- Locating the structure to the north makes it easier for the pipeline to cross between the Sacramento River and Delevan National Wildlife Refuges. A southern alignment would require crossing the Delevan National Wildlife Refuge.
- A northern alignment enables the project to incorporate Funks Reservoir. Constructing Holthouse Reservoir (an enlargement of Funks Reservoir) to the south would significantly increase the footprint and environmental impacts.

Delevan Pipeline Alignment: Three alignments for the Delevan Pipeline are depicted on Figure A-15. The northernmost alignment would cause extensive disruption of traffic on Delevan Road, an important access road for local farming operations. The middle alignment (moving north to south) would bisect several parcels and result in greater effects to local landowners during construction. The southernmost alignment takes advantage of an existing Maxwell Irrigation District easement. There are still impacts to landowners, but by using the easement and locating the pipeline closer to the parcel boundaries, the effects on landowners are reduced.

TRR Pipeline Alignment: Three alternative alignments have been considered for the TRR Pipeline joining TRR with Funks Reservoir. The alignments are tied to the preferred location for the TRR on the eastern side of the GCID Canal (TRR Alternative 1, above). Alternative 1 was developed to support updating project cost estimates for the Reclamation in 2013. The alignments for Alternatives 2 and 3 were developed in an attempt to reduce landowner impacts. The development of Alternatives 2 and 3 entailed landowner input, including a conference call on December 17, 2015. Pipeline alignment alternatives are shown on Figure A-16.

Alternative 1: This alternative follows the gentle terrain along the base of topographic ridges north of Funks Creek. Following this alignment provides a gradual downslope along the pipeline between Holthouse Reservoir and the TRR that minimizes vertical profile changes.

Alternative 2: This alternative pushes the alignment into the topographic ridges just north of Alternative 1, introducing significant vertical variation into the pipeline alignment.

Alternative 3: This alternative is similar to Alternative 2, except at the western end, where it continues through the ridges rather than transitioning down to the floodplain.

This page intentionally left blank

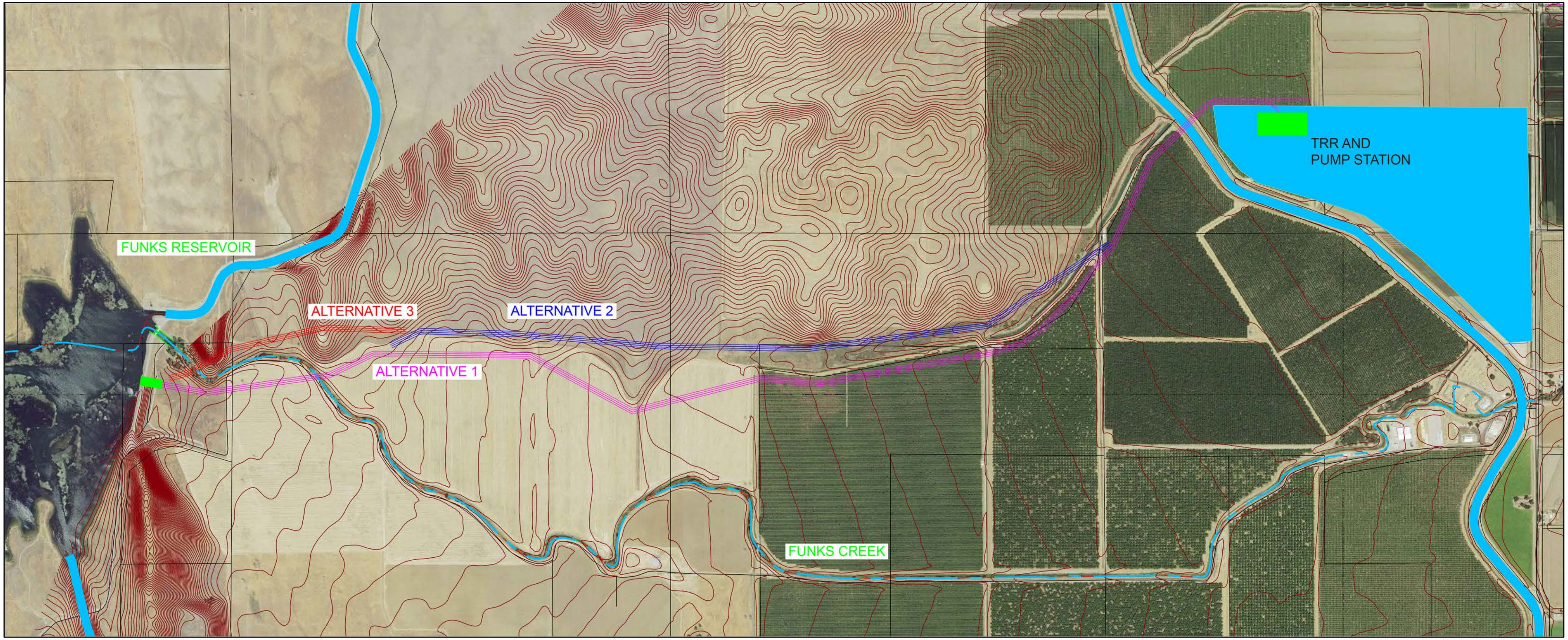


Figure A-16. Alternative TRR Pipeline Alignments

This page intentionally left blank

Table A-42 presents the pros and cons of each alternative. Alternative 1 is tentatively recommended as the preferred alternative for the TRR Pipeline to be included in the feasibility study. It is the only alternative that ensures gravity flow from Funks Reservoir to the TRR. We recommend finalizing the pipeline route after the completion of surveying during the preliminary engineering phase. There is currently some uncertainty regarding the topography, particularly at the extreme western end of the pipeline.

Table A-42. Alternative TRR Pipeline Alignments

Alternative 1 TRR Pipeline Alignment	Alternative 2 TRR Pipeline Alignment	Alternative 3 TRR Pipeline Alignment
Pros • Gentle topography for pipeline construction • Provides best hydraulic pipeline profile • No restriction on gravity flow out of Funks Reservoir back to TRR. • Minimum number of air-vacuum valve and blow-off facilities needed. • Easy access for inspection and maintenance. • No blasting anticipated for pipeline trench excavations.	Pros • Avoids cultivated land • Minimized property-owner concerns.	Pros • Avoids cultivated land • Minimized property-owner concerns.
Cons • Property-owner concerns • Replacement of existing irrigation outlets from Funks Creek required to continue serving cultivated land to the south. • Loss of a strip of land for tree planting.	Cons • Poor hydraulic profile is unsuitable for gravity flow to the east. • Difficult pipeline excavation that will likely require blasting. • Deeper excavation at some ridge crossings to ensure gravity flow capability from Funks Reservoir to TRR. • More air-vacuum valve and blow-off facilities needed. • More difficult access for inspection and maintenance. • Construction scars on hillside and potential for increased erosion on disturbed areas. • More costly construction; lengthens construction schedule. • Requires construction within an existing drainage channel and potential wetland impacts in the eastern third of the alignment.	Cons • Poor hydraulic profile is unsuitable for gravity flow to the east. • Difficult pipeline excavation that will likely require blasting. • Deeper excavation at more ridge crossings to ensure gravity flow capability from Funks Reservoir to TRR. • More air-vacuum valve and blow-off facilities needed. • More difficult access for inspection and maintenance. • Construction scars on hillside and potential for increased erosion on disturbed areas. • More costly construction; lengthens construction schedule.

TRR = Terminal Regulating Reservoir

Grid Interconnection Study

Power sources evaluated included existing WAPA and Pacific Gas and Electric Company (PG&E) transmission systems.

The primary loads evaluated include the pumping stations at Sites Pumping Plant, TRR Pumping Plant, and the Delevan Pumping Plant. For this study, the pumping plants were only discussed as pumping loads. Generation in the future was mentioned to the utilities, but was noted to be a future improvement.

The pumping station loads are noted as follows:

- Sites Reservoir: total load of 226 megavolt-amperes (MVA)
- TRR Pumping Plant: total load of 20 MVA
- Delevan Pumping Plant: total load of 82 MVA

This section presents previous work on power interconnections, the results from meetings held with WAPA and PG&E, and a summary of the available information.

Previous Power Studies: A study was performed by Utility System Efficiencies Inc. (USE 2007) for the addition of 100 megawatts (MW) of generation capacity from the project. This study looked at connecting into existing WAPA and PG&E power lines that run north-south near the Sites Reservoir project. The study considered line loading for addition of power generation, but not for pumping plant loads.

This study was developed before the completion of the Colusa natural gas generating plant. The Colusa Plant was developed and is now operational, producing approximately 660 MW from natural gas turbines. The plant interconnects with a large substation that connects to 230-kilovolt (kV) lines owned and operated by PG&E. This area has four 230 kV lines. The study also identified the two WAPA 230 kV lines in the Sites Project area, and noted future lines being considered by the Sacramento Municipal Utility District.

Due to the study scope focusing only on 100 MW of generation, the cost estimates and results of the study are of limited value to the current effort. The study did identify possibly viable configuration options for how the power could be interconnected to the 230 kV lines nearest the project site.

A System Impact Study (SIS) developed by WAPA (WAPA 2013) considered pumping and generation scenarios at the Sites Reservoir location. Three power options were developed to interconnect into the existing WAPA 230 kV lines. All options found certain deficiencies in the existing transmission line capacity. The interconnection study indicated that reconductoring of some distance of the 230 kV lines may be required. All options included voltage support at the Sites Substation.

The SIS indicated that a substation at Sites Reservoir could interconnect with one or both of the existing WAPA 230 kV lines routed into it. The study revealed that several power system improvements would be required for the power interconnections due to the contingency cases (transmission line or generation outages) dictated by North American Electric Reliability Corporation system reliability requirements, not normal operations.

The SIS from WAPA did not include cost impacts. WAPA will need more detailed design information for further SIS evaluations, and for the next level of detailed study, a Facilities Study, which would estimate cost impacts.

Substation and Power Line Siting: Previous conceptual engineering studies for the Sites Reservoir project included typical substation and switchyard layouts for the proposed project pumping plants and auxiliary loads. Preliminary substation areas that would be required for taking power from existing transmission lines have been identified, but the locations have not been finalized because they will depend on the transmission line(s) providing the power source(s).

Near the Sites Pumping Plant, the existing WAPA and PG&E 230 kV lines are the most probable power sources large enough for project use. The areas near the power lines are generally used for grazing or farming. Procurement of appropriate land for sale or lease is not expected to be a major issue. To reach the Sites Pumping Plant, a short transmission line (1 to 4 miles long) may be required from the substation to the pumping plant.

Previous alternatives (A, B, and C) proposed a transmission line from the Sites area substation to feed the Delevan Pumping Plant. This transmission line, probably at 115 kV or 230 kV, crossed multiple properties in a west-to-east alignment. This transmission line alignment resulted in significant feedback from local landowners and has prompted a new alternative.

Alternative D, developed by the Authority, proposes a second power source closer to the Delevan Pumping Plant. Alternative D would seek to obtain a power source near the town of Colusa. With a power source in this area, existing ROWs may be available along State Highway 45. Existing farm land may be useful for substation siting. The routing of a 115 kV or 230 kV line running north from this location could possibly be sited along county roads and State Highway 45.

The WAPA 230 kV lines running by the Sites Reservoir project extend to the south, and are then routed west-to-east. The change in direction from North-South to West-East occurs between Maxwell and Williams. The parallel lines run in a southeasterly direction approximately 2 miles southwest of Williams. These WAPA lines appear to be the only viable major power source in the area. In conversations with PG&E, the utility identified that they have no suitable power sources close to Colusa. Their 69 kV lines in the area appear to be fed from a 230 kV source in Cortina, approximately 15 miles to the southwest of Colusa.

Available Power Generation Sources: This study is not able to accurately determine where the power sources (generation) for the Sites Project would originate. A few general observations are noted, however:

- The Colusa Generating Station, approximately 4 miles northeast of the Sites Pumping Station, started full production in late 2011. The natural gas plant is rated at 657 MW. PG&E indicated that if they were to provide power to the Sites Project, the Colusa Switching Station would be a likely location for a major power connection.
- In early 2016, Calpine shuttered their natural gas plant near Yuba City, citing “steep transmission fees” (Patel and Overton 2016).

- The California Independent System Operator 2015 Resources Assessment appears to indicate adequate power resources and reserves exist. The WAPA SIS indicated, however, a lack of Available Transfer Capacity.

Recommendations for Grid Interconnection: Based on the information available for this study, and based on conversations with the local utilities, it appears that a second power source, as proposed in Alternative D, may be available, and perhaps even desirable, to reduce the amount of power required from one source.

The power source near Sites Pumping Plant could originate from either the WAPA or PG&E 230 kV lines running 1 to 2 miles east of the proposed station location. Based on the previous SIS performed by WAPA, which indicated a lack of available generation, it is recommended that the Authority request a SIS from PG&E. With four 230 kV lines in the area, and the proximity to an existing substation, PG&E may indicate a greater availability of generation sources.

For the Alternative D power source for the Delevan Pumping Plant, it is recommended that WAPA be requested to provide a new SIS for a location near Colusa. The request should include an optional scenario of the possible restarting of the Calpine combined-cycle natural gas plant near Yuba City. The siting of a new substation near the WAPA transmission lines and a power line up to the Delevan Pumping Plant appear feasible at this level of investigation.

This study does not identify any preference of which power utility would best serve the Authority. Interconnection with either PG&E or WAPA would require substantial power and control system equipment be provided for the Sites Reservoir and Delevan Pumping Plant loads. When large power interconnections are made, the providing utility often has to make improvements to their systems as well. These system improvements are evaluated, and then estimated in the SIS and Facilities Studies, respectively, which must be performed by the utility. The power system operational data and power system equipment details to perform these studies are not generally available to consultants.

The potential for future power generation will also be a factor when considering the utility interconnection. At certain times of the year, generation could be constrained by existing power flows on the transmission lines. Partnering agencies, such as Reclamation, may have influence on the choice of utility with respect to Federal Energy Regulatory Commission licensing requirements for hydroelectric generation.

A.11 Physical Accomplishments of Final Alternatives

This section describes the physical accomplishments of Alternatives A, B, C, and D, which are developed in Chapter 6, Alternative Development, of the main text.

Improving System Flexibility

The amount of total storage defines the capacity of each alternative to meet the NODOS project objectives. Table A-43 summarizes the amount of storage that would be maintained in Sites Reservoir.

Table A-43. Sites Reservoir Storage

Parameter	Alternative A	Alternative B	Alternative C	Alternative D
End-of-May Storage (TAF)				
Full Simulation	985	1,235	1,441	1,447
Dry (22%)	839	1,004	1,268	1,330
Critical (15%)	447	507	683	641
End-of-September Storage (TAF)				
Full Simulation	687	947	1,114	1,083
Dry (22%)	515	644	885	813
Critical (15%)	259	262	423	317

TAF = thousand acre-feet

Figure A-17 depicts the increase in water supply for both water supply and Delta environmental water quality that would be achieved with the action alternatives.

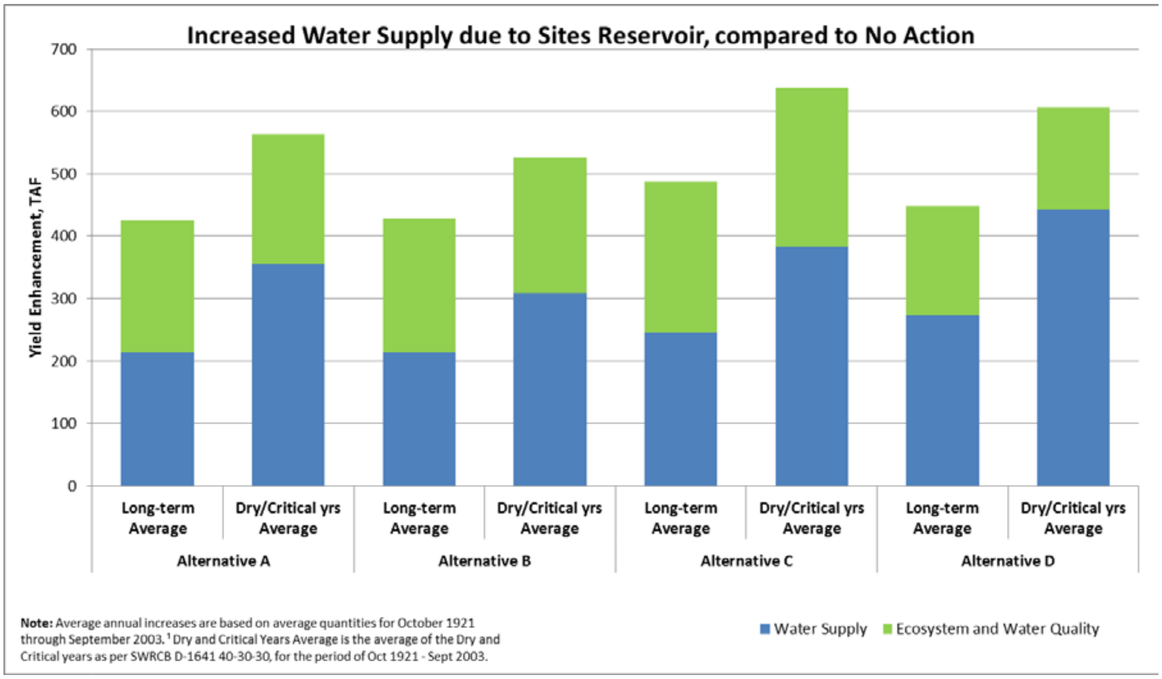


Figure A-17. Enhancement of Water Supply for Project Purposes with Respect to No Project Alternative

Figure A-18 compares the systemwide increases in storage for the four alternatives. Both the long-term average and the driest-period average end-of-May storage are provided. This additional storage (800 to 1,500 TAF) appreciably increases the flexibility of system operations to respond to system needs. Alternatives C and D provide the greatest increase in storage throughout the system.

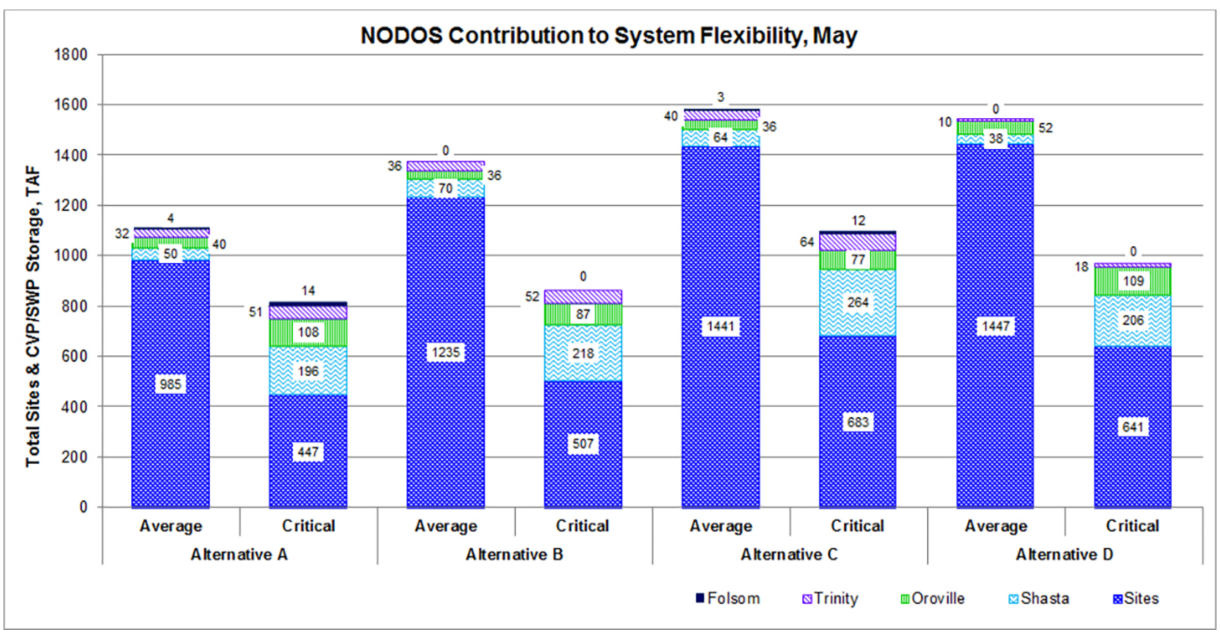


Figure A-18. Increases in Average System Storage

All alternatives would appreciably contribute to reducing the frequency of extreme occurrences (i.e., corresponding to dead pool conditions in modeling simulations) where severe droughts necessitate agency consultation to manage dwindling reservoir supplies. The occurrences of dead pool conditions over the 984-month (82-year) simulation period are provided in Table A-44.

Table A-44. Occurrences of Dead Pool Conditions

Alternative	Months with Dead Pool Conditions in CVP and SWP Reservoirs over 82-Year Period
No Action	28
A	14
B	15
C	9
D	10

CVP = Central Valley Project
SWP = State Water Project

Water Supply and Water Supply Reliability (Primary Objective)

Water supply increases over the long-term average and under Dry and Critical years were used to evaluate the accomplishments of each alternative with respect to water supply and water supply reliability.

CVP Contractors would experience modest increases in water supply. The most notable increases occur in Dry years, ranging from an additional 33 TAF/year under Alternative B to 86 TAF/year under Alternative A. Alternative B provides appreciably less water supply due to the absence of the Delevan Intake Pumping/Generating Plant. Without the new pumping plant, it is not possible to recapture water downstream of Red Bluff and Hamilton City, and the water supply is reduced.

The ability of Sites Reservoir to improve water supply for the SWP in years with less than an 85 percent allocation of contract amounts was evaluated with an increasing emphasis on years below 65 percent allocation. Over the full simulation period, the increases are modest (3 to 3.5 percent for all alternatives); however, during Critical years (approximately 15 percent of all years fall into the Critical year category), increases in deliveries of 13 to 18 percent are observed (309 to 369 TAF/year). These increases are a notable improvement in water supply reliability. Alternative A performs slightly better than Alternative B in Critical years, providing an additional 19 TAF/year. The model simulation results show that Alternative C, with both the additional intake and the larger reservoir, is the best performer.

Alternative D provides additional water to Sites Reservoir participants in the Sacramento Valley. This supply of 79 TAF on average and up to 182 TAF in Critical years is unique to Alternative D (these participants would receive a much smaller amount of water through the CVP under Alternatives A, B, and C).

The overall increase in water supply is summarized in Table A-45.

Table A-45. Increase in Water Supply

	Alternative A		Alternative B		Alternative C		Alternative D	
	Average	Dry and Critical (TAF)	Average	Dry and Critical (TAF)	Average	Dry and Critical (TAF)	Average	Dry and Critical (TAF)
SWP	122	267	130	248	134	294	116	228
CVP	47	67	10	22	39	55	30	40
Local	0	0	0	0	0	0	78	150
Total	169	334	140	270	173	349	224	418

CVP = Central Valley Project
SWP = State Water Project
TAF = thousand acre-feet

Key findings regarding water supply and water supply reliability include the following:

- Alternative D provides the highest average long-term annual water supply increases (224 TAF) and Dry and Critical year increases (418 TAF).
- Alternatives A and C show similar average long-term annual water supply gains. However, during Dry/Critical years, Alternative C provides appreciably more water.

Figure A-19 presents the south-of-the Delta export for the four alternatives.

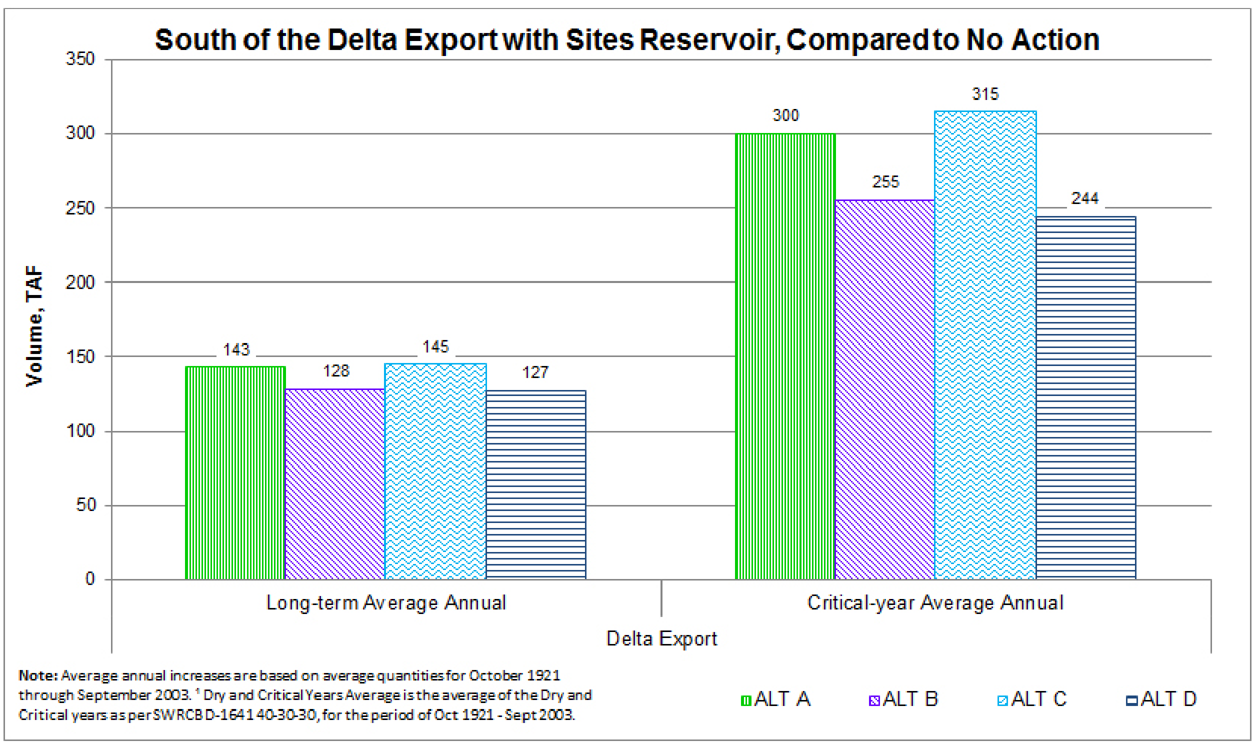


Figure A-19. Simulated Increase in South-of-the Delta Exports

Incremental Level 4 Water Supply for Wildlife Refuges (Primary Objective)

The alternatives would provide an alternate source for incremental water for incremental Level 4 water supply for wildlife refuges. Water is currently purchased both north of the Delta (3.35 TAF/year maximum) and south of the Delta (101.09 TAF/year maximum) to supplement refuge water supplies up to incremental Level 4 criteria. The Sites Reservoir alternatives show a notable ability to provide replacement water over the full simulation period, ranging from 44 TAF under Alternative A to 74 TAF under Alternative C. The ability to provide replacement water is appreciably constrained in Critical years (an additional 6 to 12 TAF could be provided). Most of the water would be made available to refuges south of the Delta.

Survival of Anadromous Fish and Other Aquatic Species (Primary Objective)

Several operational actions were included in simulations for the alternatives to improve conditions in ways that would support anadromous fish and other aquatic species (Figure A-20). These actions include:

- Shasta Lake coldwater pool improvement
- Sacramento River flows for temperature control
- Folsom Lake coldwater pool improvement
- Stabilizing American River flows
- Lake Oroville coldwater pool improvement
- Stabilizing Sacramento River fall flows
- Sacramento River diversion reduction at Red Bluff and Hamilton City

These parameters are summarized for the four alternatives in Table A-46.

The alternatives were evaluated in terms of their ability to contribute to these improved conditions. Alternatives C and D are the most effective in increasing coldwater pool volumes. Alternative C has a higher end-of-May storage in Shasta Lake, but the storage is greater at the end of September under Alternative D. Alternative D is also the most effective in stabilizing flows in the Sacramento River in all but Critical years, when Alternative C provides slightly more water.

Water temperature is one of the principal drivers for salmonid production. Temperature can have an important influence on the timing of smolt runs. A threshold water temperature or a pattern of variation for a prolonged period may initiate downstream migration. Evidence suggests a strong correlation between daytime migratory activity and water temperature. Although many juveniles migrate in higher numbers at night, a temperature cue may be their initial prompt to begin seaward migration. Temperature is also known to be a highly important factor in determining mortality rates. There are optimum temperatures for survival and growth in which mortality is minimized. However, as temperatures reach maximum threshold values, fish stress levels elevate and mortality increases.

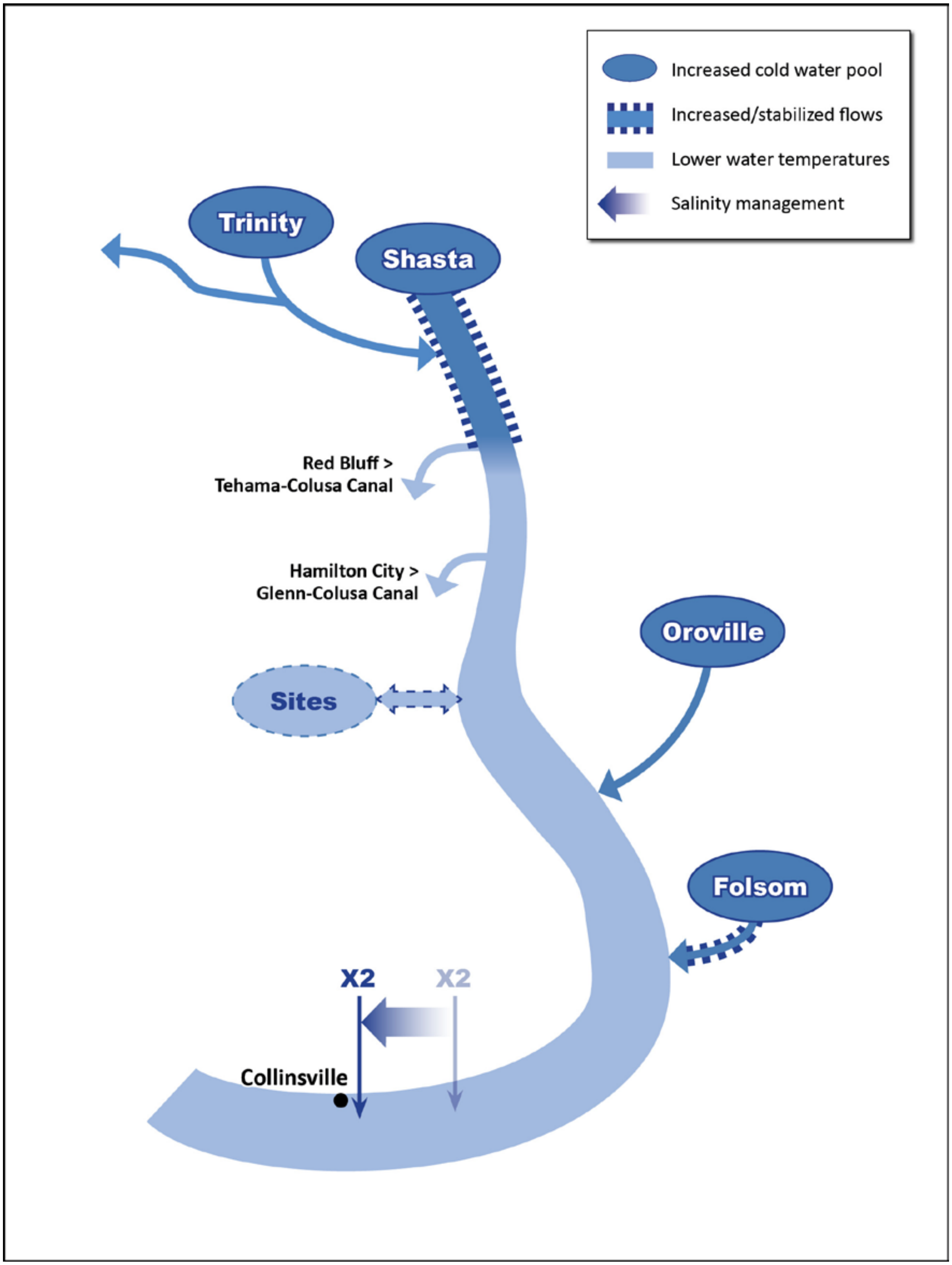


Figure A-20. Conceptual Model of Benefits to Anadromous Fish from the NODOS Project

Table A-46. Ecosystem Enhancement Actions

	No Project Alternative	NODOS Alternative A	NODOS Alternative A minus No Project Alternative		NODOS Alternative B	NODOS Alternative B minus No Project Alternative		NODOS Alternative C	NODOS Alternative C minus No Project Alternative		NODOS Alternative D	NODOS Alternative D minus No Project Alternative	
			Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference
EESA-1. Shasta Lake Coldwater Pool Improvement													
Improve the reliability of coldwater pool storage in Shasta Lake to increase Reclamation's operational flexibility to provide suitable water temperatures in the Sacramento River. This action would operationally translate into an increase in Shasta Lake end-of- May storage levels and increased coldwater pool in storage, with particular emphasis on Below Normal, Dry, and Critical water-year types.													
Trinity Lake													
End-of-Month Storage (SW-01)													
May (TAF)													
Full Simulation Period	1,810	1,843	32	1.8%	1,846	36	2.0%	1,851	40	2.2%	1,821	10	0.6%
Dry (22%)	1,630	1,661	30	1.9%	1,671	40	2.5%	1,665	34	2.1%	1,619	-12	-0.7%
Critical (15%)	1,076	1,127	51	4.8%	1,128	52	4.8%	1,140	64	6.0%	1,092	16	1.5%
September (TAF)													
Full Simulation Period	1,374	1,417	43	3.1%	1,416	42	3.1%	1,424	51	3.7%	1,376	3	0.2%
Dry (22%)	1,132	1,185	52	4.6%	1,181	48	4.3%	1,191	58	5.1%	1,129	-3	-0.3%
Critical (15%)	658	737	79	12.0%	718	60	9.1%	753	95	14.5%	678	21	3.1%
Shasta Lake													
End-of-Month Storage (SW-07)													
May (TAF)													
Full Simulation Period	3,944	3,994	50	1.3%	4,013	70	1.8%	4,007	64	1.6%	3,982	38	1.0%
Dry (22%)	3,725	3,830	105	2.8%	3,843	118	3.2%	3,840	115	3.1%	3,770	45	1.2%
Critical (15%)	2,416	2,612	196	8.1%	2,634	218	9.0%	2,680	264	10.9%	2,622	206	8.5%
September (TAF)													
Full Simulation Period	2,630	2,731	101	3.8%	2,736	106	4.0%	2,738	108	4.1%	2,762	132	5.0%
Dry (22%)	2,413	2,564	151	6.3%	2,591	178	7.4%	2,566	153	6.3%	2,601	188	7.8%
Critical (15%)	1,187	1,308	121	10.2%	1,370	183	15.4%	1,396	208	17.6%	1,400	213	18.0%
EESA-2. Sacramento River Flows for Temperature Control													
Provide releases from Shasta Dam of appropriate water temperatures—and subsequently from Keswick Dam—to maintain mean daily water temperatures year-round at levels suitable for all species and life stages of anadromous salmonids in the Sacramento River between Keswick Dam and Red Bluff Diversion Dam, with particular emphasis on the months of highest potential water-temperature-related impacts (i.e., July through November) during Below Normal, Dry, and Critical water-year types.													
Trinity River below Lewiston a													
Monthly Temperature (SQ-33)													
Aug-Sep (Deg-F)													
Full Simulation Period	51.2	50.9	-0.3	-0.5%	50.9	-0.3	-0.5%	50.8	-0.3	-0.6%	51.0	-0.2	-0.3%
Dry (22%)	50.2	50.4	0.2	0.4%	50.1	-0.1	-0.3%	50.3	0.1	0.2%	50.2	0.2	0.5%
Critical (15%)	55.5	53.6	-2.0	-3.5%	54.0	-1.5	-2.7%	53.8	-1.8	-3.2%	55.5	-0.8	-1.4%
Clear Creek at Igo													
Monthly Temperature (SQ-37)													
Sep-Oct (Deg-F)													
Full Simulation Period	52.9	52.7	-0.2	-0.4%	52.7	-0.2	-0.4%	52.6	-0.3	-0.5%	52.9	0.0	-0.1%
Dry (22%)	52.8	52.7	-0.1	-0.2%	52.7	-0.2	-0.3%	52.6	-0.2	-0.3%	53.0	0.1	0.3%
Critical (15%)	56.7	55.6	-1.0	-1.8%	55.8	-0.9	-1.6%	55.7	-1.0	-1.8%	56.3	-0.3	-0.6%
Sacramento River at Bend Bridge													
Monthly Temperature (SQ-05)													
Aug-Sep (Deg-F)													
Full Simulation Period	57.5	57.2	-0.3	-0.5%	57.2	-0.3	-0.5%	57.1	-0.4	-0.6%	57.2	-0.4	-0.6%

	No Project Alternative	NODOS Alternative A	NODOS Alternative A minus No Project Alternative		NODOS Alternative B	NODOS Alternative B minus No Project Alternative		NODOS Alternative C	NODOS Alternative C minus No Project Alternative		NODOS Alternative D	NODOS Alternative D minus No Project Alternative	
			Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference
Dry (22%)	57.9	57.5	-0.4	-0.7%	57.4	-0.5	-0.8%	57.4	-0.6	-1.0%	57.4	-0.5	-0.9%
Critical (15%)	61.5	60.1	-1.4	-2.2%	60.5	-1.0	-1.7%	59.9	-1.5	-2.5%	59.9	-1.6	-2.6%
Sacramento River Winter-Run Chinook Salmon													
Egg to Fry Survival (AQ-01 IOS)													
Annual (fraction)													
Full Simulation Period	0.79	0.81	0.02	2.8%	0.81	0.02	3.1%	0.82	0.03	3.8%	0.82	0.03	3.8%
Dry (22%)	0.76	0.80	0.04	4.8%	0.81	0.05	6.3%	0.81	0.05	6.8%	0.81	0.05	6.8%
Critical (15%)	0.38	0.48	0.10	26.1%	0.46	0.08	21.2%	0.50	0.12	33.1%	0.50	0.13	33.8%
Returning Female Spawners (AQ-01 IOS)													
Annual (#)													
Full Simulation Period	15,636	16,902	1,266	8.1%	16,906	1,270	8.1%	16,941	1,305	8.3%	17,393	1,757	11.2%
Dry (22%)	15,604	16,718	1,113	7.1%	16,598	994	6.4%	16,501	896	5.7%	16,733	1,129	7.2%
Critical (15%)	13,030	14,355	1,325	10.2%	14,487	1,458	11.2%	14,139	1,109	8.5%	14,413	1,383	10.6%
EESA-3. Folsom Lake Coldwater Pool Improvement													
Increase the availability of coldwater pool storage in Folsom Lake by increasing end-of-*May storage and coldwater pool storage to allow Reclamation additional operational flexibility to provide suitable water temperatures in the lower American River. This action would utilize additional coldwater pool storage by providing releases from Folsom Dam (and subsequently from Nimbus Dam) to maintain mean daily water temperatures at levels suitable for juvenile steelhead over-summer rearing and fall-run Chinook salmon spawning in the lower American River from May through November during all water-year types.*													
Folsom Lake													
End-of-Month Storage (SW-24)													
May (TAF)													
Full Simulation Period	840	844	4	0.5%	840	0	0.0%	843	3	0.3%	839	0	-0.1%
Dry (22%)	777	789	12	1.5%	789	11	1.5%	786	8	1.1%	786	9	1.2%
Critical (15%)	437	452	14	3.3%	426	-12	-2.7%	449	12	2.8%	425	-12	-2.8%
September (TAF)													
Full Simulation Period	496	518	22	4.5%	518	22	4.5%	520	24	4.9%	524	28	5.7%
Dry (22%)	420	450	29	7.0%	460	39	9.4%	451	30	7.2%	459	38	9.1%
Critical (15%)	239	243	5	1.9%	260	22	9.1%	256	17	7.3%	257	18	7.7%
American River at Watt Ave. (Sacramento)													
Monthly Temperature (SQ-19)													
Jul-Sep (Deg-F)													
Full Simulation Period	68.6	68.5	0.0	-0.1%	68.6	0.0	0.0%	68.6	0.0	0.0%	68.6	0.0	0.0%
Dry (22%)	68.8	68.9	0.1	0.2%	68.9	0.1	0.1%	68.9	0.1	0.2%	68.9	0.1	0.2%
Critical (15%)	71.2	70.6	-0.6	-0.9%	71.0	-0.2	-0.3%	70.8	-0.4	-0.5%	71.1	-0.1	-0.1%
EESA-4. Stabilizing American River Flows													
Stabilize flows in the lower American River to minimize dewatering of fall-run Chinook salmon redds (i.e., October through March) and steelhead redds (i.e., January through May) and reduce isolation events (specifically, flow increases to 4,000 cfs with subsequent reduction to less than 4,000 cfs) of juvenile anadromous salmonids, particularly from October through June. Reduce the reliance on Folsom Lake as a "real-time, first response facility" to meet Delta objectives and demands, particularly from January through August, to reduce flow fluctuation and water-temperature-related impacts to fall-run Chinook salmon and steelhead in the lower American River.													
Not applicable: Reporting metrics require daily time-step modeling of flow operations to demonstrate how flexibility in storage operations supports stabilization of flows throughout late fall through spring.													

	No Project Alternative	NODOS Alternative A	NODOS Alternative A minus No Project Alternative		NODOS Alternative B	NODOS Alternative B minus No Project Alternative		NODOS Alternative C	NODOS Alternative C minus No Project Alternative		NODOS Alternative D	NODOS Alternative D minus No Project Alternative	
			Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference
EESA-5. Delta Outflow for Delta Smelt Habitat Improvement (Summer/Fall)													
Provide supplemental Delta outflow during summer and fall months (i.e., May through December) to improve X2 (if possible, west of Collinsville, 81 km) and increase estuarine habitat, reduce entrainment, and improve food availability for anadromous fishes and other estuarine-dependent species (e.g., Delta smelt, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp)													
X2 Position													
Monthly Averaged X2 (SQ-01)													
Jul-Aug (km)													
Full Simulation Period	82.7	81.5	-1.2	-1.4%	81.5	-1.2	-1.5%	81.4	-1.3	-1.6%	81.7	-1.0	-1.2%
Dry (22%)	85.6	84.2	-1.4	-1.6%	84.2	-1.4	-1.7%	84.0	-1.7	-1.9%	84.6	-1.0	-1.2%
Critical (15%)	88.5	88.0	-0.6	-0.6%	87.9	-0.6	-0.7%	87.9	-0.7	-0.8%	88.3	-0.2	-0.3%
Sep-Nov (km)													
Full Simulation Period	83.4	82.8	-0.5	-0.6%	82.8	-0.6	-0.7%	82.6	-0.8	-0.9%	83.0	-0.3	-0.4%
Dry (22%)	89.9	89.0	-0.9	-1.0%	88.9	-1.0	-1.1%	88.4	-1.5	-1.6%	89.3	-0.6	-0.7%
Critical (15%)	92.2	91.9	-0.3	-0.3%	91.7	-0.6	-0.6%	91.6	-0.6	-0.7%	92.1	-0.1	-0.1%
Delta Outflow													
Delta Outflow (SW-33)													
May-Dec (TAF)													
Full Simulation Period	5,851	5,942	91	1.6%	5,951	100	1.7%	5,956	105	1.8%	5,900	50	0.8%
Dry (22%)	3,927	4,059	132	3.4%	4,088	161	4.1%	4,127	200	5.1%	4,028	101	2.6%
Critical (15%)	2,335	2,409	73	3.1%	2,444	109	4.7%	2,422	87	3.7%	2,357	22	0.9%
EESA-6. Lake Oroville Coldwater Pool Improvement													
Improve the reliability of coldwater pool storage in Lake Oroville to improve water temperature suitability for juvenile steelhead and spring-run Chinook salmon over-summer rearing and fall-run Chinook salmon spawning in the lower Feather River from May through November during all water-year types. Provide releases from Oroville Dam to maintain mean daily water temperatures at levels suitable for juvenile steelhead and spring-run Chinook salmon over-summer rearing and fall-run Chinook salmon spawning in the lower Feather River. Stabilize flows in the lower Feather River to minimize redd dewatering, juvenile stranding, and isolation of anadromous salmonids.													
Lake Oroville													
End-of-Month Storage (SW-18)													
May (TAF)													
Full Simulation Period	3,002	3,041	40	1.3%	3,038	36	1.2%	3,038	36	1.2%	3,053	52	1.7%
Dry (22%)	2,621	2,672	51	1.9%	2,683	62	2.4%	2,700	79	3.0%	2,710	89	3.4%
Critical (15%)	1,760	1,868	108	6.1%	1,847	87	4.9%	1,837	77	4.4%	1,869	109	6.2%
September (TAF)													
Full Simulation Period	1,831	1,844	13	0.7%	1,841	9	0.5%	1,838	7	0.4%	1,863	32	1.7%
Dry (22%)	1,297	1,301	5	0.4%	1,319	23	1.7%	1,303	7	0.5%	1,374	77	5.9%
Critical (15%)	941	1,014	73	7.8%	990	49	5.2%	1,010	69	7.3%	983	42	4.4%
Feather River below Thermalito													
Monthly Temperature (SQ-16)													
Aug-Sep (Deg-F)													
Full Simulation Period	65.7	65.7	0.0	0.0%	65.7	0.0	0.0%	65.7	0.0	0.0%	65.8	0.1	0.1%
Dry (22%)	65.6	65.7	0.1	0.1%	65.6	0.0	0.0%	65.6	0.0	-0.1%	65.9	0.2	0.3%
Critical (15%)	67.3	66.8	-0.5	-0.8%	66.8	-0.5	-0.8%	66.7	-0.6	-0.9%	66.9	-0.5	-0.7%

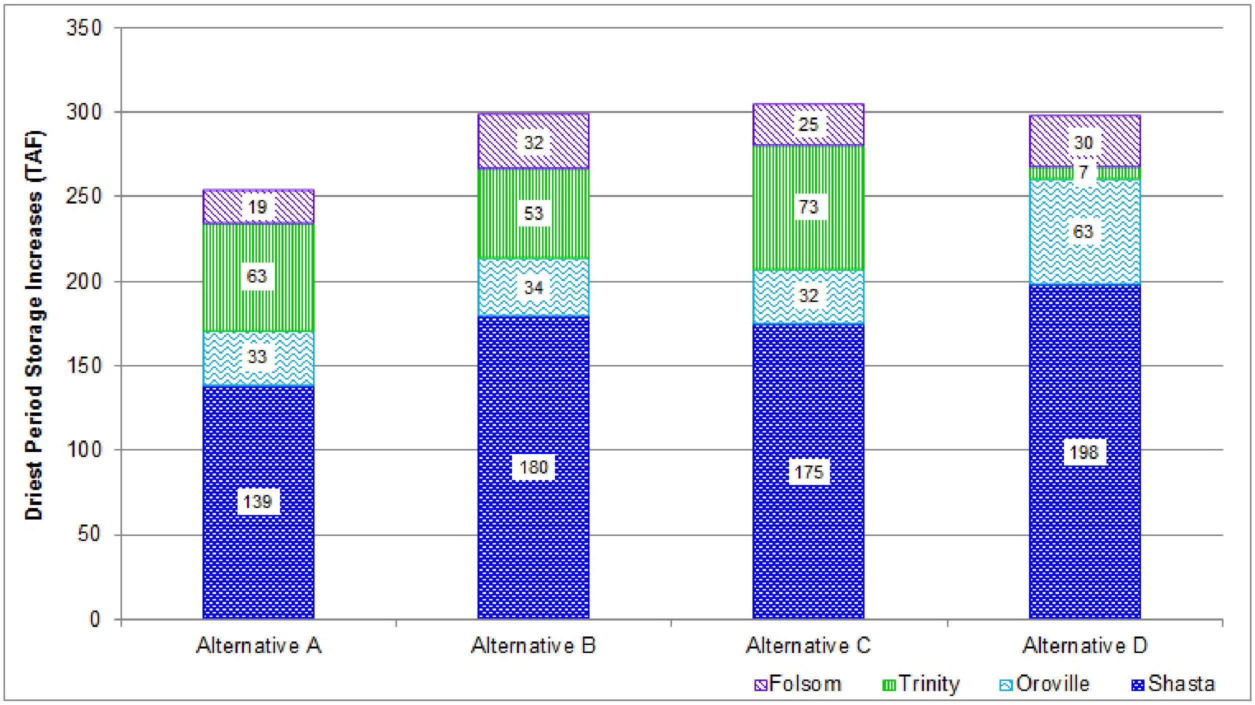
	No Project Alternative	NODOS Alternative A	NODOS Alternative A minus No Project Alternative		NODOS Alternative B	NODOS Alternative B minus No Project Alternative		NODOS Alternative C	NODOS Alternative C minus No Project Alternative		NODOS Alternative D	NODOS Alternative D minus No Project Alternative	
			Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference		Difference	Relative Difference
EESA-7. Stabilizing Sacramento River Fall Flows													
Stabilize flows in the Sacramento River between Keswick Dam and Red Bluff Diversion Dam to minimize dewatering of fall-run Chinook salmon redds (for the spawning and embryo incubation life stage periods extending from October through March), particularly during fall months. (Avoid abrupt changes; operation limited so as to not greatly impact coldwater pool operations in Dry and Critical years.)													
Sacramento River below Keswick													
Monthly Flow (SW-10)													
Dec-Feb (cfs)													
Full Simulation Period	8,394	8,980	586	7.0%	8,965	572	6.8%	8,934	540	6.4%	9,034	640	7.6%
Below Normal (17%)	5,040	5,637	598	11.9%	5,669	629	12.5%	5,625	585	11.6%	5,733	694	13.8%
Dry (22%)	3,858	4,662	804	20.8%	4,701	842	21.8%	4,650	792	20.5%	4,677	819	21.2%
Critical (15%)	3,571	3,932	361	10.1%	3,942	371	10.4%	3,898	327	9.2%	3,873	302	8.5%
EESA-8. Sacramento River Diversion Reduction at Red Bluff and Hamilton City													
Provide increased flows from spring through fall in the lower Sacramento River by reducing diversions at Red Bluff Diversion Dam (into the Tehama-Colusa Canal) and at Hamilton City (into the Glenn-Colusa Irrigation District Canal) and by providing supplemental flows (at Delevan Pipeline). This action would provide multiple benefits to riverine and estuarine habitats and to anadromous fishes and estuarine-dependent species (e.g., Delta smelt, splittail, longfin smelt, Sacramento splittail, starry flounder, and California bay shrimp) by reducing entrainment, providing or augmenting transport flows, increasing habitat availability, increasing productivity, and improving nutrient transport and food availability.													
Glenn-Colusa Canal, Hamilton City Intake													
Diversions (OP-02a)													
Jun-Aug volume above diversion rate of 2000 cfs (TAF/season)													
Full Simulation Period	111	39	-72	-64.5%	90	-21	-19.2%	37	-74	-66.8%	72	-39	-35.0%
Dry (22%)	117	23	-95	-80.5%	90	-28	-23.5%	21	-96	-81.8%	45	-72	-61.4%
Critical (15%)	58	20	-39	-66.6%	48	-10	-17.4%	13	-45	-77.4%	36	-23	-38.9%
Tehama-Colusa Canal, Red Bluff Intake and Glenn-Colusa Canal, Hamilton City Intake													
Diversions (OP-01a and 02a)													
Jun-Aug volume (TAF/season)													
Full Simulation Period	607	442	-165	-27.2%	556	-51	-8.4%	431	-176	-29.0%	527	-80	-13.1%
Dry (22%)	563	393	-170	-30.2%	511	-52	-9.3%	370	-193	-34.3%	444	-119	-21.1%
Critical (15%)	450	330	-120	-26.6%	414	-36	-8.0%	321	-129	-28.6%	414	-36	-8.0%

[a] Modeled result does not account for use of the auxiliary outlet works; nevertheless, the coldwater pool at Trinity would be increased.

cfs = cubic feet per second
Deg-F = degrees Fahrenheit
EESA = Ecosystem Enhancement Storage Account
km = kilometer
NODOS = North-of-the-Delta Offstream Storage
TAF = thousand acre-feet
X2 = the distance in kilometers from the Golden Gate Bridge to the location where salinity in the Delta is 2 parts per thousand

Beyond the threshold temperatures, mortality is high and can have a notable impact on abundance.

The feeding behavior of predators is also influenced by temperature. Metabolism increases with rising temperature; therefore, the predator is capable of consuming more prey. Temperature has other physiological effects that may influence the amount of prey consumed. Each of the NODOS project action alternatives increases the coldwater pool at Trinity Lake, Shasta Lake, Lake Oroville, and Folsom Lake. The most important increases in coldwater pool occur in the driest periods, as is shown on Figure A-21, which depicts the corresponding September storage.



Note: Driest periods are essentially the drought years in the 83-year full simulation sequence (i.e., 1928 to 1934, 1976 to 1977, and 1987 to 1992). The indices designate these years as multiple-year dry sequences rather than each individual year.

Figure A-21. Driest Period September Carryover Storage

Stabilizing flows in the Sacramento and American Rivers would reduce isolation events to support the migration of fish. Water flow and net river discharge have been shown to be highly influential in the rates at which young salmon migrate. Increased flow appears to increase the migrants' rate of passage. Survival of smolts passing through the Delta is highly correlated with the discharge of the Sacramento River (Groot and Margolis 1991), presumably due to less exposure time to potential threats during migration.

The SALMOD interactive object-oriented simulation (IOS) and Delta Passage Model (DPM) were used to evaluate the potential benefits to anadromous fish from the water temperature and flow improvements. Both models provide computer simulations of Chinook salmon populations to assess the results of the ecosystem enhancement actions.

- SALMOD was used to evaluate the linkage between habitat dynamics and smolt growth, movement, and survival between Keswick Dam and Red Bluff (Figure A-22). SALMOD was also used to quantify the effects of flow and temperature regimes for the alternatives on annual production potential. SALMOD is habitat-based and only examines the juvenile (freshwater) life history phase, but it provides output for all four Sacramento Chinook stocks (winter, spring, fall, and late fall runs).
- IOS was used to evaluate the influence of different Central Valley water operations and estimate the long-term response of Sacramento River winter-run Chinook populations to changing environmental conditions (e.g., river discharge, temperature, and habitat quality throughout a larger geographical reach). IOS is a life-cycle model that incorporates the whole life cycle of a salmonid stock, but was used here only to evaluate winter-run Chinook salmon.
- IOS/Delta Passage Model was used to determine how salmonid smolt survival to Chipps Island might be influenced by the proposed NODOS project alternatives.

No single alternative resulted in the greatest benefit during all year-types and for all Chinook stocks. Different life stages of the four Chinook salmon stocks (winter, spring, fall, and late fall) are responsive to different habitat conditions. The SALMOD results indicated that water temperature changes had a greater effect on mortality than river flow changes. Sites Reservoir would have beneficial temperature effects for all four Chinook salmon stocks. Modeling results suggest a negative impact from flow-related changes associated with pumping operations to fill the reservoir on spring- and fall-run Chinook salmon; however, the beneficial effects of lower temperatures still result in an overall predicted increase in the population for these runs.

Figure A-23 shows the simulated increase in juvenile Chinook salmon based on the SALMOD results. Figure A-24 provides the estimated improvements in annual survival for winter-run Chinook salmon based on IOS model results. Figure A-25 provides the IOS results for winter-run Chinook salmon female spawners.

The IOS model results indicated better survival of winter-run Chinook for egg-to-fry and fry-to-smolt life stages during Critical year periods (Figure A-23). The IOS model also predicted that the escapement (number of female spawners) of winter-run Chinook would be higher during the Critical year scenario (Figure A-24).

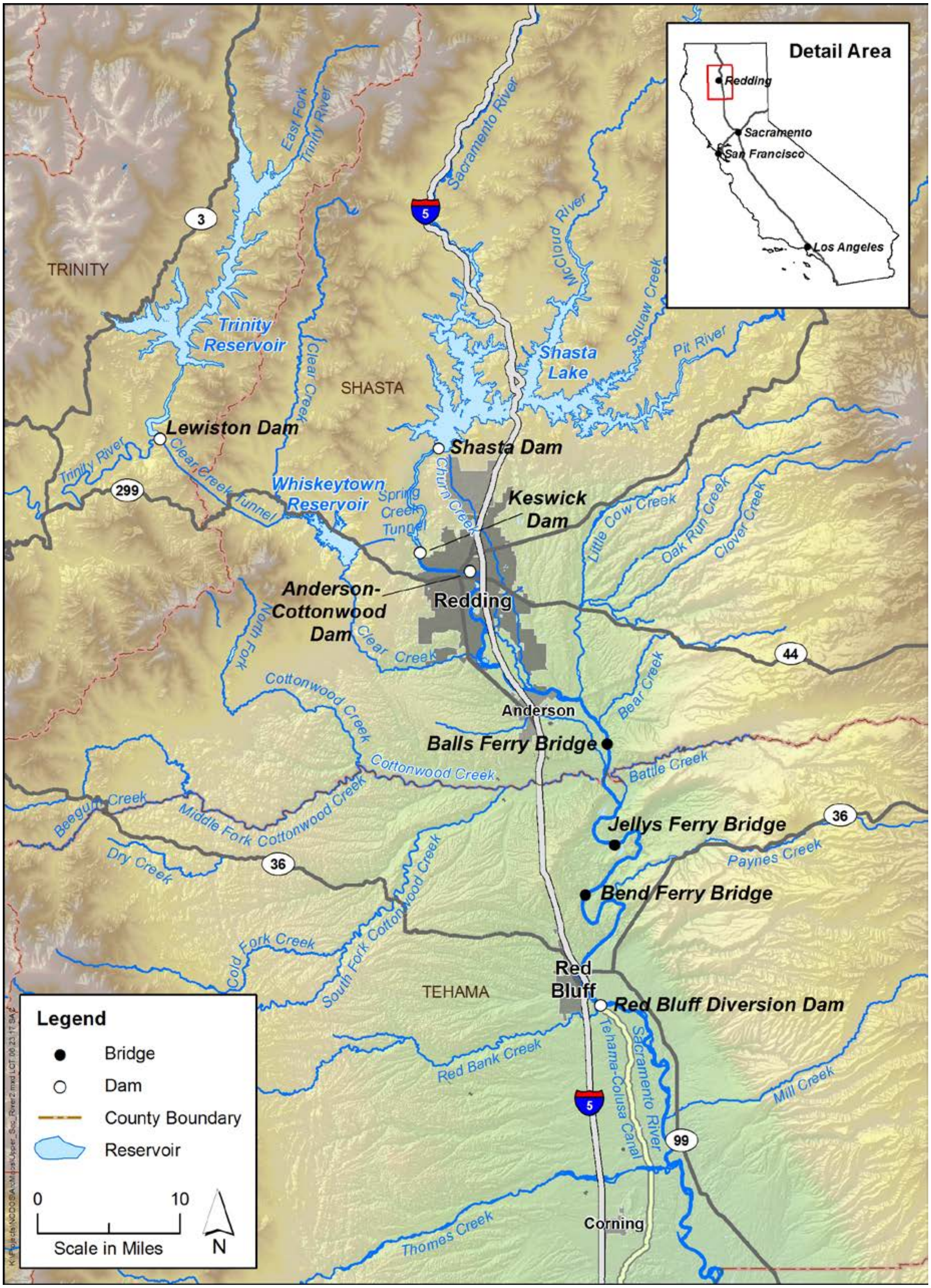


Figure A-22. Area of Salmon Habitat Improvement Evaluated by SALMOD Model

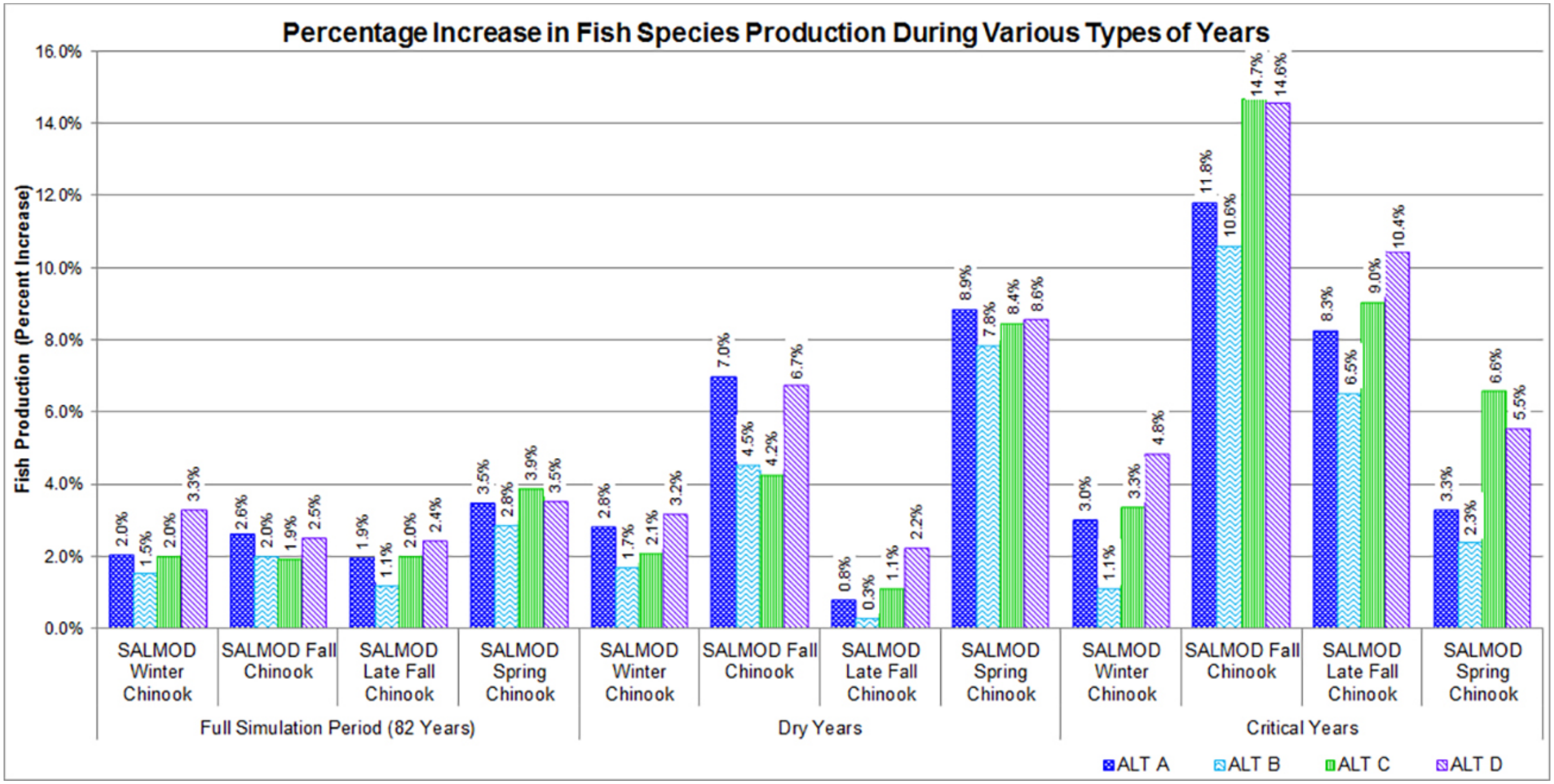


Figure A-23. Anticipated Effects of Alternatives A, B, C, and D Compared to No Project Alternative on Sacramento River Chinook Salmon Juvenile Production (SALMOD Model)

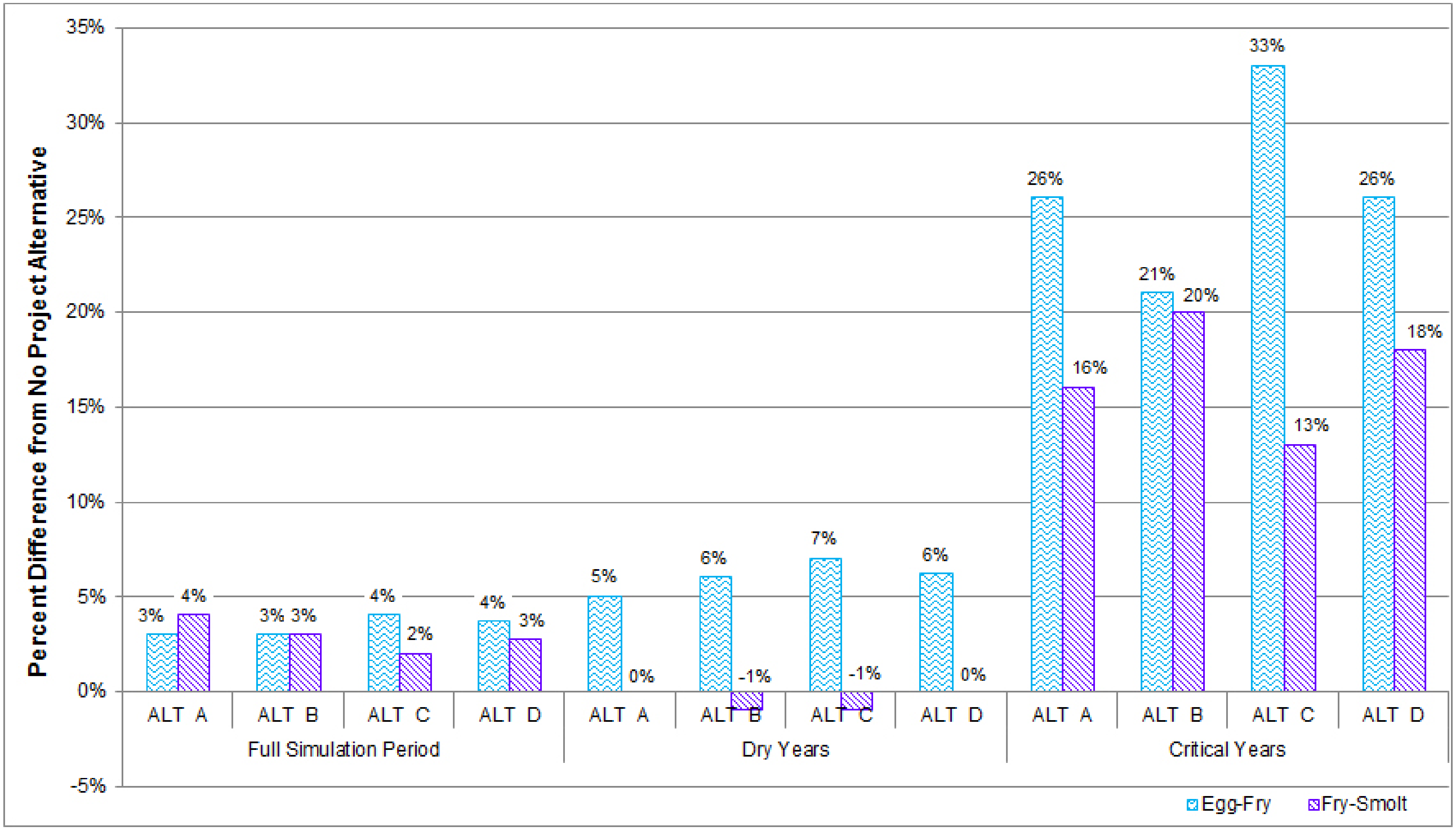


Figure A-24. Anticipated Effects of Alternatives A, B, C, and D Compared to No Project Alternative on Sacramento River Winter-Run Chinook Salmon Annual Survival (IOS Model)

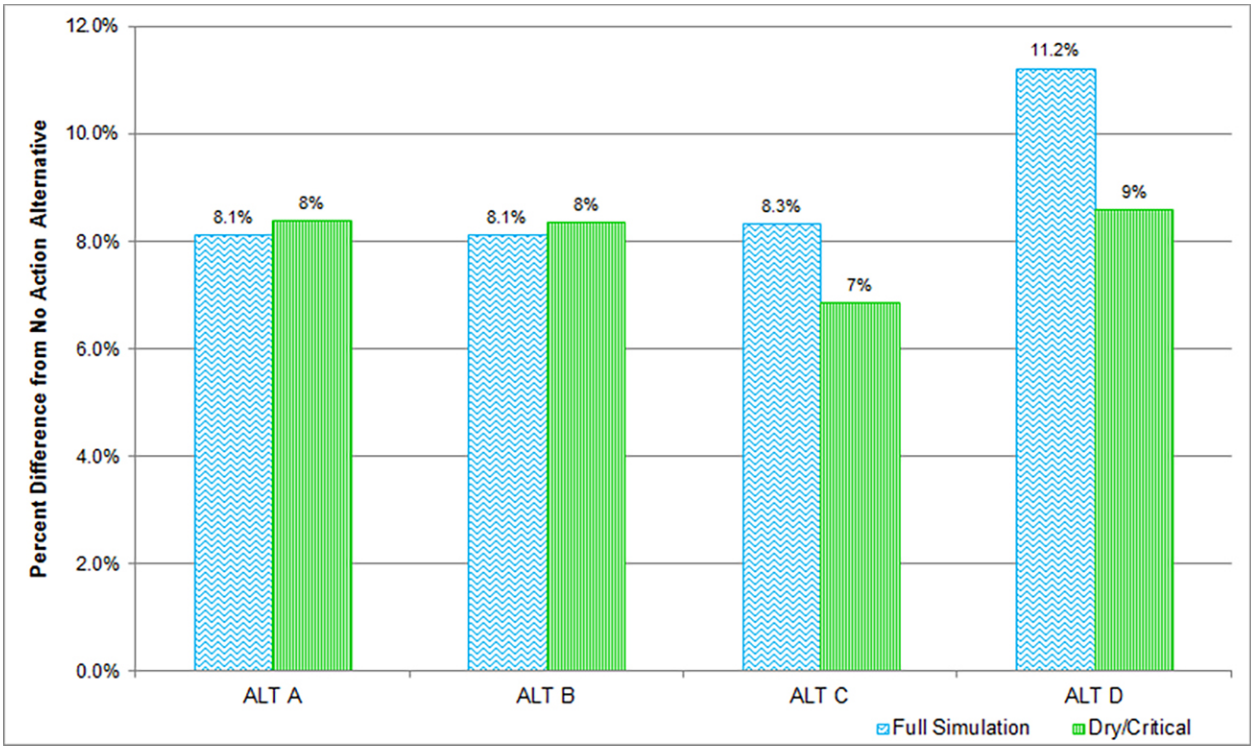


Figure A-25. Anticipated Effects of Alternatives A, B, C, and D Compared to No Project Alternative on Sacramento River Winter-Run Chinook Salmon Annual (Escapement) Female Spawner Numbers (IOS Model)

All alternatives would improve the survival of anadromous fish populations (all Chinook stocks) in the Sacramento River. Temperature reductions in the Sacramento River and its tributaries resulting from these alternatives and the resulting modifications to the operation of Folsom Lake, Shasta Lake, Lake Oroville, and Trinity Lake would help increase the survival of the anadromous fish population. Modeling results suggest that Alternative D would be the most beneficial to anadromous fish, followed by Alternative C. Operations focused on increasing end-of-September storage in Shasta Lake appear to provide the greatest benefit to Chinook salmon. Alternative B provides the least benefit to anadromous fish.

Increased flow and decreased temperatures in the Upper Sacramento River would also benefit the ESA-listed green sturgeon in terms of better spawning and rearing habitat for juveniles. Temperature alterations in the Sacramento River resulting from these alternatives and the resulting modifications to the operation of Folsom, Shasta, Oroville, and Trinity Dams may also increase survival for other native fish populations.

Delta Water Quality (Primary Objective)

All alternatives improve water quality in the Delta and in Delta exports. This section evaluates the ability of the alternatives to provide these benefits.

Delta Environmental Water Quality

Increased flows through the Delta and through San Francisco Bay provide a wide range of benefits. These flows increase estuarine habitat, reduce entrainment, and improve food availability for anadromous fish and other estuarine-dependent species (e.g., Delta smelt, longfin smelt, Sacramento splittail, starry flounder, California bay shrimp). The SWRCB has concluded that the best available science suggests that current Delta flows are insufficient to protect public trust resources, including fish populations (SWRCB 2010). The improvements in Delta environmental water quality include improvements in the position of X2 and Delta outflow.

- X2 (Delta salinity): The potential for water quality improvements within the Delta was evaluated in terms of the position of X2 and the resulting Delta outflows. Shifting X2 downstream improves the habitat for Delta smelt and reduces water quality stress for other species, including salmonids. X2 is a Delta management tool; it is defined as the distance in kilometers from the Golden Gate Bridge to the location where the tidally averaged near-bottom salinity in the Delta measures 2 parts per thousand (ppt). East of X2, water becomes progressively fresher, and west of X2 the water becomes more saline until it reaches the ocean, which has a salinity of approximately 35 ppt.

  Habitat quality in the Delta is degraded when the salinity in the Delta increases. The highest salinities occur during the fall and early winter, when Delta outflow is at its lowest. Water quality degradation is most pronounced in Dry and Critical years. Figure A-26 shows the change in the average X2 positions during September and October in Dry and Critical years for each of the alternatives. Alternative C performs best in terms of the shift in the location of X2 by 1 to 2.5 km seaward, followed by Alternative B and then Alternative A. Alternative D provides the least water quality benefit, with an average shift of 1 km to the east in July through August and a 0.3 km shift in September through November. All alternatives would shift the position of X2 from 81.4 to 81.7 km (close to Collinsville) from July to August on average.

- Delta outflow: Increasing Delta outflow increases estuarine habitat, reduces entrainment, and improves food availability for Delta species. Outflow from natural runoff is usually high enough during the months of April through July to push seawater out of the Delta. This period is also outside of the peak loading time related to agricultural drainage. As the Delta outflow decreases, the water quality is appreciably degraded during the late summer and fall. A series of probability-of-exceedance plots on Figure A-27 show Delta outflows in May through December. The greatest improvement in water quality would occur during Dry and Critical years. The monthly Delta outflows show the greatest increase under Alternative C, followed by Alternative B, then Alternative A, and then Alternative D.