APPENDIX F

Climate Change Sensitivity Analysis

OPERATIONS SENSITIVITY TO CLIMATE CHANGE PROJECTIONS

This appendix summarizes key findings from a sensitivity analysis of operational changes to existing conditions and Proposed Project under climate change and sea level rise conditions. The existing conditions and the Proposed Project were simulated using CalSim II under the current climate, Q5 (central tendency) climate centered around year 2030 with 15 cm of sea level rise, and Q5 climate centered around year 2030 with 45 cm of sea level rise. The Q5 climate projections were developed for Bay-Delta Conservation Plan/California WaterFix Analyses (ICF 2016). Differences between CMIP 3 and CMIP 5 model projections of changes to average annual temperature and precipitation are described in Attachment 1.

The selected climate change projection reflects the expected likely duration of the SWP permit. The two sea-level rise scenarios considered reflect the range of projected sea level values identified in the latest Ocean Protection Council Sea-Level Rise Guidance released in 2018. The operations results from these simulations were analyzed to understand the range of uncertainty in the incremental changes between the existing conditions and the Proposed Project. This section summarizes key CalSim II results for the existing conditions and the Proposed Project under the three climate and sea level rise scenarios.

Study Objectives

The CalSim II model was applied to evaluate the sensitivity of the existing conditions and Proposed Project to the future climate and sea level rise conditions listed above. The CalSim II model was used for quantifying the changes in river flows, delta channel flows, exports, and water deliveries. Key output parameters from this analysis are shown in Figures 1 through 9. Effects of climate change and sea level rise are summarized below.

Climate Sensitivity Analyses

The existing conditions and Proposed Project simulations described in the EIR were modeled under current or historic climate and sea level conditions. For this sensitivity analysis, the existing conditions and Proposed Project models were generated using the modified hydrologic inputs based on the projected runoff changes under Q5 climate scenarios at year 2030, and compared to a model run that used the historical hydrologic conditions (Q0). This Q5 scenario represents the ensemble-based change from the 20 to 30 climate projections that most closely reflect the change in annual temperature and precipitation (projections within the 25th to 75th percentile changes). The purpose of conducting these simulations is to help describe the sensitivity in projected CVP/SWP system operations with respect to climate change and sea level rise. The scenario with historical climate (Q0) did not include any sea level rise. The CalSim II simulations in this sensitivity analysis only differ in the hydrology inputs depending on the climate scenario considered and/or sea level rise effect. None of the other system parameters have been changed.

Figures 1 through 9 show the system responses for historical climate or Q0 (black lines), Q5 climate scenario with 15 cm of sea level rise (green lines), and Q5 climate scenario with 45 cm of sea level rise (purple lines). For each climate scenario, each dashed line represents the existing conditions and each solid line represents the Proposed Project. Each plot includes results from the CalSim II simulations for the existing conditions and the Proposed Project under the above climate scenarios. Several key observations can be made based on these simulations:

- Under all climate and sea level rise scenarios, Sacramento River flow at Freeport remains similar. Consistent with the current climate, the Proposed Project flow would be less than existing conditions flow in September and November as a result of changes delta smelt fall habitat outflow.
- Yolo Bypass flows are higher during December through March under the future climate projections considered in this analysis. However, flows under the Proposed Project and existing conditions are nearly identical when comparing to the conditions with the same climate and sea level rise assumptions.
- Incremental changes to flows at Georgiana Slough and Delta Cross Channel (DCC) are similar under all climate and sea level rise conditions. These flows reflect the changes in Sacramento River flow at Freeport due to climate change and sea level rise influence on tidal conditions in the estuary. Georgiana Slough flow under Proposed Project is consistently lower in September and November similar to the Sacramento River flow at Freeport. Whereas, DCC flow under Proposed Project is consistently greater in September and October as a result of reduction in likely closure of DCC gates associated with scour concerns.
- Incremental changes in QWEST flows due to the Proposed Project operations are consistent across all climate change scenarios evaluated. Proposed Project result in lower Qwest flows in April and May, and in fall months, with slightly greater flows in winter and summer months under all climate and sea level rise scenarios.
- Incremental changes in Delta outflow due to the Proposed Project under all climate and sea level scenarios are consistent with current climate and sea level scenario. Under all climate and sea level rise scenarios, Delta outflow is lower in April, May, September and November under the Proposed Project as compared to the existing conditions.
- Old and Middle river flows are reflective of the south Delta export changes. The incremental changes during December – June are consistent across all climate and sea level scenarios.
- Modeled exports are most sensitive to the climate and sea level rise scenarios in the summer and fall reflecting the changes in available water supply for south-of-Delta SWP and CVP deliveries. With increasing warming and sea level rise, exports under existing conditions and Proposed Project decrease. Exports in the months that are significantly constrained (February through June) are not as sensitive to climate change and sea level rise.

Overall the relative changes due to the Proposed Project as compared to the existing conditions under the future climate and sea level rise scenarios are similar to that described under the current climate scenario.

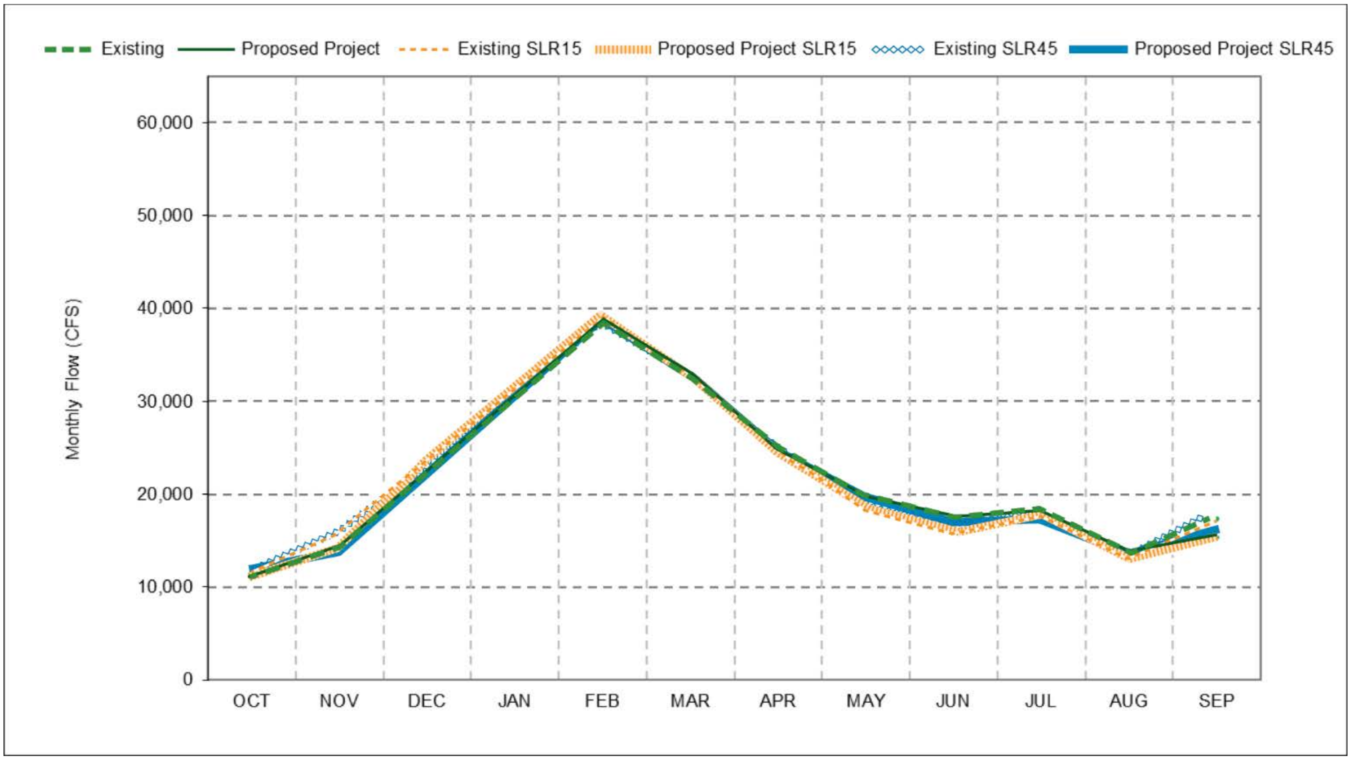

Figure F-1. Sacramento River at Freeport Monthly Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

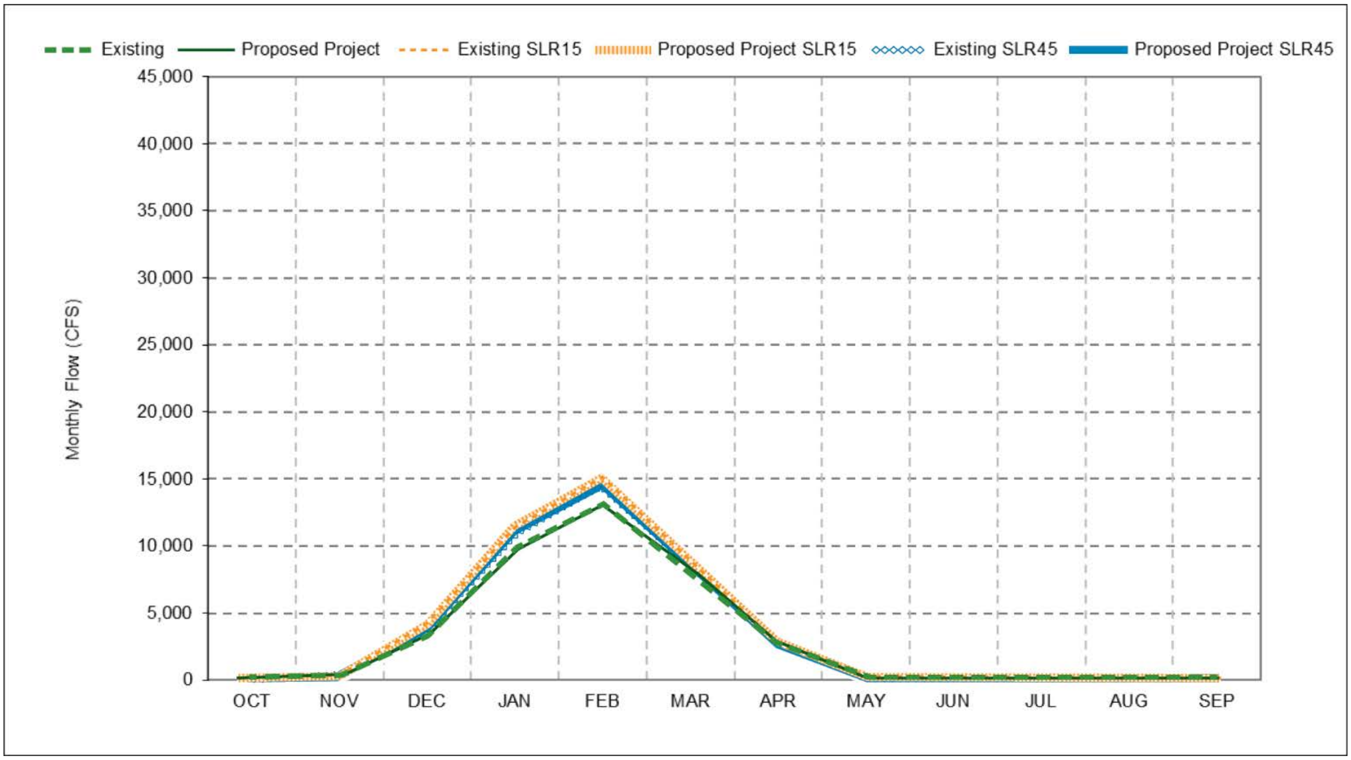

Figure F-2. Monthly Yolo Bypass Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

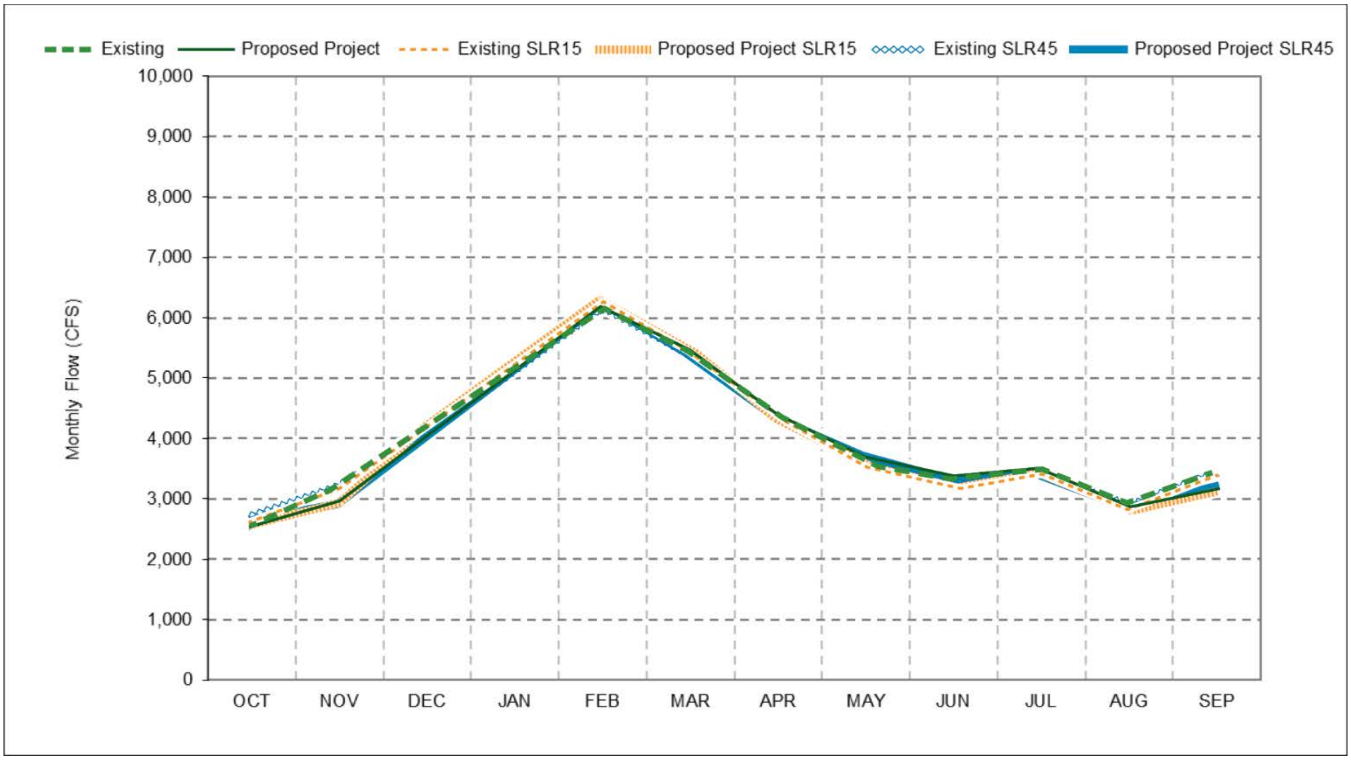

Figure F-3. Monthly Georgiana Slough Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

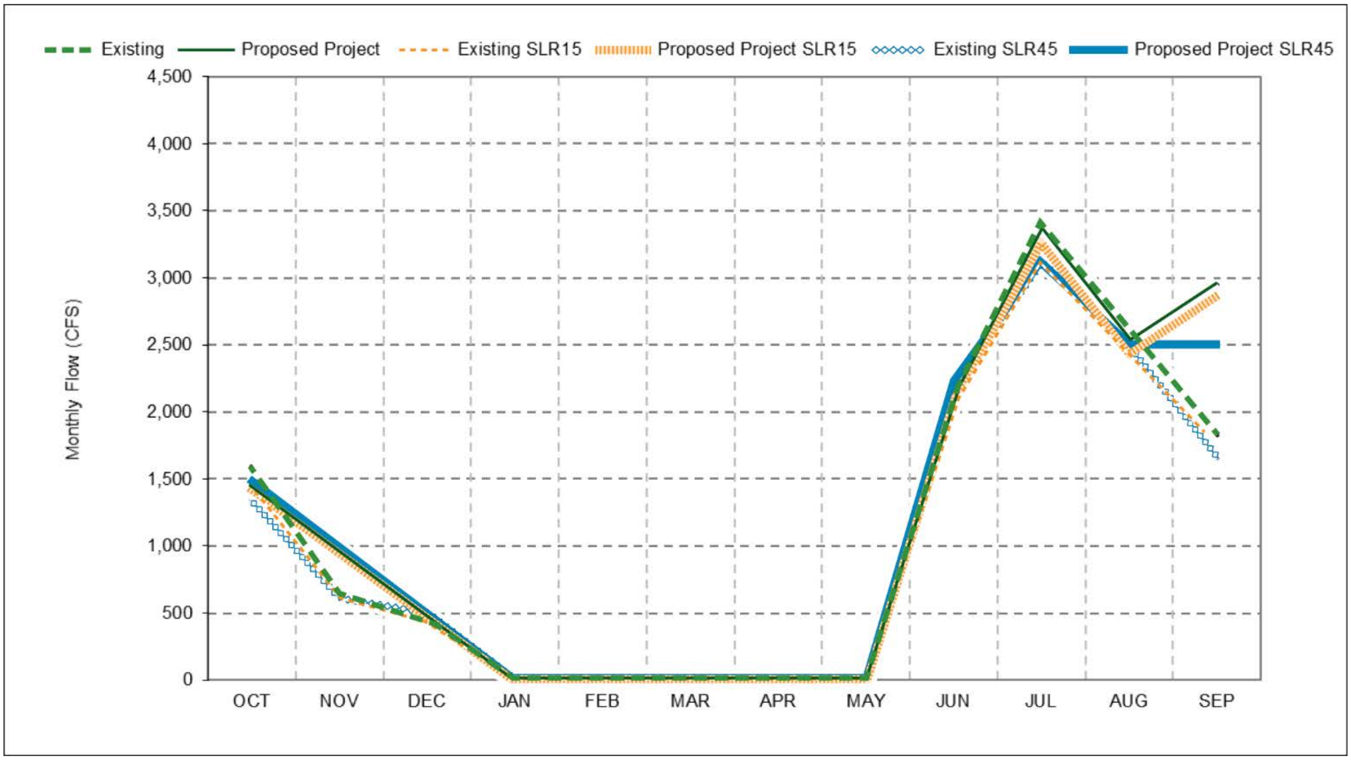

Figure F-4. Monthly DCC Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

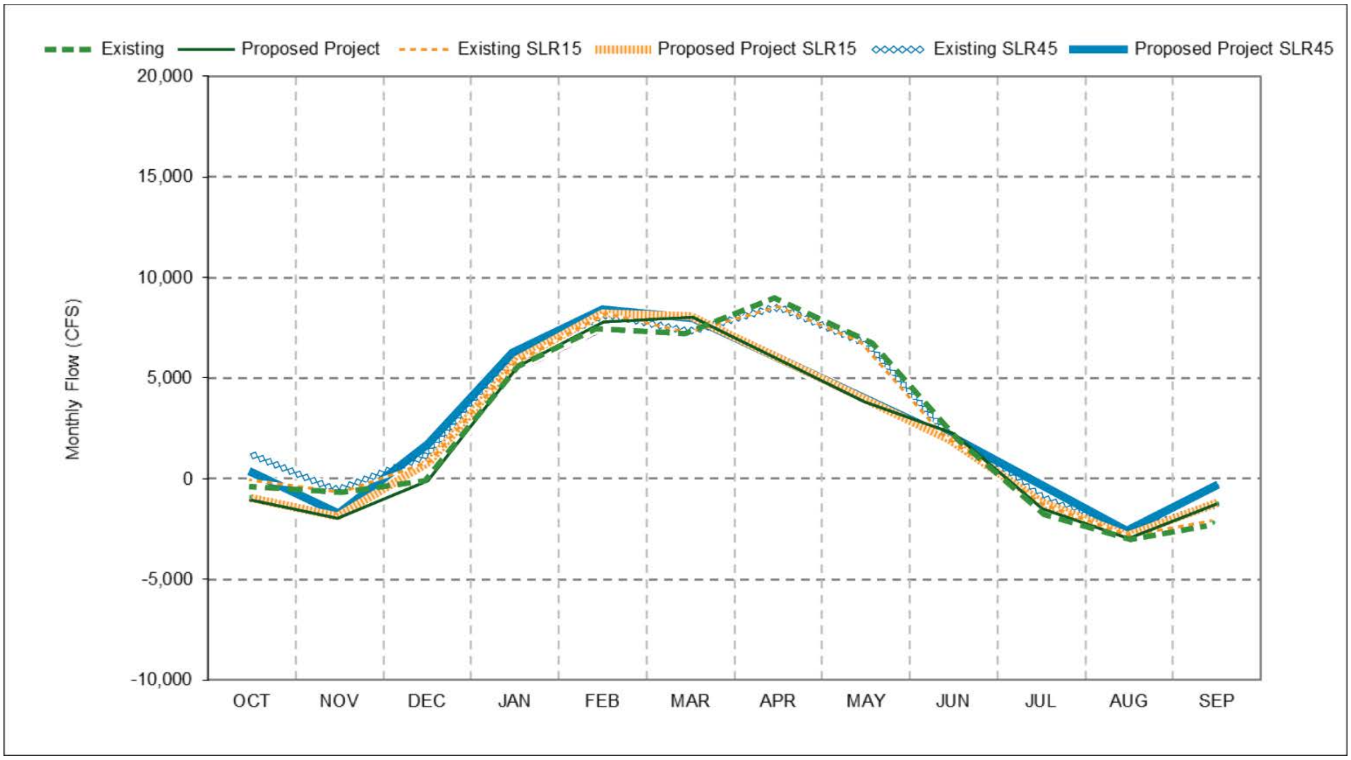

Figure F-5. Monthly Qwest Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

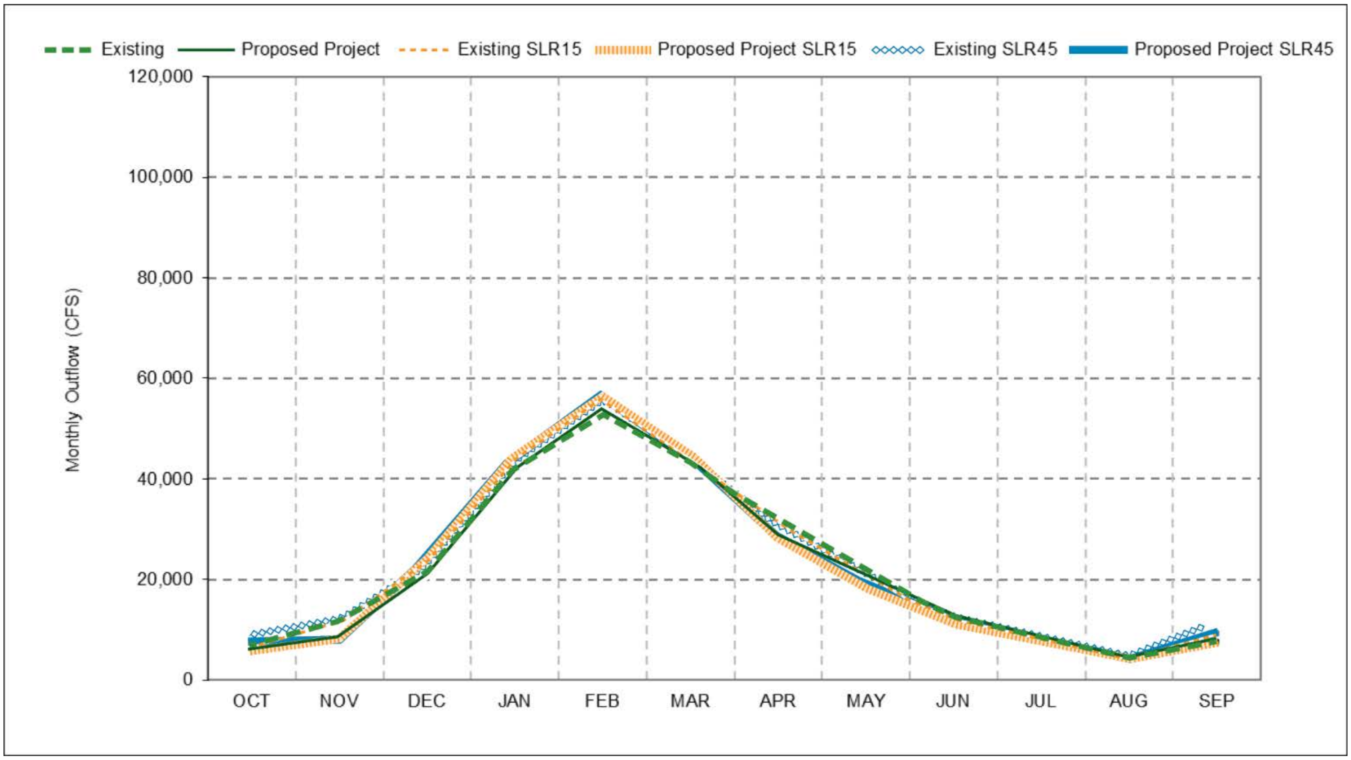

Figure F-6. Monthly Delta Outflow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

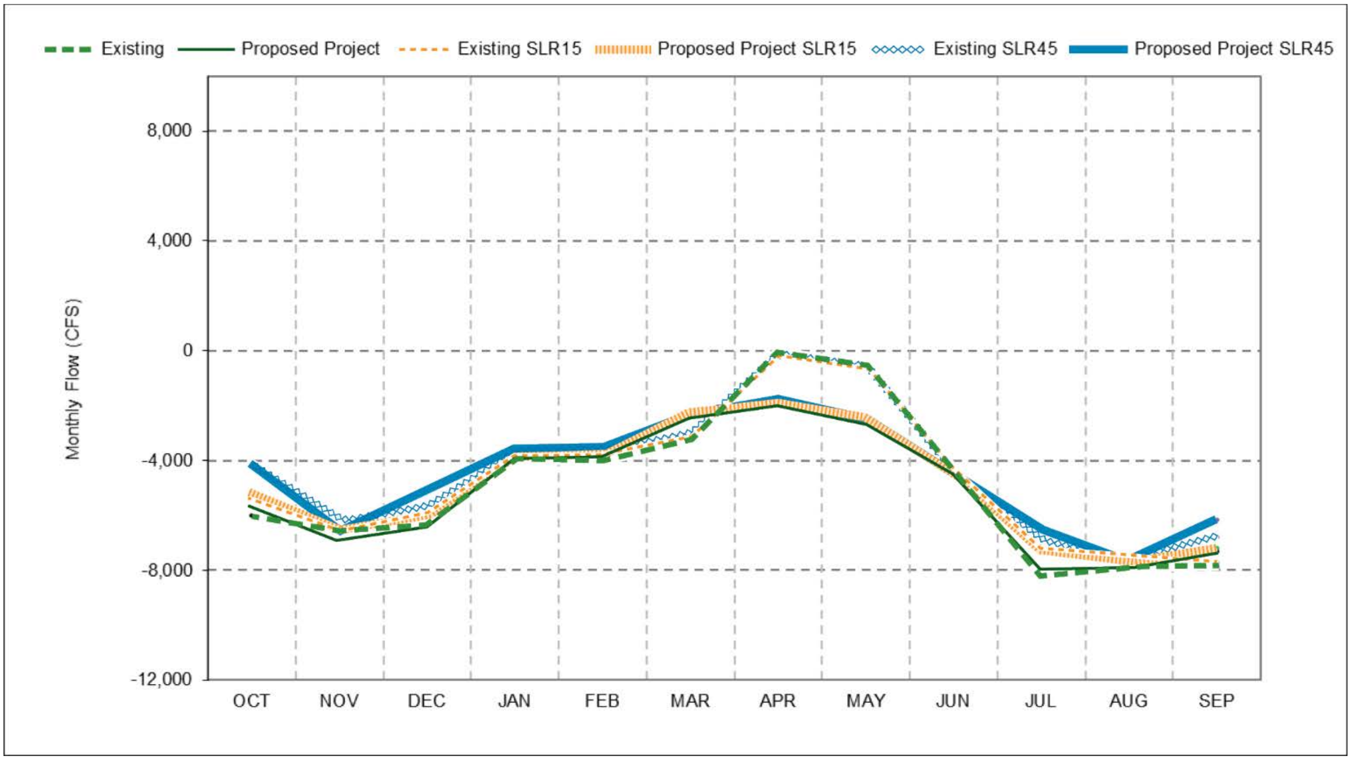

Figure F-7. Combined Old and Middle River Monthly Flow for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

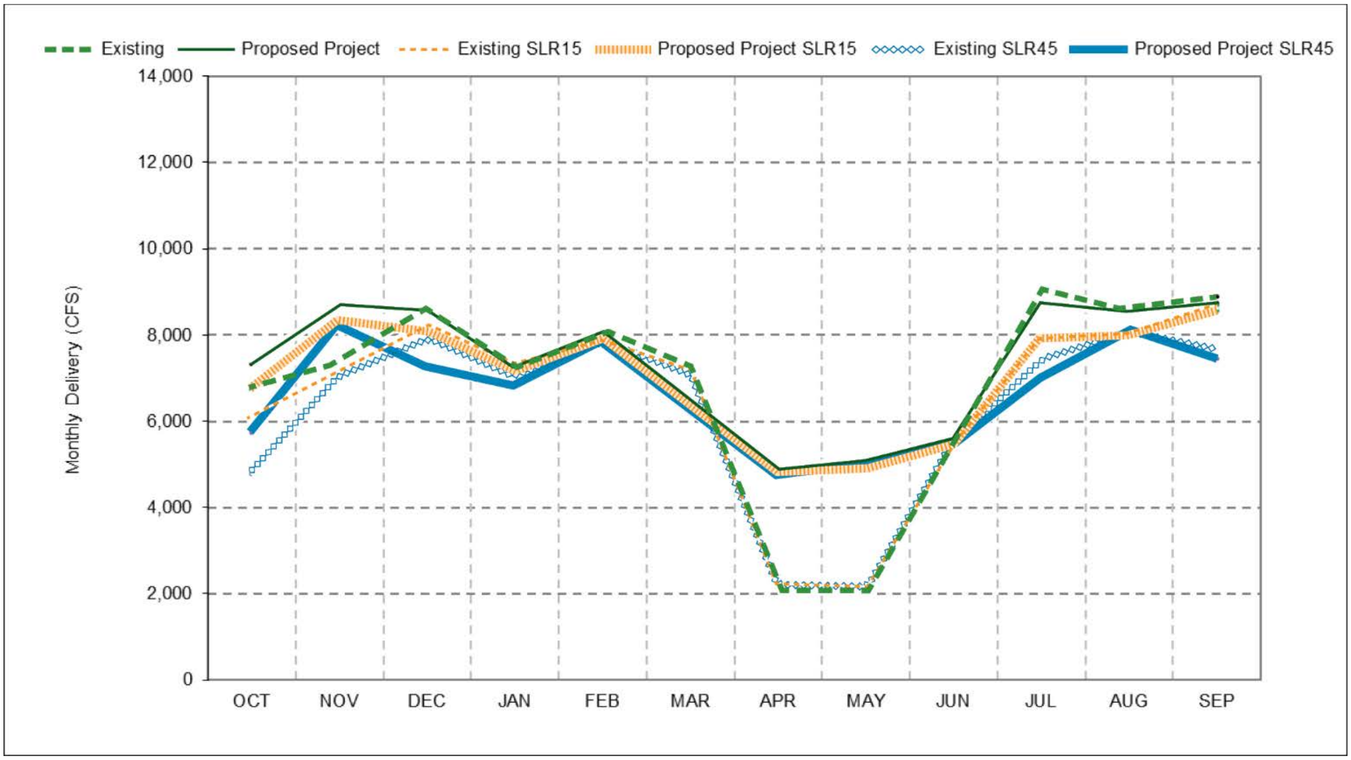

Figure F-8. Monthly Delta Exports for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

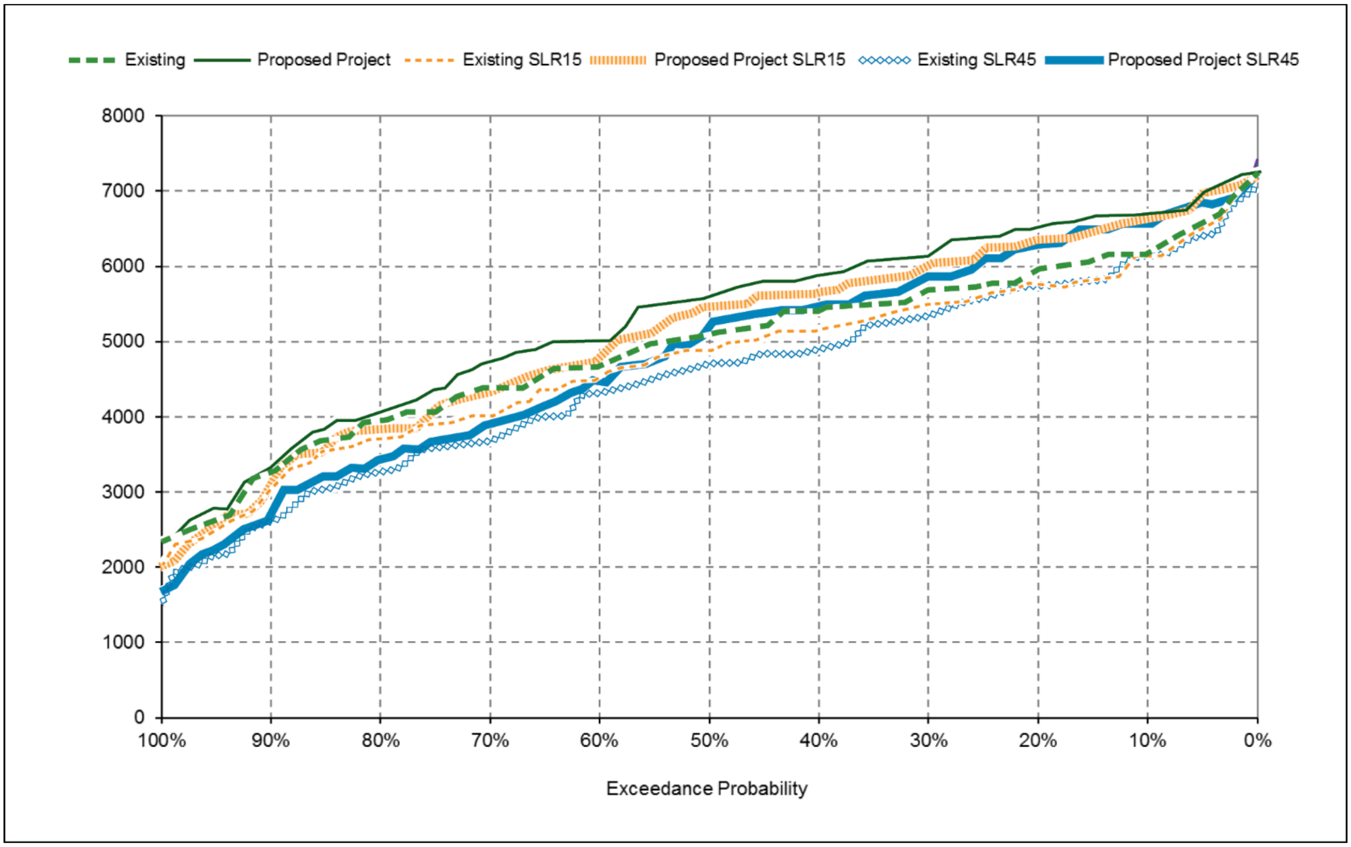

Figure F-9. Annual Delta Exports for the existing conditions and Proposed Project under Q0, Q5 SLR 15 cm, and Q5 SLR 45 cm climate scenarios and sea level rise scenarios at Year 2030

References

ICF International. 2016. Biological Assessment for the California WaterFix. Appendix 5A CalSim II Modeling and Results, July 2016.

Attachment 1

Date: Oct 9, 2019

To: Erik Reyes, Supervising Engineer, Central Valley Modeling

From: Romain Maendly, Senior Engineer, Climate Change Program
Wyatt Arnold, Engineer, Climate Change Program

Subject: ***Climate Change Projection Comparison between CMIP 3 and CMIP 5 for the Incidental Take Permit***

Objectives

The purpose of this memorandum is to present a high-level comparison between a subset of climate change projections contained in the Coupled Model Intercomparison Project 3 (CMIP3) and 5 (CMIP3) archives for a thirty-year period centered on 2030 and for the geographic area covering watersheds that drain into the Sacramento-San Joaquin Delta. The comparison will focus on two metrics – average annual temperature and precipitation change – and whether using one archive over the other would have substantial implications for determining social and environmental impacts related to the Incidental Take Permit (ITP) of the State Water Project.

Findings

Due to the short permitting timeline of the ITP (10 years), differences between CMIP3 and CMIP5 model projections of changes in average annual temperature and precipitation are found to be relatively small, suggesting a non-substantial outcome related to the permitting process. Furthermore, in accordance with step 1 screening criteria under DWR Phase II Climate Change Analysis Guidance, this study would not be required to complete climate change analysis due to the ITP short implementation horizon.

Introduction

The ITP for the State Water Project requires the California Department of Water Resources to consider climate change effects relevant over the permit timeframe where climate change refers to any significant change in average climatic conditions (such as mean temperature, precipitation, or wind) or variability (such as seasonality or storm frequency) lasting for an extended period (decades or longer).

In an earlier analysis, climate change was considered in the environmental effects analysis on how it may affect the Project’s impacts on resources, i.e., how the resources that are managed are likely to change in response to changing climate conditions and how that modifies or otherwise affects management actions and the impacts of those actions on the resource (California Department of Water Resources 2016). At the time, projections from CMIP3 for temperature and precipitation were used and showed a non-substantial effect of the project under future conditions. However, newer projections generated from CMIP5 are now available. This memorandum explores differences in average annual temperature and precipitation between CMIP3 and CMIP5 projections for a thirty-year period centered on 2030 and determines whether these differences could have a substantial impact on the ITP analysis.

CMIP3

CMIP3 is the model ensemble for the IPCC's Fourth Assessment Report and was released in 2010. CMIP3 is used to generate projections of future climate conditions across the globe. CMIP3 uses four Special Report on Emission Scenarios (SRES) each of which represents a level of greenhouse gas emission trajectories. In total there are 16 general circulation models (GCM) in the CMIP3 archive which use the SRES to represent potential future conditions related to temperature and precipitation changes.

Current climate change analysis used in ITP

The current climate change ITP analysis uses a subset of CMIP3 which includes 16 GCM with three SRES emission scenarios (A2, A1b, and B1) for a total of 112 future climate projections[1] that have been subsequently bias-corrected and statistically downscaled to 1/8th degree (~12km) resolution. The ensemble of 112 projections is broken into quadrants representing (Q1) drier, less warming, (Q2) drier, more warming, (Q3) wetter, more warming, and (Q4) wetter, less warming than the ensemble median. A fifth region (Q5) located in the inner-quartiles (25th to 75th percentile) of the ensemble is used in the ITP analysis for a thirty-year period centered on 2030. The Q5 scenario reflects a composite projection from the individual projections that are closest to the median change, and thus reflect the "consensus" of projections. Figure 1 shows an example of the downscaled ensemble of climate projections and sub-ensembles used for deriving the quadrants. The following steps were applied to incorporate an expended time series which allow the use of long term observed records with the climate change signal from Q5:

1. Extract a 30-year slice of downscaled climate projections based on the ensemble subset for the quadrant of interest and centered on the year of investigation (i.e. 2025 or 2060)
2. For each calendar month (i.e. January) of the future period, determine the statistical properties (cumulative distribution function, CDF) of temperature and precipitation at each grid cell
3. For each calendar month of the historical period (1971-2000 in our case), determine the statistical properties (CDFs) of temperature and precipitation at each grid cell
4. Develop quantile maps between the historic observed CDFs and the future downscaled climate CDFs, such that the entire probability distribution (including means, variance, skew, etc.) at the monthly scale is transformed to reflect the climate scenario
5. Using the quantile maps, redevelop a monthly time series of temperature and precipitation over the observed period (1915 -2003) that incorporates the climate shift of the future period
6. Convert monthly time series to a daily time series by scaling monthly values to daily sequence found in the observed record

The result of the quantile mapping approach is a daily time series of temperature and precipitation that has the range of variability observed in the historical record but also contains the shift in climate

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[1] Some GCM are run with multiple initial conditions resulting in multiple projections for the same GCM and SRES scenario.

properties (both mean and expanded variability) found in the downscaled climate projection using CMIP3.

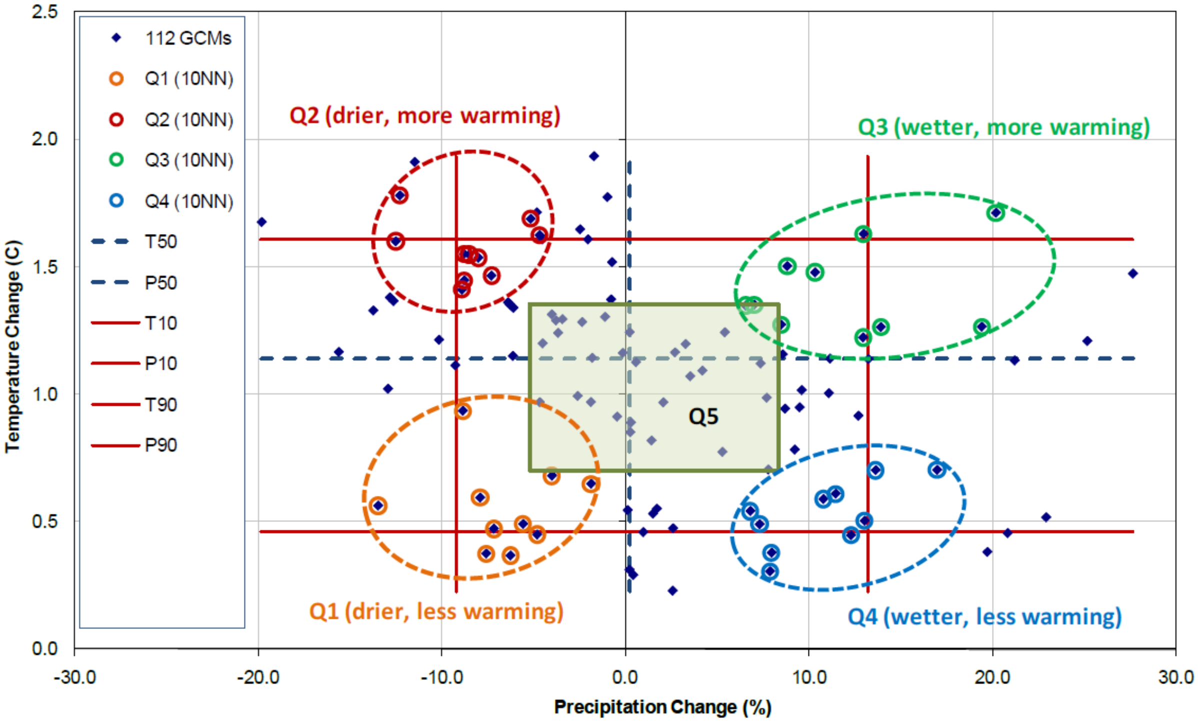

Figure 1. Example downscaled climate projections and sub-ensembles used for deriving climate scenarios (Q1-Q5). The Q5 scenario is bounded by the 25th and 75th percentile joint temperature-precipitation change. Scenarios Q1-Q4 are selected to reflect the results of the 10 projections nearest each of the 10th and 90th joint temperature-precipitation change bounds

CMIP5

CMIP5 is the model ensemble for the IPCC’s fifth assessment report and was released in 2013. Similar to CMIP3, CMIP5 is used to generate projections of future climate conditions across the globe. CMIP5 uses four Representative Concentration Pathway (RCP-2.6, -4.5, -6.0 and -8.5) which supersede the SRES and represent greenhouse gas concentration rather than emissions. In overall there are 36 general circulation models (GCM) that are using these scenarios to represent potential future conditions related to temperature and precipitation changes.

Comparison of CMIP5 and CMIP3 Model Projections

Knutti et al. (2012) compared the CMIP3 and CMIP5 model archives and determined that CMIP5 projections are largely consistent with CMIP3. They conclude that differences in global temperature projections are largely attributable to the different greenhouse gas emissions scenarios used in the IPCC AR assessments.

Figures 2 and 3 show the average annual precipitation and annual average temperature anomalies of CMIP5[2] and CMIP3 archives for the region contributing flow to the Sacramento-San Joaquin Delta (see

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[2] In this comparison analysis, RCP’s 2.6 and 6.0 were not used from the CMIP5 archive. RCP 2.6 scenario is a relatively low greenhouse-gas emission scenario, while RCP 4.5, RCP 6.0, and RCP 8.5 appear as reasonable choices to represent low and high emissions scenarios, given current rates of global fossil fuel consumption and economic development (CCTAG 2015).

Figure 4). The darker lines are mean anomaly across all models in CMIP3 (orange) and CMIP5 (blue) archives. Bars extend to the 95th and 5th percentile model anomalies. Anomaly is calculated using the baseline historical model simulation period 1950-2005.

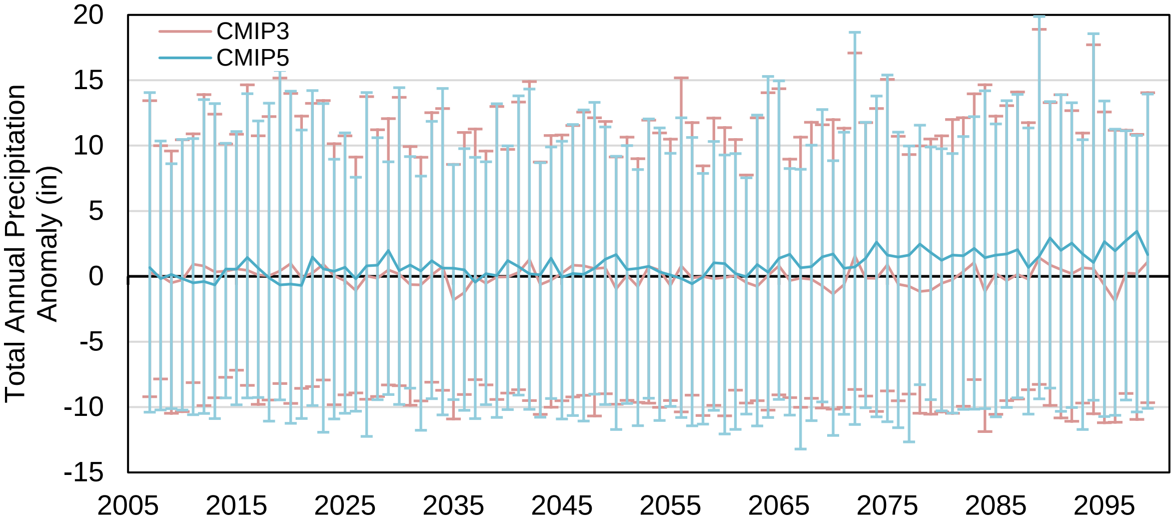

Figure 2. Total Annual Precipitation Anomaly of CMIP5 and CMIP3. Darker lines are mean annual anomaly of the CMIP3 (orange) and CMIP5 (blue) archives. Bars extend to 95th and 5th percentile model anomalies. Anomaly is calculated from baseline1950-2006 historical model simulation period

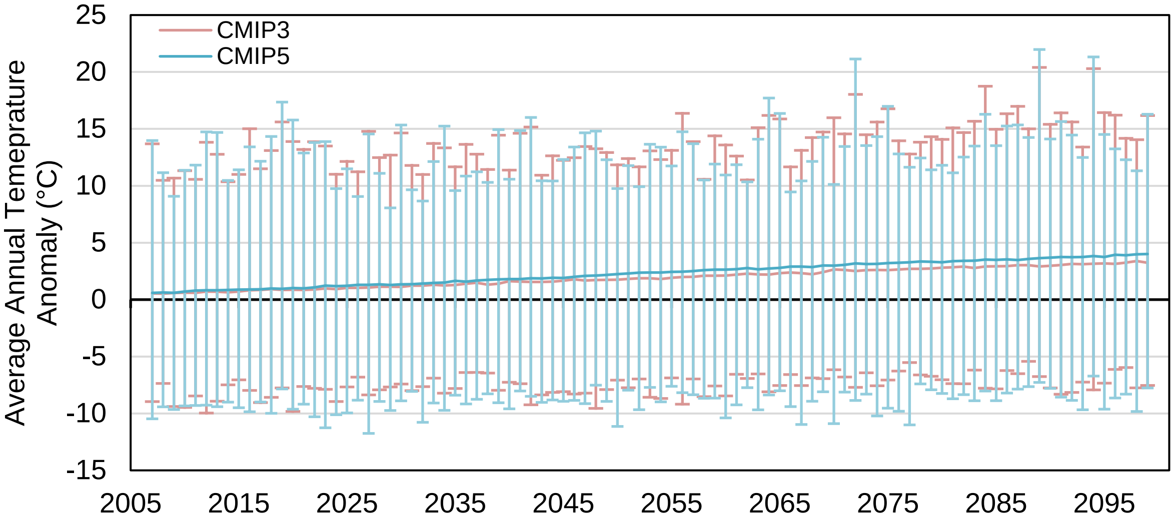

Figure 3. Average Annual Temperature Anomaly of CMIP5 and CMIP3. Darker lines are mean annual anomaly of the CMIP3 (orange) and CMIP5 (blue) archives. Bars extend to 95th and 5th percentile model anomalies. Anomaly is calculated from baseline 1950-2006 historical model simulation period

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RCP 6.0 was also not included because there are fewer model run for this specific emission scenarios compared to RCP 4.5 and 8.5.

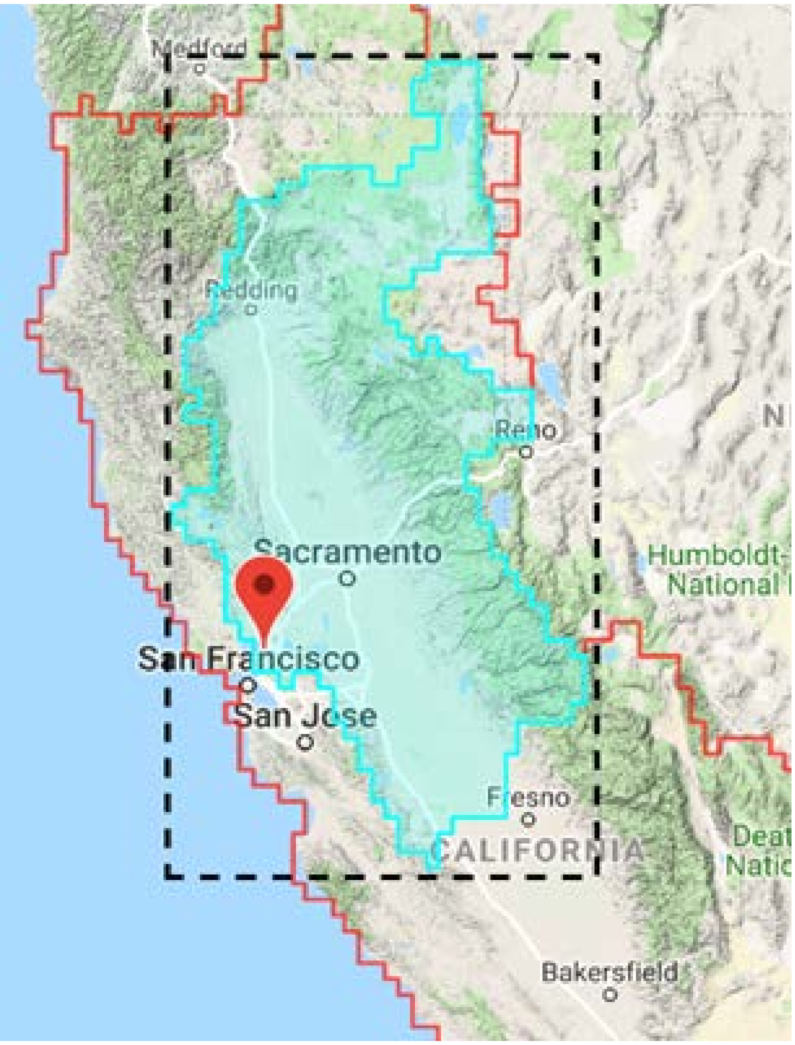

Figure 4: Geographic extent of the region contributing flow to the Sacramento San-Joaquin Delta (polygon highlighted in blue). A bounding box (rectangle is drawn with a dotted line) indicates the area over which GCM grids from the CMIP3 and CMIP5 archives were spatially averaged

An increasing trend in the average CMIP5 archive annual precipitation anomaly is seen in Figure 2. The CMIP3 archive has no such discernible trend. However, the difference in the average precipitation anomaly between CMIP5 and CMIP3 is difficult to distinguish until mid-century. Similar observations can be made for the annual average temperature anomalies. In the long term, the increasing trend in average CMIP5 archive annual average temperature than CMIP3 as shown in Figure 3. However, the difference between CMIP5 and CMIP3 for years up until 2045 is difficult to distinguish.

Tables 1 and 2 show the average annual precipitation and temperature anomaly change for a thirty-year period centered on 2030 from the baseline historical model simulation period 1950-2005. The tables compare the max, min, 25th and 75th percentile, median, and average values under CMIP3 and CMIP5. Table 1 shows that the average annual precipitation change is greater CMIP5 than CMIP3 for the average, median, 25 percentile and 75 percentile values, yet less or equal to 3%.

Table 1. Change in the average annual precipitation anomaly for a thirty-year period centered on 2030 compared to the baseline 1950-2005 historical model period

Annual Precipitation Anomaly Change (%) at Year 2030	Annual Precipitation Anomaly Change (%) at Year 2030 CMIP3	Annual Precipitation Anomaly Change (%) at Year 2030 CMIP5
Average	0%	2%
Median	-2%	1%
25%	-6%	-3%
75%	5%	7%
Min	-14%	-16%
Max	28%	20%

Table 2 shows that the annual average temperature change is greater in CMIP5 than CMIP3 yet that the difference is relatively small (≤0.3°C).

Table 2. Change in the annual average temperature anomaly for a thirty-year period centered on 2030 compared to the baseline 1950-2005 historical model period

Annual Average Temperature Anomaly Change (°C) at Year 2030	Annual Average Temperature Anomaly Change (°C) at Year 2030 CMIP3	Annual Average Temperature Anomaly Change (°C) at Year 2030 CMIPS
Average	1.18	1.39
Median	1.22	1.40
25%	0.83	1.14
75%	1.46	1.67
Min	0.41	0.63
Max	2.02	2.17

Climate Action Plan, Phase II: Climate Change Analysis Guidance

In 2018, DWR published a climate change analysis guidance document to guide DWR in its decision making and assist DWR managers as they incorporate climate change analysis into their planning for DWR activities, such as strategic planning documents, investment decisions, risk assessments, and infrastructure development.

In accordance with step 1 screening criteria under DWR Phase II Climate Change Analysis Guidance, this study would not be required to complete climate change analysis due to the ITP short implementation horizon.

Summary and Conclusion

Based on the differences observed between CMIP3 and CMIP5 average and median anomalies for temperature and precipitation, the use of either archive does not suggest substantial differences in the outcome of the current ITP climate change analysis were a Q5 CMIP5-based ensemble to be used. In general, the slight difference in the CMIP5 precipitation signal would most likely lead to an improvement in the performance objective of the study.

References

California Department of Water Resources. 2016. Bay Delta Conservation Plan. Chapter 29.

California Department of Water Resources. 2018. Climate Action Plan, Phase II: Climate Change Analysis Guidance.

Knutti, Reto, and Jan Sedláček. 2012. Robustness and Uncertainties in the New CMIP5 Climate Model Projections." Nature Climate Change 3 (October:369).