Appendix 30A
CalSim 3 Results Sensitivity to 2040 Climate Change and Sea Level Projections

This appendix summarizes the key findings from a sensitivity analysis performed to analyze project impacts considering different climate change and sea level rise projections at 2040 than what were analyzed in the EIR for the No Project Alternative (2040) and Alternative 5 (2040). While the Draft EIR utilizes the reasonably foreseeable climate change and sea level rise projections as supported by substantial evidence in the administrative record, this sensitivity analysis is intended to help the public and decision-maker to understand how the No Project Alternative would differ from existing conditions under different climate change and sea level assumptions at 2040 compared to those presented in appendices to the Draft EIR, e.g. Appendix 6A, Water Supply 2040 Analysis. (see the list of appendices in Chapter 4, *Framework for Environmental Analysis*, Section 4.1.1.2 *Baseline Assumptions and Alternatives Comparison*). In addition, it also helps to identify whether the proposed project impacts detailed in the EIR would remain similar or differ under different climate change and sea level rise assumptions at 2040.

This analysis is not required by CEQA and is not used in support of the CEQA findings provided in Chapters 7–32 of the Draft Environmental Impact Report (EIR).

30A.1 CalSim 3 2040 Climate Sensitivity Analysis

Because there is a broad range of potential future climate and sea level rise conditions, the comparisons shown here cover three different climate change and sea level rise scenarios at 2040. The first is the 2040 Central Tendency (CT) climate scenario with 1.8 feet of sea level rise, which is the same scenario analyzed in the 2040 appendices to the EIR, for example, Appendix 5B, *Surface Water 2040 Analysis*. Given the high degree of uncertainty regarding future climate and sea level rise conditions, two additional 2040 climate change and sea level rise scenarios are added in this appendix for comparison. These are a 2040 CT climate scenario with 0.5 foot of sea level rise and a 2040 Median climate scenario with 1.8 feet of sea level rise. The two additional scenarios help depict the variability in the CalSim 3 results under a different climate change hydrology and sea level rise projections assumed at 2040 compared to the 2040 condition analyzed in the Draft EIR appendices. The CalSim 3 simulations in this sensitivity analysis do not differ from the other 2040 simulations analyzed in this Draft EIR, or from each other in terms of the operational rules and criteria, including those for the north Delta diversion.

30A.1.1 Climate Change Assumptions

Modeling Appendix 5A, *Modeling Technical Appendix*, Section B, Attachment 4 describes the steps and assumptions used in developing climate change boundary conditions (i.e., hydrology) for the CalSim 3 No Project Alternative (2040 CT) model. The second climate projection, 2040 Median, used in this sensitivity analysis, differs from the 2040 CT mainly in terms of the ensemble of general circulation models (GCMs) that were used to represent climate change at 2040. There were also additional differences in the processes used to convert GCM results to CalSim 3 inputs. In both cases, GCM results were used to derive Locally Constructed Analogs (LOCA) statistically downscaled

datasets of bias-corrected monthly precipitation and temperature, which were then used as inputs for the VIC hydrologic model which was used to simulate streamflow. There were, however, some differences in the exact methods. Table 30A-1 summarizes the methods used for each scenario.

Table 30A-1. Methods Used to Generate CalSim 3 inputs for the 2040 CT and 2040 Median Scenarios

Method	2040 CT	2040 Median
GCM Selection	20 GCM projections selected by CCTAG (10 GCMs were selected; for each GCM two RCPs were considered)	10 GCM projections selected by DWR Climate Change Program (CCP)
Climate Change Scenarios	With quantile mapping, perturb precipitation and temperature based on ensemble of the 20 CCTAG GCM projections	10 hydrologic scenarios, one for each CCP GCM projection, were conducted
Rim Inflows	• Conduct two VIC simulations: (1) representing historical climate conditions; (2) representing future climate conditions (based on quantile mapping of precipitation and temperature) over the 1915 – 2015 period • Calculate a timeseries of changes in VIC simulated streamflow (future divided by historical) at each rim inflow location • At each rim inflow location, for each monthly time step in the CalSim 3 planning simulation period, apply VIC simulated changes to streamflow. • Apply second order correction to confirm annual shifts	• Develop cumulative distribution function (CDF) for historical CalSim 3 rim inflows • Develop CDFs for VIC simulated historical reference period (WY 1981 – 2010) and VIC simulated future period (WY 2026 – 2055) across all 10 selected GCM projections • Calculate the ratio between the VIC simulated future period and the VIC simulated historical period for each quantile of the CDF • At each rim inflow location, for each monthly time step in the CalSim 3 planning simulation period, identify the quantile associated with the inflow value. • Apply ratio (from step 3) to each value based on its quantile (from step 4) • Apply second order correction to confirm annual shifts
Valley Floor Flows (CalSimHydro), Delta Channel Depletion (DETAW/DCD), Reservoir Evaporation, Groundwater	• Similar to rim inflows • Perturbation based on the differences in historical and projection scenarios	• Similar to rim inflows • Perturbation based on the ensemble of differences in the 10 scenarios

Because GCM selection was the most significant difference between the scenarios, that process is described in more detail here. In both cases, GCM selection was made from an available dataset of statistically downscaled GCM products for California, which is the LOCA archive of 32 GCMs from the Coupled Model Intercomparison Project Phase 5 (CMIP5) archive at 1/16th degree spatial resolution (Pierce et al. 2014) and for two future emissions scenarios, or Representative Concentration Pathways (RCPs), RCP 4.5 and 8.5, bringing the total number of LOCA archive datasets to 64.

The 2040 CT scenario used the 20 GCM-RCP climate projections that were selected by the California Department of Water Resources (DWR) Climate Change Technical Advisory Group (CCTAG) as the

most appropriate projections for California water resources evaluation and planning (California Department of Water Resources Climate Change Technical Advisory Group 2015:18). The 20 climate model projections were generated with 10 GCMs and the two available emission scenarios (RCP 4.5 and 8.5) from the LOCA archive.

For the 2040 Median scenario, 10 GCM-RCP climate projections were selected from the 64 datasets of the LOCA archive based on three metrics of projected change over the future 30-year period centered at 2040 (2026–2055) relative to a 30-year historical reference period centered on 1995 (1981–2010).[1] The three change metrics are as follows.

1. Mean annual streamflow (Q_u), computed as a change factor.
2. Coefficient of variation (CV) of streamflow (Q_{cv}), computed as a change factor.
3. Average annual temperature (T_{avg}), computed as absolute change in degrees Celsuis.

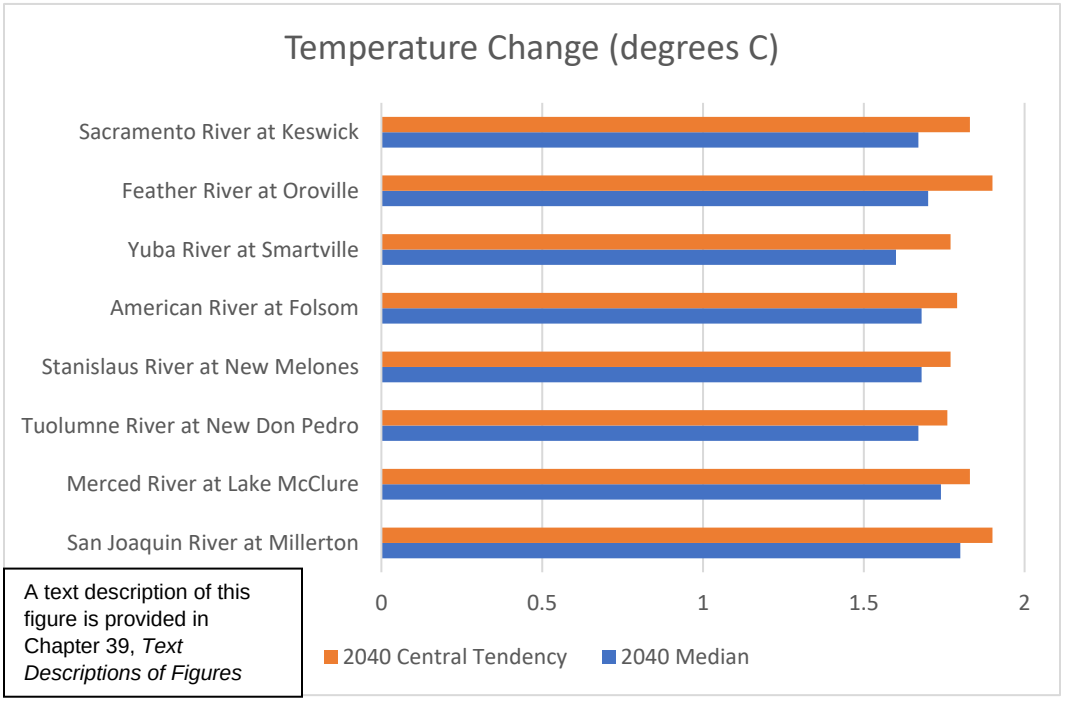
The 10 GCM-RCP climate projections were selected based on the collective similarity of the above three metrics to target values that represent the median climate change condition across all 64 archive members at 2040 compared to 1995. The 10 GCM-RCP climate projections with the nearest weighted normalized distance to the target metrics were selected. The selection procedure used for the 2040 Median incorporates the projected variability in the annual streamflow, which is identified as an important driver affecting California water supply (Delta Stewardship Council 2021:5-58). Table 30A-1. shows a comparison of GCM-RCP climate projections used in the 2040 CT and 2040 Median scenarios.

Table 30A-2. Global Climate Models used for 2040 CT and 2040 Median Scenarios

Model	2040 CT	2040 Median
ACCESS 1-0	rcp45, rcp85	-
ACCESS1-3	-	rcp85
CCSM4	rcp45, rcp85	rcp85
CESM1-BGC	rcp45, rcp85	rcp45, rcp85
CMCC-CMS	rcp45, rcp85	-
CNRM-CM5	rcp45, rcp85	-
CSIRO-MK3-6-0	-	rcp45, rcp85
CanESM2	rcp45, rcp85	-
FGOALS-G2	-	rcp45
GFDL-CM3	rcp45, rcp85	-
GISS-E2-H	-	rcp85
HADGEM2-CC	rcp45, rcp85	rcp45
HADGEM2-ES	rcp45, rcp85	-
MIROC5	rcp45, rcp85	rcp45

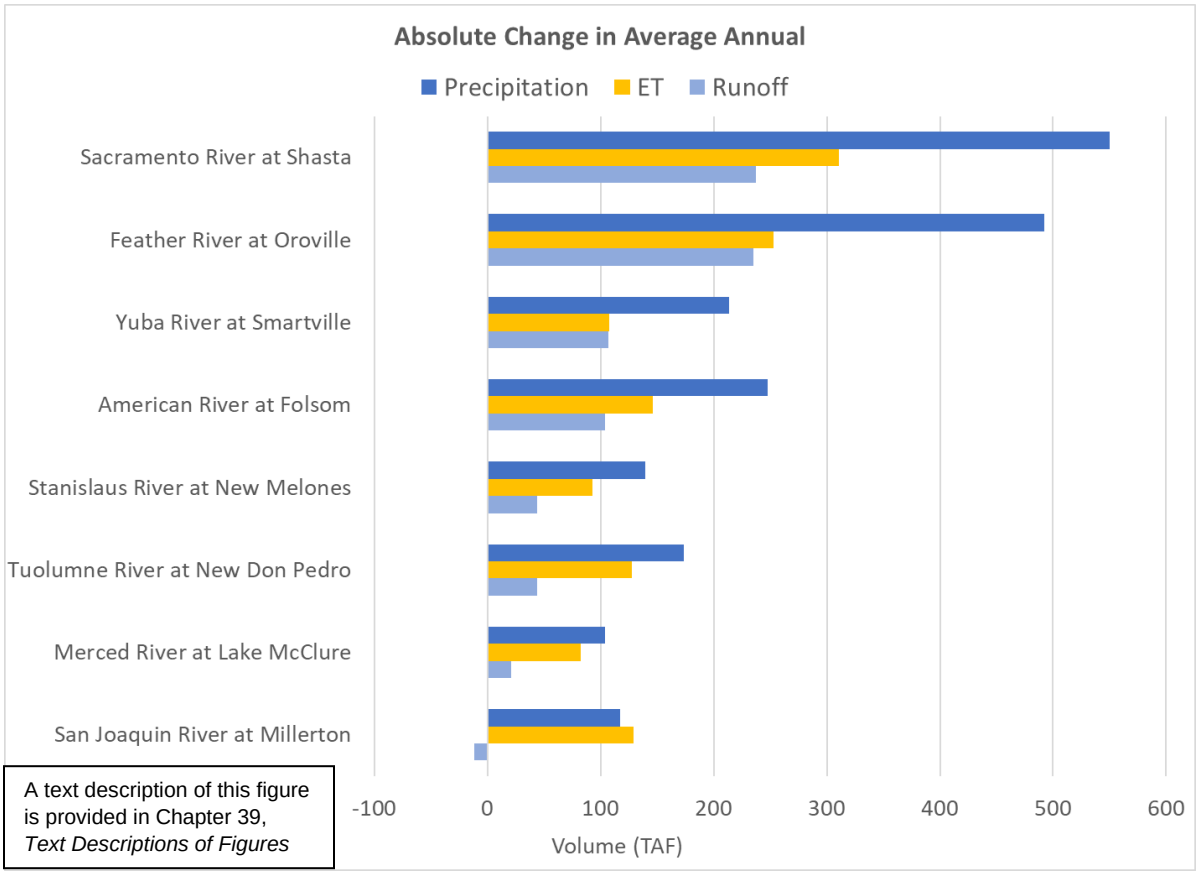
[1] This historical reference period was chosen for consistency with the NOAA 30-year climate normal period as of the date of the Notice of Preparation for this EIR. In addition, CMIP5 GCMs simulate historical climate conditions through 2005, and commence simulation of projected climate conditions beginning in 2006. This means it is inadvisable to use a more recent 30-year period as the historical reference period, e.g. 1991-2020.

Figure 30A-1 shows comparisons of change in average temperature for eight major watersheds for the 2040 CT and 2040 Median scenarios, compared to a historical reference period centered on 1995. Temperatures increase for all watersheds, with the 2040 CT showing slightly greater increases than the 2040 Median. Figures 30A-2 and 30A-3 show comparisons of changes in average annual precipitation, evapotranspiration (ET), and runoff for eight major watersheds for the 2040 CT and 2040 Median scenarios, compared to a historical reference period centered on 1995. Precipitation, ET, and runoff increase in most cases, except there is a decrease in precipitation on the Sacramento River at Shasta in the 2040 Median, decreases in runoff for the San Joaquin River at the Millerton watershed in the 2040 CT, and decreases for all watersheds in the 2040 Median. Figures 30A-4 through 30A-7 show monthly average unimpaired hydrology inputs to CalSim 3 for selected rivers and indexes for 2040 CT and 2040 Median, compared to existing conditions (2020). Both 2040 climate scenarios have a consistent increase in flow in the December–March period and decreases during the April–July period compared to existing conditions. The decrease from April–July is more extreme in the 2040 Median scenario, especially prominent for the Shasta inflow.



A text description of this figure is provided in Chapter 39, *Text Descriptions of Figures*

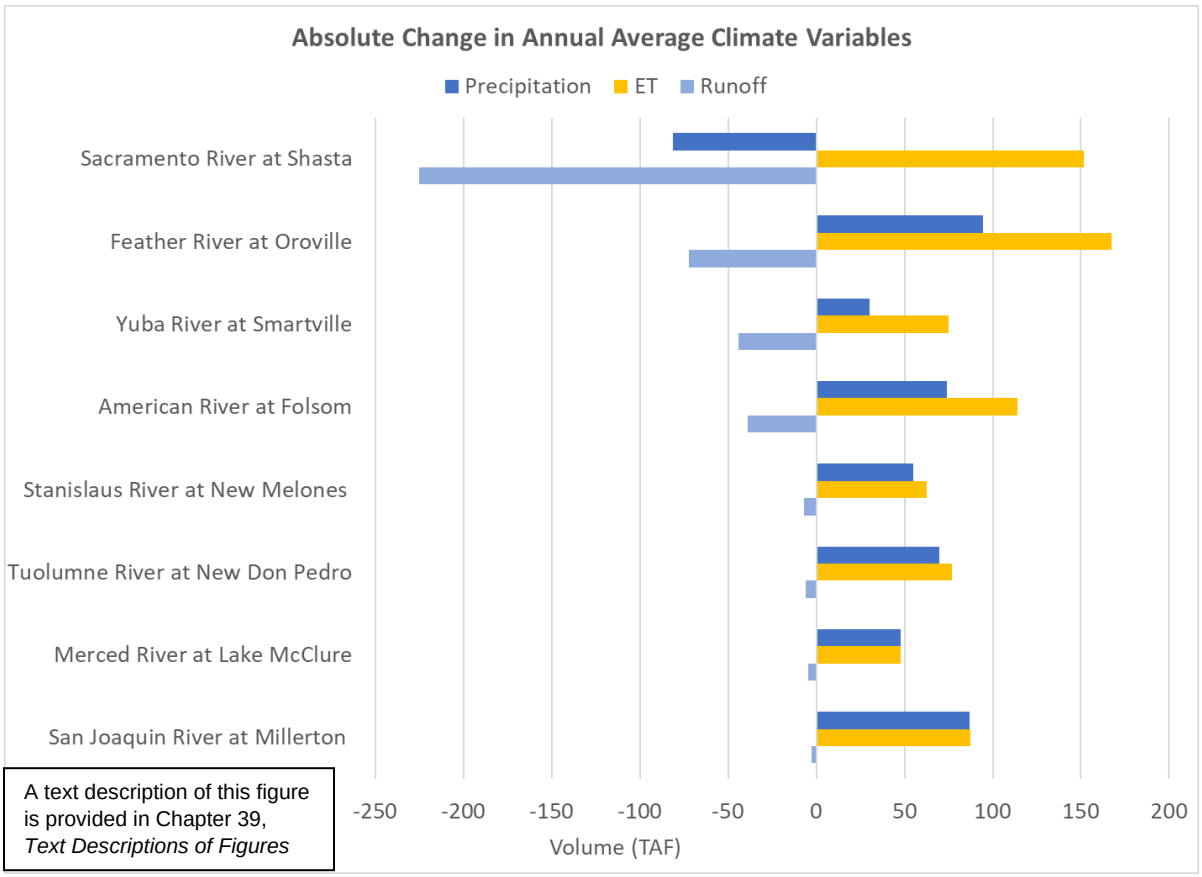
Figure 30A-1. Projected Changes in Average Temperature for Major Watersheds in the Sacramento and San Joaquin River Basins for 2040 CT and 2040 Median, Compared to Historical Reference Period (1995)



A text description of this figure is provided in Chapter 39, *Text Descriptions of Figures*

ET= evapotranspiration
TAF=thousand acre-feet

Figure 30A-2. Projected Absolute Changes in Precipitation, Evapotranspiration, and Runoff for Major Watersheds in the Sacramento and San Joaquin River Basins for 2040 CT, Compared to Historical Reference Period (1995)



A text description of this figure is provided in Chapter 39, *Text Descriptions of Figures*

ET= evapotranspiration
TAF=thousand acre-feet

Figure 30A-3. Projected Changes in Precipitation, ET, and Runoff for Major Watersheds in the Sacramento and San Joaquin River Basins for 2040 Median, Compared to Historical Reference Period (1995)

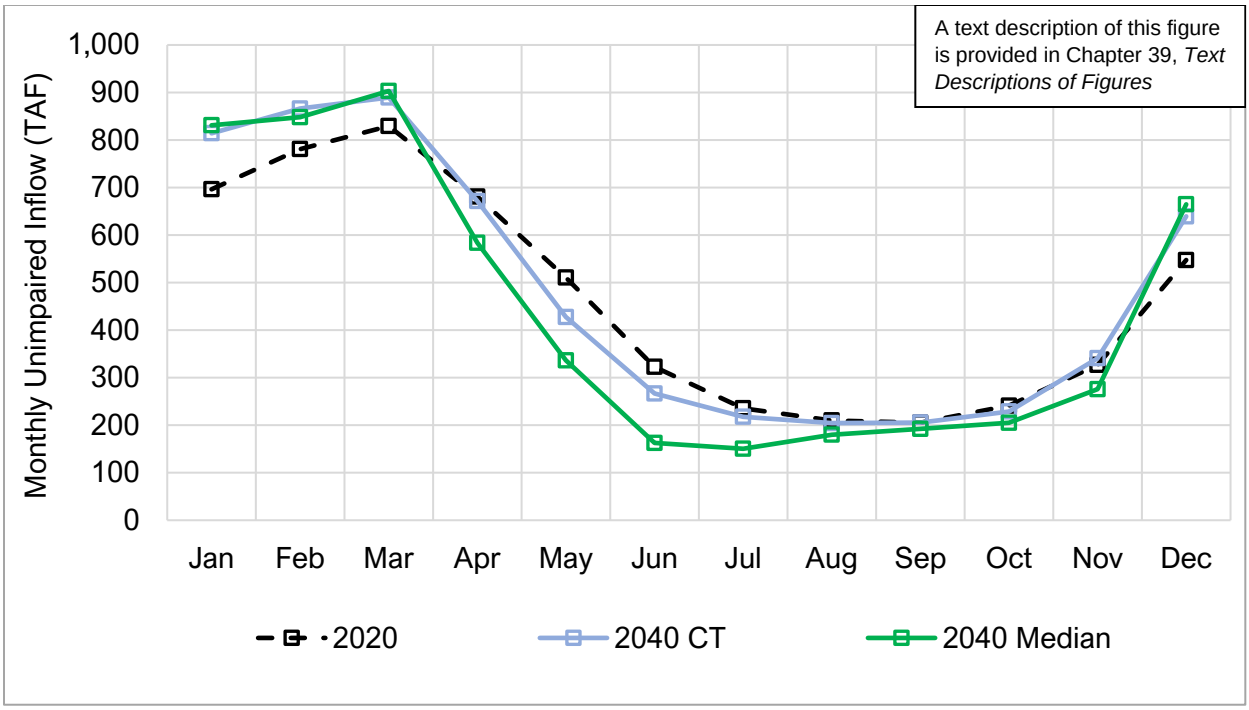


Figure 30A-4. Shasta Unimpaired Inflow (UNIMP_SHAS), Monthly Average Inflow (thousand acre-feet), 2020, 2040 CT, and 2040 Median

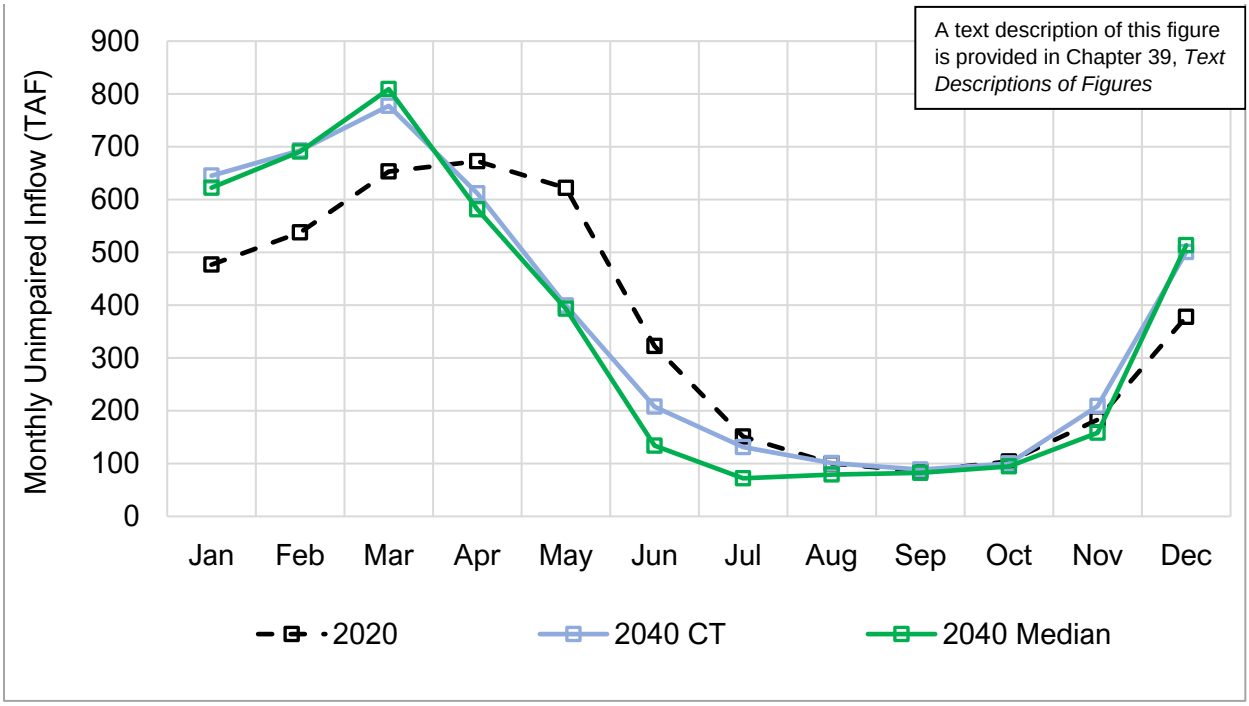


Figure 30A-5. Oroville Unimpaired Inflow (UNIMP_OROV), Monthly Average Inflow (thousand acre-feet), 2020, 2040 CT, and 2040 Median

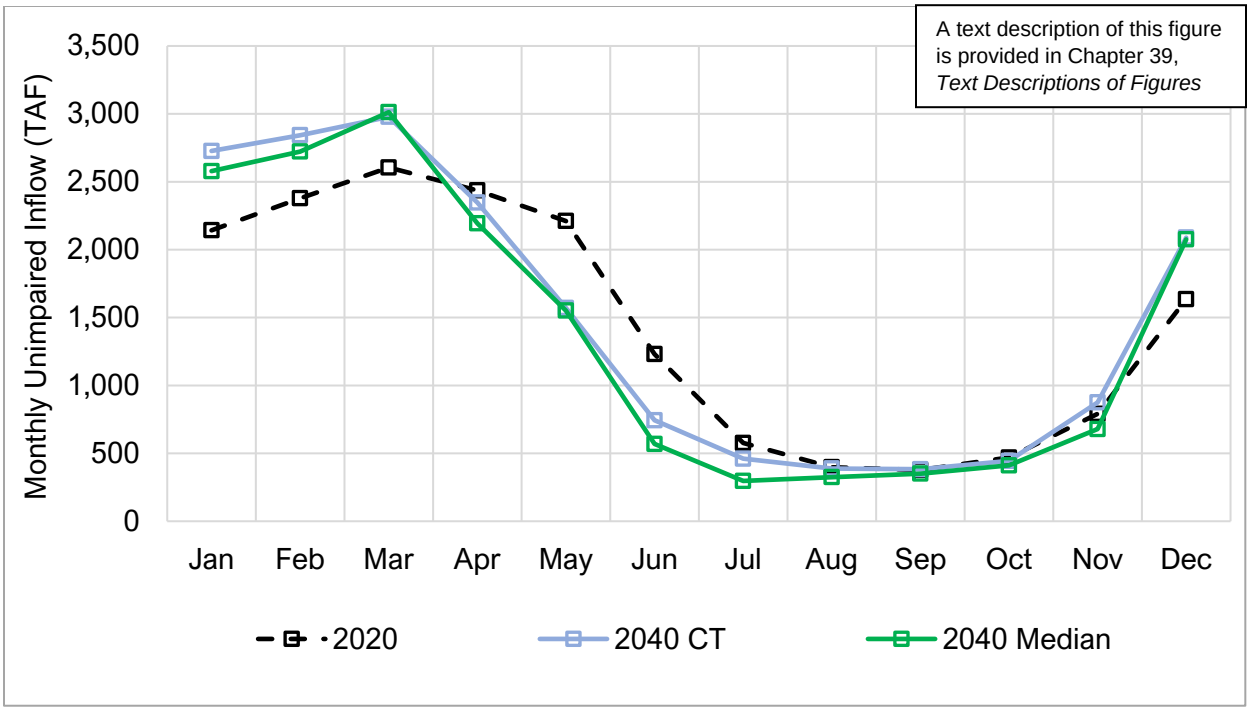


Figure 30A-6. Four River Index (UNIMP_OROV + UNIMP_FOLS + UNIMP_YUBA + UNIMP_SRBB), Monthly Average Inflow (thousand acre-feet), 2020, 2040 CT, and 2040 Median

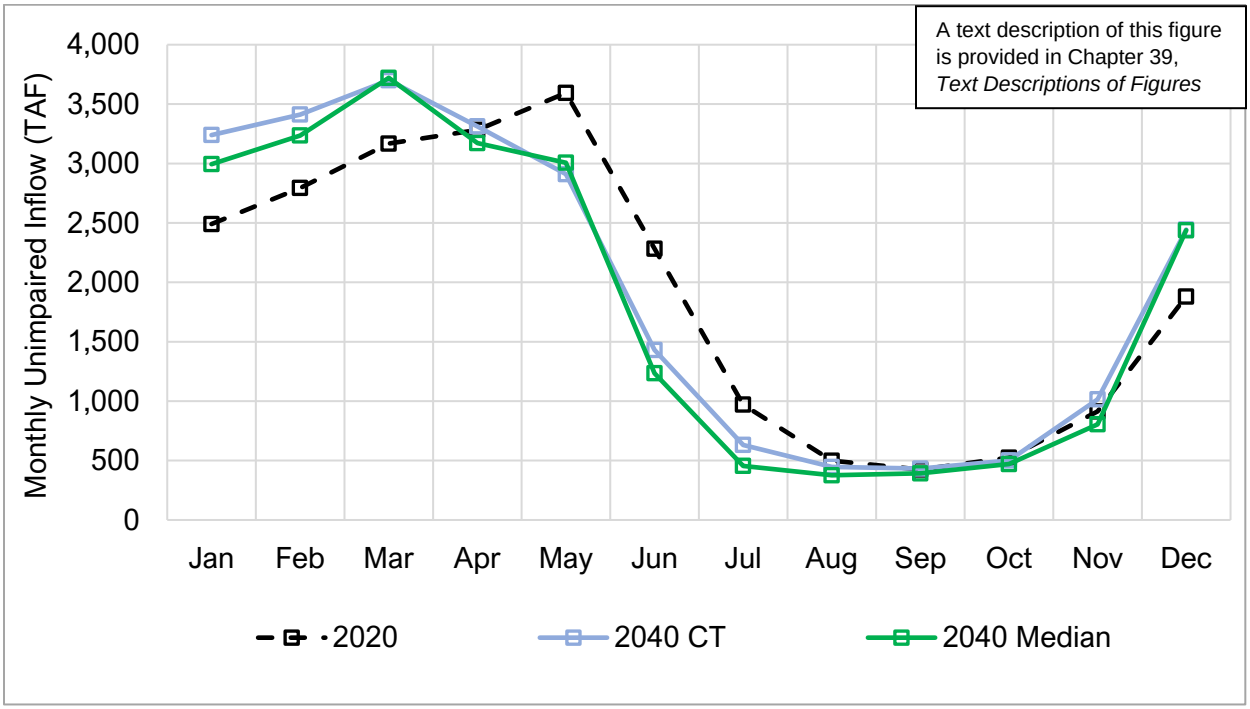


Figure 30A-7. Eight River Index (UNIMP_OROV + UNIMP_FOLS + UNIMP_YUBA + UNIMP_SRBB + UNIMP_ST + UNIMP_TU + UNIMP_ME + UNIMP_SJ), Monthly Average Inflow (thousand acre-feet), 2020, 2040 CT, and 2040 Median

30A.1.2 Sea Level Rise Assumptions

As described in Appendix 5A, *Modeling Technical Appendix*, Section B, the 2040 analysis in the Draft EIR assumed a 1.8 feet sea level rise. For this sensitivity analysis, a lower level of sea level rise of 0.5 foot, which is predicted to occur with a 66% probability by 2040, was assumed in conjunction with the 2040 CT climate change project to understand the sensitivity of CalSim 3 operations results to the different sea level rise assumptions. The higher level sea level rise of 1.8 feet assumed in the Draft EIR has a probability of occurrence of less than 0.5%. It is from the H++ modeling scenario, an extreme modeling scenario resulting from loss of the West Antarctic ice sheet (California Natural Resources Agency and California Ocean Protection Council 2018:18). Sea level rise is incorporated into CalSim 3 through use of an Artificial Neural Network (ANN), which is trained on Delta hydrodynamic model salinity results. Separate ANNs were developed for the 0.5-foot and 1.8-feet sea level rise scenarios.

30A.1.3 Sensitivity Analysis Results

30A.1.3.1 General Observations

Figures 30A-8 through 30A-30 show the system responses for the 2040 CT climate scenario with 1.8 feet of sea level rise (black lines), the 2040 CT climate scenario with 0.5 foot of sea level rise (blue lines), and the 2040 Median climate scenario with 1.8 feet of sea level rise (green lines). Each plot includes results from the CalSim 3 simulations for the No Project Alternative (solid lines) and Alternative 5 (dashed lines) under the above climate scenarios. Some general observations based on these simulations are discussed below.

Central Valley Project (CVP) reservoir storages in Shasta, Trinity, and Folsom are sensitive to the modeled climate scenario. Relative to the 2040 CT with 1.8-feet sea level rise scenario, storages are consistently higher in the 2040 CT with 0.5-foot sea level rise scenario, and consistently lower in the 2040 Median with 1.8-feet sea level rise scenario. The magnitude of sea level rise (i.e., 1.8-feet versus 0.5-foot) has less of an effect on storage than differences in hydrology between the two climate scenarios (i.e., 2040 CT versus 2040 Median). Storage differences between climate scenarios are typically greatest in September (as opposed to May) and at lower storage levels. Oroville shows similar patterns as the CVP reservoirs, although storage differences between scenarios in September are smaller than for the CVP reservoirs. Extremely low storage conditions, which are indicative of stressed water supply conditions, are most common in the 2040 Median scenario.

Alternative 5, the proposed project, has either equivalent or slightly increased reservoir storages in drier conditions compared to the No Project Alternative, with increases more pronounced in September across all three climate scenarios. The increase in reservoir storage is largest in the 2040 CT with 1.8-feet sea level rise scenario, and less in the other two scenarios.

30A.1.3.2 Figure-Specific Observations

As illustrated in Figures 30A-16 through 30A-20, flows across all rivers upstream of the north Delta diversions are moderately sensitive to differences in hydrology between the two climate scenarios (i.e., 2040 CT versus 2040 Median), though differences in sea level rise had little effect on these river flows. Compared to the two 2040 CT hydrology scenarios, the 2040 Median hydrology scenario had generally lower flows throughout the year, except for the American River in May–July, where flows

are higher. Flows under Alternative 5 are nearly identical to flows under the No Project Alternative in all cases.

Figures 30A-21 through 30A-23 show that flows on the San Joaquin River at Vernalis are lower from January–March in the 2040 Median hydrology scenario than in the 2040 CT hydrology scenarios, and similar in other months. Flows under Alternative 5 are identical to flows in the No Project Alternative in all cases. As with other river flows, differences in sea level rise had no effect, so flows in the two 2040 CT scenarios are very similar.

X2 position is sensitive to the modeled climate scenario during the winter and spring, as shown in Figure 30A-24. Relative to the 2040 CT with 1.8-feet sea level rise scenario, in those months X2 position in the 2040 Median with 1.8-feet sea level rise scenario is approximately 1 kilometer (km) further east, and X2 position in the 2040 CT with 0.5-foot sea level rise is 1–3 km further west. Alternative 5 results in an approximately 1 km eastward shift of X2 relative to the No Project Alternative from December–March in all scenarios. Outside of the winter and spring, the X2 position is approximately the same for all models regardless of climate scenario and with the proposed project.

During the December–June period, Old and Middle River (OMR) flow remains relatively consistent across all three 2040 climate scenarios (Figure 30A-25). Alternative 5 also does not affect OMR flows compared to the No Project Alternative during the December–June period, for all 2040 scenarios.

Total Delta exports are sensitive to the modeled climate scenario from late summer through the early winter but are relatively consistent across all scenarios throughout the rest of the year (Figure 30A-26). Compared to the 2040 CT with 1.8-feet sea level rise scenario, exports are higher in the 2040 CT with 0.5-foot sea level rise scenario and lower in the 2040 Median with 1.8-feet sea level rise scenario. Exports in Alternative 5 increase significantly relative to the No Project Alternative in the winter and early spring, as the north Delta diversions exports substantial volumes of excess Delta flows. More modest export increases occur in Alternative 5 in the fall. Alternative 5 export increases are similar in all three 2040 climate scenarios.

North Delta diversion annual exports are somewhat affected by the modeled climate scenario (Figure 30A-27). Compared to the 2040 CT with 1.8-feet sea level rise scenario, annual exports are slightly higher in the 2040 CT with 0.5-foot sea level rise scenario (mostly in the wettest years) and are lower in the 2040 Median with 1.8-feet sea level rise scenario.

As shown in Figures 30A-28 through 30A-30, salinities at Emmaton, Jersey Point, and Rock Slough vary depending on the climate scenario and alternative. Salinities shown here are from CalSim 3, in which they are calculated using an ANN that is trained on Delta hydrodynamic model (DSM2) salinity results. Separate ANNs were developed for the 0.5-foot and 1.8-feet sea level rise scenarios. The results shown here are not intended to be a detailed water quality analysis but are indicative of water quality changes. Detailed water quality results from Delta hydrodynamic modeling for the 2040 CT 1.8-feet sea level rise scenario are available in Appendix 9L, *Water Quality 2040 Analysis*.

Salinity is different between climate scenarios in all months except for March and April for Emmaton and Jersey Point, and May for Rock Slough. Compared to the 2040 CT 1.8-feet sea level rise scenario, salinity is lower at all locations in the 2040 CT 0.5-foot sea level rise scenario, and higher in the 2040 Median 1.8-feet sea level rise scenario. Alternative 5 has slightly higher salinities than the No Project Alternative in all cases during the September–January period.

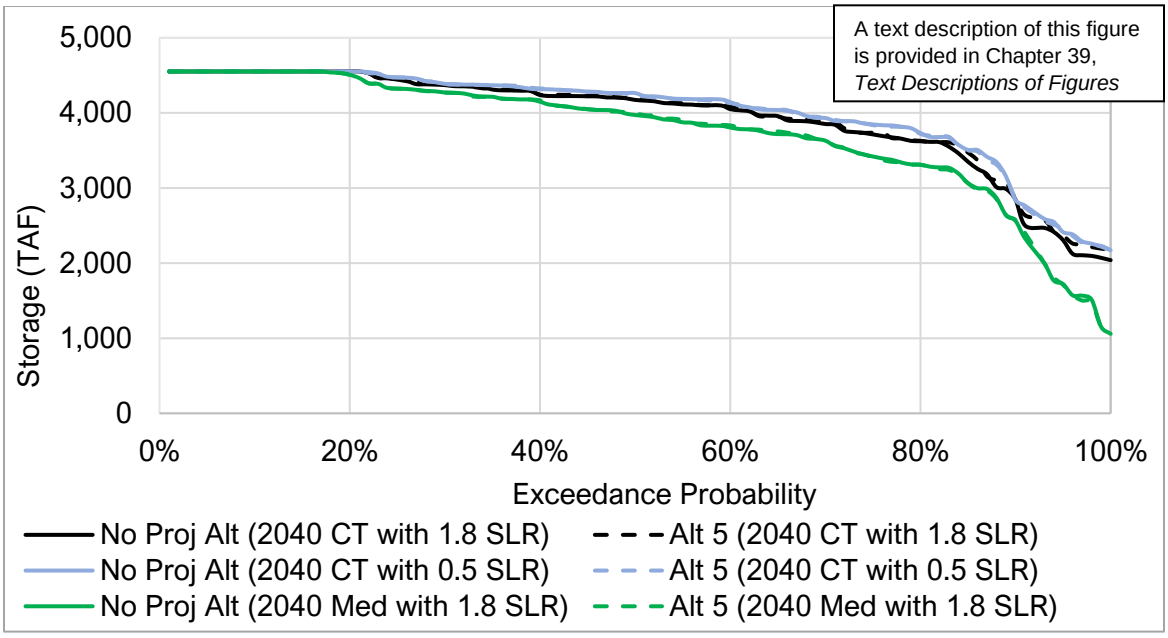


Figure 30A-8. Shasta End-of-Month Storage (S_SHSTA), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for May, No Project Alternative and Alternative 5 (2040)

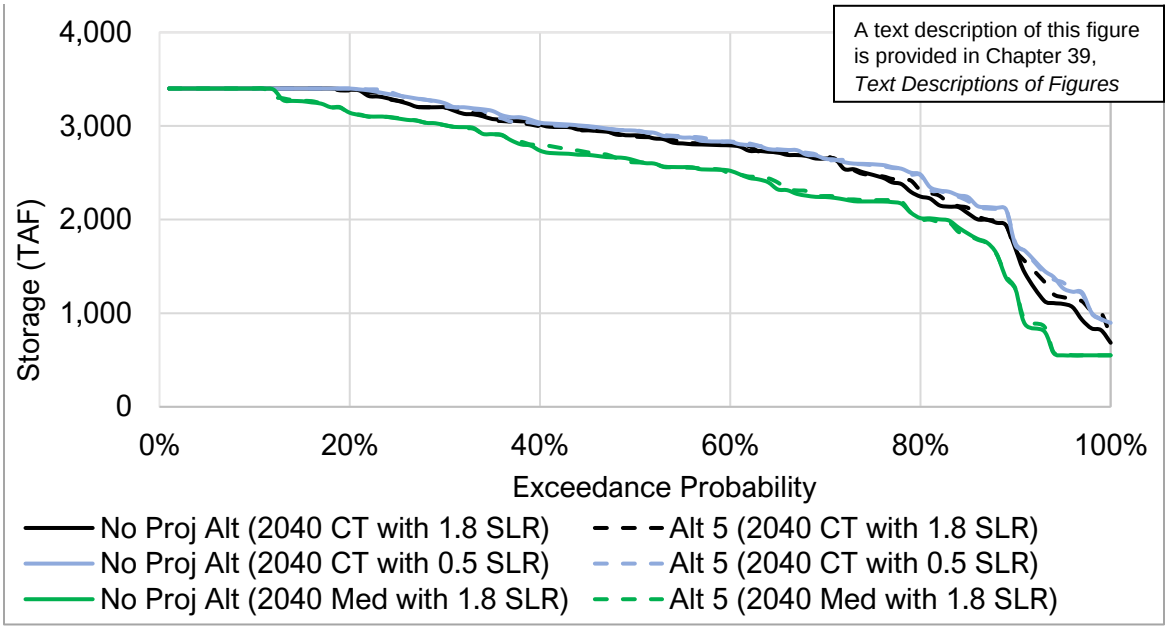


Figure 30A-9. Shasta End-of-Month Storage (S_SHSTA), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for September, No Project Alternative and Alternative 5 (2040)

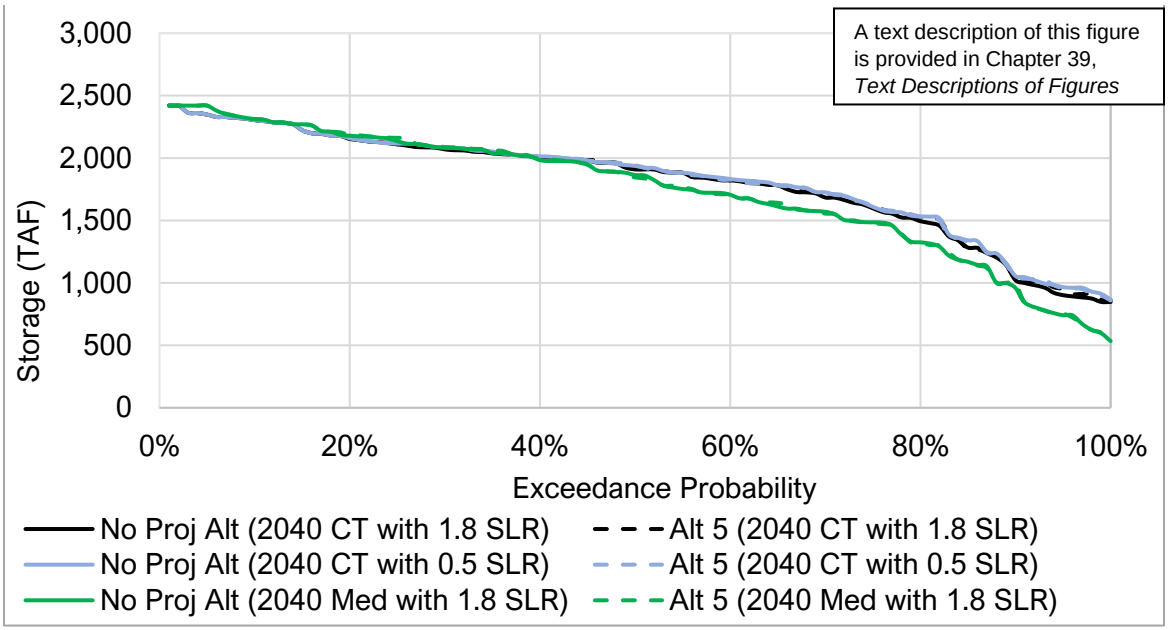


Figure 30A-10. Trinity End-of-Month Storage (S_TRNTY), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for May, No Project Alternative and Alternative 5 (2040)

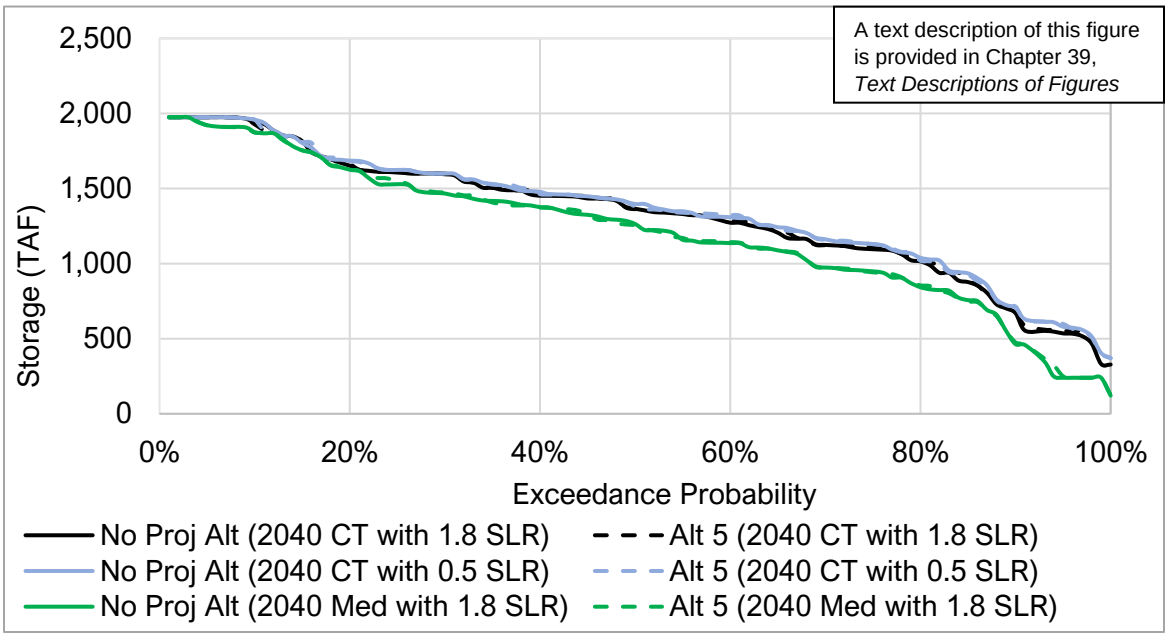


Figure 30A-11. Trinity End-of-Month Storage (S_TRNTY), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for September, No Project Alternative and Alternative 5 (2040)

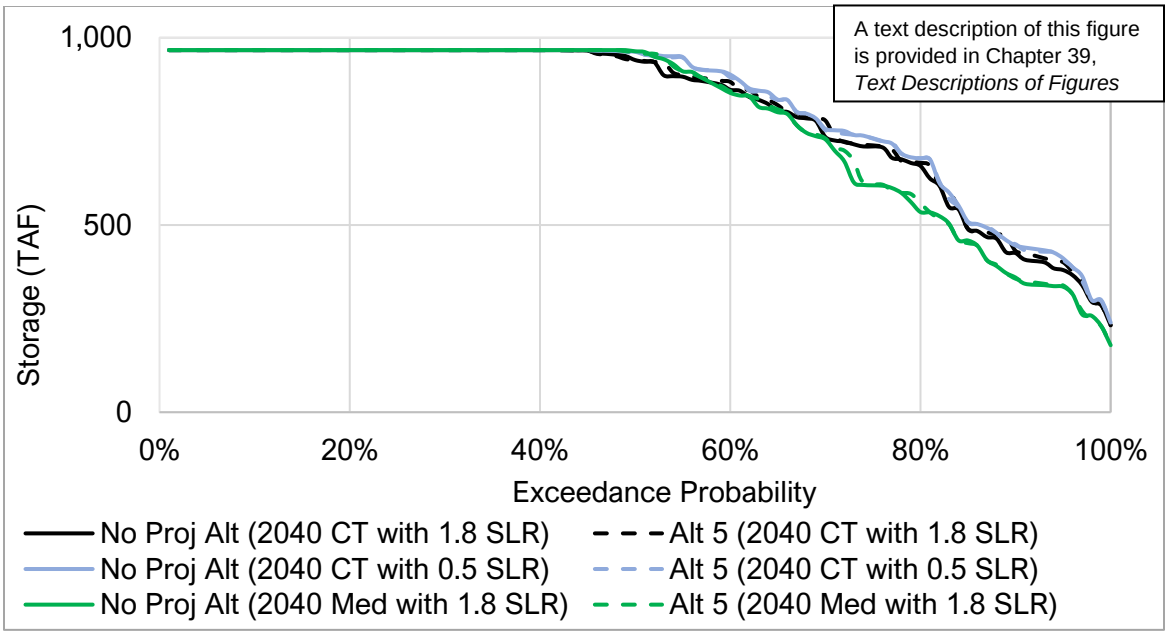


Figure 30A-12. Folsom End-of-Month Storage (S_FOLSM), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for May, No Project Alternative and Alternative 5 (2040)

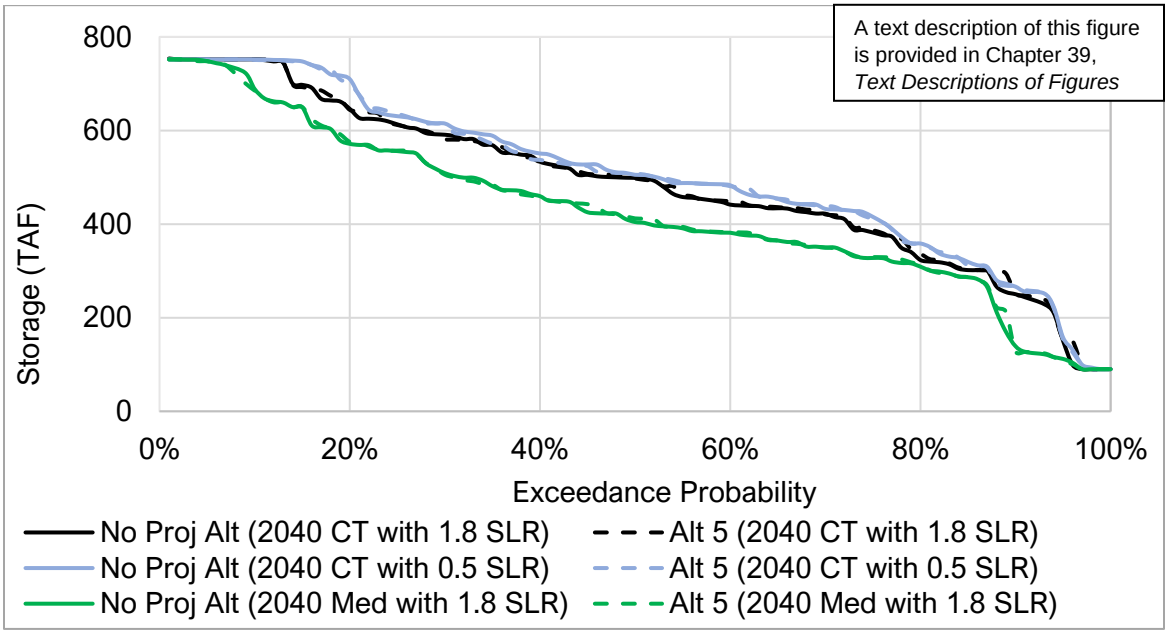


Figure 30A-13. Folsom End-of-Month Storage (S_FOLSM), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for September, No Project Alternative and Alternative 5 (2040)

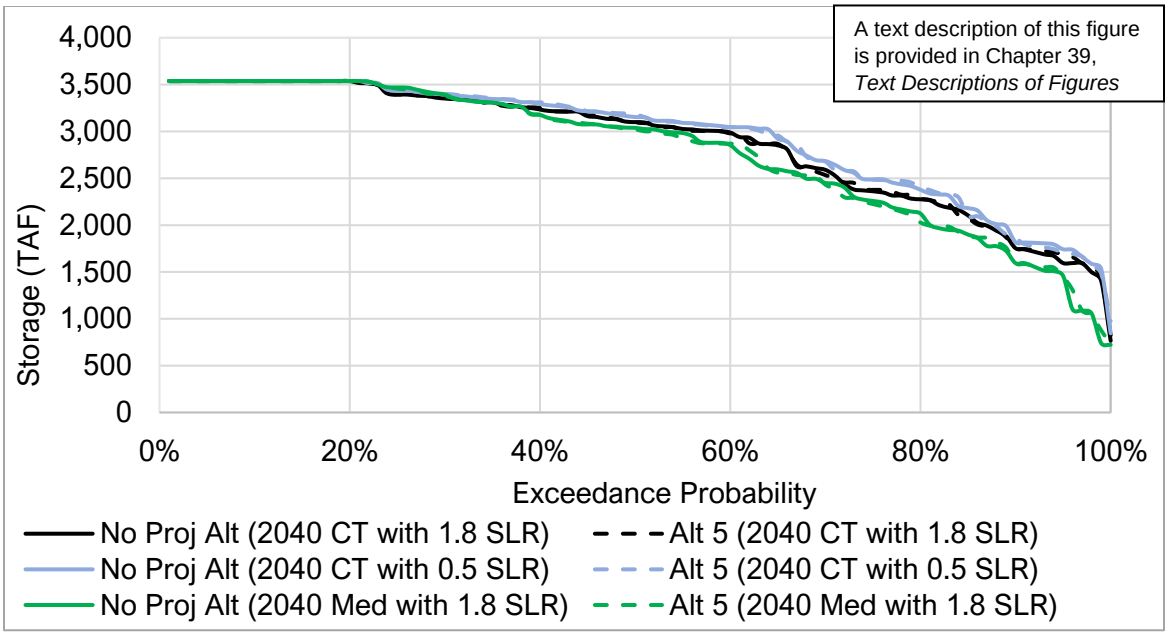


Figure 30A-14. Oroville End-of-Month Storage (S_OROVL), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for May, No Project Alternative and Alternative 5 (2040)

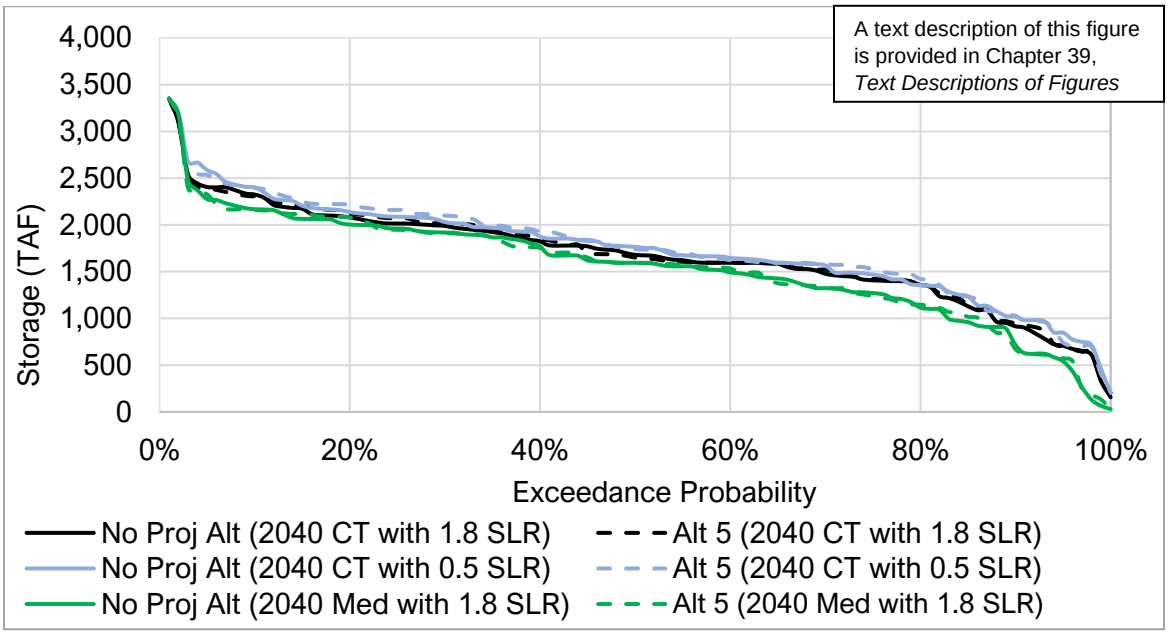


Figure 30A-15. Oroville End-of-Month Storage (S_OROVL), Exceedance Probability for Monthly Average End-of-Month Storage (thousand acre-feet) for September, No Project Alternative and Alternative 5 (2040)

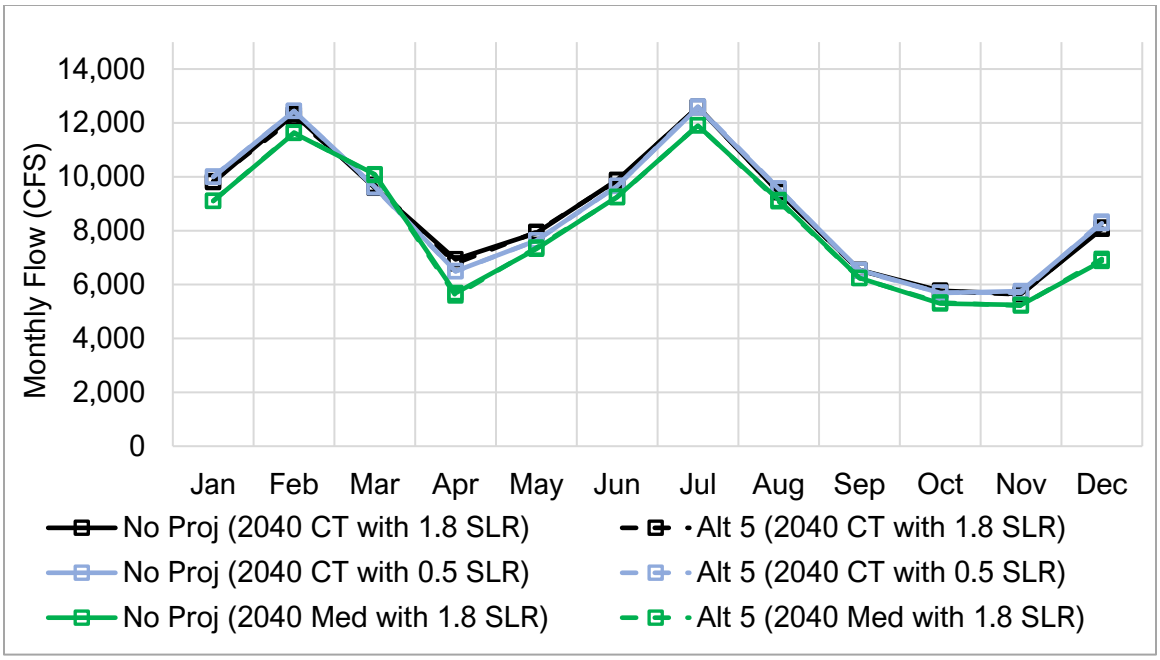


Figure 30A-16. Sacramento River at Keswick (C_KSWCK), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

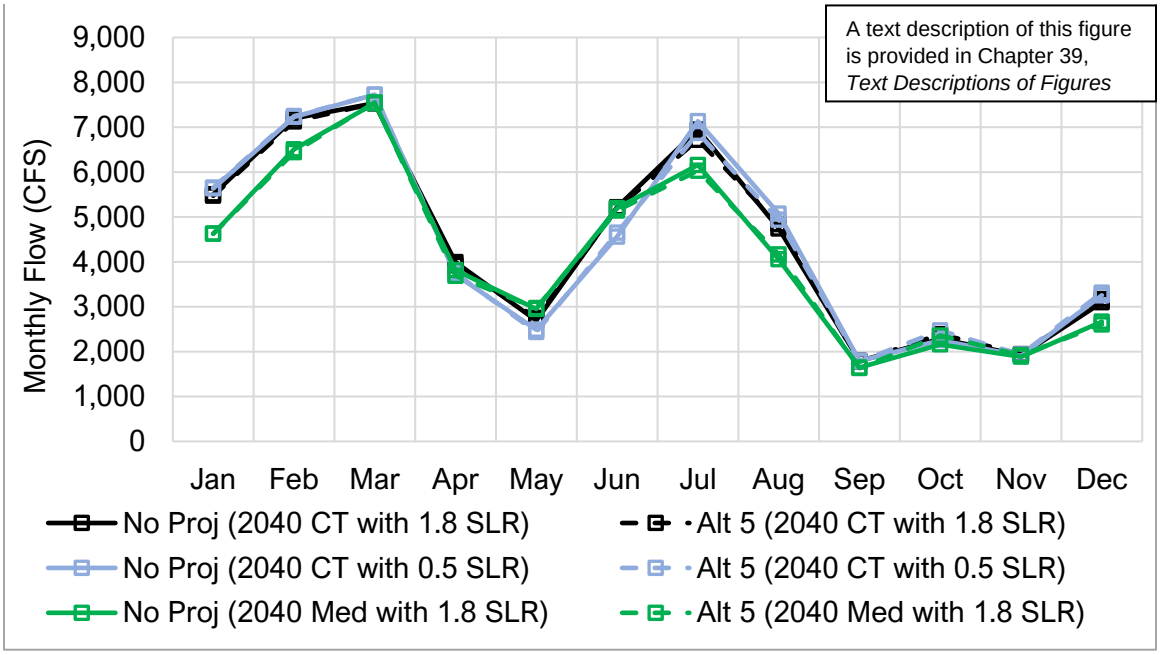


Figure 30A-17. Feather River at Thermalito (C_FTR059), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

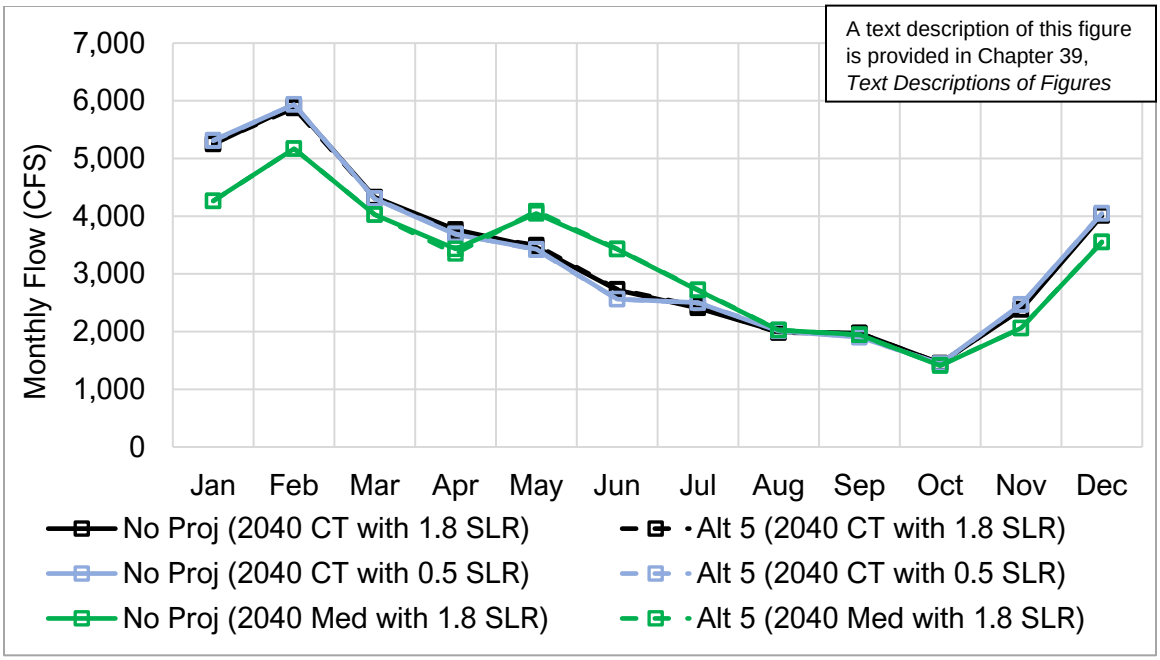


Figure 30A-18. American River at Nimbus (C_NTOMA), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

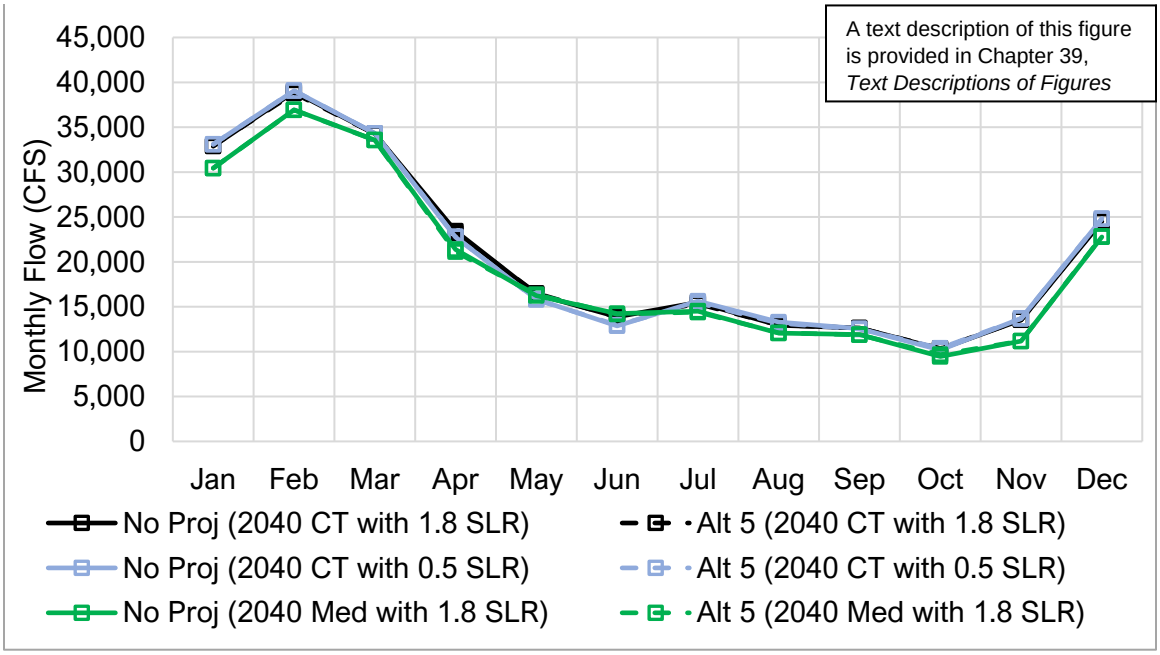


Figure 30A-19. Sacramento River at Freeport (C_SAC048), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

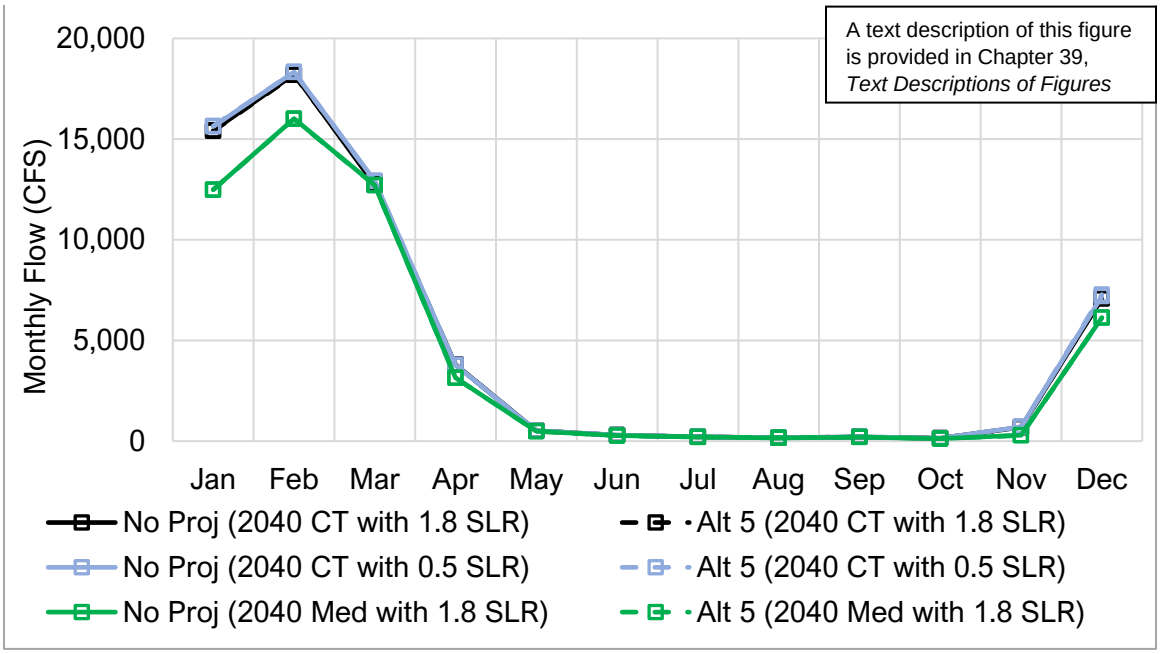


Figure 30A-20. Yolo Bypass at Delta (C_YBP020), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

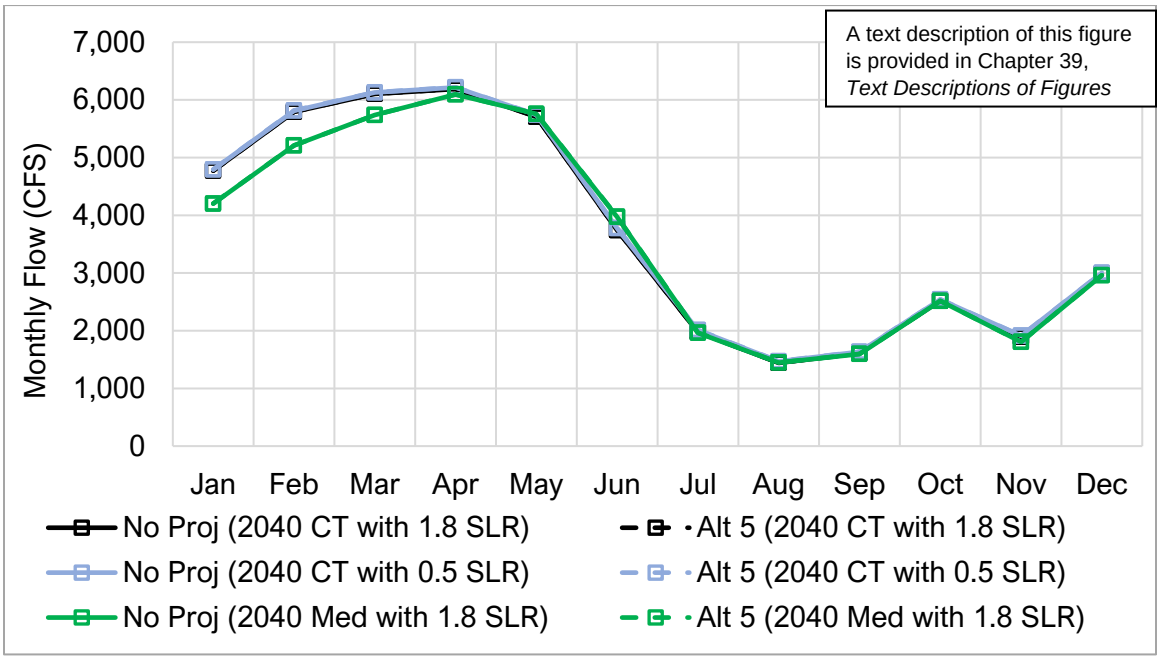


Figure 30A-21. San Joaquin River at Vernalis (C_SJR070), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

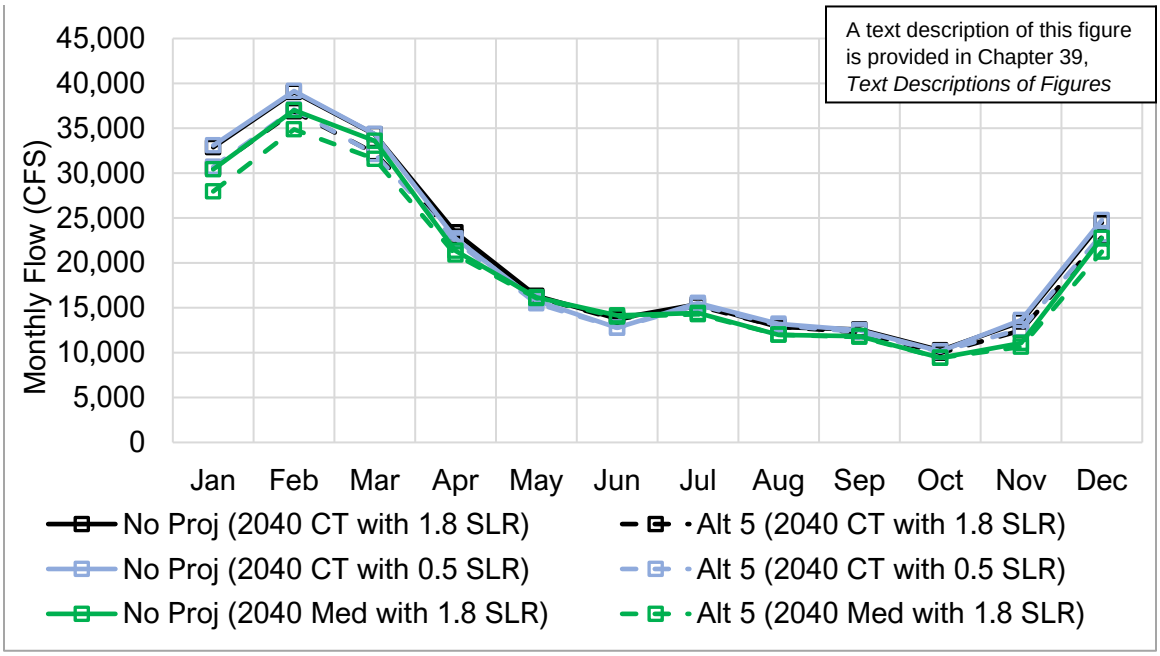


Figure 30A-22. Sacramento River Downstream of North Delta Diversion (C_SAC041), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

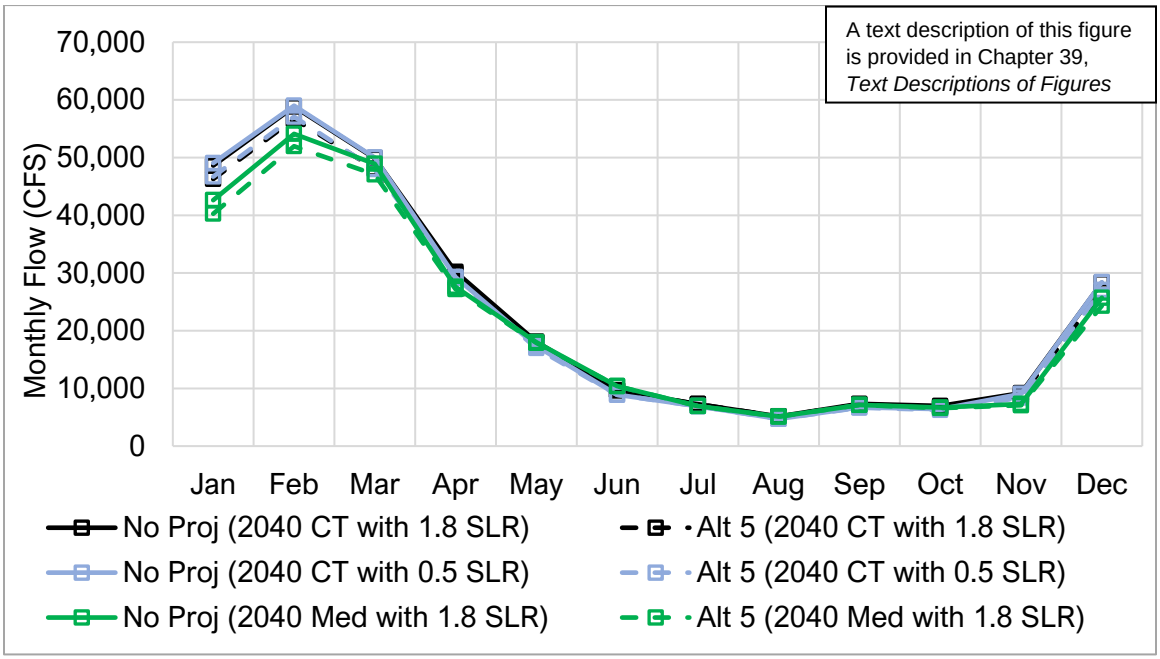


Figure 30A-23. Delta Outflow (NDOI), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

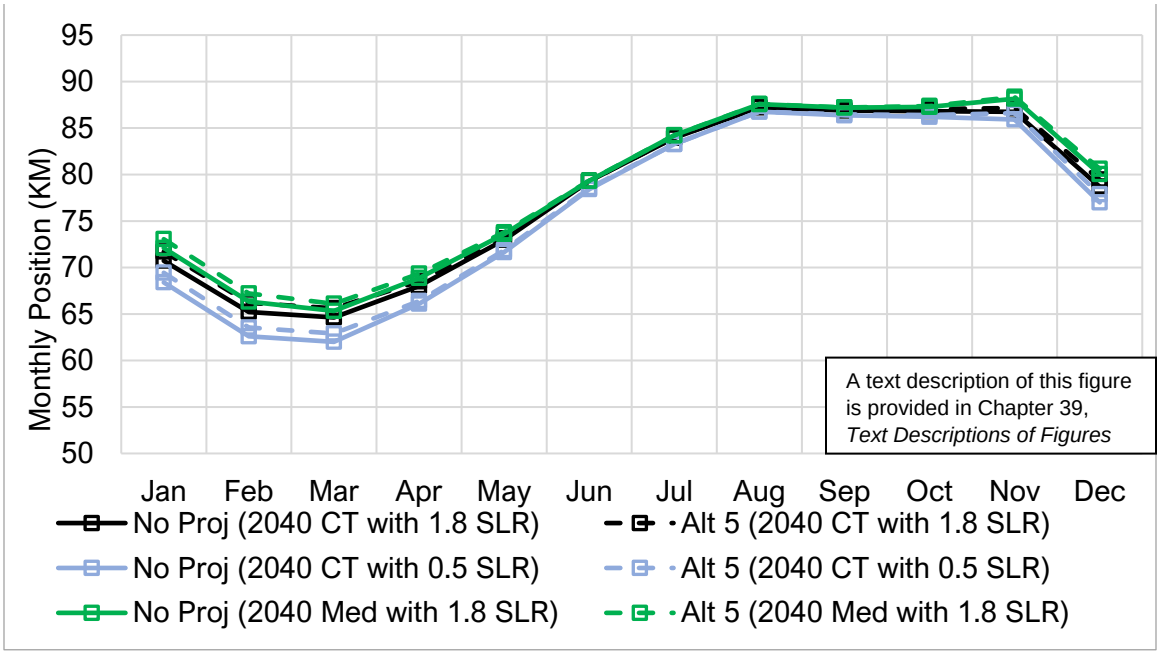


Figure 30A-24. X2 Position (X2_PRV), Monthly Average Position (kilometers), No Project Alternative and Alternative 5 (2040)

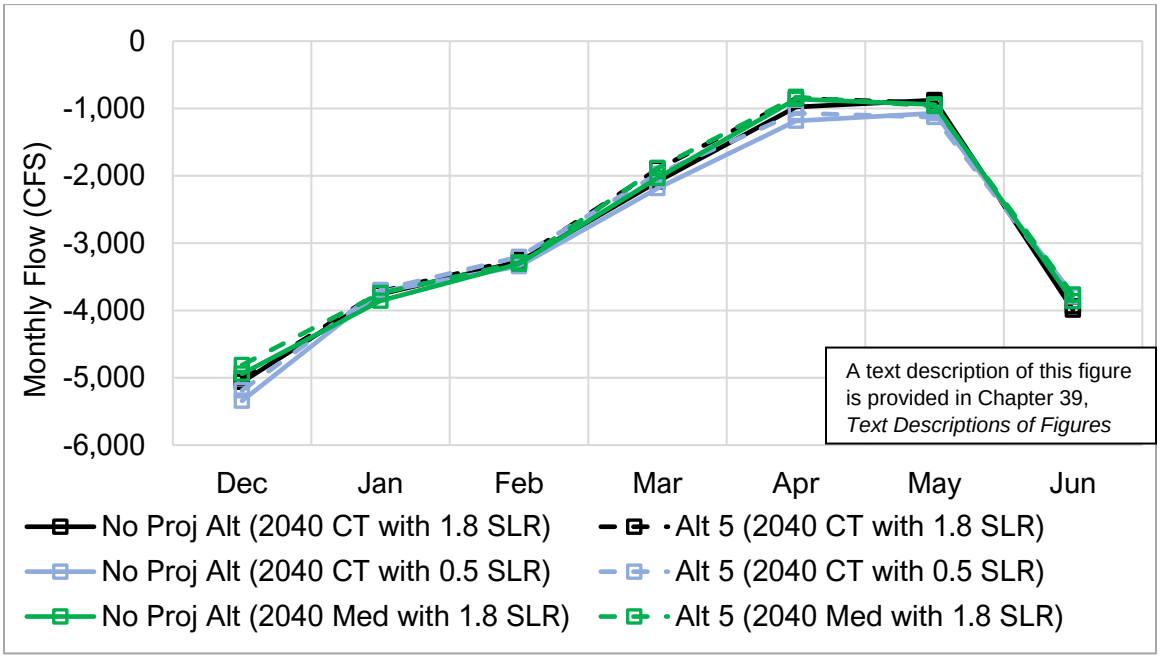


Figure 30A-25. Combined Old and Middle River (C_OMR014), Monthly Average Flow (cubic feet per second), No Project Alternative and Alternative 5 (2040)

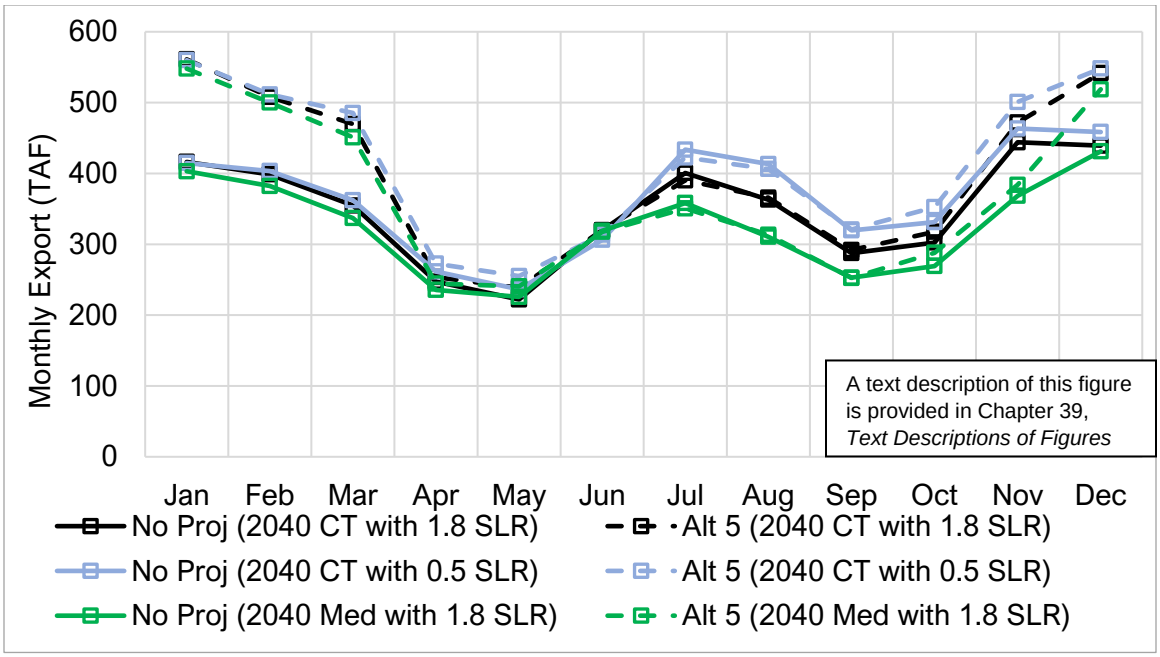


Figure 30A-26. Total Delta Exports (EXPORTACTUALTD + EXPORTACTUALIF), Monthly Average Exports (thousand acre-feet), No Project Alternative and Alternative 5 (2040)

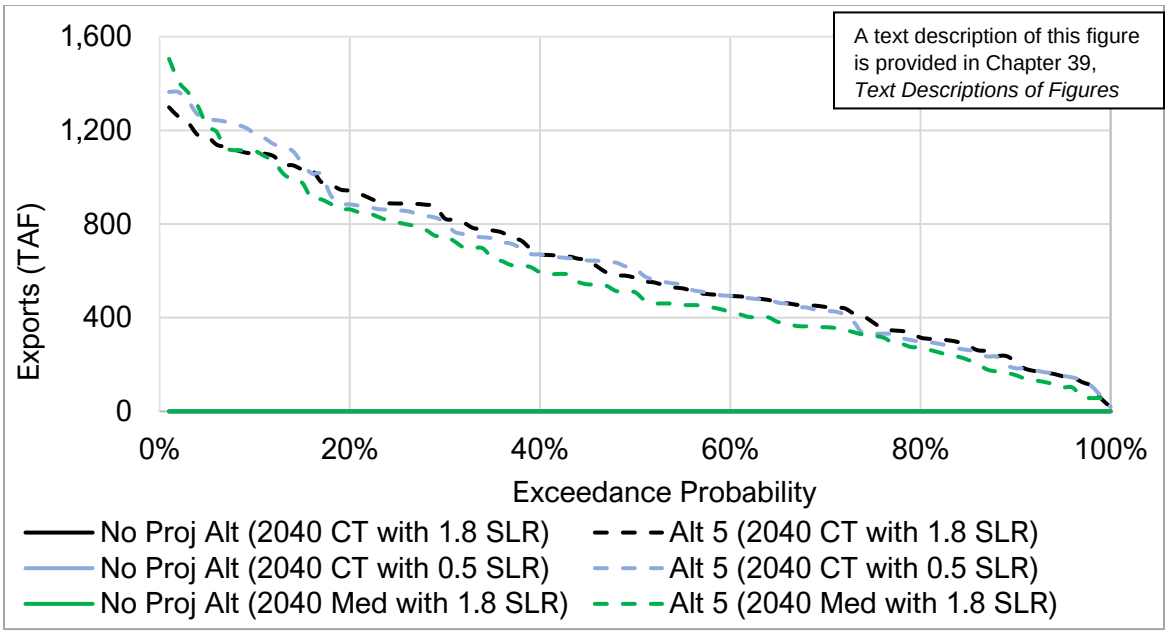


Figure 30A-27. North Delta Diversion Exports (EXPORTACTUALIF), Exceedance Probability for Annual Water Year Exports (thousand acre-feet), No Project Alternative and Alternative 5 (2040)

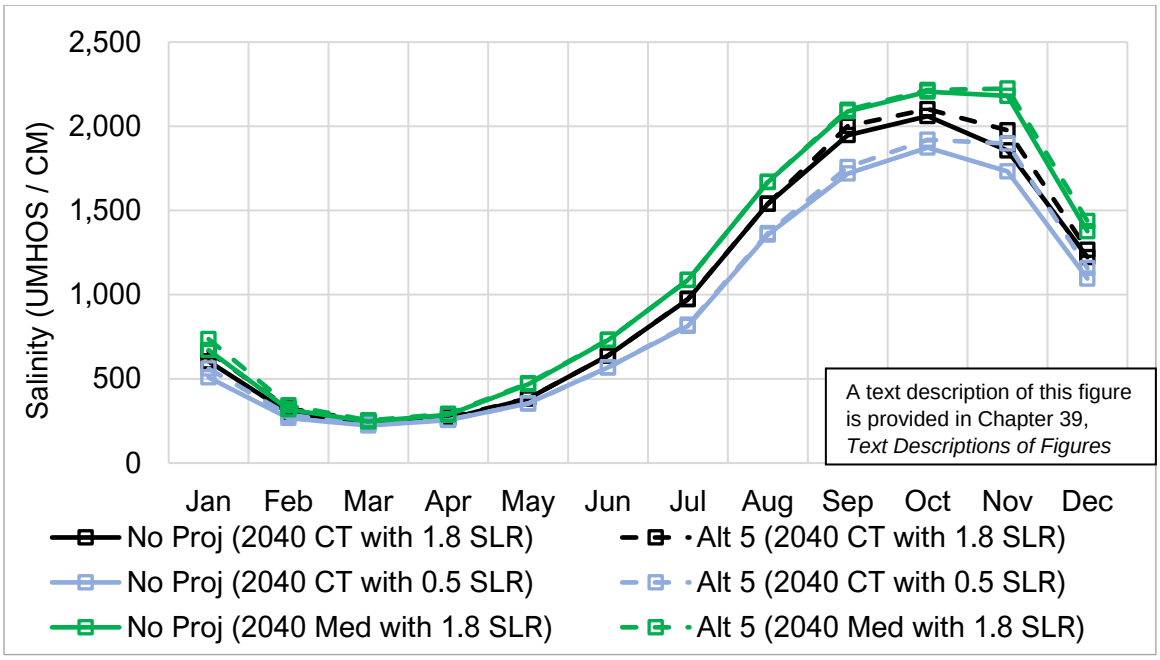


Figure 30A-28. Emmaton Salinity (EM_EC_MONTH), Monthly Average EC (UMHOS/CM), No Project Alternative and Alternative 5 (2040)

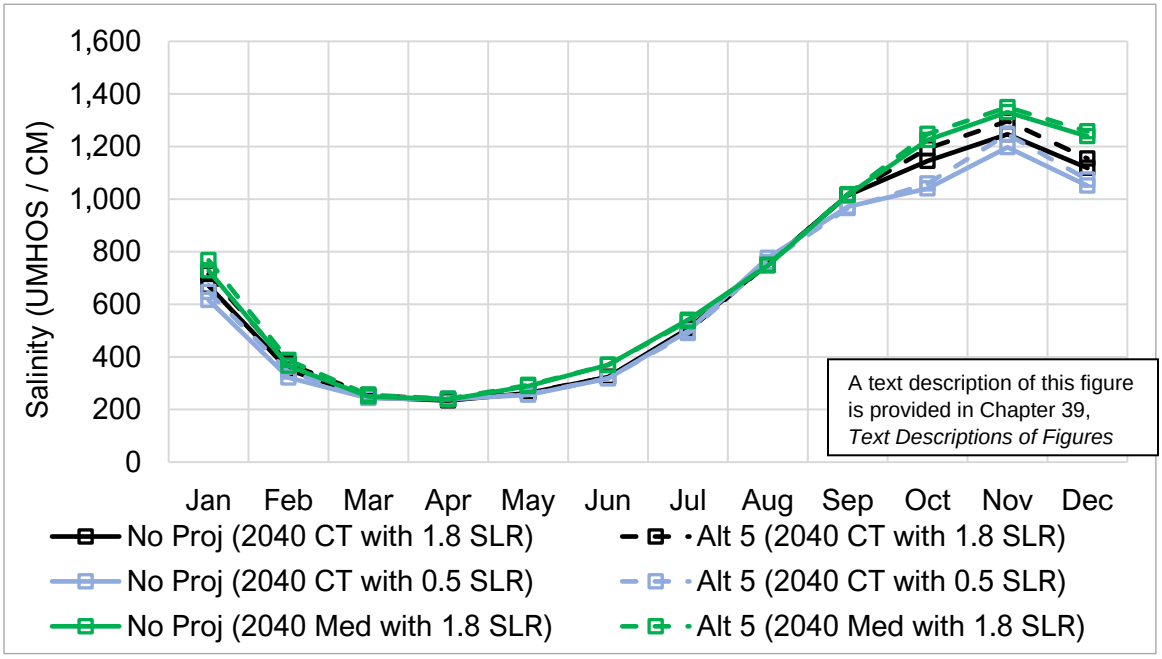


Figure 30A-29. Jersey Point Salinity (JP_EC_MONTH), Monthly Average EC (UMHOS/CM), No Project Alternative and Alternative 5 (2040)

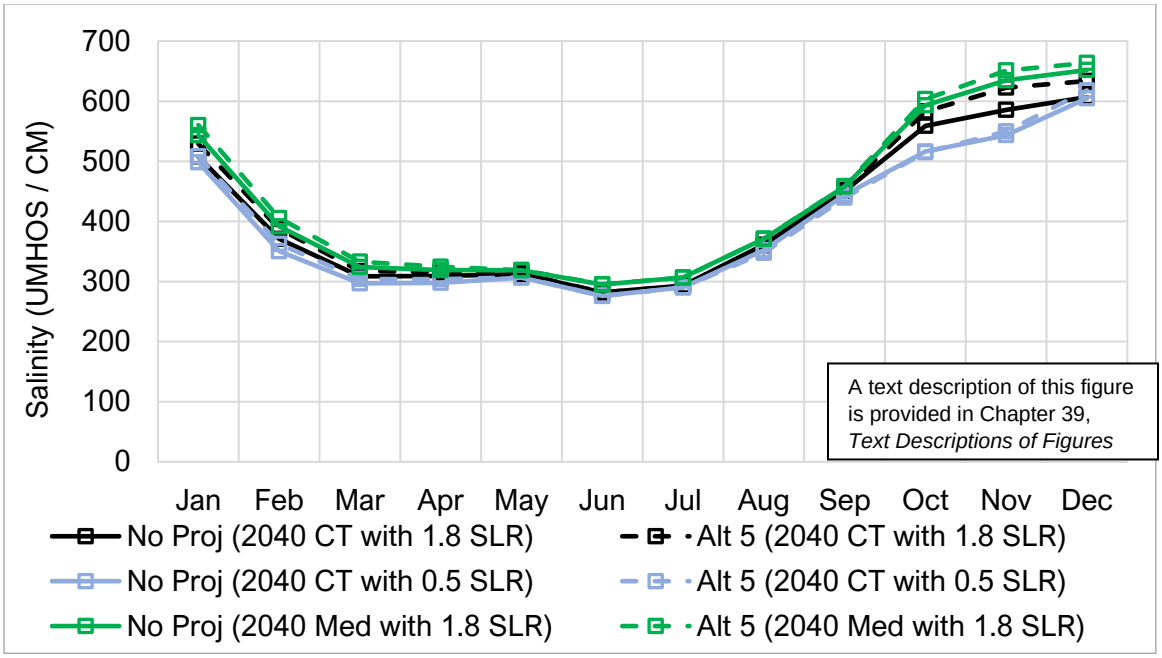


Figure 30A-30. Rock Slough Salinity (RS_EC_MONTH), Monthly Average EC (UMHOS/CM), No Project Alternative and Alternative 5 (2040)

30A.2 References Cited

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