i.e., 29 cm per second [~1 foot per second] or greater depending on month), suggesting that green sturgeon juveniles would be protected, particularly given that they would be larger in size than the larvae tested by Verhille et al. (2014). Juvenile green sturgeon were found to frequently contact or become impinged on laboratory fish screens with approach velocity several times greater than proposed for the north Delta intakes (~0.66 and ~1.2 feet per second; Poletto et al. 2014), but those screens were in a V-shape across the test channel. The very low approach velocity of the proposed north Delta intake screens indicates that the potential for negative effects would be very small; in addition, as discussed for winter-run Chinook salmon, the cylindrical tee-screen design has been noted to reduce the potential for near-field effects because of a "bow wave" hydraulic effect (Coutant 2021; albeit with the caveats previously described for winter-run Chinook salmon).

Month	Upper River	Middle River	Lower River/Delta/Bays
January	>50 cm/s	>50 cm/s	>50 cm/s
February	>50 cm/s	WS early larvae	>50 cm/s
March	>50 cm/s	WS early larvae	>50 cm/s
April	GS early larvae	WS early larvae	>50 cm/s
May	GS early larvae	WS early larvae	>50 cm/s
June	GS and WS ≤ 29 cm/s	GS and WS ≤ 29 cm/s	GS and WS ≤ 29 cm/s
July	>50 cm/s	WS ≤ 45 cm/s	WS ≤ 45 cm/s
August	>50 cm/s	GS ≤ 50 cm/s	GS ≤ 50 cm/s
September	>50 cm/s	>50 cm/s	>50 cm/s
October	>50 cm/s	GS ≤ 40 cm/s	GS ≤ 40 cm/s
November	>50 cm/s	GS ≤ 40 cm/s	GS ≤ 40 cm/s
December	>50 cm/s	>50 cm/s	>50 cm/s

Source: This table was presented as a non-ADA-compliant figure in Verhille et al. (2014). As such, it has been converted to a functional table while retaining the figure title.

Note: 'GS early larvae' and 'WS early larvae demarcate presence of life stages that are predicted to be intolerant of even very low water velocities. Behavioral (e.g., avoidance) considerations were not part of this analysis, and they remain an important topic for future research. The north Delta intakes are in the "Lower River/Delta/Bays" area.

ADA = Americans with Disabilities Act.

Figure 12-2. Overview of Flow-Tolerance Limitations of Green (GS) and White (WS) Sturgeon Throughout the Sacramento-San Joaquin Watershed According to Location and Time of Year, Based on Critical Swimming Speed

Green sturgeon entrainment at the south Delta export facilities can occur in most months of the year, reflecting the year-round presence of juveniles in the Delta. However, salvage of green sturgeon has been very low in recent years, and entrainment is regarded as a threat of low importance to the population in the NMFS green sturgeon recovery plan (National Marine Fisheries Service 2018:26). The salvage-density analysis (see description in Appendix 12B, Section 12B.2, *Salvage-Density Method*) was used to assess the potential for differences in south Delta entrainment between alternatives. The method weights south Delta exports at the south Delta export facilities by historical salvage per unit volume (i.e., salvage density) of juvenile green sturgeon. The results of the analysis suggest that there would be very little difference in south Delta entrainment risk between the project alternatives and existing conditions at either export facility (Table 12-150; Table 12-151).[48]

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[48] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-11 and 12B-12).

Table 12-150. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	1	1 (-12%)	1 (-10%)	1 (-7%)	1 (-10%)	1 (-13%)
Above normal	N/A	(-7%)	(-1%)	(0%)	(-1%)	(-7%)
Below normal	1	1 (0%)	1 (1%)	1 (-2%)	1 (-1%)	1 (0%)
Dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Critically dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-151. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7	7 (5%)	7 (-1%)	7 (3%)	7 (5%)	7 (5%)
Above normal	N/A	(6%)	(-3%)	(0%)	(1%)	(6%)
Below normal	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Critically dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Based on observations in the Delta on white sturgeon (Stewart et al. 2004), selenium bioaccumulation is a concern for sturgeon. As discussed in detail in Chapter 9, *Water Quality*, changes in water operations under the project alternatives would have little effect on sturgeon tissue concentrations of selenium, relative to existing conditions. Methylmercury is also a concern for green sturgeon (Lee et al. 2011), but analyses described in Chapter 9 found there would be little difference in fish tissue methylmercury between the project alternatives and existing conditions.

The NMFS green sturgeon recovery plan suggested that larval abundance and distribution may be influenced by spring and summer outflow and recruitment may be highest in wet years, making water flow an important habitat parameter (National Marine Fisheries Service 2018:12). As noted by NMFS (2018:12), there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016a:5-197–5-205). It is uncertain the extent to which the correlations observed for white sturgeon would also apply to green sturgeon given differences in life history. The mechanism behind the importance of higher flows for white sturgeon is not known and may involve both upstream and downstream

(Delta) factors. Hypotheses for the mechanism underlying flow effects include higher flows facilitating young white sturgeon dispersal downstream, providing increased freshwater rearing habitat, increasing spawning activity cued by higher upstream flows, increasing nutrient loading into nursery areas, or increasing downstream migration rate and survival through reduced exposure time to predators (U.S. Fish and Wildlife Service 1995:2-VII-39; Israel pers. comm.). Regression analyses conducted for white sturgeon and described in Impact AQUA-9: *Effects of Operations and Maintenance of Water Conveyance Facilities on White Sturgeon*, relate year-class strength to March–July and April–May Delta outflow. The results of the analyses differ depending on Delta outflow averaging period used: the water-year-type means for March through July under the project alternatives for wet and above normal years (which have much higher year class strength than other water year types) were 3% to 16% lower than existing conditions (Table 12-157), but were 2% to 8% lower for April through May, when requirements of the CDFW (2020a) for April through May Delta outflow apply for the project alternatives as well as for existing conditions. The March–July differences in estimated year-class strength reflect lower Delta outflow being required under the project alternatives for meeting Delta salinity requirements. As shown in Appendix 12B and discussed further below in Impact AQUA-9 for white sturgeon, prediction intervals on the estimates of year-class strength are broad.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on green sturgeon. Screen pressure washing and sediment jetting would have very small effects at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The near-field effects of the NDD on green sturgeon would be limited, and south Delta entrainment risk would be similar between the project alternatives and existing conditions. There would be little difference in metals (selenium and methylmercury) effects on green sturgeon (see additional discussion in Chapter 9).

The largest recruitment of sturgeon occurs in wetter years (Fish 2010), indicating the importance of hydrological conditions. Although the year-class strength estimates from March–July Delta outflow suggested the potential to exceed the significance threshold of approximately 5% lower population abundance, it is highly uncertain that less summer Delta outflow under the project alternatives—which would occur because of less Delta outflow being necessary to meet Delta salinity requirements—would result in a significant impact on green sturgeon for the following reasons: the statistical relationships are based on a surrogate species and may be related to upstream flow or Delta inflow as opposed to Delta outflow; changes are limited to differences within water year type, as opposed to hydrological-condition-scale differences; the prediction intervals of the statistical relationship range over several orders of magnitude; and there is little difference in estimates based on one (April–May) of the averaging periods examined. For these reasons, it is concluded that the impact of less Delta outflow on green sturgeon would be less than significant.

In consideration of the above impacts analyzed, it is concluded that the impact of operations and maintenance of the project alternatives on green sturgeon would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on green sturgeon as analyzed in this chapter. Following completion of compensatory mitigation construction (tidal perennial habitat and channel margin habitat for operations impacts; see Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*), there is some uncertainty what effect this habitat would have on green sturgeon, although there is evidence that the effects would be limited. Acoustically tagged juvenile green sturgeon released in the mainstem San Joaquin River channel generally remained in the mainstem in depths of 9.8–32.8 feet (3–10 meters), with only one of six individuals leaving the mainstem (Thomas et al. 2019). Although conducted on white sturgeon, Patton et al. (2020) found only one sturgeon in tidal wetland, compared to more than 50 individuals each in adjacent deep water channel and shallow water shoal habitats. Patton et al. (2020) suggested that the presence or absence of sturgeon in wetland habitats may be driven by habitat size and configuration, food and prey availability, and substrate type. Based on the available limited information, compensatory mitigation would have little effect on green sturgeon, albeit with some uncertainty.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on green sturgeon during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact green sturgeon during operation and maintenance, and there would be no impact.

Overall, the impact on green sturgeon during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. Although there would be differences in south Delta exports between the No Project Alternative and existing conditions, south Delta entrainment risk of green sturgeon would be similar and low based on the results of the salvage-density method (Tables 12-152 and 12-153). As described for the white sturgeon No Project Alternative analysis below in Impact AQUA-9, application of the Delta outflow-white sturgeon year class strength regressions suggested the potential for lower year class strength in wetter years under the No Project Alternative during the April–May period compared to similar year class strength during the March–July. This reflects climate change-related differences in watershed precipitation/runoff and, as discussed for the project alternatives, there is uncertainty in the effect because the mechanisms (e.g., relative importance of Delta inflow vs. Delta outflow vs. upstream flows) are not known and the extent to which a similar correlation may also exist for green sturgeon is also not known.

Table 12-152. Salvage of Green Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	1	1 (8%)
Above normal	N/A	(13%)
Below normal	1	1 (4%)
Dry	0	0 (0%)
Critically dry	0	0 (0%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-153. Salvage of Green Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7	4 (-39%)
Above normal	N/A	(-67%)
Below normal	0	0 (0%)
Dry	0	0 (0%)
Critically dry	0	0 (0%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-9: Effects of Operations and Maintenance of Water Conveyance Facilities on White Sturgeon

Operations and Maintenance—All Project Alternatives

Analyses of potential effects of the project alternatives on white sturgeon were developed in consideration of habitat attributes believed to be of importance to the species based on existing conceptual models (Heublein et al. 2017a, 2017b) and best available methods (e.g., ICF International 2016a; California Department of Water Resources 2020a).

As noted for green sturgeon, relative to juvenile salmonids, there are no field-based investigations informing the risk from near-field effects of the project alternatives at the north Delta intakes for white sturgeon. Laboratory investigations are available from which risk can be inferred, however.

Larval white sturgeon occur from upstream of the Delta to approximately Chipps Island in the Delta, particularly in wetter water years (see discussion in species account in Appendix 12A). On the basis of larval white sturgeon size (generally below 0.8 inch [20 mm]; Stevens and Miller 1970) and the size (0.8 inch [20 mm]) at which morphologically similar pallid sturgeon were entrained through similarly sized screens as the cylindrical tee screens that would be used for the project alternatives (Mefford and Sutphin 2008), there is the potential for larval white sturgeon entrainment at the north Delta intakes. The key period of concern for potential larval white sturgeon entrainment would be February–May (Figure 12-2 in Impact AQUA-8). CalSim modeling suggests that the median percentage of flow diverted would be 5% in February (range: 0%–21%; Table 12-154), 6%–7% in March (range: 0%–22%), 0% in April (range: 0%–16%), 0% in May (range: 0%–22%), and 0% in June (range: 0%–19%) (see Table 12-88 in Impact AQUA-6). The entrained percentage of white sturgeon larvae is likely to be considerably lower than the percentage of flow diverted because of the very low approach velocity, as well as the cylindrical tee screen design that has been noted to reduce the potential for near-field effects because of a "bow wave" hydraulic effect (Coutant 2021; albeit with the caveats previously described for winter-run Chinook salmon); such factors presumably have contributed to observed entrainment of larval/early juvenile fish being much less than might be predicted based on fish size relative to screen opening size (e.g., delta smelt; Nobriga et al. 2004). Outside the February–May larval vulnerability period and as described in Impact AQUA-8 for green sturgeon, the proposed north Delta intake approach velocity of 0.2 foot per second would be well below the criteria described by Verhille et al. (2014; i.e., ~1 foot per second [29 cm per second] or greater depending on month), suggesting that white sturgeon juveniles would be protected, particularly given that they would be larger than the larvae tested by Verhille et al. (2014). Although juvenile white sturgeon were found to frequently contact or become impinged on laboratory fish screens with approach velocity several times greater than proposed for the north Delta intakes (~0.66 and ~1.2 feet per second; Poletto et al. 2014), those screens were in a V-shape across the narrow test channel, in contrast to the configuration of the north Delta intake screens at the side of a broad (~600-foot) channel and parallel to flow.

Table 12-154. Percentage of Sacramento River Flow Diverted by the North Delta Diversions, February

Percentile	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Minimum	0%	0%	0%	0%	0%
10%	0%	0%	0%	0%	0%
20%	0%	0%	0%	0%	0%
30%	2%	1%	1%	1%	2%
40%	4%	3%	3%	4%	4%
50%	5%	5%	5%	5%	5%
60%	8%	8%	6%	7%	8%
70%	10%	10%	6%	8%	9%
80%	12%	13%	8%	10%	12%
90%	14%	15%	9%	12%	14%
Maximum	18%	21%	12%	15%	18%

Alt = alternative.

As with green sturgeon, the salvage-density analysis (see description in Appendix 12B, Section 12B.2, *Salvage-Density Method*) was used to assess the potential for differences in south Delta entrainment risk of juvenile white sturgeon between alternatives. The results of the analysis suggest that there would be very little difference in white sturgeon south Delta entrainment risk between the project alternatives and existing conditions at either export facility (Tables 12-155 and 12-156).[49]

Table 12-155. Salvage of White Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	19	18 (-5%)	18 (-4%)	18 (-3%)	18 (-5%)	18 (-6%)
Above normal	N/A	(-9%)	(-6%)	(-5%)	(-7%)	(-9%)
Below normal	11	11 (-8%)	11 (-4%)	11 (-6%)	11 (-6%)	11 (-8%)
Dry	5	5 (-6%)	5 (-5%)	5 (-9%)	5 (-8%)	5 (-5%)
Critically dry	5	5 (-3%)	5 (-4%)	5 (-4%)	5 (-3%)	5 (-5%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-156. Salvage of White Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	83	85 (2%)	83 (0%)	84 (1%)	85 (2%)	85 (2%)
Above normal	N/A	(2%)	(0%)	(0%)	(0%)	(2%)
Below normal	18	18 (1%)	18 (2%)	18 (1%)	18 (1%)	18 (1%)
Dry	2	2 (3%)	2 (0%)	2 (2%)	2 (3%)	2 (3%)
Critically dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

As previously discussed for green sturgeon, selenium and methylmercury bioaccumulation are a concern for white sturgeon (Stewart et al. 2004; Lee et al. 2011). However, as discussed in detail in Chapter 9, changes in water operations under the project alternatives would have little effect on sturgeon tissue concentrations of selenium or fish tissue methylmercury, relative to existing conditions.

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[49] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-13 and 12B-14).

As noted by NMFS (2018:12) and as previously discussed for green sturgeon, there are correlations between white sturgeon and Delta outflow, which have previously been used to infer potential effects on green sturgeon (ICF International 2016a:5-197–5-205). The mechanism behind the importance of higher flows for white sturgeon is not known and may involve both upstream and downstream (Delta) factors. Hypotheses for the mechanism underlying flow effects include higher flows facilitating young white sturgeon dispersal downstream, providing increased freshwater rearing habitat, increasing spawning activity cued by higher upstream flows, increasing nutrient loading into nursery areas, or increasing downstream migration rate and survival through reduced exposure time to predators (U.S. Fish and Wildlife Service 1995:2-VII-39; Israel pers. comm.). Higher spring flows may also benefit incubating eggs (Heublein et al. 2017b:17), an effect occurring upstream of the Delta. Regression analyses were conducted that relate year-class strength to March–July and April–May Delta outflow (see Appendix 12B, Section 12B.20, *White Sturgeon Delta Outflow—Year Class Strength Regression*). The results of the analyses differ depending on Delta outflow averaging period used: the water-year-type means for March–July under the project alternatives for wet and above normal years (which have much higher year class strength than other water year types) were 3%–16% lower than existing conditions (Table 12-157) but were 2%–8% lower for April–May (Table 12-158). The March–July differences in estimated year-class strength reflect lower Delta outflow being required under the project alternatives for meeting Delta salinity requirements. The prediction intervals on the estimates of year-class strength are broad, spanning several orders of magnitude (Tables 12B-80 and 12B-81 in Appendix 12B).

Table 12-157. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on March–July Delta Outflow-Year Class Strength Regression

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	117	113 (-3%)	113 (-3%)	113 (-3%)	113 (-3%)	113 (-3%)
Above normal	46	38 (-16%)	38 (-17%)	40 (-13%)	38 (-16%)	38 (-16%)
Below normal	7	5 (-22%)	5 (-25%)	6 (-15%)	5 (-21%)	5 (-23%)
Dry	1	0 (-39%)	0 (-52%)	0 (-17%)	0 (-27%)	0 (-39%)
Critically dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-158. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on April–May Delta Outflow-Year Class Strength Regression

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	144	140 (-2%)	140 (-2%)	141 (-2%)	141 (-2%)	140 (-2%)
Above normal	62	58 (-7%)	58 (-8%)	58 (-7%)	58 (-7%)	58 (-7%)
Below normal	20	19 (-3%)	19 (-3%)	19 (-2%)	19 (-3%)	19 (-3%)
Dry	4	4 (3%)	4 (5%)	4 (-2%)	4 (-1%)	4 (3%)
Critically dry	0	0 (16%)	0 (10%)	0 (1%)	0 (9%)	0 (15%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on white sturgeon. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The near-field effects of the NDD on white sturgeon would be limited, and south Delta entrainment risk would be similar between the project alternatives and existing conditions. There would be little difference in metals (selenium and methylmercury) effects on white sturgeon (see additional discussion in Chapter 9).

As discussed for green sturgeon, although the white sturgeon year-class strength estimates from March–July Delta outflow suggested the potential to exceed the significance threshold of approximately 5% lower population abundance, it is highly uncertain that less summer Delta outflow under the project alternatives—which would occur because of less Delta outflow being necessary to meet Delta salinity requirements—would result in a significant impact on white sturgeon for the following reasons: the statistical relationships may be related to upstream flow or Delta inflow as opposed to Delta outflow; changes are limited to differences within water year type as opposed to hydrological-condition-scale differences (i.e., greatest recruitment in wetter years; see also Figure 12B-104 in Appendix 12B); the prediction intervals of the statistical relationship range over several orders of magnitude; and there is little difference in estimates based on one (April–May) of the averaging periods examined. For these reasons, it is concluded that the impact of less Delta outflow on white sturgeon would be less than significant, and therefore that the overall impact of operations and maintenance would be less than significant.

Mitigation Impacts

<u>*Compensatory Mitigation*</u>

The Compensatory Mitigation Plan could result in impacts on white sturgeon as analyzed in this chapter. As discussed for green sturgeon, effects on white sturgeon from compensatory mitigation are uncertain but may be limited given observations of little white sturgeon use of tidal wetland habitat (Patton et al. 2020) and acoustically tagged juvenile green sturgeon generally remaining in the mainstem river channel (Thomas et al. 2019).

<u>*Other Mitigation Measures*</u>

Other mitigation measures proposed would have no impacts on white sturgeon during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact white sturgeon during operation and maintenance, and there would be no impact.

Overall, the impact on white sturgeon during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. Overall, south Delta entrainment risk of white sturgeon would be similar and low based on the results of the salvage-density method (Tables 12-159 and 12-160). Application of the Delta outflow-year class strength regressions suggested the potential for lower year class strength in wetter years under the No Project Alternative during the April–May period compared to similar year class strength during the March–July (Tables 12-161 and 12-162). This reflects climate change-related differences in watershed precipitation/runoff and, as discussed for the project alternatives, there is uncertainty in the effect because the mechanisms (e.g., relative importance of Delta inflow vs. Delta outflow vs. upstream flows) are not known.

Table 12-159. Salvage of White Sturgeon at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	19	20 (5%)
Above normal	N/A	(10%)
Below normal	11	16 (41%)
Dry	5	5 (-5%)
Critically dry	5	4 (-16%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-160. Salvage of White Sturgeon at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	83	61 (-26%)
Above normal	N/A	(-53%)
Below normal	18	13 (-26%)
Dry	2	2 (-5%)
Critically dry	0	0 (0%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years. Results are not future predictions and are intended only to compare alternatives.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-161. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on March–July Delta Outflow-Year Class Strength Regression, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	117	111 (-5%)
Above normal	46	45 (-1%)
Below normal	7	9 (28%)
Dry	1	2 (308%)
Critically dry	0	0 (0%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-162. White Sturgeon Year-Class Strength Averaged by Water Year Type, Based on April–May Delta Outflow-Year Class Strength Regression, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	144	126 (-13%)
Above normal	62	55 (-13%)
Below normal	20	23 (18%)
Dry	4	6 (39%)
Critically dry	0	0 (-100%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-10: Effects of Operations and Maintenance of Water Conveyance Facilities on Pacific Lamprey and River Lamprey

Operations and Maintenance—All Project Alternatives

Pacific and river lamprey ammocoetes smaller than 40–50-mm total length could be entrained by the north Delta intakes if passing close by during operational periods. The probability of entrainment will be reduced to almost zero at 60-mm total length (Rose and Mesa 2012). It is not known what proportion of ammocoetes may pass the intakes. Larger migrating juvenile lamprey (macrophthalmia, around 120-mm total length) would not be at risk of entrainment because of their size. Impingement risk for lamprey macrophthalmia would be very low because the intakes' fish screens are designed to be protective of delta smelt and have approach velocity of 0.2 feet per second (Moser et al. 2015). Given the tendency for elevated river flows/precipitation events to coincide with Pacific lamprey macrophthalmia migrating in very high numbers (Goodman et al. 2015) or ammocoetes being flushed from burrows (Rose and Mesa 2012), potential near-field effects from the north Delta intakes would be limited under all project alternatives by inclusion of pulse flow protection measures (see Chapter 3, Sections 3.16.1.3, *Pulse Protection*, and 3.16.1.4, *Low Level Pumping*). As previously discussed for delta smelt in Impact AQUA-6, the cylindrical tee screen proposed for the north Delta intakes may exclude a considerably greater proportion of small fish than would be expected based solely on theoretical calculations (Nobriga et al. 2004), with mechanisms for this including detection and avoidance of near-field hydraulic conditions created by the screens (Coutant 2021; albeit with the caveats previously described for winter-run Chinook salmon). As discussed for winter-run Chinook salmon in Impact AQUA-2, available studies do not suggest elevated predation mortality in association with screening facilities (Vogel 2008b; Demetras et al. 2013; Michel et al. 2014; Henderson et al. 2019), although there is uncertainty. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the development of future operations and adaptive management (see Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

Application of the salvage-density method (Appendix 12B, Section 12B.2, *Salvage-Density Method*) indicated that there would be little difference in south Delta exports between the project alternatives and existing conditions during the time period of lamprey[50] salvage (Table 12-163; Table 12-164).[51] It is not known what proportion of lamprey are entrained at the south Delta export facilities, but the available information on overall Delta habitat occupancy suggests that the proportion would be low, given low occurrence in the south Delta (Goertler et al. 2020).

Table 12-163. Salvage of Lamprey at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	842	817 (-3%)	822 (-2%)	827 (-2%)	820 (-3%)	815 (-3%)
Above normal	N/A	(-3%)	(1%)	(0%)	(-1%)	(-3%)
Below normal	160	149 (-7%)	157 (-2%)	153 (-4%)	150 (-6%)	149 (-7%)
Dry	62	60 (-3%)	61 (-2%)	60 (-4%)	60 (-4%)	60 (-3%)
Critically dry	54	53 (-2%)	54 (-1%)	54 (-1%)	53 (-2%)	54 (-2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-164. Salvage of Lamprey at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	6,595	6,648 (1%)	6,616 (0%)	6,416 (-3%)	6,594 (0%)	6,636 (1%)
Above normal	N/A	(1%)	(-1%)	(0%)	(1%)	(1%)
Below normal	1,509	1,560 (3%)	1,555 (3%)	1,578 (5%)	1,558 (3%)	1,555 (3%)
Dry	1,570	1,472 (-6%)	1,439 (-8%)	1,525 (-3%)	1,522 (-3%)	1,471 (-6%)
Critically dry	40	40 (1%)	39 (-2%)	40 (1%)	41 (2%)	41 (2%)

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[50] Lamprey are generally not identified to species in salvage samples, so were grouped for this analysis.

[51] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-15 and 12B-16).

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on lampreys. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The cylindrical tee screen design and north Delta intake operational criteria would limit the potential for negative effects of the project alternatives on Pacific and river lamprey. Available information does not suggest that predation risk would be significantly elevated by the north Delta intakes, with uncertainty being addressed by fisheries studies. South Delta entrainment risk under the project alternatives would be negligibly different from existing conditions, and maintenance and compensatory mitigation would not have significant negative effects. As a result, it is concluded that the project alternatives would have a less-than-significant impact on Pacific and river lamprey.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on Pacific lamprey and river lamprey as analyzed in this chapter. Effects from compensatory mitigation (tidal perennial and channel margin habitat restoration) are uncertain given relatively little information about lamprey habitat use, but given availability of sediment for ammocoete burrowing, it would be expected that some lamprey would occupy compensatory mitigation sites given suitable conditions including temperature (Goertler et al. 2020). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs. Lamprey ammocoetes buried in substrate may not be exposed to CHABs occurring in compensatory mitigation sites because CHABs tend to occur at the water surface (see discussion in Chapter 9).

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on Pacific lamprey and river lamprey during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact Pacific lamprey and river lamprey during operation and maintenance, and there would be no impact.

Overall, the impact on Pacific lamprey and river lamprey during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, water operations would be the same as existing conditions at 2020, whereas there would be differences at 2040. No Project Alternative south Delta exports during lamprey salvage periods would be somewhat greater than existing conditions at SWP (Table 165) and somewhat less than existing conditions at CVP (Table 12-165).

Table 12-165. Salvage of Lamprey at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	842	969 (15%)
Above normal	N/A	(22%)
Below normal	160	226 (41%)
Dry	62	61 (-2%)
Critically dry	54	51 (-6%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-166. Salvage of Lamprey at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	6,595	6,437 (-2%)
Above normal	N/A	(-7%)
Below normal	1,509	1,459 (-3%)
Dry	1,570	1,386 (-12%)
Critically dry	40	35 (-13%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-11: Effects of Operations and Maintenance of Water Conveyance Facilities on Native Minnows (Sacramento Hitch, Sacramento Splittail, Hardhead, and Central California Roach)

Operations and Maintenance—All Project Alternatives

The north Delta intakes would have limited effects on native minnows because of screen design in relation to species size and distribution. The bulk of Sacramento splittail reproduction occurs on inundated floodplains (Sommer et al. 1997), particularly the Yolo Bypass, which discharges downstream of the north Delta intakes, therefore, larvae and small juveniles would avoid the north Delta intakes. As described for winter-run Chinook salmon (Impact AQUA-2) in the section discussing *Riparian and Wetland Bench Inundation*, there is the potential for less inundation of riparian bench habitat as a result of north Delta intake operations. This could negatively affect spawning habitat availability for Sacramento splittail, although this would be limited relative to floodplain habitat availability that drives population dynamics (Sommer et al. 1997), and mitigation for lower inundation provided as a result of significant impacts to juvenile Chinook salmon would limit negative effects. Larval entrainment in lower flow years when the Yolo Bypass is not inundated would be limited because bypass flow criteria would limit operations of the north Delta intakes in these years, with low percentages of river flow diverted during the spring period when larval splittail would occur (+). As previously discussed for delta smelt, the cylindrical tee screen proposed for the north Delta intakes may exclude a considerably greater proportion of small fish than would be expected based solely on theoretical calculations (Nobriga et al. 2004), with mechanisms for this including detection and avoidance of near-field hydraulic conditions created by the screens (Coutant 2021; albeit with the caveats previously described for winter-run Chinook salmon). Laboratory investigations suggest splittail exposed to fish screens do not have significant sublethal effects or increased mortality (Danley et al. 2002). As discussed for winter-run Chinook salmon in Impact AQUA-2, available studies do not suggest elevated predation mortality in association with screening facilities (Vogel 2008b; Demetras et al. 2013; Michel et al. 2014; Henderson et al. 2019), although there is uncertainty. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the development of future operations and adaptive management (see Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

Hardhead occur in relatively small numbers in the Delta compared to upstream (see discussion in Appendix 12A), so effects of the north Delta intakes on the species would be limited. Sacramento hitch spawning takes place mostly in stream riffles rather than the mainstem river and juveniles do not move into open water until they are 50-mm fork length, at which point they would be too large to be entrained by the north Delta intakes. In addition, Sacramento hitch abundance is relatively low in the Delta and the species is widespread upstream of the Delta in the Sacramento River (see Appendix 12A and Moyle et al. 2015:287-288). As described in Appendix 12A, Central California roach are mostly distributed upstream of the Delta, resulting in limited potential effects of the north Delta intakes.

Changes in south Delta operations as a result of the project alternatives would have limited impacts on native minnows. Data collated for the salvage-density method (Appendix 12B, Section 12B.2, *Salvage-Density Method*) indicate that very few Sacramento hitch, hardhead, or Central California roach are salvaged at the south Delta export facilities, reflecting very low abundance in the south Delta, so operations under the project alternatives would continue to entrain very few individuals. Relative to the other native minnow species, Sacramento splittail can be salvaged in very high numbers, but the salvage-density method indicated that there would be little difference in south Delta exports between the project alternatives and existing conditions during the period of historical splittail salvage (Tables 12-167 and 12-168),[52] indicating that entrainment risk would be similar under the project alternatives and existing conditions.

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[52] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-17 and 12B-18).

Table 12-167. Salvage of Sacramento Splittail at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	639,129	607,558 (-5%)	628,322 (-2%)	642,030 (0%)	622,670 (-3%)	607,098 (-5%)
Above normal	N/A	(-12%)	(-5%)	(1%)	(-7%)	(-12%)
Below normal	6,687	6,113 (-9%)	6,488 (-3%)	6,207 (-7%)	6,154 (-8%)	6,114 (-9%)
Dry	678	668 (-2%)	670 (-1%)	668 (-1%)	659 (-3%)	668 (-2%)
Critically dry	543	525 (-3%)	528 (-3%)	527 (-3%)	522 (-4%)	525 (-3%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-168. Salvage of Sacramento Splittail at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7,608,959	8,090,079 (6%)	7,923,573 (4%)	7,897,785 (4%)	7,962,208 (5%)	8,090,053 (6%)
Above normal	N/A	(9%)	(7%)	(4%)	(6%)	(9%)
Below normal	74,684	74,180 (-1%)	73,961 (-1%)	74,914 (0%)	75,637 (1%)	74,182 (-1%)
Dry	1,501	1,484 (-1%)	1,438 (-4%)	1,491 (-1%)	1,494 (0%)	1,485 (-1%)
Critically dry	12	12 (1%)	12 (0%)	12 (0%)	13 (2%)	13 (3%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Selenium exposure has been noted as a concern for Sacramento splittail (Johnson et al. 2020). As discussed in detail in Chapter 9, *Water Quality*, changes in water operations under the project alternatives would have little effect on Delta fish tissue concentrations of selenium, relative to existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on native minnows. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

Effects of operations and maintenance of the project alternatives would be less than significant for native minnows. This is because of factors including low spatial overlap with the north Delta intakes at sizes vulnerable to entrainment, screen design limiting the potential for entrainment, little difference in south Delta exports during periods of entrainment risk, little effect of changes in water operations to fish tissue selenium concentrations, and very limited effects of north Delta intake maintenance.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on native minnows as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would provide additional habitat for native minnows, primarily Sacramento splittail given their observed use of restored habitat in the Delta (Grimaldo et al. 2012). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs. The effects of compensatory mitigation on Sacramento splittail would be less than significant.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on native minnows during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact native minnows during operation and maintenance, and there would be no impact.

Overall, the impact on native minnows during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, water operations would be the same as existing conditions at 2020, whereas there would be differences at 2040. This is reflected by some increases or decreases in south Delta exports during the period of Sacramento splittail salvage, as indicated by the salvage-density method (Table 12-169; Table 12-170). As previously noted for the project alternatives, there would be little salvage of other native minnow species at the south Delta export facilities.

Table 12-169. Salvage of Sacramento Splittail at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	639,129	631,583 (-1%)
Above normal	N/A	(28%)
Below normal	6,687	10,797 (61%)
Dry	678	711 (5%)
Critically dry	543	506 (-7%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-170. Salvage of Sacramento Splittail at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7,608,959	6,115,517 (-20%)
Above normal	N/A	(-30%)
Below normal	74,684	28,986 (-61%)
Dry	1,501	435 (-71%)
Critically dry	12	12 (-5%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-12: Effects of Operations and Maintenance of Water Conveyance Facilities on Starry Flounder

Operations and Maintenance—All Project Alternatives

The north Delta intake facilities are upstream of areas where starry flounder typically occur (Baxter 1999; see also Appendix 12A), so there would be very little to no potential for near-field effects of the north Delta intakes. The project alternatives would have similar or slightly lower levels of south Delta exports and therefore entrainment risk compared to existing conditions, as illustrated by the salvage-density method (Tables 12-171 and 12-172;[53] method described in Appendix 12B, Section 12B.2, *Salvage-Density Method*). Application of the X2-abundance index regression (Appendix 12B, Section 12B.21, *X2–Abundance Index Regressions (Starry Flounder, Striped Bass, American Shad, and California Bay Shrimp)*) suggested that the abundance index of starry flounder could be similar or slightly lower under the project alternatives compared to existing conditions as a result of small changes in mean March–June X2 (Table 12-173).

Table 12-171. Salvage of Starry Flounder at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	66	61 (-8%)	63 (-5%)	63 (-5%)	61 (-7%)	61 (-8%)
Above normal	N/A	(-13%)	(-7%)	(-6%)	(-10%)	(-13%)
Below normal	136	128 (-6%)	134 (-1%)	130 (-5%)	128 (-6%)	128 (-6%)
Dry	23	23 (0%)	23 (0%)	23 (-2%)	23 (-2%)	23 (0%)

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[53] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-19 and 12B-20).

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Critically dry	18	18 (-1%)	18 (-2%)	18 (-2%)	18 (-2%)	18 (-1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-172. Salvage of Starry Flounder at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	14	15 (2%)	14 (-1%)	15 (1%)	15 (2%)	15 (2%)
Above normal	N/A	(2%)	(-1%)	(-1%)	(0%)	(2%)
Below normal	27	27 (0%)	26 (-2%)	27 (0%)	27 (1%)	27 (0%)
Dry	16	16 (1%)	16 (0%)	16 (1%)	16 (2%)	16 (1%)
Critically dry	7	7 (-1%)	7 (-3%)	7 (-2%)	7 (-1%)	7 (1%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-173. Starry Flounder Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	200	194 (-3%)	194 (-3%)	195 (-2%)	195 (-3%)	194 (-3%)
Above normal	148	139 (-6%)	139 (-6%)	142 (-5%)	140 (-6%)	139 (-6%)
Below normal	89	85 (-5%)	85 (-5%)	86 (-4%)	85 (-5%)	85 (-5%)
Dry	66	64 (-3%)	64 (-3%)	65 (-2%)	64 (-3%)	64 (-3%)
Critically dry	44	43 (-2%)	43 (-2%)	43 (-1%)	43 (-1%)	43 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on starry flounder, particularly because the location of the north Delta intake facilities is upstream of areas where starry flounder typically occur (Baxter 1999). Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The above analysis indicated that south Delta entrainment risk would differ little between the project alternatives and existing conditions. The X2-abundance index analysis indicated similar or slightly lower abundance index under the project alternatives based on March through May X2. Given that the differences are close to the threshold of significance (5%) and that there is uncertainty in such statistical relationships when assessing relatively small, operations-related differences, and because starry flounder are wide-ranging and occur not just in the San Francisco Estuary but also broadly along the Pacific coast (Appendix 12A), the impact of the project alternatives on starry flounder would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on starry flounder as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would be upstream of areas where starry flounder typically occur (Baxter 1999) although there could be some spatial overlap, thereby providing some additional habitat for the species. Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on starry flounder during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact starry flounder during operation and maintenance, and there would be no impact.

Overall, the impact on starry flounder during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. This is reflected by some increases or decreases in south Delta exports during the period of starry flounder salvage, as indicated by the salvage-density method (Tables 12-174 and 12-175). Salvage of starry flounder is low because the south Delta export facilities are upstream of the main estuarine range of the species.

Table 12-174. Salvage of Starry Flounder at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	66	70 (6%)
Above normal	N/A	(26%)

Water Year Type	EC	NPA
Below normal	136	220 (62%)
Dry	23	19 (-17%)
Critically dry	18	16 (-13%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-175. Salvage of Starry Flounder at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	14	10 (-29%)
Above normal	N/A	(-56%)
Below normal	27	12 (-57%)
Dry	16	10 (-38%)
Critically dry	7	7 (-2%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

The X2-abundance index relationship suggested that the starry flounder abundance index under the No Project Alternative could be similar (<5% different) in dry and critically dry water years, and 12%–32% lower in below normal, above normal, and wet years (Table 12-176).

Table 12-176. Starry Flounder Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	200	135 (-32%)
Above normal	148	111 (-25%)
Below normal	89	78 (-12%)
Dry	66	64 (-3%)
Critically dry	44	43 (-1%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-13: Effects of Operations and Maintenance of Water Conveyance Facilities on Northern Anchovy

Operations and Maintenance—All Project Alternatives

The north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and their locations are well upstream of areas where northern anchovy typically occur (Fleming 1999), so there would be no impact on northern anchovy.

Northern anchovy generally occur well downstream of the Delta. Any potential changes in salinity as a result of the project alternatives would be small relative to the salinity tolerance of northern anchovy (Fleming 1999). Neither indices of northern anchovy abundance nor indices of northern anchovy habitat extent are related to X2 (Kimmerer et al. 2009), which is an index of Delta outflow and its effects. This indicates that the minor differences in salinity between the project alternatives and existing conditions (see, for example, Appendix 5A, Attachment 3, Figure B.2.1.1)) would have little effect on northern anchovy.

CEQA Conclusion—All Project Alternatives

The distribution of northern anchovy generally well downstream of the Delta coupled with no statistically significant relationships between X2 and abundance indices or habitat extent and little difference in salinity as a result of the project alternatives compared to existing conditions, in addition to the broad distribution of the species beyond the San Francisco Estuary (Appendix 12A), indicates that impact of the project alternatives on northern anchovy would be less than significant.

Mitigation Impacts

<u>Compensatory Mitigation</u>

The Compensatory Mitigation Plan could result in impacts on northern anchovy as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would be upstream of areas where northern anchovy typically occur (Baxter 1999), although there could be some spatial overlap, thereby providing some additional habitat for the species. Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs

<u>Other Mitigation Measures</u>

Other mitigation measures proposed would have no impacts on northern anchovy during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact northern anchovy during operation and maintenance, and there would be no impact.

Overall, the impact on northern anchovy during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. As discussed for the project alternatives, there are no statistically significant relationships between X2 and indices of northern anchovy abundance or habitat extent (Kimmerer et al. 2009), and project-related differences in salinity would be well within the range of the species' tolerance, so the No Project Alternative would have little effect on the species.

Impact AQUA-14: Effects of Operations and Maintenance of Water Conveyance Facilities on Striped Bass

Operations and Maintenance—All Project Alternatives

Given the species' biology (spawning in the Sacramento River upstream of the Delta, eggs moving downstream into the Delta; see Appendix 12A), early life stages of striped bass would be exposed to potential negative effects from the north Delta intakes. Such effects would be limited for several reasons. First, the 1.75-mm opening of the cylindrical tee screens would tend to exclude striped bass eggs from entrainment: striped bass eggs are spherical (Wang 2010:299) and although they may be 1–1.35 mm in diameter when ready to be spawned (Woodhull 1947:99) and similar in size to the cylindrical tee screen openings following spawning but before water hardening (a mean diameter of 1.78 mm was observed for newly spawned eggs in the lower San Joaquin River by Woodhull [1947:101]), the diameter increases rapidly following water hardening such that eggs collected in the Sacramento River at Sacramento range in size from around 2.5 to 3.8 mm (Albrecht 1964:108). 100% exclusion of similarly sized eggs was demonstrated in laboratory tests of 3-mm-diameter white sucker eggs released upstream of 2-mm-opening cylindrical screens with 0.25- and 0.5-foot-per-second slot velocity and 0.25- to 1-foot-per-second flume velocity[54] (Normandeau Associates and ASA Analysis and Communications 2011:50). Second, although exclusion from entrainment could lead to impingement risk, the laboratory tests found sweep off of eggs from the screens increased from approximately 50% at 0.25-foot-per-second flume velocity to 100% at 1-foot-per-second flume velocity (Normandeau Associates and ASA Analysis and Communications 2011:50). Third, diversions at the north Delta intakes would be quite limited during the spring striped bass spawning period: As shown in Table 12-88 in the discussion of delta smelt impacts in Impact AQUA-6, the median percentage of Sacramento River flow diverted by the north Delta intakes is 0% in April, May, and June, with maximum of 14%–20%. Lastly, although there may be some near-field losses of striped bass early life stages to the north Delta intakes, available studies suggest that even considerable levels of historical estimated population-level entrainment (33%–99% of the population) did not give discernible population-level effects (Kimmerer et al. 2000, 2001; see additional discussion in Appendix 12A).

Based on the observed association of striped bass with anthropogenically altered habitats (Sabal et al. 2016), the north Delta intakes may provide additional habitat for striped bass, although this addition would be limited relative to the overall available habitat in the Delta.

Application of the salvage-density method (Appendix 12B, Section 12B.2, *Salvage-Density Method*) indicated that project alternative south Delta exports would be similar or lower than existing

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[54] Slot velocity is analogous to approach velocity and flume velocity is analogous to sweeping velocity.

conditions during the period of striped bass salvage (Tables 12-177 and 12-178),[55] indicating that south Delta entrainment risk would not be greater under the project alternatives.

Table 12-177. Salvage of Striped Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	330,367	305,968 (-7%)	311,060 (-6%)	310,247 (-6%)	306,929 (-7%)	305,832 (-7%)
Above normal	N/A	(-16%)	(-13%)	(-12%)	(-15%)	(-16%)
Below normal	359,724	317,881 (-12%)	338,966 (-6%)	324,742 (-10%)	319,576 (-11%)	317,903 (-12%)
Dry	141,749	136,780 (-4%)	140,123 (-1%)	135,387 (-4%)	135,496 (-4%)	136,845 (-3%)
Critically dry	77,867	73,511 (-6%)	73,525 (-6%)	76,047 (-2%)	75,886 (-3%)	73,248 (-6%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-178. Salvage of Striped Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	61,578	62,353 (1%)	61,516 (0%)	61,805 (0%)	62,569 (2%)	62,335 (1%)
Above normal	N/A	(3%)	(1%)	(0%)	(2%)	(2%)
Below normal	105,493	105,208 (0%)	102,283 (-3%)	105,442 (0%)	105,750 (0%)	105,217 (0%)
Dry	186,099	183,984 (-1%)	178,513 (-4%)	184,990 (-1%)	185,333 (0%)	184,031 (-1%)
Critically dry	61,043	62,407 (2%)	62,282 (2%)	61,469 (1%)	62,120 (2%)	62,411 (2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Various statistically significant relationships exist between striped bass juvenile survival or abundance indices and X2 (Kimmerer et al. 2009). Application of these relationships (see methods description in Appendix 12B, Section 12B.21, *X2–Abundance Index Regressions (Starry Flounder, Striped Bass, American Shad, and California Bay Shrimp)*) suggested that there would be little difference in survival (Table 12-179) or abundance indices (Tables 12-180, 12-181, 12-182, and 12-183) between the project alternatives and existing conditions.

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[55] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-21 and 12B-22).

Table 12-179. Striped Bass Townet Survey Survival Index Averaged by Water Year Type, Based on X2-Survival Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	202	197 (-3%)	197 (-3%)	197 (-2%)	197 (-2%)	197 (-3%)
Above normal	156	148 (-5%)	148 (-5%)	150 (-4%)	149 (-4%)	148 (-5%)
Below normal	100	98 (-2%)	98 (-2%)	99 (-2%)	98 (-2%)	98 (-2%)
Dry	77	76 (-1%)	76 (-1%)	76 (-1%)	76 (-1%)	76 (-1%)
Critically dry	57	57 (0%)	57 (0%)	57 (0%)	57 (0%)	57 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-180. Striped Bass Townet Survey Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	1.5	1.5 (-2%)	1.5 (-2%)	1.5 (-2%)	1.5 (-2%)	1.5 (-2%)
Above normal	1.2	1.2 (-3%)	1.2 (-4%)	1.2 (-3%)	1.2 (-3%)	1.2 (-4%)
Below normal	0.9	0.9 (-2%)	0.9 (-2%)	0.9 (-1%)	0.9 (-2%)	0.9 (-2%)
Dry	0.7	0.7 (0%)	0.7 (0%)	0.7 (0%)	0.7 (-1%)	0.7 (0%)
Critically dry	0.6	0.6 (0%)	0.6 (0%)	0.6 (0%)	0.6 (0%)	0.6 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-181. Striped Bass Fall Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	340	336 (-1%)	336 (-1%)	337 (-1%)	336 (-1%)	336 (-1%)
Above normal	305	299 (-2%)	299 (-2%)	300 (-2%)	299 (-2%)	299 (-2%)
Below normal	251	249 (-1%)	249 (-1%)	249 (-1%)	249 (-1%)	249 (-1%)
Dry	224	224 (0%)	224 (0%)	224 (0%)	223 (0%)	224 (0%)
Critically dry	197	197 (0%)	196 (0%)	197 (0%)	197 (0%)	196 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-182. Striped Bass Bay Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	1,767	1,720 (-3%)	1,720 (-3%)	1,724 (-2%)	1,722 (-3%)	1,720 (-3%)
Above normal	1,329	1,262 (-5%)	1,260 (-5%)	1,277 (-4%)	1,266 (-5%)	1,260 (-5%)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Below normal	829	809 (-2%)	809 (-2%)	812 (-2%)	810 (-2%)	809 (-2%)
Dry	617	613 (-1%)	613 (-1%)	614 (-1%)	613 (-1%)	613 (-1%)
Critically dry	448	448 (0%)	447 (0%)	448 (0%)	448 (0%)	447 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-183. Striped Bass Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	3,173	3,119 (-2%)	3,119 (-2%)	3,124 (-2%)	3,121 (-2%)	3,118 (-2%)
Above normal	2,699	2,620 (-3%)	2,618 (-3%)	2,637 (-2%)	2,624 (-3%)	2,618 (-3%)
Below normal	2,037	2,010 (-1%)	2,009 (-1%)	2,014 (-1%)	2,010 (-1%)	2,010 (-1%)
Dry	1,720	1,713 (0%)	1,712 (0%)	1,714 (0%)	1,712 (0%)	1,713 (0%)
Critically dry	1,422	1,421 (0%)	1,420 (0%)	1,421 (0%)	1,422 (0%)	1,420 (0%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

As described in Chapter 9, *Water Quality*, the State Water Board's *Water Quality Control Plan for the San Francisco Bay/Sacramento–San Joaquin Delta Estuary* (Bay-Delta WQCP) also includes water quality objectives for electrical conductivity (EC) for protection of fish and wildlife applicable at the San Joaquin River at Jersey Point and San Joaquin River at Prisoners Point (refer to Appendix 9G, *Electrical Conductivity*, Table 9G-7). These objectives are for provision of suitable EC for striped bass spawning habitat. Under the project alternatives, the modeled percent of days EC exceeding the Bay-Delta WQCP fish and wildlife objectives for EC at Jersey Point was 0.02% greater than existing conditions, while at Prisoners Point the modeled percent of days the objective would be exceeded was 0.25% to 0.50% greater than existing conditions (refer to Appendix 9G, Table 9G-7).

The modeled increases in the frequency of exceeding Bay-Delta WQCP objectives at Jersey Point and Prisoners Point are attributable to the monthly timestep of the hydrologic modeling conducted by CalSim 3, as compared to the 15-minute timestep of DSM2. CalSim 3 includes an algorithm to operate the SWP/CVP to meet Bay-Delta WQCP objectives, among other requirements. While CalSim 3 simulates operations on a monthly timestep, actual decisions associated with real-time system operations are conducted on a daily timestep. The small modeled increase in frequency of exceedance of objectives relative to the 93-year period of record modeled indicates that the alternatives would not be expected to increase the frequency of exceeding Bay-Delta WQCP objectives with actual real-time operations. As described in Section 3.16.3, *Integration of North Delta Intakes with South Delta Facilities*, the project facilities would be operated to meet Bay-Delta WQCP EC objectives, as implemented through State Water Board Decision 1641.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on striped bass.

Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

Although the project alternatives would have the potential for negative near-field effects on striped bass early life stages, the effects would be limited because of the north Delta intake cylindrical tee screen design and operations limiting diversions during the spring striped bass spawning period. South Delta entrainment potential under the project alternatives would be similar or slightly lower than existing conditions, and survival or abundance indices of juveniles would differ little between the project alternatives and existing conditions. The project alternatives would not give increases in exceedances of water quality objectives pertaining to lower San Joaquin River striped bass spawning conditions. The impact of the project alternatives on striped bass would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on striped bass as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would provide additional habitat for striped bass given their observed use of restored habitat in the Delta (Grimaldo et al. 2012). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on striped bass during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact striped bass during operation and maintenance, and there would be no impact.

Overall, the impact on striped bass during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. The salvage-density method suggested that south Delta exports during the striped bass salvage period would be similar or greater under the No Project Alternative for the SWP (Table 12-184) but less at the CVP (Table 12-185), relative to existing conditions.

Table 12-184. Salvage of Striped Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	330,367	324,311 (-2%)

Water Year Type	EC	NPA
Above normal	N/A	(1%)
Below normal	359,724	465,094 (29%)
Dry	141,749	155,647 (10%)
Critically dry	77,867	69,626 (-11%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-185. Salvage of Striped Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	61,578	46,924 (-24%)
Above normal	N/A	(-48%)
Below normal	105,493	41,286 (-61%)
Dry	186,099	58,588 (-69%)
Critically dry	61,043	42,500 (-30%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Application of the various statistical relationships between striped bass survival/abundance indices and X2 indicated the potential for appreciably lower survival/abundance indices under the No Project Alternative compared to existing conditions, primarily in below normal, above normal, and wet water years (Tables 12-186, 12-187, 12-188, 12-189, and 12-190). DSM2-QUAL modeling indicated that there would be little difference in the percentage of days exceeding the lower San Joaquin River striped bass spawning water quality objective between the No Project Alternative (Jersey Point: 0.28% of days; Prisoners Point: 0% of days) and existing conditions (0% of days at both Jersey Point and Prisoners Point).

Table 12-186. Striped Bass Townet Survey Survival Index Averaged by Water Year Type, Based on X2-Survival Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	202	140 (-31%)
Above normal	156	119 (-24%)
Below normal	100	90 (-11%)
Dry	77	75 (-3%)

Water Year Type	EC	NPA
Critically dry	57	56 (-2%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-187. Striped Bass Townet Survey Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	1.5	1.1 (-24%)
Above normal	1.2	1.0 (-18%)
Below normal	0.9	0.8 (-8%)
Dry	0.7	0.7 (-2%)
Critically dry	0.6	0.6 (-2%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-188. Striped Bass Fall Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	340	291 (-15%)
Above normal	305	272 (-11%)
Below normal	251	240 (-5%)
Dry	224	222 (-1%)
Critically dry	197	195 (-1%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-189. Striped Bass Bay Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	1,767	1,185 (-33%)
Above normal	1,329	992 (-25%)

Water Year Type	EC	NPA
Below normal	829	734 (-11%)
Dry	617	600 (-3%)
Critically dry	448	438 (-2%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-190. Striped Bass Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	3,173	2,518 (-21%)
Above normal	2,699	2,277 (-16%)
Below normal	2,037	1,901 (-7%)
Dry	1,720	1,695 (-1%)
Critically dry	1,422	1,403 (-1%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-15: Effects of Operations and Maintenance of Water Conveyance Facilities on American Shad

Operations and Maintenance—All Project Alternatives

The early life stages of American shad could be exposed to near-field effects of the north Delta intakes, although as described in Appendix 12A and in contrast to striped bass, appreciable numbers rear upstream of the Delta. As with striped bass, American shad eggs are sufficiently large (2.5–4.4-mm diameter; Wang 2010:65) to be excluded from entrainment the north Delta intake cylindrical tee screens and, as discussed for striped bass, have an increasing probability of being swept off the screens (avoiding impingement) with increasing sweeping velocity. Larval American shad could be entrained by the north Delta intakes, but as discussed for striped bass, the spring spawning and egg/larval period has relatively low north Delta diversions (see Table 12-88 in the delta smelt impact discussion of Impact AQUA-6). As discussed for winter-run Chinook salmon in Impact AQUA-2, available studies do not suggest elevated predation mortality in association with screening facilities (Vogel 2008b; Demetras et al. 2013; Michel et al. 2014; Henderson et al. 2019), thereby suggesting such effects on American shad would be limited, although there is uncertainty. Fisheries studies would be undertaken to provide information on predatory fish and predation rate at the north Delta intakes once they are operational, to inform the development of future operations and adaptive management (see Chapter 3, Section 3.18, *Adaptive Management and Monitoring Program*).

There would be little difference in south Delta exports between the project alternatives and existing conditions during the American shad salvage periods, based on the results of the salvage-density method (Tables 12-191 and 12-192;[56] see methods description in Appendix 12B, Section 12B.2, *Salvage-Density Method*).

Table 12-191. Salvage of American Shad at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	339,862	320,506 (-6%)	323,701 (-5%)	323,786 (-5%)	321,567 (-5%)	320,375 (-6%)
Above normal	N/A	(-12%)	(-11%)	(-10%)	(-12%)	(-13%)
Below normal	252,802	222,451 (-12%)	234,634 (-7%)	227,078 (-10%)	223,101 (-12%)	222,324 (-12%)
Dry	131,550	125,199 (-5%)	128,711 (-2%)	123,791 (-6%)	124,579 (-5%)	125,408 (-5%)
Critically dry	72,248	68,761 (-5%)	70,602 (-2%)	69,316 (-4%)	68,778 (-5%)	68,458 (-5%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-192. Salvage of American Shad at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	240,418	241,341 (0%)	240,218 (0%)	239,914 (0%)	242,635 (1%)	241,282 (0%)
Above normal	N/A	(0%)	(0%)	(-1%)	(0%)	(0%)
Below normal	66,289	66,094 (0%)	63,919 (-4%)	66,537 (0%)	66,522 (0%)	66,087 (0%)
Dry	75,940	74,746 (-2%)	72,295 (-5%)	75,946 (0%)	75,667 (0%)	74,706 (-2%)
Critically dry	3,183	3,217 (1%)	3,157 (-1%)	3,122 (-2%)	3,178 (0%)	3,245 (2%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

A statistically significant relationship exists between the American shad Fall Midwater Trawl index and X2 (Kimmerer et al. 2009). Application of this relationship (see methods description in Appendix 12B, Section 12B.21, *X2–Abundance Index Regressions (Starry Flounder, Striped Bass, American Shad, and California Bay Shrimp)*) suggested that there would be little difference in abundance indices between the project alternatives and existing conditions (Tables 12-193 and 12-194).

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[56] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-23 and 12B-24).

Table 12-193. American Shad Fall Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	3,031	3,004 (-1%)	3,003 (-1%)	3,009 (-1%)	3,006 (-1%)	3,004 (-1%)
Above normal	2,686	2,619 (-2%)	2,614 (-3%)	2,635 (-2%)	2,621 (-2%)	2,618 (-3%)
Below normal	2,137	2,075 (-3%)	2,075 (-3%)	2,090 (-2%)	2,080 (-3%)	2,075 (-3%)
Dry	1,882	1,832 (-3%)	1,828 (-3%)	1,848 (-2%)	1,840 (-2%)	1,832 (-3%)
Critically dry	1,531	1,507 (-2%)	1,506 (-2%)	1,509 (-1%)	1,510 (-1%)	1,504 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Table 12-194. American Shad Bay Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	7,809	7,715 (-1%)	7,713 (-1%)	7,734 (-1%)	7,723 (-1%)	7,715 (-1%)
Above normal	6,594	6,368 (-3%)	6,354 (-4%)	6,423 (-3%)	6,378 (-3%)	6,365 (-3%)
Below normal	4,815	4,625 (-4%)	4,624 (-4%)	4,670 (-3%)	4,640 (-4%)	4,625 (-4%)
Dry	4,045	3,897 (-4%)	3,884 (-4%)	3,944 (-2%)	3,920 (-3%)	3,897 (-4%)
Critically dry	3,036	2,970 (-2%)	2,968 (-2%)	2,978 (-2%)	2,978 (-2%)	2,964 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on American shad. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

As discussed in detail above, the potential effects of the project alternatives on American shad (i.e., near-field effects; south Delta entrainment risk; project operations changing Delta outflow and therefore potentially abundance through X2-abundance relationships; maintenance activities; and compensatory mitigation) would be limited compared to existing conditions. The impact of the project alternatives on American shad would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on American shad as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would provide additional habitat for American shad given their observed use of restored habitat in the

Delta (Grimaldo et al. 2012). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on American shad during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact American shad during operation and maintenance, and there would be no impact.

Overall, the impact on American shad during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, south Delta exports during the American shad salvage period would be lower than existing conditions (Tables 12-195 and 12-196), therefore entrainment risk under the No Project Alternative would not be greater than existing conditions. Application of the X2-abundance index relationships suggested that the abundance index under the No Project Alternative generally could be similar to existing conditions in below normal, dry, and critically dry years and 9%–16% lower in above normal and wet years (Tables 12-197 and 12-198).

Table 12-195. Salvage of American Shad at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	339,862	315,950 (-7%)
Above normal	N/A	(-8%)
Below normal	252,802	205,185 (-19%)
Dry	131,550	103,418 (-21%)
Critically dry	72,248	61,045 (-16%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-196. Salvage of American Shad at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	240,418	198,256 (-18%)
Above normal	N/A	(-42%)

Water Year Type	EC	NPA
Below normal	66,289	43,154 (-35%)
Dry	75,940	51,846 (-32%)
Critically dry	3,183	3,012 (-5%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-197. American Shad Fall Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	3,031	2,662 (-12%)
Above normal	2,686	2,439 (-9%)
Below normal	2,137	2,049 (-4%)
Dry	1,882	1,870 (-1%)
Critically dry	1,531	1,537 (0%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Table 12-198. American Shad Bay Midwater Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	7,809	6,523 (-16%)
Above normal	6,594	5,768 (-13%)
Below normal	4,815	4,539 (-6%)
Dry	4,045	4,006 (-1%)
Critically dry	3,036	3,057 (1%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-16: Effects of Operations and Maintenance of Water Conveyance Facilities on Threadfin Shad

Operations and Maintenance—All Project Alternatives

The project alternatives would have the potential for similar near-field effects as discussed for other species, such as entrainment of larvae, although threadfin shad eggs are adhesive and spawned on vegetation and other floating material (Wang 2010:73), and therefore not likely to be entrained in large numbers. Any near-field effects would be limited because threadfin shad are widely distributed in the Delta, with by far the greatest abundance in the southeast Delta near Stockton (Feyrer et al. 2009). Application of the salvage-density method (Appendix 12B, Section 12B.2, *Salvage-Density Method*) indicated that south Delta exports and therefore entrainment risk would be similar or slightly lower under the project alternatives relative to existing conditions (Tables 12-199 and 12-200).[57]

Table 12-199. Salvage of Threadfin Shad at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	511,378	482,412 (-6%)	487,249 (-5%)	487,266 (-5%)	484,464 (-5%)	482,387 (-6%)
Above normal	N/A	(-13%)	(-11%)	(-10%)	(-12%)	(-13%)
Below normal	1,435,055	1,213,366 (-15%)	1,323,568 (-8%)	1,252,178 (-13%)	1,214,877 (-15%)	1,211,980 (-16%)
Dry	1,292,223	1,275,902 (-1%)	1,288,289 (0%)	1,252,484 (-3%)	1,277,772 (-1%)	1,277,559 (-1%)
Critically dry	383,808	368,864 (-4%)	360,337 (-6%)	365,232 (-5%)	365,792 (-5%)	368,544 (-4%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-200. Salvage of Threadfin Shad at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	751,727	755,075 (0%)	749,036 (0%)	752,468 (0%)	759,602 (1%)	754,987 (0%)
Above normal	N/A	(0%)	(0%)	(-1%)	(0%)	(0%)
Below normal	955,956	947,716 (-1%)	902,141 (-6%)	954,847 (0%)	953,782 (0%)	947,947 (-1%)
Dry	3,015,222	3,022,146 (0%)	2,974,330 (-1%)	3,038,768 (1%)	3,026,018 (0%)	3,022,602 (0%)

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[57] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-25 and 12B-26).

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Critically dry	165,694	172,493 (4%)	171,615 (4%)	168,279 (2%)	171,380 (3%)	172,271 (4%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on threadfin shad, which are most abundant in the southeast Delta (Feyrer et al. 2009), well away from the maintenance activities. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The project alternatives would have limited effects on threadfin shad, which are primarily distributed in the southeast Delta, well away from potential near-field and maintenance effects from the project alternatives. South Delta entrainment risk, as indicated by south Delta exports, would not be greater under the project alternatives. The impact of the project alternatives on threadfin shad would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on threadfin shad as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would provide additional habitat for threadfin shad given their observed use of restored habitat in the Delta (Grimaldo et al. 2012). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on threadfin shad during operations and maintenance of Water Conveyance Facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact threadfin shad during operation and maintenance, and there would be no impact.

Overall, the impact on threadfin shad during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. Under the No Project Alternative, south Delta exports during the threadfin shad salvage period would be less-than-existing conditions (Table 12-201 and 12-202).

Table 12-201. Salvage of Threadfin Shad at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	511,378	453,379 (-11%)
Above normal	N/A	(-12%)
Below normal	1,435,055	1,240,225 (-14%)
Dry	1,292,223	744,139 (-42%)
Critically dry	383,808	254,675 (-34%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-202. Salvage of Threadfin Shad at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	751,727	609,277 (-19%)
Above normal	N/A	(-43%)
Below normal	955,956	459,439 (-52%)
Dry	3,015,222	1,653,939 (-45%)
Critically dry	165,694	160,369 (-3%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-17: Effects of Operations and Maintenance of Water Conveyance Facilities on Black Bass

Operations and Maintenance—All Project Alternatives

Black bass would be susceptible to near-field effects such as entrainment or impingement at the north Delta intakes, although population-level effects would be expected to be minimal because the species is widespread in the Delta and the nearshore habitat they occupy makes them less susceptible to entrainment (Grimaldo et al. 2009). The added in-water structure of the north Delta intakes and the associated riprap installed to prevent scour would create additional habitat for black bass, although very limited relative to the amount of habitat already occurring in the Delta. South Delta exports under the project alternatives would be relatively similar to existing conditions during the time periods that black bass are salvaged, as indicated by the salvage-density method (Tables 12-203, 12-204, 12-205, and 12-206;[58] for methods see Appendix 12B, Section 12B.2, *Salvage-Density Method*), and entrainment risk would be expected to be similar in any case because overall hydrodynamic conditions are not well correlated with black bass salvage (Grimaldo et al. 2009[59]).

Table 12-203. Salvage of Largemouth Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	21,163	19,686 (-7%)	20,252 (-4%)	19,918 (-6%)	19,725 (-7%)	19,685 (-7%)
Above normal	N/A	(-17%)	(-13%)	(-12%)	(-15%)	(-17%)
Below normal	15,856	13,412 (-15%)	14,591 (-8%)	13,913 (-12%)	13,440 (-15%)	13,409 (-15%)
Dry	9,289	9,225 (-1%)	9,325 (0%)	9,068 (-2%)	9,176 (-1%)	9,230 (-1%)
Critically dry	3,881	3,714 (-4%)	3,658 (-6%)	3,728 (-4%)	3,762 (-3%)	3,698 (-5%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-204. Salvage of Largemouth Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	49,551	50,838 (3%)	49,387 (0%)	50,407 (2%)	50,908 (3%)	50,831 (3%)
Above normal	N/A	(5%)	(1%)	(1%)	(3%)	(5%)
Below normal	70,797	70,040 (-1%)	67,881 (-4%)	70,434 (-1%)	70,475 (0%)	70,053 (-1%)
Dry	75,222	74,670 (-1%)	72,591 (-3%)	75,089 (0%)	75,191 (0%)	74,682 (-1%)
Critically dry	41,271	42,540 (3%)	42,375 (3%)	41,791 (1%)	42,373 (3%)	42,513 (3%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

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[58] Results averaged by water year type and month are provided in Appendix 12B (Tables 12B-27, 12B-28, 12B-29, and 12B-30).

[59] The overwhelming majority of black bass south Delta salvage consists of largemouth bass, with very few smallmouth bass collected, based on data collated for the salvage-density method.

Table 12-205. Salvage of Smallmouth Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	6	6 (-7%)	6 (-6%)	6 (-5%)	6 (-6%)	6 (-7%)
Above normal	N/A	(-4%)	(1%)	(2%)	(-3%)	(-4%)
Below normal	7	7 (-3%)	7 (1%)	7 (-6%)	7 (-3%)	7 (-4%)
Dry	14	15 (5%)	15 (6%)	15 (5%)	15 (5%)	15 (5%)
Critically dry	11	11 (-1%)	11 (1%)	10 (-7%)	11 (-3%)	11 (-4%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Table 12-206. Salvage of Smallmouth Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Above normal	N/A	(0%)	(0%)	(0%)	(0%)	(0%)
Below normal	10	10 (2%)	10 (2%)	10 (1%)	10 (3%)	10 (2%)
Dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Critically dry	0	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)

Notes: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

Alt = alternative; EC = existing conditions; N/A = not applicable.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on black bass. Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

The project alternatives would have a less-than-significant impact on black bass because the species is widespread in the Delta, and any effects from operations and maintenance would be minimal for the reasons discussed above.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on black bass as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would provide additional habitat for black bass given their observed use of restored habitat in the Delta (Grimaldo et al. 2012). Analysis included in Chapter 9 for Impact WQ-14 found that compensatory mitigation would have a less-than-significant impact on CHABs.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on black bass during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact black bass during operation and maintenance, and there would be no impact.

Overall, the impact on black bass during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

South Delta exports under the No Project Alternative would differ somewhat from existing conditions during the time periods that black bass are salvaged, as indicated by the salvage-density method (Tables 12-207, 12-208, 12-209, and 12-210), but as noted for the project alternatives, entrainment risk would be expected to be similar because overall hydrodynamic conditions are not well correlated with black bass salvage (Grimaldo et al. 2009).

Table 12-207. Salvage of Largemouth Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	21,163	21,422 (1%)
Above normal	N/A	(13%)
Below normal	15,856	17,563 (11%)
Dry	9,289	7,279 (-22%)
Critically dry	3,881	2,900 (-25%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-208. Salvage of Largemouth Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	49,551	34,556 (-30%)
Above normal	N/A	(-55%)
Below normal	70,797	23,316 (-67%)
Dry	75,222	26,821 (-64%)
Critically dry	41,271	30,487 (-26%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-209. Salvage of Smallmouth Bass at SWP Banks Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	6	7 (6%)
Above normal	N/A	(13%)
Below normal	7	5 (-31%)
Dry	14	9 (-36%)
Critically dry	11	6 (-41%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Table 12-210. Salvage of Smallmouth Bass at CVP Jones Pumping Plant, Averaged by Water Year Type, Based on the Salvage-Density Method, Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	0	0 (0%)
Above normal	N/A	(0%)
Below normal	10	6 (-41%)
Dry	0	0 (0%)
Critically dry	0	0 (0%)

Notes: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent.

The analysis was based on historical salvage data during 2009–2019, which did not include any above normal water years; results for above normal years focus only on relative difference in exports based on salvage-density patterns from wet years.

NPA = No Project Alternative; EC = existing conditions; N/A = not applicable.

Impact AQUA-18: Effects of Operations and Maintenance of Water Conveyance Facilities on California Bay Shrimp

Operations and Maintenance—All Project Alternatives

California bay shrimp occur well downstream of the north Delta intakes (Appendix 12A; Hieb 1999:78–90), so there would be no risk of near-field effects from the project alternatives. Kimmerer et al. (2009) found a statistically significant negative relationship between annual mean April–June X2 and the bay shrimp Bay otter trawl abundance index. Application of this relationship (Appendix 12B, Section 12B.21, *X2–Abundance Index Regressions (Starry Flounder, Striped Bass, American Shad, and California Bay Shrimp)*) suggested that the bay shrimp abundance index under the project alternatives would be similar or slightly lower than under existing conditions (Table 12-211).

Table 12-211. California Bay Shrimp Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009)

Water Year Type	EC	Alts 1, 3	Alts 2a, 4a	Alts 2b, 4b	Alts 2c, 4c	Alt 5
Wet	368	363 (-1%)	363 (-1%)	364 (-1%)	363 (-1%)	363 (-1%)
Above normal	305	295 (-3%)	294 (-4%)	297 (-3%)	295 (-3%)	295 (-3%)
Below normal	220	211 (-4%)	211 (-4%)	213 (-3%)	212 (-4%)	211 (-4%)
Dry	178	173 (-3%)	172 (-3%)	174 (-2%)	174 (-2%)	173 (-3%)
Critically dry	131	129 (-1%)	129 (-2%)	129 (-1%)	129 (-1%)	129 (-2%)

Note: Percentage values in parentheses indicate differences of alternatives compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

Alt = alternative; EC = existing conditions.

Maintenance of the north Delta intake facilities for each alternative would have very limited effects on the adjacent aquatic environment and hence very little potential for effects on California bay shrimp, which in any case are distributed well downstream (Hieb 1999:78–90). Screen pressure washing and sediment jetting would have very small impacts at the riverscape scale based on redistribution of sediment or accumulated vegetation and other materials.

CEQA Conclusion—All Project Alternatives

Near-field operations and maintenance effects of the project alternatives would not affect California bay shrimp, which are distributed well downstream of the intakes. The X2-abundance index analysis indicated similar or slightly lower abundance index under the project alternatives based on April through June X2. Given that the differences were below the general threshold of significance (5%) and that there is uncertainty in such statistical relationships when assessing relatively small, operations-related differences, the impacts of the project alternatives on California bay shrimp would be less than significant.

Mitigation Impacts

Compensatory Mitigation

The Compensatory Mitigation Plan could result in impacts on California bay shrimp as analyzed in this chapter. Compensatory mitigation (tidal perennial and channel margin habitat restoration) would be upstream of areas where California bay shrimp typically occur (Hieb 1999:78–90), and therefore any impacts would have little effect on the species.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on California bay shrimp during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact California bay shrimp during operation and maintenance, and there would be no impact.

Overall, the impact on California bay shrimp during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Under the No Project Alternative, the effects of water operations would be the same as existing conditions at 2020, whereas there could be differences at 2040. Application of the X2-abundance index relationship suggested that the abundance index could be similar to existing conditions in dry and critically dry years, and 7%–20% lower in below normal, above normal, and wet years (Table 12-212).

Table 12-212. California Bay Shrimp Bay Otter Trawl Abundance Index Averaged by Water Year Type, Based on X2-Abundance Index Relationship (Kimmerer et al. 2009), Comparing No Project Alternative to Existing Conditions

Water Year Type	EC	NPA
Wet	368	296 (-20%)
Above normal	305	261 (-15%)
Below normal	220	204 (-7%)
Dry	178	178 (0%)
Critically dry	131	131 (0%)

Note: Percentage values in parentheses indicate differences of No Project Alternative compared to existing conditions. Absolute and percentage values are rounded; as a result, differences between absolutes and differences between percentages may not always appear consistent. Table only includes mean responses and does not consider model uncertainty.

NPA = No Project Alternative; EC = existing conditions.

Impact AQUA-19: Effects of Operations and Maintenance of Water Conveyance Facilities on Southern Resident Killer Whale

Operations and Maintenance—All Project Alternatives

Southern resident killer whale diet in the Pacific Ocean is largely Chinook salmon, including Central Valley Chinook salmon and fall-run in particular (see, for example, National Marine Fisheries Service 2019:128). The impacts analyses for winter-run (Impact AQUA-2), spring-run (Impact AQUA-3), and fall-/late fall-run (Impact AQUA-4) Chinook salmon discuss operations and maintenance effects on these species.

CEQA Conclusion—All Project Alternatives

As described in the impact analyses for winter-run (Impact AQUA-2), spring-run (Impact AQUA-3), and fall-/late fall–run (Impact AQUA-4) Chinook salmon, the project alternatives would have a significant impact on winter-run and spring-run and a less-than-significant impact on fall/late fall–run. These species form only a portion of the Chinook salmon diet of southern resident killer whales and given the numerical dominance of fall-run Chinook salmon relative to other Central Valley runs, the combined impact would be less than significant for southern resident killer whales. Mitigation discussed in Impact AQUA-2 for winter-run and spring-run Chinook salmon would reduce negative hydrodynamic effects such as flow reversals in the Sacramento River at Georgiana Slough (Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles*) and effects from reduced inundation of riparian/wetland benches as a result of NDD operations (CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles*). The impact of operations and maintenance of the project alternatives on winter-run and spring-run Chinook salmon would be less than significant with mitigation, and mitigation would reduce potential negative effects on fall/late fall–run Chinook salmon, thereby also further reducing potential negative effects on southern resident killer whale as a result of changes in Chinook salmon prey.

Mitigation Impacts

Compensatory Mitigation

Compensatory mitigation impacts on winter-run (Impact AQUA-2), spring-run (Impact AQUA-3), and fall-/late fall–run (Impact AQUA-4) Chinook salmon would be less than significant, and therefore compensatory mitigation impacts would also be less than significant for southern resident killer whales.

Other Mitigation Measures

Other mitigation measures proposed would have no impacts on winter-run (Impact AQUA-2), spring-run (Impact AQUA-3), and fall-/late fall–run (Impact AQUA-4) Chinook salmon, and therefore no impacts on southern resident killer whales during operations and maintenance of water conveyance facilities because other mitigation measures would be limited to temporary activities during the construction phase. Refer to the other mitigation measures covered in Impact AQUA-1 if maintenance repairs require in-water construction. Therefore, implementation of mitigation measures is unlikely to impact southern resident killer whales during operation and maintenance, and there would be no impact.

Overall, the impact on southern resident killer whales during operation and maintenance from construction of compensatory mitigation and implementation of other mitigation measures, combined with project alternatives, would not change the less-than-significant impact conclusion.

No Project Alternative

Please see impact analyses for winter-run (Impact AQUA-2), spring-run (Impact AQUA-3), and fall-/late fall–run (Impact AQUA-4) Chinook salmon for discussion of No Project Alternative impacts relative to existing conditions. As discussed therein, at 2020 climate, there would be no difference in operational effects between the No Project Alternative and existing conditions. There may be a number of differences at 2040. For example, climate change-related shifts would generally increase Sacramento River flows into the Delta under the No Project Alternative at 2040 relative to existing conditions during December through April, with potential increases in through-Delta juvenile Chinook salmon survival, whereas flows in May/June may decrease as a result of climate change-related shifts, potentially reducing survival for juvenile Chinook salmon migrating in those months.

12.3.4 Cumulative Analysis

12.3.4.1 Cumulative Impacts of the No Project Alternative

The cumulative impacts with No Project Alternative scenario would include projects described generally in Section 12.3.3.1, *No Project Alternative,* and would include other water supply projects that could be implemented if the Delta Conveyance Project is not approved. As described in that section, some of these projects could create impacts on fish and aquatic resources. These other water supply projects that could be implemented under the No Project Alternative scenario would not occur in the study area and would not be expected to contribute to cumulative study area impacts on study area fish and aquatic resources. To the extent that other projects occur within the study area and have the potential to affect fish and aquatic resources, impacts identified under these projects would be required to be reduced by CEQA and permit requirements to compensate for, avoid, and minimize impacts that would reduce the potential for cumulative impacts on fish and aquatic resources. Therefore, the potential for cumulative impacts to fish and aquatic resources under the No Project Alternative is considered to be less than significant and the No Project Alternative contribution would not be cumulatively considerable.

12.3.4.2 Cumulative Impacts of the Project Alternatives

Cumulative Effects of Construction on Fish and Aquatic Species

Construction—All Project Alternatives

The effects of construction of water conveyance facilities on fish and aquatic species are described under Impact AQUA-1: *Effects of Construction of Water Conveyance Facilities on Fish and Aquatic Species*. As described therein, there are potentially significant effects from construction of water conveyance facilities under the project alternatives. Construction effects related to other programs, projects, and policies could combine with the effects of construction of the project alternatives.

CEQA Conclusion—All Project Alternatives

The cumulative effects of construction on fish and aquatic species would be potentially significant, as discussed in Impact AQUA-1. As previously discussed for Impact AQUA-1, the project alternatives will include Mitigation Measures AQUA-1a: *Develop and Implement an Underwater Sound Control and Abatement Plan*, AQUA-1b: *Develop and Implement a Barge Operations Plan*, AQUA-1c: *Develop and Implement a Fish Rescue and Salvage Plan*, and Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-23: *Tidal Perennial Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* and CMP-24: *Channel Margin Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* (Attachment 3F.1, Table 3F.1-3), as well as several project components environmental commitments described in Appendix 3B, *Environmental Commitments and Best Management Practices* (project components *Disposal of Reusable Tunnel Material*; *Disposal of Dredged Material*; Environmental Commitments EC-1: *Conduct Worker Awareness Training*; EC-2: *Develop and Implement Hazardous Materials Management Plans*; EC-3: *Develop and Implement Spill Prevention, Containment, and Countermeasure Plans*; EC-4a: *Develop and Implement Erosion and Sediment Control Plans*; EC-4b: *Develop and Implement Stormwater Pollution Prevention Plans*; EC-14: *Construction Best Management Practices for Biological Resources*). Other programs, projects, and policies involving construction include or would be anticipated to include similar mitigation and environmental commitments as the project alternatives (e.g., in-water construction windows) to reduce potentially significant impacts. The means by which mitigation measures reduce the significance of impacts are discussed in the *CEQA Conclusion—All Project Alternatives* section for Impact AQUA-1. This cumulative impact would be less than significant with inclusion of the mitigation measures described below.

Mitigation Measure AQUA-1a: Develop and Implement an Underwater Sound Control and Abatement Plan

All Project Alternatives

See description of Mitigation Measure AQUA-1a under Impact AQUA-1.

Mitigation Measure AQUA-1b: Develop and Implement a Barge Operations Plan

All Project Alternatives

See description of Mitigation Measure AQUA-1a under Impact AQUA-1.

Mitigation Measure AQUA-1c: Develop and Implement a Fish Rescue and Salvage Plan

All Project Alternatives

See description of Mitigation Measure AQUA-1a under Impact AQUA-1.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-23: *Tidal Perennial Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-24: *Channel Margin Habitat Restoration for Construction Impacts on Habitat for Fish and Aquatic Resources* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Cumulative Effects of Operations and Maintenance of Water Conveyance Facilities on Fish and Aquatic Species

Operations and Maintenance—All Project Alternatives

The effects of operations and maintenance of water conveyance facilities on fish and aquatic species are described under Impact AQUA-2 through Impact AQUA-19. As described therein, there are potentially significant effects from operations and maintenance of water conveyance facilities under the project alternatives for Impact AQUA-2 (winter-run Chinook salmon), Impact AQUA-5 (Central Valley steelhead), Impact AQUA-6 (delta smelt), and Impact AQUA-7 (longfin smelt). Operations and maintenance effects related to other programs, projects, and policies could combine with the effects of operations and maintenance of the project alternatives. For example, projects diverting water from the Sacramento River could affect fish and aquatic species in an analogous manner to that analyzed for the project alternatives, e.g., by reducing river flow, thereby potentially affecting migration survival for juvenile salmonids (Perry et al. 2018) or abundance of longfin smelt through Delta outflow-abundance relationships (see Impact AQUA-7). Operations effects of many of the existing programs, projects, or policies are included in the modeling undertaken to assess the project alternatives, whereas others (e.g., Sites Reservoir Project) are not included in the modeling.

CEQA Conclusion—All Project Alternatives

The cumulative effects of operations and maintenance on fish and aquatic species would be potentially significant for some species, as discussed in Impact AQUA-2 (winter-run Chinook salmon), Impact AQUA-5 (Central Valley steelhead), Impact AQUA-6 (delta smelt), and Impact AQUA-7 (longfin smelt). As previously discussed for these impacts, the project alternatives will include Mitigation Measure CMP: *Compensatory Mitigation Plan*, specifically CMP-25: *Tidal Habitat Restoration to Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles*, CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles*, CMP-27: *Tidal Habitat Restoration for Operations Impacts on Delta Smelt*; and CMP-28: *Tidal Habitat Restoration for Operations Impacts on Longfin Smelt* (Attachment 3F.1, Table 3F.1-3). Other programs, projects, and policies involving water operations effects include or would be anticipated to include similar types of mitigation as the project alternatives to mitigate for impacts to fish and aquatic species. For example, the Sites Reservoir Project proposes, and the Incidental Take Permit for Long-Term Operation of the State Water Project in the Sacramento-San Joaquin Delta includes, tidal habitat restoration for operations impacts to longfin smelt. The means by which mitigation measures reduce the significance of impacts are discussed in the *CEQA Conclusion—All Project Alternatives* section for Impact AQUA-2, Impact AQUA-5, Impact AQUA-6, and Impact AQUA-7. This cumulative impact would be less than significant with mitigation.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, *Compensatory Mitigation Plan for Special-Status Species and Aquatic Resources*, specifically CMP-25: *Tidal Habitat Restoration to*

Mitigate North Delta Hydrodynamic Effects on Chinook Salmon Juveniles in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-26: *Channel Margin Habitat Restoration for Operations Impacts on Chinook Salmon Juveniles* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-27: *Tidal Habitat Restoration for Operations Impacts on Delta Smelt* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.

Mitigation Measure CMP: Compensatory Mitigation Plan

See description of Mitigation Measure CMP in Appendix 3F, specifically CMP-28: *Tidal Habitat Restoration for Operations Impacts on Longfin Smelt* in Table 3F.1-3 in Attachment 3F.1, *Compensatory Mitigation Design Guidelines*.