Long-Term Operation – Final Environmental Impact Statement

Appendix F – Modeling

November 2024

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Figures

Appendix F Modeling

F.1 Introduction

The LTO project team has developed model simulations to support analysis of the Central Valley Project (CVP) and State Water Project (SWP) long-term operations as part of reviewing proposed operations under the LTO. This appendix describes the overall analytical framework and contains descriptions of the key analytical tools and approaches used.

The assumptions used for each alternative and each model listed above are documented in the following sections:

- Appendix F, *Modeling*, Section F.1-1, *Modeling Methodology*
- Appendix F, *Modeling*, Section F.1-2, *Callouts Tables*
- Appendix F, *Modeling*, Section F.1-3, *CalSim 3 Contracts*

Additional documentation of climate change, modeled representation of Old and Middle River actions, and model updates are documented in the following attachments:

- Appendix F, *Modeling*, Attachment F.1-1, *Climate Change*
- Appendix F, *Modeling*, Attachment F.1-2, *Modeled Representation of Old and Middle River Actions*
- Appendix F, Numeric Modeling, Attachment F.1-3, *Model Updates*

CalSim 3, DSM2 and HEC-5Q model results are documented in the following attachments:

- Appendix F, *Modeling*, Attachment F.2-1, *CalSim 3 Storage and Elevation*
- Appendix F, *Modeling*, Attachment F.2-2, *CalSim 3 Flow*
- Appendix F, *Modeling*, Attachment F.2-3, *CalSim 3 Diversions*
- Appendix F, *Modeling*, Attachment F.2-4, *CalSim 3 Water Supply*
- Appendix F, *Modeling*, Attachment F.2-5, *DSM2 Salinity*
- Appendix F, *Modeling*, Attachment F.2-6, *DSM2 X2*
- Appendix F, *Modeling*, Attachment F.2-7, *DSM2 Chloride*
- Appendix F, Modeling, Attachment F.2-8, *DSM2 Compliance*
- Appendix F, *Modeling*, Attachment F.2-11, *HEC-5Q*

Note that Attachments F.2-9 through F.2-10 are intentionally not included in this document.

Climate Change Sensitivity Analyses are documented in the following attachments:

- Appendix F, *Modeling*, Section F.2-1, *Climate Sensitivity, No Action Alternative*
- Appendix F, *Modeling*, Section F.2-2, *Climate Sensitivity, Alternative 1*
- Appendix F, *Modeling*, Section F.2-3, *Climate Sensitivity, Alternative 2v1 without TUCP*
- Appendix F, *Modeling*, Section F.2-4, *Climate Sensitivity, Alternative 2v1 with TUCP*
- Appendix F, *Modeling*, Section F.2-5, *Climate Sensitivity, Alternative 2v3*
- Appendix F, *Modeling*, Section F.2-6, *Climate Sensitivity, Alternative 2v2*
- Appendix F, *Modeling*, Section F.2-7, *Climate Sensitivity, Alternative 3*
- Appendix F, *Modeling*, Section F.2-8, *Climate Sensitivity, Alternative 4*

June Delta Outflow Action Sensitivity Analysis is documented in the following attachments:

- Appendix F, *Modeling*, Section F, *June Delta Outflow Action Sensitivity Analysis*

F.2 Linkage Schematic

A suite of modeling tools was developed to support the quantitative assessment of the LTO. A framework of integrated analyses including hydrologic, operations, hydrodynamics, water quality, and fisheries analyses is required to provide information for the quantitative assessment of several resources, such as water supply, surface water, groundwater, and aquatic resources.

The alternatives include operational changes in the coordinated operation of the CVP and SWP. Both these operational changes and other external factors such as climate and sea-level changes influence the future conditions of reservoir storage, river flow, Delta flows, exports, water temperature, and water quality. Evaluation of these conditions is the primary focus of the physically based modeling analyses.

Figure F-1, the model linkage schematic shows the analytical tools applied in these assessments and the relationship between these tools. Each model included in Figure F-1 provides information to the subsequent model in order to provide various results to support the impact analyses.

Changes to the historical hydrology related to the future climate are applied in the CalSim model and combined with the assumed operations for each alternative. The CalSim model simulates the operation of the major CVP and SWP facilities in the Central Valley and generates estimates of river flows, exports, reservoir storage, deliveries, and other parameters. Agricultural and municipal and industrial deliveries resulting from CalSim are used for assessment of changes in groundwater resources and in agricultural, municipal, and regional economics. Changes in land use reported by the agricultural economics model are subsequently used to assess changes in air quality.

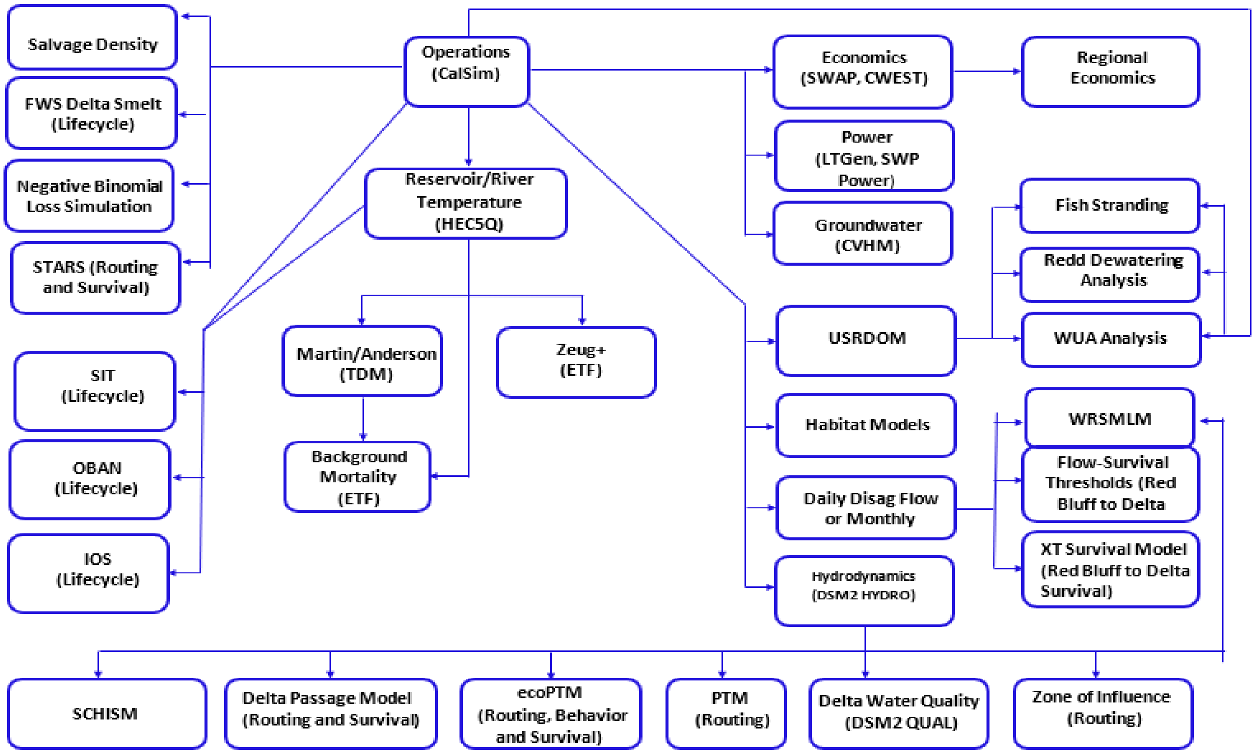

Figure F-1. Model Linkage Schematic

The Delta boundary flows and exports from CalSim 3 are used to drive the DSM2 Delta hydrodynamic and water quality models for estimating tidally based flows, stage, velocity, and salt transport within the estuary. DSM2 water quality and volumetric fingerprinting results are used to assess changes in concentrations of selenium and methylmercury in Delta waters.

Power generation models use CalSim 3 reservoir levels and releases to estimate power use and generation capability of the CVP.

Temperature models for the primary river systems use the CalSim 3 reservoir storage, reservoir releases, river flows, and meteorological conditions to estimate reservoir and river temperatures under each scenario.

Results from these temperature models are further used as an input to fisheries models (e.g., SalMod, Reclamation Egg Mortality Model, and IOS) to assess changes in fisheries habitat due to flow and temperature. CalSim 3 and DSM2 results are also used for fisheries models (IOS, DPM) or aquatic species survival/habitat relationships developed based on peer-reviewed scientific publications. The results from this suite of physically based models are used to describe the effects of each individual scenario.

A brief description of the hydrologic and hydrodynamic models is provided below. All other subsequent models presented int the Model Linkage Schematic are described in detail in the respective appendix where their results are used.

F.3 Model Description

F.3.1 Climate Change and Sea Level Rise

The LTO project team has developed model simulations to support analysis of the CVP and SWP long-term operations as part of reviewing proposed operations under the LTO. Climate change impact representing 2022±15 climate conditions were analyzed by updating CalSim 3 meteorologic and hydrologic boundary conditions for Long Term Operations. The 2022±15 future climate condition was developed with 40 Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate projections, selected for LTO. Future climate change analysis was based on the 2022 median climate change scenario.

Additional information on this Climate Scenario can be found in Appendix F, Attachment F.1-1, *Climate Change*.

Model simulations also include 15 cm of assumed sea level rise (SLR). CalSim 3 uses an Artificial Neural Network (ANN) algorithm developed by DWR to translate water quality standards into flow equivalents that are to be met through SWP and CVP simulated operations (Sandhu et al. 1999). The ANN mimics the flow-salinity relationships as simulated in DSM2 and provides a rapid transformation of this information into a form usable by CalSim 3 operations.

Additional information on the ANN can be found in Appendix F, Attachment F.1-3, *Model Updates*, under DSM2 Updates.

F.4 CalSim 3

The United States Department of the Interior, Bureau of Reclamation (Reclamation) and the California Department of Water Resources (DWR) jointly developed CalSim 3 as a planning model to simulate operations of the CVP and SWP over a range of hydrologic conditions. The model represents the best available planning-level analytical tool for SWP and CVP system operations and is an improved and expanded version of CalSim II, which has been the standard planning model for system operations since the early 2000s. A detailed description of CalSim 3 is available at [https://data.cnra.ca.gov/dataset/2395530a-5421-487e-921e- d6e594f23ac6/resource/2d4160d7-cbe1-4e63-8cdd- 98f322e74cf2/download/cs3_mainreport_updates.pdf]. Additional updates since this report are provided in Appendix F, Attachment F.1-3.

Inputs to CalSim 3 include unimpaired inflows and rainfall runoff, agricultural, urban, and wetland water demands, return flows, and groundwater recharge from precipitation and irrigation. Sacramento and San Joaquin Valley and tributary rim basin hydrology are developed using a process designed to adjust the historical sequence of monthly stream flows over a 100-year period (1922–2021) to represent a sequence of flows at existing and future levels of development.

CalSim 3 outputs include river and stream flows, water diversions and return flows, reservoir storage, Delta channel flows, Delta diversions and exports, Delta outflow, deliveries to project and non-project users, and controlling factors on project operations. These can be used to assess effects resulting from the project alternatives.

CalSim 3 outputs are used as boundary conditions for and inputs to other hydrologic, hydrodynamic, and biological models and analyses.

F.5 DSM2 Version 8.2.2

DSM2 is a one-dimensional hydrodynamic and water quality simulation model used to simulate tidal flows, water quality, and particle tracking in the Delta (California Department of Water Resources 2021b). DSM2 represents the best available planning-level analytical tool for Delta flow and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by future facilities and operations.

DSM2 model has three separate components or modules that are run sequentially: HYDRO, QUAL, and PTM. HYDRO simulates velocities and water surface elevations and provides the flow input for QUAL and PTM. HYDRO outputs are used to predict changes in flow rates and depths, and their effects resulting from the project alternatives. QUAL simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs are used to estimate changes in salinity, and their effects resulting from the project alternatives.

Additional information on DSM2 is available from DWR (California Department of Water Resources 2021b). Further updates were performed under the LTO and are described in Appendix F, Attachment F.1-3.

F.6 HEC 5Q

HEC-5Q is a generalized FORTRAN-based code that simulates reservoir and river water temperatures based on input storage, flow, and meteorological data. HEC-5Q consists of two model components, HEC-5 and HEC-5Q. HEC-5 is the daily flow simulation component of the model, whereby daily storage and flows are simulated at specific nodes (U.S. Army Corps of Engineers, Hydrologic Engineering Center 1998). HEC-5Q is the temperature simulation component of the model, where 6-hour input meteorological data (equilibrium temperatures, exchange rates, shortwave radiation, and wind speed) are applied to the simulated storage and flows from the HEC-5 model to simulate water temperatures at specified locations (Resource Management Associates 1998).

The Trinity-Sacramento River, American River, and Stanislaus HEC-5Q models used for the project are specific implementations of the general HEC-5Q model described above. The models use inputs derived from CalSim 3 outputs that have been temporally downscaled to daily timeseries, and 6-hour meteorological data derived from calculated and observed data. These models were previously used in Reclamation’s Biological Assessment for the 2019 Reinitiation of Consultation on the Coordinated Long-Term Operation of the CVP and SWP (Bureau of Reclamation 2019) but have been updated to use CalSim 3 outputs Further methodological updates were performed under the LTO and are described in Appendix F, Attachment F.1-3.

The temperature analysis contains three separate models that simulate reservoir and river temperatures:

- The Trinity River from Trinity Dam to below Lewiston Dam and the Sacramento River from Shasta Dam to the Feather River confluence. Reservoir temperatures are simulated for Trinity Lake, Lewiston Reservoir, Shasta Lake, Keswick Reservoir, and Black Butte Reservoir.
- The American River from Folsom Dam to the confluence with the Sacramento River. Reservoir temperatures were simulated for Folsom Lake and Lake Natoma.
- The Stanislaus River from upstream of New Melones Reservoir to the confluence with the San Joaquin River and the lower San Joaquin River from the Stanislaus River confluence to below Vernalis. Reservoir temperatures were simulated for New Melones Reservoir

F.7 Temperature Dependent Mortality (TDM)

The Anderson and Martin temperature dependent mortality (TDM) models were used to estimate temperature-dependent egg mortality for Sacramento River Winter run chinook salmon (Oncorhynchus tshawytscha) using different egg mortality estimation methods (Martin et al. 2017; Anderson 2018). The two models were applied using HEC-5Q Sacramento River temperature results. Sensitivity to the spatial-temporal distribution of redds in each year was estimated by using the 80th TDM percentile of redd distributions from carcass surveys from 2001–2021. Both models simulate redds' lifetime by counting the days required to cross a known cumulative degree-days threshold, and both models estimate mortality as a linear, increasing function of temperature past a known temperature threshold, but each uses a different set of assumptions to implement this conceptual model. The methods were applied to a set of simulated redds, and the results are summarized on a seasonal level for comparison of mortality outcomes between scenarios.

F.8 OBAN

The OBAN and IOS models were developed by a private research team, have been peer-reviewed, but are not publicly available. Reclamation's LTO consultant includes staff able to run OBAN models.

F.9 IOS

The IOS models were developed by a private research team, have been peer-reviewed, but are not publicly available. Reclamation will use the IOS and SIT WRLCM in the LTO lifecycle analyses.

F.10 CVPIA Winter-run Chinook Salmon Decision Support Model

USFWS and Reclamation have been developing lifecycle models for use in structured decision making for CVPIA. Through a participatory process, the Science Integration Team (SIT) has developed a winter-run Chinook Salmon decision support model, or DSM. This model has been peer-reviewed and is publicly available. The participatory team's model proposals and meeting notes, background, documentation, and code for the model are available at: Resources - CVPIA Science Integration Team. Reclamation used the SIT DSM in the LTO lifecycle analyses.

Model description, assumptions, and results are presented in Attachment F.X, *CVPIA Winter-run LCM*.

F.11 CVPIA Spring-run Chinook Salmon Decision Support Model

USFWS and Reclamation have been working to develop lifecycle models for use in structured decision making for CVPIA. Through a participatory process, the SIT has developed a model for spring-run Chinook Salmon (SIT SRLCM) has been peer- reviewed, and, is publicly available. The participatory team's model proposals and meeting notes, background, documentation, and code for the model is available at: Resources - CVPIA Science Integration Team. Model description, assumptions, and results are presented in Attachment F.X, *CVPIA Spring-run LCM*.

F.12 Delta Smelt Lifecycle Model–Entrainment

Polansky et al. (2021) developed a hierarchical stage-structured state-space life cycle model for Delta Smelt to identify factors with the strongest statistical support for having influence on the species' recruitment and survival. This modeling approach is useful as an ecological modeling tool because it can separate descriptions of state and observation processes and permit the integration of disparate data sets. This Delta Smelt life cycle model was later expanded from four to seven life stages with a component that separately describes the entrainment process at the Delta export facilities (Smith et al. 2021). This model produces expected values for larval recruitment and survival at the subsequent life stages. The most statistically supported model variant in Smith et al. (2021) used means of December-June OMR values and June-August outflow aggregated from monthly values and therefore, CalSim output for the alternatives can be directly incorporated into the model framework. As such, Reclamation can use this model to calculate expected annual population growth rate (λ) for alternative flow scenarios. The metric of interest will be geometric mean of λ for a specified time period (e.g., 1995-2014), which will be compared across alternatives. For the purpose of this text, Smith et al.'s (2021) model will be referred to as the Delta Smelt Life Cycle Model with Entrainment (LCME).

Model description, assumptions, and results are presented in Attachment F.4, *LCA Delta Smelt LCM*.

F.13 Maunder and Deriso in R Model

The Delta Smelt life cycle model published by Maunder and Deriso (2011) was updated in 2021 following the approach of Polansky et al. (2021) as far as practical, by modifying and generalizing the originally published model. This update to the publication version (henceforth referred to as the Maunder and Deriso model in R, or MDR) models a single cohort life strategy species that dies after it reproduces (i.e. the final transition is from adults to recruits and very few adults survive to the next time period e.g. an annual species). It is modelled in a Frequentist state-space framework allowing for both process variation and observation error. Transition between stages (i.e. survival and the stock-recruitment relationship) can be a function of density and covariates, in addition to unexplained temporal variation (process error). Covariates can also be used to influence the density dependent relationship or the survey catchability (bias). The model can be fitted to any number of surveys representing any of the stages.

Relative to the 2011 publication, the MDR includes an additional stage (sub-adults), with stages adjusted appropriately, fit to two additional indices of abundance for adults (spring midwater trawl prior to 2001 and spring Kodiak trawl for 2001 and later). Additionally, catchability (survey bias) is now estimated for the spring midwater trawl, and the likelihood function was changed to a log normal. The time period was also extended and now includes cohorts between 1995 and 2015. Potential covariates of survival and recruitment were borrowed from Smith et al. (2021). The surveys were fitted at the start of the stage before any other processes occurred.

Covariates and process variation were added after density dependence when it was included.

Model description, assumptions, and results are presented in Attachment F.1, *Maunder and Deriso in R Model*.

F.14 Model Limitations and Appropriate Use of Model Results

Numerical models developed and applied for the LTO are generalized and simplified representations of a complex water resources system. The models are not predictive models of project operations and results cannot be considered as absolute with a quantifiable confidence interval. The model results are only useful in a comparative analysis and can only serve as an indicator of conditions.

Due to the assumptions involved in the input data sets and model logic, care must be taken to select the most appropriate timestep for the reporting of model results. Sub-monthly (e.g., weekly, or daily) reporting of raw model results is not consistent with how the models were developed, and results should be presented on a monthly or more aggregated basis.

Absolute differences computed at a point in time between model results from an alternative and a baseline to evaluate impacts is an inappropriate use of model results (e.g., computing differences between the results from a baseline and an alternative for a particular month and year within the period of record of simulation). Likewise computing absolute differences between an alternative or a baseline and a specific threshold value or standard is an inappropriate use of model results.

Statistics computed based on the absolute differences at a point in time (e.g., average of monthly differences) are an inappropriate use of model results. Computing the absolute differences in this way disregards the changes in antecedent conditions between individual scenarios and distorts the evaluation of impacts of a specific action.

Reporting seasonal patterns from long-term averages and water year-type averages is appropriate. Statistics computed based on long-term and water year-type averages are an appropriate use of model results. Computing differences between long-term or water year-type averages of model results from two scenarios are appropriate.

All models include simplifications and generalizations compared to the “real-world” scenarios that they represent. Therefore, all models will have limitations to how accurately they can represent the real world. It is necessary to understand these limitations to correctly interpret results. Some of these limitations are discussed in general terms above, but because limitations are often model-specific, each section of the Modeling Technical Appendix includes subsections that further describe model limitations specific to the model being discussed and appropriate presentation and use of model results.

F.15 References

Bureau of Reclamation. 2019. Appendix D Modeling. Reclamation ROC on LTO Modeling to Support the January 2019 BA Qualitative Analysis. Available: https://www.usbr.gov/mp/bdo/docs/ba-appendix-d-modeling.pdf. Accessed: June 26, 2021.

California Department of Water Resources. 2021a. CalSim 3. Modeling Support Branch, Bay-Delta Office, Sacramento, CA. Available: https://water.ca.gov/Library/Modeling-and-Analysis/Central-Valley-models-and-tools/CalSim-3.

California Department of Water Resources. 2021b. DSM2: Delta Simulation Model II. Modeling Support Branch, Bay-Delta Office, Sacramento, CA. Available: https://water.ca.gov/Library/Modeling-and-Analysis/Bay-Delta-Region-models-and-tools/Delta- Simulation-Model-II.

Resource Management Associates, Inc. 1998. HEC-5 User’s Manual: Simulation of Flood Control and Conservation Systems, Appendix on Water Quality Analysis.

Sandhu, N. and D. Wilson, R. Finch, and F. Chung. 1999. Modeling Flow-Salinity Relationships in the Sacramento-San Joaquin Delta Using Artificial Neural Networks. Technical Information Record OSP-99-1. California Department of Water Resources, Sacramento, CA.

U.S. Army Corps of Engineers, Hydrologic Engineering Center. 1998. HEC-5. Simulation of Flood Control and Conservation Systems: User's Manual Version 8.0. Available: https://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/HEC5_UsersManual_(CPD-5).pdf. Accessed: June 26, 2021.

Appendix F, Modeling

Section F.1-1 CalSim 3, DSM2 and HEC-5Q Modeling Simulations and Assumptions

F.1-1.1 Introduction

This section summarizes the modeling simulations and assumptions for the No Action Alternative, Alternative 1, Alternative 2, Alternative 3, and Alternative 4.

F.1-1.2 No Action Alternative

This section presents the assumptions used in developing the CalSim 3, DSM2 and HEC5Q simulations of the No Action Alternative considered for the LTO. The No Action Alternative represents CVP and SWP operations to comply with the "current" regulatory environment as of February 28, 2022 under projected Year 2040 conditions. The No Action Alternative assumptions include existing facilities and on going programs that existed as of February 28, 2022, the publication date of the Notice of Intent (NOI). The No Action Alternative assumptions also include facilities and programs that received approvals and permits by February 28, 2022 because those programs were consistent with existing management direction as of the Notice of Intent. The No Action Alternative model does not include any potential future habitat restoration areas due to the uncertainty on system effects depending on potential locations of such areas within the Delta.

The No Action Alternative includes projected climate change and sea level rise assumptions corresponding to 2022 median ±15 and 15cm sea level rise (SLR). Changes in climate results in the changes in the reservoir and tributary inflows included in CalSim 3. The sea level rise changes result in modified flow-salinity relationships in the Delta. The climate change and sea level rise assumptions are described in detail Appendix F, Attachment F.1-1, *Climate Change*. The CalSim 3 simulation for the No Action Alternative does not consider any adaptation measures that would result in managing the CVP and SWP system in a different manner than today to reduce climate impacts. For example, future changes in reservoir flood control reservation to better accommodate a seasonally changing hydrograph may be considered under future programs but are not considered under this consultation.

Modeling and simulations that were done for this analysis are an accurate representation of the hydrologic conditions under which a TUCP would be submitted to the SWRCB. Operations under TUCPs are analyzed in the preferred alternative for implementation without further NEPA compliance provided impacts are within the range analyzed.

F.1-1.2.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2, *Callouts Tables*.

F.1-1.2.1.1 Hydrology

Inflows/Supplies

The CalSim 3 model includes 2022 Median ±15 and 15cm SLR as described in Appendix F, Attachment F.1-1.

Level of Development

CalSim 3 assumes an average 2004-2013 historical land use, which determines irrigation demand, surface runoff, field scale deep percolation, and other local hydrology inputs.

Urban demands are based on the 2020 Urban Water Management Plans.

Demands, Water Rights, CVP/SWP Contracts

CalSim 3 uses applied water demands, determined by CalSimHydro, based on average 2004-2013 land use. Urban demands are based on 2020 Urban Water Management Plans. Demand units are classified as CVP project, SWP project, local project or non-project. CVP and SWP demands are separated into different classes based on contract type.

Deliveries are limited by water rights and/or project contract obligations, as applicable.

CVP south of Delta service contractor demands are reflected as full contract obligation.

The detailed listing of CVP and SWP contract assumptions are included in the delivery specifications tables in Appendix F, Section F.1-3, *CalSim 3 Contracts*.

F.1-1.2.2 Facilities

All CVP-SWP existing facilities are simulated based on operations criteria under the current regulatory environment.

CalSim 3 includes representation of all the existing CVP and SWP storage and conveyance facilities. Assumptions regarding selected key facilities are included in the callout tables in Appendix F, Section F.1-2.

CalSim 3 also represents flood control weirs located along the Sacramento River—including Moulton Weir, Colusa Weir, Tisdale Weir, Fremont Weir at the upstream end of the Yolo Bypass (Bureau of Reclamation 2017), and the Sacramento Weir.

The No Action Alternative includes the Freeport Regional Water Project located along the Sacramento River near Freeport and the City of Stockton Delta Water Supply Project (30 mgd capacity).

A brief description of the key export facilities that are located in the Delta and included under the No Action Alternative is provided below.

The Delta serves as a natural system of channels to transport river flows and reservoir storage to the CVP and SWP facilities in the south Delta, which export water to the projects' contractors through two pumping plants: CVP's C.W. Jones Pumping Plant and SWP's Harvey O. Banks Pumping Plant. Jones and Banks Pumping Plants supply water to agricultural and urban users throughout parts of the San Joaquin Valley, South Lahontan, Southern California, Central Coast, and South San Francisco Bay Area regions.

The Contra Costa Canal and the North Bay Aqueduct supply water to users in the northeastern San Francisco Bay and Napa Valley areas.

F.1-1.2.2.1 Fremont Weir

Fremont Weir is a flood control structure located along the Sacramento River at the head of the Yolo Bypass. To enhance the potential benefits of the Yolo Bypass for various fish species, the Fremont Weir is assumed to be notched to provide increased seasonal floodplain inundation in all of the alternatives simulated for this consultation. For this alternative, it is assumed that an opening in the existing weir and operable gates are constructed at invert elevation 14 feet along with two smaller openings and operable gates at invert elevation 18 feet.

F.1-1.2.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

The Jones Pumping Plant consists of six pumps including one rated at 800 cfs, two at 850 cfs, and three at 950 cfs. Maximum pumping capacity is assumed to be 4,600 cfs with the 400 cfs Delta Mendota Canal (DMC)–California Aqueduct Intertie that became operational in July 2012.

F.1-1.2.2.3 SWP Banks Pumping Plant Capacity

SWP Banks pumping plant has an installed capacity of about 10,300 cfs. The SWP water rights for diversions specify a maximum of 10,300 cfs, but the U. S. Army Corps of Engineers (ACOE) permit for SWP Banks Pumping Plant allows a maximum pumping of 6,680 cfs. With additional diversions depending on Vernalis flows the total diversion can go up to 10,300 cfs during December 15–March 15. Additional capacity of 500 cfs (pumping limit up to 7,180 cfs) is allowed in July–September to limit the SWP water supply impacts of Spring Delta export reduction actions.

F.1-1.2.2.4 San Luis Reservoir

The No Action Alternative reflects the current size of San Luis Reservoir and does not address the crest raise actions per the B.F. Sisk Dam Safety of Dams (SOD) Modification Project ROD (Bureau of Reclamation 2019). San Luis reservoir storage is split into two pools, split between the CVP and SWP with 972 TAF and 1067 TAF capacities respectively.

F.1-1.2.2.5 Contra Costa Water District Intakes

The Contra Costa Canal originates at Rock Slough, about four miles southeast of Oakley, and terminates after 47.7 miles at Martinez Reservoir. Historically, diversions at the unscreened Rock Slough facility (Contra Costa Canal Pumping Plant No. 1) have ranged from about 50 to 250 cfs. The canal and associated facilities are part of the CVP; but are operated and maintained by the Contra Costa Water District (CCWD). CCWD also operates a diversion on Old River and the Alternative Intake Project (AIP), the new drinking water intake at Victoria Canal, about 2.5 miles east of Contra Costa Water District's (CCWD) intake on the Old River. CCWD can divert water to the Los Vaqueros Reservoir to store good quality water when available and supply to its customers.

F.1-1.2.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under the No Action Alternative are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.2.3.1 D-1641 Operations

The SWRCB Water Quality Control Plan (WQCP) and other applicable water rights decisions, as well as other agreements are important factors in determining the operations of both the Central Valley Project (CVP) and the State Water Project (SWP). The December 1994 Accord committed the CVP and SWP to a set of Delta habitat protective objectives that were incorporated into the 1995 WQCP and later, were implemented by D-1641. Significant elements in D-1641 include X2 standards, export/inflow (E/I) ratios, Delta water quality standards, real-time Delta Cross Channel operation, and flow and water quality standards for the San Joaquin River at Vernalis.

F.1-1.2.3.2 Coordinated Operations Agreement (COA)

The CVP and SWP use a common water supply in the Central Valley of California. Reclamation and DWR have built water conservation and water delivery facilities in the Central Valley in order to deliver water supplies to project contractors. The water rights of the projects are conditioned by the SWRCB to protect the beneficial uses of water within each respective project and jointly for the protection of beneficial uses in the Sacramento Valley and the Sacramento-San Joaquin Delta Estuary. The agencies coordinate and operate the CVP and SWP to meet the joint water right requirements in the Delta.

The Coordinated Operations Agreement (COA), signed in 1986, defines the project facilities and their water supplies, sets forth procedures for coordination of operations, identifies formulas for sharing joint responsibilities for meeting Delta standards as they existed in SWRCB Decision 1485 (D-1485), identifies how unstored flow will be shared, sets up a framework for exchange of water and services between the Projects, and provides for periodic review of the agreement.

Reclamation and DWR re-negotiated COA in 2018 and this ROC on LTO includes the amended COA, which stipulates a change in responsibility for making storage withdrawals to meet in-basin use (as noted in Table F.1-1) and a change in export capacity when exports are constrained (Table F.1-2).

Table F.1-1. Sharing of Responsibility for Meeting In-Basin Use

Water Year Types	**Central Valley Project**	**State Water Project**
Wet	80%	20%
Above Normal	80%	20%
Below Normal	75%	25%
Dry	65%	35%
Critical	60%	40%

Table F.1-2. Sharing of Applicable Export Capacity When Exports are Constrained

	Central Valley Project	**State Water Project**
Balanced Water Conditions	65%	35%
Excess Water Conditions	60%	40%

F.1-1.2.3.3 CVPIA (b)(2) Assumptions

The Central Valley Project Improvement Act (CVPIA) 3406(b)(2) water allocation, management, and related actions (B2) are not modeled in this alternative.

F.1-1.2.3.4 Continued CALFED Agreements

The Environmental Water Account (EWA) was established in 2000 by the CALFED Record of Decision (ROD). The EWA was initially identified as a 4-year cooperative effort intended to operate from 2001 through 2004 but was extended through 2007 by agreement between the EWA agencies. It is uncertain, however, whether the EWA will be in place in the future and what actions and assets it may include. Because of this uncertainty, the EWA has not been included in the current CalSim 3 implementation.

One element of the EWA available assets is the Lower Yuba River Accord (LYRA) Component 1 water. Despite the absence of the EWA in CalSim 3, the LYRA Component 1 water is assumed to be transferred to South of Delta (SOD) State Water Project (SWP) contractors to reduce the impact of Spring export limits. An additional 500 cfs of capacity is permitted at Banks Pumping Plant from July through September to export this transferred water.

F.1-1.2.3.5 Temporary Urgency Change Petitions (TUCPs)

Reclamation and DWR may request a TUCP to meet public health and safety needs when dry conditions prevent meeting D-1641. Reclamation and DWR would not apply for TUCPs to preserve storage in upstream reservoirs beyond water required to maintain public health and safety. It is assumed that the following relaxations of D-1641 criteria will be triggered by low Shasta storage and/or Sacramento Index value:

- **Season: February–April:**
    - 4,000 cfs NDOI required in lieu of Spring X2 standards
- **Season: May–September:**
    - Emmaton EC standard moved to Threemile Slough
    - 4,000 cfs NDOI required in lieu of X2 in May
    - 3,000 cfs NDOI standard applied in June–September

When TUCPs are active, Delta exports are limited to Health and Safety.

F.1-1.2.4 Water Transfers and Wheeling

F.1-1.2.4.1 Lower Yuba River Accord (LYRA)

Acquisitions of Component 1 water under the Lower Yuba River Accord, and use of 500 cfs dedicated capacity at Banks PP during July–September, are assumed to be used to reduce as much of the impact of the Apr–May Delta export actions on SWP contractors as possible.

Phase 8 Transfers

Phase 8 transfers are not included in the No Action Alternative simulation.

Short-term or Temporary Water Transfers

Short term or temporary transfers such as Sacramento Valley acquisitions conveyed through Banks PP are not included in the No Action Alternative simulation.

Cross Valley Canal Wheeling and Joint Point of Diversion

Cross Valley Canal (CVC) wheeling is modeled up to a maximum of 128 TAF per year. Joint Point of Diversion (JPOD) is operated per the CALFED ROD, where only Delta surplus can be wheeled under JPOD. No CVC or JPOD wheeling is allowed in months when there is an ITP export cut.

Contra Costa Wheeling through Freeport

Through existing agreements and consistent with CCWD's CVP water service contract, CCWD may wheel 3.2 TAF of water through the East Bay Municipal Utility District (EBMUD) share of the Freeport Regional Water Authority (FRWA) Intake Facility each year. Wheeled water is conveyed to CCWD via the FRWA pipeline, Folsom South Canal, Mokelumne Aqueduct, and finally the CCWD-EBMUD intertie. EBMUD diversions take priority over CCWD wheeling.

F.1-1.2.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.2.5.1 Trinity River

Minimum Flow below Lewiston Dam

Trinity EIS Preferred Alternative which includes variable annual instream flows for the Trinity River based on the forecasted hydrology according to the Trinity River Restoration Program Water Year type, ranging from 369 TAF in critically dry years to 815 TAF in extremely wet years. Additional 50 TAF of releases under the Long-Term Plan to Protect Adult Salmon in the Lower Klamath River during August-September in all but Wet years.

Trinity Reservoir End-of-September Minimum Storage

Trinity EIS Preferred Alternative, modeled as 600 TAF, as able.

Trinity Import

The No Action Alternative assumes that the CVP can import water from Trinity. Imports consider Trinity and Shasta storage and required Trinity release. The No Action Alternative targets the highest imports in June through August.

F.1-1.2.5.2 Clear Creek

Reclamation operates Clear Creek flows in accordance with the 1960 Memorandum of Agreement (MOA) with CDFW, and the April 15, 2002 SWRCB permit, which established minimum flows to be released to Clear Creek at Whiskeytown Dam. Reclamation operates to a minimum baseflow in Clear Creek of 200 cfs from October through May, and 150 cfs from June through September in all Sacramento Valley (40-30-30) Index Water Year types except Critical year types. In Critical years, Clear Creek base flows are 150 cfs in all months.

In addition, Reclamation creates additional flows for both channel maintenance and spring attraction flows. Channel maintenance releases are 10 TAF in February of BN, AN, and Wet years. Spring attraction flows are supported by 10 TAF of releases in June of non-critical years, and a 3-day 900 cfs pulse release in June in critical years.

F.1-1.2.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage

NMFS 2004 Winter-run BO (1,900 TAF in non-critical dry years), which is not explicitly modeled but is met when hydrologically feasible).

Minimum Flow Below Keswick Dam

Order 90-5 set the minimum flow below Keswick Dam from September through February to be 3,250 cfs in all critically dry years as defined in the 1960 water rights agreement between the Bureau of Reclamation and Department of Fish and Game. Order 90-5 also requires operations at Shasta Dam, Keswick Dam, and Spring Creek Power Plant to meet temperature objectives, which is modeled in CalSim as a 3,250 cfs release in all months.

Reclamation tries to stabilize fall flows below Keswick to reduce redd dewatering and rebuild coldwater pool. In CalSim, this is implemented as a target Keswick release in October through February based on Shasta end-of-September storage.

Table F.1-3. Keswick Release Target October through February

Shasta End-of-September	Keswick Release Target
<2.2 MAF	3,250 cfs
2.2-2.8 MAF	4,000 cfs
2.8-3.2 MAF	4,500 cfs
>3.2 MAF	5,000 cfs

The rice decomposition smoothing action is implemented through review of the demands to reduce large peaks.

A Spring Pulse flow of up to 150 TAF is released in March and April if it is expected that the release will not impact Shasta's ability to fill to at least 4.1 MAF by the end of April. Flood control releases can contribute to the 150 TAF pulse volume.

Flow Objective at Wilkins Slough

Flow objective at Wilkins Slough based on month, CVP allocation, and Shasta storage condition.

Minimum Flow Near Rio Vista

The minimum flow standard at Rio Vista is a September through December minimum flow of 3,000-4,500 cfs based on month and Sacramento Valley (40-30-30) Index Water Year type from D-1641.

Voluntary Agreements

None

F.1-1.2.5.4 Feather River

Minimum Flow Below Thermalito

Minimum flows below Thermalito Diversion Dam (low flow channel) are based on the 2006 Settlement Agreement which targets 700 cfs April 1 through September 9 and 800 cfs September 10 through March 31. Minimum flows below Thermalito Afterbay outlet (high flow channel) range from 750-1,750 cfs based on the 1983 DWR and CDFW agreement.

Voluntary Agreements

None

F.1-1.2.5.5 American River

Folsom Dam Flood Control

Folsom operates to flood control rules per the 2018 revision of the Water Control Manual for Folsom Dam and Lake, which incorporates the auxiliary spillway and forecast-informed decision making.

Minimum Flow Below Nimbus Dam

Minimum flow below Nimbus Dam is determined by the 2017 American River Modified Flow Management Standard.

Minimum Flow At H Street

The No Action Alternative applies D-893 at H Street, which is modeled as 250 cfs between January 1 and September 15 or 500 cfs at other times, with some reductions allowed in years where April through November inflows to Folsom are projected to be less than 600 TAF.

Voluntary Agreements

None

F.1-1.2.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam

New Melones minimum flows below Goodwin are per the Stepped Release Plan (SRP). These flows are patterned to provide fall attraction flows in October and outmigration pulse flows in spring months (April 15 through May 15 in all years), and total up to 185.3 TAF to 483.7 TAF annually depending on the San Joaquin Valley (60-20-20) Index Water Year type (Tables F.1-4, F.1-5, and F.1-6).

Table F.1-4. Annual Stepped Release Plan Flow Allocation

San Joaquin Valley (60-20-20) Index Water Year Type	SRP Flows (TAF)
Critical	185.3
Dry	234.1
Below Normal	346.7
Above Normal	346.7
Wet	483.7

Table F.1-5. Monthly “Base” Stepped Release Plan (SRP) Flows Based on the Annual SRP Volume

Annual SRP Flow Volume (TAF)	Monthly SRP Base Flows (cfs)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr. 1–14	May 16–31	Jun.	Jul.	Aug.	Sep.
185.3	577.4	200	200	212.9	214.3	200	200	150	150	150	150	150
234.1	635.5	200	200	219.4	221.4	200	500	284.4	200	200	200	200
346.7	774.2	200	200	225.8	228.6	200	1,471.4	1,031.3	363.3	250	250	250
483.7	796.8	200	200	232.3	235.7	1,521	1,614.3	1,200	940	300	300	300

Table F.1-6. April 15 through May 15 “Pulse” Flows for Fishery Purposes Based on the Annual Fishery Volume

Annual SRP Flow Volume (TAF)	SRP Pulse Flows (cfs)	
	April 15–30	May 1–15
185.3	687.5	666.7
234.1	1,000	1,000
346.7	1,625	1,466.7
483.7	1,212.5	1,933.3

Minimum Dissolved Oxygen

Releases are made to the Stanislaus River below Goodwin Dam to meet the D-1422 dissolved oxygen content objective. Surrogate flows representing releases for dissolved oxygen requirement in CalSim are presented in Table F.1-7. These flows are met through releases from New Melones without any annual volumetric limit but are only released if not met by other releases.

Table F.1-7. Surrogate Flows Representing Releases for Dissolved Oxygen

Month	Surrogate Flow (TAF)
Jan.	0.0
Feb.	0.0
Mar.	0.0
Apr.	0.0
May	0.0
Jun.	15.2
Jul.	16.3
Aug.	17.4

Month	Surrogate Flow (TAF)
Sep.	14.8
Oct.	0.0
Nov.	0.0
Dec.	0.0

Water Supply

Water supply refers to deliveries from New Melones to water rights holders (Oakdale Irrigation District [ID] and South San Joaquin ID) and CVP eastside contractors (Stockton East Water District [WD] and Central San Joaquin Water Control District [WCD]).

Water is provided to Oakdale ID and South San Joaquin ID in accordance with their 1988 Settlement Agreement with Reclamation (up to 600 TAF based on hydrologic conditions), limited by consumptive use. The conservation account of up to 200 TAF storage capacity defined under this agreement is not modeled in CalSim 3.

Annual allocations for Stockton East WD and Central San Joaquin WCD are determined using the San Joaquin Valley (60-20-20) Index Water Year type (Table F.1-8) and are distributed using monthly patterns.

Table F.1-8. Annual Allocations for the Stockton East Water District and Central San Joaquin Water Control District

San Joaquin Valley (60-20-20) Index Water Year Type	CVP Contractor Allocation (TAF)
Critical	0
Dry	49
Below Normal, Above Normal, and Wet	155

F.1-1.2.5.7 San Joaquin River

San Joaquin River Restoration Program

San Joaquin River Restoration Program releases per the Restoration Flow Guidelines. Restoration Flow requirements are implemented at Friant Dam and in the proposed Mendota Pool Bypass.

Recapture of Restoration Flows is simulated at Patterson Irrigation District, Banta Carbona Irrigation District, West Stanislaus Irrigation District, and in the Delta.

Maximum Salinity Near Vernalis

New Melones contribution per the SRP.

Minimum Flow Near Vernalis

New Melones contribution per the SRP.

Voluntary Agreements

None

F.1-1.2.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641

All Delta outflow requirements per SWRCB D-1641 are included in the No Action Alternative simulation. However, not all salinity requirements are included as CalSim 3 is not capable of predicting salinities in the Delta. Instead, empirically based equations and models are used to relate interior salinity conditions with the flow conditions. DWR's Artificial Neural Network (ANN) trained for salinity is used to predict and interpret salinity conditions at the Collinsville, Emmaton, Jersey Point, and Rock Slough stations. Emmaton and Jersey Point standards are for protecting water quality conditions for agricultural use in the western Delta and they are in effect from April 1 to August 15. The EC requirement at Emmaton varies from 0.45 mmhos/cm to 2.78 mmhos/cm, depending on the Sacramento Valley (40-30-30) Index Water Year type. The EC requirement at Jersey Point varies from 0.45 to 2.20 mmhos/cm, depending on the water year type. The Rock Slough standard is for protecting water quality conditions for M&I use for water exported through the Contra Costa Canal. It is a year-round standard that requires a certain number of days in a year with chloride concentration less than 150 mg/L. The number of days requirement is dependent upon the water year type. The standard at Jersey Point is extended beyond the April through August D-1641 standard, to include September through January to help manage central Delta salinity and the Rock Slough water quality standard.

Delta Smelt Summer-Fall Habitat Action

SWP provides an additional 100 TAF volume of water to supplement Delta outflow in summer or fall months of a Sacramento Valley (40-30-30) Index wet or above normal year. This action is modeled with 100 TAF of additional outflow in August of wet and above normal years.

Combined Old and Middle River Flows

Projects operate to an OMR index no more negative than a 14-day moving average of -5,000 CFS between January 1 and May 31st except for the following conditions:

- **Integrated Early Winter Pulse Protection ("First Flush"):** After December 1 and through January 31, when running 3-day average of the daily flows at Freeport is greater than 25,000 cfs and running 3-day average of the daily turbidity at Freeport is 50 NTU or greater, or real-time monitoring indicates a high risk of migration and dispersal into areas at high risk of future entrainment, but not be required if ripe or spent female Delta Smelt are collected in monitoring surveys, Reclamation and DWR propose to operate to OMR index of negative 2,000 CFS for 14 days. The Sacramento River Index (SACRI) is used to determine first flush conditions (SACRI greater than or equal to 20,000 CFS).
- **Turbidity Bridge Avoidance:** January and February in any Sacramento (40-30-30) Index Water Year type, if first flush occurred in December and if the turbidity trigger is reached (SACRI greater than or equal to 20,000 CFS), Projects operate to OMR Index of negative 2,000 CFS for five days.

- **WIIN Act Storm-Related OMR Flexibility:** It is assumed that there may be storm-related OMR management flexibility in January and February. In all water year types, it is assumed that this action is triggered under the following conditions which dynamically determined in CalSim: the Delta is in excess conditions, X2 < 81 km, SACRI < 20,000 cfs, and Qwest > +1,000 cfs. Each condition is determined based on the monthly timestep in CalSim.
- **Species-Specific Cumulative Salvage or Loss Threshold:** Since salvage or loss cannot be directly modeled in CalSim, historic salvage data at the fish facilities at Banks and Jones Pumping Plants and fish catch data at Chipps Island trawl during water years 2010-2022 were analyzed. Historic salvage data provides the potential timing of triggering the 50% and 75% levels of the proposed single year loss thresholds. The Chipps Island catch data provides the migration timing and estimates for when the 95% of Winter-Run and Steelhead have migrated out of the Delta, which is the proposed offramp for the real-time OMR management for these species. Based on this historic data, the modeling used an OMR index of negative 3,500 CFS in a portion of each month from January through May.

South Delta Exports (Banks and Jones PP)

Exports at Jones and Banks Pumping Plant are restricted to their permitted capacities per SWRCB D-1641 requirements.

Under D-1641 the combined export of the CVP Tracy Pumping Plant and SWP Banks Pumping Plant is limited to a percentage of Delta inflow. The percentage ranges from 35 to 45 percent during February depending on the January eight river index and is 35 percent during March through June months. For the rest of the months 65 percent of the Delta inflow is allowed to be exported.

D-1641 also limits combined exports April 15–May 15 to the maximum of 1500 cfs or flow in the San Joaquin River at Vernalis.

Additional 500 cfs SWP pumping is allowed during the July through September period.

A minimum health and safety pumping of 1,500 cfs is assumed from January through June.

Spring Outflow Requirement

Under the ITP, the SWP operates to the San Joaquin River Inflow to Export Ratio (SJR IE). The maximum allowable SWP export is 600 cfs or 40% of the total export under SJR IE in April and May. The ratio varies by the San Joaquin Valley (60-20-20) Water Year type (Table F.1-9). SJR IE does not apply when Delta outflow is greater than 44,500 cfs.

Table F.1-9. San Joaquin River Inflow to Export Ratio by San Joaquin Valley (60-20-20) Water Year Type

San Joaquin Valley (60-20-20) Water Year Type	Total Export: Vernalis Flow
Wet and Above Normal	4:1
Below Normal	3:1
Dry	2:1
Critical	1:1

Suisun Marsh Salinity Control Gates

Operate to meet D-1641 water quality standards October through May.

Summer/Fall Delta Smelt habitat action operates for 60 days June through October of Sacramento Valley (40-30-30) Index Wet, Above Normal, and Below Normal years. Additional SWP ITP action in Dry years, where the gate will operate for 30 days if the previous year was Below Normal or 60 days if the previous year was Above Normal or Wet and there was sufficient carryover.

Delta Cross Channel Gate Operation

Gate operations per Multi-Year Study Program.

The nuances of this operation cannot be modeled in the monthly CalSim timestep, so gate closures represented in the model reflect actions under the NMFS 2009 BO Action 4.1.2 along with D-1641.

D-1641 calls for gates to be closed for 45 out of 92 days November through January, every day February through May 20, and 14 out of 26 days May 21 through June 15. CalSim assumptions for these criteria close the gates for 10 days in November, 15 days in December, 20 days in January, all days in May, and 4 days in June.

Additional gate closures to represent the NMFS BO are triggered in October and November by indications that daily flow at Wilkins Slough would exceed 7,500 cfs, corresponding to a high risk of fish presence. Gates are modeled as fully closed in December and January.

Reclamation determines the timing and duration of actual gate closures after discussion with USFWS, CDFW, and NMFS.

X2

The D-1641 February through June X2 criteria is included in the No Action Alternative simulation.

Delta outflow to manage X2 in the fall months following Sacramento Valley (40-30-30) Index wet and above normal years targets maintaining an average X2 for September and October no greater (more eastward) than 80 kilometers. This criteria is modeled with transitional flows in the last half of August.

Voluntary Agreements

None

Temporary Urgency Change Petition Representation

Some D-1641 criteria is relaxed under severe water supply conditions, determined by a combination of Sac River Index and Shasta storage. Water quality standards at Emmaton are modified to represent moving the standard upstream to Three-Mile Slough, X2 requirements are suspended, and Net Delta Outflow Index standards are relaxed by 1,000 cfs in summer months. When TUCPs are triggered, Delta exports are limited to health and safety levels.

F.1-1.2.6 Systemwide Operational Rules

F.1-1.2.6.1 CVP Water Allocation

CalSim includes allocation logic for determining deliveries to north-of-Delta and south-of-Delta CVP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty in the hydrology, and a rule curve which relates water supply to the allocation. Water supply is defined by forecasted inflow and Spring reservoir storage. Allocation is first determined in March and updated in April and May as runoff forecasts become more certain. South of Delta CVP allocation can be affected by export potential, which is represented in a rule curve based on the Sac River Index.

CVP Settlement Contractors, Exchange Contractors, and Refuges receive 100% allocation in all except for Shasta Critical Years. In Shasta Critical Years, the Settlement Contractors and the Refuges are given a 75% allocation and Exchange contractors are given a 77% allocation.

CVP water service contracts are determined based on water supply (except the East Side contractors which are determined in CalSim by the San Joaquin 60-20-20 Index). CVP agriculture allocations are 0–100% and CVP municipal and industrial allocations are 50–100%.

F.1-1.2.6.2 SWP Water Allocation

CalSim includes allocation logic for determining deliveries to north-of-Delta and south-of-Delta SWP contractors. The delivery logic uses runoff forecast information, which incorporates uncertainty in the hydrology, and standardized rule curves (i.e., Water Supply Index versus Demand Index Curve). The rule curves relate forecasted water supplies to deliverable "demand," and then use deliverable "demand" to assign subsequent delivery levels to estimate the water available for delivery and carryover storage. Updates of delivery levels occur monthly from January 1 through May 1 for the SWP as runoff forecasts become more certain. The south-of-Delta SWP delivery is determined based on water supply parameters and operational constraints.

F.1-1.2.7 DSM2

The following is a description of the assumptions tabulated in Section F.1-2.

F.1-1.2.7.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.2.7.2 Tidal Boundary

The tidal boundary condition at Martinez is based on an adjusted astronomical tide normalized for sea level rise (Ateljevich and Yu 2007).

F.1-1.2.7.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.2.7.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.2.7.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Clifton Court Forebay gates are operated based on the Priority 3 operation, where the gate operations are synchronized with the incoming tide to minimize the impacts to low water levels in nearby channels. The Priority 3 operation is described in the 2008 OCAP BA Appendix F Section 5.2 (Bureau of Reclamation 2008).

F.1-1.2.7.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.2.8 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.2.8.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to “2019 tiers” as described in Appendix F, Attachment F.1-3, *Model Updates*.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.2.8.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.2.8.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.3 Alternative 1–Water Quality Control Plan

F.1-1.3.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.3.1.1 Hydrology

Inflows/Supplies

Same as No Action Alternative.

Level of Development

Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts

Same as No Action Alternative.

F.1-1.3.2 Facilities

F.1-1.3.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.3.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Delta-Mendota Canal–California Aqueduct Intertie capacity increased to 700 cfs.

F.1-1.3.2.3 SWP Banks Pumping Plant Capacity

Same as No Action Alternative.

F.1-1.3.2.4 San Luis Reservoir

CVP storage capacity in San Luis is increased by 130 TAF to 1102 TAF; SWP storage capacity is unchanged.

F.1-1.3.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.3.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 1 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.3.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.3.3.2 Coordinated Operations Agreement (COA)

Same as No Action Alternative

F.1-1.3.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.3.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.3.3.5 Temporary Urgency Change Petitions (TUCPs)

Not assumed in Alternative 1.

F.1-1.3.4 Water Transfers and Wheeling

F.1-1.3.4.1 Lower Yuba River Accord (LYRA)

Same as No Action Alternative.

F.1-1.3.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.3.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.3.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Same as No Action Alternative.

F.1-1.3.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.3.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.3.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir end-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.3.5.2 Clear Creek

Minimum flows are per the Instream Flow Preservation Agreement (2000), which are 50 cfs January-October and 100 cfs November-December (70 cfs in Shasta Critical years).

F.1-1.3.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage
Same as No Action Alternative.

Minimum Flow Below Keswick Dam
Same as No Action Alternative, except that the Spring Pulse flow requirement is removed.

Flow Objective at Wilkins Slough
Same as No Action Alternative.

Minimum Flow Near Rio Vista
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.3.5.4 Feather River

Minimum Flow Below Thermalito
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.3.5.5 American River

Folsom Dam Flood Control
Same as No Action Alternative.

Minimum Flow Below Nimbus Dam
Minimum flows are based on State Water Board Decision 893 (D-893) flow requirements. This is modeled as 250 cfs between January 1 and September 15 or 500 cfs at other times, with some reductions allowed in years where April through November inflows to Folsom are projected to be less than 600 TAF.

Minimum Flow At H Street
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.3.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam

Minimum flows are based on New Melones Interim Plan of Operations (IPO), which includes flow requirements from the 1987 Stipulation Agreement between Reclamation and CDFW, with additional flows provided under CVPIA Section 3406(b)(2). The annual fisheries release volume is based on the end of February New Melones storage plus the forecasted March through September inflows (50% exceedance), according to the schedule shown in Table F.1-10. Monthly flow releases are shown in Figure F.1-1 below. Monthly flows are linearly interpolated from the annual volume (the lines in Figure F.1-1).

Table F.1-10. Stanislaus Annual Fisheries Volume Schedule

New Melones End of Feb storage + March–September inflows (TAF)	Fisheries Volume (TAF)
1400	98
2000	125
2500	345
3000	467
6000	467

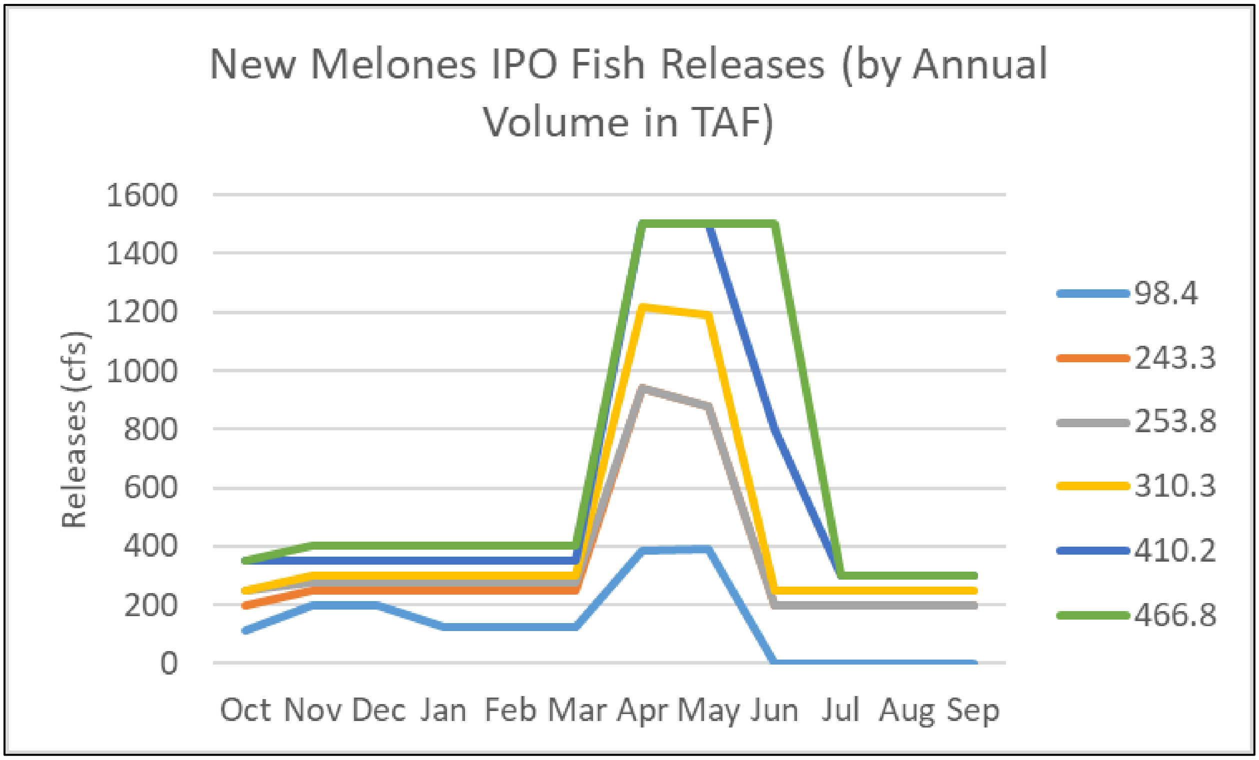

Figure F.1-1. Stanislaus Monthly Fisheries Volume Schedule

Minimum Dissolved Oxygen

Same as No Action Alternative.

Water Supply

Same as No Action Alternative.

F.1-1.3.5.7 San Joaquin River

San Joaquin River Restoration Program

Same as No Action Alternative.

Maximum Salinity Near Vernalis

D-1641 salinity standards are implemented, met with releases from New Melones. Standards are 0.7 EC April-August and 1.0 EC September-March.

Minimum Flow Near Vernalis

D-1641 minimum flow standards are implemented (not including the pulse flows during the April 15–May 15 period), met with releases from New Melones. The flow requirement is based on the required location of X2 and the San Joaquin Valley (60-20-20) Index Water Year type as summarized in Table F.1-11.

Table F.1-11. D-1641 Vernalis Flow Objectives (average monthly cfs)

San Joaquin Valley (60-20-20) Index Water Year Type	Flow Required if X2 is West of Chipps Island	Flow Required if X2 is East of Chipps Island
Wet	3,420	2,130
Above Normal	3,420	2,130
Below Normal	2,280	1,420
Dry	2,280	1,420
Critical	1,140	710

Voluntary Agreements

None

F.1-1.3.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641

Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action

Not included.

Combined Old and Middle River Flows

No OMR standards included.

South Delta Exports (Banks and Jones PP)

Same as No Action Alternative.

Spring Outflow Requirement

Not included.

Suisun Marsh Salinity Control Gates

Operated to meet D-1641 water quality standards October through May only.

Delta Cross Channel Gate Operation

Operated to meet D-1641 requirements only.

X2

The D-1641 February through June X2 standard is included. Fall X2 standards (mid-August to October) are not included.

Voluntary Agreements

None

Temporary Urgency Change Petition Representation

TUCPs are not included.

F.1-1.3.6 Systemwide Operational Rules

F.1-1.3.6.1 CVP Water Allocation

Same as No Action Alternative.

F.1-1.3.6.2 SWP Water Allocation

Same as No Action Alternative.

F.1-1.3.7 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.3.7.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.3.7.2 Tidal Boundary

Same as No Action Alternative

F.1-1.3.7.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.3.7.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.3.7.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.3.7.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.3.8 HEC-5Q

F.1-1.3.8.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to 90-5 logic as described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.3.8.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.3.8.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.4 Alternative 2 v1–Multi-Agency Consensus

F.1-1.4.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.4.1.1 Hydrology

Inflows/Supplies

Same as No Action Alternative.

Level of Development

Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts

Same as No Action Alternative.

F.1-1.4.2 Facilities

Same as Alternative 1.

F.1-1.4.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.4.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Same as Alternative 1.

F.1-1.4.2.3 SWP Banks Pumping Plant Capacity

SWP Banks pumping plant has an installed capacity of about 10,300 cfs. The SWP water rights for diversions specify a maximum of 10,300 cfs, but the U.S. Army Corps of Engineers (ACOE) permit for SWP Banks Pumping Plant allows a maximum pumping of 6,680 cfs. With additional diversions depending on Vernalis flows the total diversion can go up to 10,300 cfs during December 1–March 31. Additional capacity of 500 cfs (pumping limit up to 7,180 cfs) is allowed in July–September to limit the SWP water supply impacts of Spring Delta export reduction actions.

The key difference from No Action Alternative is that SWP Banks diversions may reach 10,300 cfs in December 1 through March 31, rather than in December 15 through March 15.

F.1-1.4.2.4 San Luis Reservoir

Same as Alternative 1.

F.1-1.4.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.4.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 2 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.4.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.4.3.2 Coordinated Operations Agreement (COA)

COA is modified from the No Action Alternative to account for reductions to the Sacramento River Settlement Contractors in Bin 3B years to encourage the conserved water to remain in Shasta storage.

F.1-1.4.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.4.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.4.4 Water Transfers and Wheeling

F.1-1.4.4.1 Lower Yuba River Accord (LYRA)

Same as No Action Alternative.

F.1-1.4.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.4.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.4.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Same as No Action Alternative.

F.1-1.4.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.4.4.6 Temporary Urgency Change Petitions (TUCPs)

Not assumed in Alternative 2v1.

F.1-1.4.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.4.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir end-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.4.5.2 Clear Creek

Reclamation proposes to release Clear Creek flows in a variable hydrograph in all except Sacramento Valley (40-30-30) Index Critical year-types (Table F.1-12). In Critical year-types, releases from Whiskeytown Dam target 150 cfs in all months.

In addition, Reclamation proposes to create pulse flows for channel maintenance, spring attraction flows, and to meet other physical and biological objectives. These pulses are modeled as 5 TAF in May and June in all except Critical year-types. In Critical year-types a 5 TAF pulse flow is modeled in May.

Table F.1-12. Clear Creek Seasonal Variable Hydrograph Monthly Minimum Flows, Except Sacramento Valley (40-30-30) Index Critical Years

Month	Flow (cfs)
Oct.	168
Nov.	221
Dec.	269
Jan.	295
Feb.	286
Mar.	271
Apr.	234
May	185
Jun.	136
Jul.	106
Aug.	114
Sep.	134

F.1-1.4.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage

Shasta is operated using the Water Temperature and Storage Framework approach which establishes management “Bins”.

The Bin is determined February through May based on estimated Shasta fill and carryover, forecasted inflow, projected delivery, and projected regulatory cost. The May Bin estimate endures through September.

- **Bin 1A:** End of April (EOA) estimate > 3.7 MAF and End of September (EOS) estimate > 3.0 MAF. Under Bin 1A normal operations occur.
- **Bin 1B:** EOA estimate > 3.7 MAF and EOS estimate > 2.4 MAF. Under Bin 1B, a factor is applied to the reservoir balancing goals to prioritize Shasta storage if possible.
- **Bin 2A:** EOA estimate > 3.0 MAF and EOS estimate > 2.2 MAF. Under Bin 2A, additional cuts to CVP Service Contract allocations are based on the estimated and target carryover.
- **Bin 2B:** EOA estimate > 3.0 MAF and EOS estimate > 2.0 MAF. Under Bin 2B, additional cuts to CVP Service Contract allocations are based on the estimated and target carryover.

- **Bin 3A:** EOA estimate > 3.0 MAF and EOS estimate < 2.0 MAF, or EOA estimate < 3.0 MAF and EOS estimate > 2.0 MAF, or EOA estimate < 3.0 MAF and EOS estimate < 2.0 MAF and October through April Shasta inflow > 2.5 MAF. Under Bin 3A, additional cuts are made to CVP Agriculture allocation and CVP Municipal and Industrial allocation can be cut down to Public Health and Safety (25% allocation) based on the estimated and target carryover.
- **Bin 3B:** EOA estimate > 3.0 MAF and EOS estimate < 2.0 MAF and October through April Shasta Inflow < 2.5 MAF. Under Bin 3B, CVP Agriculture Service allocation is 0% and CVP Municipal and Industrial Service allocation is 25%. Sacramento River Settlement Contractor (SRSC) allocation is reduced by up to 500 TAF (modeled by allocations as low as 47%). CVP North of Delta Refuge is given the same allocation as SRSC. Up to 280 TAF of reduced delivery to SRSC and Refuge demands is tracked in a storage account in Shasta. Reductions in storage withdrawal are tracked and used to adjust the COA balance.

A decision tree for determining Shasta Management Bin is shown in Figure F.1-2.

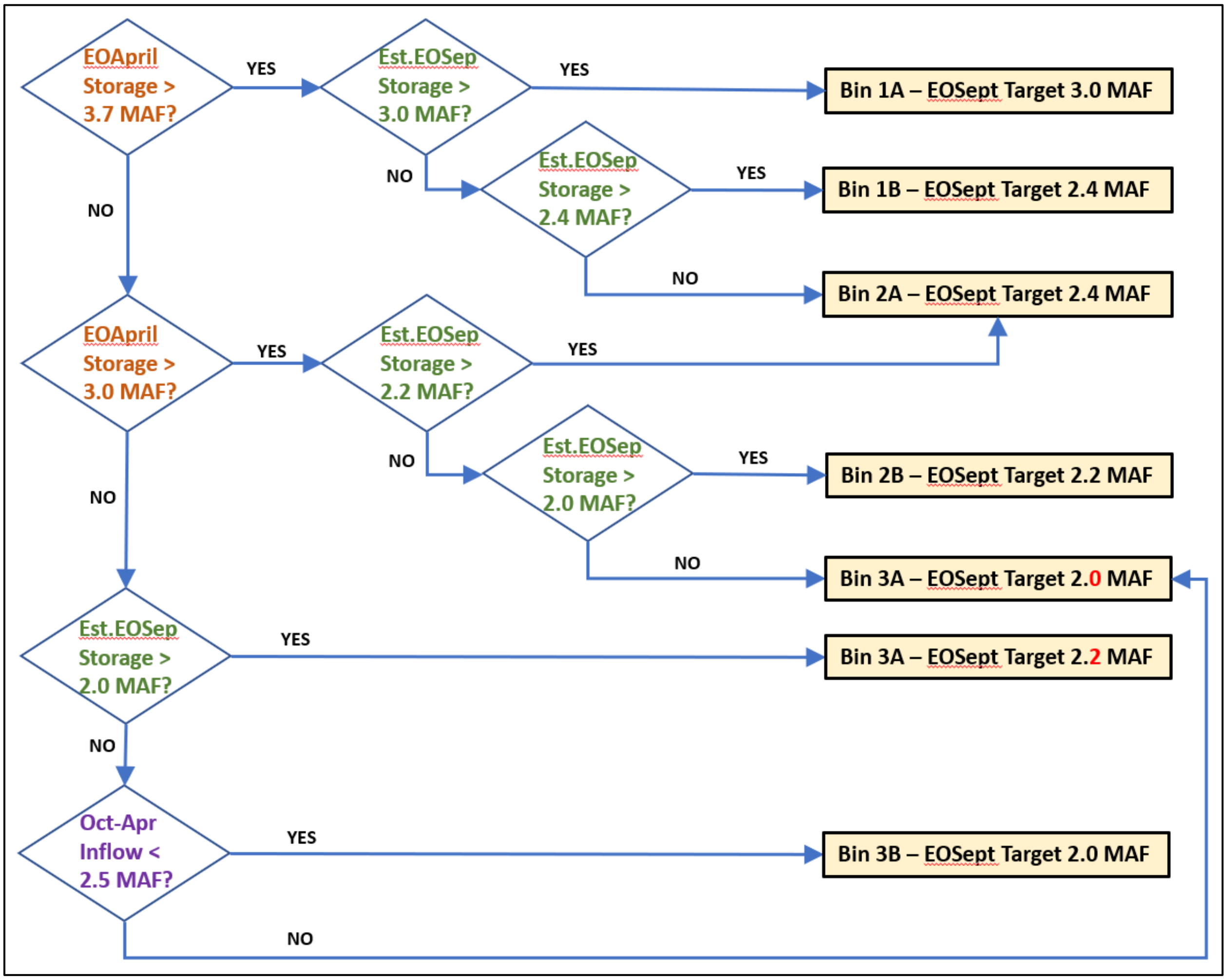

Figure F.1-2. Decision Tree for Shasta Management Bin

Minimum Flow Below Keswick Dam

Same as No Action Alternative.

Flow Objective at Wilkins Slough

Same as No Action Alternative.

Minimum Flow Near Rio Vista

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.4.5.4 Feather River

Minimum Flow Below Thermalito

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.4.5.5 American River

Folsom Dam Flood Control

Same as No Action Alternative.

Minimum Flow Below Nimbus Dam

Minimum flow below Nimbus Dam is determined by the 2017 American River Modified Flow Management Standard but using the 90 percent forecast exceedance for unimpaired inflows to Folsom and the Sacramento Valley (40-30-30) Index.

Minimum Flow At H Street

Same as No Action Alternative

Voluntary Agreements

None

F.1-1.4.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam

New Melones minimum flows below Goodwin are per the modified Stepped Release Plan (SRP). These flows are patterned to provide fall attraction flows in October and outmigration pulse flows in spring months (April 15 through May 15 in all years) and total up to 188.8 TAF to 492.6 TAF annually depending on the San Joaquin 60-20-20 Index using the 90 percent forecast exceedance (Tables F.1-13, F.1-14, and F.1-15).

In Shasta Bin 3B years, if May New Melones storage is above 1.4 MAF and the EOS Shasta storage estimate is below 1,225 TAF, the minimum flow at Goodwin is increased to 1,500 cfs in June through August to support Delta Outflow.

Table F.1-13. Annual Stepped Release Plan Flow Allocation

San Joaquin Valley (60-20-20) Index Water Year Type	SRP Flows (TAF)
Critical	188.8
Dry	239.5
Below Normal	352.9
Above Normal	352.9
Wet	492.6

Table F.1-14. Monthly "Base" Stepped Release Plan (SRP) Flows Based on the Annual SRP Volume

Annual SRP Flow Volume (TAF)	Monthly SRP Base Flows (cfs)											
	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr. 1–14	May 16–31	Jun.	Jul.	Aug.	Sep.
188.8	577.4	200	200	200	292.9	200	200	150	150	150	150	150
239.5	635.5	200	200	200	339.3	200	500	284.4	200	200	200	200
352.9	774.2	200	200	200	385.7	200	1,471.4	1,031.3	363.3	250	250	250
492.6	796.8	200	200	200	432.1	1,521	1,614.3	1,200	940	300	300	300

Table F.1-15. April 15 through May 15 "Pulse" Flows for Fishery Purposes Based on the Annual Fishery Volume

Annual SRP Flow Volume (TAF)	SRP Pulse Flows (cfs)	
	April 15–30	May 1–15
185.3	687.5	666.7
234.1	1,000	1,000
346.7	1,625	1,466.7
483.7	1,212.5	1,933.3

Minimum Dissolved Oxygen

Same as No Action Alternative.

Water Supply

Same as No Action Alternative.

F.1-1.4.5.7 San Joaquin River

San Joaquin River Restoration Program
Same as No Action Alternative.

Maximum Salinity Near Vernalis
Same as No Action Alternative.

Minimum Flow Near Vernalis
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.4.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641
Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action
Not included.

Combined Old and Middle River Flows
Projects operate to an OMR index no more negative than a 14-day moving average of -5,000 CFS between January 1 and June 30th except for the following conditions:

- **Integrated Early Winter Pulse Protection ("First Flush"):** After December 1 and through January 31, when running 3-day average of the daily flows at Freeport is greater than 25,000 cfs and running 3-day average of the daily turbidity at Freeport is 50 NTU or greater, or real-time monitoring indicates a high risk of migration and dispersal into areas at high risk of future entrainment, but not be required if ripe or spent female Delta Smelt are collected in monitoring surveys, Reclamation and DWR propose to operate to OMR index of negative 2,000 CFS for 14 days. The model index of SACRI is used to determine first flush conditions (SACRI greater than or equal to 20,000 CFS). This action is offramped when flows at Rio Vista are greater than 55,000 cfs OR flows at Vernalis are greater than 8,000 cfs.
- **Turbidity Bridge Avoidance:** January through March in any Sacramento (40-30-30) Index Water Year type, if first flush has already occurred and if the turbidity trigger is reached (SACRI greater than or equal to 20,000 CFS), Projects operate to OMR Index of negative 2,000 CFS for ten days.
- **WIIN Act Storm-Related OMR Flexibility:** It is assumed that there may be storm-related OMR management flexibility in January and February. In all water year types, it is assumed that this action is triggered under the following conditions which dynamically determined in CalSim: the Delta is in excess conditions, X2 < 81 km, SACRI < 20,000 cfs, and QWest > +1,500 cfs. Each condition is determined based on the monthly timestep in CalSim.

- **Species-Specific Cumulative Salvage or Loss Threshold:** Since salvage or loss cannot be directly modeled in CalSim, historic salvage data at the fish facilities at Banks and Jones Pumping Plants and other triggers for these actions were analyzed for the 2010–2022 period. Based on this historic data and water year type, the modeling used an OMR index of negative 3,500 CFS in a portion of each January through June.

South Delta Exports (Banks and Jones PP)

Same as No Action Alternative.

Spring Outflow Requirement

No additional actions.

Suisun Marsh Salinity Control Gates

Operate to meet D-1641 water quality standards October through May.

Summer/Fall Delta Smelt habitat action operates for 60 days June through October of Sacramento Valley (40-30-30) Index Above Normal, Below Normal, and Dry years following Wet or Above Normal years and 30 days in Dry years following Below Normal years using a 7 on, 7 off schedule.

Delta Cross Channel Gate Operation

Same as No Action Alternative.

X2

Same as No Action Alternative.

Voluntary Agreements

None.

Temporary Urgency Change Petition Representation

TUCPs are not included.

F.1-1.4.6 Systemwide Operational Rules

F.1-1.4.6.1 CVP Water Allocation

Similar to No Action Alternative with additional cuts as detailed in Shasta Lake End-of-September Minimum Storage.

F.1-1.4.6.2 SWP Water Allocation

Same as No Action Alternative.

F.1-1.4.7 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.4.7.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.4.7.2 Tidal Boundary

Same as No Action Alternative

F.1-1.4.7.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.4.7.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.4.7.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.4.7.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.4.8 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.4.8.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to "mixed” as described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.4.8.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.4.8.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.5 Alternative 2 v2–Multi-Agency Consensus (Early Implementation Voluntary Agreements)

F.1-1.5.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.5.1.1 Hydrology

Inflows/Supplies

Same as No Action Alternative.

Level of Development

Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts

Same as No Action Alternative.

F.1-1.5.2 Facilities

Same as Alternative 1.

F.1-1.5.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.5.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Same as Alternative 1.

F.1-1.5.2.3 SWP Banks Pumping Plant Capacity

Same as Alternative 2 v1.

F.1-1.5.2.4 San Luis Reservoir

Same as Alternative 1.

F.1-1.5.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.5.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 2 v2 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.5.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.5.3.2 Coordinated Operations Agreement (COA)

Same as Alternative 2 v1.

F.1-1.5.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.5.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.5.3.5 Temporary Urgency Change Petitions (TUCPs)

Not assumed in Alternative 2v2.

F.1-1.5.4 Water Transfers and Wheeling

F.1-1.5.4.1 Lower Yuba River Accord (LYRA)

Same as No Action Alternative.

F.1-1.5.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.5.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.5.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Same as No Action Alternative.

F.1-1.5.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.5.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.5.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir End-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.5.5.2 Clear Creek

Same as Alternative 2 v1.

F.1-1.5.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage
Same as Alternative 2 v1.

Minimum Flow Below Keswick Dam
Same as Alternative 2 v1.

Flow Objective at Wilkins Slough
Same as No Action Alternative.

Minimum Flow Near Rio Vista
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.5.5.4 Feather River

Minimum Flow Below Thermalito
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.5.5.5 American River

Folsom Dam Flood Control
Same as No Action Alternative.

Minimum Flow Below Nimbus Dam
Same as Alternative 2 v1.

Minimum Flow At H Street
Same as No Action Alternative

Voluntary Agreements
None

F.1-1.5.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam
Same as Alternative 2 v1.

Minimum Dissolved Oxygen

Same as No Action Alternative.

Water Supply

Same as No Action Alternative.

F.1-1.5.5.7 San Joaquin River

San Joaquin River Restoration Program

Same as No Action Alternative.

Maximum Salinity Near Vernalis

Same as No Action Alternative.

Minimum Flow Near Vernalis

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.5.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641

Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action

Same as Alternative 2 v1.

Combined Old and Middle River Flows

Same as Alternative 2 v1.

South Delta Exports (Banks and Jones PP)

Same as No Action Alternative, but also includes CVP and SWP export cuts under the Delta VA during March-May (see the *Voluntary Agreements* section below).

Spring Outflow Requirement

Same as Alternative 2 v1, with additional outflow provided by the Delta VA (see the *Voluntary Agreements* section below).

Suisun Marsh Salinity Control Gates

Same as Alternative 2 v1.

Delta Cross Channel Gate Operation

Same as No Action Alternative.

X2

Same as No Action Alternative.

Voluntary Agreements

Delta VA implemented to provide additional outflow March-May through export cuts. Export cut amounts are defined according to the Sacramento Valley (40-30-30) Index Water Year type and resulting flows are protected as Delta outflow. Total export cuts include SOD PWA water purchase program amounts. Cut amounts are shown in Tables F.1-16 and F.1-17. The CVP makes export cuts and also cuts corresponding deliveries. The SWP cuts exports but no explicit delivery cuts are made in the model.

Table F.1-16. Central Valley Project Export Cuts and Corresponding Delivery Cuts

Sacramento Valley (40-30-30) Index Water Year Type	Export Cuts (TAF)	General Delivery Cuts (TAF)–Distributed between All CVP SOD Ag Contractors	PWA Purchase CVP SOD (TAF)–Distributed between All CVP SOD Ag Contractors	PWA Purchase Add CVP SOD (TAF), Applied to Del Puerto Only, Minimum of Amount Below and Del Puerto Ag Allocation	PWA Purchase WWD SOD (TAF), Applied to Westlands WD Only, Minimum of Amount Below and 31.185 * CVP SOD Ag Allocation
Wet	27	0	0	0	27
Above Normal	147	87.5	35	5	19.5
Below Normal	107	62.5	24.5	5	15
Dry	86	62.5	12.5	5	6
Critical	3	0	0	0	3

Table F.1-17. State Water Project Export Cuts

Sacramento Valley (40-30-30) Index Water Year Type	Export Cuts (TAF)
Wet	0
Above Normal	117.5
Below Normal	92.5
Dry	92.5
Critical	0

The timing and volume of export cuts under the Delta VA are determined according to the following criteria:

- Water year types are determined using 90% exceedance forecast in March-April, and 50% exceedance forecast in May.
- All CVP export cuts begin March 10th and continue through May or until the annual requirement is fully met.
- SWP AN year export cuts begin March 22nd and continue through May or until the annual requirement is fully met.
- SWP BN/D year export cuts begin March 11th and continue through May or until annual requirement is fully met.
- No export cuts when in Balanced and IBU conditions
- SWP export cut maximum applied in March: 50 TAF in AN/BN/D years
- No export cuts when in Balanced In-Basin Use (IBU) conditions
- Export cuts restricted to CVP or SWP volume of Unstored Water for Export (UWFE)
- Export cuts restricted to volume of exports above minimum H&S exports. This is 900 cfs (for CVP) and 600 cfs (for SWP)
- Export cuts restricted to volume in CVP or SWP San Luis above dead pool

F.1-1.5.6 Systemwide Operational Rules

F.1-1.5.6.1 CVP Water Allocation

Same as Alternative 2 v1.

F.1-1.5.6.2 SWP Water Allocation

Same as No Action Alternative.

F.1-1.5.7 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.5.7.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.5.7.2 Tidal Boundary

Same as No Action Alternative

F.1-1.5.7.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.5.7.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.5.7.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.5.7.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.5.8 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.5.8.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to "mixed" as described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.5.8.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.5.8.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.6 Alternative 2 v3–Multi-Agency Consensus (All Voluntary Agreements)

F.1-1.6.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.6.1.1 Hydrology

Inflows/Supplies

Same as No Action Alternative.

Level of Development

Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts

Same as No Action Alternative.

F.1-1.6.2 Facilities

Same as Alternative 1.

F.1-1.6.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.6.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Same as Alternative 1.

F.1-1.6.2.3 SWP Banks Pumping Plant Capacity

Same as Alternative 2 v1.

F.1-1.6.2.4 San Luis Reservoir

Same as Alternative 1.

F.1-1.6.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.6.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 2 v2 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.6.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.6.3.2 Coordinated Operations Agreement (COA)

Same as Alternative 2 v1.

F.1-1.6.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.6.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.6.3.5 Temporary Urgency Change Petitions (TUCPs)

Not assumed in Alternative 2 v3.

F.1-1.6.4 Water Transfers and Wheeling

F.1-1.6.4.1 Lower Yuba River Accord (LYRA)

Same as No Action Alternative.

F.1-1.6.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.6.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.6.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Same as No Action Alternative.

F.1-1.6.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.6.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.6.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir end-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.6.5.2 Clear Creek

Same as Alternative 2 v1.

F.1-1.6.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage

Same as Alternative 2 v1.

Minimum Flow Below Keswick Dam

Same as Alternative 2 v1.

Flow Objective at Wilkins Slough

Same as No Action Alternative.

Minimum Flow Near Rio Vista
Same as No Action Alternative.

Voluntary Agreements
Sacramento VA implemented according to the following assumptions:

- Water for pulse flows is generated through 25,000 acres of land fallowing in the Sacramento Basin.
- Pulse flows are protected through the Delta.
- Pulse amounts are determined using 50% exceedance of forecasted Sacramento Valley (40-30-30) Index Water Year type in April.
    - In AN/BN years, 95 TAF pulse release split between April and May.
    - In Dry years, water saved from land fallowing is stored in an account in Shasta, then released as a pulse in the following year split between April-May. Account storage is water savings that can be backed up into Shasta, reduced by the volume that spills. Spills of this VA water occur only after all Proposed Action account water has spilled. If the following year is an AN/BN year then the pulse is 95 TAF + any Dry year carryover.
- Water savings from land fallowing occurs throughout irrigation season. Water is either released for the VA pulse directly (April–May in AN/BN years) or backed up into Shasta. In months where water cannot be backed up, water is exported at Jones if possible, or routed out the Delta.

Putah Creek VA is implemented providing additional flow of 6 TAF in November-May in all but Sacramento Valley (40-30-30) Index Water Year type Wet years through reservoir reoperation. Not protected through Delta.

F.1-1.6.5.4 Feather River

Minimum Flow Below Thermalito
Same as No Action Alternative.

Voluntary Agreements
Feather VA implemented according to the following assumptions:

- Water for pulse flows is generated through 10,000 acres of land fallowing in the Feather River Basin.
- Pulse flows are protected through the Delta.
- Pulse amounts are determined using 50% exceedance of forecasted Sacramento Valley (40-30-30) Index Water Year type in April.
- Pulse releases of 60 TAF in AN/BN/D years
- Pulse release split between April and May, but flow releases can continue later in year depending on timing of spills

Yuba VA implemented providing additional flow of 50 TAF in April-June in Sacramento Valley (40-30-30) Index Water Year type AN/BN/D years, provided through reservoir reoperation and protected through Delta. Timeseries of flows provided by Yuba Water Agency.

F.1-1.6.5.5 American River

Folsom Dam Flood Control
Same as No Action Alternative.

Minimum Flow Below Nimbus Dam
Same as Alternative 2 v1.

Minimum Flow At H Street
Same as No Action Alternative

Voluntary Agreements
American VA implemented according to the following assumptions:

- Pulse flows provided in March-May in all but Sacramento Valley (40-30-30) Index Water Year type Wet years.
- Pulse flows are protected through the Delta.
- Pulse volumes are as follows:
    - 10 TAF in AN/BN years provided through reservoir operation (7 TAF from Hell Hole Reservoir and 3 TAF from Caples Reservoir)
    - 30 TAF in Dry and Critical years provided through groundwater substitution by Carmichael Water District, City of Roseville, City of Sacramento, Golden State Water Company, and Sacramento County Groundwater Agency
    - 10 TAF in Dry years provided through reservoir reoperation (5 TAF from Hell Hole Reservoir) and groundwater substitution (5 TAF from same agencies as above)

F.1-1.6.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam
Same as Alternative 2 v1.

Minimum Dissolved Oxygen
Same as No Action Alternative.

Water Supply
Same as No Action Alternative.

F.1-1.6.5.7 San Joaquin River

San Joaquin River Restoration Program
Same as No Action Alternative.

Maximum Salinity Near Vernalis
Same as No Action Alternative.

Minimum Flow Near Vernalis
Same as No Action Alternative.

Voluntary Agreements
Friant VA implemented according to the following assumptions:

- 50 TAF flow contribution in San Joaquin River Restoration Program Dry, Normal-Dry, and Normal-Wet years during February-May
- Flows are protected through the Delta
- Friant flood releases and restoration flows can contribute to meeting the VA.
- If necessary, recapture is reduced so that restoration flows can go to outflow. Delta recapture is foregone first, and Lower San Joaquin River recapture second (only if needed)
- Restoration flows can be recaptured whether or not Friant is spilling, and hence foregone under the same conditions
- Recapture can be foregone up to a maximum of 50% during the period of February through May. If 50% is not sufficient to meet the 50 TAF flow goal, then no more contribution is required.

F.1-1.6.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641
Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action
Same as Alternative 2 v1.

Combined Old and Middle River Flows
Same as Alternative 2 v1.

South Delta Exports (Banks and Jones PP)
Same as Alternative 2 v2.

Spring Outflow Requirement

Same as Alternative 2 v1, with additional flows provide by the Delta VA, Sacramento VA, Feather VA, American VA, Mokelumne VA, Yuba VA, Friant VA, and Putah Creek VA.

Suisun Marsh Salinity Control Gates

Same as Alternative 2 v1.

Delta Cross Channel Gate Operation

Same as No Action Alternative.

X2

Same as No Action Alternative.

Voluntary Agreements

Delta VA implemented as in Alternative 2 v2

Mokelumne VA implemented to provide additional flow of 45 TAF in AN years, 20 TAF in BN years, 10 TAF in D years, based on Mokelumne JSA Water Year type. 79% of water released in March-May and 21% in October. Water provided through reservoir reoperation. Not protected through Delta.

F.1-1.6.6 Systemwide Operational Rules

F.1-1.6.6.1 CVP Water Allocation

Same as Alternative 2 v1.

F.1-1.6.6.2 SWP Water Allocation

Same as No Action Alternative.

F.1-1.6.7 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.6.7.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.6.7.2 Tidal Boundary

Same as No Action Alternative

F.1-1.6.7.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.6.7.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.6.7.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.6.7.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.6.8 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.6.8.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to "mixed" as described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.6.8.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.6.8.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.7 Alternative 3–Modified Natural Hydrograph

F.1-1.7.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.7.1.1 Hydrology

Inflows/Supplies

Same as No Action Alternative.

Level of Development

Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts

Same as No Action Alternative.

F.1-1.7.2 Facilities

Same as Alternative 1.

F.1-1.7.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.7.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Same as Alternative 1.

F.1-1.7.2.3 SWP Banks Pumping Plant Capacity

Same as No Action Alternative.

F.1-1.7.2.4 San Luis Reservoir

Same as Alternative 1.

F.1-1.7.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.7.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 3 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.7.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.7.3.2 Coordinated Operations Agreement (COA)

Same as Alternative 2 v1.

F.1-1.7.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.7.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.7.3.5 Temporary Urgency Change Petitions (TUCPs)

Not assumed in Alternative 3.

F.1-1.7.4 Water Transfers and Wheeling

F.1-1.7.4.1 Lower Yuba River Accord (LYRA)

Not included in latest Alternative 3 model.

F.1-1.7.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.7.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.7.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Not included in latest Alternative 3 model.

F.1-1.7.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.7.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.7.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir end-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.7.5.2 Clear Creek

Same as Alternative 2 v1.

F.1-1.7.5.3 Sacramento River

Shasta Lake End-of-April and End-of-September Minimum Storage

Alternative 3 includes the following storage requirements for Shasta Reservoir:

- **End of April:**
  - Critical Year: 3.6 MAF
  - All Other Years: 3.9 MAF
- **End of September:**
  - Critical Year: 1.9 MAF
  - All Other Years: 2.2 MAF

Water year types are based on the Sacramento Valley (40-30-30) water year hydrologic classification index.

The Shasta Reservoir storage requirements are achieved through reduced reservoir releases. Beginning in February, Shasta inflow and outflow is estimated to predict end-of-April and end-of-September storage. Shasta inflow is estimated using 90% exceedance forecasts. Shasta outflow is estimated based on projected volumes of water needed to meet downstream demands and regulatory requirements. If storage conditions are estimated to be below storage targets, then CVP deliveries are adjusted based on what the projected Shasta water supply can support. Deliveries are reduced first from Agricultural service contracts, second from M&I service contracts, and third from settlement contracts.

Minimum Flow Below Keswick Dam

Same as No Action Alternative; includes Order 90-5 and stabilizing fall flows.

Winter-Spring Flow Objective at Bend Bridge

Subject to monthly modeling demonstrating that operations are reasonably likely to meet the Shasta storage requirements, Alternative 3 bypasses 55% of unimpaired inflow to Shasta Reservoir and inflows above Bend Bridge from December through May to achieve the monthly Delta Outflow Criteria in Table F.1-18, as described below for the Delta under the section on Delta Outflow. If the monthly Delta Outflow Criteria in Table F.1-18 can be met, then releases from Shasta Reservoir that month may be reduced to 45% of unimpaired inflows from December through May. If the Shasta storage requirement is not likely to be met, then releases from Shasta Reservoir may be reduced to 35% of unimpaired inflows.

Flow Objective at Wilkins Slough

Flow objective at Wilkins Slough is 3,250 cfs.

Minimum Flow Near Rio Vista

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.7.5.4 Feather River

Lake Oroville End-of-September Minimum Storage

Alternative 3 includes an end-of-September storage requirement of 1.6 MAF at Lake Oroville.

The Oroville storage requirement is achieved through reduced reservoir releases. Beginning in February, Oroville inflow and outflow is estimated to predict end-of-September storage. Oroville inflow is estimated using 90% exceedance forecasts. Oroville outflow is estimated based on projected volumes of water needed to meet downstream demands and regulatory requirements. If storage conditions are estimated to be below storage targets, then SWP deliveries are adjusted based on what the projected Oroville water supply can support. Deliveries are reduced first from service contracts, and then from settlement contracts.

Minimum Flow Below Thermalito

Same as No Action Alternative.

Winter-Spring Flow Objective Below Thermalito

Subject to monthly modeling demonstrating that operations are reasonably likely to meet the Oroville storage requirements, Alternative 3 bypasses 55% of unimpaired inflow to Oroville Reservoir and inflows above Thermalito from December through May to achieve the monthly Delta Outflow Criteria in Table F.1-18, as described below for the Delta under the section on Delta Outflow. If the monthly Delta Outflow Criteria in Table F.1-18 can be met, then releases from Oroville Reservoir that month may be reduced to 45% of unimpaired inflows from December through May. If the Oroville storage requirement is not likely to be met, then releases from Oroville Reservoir may be reduced to 35% of unimpaired inflows.

Voluntary Agreements

None

F.1-1.7.5.5 American River

Folsom Dam Flood Control

Same as No Action Alternative.

Minimum Flow Below Nimbus Dam

Minimum flow below Nimbus Dam is determined by the 2017 American River Modified Flow Management Standard, but using the 90 percent forecast exceedance for unimpaired inflows to Folsom and the Sacramento Valley (40-30-30) Index.

Winter-Spring Flow Objective Below Nimbus Dam

Subject to monthly modeling demonstrating that operations are reasonably likely to meet the Folsom storage requirements, Alternative 3 bypasses 55% of unimpaired inflow to Folsom Reservoir and inflows above Nimbus Dam from December through May to achieve the monthly Delta Outflow Criteria in Table F.1-18, as described below for the Delta under the section on Delta Outflow. If the monthly Delta Outflow Criteria in Table F.1-18 can be met, then releases from Folsom Reservoir that month may be reduced to 45% of unimpaired inflows from December through May. If the Folsom storage requirement is not likely to be met, then releases from Folsom Reservoir may be reduced to 35% of unimpaired inflows.

Minimum Flow At H Street

Same as No Action Alternative

Minimum Instream Flows (Minimum Release Requirements)

Alternative 3 includes the following storage requirements for Folsom Reservoir:

- **End of September:**
    - Second Consecutive Dry or Critical Year: 230 TAF
    - All Other Years: 300 TAF
- **End of December:**
    - All Years: 300 TAF

Water year types are based on the Sacramento Valley (40-30-30) water year hydrologic classification index.

Subject to monthly modeling demonstrating that operations are reasonably likely to meet the Folsom storage requirements, Alternative 3 bypasses 55% of unimpaired inflow to Folsom Reservoir from December through May to achieve the monthly Delta Outflow Criteria in Table F.1-18, as described below for the Delta under the section on Delta Outflow. If the monthly Delta Outflow Criteria in Table F.1-10 is met, then releases from Folsom Reservoir that month may be reduced to 45% of unimpaired inflows from December through May. If storage requirements are not likely to be met, then releases from Oroville Reservoir may be reduced to 35% of unimpaired inflows.

Voluntary Agreements

None

F.1-1.7.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam

Consistent with the 2018 Bay-Delta Water Quality Control Plan, this component is consistent with No Action in the summer and fall, and it requires reservoir releases to meet 40% of unimpaired flow to the confluence with the San Joaquin in February through June.

Minimum Dissolved Oxygen

Same as No Action Alternative.

Water Supply

Same as No Action Alternative, except under cases when the 40% unimpaired inflow requirement to New Melones controls, in which case, deliveries may be reduced to achieve the UIF requirement and a minimum end-of-September storage in New Melones of 700 TAF.

F.1-1.7.5.7 San Joaquin River

San Joaquin River Restoration Program

Same as No Action Alternative.

Maximum Salinity Near Vernalis

Same as No Action Alternative, and subject to off-ramps to meet storage requirements and bypass inflow up to 40% of unimpaired inflow to New Melones in February through June.

Minimum Flow Near Vernalis

In February through Junes, releases from New Melones contribute 29% of meeting the 1,000 cfs minimum flow required by the Bay Delta WQCP.

Voluntary Agreements

None

F.1-1.7.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641
Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action
Not included.

Combined Old and Middle River Flows
From the earlier of January 1 or the onset of Old and Middle River management, until the earlier of June 30 or the offramp of Old and Middle River Management, Old and Middle River flows shall not exceed -5,000 cfs. These requirements do not apply when San Joaquin River flows at Vernalis are greater than 20,000 cfs. In addition, when the Sacramento Valley index has been classified as a critically dry year for a second (or more) consecutive year, Old and Middle River flows shall not exceed -2,500 cfs.

From April 1 to May 31, Alternative 3 operates to achieve a 2:1 ratio of San Joaquin River inflow at Vernalis to combined CVP/SWP exports.

Delta Outflow
Winter-spring Delta outflow criteria are intended to reduce the adverse impacts of CVP/SWP operations on listed species, by increasing the abundance and productivity of Longfin Smelt, increasing survival of winter-run Chinook salmon, spring-run Chinook salmon, and Central Valley Steelhead (as a result of increased flows that increased survival in the Sacramento River and increase survival through the Delta), increasing recruitment of Delta Smelt, and increasing survival and abundance of green sturgeon. In addition to the requirements under D-1641, and consistent with modeling demonstrating that operations are reasonably likely to meet storage requirements described above, on a monthly basis, Reclamation and DWR operate to meet Delta Outflow that is the lesser of 65% of unimpaired Delta inflow or the Delta Outflow criteria in Table F.1-18.

Table F.1-18. Maximum Required Delta Outflow Criteria by Month and Water-Year Type (Lesser of 65% of Unimpaired Delta Outflow or Maximum Required Delta Outflow for month of December through June).

	Wet (cfs)	**Above Normal (cfs)**	**Below Normal (cfs)**	**Dry (cfs)**	**2nd consecutive Dry (cfs)**	**Critical (cfs)**	**2nd consecutive Critical (cfs)**	**3rd or more consecutive Critical (cfs)**
Jan.	90,000	90,000	29,000	20,000	11,400	11,400	7,100 cfs + OMR -2,500 cfs	No change
Feb. to May	90,000	90,000	29,000	20,000	11,400	11,400	7,100 cfs + OMR -2,500 cfs	No change
Jun.	D-1641	D-1641	D-1641	8,000	8,000	8,000	7,100 cfs to Jun. 15 then July criteria	4,000
Jul.	8,000	8,000	7,100	6,500	No change	5,000	No change	4,000
Aug.	7,100	7,100	6,900	6,900	No change	5,000	4,000	4,000
Sep.	8,100	7,100	5,000	4,000	No change	3,000	No change	No change
Oct.	8,100	7,100	5,000	4,000	No change	3,000	No change	No change
Nov.	Reservoir Inflow up to 7,100	Reservoir Inflow up to 7,100	5,000	4,500	No change	3,500	No change	No change
Dec.	65% UIF	65% UIF	65% UIF	65% UIF	No change	65% UIF	No change	No change

To meet the Delta outflow in Table F.1-18, consistent with annual modeling demonstrating that storage requirements are reasonably likely to be achieved, for the months of December through May Reclamation and DWR shall bypass 55% of unimpaired inflow to Shasta, Folsom, and Oroville reservoirs and 40% of unimpaired inflow to New Melones. In addition, for December through May, bypass of Delta exports may be used to achieve outflow criteria in Table F.1-18 or 65% of unimpaired Delta outflow if possible, as long as human Health and Safety requirements are met. If the storage requirements and monthly Delta Outflow criteria in Table F.1-18 can be met, then releases from Shasta, Folsom, and Oroville reservoirs that month may be reduced to 45% of unimpaired inflows from December through May. Release of stored water may be used to meet Delta outflow criteria in June through November.

The storage requirements described herein are prioritized above making additional reservoir releases beyond what is required to meet D-1641 and human health and safety.

South Delta Exports (Banks and Jones PP)

In addition to No Action Alternative, bypass of South Delta exports are issued to meet Delta Outflow criteria in Table F.1-18.

Spring Outflow Requirement

No additional actions.

Suisun Marsh Salinity Control Gates

The latest CalSim 3 model does not include the 7-day on/7-day off schedule implemented in Alternative 2v1.

Delta Cross Channel Gate Operation

Same as No Action Alternative.

X2

Same as No Action Alternative.

Voluntary Agreements

None.

Temporary Urgency Change Petition Representation

None.

F.1-1.7.6 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.7.6.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.7.6.2 Tidal Boundary

Same as No Action Alternative

F.1-1.7.6.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.7.6.4 Morphological Changes

No additional morphological changes were assumed.

F.1-1.7.6.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.7.6.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

DSM2 modeling for Alternative 3 includes the 7-day on/7-day off schedule implemented in Alternative 2v1.

F.1-1.7.7 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.7.7.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to "NGO" as described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.7.7.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3.

F.1-1.7.7.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.8 Alternative 4–Risk Informed Operations

F.1-1.8.1 CalSim 3

The following is description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.8.1.1 Hydrology

Inflows/Supplies
Same as No Action Alternative.

Level of Development
Same as No Action Alternative.

Demands, Water Rights, CVP/SWP Contracts
Same as No Action Alternative.

F.1-1.8.2 Facilities

Same as Alternative 1.

F.1-1.8.2.1 Fremont Weir

Same as No Action Alternative.

F.1-1.8.2.2 CVP C.W. Bill Jones Pumping Plant (Tracy PP) Capacity and Delta-Mendota Canal/California Aqueduct Intertie Capacity

Same as Alternative 1.

F.1-1.8.2.3 SWP Banks Pumping Plant Capacity

Same as No Action Alternative.

F.1-1.8.2.4 San Luis Reservoir

Same as Alternative 1.

F.1-1.8.2.5 CCWD Intakes

Same as No Action Alternative.

F.1-1.8.3 Regulatory Standards

The regulatory standards that govern the operations of the CVP and SWP facilities under Alternative 4 are briefly described below. Specific assumptions related to key regulatory standards are also outlined below.

F.1-1.8.3.1 D-1641 Operations

Same as No Action Alternative

F.1-1.8.3.2 Coordinated Operations Agreement (COA)

Same as Alternative 2v1.

F.1-1.8.3.3 CVPIA (b)(2) Assumptions

Same as No Action Alternative.

F.1-1.8.3.4 Continued CALFED Agreements

Same as No Action Alternative.

F.1-1.8.3.5 Temporary Urgency Change Petitions (TUCPs)

Same as No Action Alternative.

F.1-1.8.4 Water Transfers and Wheeling

F.1-1.8.4.1 Lower Yuba River Accord (LYRA)

Same as No Action Alternative.

F.1-1.8.4.2 Phase 8 Transfers

Same as No Action Alternative.

F.1-1.8.4.3 Short-term or Temporary Water Transfers

Same as No Action Alternative.

F.1-1.8.4.4 Cross Valley Canal Wheeling and Joint Point of Diversion

Same as No Action Alternative.

F.1-1.8.4.5 Contra Costa Wheeling through Freeport

Same as No Action Alternative.

F.1-1.8.5 Specific Regulatory Assumptions and Site-Specific Operations Criteria

F.1-1.8.5.1 Trinity River

Minimum Flow below Lewiston Dam

Same as No Action Alternative.

Trinity Reservoir end-of-September Minimum Storage

Same as No Action Alternative.

Trinity Import

Same as No Action Alternative.

F.1-1.8.5.2 Clear Creek

Same as Alternative 2v1.

F.1-1.8.5.3 Sacramento River

Shasta Lake End-of-September Minimum Storage

Shasta is operated using the Water Temperature and Storage Framework, similar to Alternative 2, with the following key differences.

- Carryover storage targets in all years are 2000 TAF instead of varying by Bin. The target carryover is used to calculate cuts to CVP Service Contractors in Bin2 and Bin3 years, and to determine cuts to Sacramento River Settlement Contractors in Bin3 years.
- October through April Shasta Inflow < 2.5 MAF is not used as a threshold for declaring a Bin3B year.
- Sacramento River Settlement Contractor allocation can be reduced to no lower than 60%.
- Stored water in Shasta due to reduced delivery is not tracked.
- In Bin 1B years, a factor is not applied to the reservoir balancing goals to prioritize Shasta storage.

A decision tree for determining Shasta Management Bins in Alternative 4 is shown in Figure F.1-3.

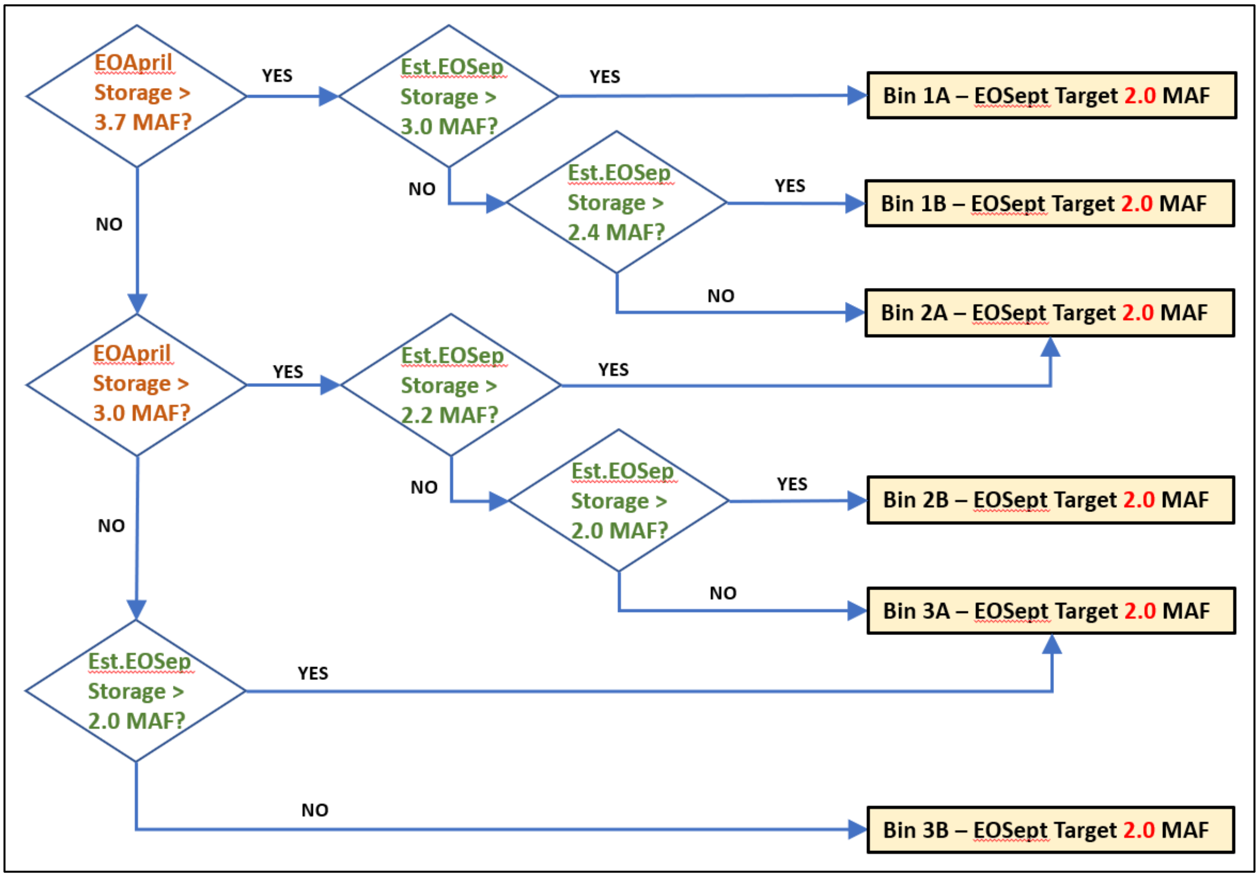

Figure F.1-3. Decision Tree for Shasta Management Bin

Minimum Flow Below Keswick Dam

Same as No Action Alternative.

Flow Objective at Wilkins Slough

Same as No Action Alternative.

Minimum Flow Near Rio Vista

Same as No Action Alternative.

Voluntary Agreements

None.

F.1-1.8.5.4 Feather River

Minimum Flow Below Thermalito

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.8.5.5 American River

Folsom Dam Flood Control

Same as No Action Alternative, but the minimum release requirement is 1,500 cfs (instead of 2,000 cfs) when the American River Index (ARI) exceeds 2,210 in October through December, 1,500 cfs (instead of 1,750 cfs) when the ARI exceeds 11,500 in January, and 1,500 cfs (instead of 1,750 cfs) when the ARI exceeds 1,958 in February and March.

Minimum Flow Below Nimbus Dam

Same as Alternative 2v1, but the end-of-December Folsom carryover target is 350 TAF instead of 275 TAF.

Minimum Flow At H Street

Same as No Action Alternative.

Voluntary Agreements

None

F.1-1.8.5.6 Stanislaus River

Minimum Flow Below Goodwin Dam

Same as Alternative 2v1. Contribution to Delta Outflow in Shasta Bin3B years is also the same as Alternative 2v1.

Minimum Dissolved Oxygen
Same as No Action Alternative.

Water Supply
Same as No Action Alternative.

F.1-1.8.5.7 San Joaquin River

San Joaquin River Restoration Program
Same as No Action Alternative.

Maximum Salinity Near Vernalis
Same as No Action Alternative.

Minimum Flow Near Vernalis
Same as No Action Alternative.

Voluntary Agreements
None

F.1-1.8.5.8 Sacramento-San Joaquin Delta

SWRCB D-1641
Same as No Action Alternative.

Delta Smelt Summer-Fall Habitat Action
Not included.

Combined Old and Middle River Flows
Projects operate to an OMR index no more negative than a 14-day moving average of -5,000 CFS between January 1 and June 30th except for the following conditions:

- **Integrated Early Winter Pulse Protection ("First Flush"):** After December 1 and through January 31, when running 3-day average of the daily flows at Freeport is greater than 25,000 cfs and running 3-day average of the daily turbidity at Freeport is 50 NTU or greater, or real-time monitoring indicates a high risk of migration and dispersal into areas at high risk of future entrainment, but not be required if ripe or spent female Delta Smelt are collected in monitoring surveys, Reclamation and DWR propose to operate to OMR index of negative 2,000 CFS for 14 days. The model index of SACRI is used to determine first flush conditions (SACRI greater than or equal to 20,000 CFS). This action is offramped when flows at Vernalis are greater than 10,000 cfs.

- **Start of OMR Management** has additional triggers which include the salvage or presence of Delta Smelt, Adult Longfin Smelt, and winter-run and spring-run Chinook Salmon. For the historical period from 2010–2022, the additional triggers causes the Start of OMR Management to occur earlier in December more often. Based on the historical record and water year type, a percentage of each December is covered by the baseline OMR Management requirement of OMR Index greater than -5,000 cfs.

- **Turbidity Bridge Avoidance:** January through March in any water year type, if first flush has already occurred and if the turbidity trigger is reached (SACRI greater than or equal to 20,000 CFS), Projects operate to OMR Index of negative 2,000 CFS for twelve days.
- **WIIN Act Storm-Related OMR Flexibility:** It is assumed that there may be storm-related OMR management flexibility in January and February. In all water year types, it is assumed that this action is triggered under the following conditions which dynamically determined in CalSim: the Delta is in excess conditions, X2 < 81 km, SACRI < 20,000 cfs, and QWest > +1,000 cfs. Each condition is determined based on the monthly timestep in CalSim.
- **Species-Specific Cumulative Salvage or Loss Threshold:** Since salvage or loss cannot be directly modeled in CalSim, historic salvage data at the fish facilities at Banks and Jones Pumping Plants and other triggers for these actions, including the use of the Graeta et al.'s machine learning model, were analyzed for the 2010–2022 period. Based on this historic data and water year type, the modeling used an OMR index of negative 3,500 CFS in a portion of each month from January through June.

Longfin Smelt actions were assumed to be covered by the actions for other species.

South Delta Exports (Banks and Jones PP)

Same as No Action Alternative.

Spring Outflow Requirement

No additional actions.

Suisun Marsh Salinity Control Gates

Similar to Alternative 2, but Alternative 4 does not have Dry year actions.

Delta Cross Channel Gate Operation

Same as No Action Alternative.

X2

The D-1641 February through June X2 criteria is included in the No Action Alternative simulation.

Delta outflow to manage X2 in the fall months following Sacramento Valley (40-30-30) Index wet and above normal years targets maintaining an average X2 for September and October no greater (more eastward) than 85 kilometers.

Voluntary Agreements

None.

Temporary Urgency Change Petition Representation

Same as No Action Alternative.

F.1-1.8.6 DSM2

The following is a description of the assumptions tabulated in Appendix F, Section F.1-2.

F.1-1.8.6.1 River Flows

For DSM2 simulation, the river flows at the DSM2 boundaries are based on the monthly flow time series from CalSim 3.

F.1-1.8.6.2 Tidal Boundary

Same as No Action Alternative.

F.1-1.8.6.3 Water Quality

Martinez EC

The Martinez EC boundary condition in the DSM2 planning simulation is estimated using the G-model based on the net Delta outflow simulated in CalSim 3 and the pure astronomical tide (Ateljevich 2001), as modified to account for the salinity changes related to the sea level rise using the correlations derived based on the three-dimensional (UnTRIM) modeling of the Bay-Delta with sea level rise at Year 2030.

Vernalis EC

For the DSM2 simulation, the Vernalis EC boundary condition is based on the monthly San Joaquin EC time series estimated in CalSim 3.

F.1-1.8.6.4 Morphological Changes

No additional morphological changes were assumed as part of the No Action Alternative.

F.1-1.8.6.5 Facilities

Delta Cross Channel

Delta Cross Channel gate operations are modeled in DSM2. The number of days in a month the DCC gates are open is based on the monthly time series from CalSim 3.

South Delta Temporary Barriers

South Delta Temporary Barriers are included in the No Action Alternative simulation. The three agricultural temporary barriers located on Old River, Middle River and Grant Line Canal are included in the model; however, the fish barrier located at the Head of Old River is not included in the model.

Clifton Court Forebay Gates

Same as No Action Alternative.

F.1-1.8.6.6 Operations Criteria

South Delta Temporary Barriers

South Delta Temporary Barriers are operated based on San Joaquin flow conditions. The agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and the one on Grant Line Canal from June 1. All three agricultural barriers are allowed to operate until November 30. The tidal gates on Old and Middle River agricultural barriers are assumed to be tied open from May 16 to May 31. Head of Old River Barrier would not be installed.

Suisun March Salinity Control Gate

The radial gates in the Suisan Marsh Salinity Control Gate Structure are assumed to be tidally operating based on the operational time series outputs from CalSim 3.

When operating, gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps. When not operating, gates are held open.

F.1-1.8.7 HEC-5Q

The following is a description of the assumptions listed in Appendix F, Section F.1-2.

F.1-1.8.7.1 Sacramento-Trinity Rivers

Reservoir Storage Conditions

Trinity Lake, Lewiston Lake, Whiskeytown Lake, Shasta Lake, Keswick Reservoir, and Black Butte Lake are all operated per CalSim 3 output.

Shasta Temperature Management

Shasta temperature control device (TCD) operated to “carryover” and “2021 tiers” described in Appendix F, Attachment F.1-3.

Trinity Temperature Management

Releases from lower, auxiliary outlet are allowed when normal outlet releases are too warm.

F.1-1.8.7.2 American River

Reservoir Storage Conditions

Folsom Lake and Lake Natoma are operated per CalSim 3 output.

Folsom Temperature Management

Similar to 2009 NMFS Biological Opinion Appendix 2D modeled as described in Appendix F, Attachment F.1-3, updated to the modified Automated Temperature Selection Protocol (ATSP) tiers under current revision.

F.1-1.8.7.3 Stanislaus River

Reservoir Storage Conditions

New Melones Lake, Lake Tulloch, and Goodwin Reservoir are all operated per CalSim 3 output.

F.1-1.9 References

Ateljevich, E. 2001. Chapter 10: Planning tide at the Martinez boundary. Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 22nd Annual Progress Report to the State Water Resources Control Board.

Ateljevich, E., and M. Yu. 2007. Chapter 4: Extended 82-year Martinez planning tide. Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh, 28th Annual Progress Report to the State Water Resources Control Board.

Bureau of Reclamation. 2008. 2008 Central Valley Project and State Water Project Operations Criteria and Plan Biological Assessment, Appendix F DSM2 Model. May.

Bureau of Reclamation. 2017. Yolo Bypass Salmonid Habitat Restoration & Fish Passage. Draft Environmental Impact Statement Environmental Impact Report, December 2017.

Bureau of Reclamation. 2019. B.F. Sisk Dam Safety of Dams Modification Project Final Environmental Impact Statement/Environmental Impact Report, August 2019.

Appendix F, Modeling

Section F.1-2 Callouts Tables

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- No Action Alternative 090723 (NAA)
- ALT1 090923 (ALT1)
- Alt2woTUCPwoVA 091324 (Alt2woTUCPwoVA)
- Alt2woTUCPDeltaVA 091324 (Alt2woTUCPDeltaVA)
- Alt2woTUCPAllVA 091324 (Alt2woTUCPAllVA)
- Alt2wTUCPwoVA 091324 (Alt2wTUCPwoVA)
- ALT3 092423 (ALT3)
- ALT4 091624 (ALT4)

F.1-2.1 CalSim 3

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
GENERAL								
Planning horizon	Year 2040	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Period of simulation	100 years (1922-2021)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Sea Level Rise	15 cm	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
HYDROLOGY								
Climate Condition	2022±15 Median	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Inflows/Supplies	Modified inflows based on historical hydrology projected 2020 modifications for operations upstream of the rim reservoirs	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Level of development	Average historical land use (2004-2013) with urban demands based on 2020 Urban Water Management Plans	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
DEMANDS, WATER RIGHTS, CVP/SWP CONTRACTS								
Sacramento River Region (excluding American River)								
CVP	Land-use based applied water demands, 2020 Urban Water Management Plan based urban demands, deliveries limited by contract amounts	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
SWP (FRSA)	Land-use based applied water demands, deliveries limited by contract amounts	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Non-project	Land use based applied water demands 2020 Urban Water Management Plan based urban demands	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Antioch Water Works	Pre-1914 water right	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Federal refuges	Firm Level 2 water supply needs	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Sacramento River Region - American River								
Water rights	Demands based on 2020 Urban Water Management Plans, deliveries limited to 2025 water rights	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
CVP	Demands based on 2020 Urban Water Management Plans, deliveries limited to 2025 water rights, including Freeport Regional Water Project	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
San Joaquin River Region								
Friant Unit	Limited by contract amounts, based on current allocation policy	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lower Basin	Land-use based applied water demand, urban demands based on 2020 Urban Water Management Plans, deliveries based on district level operations and constraints	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Stanislaus River	Land-use based demand, Stepped Release Plan (SRP)	Same as NAA	Land-use based demand, Stepped Release Plan (SRP) with modified Winter Instability Flows and 90% exceedance San Joaquin 60-20-20 WY type	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as NAA	Same as NAA
San Francisco Bay, Central Coast, Tulare Lake, and South Coast Regions (CVP/SWP project facilities)								
CVP	Demand based on full contract amounts	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
CCWD	195 TAF/yr CVP contract supply, water rights and in-Delta transfers	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
SWP	Demand based on Table A amounts	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Article 56	Based on 2014-19 initial contractor requests	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Article 21	MWD delivery up to 286.17 TAF/year January-May subject to conveyance capacity, KCWA delivery up to 543.69 TAF/year November-June, and other contractor deliveries up to 333.45 TAF/year , subject to conveyance capacity. All Article 21 demands have been scaled up by 20% to not constrain deliveries strictly by historical data.	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
North Bay Aqueduct (NBA)	77 TAF/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville, and Benicia Settlement Agreement	Same as NAA	77 TAF/yr demand under SWP contracts, up to 43.7 cfs of excess flow under Fairfield, Vacaville, and Benecia Settlement Agreement; 100 cfs limit Jan-Mar of Dry and Critical Years	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs
Federal refuges	Firm Level 2 water needs	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
FACILITIES								
Systemwide								
Systemwide	Existing facilities	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Trinity River Region								
Trinity Lake	Operated up to existing capacity of 2,448 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Clear Creek Tunnel	Operated up to existing capacity of 3,300 cfs	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Spring Creek Tunnel	Operated up to a capacity of 4,200 cfs	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Whiskeytown Lake	Operated up to existing capacity of 240 TAF.	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Sacramento River Region								
Shasta Lake	Operated up to existing 4,552 TAF capacity	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Keswick Reservoir	Operated up to existing capacity of 23.8 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Red Bluff Diversion Dam	Diversion dam gates out all year. Pumping Plant operated to deliver CVP water with capacity of 2,000 cfs.	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Hamilton City Pump Station	Pumping plant with capacity of 3,000 cfs.	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Fremont Weir	Notched Fremont Weir as represented in Yolo Bypass Salmonid Habitat Restoration and Fish Passage EIS/EIR Alternative 1 (preferred alternative)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Colusa Basin	Existing conveyance and storage facilities	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lake Oroville	Operated up to existing capacity of 3,538 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Thermalito Complex	Operated up to existing capacity of 55 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Upper American River	PCWA American River Pump Station	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Folsom Lake	Operated up to existing capacity of 976 TAF including auxiliary spillway	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Folsom South Canal	Operated up to existing capacity	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lake Natoma	Operated up to existing capacity of 8.8 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lower Sacramento River	Full water rights diversions and Freeport Regional Water Project	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
San Joaquin River Region								
Millerton Lake (Friant Dam)	Operated up to existing capacity of 524 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lower San Joaquin River	City of Stockton Delta Water Supply Project, 30-mgd capacity. SJRRP Recapture simulated at West Stanislaus ID, Patterson ID, and Banta Carbona ID	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
New Melones	Operated up to existing capacity up to 2420 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
CVP and SWP San Luis	San Luis operated to manage all exports up to existing 2041 TAF capacity	San Luis to be raised to CVP capacity of 1102 TAF; SWP capacity to remain the same	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
SWP Banks Pumping Plant (South Delta)	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months. Pumping can be up to 10,300 cfs during Dec 15 – Mar 15 depending on Vernalis flow conditions; additional capacity of 500 cfs (up to 7,180 cfs) allowed Jul – Sep	Same as NAA	Physical capacity is 10,300 cfs but 6,680 cfs permitted capacity in all months. Pumping can be up to 10,300 cfs during Dec 1 – Mar 31 depending on Vernalis flow conditions; additional capacity of 500 cfs (up to 7,180 cfs) allowed Jul – Sep	Same as Alt2v1 w/out TUCPs	Same as Alt2v1 w/out TUCPs	Same as Alt2v1 w/out TUCPs	Same as NAA	Same as NAA
CVP C.W. Bill Jones Pumping Plant (Tracy PP)	Permit capacity is 4,600 cfs in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Upper Delta-Mendota Canal Capacity	Design capacity plus 400 cfs Delta-Mendota Canal–California Aqueduct Intertie	Design capacity plus 700 cfs Delta-Mendota Canal–California Aqueduct Intertie	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1	Same as Alternative 1
CCWD Intakes	Los Vaqueros Reservoir with existing storage capacity (160 TAF), and existing intakes except for Mallard Slough Intake. Intake water quality conditions based on DSM2	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Suisun March Salinity Control Gates (SMSCG)	Delta salinity conditions are adjusted for months in which the salinity control gate is operated (see operations)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
San Francisco Bay Region								
South Bay Aqueduct (SBA)	Existing 430 cfs capacity	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
South Coast Region								
California Aqueduct East Branch	Existing capacity	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
REGULATORY STANDARDS								
North Coast Region								
Trinity River								
Minimum flow below Lewiston Dam	Trinity EIS Preferred Alternative (369-815 TAF/yr)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Trinity River Fall Augmentation Flows	420 cfs August 1 through September 30 in all but wet years	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Trinity Reservoir end-of-September minimum storage	Trinity EIS Preferred Alternative (600 TAF as able)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Sacramento River Region								
Clear Creek								
Minimum flow below Whiskeytown Dam	Downstream water rights, 1963 USBR Proposal to USFWS and NPS; and 200 cfs October through May or 150 cfs in Critical years and 150 cfs June through September with 10 TAF for channel maintenance in February of BN, AN and Wet years and 10 TAF for Spring pulse flows in June of non-Critical years; in June of Critical years, pulse of 900 cfs.	Downstream water rights, Instream Flow Preservation Agreement (2000) 50 cfs January through October and 100 cfs (70 cfs in C years) November through December	Clear Creek seasonally variable hydrograph minimum flows (200 cfs annual average; oscillating from 300 cfs in winter to 100 cfs in summer) with 10 TAF for pulse flows except in C years. 5 TAF for pulse flows in C years. Additionally: target 150 cfs in C years; not to exceed 840 cfs (safe outflow works capacity of Whiskeytown)	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Upper Sacramento River								
Shasta Lake storage targets	1,900 TAF end-of-September in non-critically dry years (not explicitly modeled - achieved through project allocation profiles when hydrologically feasible)	NMFS 2004 Winter-Run Biological Opinion (1,900 TAF end-of-September in non-critically dry years; not explicitly modeled; achieved through project allocation procedures when hydrologically feasible)	Carryover targets based upon May 1 fill and carryover projection – actions designed to help meet targets may not accomplish full intent.	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs. Carryover for Sacramento VA omitted from carryover target calculations	End-of-April: 3,900 TAF in non-critically dry years, 3,600 TAF in critically dry years - met through reduced releases. End-of-September: 2,200 TAF in non-critically dry years, 1,900 TAF in critically dry years - met through reduced releases.	Carryover target is 2,000 TAF in all years – actions designed to help meet target may not accomplish full intent
Minimum flow below Keswick Dam	SWRCB WR 90-5; and stabilize fall flows to reduce redd dewatering and rebuild cold water pool; and spring pulse flow up to 150 TAF if projected May 1 storage > 4.1 MAF	SWRCB WR 90-5 and stabilize fall flows to reduce redd dewatering and rebuild cold water pool	WR 90-5; 2019 BO Fall-Winter Base flows 3,250-5,000 cfs based on end of September Shasta storage; Up to150 taf Spring Pulse in Wet & AN year types if 4.1 MAF fill likely by May 1	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	SWRCB WR 90-5; and stabilize fall flows to reduce redd dewatering and rebuild cold water pool; and subject to storage and Delta Outflow offramps, bypass inflow up to 55% of unimpaired inflow, as measured at Bend Bridge, from Dec-May and bypass inflow up to 45% of unimpaired inflow if DO objectives met (see Table 18 in Section 1-1)	Same as Alternative 2 without VAs and without TUCPs
Feather River								
Minimum flow below Thermalito Diversion Dam	2006 Settlement Agreement (700 / 800 cfs)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Minimum flow below Thermalito Afterbay outlet	1983 DWR, DFG Agreement (750-1,700 cfs)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	1983 DWR, DFG Agreement (750-1,700 cfs); and subject to storage (target of 1.6 MAF in EO-Sep) and Delta Outflow offramps, bypass inflow up to 55% of unimpaired inflow from Dec-May and bypass inflow up to 45% of unimpaired inflow if DO objectives met (see Table 18 in Section 1-1)	Same as NAA
Yuba River								
Minimum flow below Daguerre Point Dam	D-1644 Operations (Lower Yuba River Accord)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
American River								
Minimum flow below Nimbus Dam	American River Flow Management Standard, per 2017 Water Forum Agreement with a planning minimum end of December storage target modeled as 275 TAF	SWRCB D-893	American River Flow Management Standard, per 2017 Water Forum Agreement using a 90% forecast, no reduction Apr-Jun for March pulse, with a planning minimum end of December storage target modeled as 275 TAF	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	American River Flow Management Standard, per 2017 Water Forum Agreement with a planning minimum end of December storage target modeled as 300 TAF ; and subject to storage (target 300 TAF EO-Sep and 230 TAF in consecutive D or C years) and Delta Outflow offramps, bypass inflow up to 55% of unimpaired inflow from Dec-May and bypass inflow up to 45% of unimpaired inflow if DO objectives met (see Table 18 in Section 1-1)	American River Flow Management Standard, per 2017 Water Forum Agreement with a planning minimum end of December storage target modeled as 350 TAF
Minimum Flow at H Street Bridge	SWRCB D-893	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Lower Sacramento River								
Minimum flow near Rio Vista	SWRCB D-1641	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
San Joaquin River Region								
Mokelumne River								
Minimum flow below Camanche Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Minimum flow below Woodbridge Diversion Dam	FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Stanislaus River								
Minimum flow below Goodwin Dam	Flows per New Melones SRP	1987 USBR-CDFW Agreement	Flows per New Melones SRP with modified Winter Instability Flows	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Flows per New Melones SRP; and subject to storage offramps, bypass inflow up to 40% of unimpaired inflow February through June	Same as Alternative 2 without VAs and without TUCPs
Minimum dissolved oxygen	SWRCB D-1422	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Merced River								
Minimum flow below Crocker-Huffman Diversion Dam	Cowell Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Minimum flow at Shaffer Bridge	FERC 2179 (25-100 cfs) with 12.5 TAF in October based on 2002 Merced ID and CDFW Memorandum of Understanding	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Tuolumne River								
Minimum flow at Lagrange Bridge	FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/yr)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
San Joaquin River								
San Joaquin River below Friant Dam/ Mendota Pool	5 cfs Gravelly Ford San Joaquin River Restoration-full flows, not constrained by current river capacity, model implementation includes recapture in the San Joaquin River and in the Delta	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Maximum salinity near Vernalis	Stanislaus contribution per New Melones SRP	SWRCB D-1641	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Stanislaus contribution per New Melones SRP; and subject to storage offramps, bypass inflow up to 40% of unimpaired inflow February through June	Same as NAA
Minimum flow near Vernalis	Stanislaus contribution per New Melones SRP	SWRCB D-1641 flow requirement at Vernalis, not including pulse flows during the April 15 – May 15 period	Same as NAA	Same as NAA	Same as NAA	Same as NAA	In February through June, releases from New Melones contribute 29% of meeting the 1,000 cfs minimum flow required by the Bay-Delta WQCP; and deliveries may be reduced to achieve a minimum EO-Sep storage in New Melones of 700 TAF	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Sacramento River–San Joaquin Delta Region								
Delta Outflow Index (Flow, NDOI)	SWRCB D-1641 and for Summer/Fall Delta Smelt habitat operate to meet X2 of 80 km for September and October of AN and Wet years with transitional flows in last half of August. SWP to allow up to 150 TAF of Delta outflow in April and May. Spring outflow action shall not exceed 150 TAF and is subject to a 44,500 cfs Delta Outflow off-ramp. SWP to release 100 TAF block of water in Jun through Sep of Wet and Above Normal years.	SWRCB D-1641	SWRCB D-1641 and for Summer/Fall Delta Smelt habitat operate to meet X2 of 80 km for September and October of AN and Wet years with transitional flows in last half of August.	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs with additional flow provided by Delta VA	Same as Alternative 2 without VAs and without TUCPs with additional flow provided by VAs	Subject to storage requirements, achieve NGO DO criteria that varies by month and WYT. In December through May, the maximum required Delta outflow is the lesser of 65% of unimpaired Delta outflow or the requirements in Table 18 in Section 1-1. In June through November, the maximum required Delta outflow is the requirements in Table 18 in Section 1-1. DO targets can be achieved through reduced deliveries, bypass of unimpaired inflow to Shasta, Oroville, Folsom, and New Melones, and bypass of Delta exports.	SWRCB D-1641 and for Summer/Fall Delta Smelt habitat operate to meet X2 of 85 km for September and October of AN and Wet years.
Delta Cross Channel gate operation	Gate operations per Multi Year Study Program; model representation as SRWCB D-1641 with additional days closed from Oct 1 – Jan 31. Gates closed during flushing flows from Oct 1 – Nov 30 unless adverse water quality conditions would result, and always closed during Dec 1 – January 31.	SWRCB D-1641	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
South Delta export limits (Jones PP and Banks PP)	SWRCB D-1641 Vernalis flow-based export limits Apr 1 – May 31, (additional 500 cfs allowed for Jul – Sep for reducing impact on SWP)	SWRCB D-1641 (additional 500 cfs allowed for Jul - Sep).	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Bypass of South Delta exports issued to meet Delta outflow criteria in Table 18 of Section 1-1	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Combined Flow in Old and Middle River (OMR)	OMR target of -5,000 cfs January through June except for 5 days of -2,000 cfs when turbidity bridge occurs (turbidity bridge consideration only January through March) and 7 days of -6,000 cfs when increased pumping due to storm is possible, followed by “first flush” action if it occurs in December or January (14 days of -2,000 cfs), and single year loss threshold limits OMR Index > -3,500 cfs for a portion of January-June. Health and Safety offramp when exports are low.	No target	OMR target of -5,000 cfs January through June except for 10 days of -3,500 cfs when turbidity bridge occurs (turbidity bridge consideration only January through March) and 6 days of -6,250 cfs when increased pumping due to storm flex is possible, followed by “first flush” action if it occurs in December or January (14 days of -2,000 cfs). Actions triggered by salvage of fish limit OMR Index > -3,500 cfs for a portion of January-June. Health and Safety off-ramp when exports are low.	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	From the earlier of Jan 1 or the onset of OMR management - target -5,000 cfs on a 14-day running avg. Requirements do not apply when SJR at Vernalis exceeds 20,000 cfs. In consecutive C years, OMR target is -2,500 cfs. From Apr 1 - May 31, target a 2:1 ratio of SJR inflow at Vernalis to combined CVP/SWP exports	Same as Alternative 2 without VAs and without TUCPs but with the following differences: First Flush has a high flow offramp, the OMR Management season can be triggered by the presence or salvage of protected Smelt or Salmonids, Turbidity Bridge can trigger through the end of March, and some additional differences in the actions triggered by salvage during the OMR Management season.
Temporary Urgency Change Petition	Spring and Summer relaxations of D1641 criteria triggered by low Shasta storage and/or SacIndex value; Feb-Apr 4000 cfs NDOI requirement in lieu of X2 standards; May-Sep (1) Emmaton EC standard moved to Threemile Slough via regression equation, (2) 4000 cfs NDOI requirement in lieu of X2 in May, (3) 3000 cfs NDOI standard Jun-Sep; (4) exports limited to H&S if NDOI is less than the full regulatory standard.	None	None	Same as NAA	None	None	None	Same as NAA
OPERATIONS CRITERIA: RIVER-SPECIFIC								
Sacramento River Region								

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Upper Sacramento River: Flow objective for navigation (Wilkins Slough)	Flow objective for Wilkins Slough based on month, CVP allocation, and Shasta storage condition to reflect CVP operations for local delivery	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
American River: Folsom Dam flood control	Variable 400/600 flood control diagram (without outlet modifications)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Feather River: Flow at Mouth of Feather River (above Verona)	Maintain DFW/DWR flow target of 2,800 cfs for Apr – Sep when flows available dependent on Oroville inflow and FRSA allocation	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Maintain DFW/DWR flow target of 2,800 cfs for Apr – Sep when flows available dependent on Oroville inflow and FRSA allocation; and in December through May, bypass inflow up to 55% of unimpaired inflow to Oroville storage from to achieve Delta Outflow criteria. and bypass inflow up to 45% unimpaired inflow if DO criteria is met.	Same as NAA
Sacramento VA	None	None	None	None	None	April-May pulse flows in Sac 40-30-30 WY type AN/BN/D years, protected through Delta. Source of water is 25,000 acres of land fallowing. 95 taf total provided in AN/BN years. In Dry years water from reduced deliveries is carried over in Shasta and released in the following April-May (subject to spills).	None	None
Feather VA	None	None	None	None	None	April-May pulse flows of 60 taf in Sac 40-30-30 WY type AN/BN/D years, protected through Delta. Source of water is 10,000 acres of land fallowing. Releases can continue later in year depending on spills.	None	None

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
American VA	None	None	None	None	None	Mar-May flows in all but Sac 40-30-30 WY type Wet years, protected through Delta. Water sources are GW substitution and reservoir reoperation. 10 taf in AN/BN years, 40 taf in D years, 30 taf in C years.	None	None
Mokelumne VA	None	None	None	None	None	Additional flow of 45 taf in AN years, 20 taf in BN years, 10 taf in D years, based on Mokelumne JSA WY type. 79% of water released in Mar-May and 21% in October. Water provided through reservoir reoperation. Not protected through Delta.	None	None
Yuba VA	None	None	None	None	None	April-June flows of 50 taf in Sac 40-30-30 WY type AN/BN/D years, provided through reservoir reoperation and protected through Delta. Timeseries of flows provided by Yuba Water Agency.	None	None
Putah Creek VA	None	None	None	None	None	Additional flow of 6 taf in November-May provided in all but Sac 40-30-30 WY type Wet years through reservoir reoperation. Not protected through Delta.	None	None

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
San Joaquin River Region								
Stanislaus River: Flow below Goodwin Dam	Flows per New Melones SRP	New Melones Interim Plan of Operations, which includes flows under the 1987 USBR-CDFW Agreement and CVPIA Section 3406(b)(2)	Flows per New Melones SRP with modified Winter Instability Flows, using 90% forecast of San Joaquin 60-20-20 WY type	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Flows per New Melones SRP; using 90% forecast of San Joaquin 602020 WY type; and subject to storage offramps, bypass inflow up to 40% of unimpaired inflow February through June	Same as Alternative 2 without VAs and without TUCPs
San Joaquin River: Salinity at Vernalis	Grasslands Bypass Project (full implementation)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Friant VA	None	None	None	None	None	50 taf flow contribution in February-May in SJRRP Dry, Normal-Dry, and Normal-Wet years, protected through Delta. Met through foregone SJRRP recapture and Friant flood releases. Foregone recapture is limited to 50% of total possible recapture, which can limit flow contribution.	None	None

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Sacramento – San Joaquin River Delta Region								
Suisun Marsh Salinity Control Gates	Operate to meet SWRCB D-1641 water quality standards in Montezuma Slough during salinity control season October through May; and for Summer/Fall Delta Smelt habitat operate for up to 60 days June through October of Below Normal, Above Normal, and Wet years. SWP facilitates operations for up to 60 days in June through October of Dry years.	Operate to meet SWRCB D-1641 water quality standards in Montezuma Slough during salinity control season October through May	Operate to meet D-1641 water quality standards October through May. Summer/Fall Delta Smelt habitat action operates for 60 days June through October of Sacramento Valley (40-30-30) Index Above Normal, Below Normal, and Dry years following Wet or Above Normal years and 30 days in Dry years following Below Normal years using a 7-day on, 7-day off schedule.	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs except no Dry year actions.
Delta VA	None	None	None	None	Additional Delta outflow provided Mar-May through export cuts and PWA water purchase program, based on Sac 40-30-30 WY type. CVP provides a total of 27, 147, 107, 86, and 2 taf in W, AN, BN, D, and C years respectively. SWP provides a total of 117.5 taf in AN years and 92.5 taf in BN/D years.	Same as Alternative 2 with Delta VA	None	None
OPERATIONS CRITERIA: SYSTEMWIDE								
CVP water allocation								

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
Settlement / Exchange	100% (75%/77% in Shasta critical years)	Same as NAA	Maximum potential allocation of 100% (75%/77% in Shasta critical years); Settlement allocation reduced to cut up to 500 TAF in Shasta Bin3B years as needed to meet Shasta carryover target to reflect SRSC contribution	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Maximum potential allocation of 100% (75%/77% in Shasta critical years); potential allocation is reduced to meet storage and Delta Outflow criteria (in Table 18 in Section 1-1 9); When delivery potential cannot satisfy all demand, deliveries to settlement / exchange contracts are reduced only after first reducing delivery to Ag services contracts and M&I service contracts	Maximum potential allocation of 100% (75%/77% in Shasta critical years); Settlement allocation reduced to as low as 60% in Shasta Bin3B years, as needed to meet Shasta carryover target to reflect SRSC contribution
Refuges	100% Firm Level 2 (75% in Shasta critical years)	Same as NAA	NOD Refuge allocation reduced to SRSC level in Bin3B years if less than base refuge allocation	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as NAA	Same as Alternative 2 without VAs and without TUCPs
Agriculture Service	100%-0% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action	100% - 0% based on supply	100%-0% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action; Additional allocation reductions taken to address Shasta action carryover target	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	100%-0% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action; potential allocation is reduced to meet storage and Delta Outflow criteria (in Table 18 in Section 1-1)	Same as Alternative 2 without VAs and without TUCPs
Municipal & Industrial Service	100%-50% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action; 25% in TUCP years	100% - 50% based on supply	100%-50% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action; 25% in TUCP years and Shasta Bin3B years	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	Same as Alternative 2 without VAs and without TUCPs	100%-50% based on supply, South-of-Delta allocations are additionally limited due to D-1641 and OMR action; potential allocation is reduced to meet storage and Delta Outflow criteria (in Table 18 in Section 1-1 9); When delivery potential cannot satisfy all demand, M&I deliveries are reduced after Ag service contract deliveries are reduced	Same as Alternative 2 without VAs and without TUCPs
Friant Allocation	Class 1, Class 2, and 215 water deliveries as allocated given water supply.	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
SWP water allocation								
North of Delta (FRSA)	Contract specific	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Contract specific; potential allocation is reduced to meet storage and Delta Outflow criteria (in Table 18 in Section 1-1 9); When delivery potential cannot satisfy all demand, FRSA deliveries are reduced only after service contract are reduced	Same as NAA
South of Delta (including North Bay Aqueduct)	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement; allocations are additionally limited due to D-1641 and OMR action and Spring Outflow Action.	Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Potential allocation is reduced to meet storage and Delta Outflow criteria (in Table 18 in Section 1-1); Exports are limited to flows available after Delta outflow targets are met	Same as NAA
CVP-SWP coordinated operations								
Sharing of responsibility for in-basin-use	Revised Coordinated Operations Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Sharing of surplus flows	Revised Coordinated Operations Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Sharing of restricted export capacity for project- specific priority pumping	Revised Coordinated Operations Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Water transfers	Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users; LYRA included for SWP contractors	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	None	Same as NAA
Sharing of export capacity for lesser priority and wheeling-related pumping	Cross Valley Canal wheeling (max of 128 TAF/yr), CALFED ROD defined Joint Point of Diversion (JPOD)	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	None	Same as NAA

	No Action Alternative	Alternative 1	Alternative 2 without VAs and without TUCPs	Alternative 2 without VAs and with TUCPs	Alternative 2 with Delta VAs	Alternative 2 with VAs	Alternative 3	Alternative 4
San Luis Reservoir	San Luis Reservoir is allowed to operate to a minimum storage of 80 TAF	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
CVPIA 3406(b)(2)								
Policy Decision	N/A	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Allocation	No B2 Allocation modeled	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Actions	Pre-determined upstream fish flow objectives below Whiskeytown Dam	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Accounting	No B2 Accounting modeled	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
WATER MANAGEMENT ACTIONS								
Water Transfer Supplies (long term programs)								
Lower Yuba River Accord	Yuba River acquisitions for reducing impact of D-1641 and OMR Action export restrictions on SWP	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Phase 8	None	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA	Same as NAA

F.1-2.2 DSM2

	No Action Alternative (NAA)	Alternative 1 (Alt 1)	Alternative 2 [h] (Alt 2)	Alternative 3 (Alt 3)	Alternative 4 (Alt 4)
Period of simulation	100 years (1922-2021)a	Same as NAA	Same as NAA	Same as NAA	Same as NAA
BOUNDARY CONDITIONS					
Boundary flows	Monthly timeseries from CALSIM 3 output (alternatives provide different flows and exports) [b]	Monthly timeseries from CALSIM 3 output (alternatives provide different flows and exports) [b]	Monthly timeseries from CALSIM 3 output (alternatives provide different flows and exports) [b]	Monthly timeseries from CALSIM 3 output (alternatives provide different flows and exports) [b]	Monthly timeseries from CALSIM 3 output (alternatives provide different flows and exports) [b]
Ag flows (DICU) [e]	2020 Level, DWR Bulletin 160-98 [c]	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Martinez stage	15-minute adjusted astronomical tide a	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Vernalis EC	Monthly time series from CALSIM 3 output [d]	Monthly time series from CALSIM 3 output [d]	Monthly time series from CALSIM 3 output [d]	Monthly time series from CALSIM 3 output [d]	Monthly time series from CALSIM 3 output [d]
Agricultural Return EC	Municipal Water Quality Investigation Program analysis	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Martinez EC	Monthly net Delta Outflow from CALSIM output & G-model [f]	Monthly net Delta Outflow from CALSIM output & G-model [f]	Monthly net Delta Outflow from CALSIM output & G-model [f]	Monthly net Delta Outflow from CALSIM output & G-model [f]	Monthly net Delta Outflow from CALSIM output & G-model [f]
FACILITIES					
Freeport Regional Water Project	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3
Delta Cross Channel	Monthly time series of number of days open from CALSIM 3 output	Monthly time series of number of days open from CALSIM 3 output	Monthly time series of number of days open from CALSIM 3 output	Monthly time series of number of days open from CALSIM 3 output	Monthly time series of number of days open from CALSIM 3 output
Stockton Delta Water Supply Project	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3
Barker Slough Pumping Plant	Pumping consistent with SWP contracts and excess flow under Fairfield, Vacaville, and Benicia Settlement Agreement	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Franks Tract Program	None	None	None	None	None
Veale Tract Drainage Relocation	The Veale Tract Water Quality Improvement Project, funded by CALFED, relocates the agricultural drainage outlet was relocated from Rock Slough channel to the southern end of Veale Tract, on Indian Slough [f]	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Clifton Court Forebay	Priority 3, gate operations synchronized with incoming tide to minimize impacts to low water levels in nearby channels	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Contra Costa Water District Delta Intakes	Rock Slough Pumping Plant, Old River at Highway 4 Intake and Alternate Improvement Project Intake on Victoria Canal	Same as NAA	Same as NAA	Same as NAA	Same as NAA

	No Action Alternative (NAA)	**Alternative 1 (Alt 1)**	**Alternative 2 [h] (Alt 2)**	**Alternative 3 (Alt 3)**	**Alternative 4 (Alt 4)**
South Delta barriers	Temporary Barriers Project operated based on San Joaquin River flow time series from CALSIM 3 output; Head of Old River Barrier (HORB) is not installed; Agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and on Grant Line Canal from June 1; All three barriers are allowed to be operated until November 30; May 16 to May 31; the tidal gates are assumed to be tied open for the barriers on Old and Middle Rivers.	Temporary Barriers Project operated based on San Joaquin River flow time series from CALSIM 3 output; Head of Old River Barrier (HORB) is not installed; Agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and on Grant Line Canal from June 1; All three barriers are allowed to be operated until November 30; May 16 to May 31; the tidal gates are assumed to be tied open for the barriers on Old and Middle Rivers.	Temporary Barriers Project operated based on San Joaquin River flow time series from CALSIM 3 output; Head of Old River Barrier (HORB) is not installed; Agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and on Grant Line Canal from June 1; All three barriers are allowed to be operated until November 30; May 16 to May 31; the tidal gates are assumed to be tied open for the barriers on Old and Middle Rivers.	Temporary Barriers Project operated based on San Joaquin River flow time series from CALSIM 3 output; Head of Old River Barrier (HORB) is not installed; Agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and on Grant Line Canal from June 1; All three barriers are allowed to be operated until November 30; May 16 to May 31; the tidal gates are assumed to be tied open for the barriers on Old and Middle Rivers.	Temporary Barriers Project operated based on San Joaquin River flow time series from CALSIM 3 output; Head of Old River Barrier (HORB) is not installed; Agricultural barriers on Old and Middle Rivers are assumed to be installed starting from May 16 and on Grant Line Canal from June 1; All three barriers are allowed to be operated until November 30; May 16 to May 31; the tidal gates are assumed to be tied open for the barriers on Old and Middle Rivers.
Antioch Water Works	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3	Monthly output from CALSIM 3
Suisun Marsh Salinity Control Gates	Monthly output from CALSIM 3 [g]; Gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps	Monthly output from CALSIM 3 [g]; Gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps	Monthly output from CALSIM 3 [g]; Gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps	Monthly output from CALSIM 3 [g]; Gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps	Monthly output from CALSIM 3 [g]; Gates open when upstream water level is 0.3 ft above downstream water level. Gates close when current is less than -0.1 fps

[a] An adjusted astronomical tide for use in DSM2 planning studies has been developed by DWR’s Bay Delta Office Modeling Support Branch Delta Modeling Section in cooperation with the Common Assumptions workgroup. This tide is based on a more extensive observed dataset and covers the entire 100-year period of record.

[b] Although monthly CALSIM output was used as the DSM2-HYDRO input, the Sacramento and San Joaquin rivers were interpolated to daily values in order to smooth the transition from high to low and low to high flows. DSM2 then uses the daily flow values along with a 15-minute adjusted astronomical tide to simulate effect of the spring and neap tides.

[c] The Delta Channel Depletion (DCD) model is used to calculate diversions and return flows for all Delta islands based on the level of development assumed. The projected 2020 land-use assumptions are found in Bulletin 160-98.

[d] CALSIM 3 calculates monthly EC for the San Joaquin River, which was then converted to daily EC using the monthly EC and flow for the San Joaquin River. Fixed concentrations of 150, 175, and 125 µmhos/cm were assumed for the Sacramento River, Yolo Bypass, and eastside streams, respectively.

[e] Net Delta outflow based on the CALSIM 3 flows was used with an updated G-model to calculate Martinez EC. Under changed climate conditions Martinez EC is modified to account for 15 cm sea level rise.

[f] Information was obtained based on the information from the draft final “Delta Region Drinking Water Quality Management Plan” dated June 2005 prepared under the CALFED Water Quality Program and a presentation by David Briggs at SWRCB public workshop for periodic review. The presentation “Compliance location at Contra Costa Canal at Pumping Plant #1 – Addressing Local Degradation” notes that the Veale Tract drainage relocation project will be operational in June 2005. The DICU drainage currently simulated at node 204 is moved to node 202 in DSM2.

[g] CalSim 3 determines the months during which Suisun Marsh Salinity Control Gates (SMSCG) operate to meet D-1641 water quality compliance in Montezuma Slough, or for Summer/Fall Delta Actions.

[h] DSM2 assumptions are identical for all variations of Alternative 2: Alternative 2 without VAs and without TUCPs, Alternative 2 without VAs and with TUCPs, Alternative 2 with Delta VA, and Alternative 2 with VAs.

F.1-2.3 HEC-5Q

	No Action Alternative (NAA)	**Alternative 1 (Alt 1)**	**Alternative 2 [a] (Alt 2)**	**Alternative 3 (Alt 3)**	**Alternative 4 (Alt 4)**
Period of simulation	100 years (1922-2003)	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Climate	2022 Median climate conditions	Same as NAA	Same as NAA	Same as NAA	Same as NAA
Boundary flows and storages	Monthly timeseries (from CALSIM 3 output).	Monthly timeseries (from CALSIM 3 output).	Monthly timeseries (from CALSIM 3 output).	Monthly timeseries (from CALSIM 3 output).	Monthly timeseries (from CALSIM 3 output).
Trinity Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Lewistown Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Whiskeytown Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Shasta Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Keswick Reservoir	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Black Butte Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Shasta Temperature Management	Temperature schedules developed to match Shasta Summer Cold Water Pool Management in 2019 NMFS BiOp.	Similar to 2009 NMFS BiOps Appendix 2D (See 2015 LTO for details).	"Mixed" TCD management, detailed in Appendix F Modeling, Attachment 1-3, Model Updates.	"NGO" TCD management, detailed in Appendix F Modeling, Attachment 1-3, Model Updates.	"Carryover" TCD management, detailed in Appendix F Modeling, Attachment 1-3, Model Updates.
Trinity Temperature Management	Releases allowed from lower, auxiliary outlet when normal outlet release are too warm.	Releases allowed from lower, auxiliary outlet when normal outlet release are too warm.	Releases allowed from lower, auxiliary outlet when normal outlet release are too warm.	Releases allowed from lower, auxiliary outlet when normal outlet release are too warm.	Releases allowed from lower, auxiliary outlet when normal outlet release are too warm.
Folsom Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Lake Natoma	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.

	No Action Alternative (NAA)	Alternative 1 (Alt 1)	Alternative 2 [a] (Alt 2)	Alternative 3 (Alt 3)	Alternative 4 (Alt 4)
Folsom Temperature Management	Similar to 2009 NMFS BiOp Appendix B (See 2015 LTO for details).	Similar to 2009 NMFS BiOp Appendix B (See 2015 LTO for details).	Similar to 2009 NMFS BiOp Appendix B (See 2015 LTO for details).	Similar to 2009 NMFS BiOp Appendix B (See 2015 LTO for details).	Updated AMFS temperature schedule. See Appendix F: Modeling Attachment 1-3, Model Updates for more details.
New Melones Lake	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Lake Tulloch	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.
Goodwin Reservoir	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.	Monthly timeseries (from CALSIM 3 output). Limited to physical specifications of reservoir.

[a] HEC5Q assumptions are identical for all variations of Alternative 2: Alternative 2 without VAs and without TUCPs, Alternative 2 without VAs and with TUCPs, Alternative 2 with Delta VA, and Alternative 2 with VAs.

Appendix F, Modeling

Section F.1-3 CalSim 3 Contracts

F.1-3.1 Central Valley Project and State Water Project Contract Assumptions

This section summarizes the SWP and CVP contract assumptions for CalSim 3 modeling conducted for the LTO. The annual contract amounts reported in the tables below reflect estimates of what is simulated in CalSim 3; however, any discrepancies would be minor and have no significant effect on the model results.

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Table F.3-1. CVP Sacramento River Settlement Contracts

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile [13]	Size (acres)	Base	Project	Total
WATER BUDGET AREA 02: SACRAMENTO RIVER RIGHT BANK, RM 254.1 – RM 309.5										
Redding, City of [1]	**14-06-200-2871A**	**District**	**02_SU**	**SAC296**	**246.25**	**295.3**		**8,926**	**1,574**	**10,500**
Subtotal										***10,500***
Anderson-Cottonwood ID [3]	**14-06-200-3346A**	**District**	**02_SA**	**SAC296**	**246.0**	**295.0**		**102,850**	**5,950**	**108,800**
Lake California Property Owners As. Inc.	14-06-200-4961A	Short	02_SA	SAC296	221.0	269.4		580	200	780
Leviathan, Inc.	14-06-200-7308A	Short	02_SA	SAC296	221.0	269.4	160	355	345	700
Subtotal										***110,280***
WATER BUDGET AREA 03: SACRAMENTO RIVER LEFT BANK, RM 250.1 – RM 309.5										
Redding, City of [2]	**14-06-200-2871A**	**District**	**03_SU**	**SAC296**	**246.7**	**295.7**		**8,925**	**1,575**	**10,500**
Subtotal										***10,500***
Anderson-Cottonwood ID [4]	**14-06-200-3346A**	**District**	**03_SA**	**SAC289**	**240.5**	**289.3**		**18,150**	**1,050**	**19,200**
Riverview Golf and Country Club	14-60-200-8286A	Short	03_SA	SAC289	240.8	289.9	100	255	25	280
Daniell, Harry W.	14-06-200-4348A	Short	03_SA	SAC289	240.3	289.0	6	13	7	20
Redding Rancheria Tribe	7-07-20-W0006	Short	03_SA	SAC289	240.2	288.8	73	70	135	205
Driscoll Strawberry Associates, Inc.	14-06-200-4736A	Short	03_SA	SAC289	207.5	255.2	160	330	490	820
Subtotal										***20,525***
WATER BUDGET AREA 04: SACRAMENTO RIVER RIGHT BANK, RM 206.1 – RM 254.1										
Exchange Bank (Nature Conservancy)	14-06-200-3774A	Short	04_NA	SAC224	168.85	219.5	320	210	570	780
Rubio, Exequiel P. and Elsa A.	14-06-200-2368A	Short	04_NA	SAC224	166.8	217.4	8	11	5	16
Penner, Roger & Leona	14-06-200-960A	Short	04_NA	SAC224	156.8	207.6	52	159	21	180
Freeman, Vola	2212A	Short	Not renewed	SAC224	156.1	207.2	8	0	0	0
Mclane, Robert and Naomi	4446A	Short	Not renewed	SAC224	155.6	206.5	13	0	0	0
Alexander, Thomas and Karen	14-06-200-7754A	Short	04_NA	SAC224	155.6	206.5	5	9	13	22
Subtotal										***998***
WATER BUDGET AREA 05: SACRAMENTO RIVER LEFT BANK, RM 195.7 – RM 250.1										
J. B. Unlimited, Inc.	14-06-200-2519A	Short	05_NA	SAC240	197.0	245.7	154	220	290	510
Micke, Daniel H. and Nina J.	14-06-200-7995A	Short	05_NA	SAC240	196.6	245.3	34	81	19	100
Gjermann, Hal	14-06-200-4010A	Short	05_NA	SAC240	196.55	245.0	5	8	4	12
Subtotal										***622***
WATER BUDGET AREA 08N: SACRAMENTO RIVER RIGHT BANK, RM 153.7 – RM 206.1										
Princeton-Cordora-Glenn ID	**14-06-200-849A**	**District**	**08N_SA1**	**SAC178**	**154.8, 123.9**	**178.0**		**52,810**	**15,000**	**67,810**
Provident ID	**14-06-200-856A**	**District**	**08N_SA1**	**SAC178**	**123.9**	**178.0**		**49,730**	**5,000**	**54,730**

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile [13]	Size (acres)	Base	Project	Total
Maxwell ID [5]	**14-06-200-6078A**	**District**	**08N_SA1**	**SAC159**	**103.8, 104.1**	**159.6**		**599**	**300**	**899**
Green Valley Corporation	14-06-200-5210A	Long	08N_SA1	SAC159	106.0	161.5	286	680	210	890
Swenson Farms, LLC	14-06-200-5211A	Short	08N_SA1	SAC159	106.0	161.5	184	555	325	880
Tuttle, Charles Jr. and Noack, Sue T. Trustees	14-06-200-7296A	Short	08N_SA1	SAC159	103.9	159.6	140	120	270	390
Cachil Dehe Band of Wintun Indians	14-06-200-7206A	Short	08N_SA1	SAC159	103.7	159.4	23	80	100	180
Seaver, Charles W. and B.J., Trustees	14-06-200-3296A	Short	08N_SA1	SAC159	99.3	154.4	161	210	270	480
Subtotal										***126,259***
Glenn-Colusa ID [7]	**14-06-200-855A**	**District**	**08N_SA2**	**SAC207**	**154.8**	**206.6**		**396,000**	**57,750**	**453,750**
Subtotal										***453,750***
WATER BUDGET AREA 08S: SACRAMENTO RIVER RIGHT BANK, RM 92.8 – RM 153.7										
Maxwell ID [6]	**14-06-200-6078A**	**District**	**08S_SA1**	**SAC159**	**103.8, 104.1**	**159.6**		**11,381**	**5,700**	**17,081**
Odysseus Farms Partnership	1664A	Long	Not renewed	SAC159	93.15	149.2	758	0	0	0
Roberts Ditch Irrigation Company, Inc.	14-06-200-935A	District	08S_SA1	SAC159	90.7	146.8		4,140	300	4,440
King, Benjamin and Laura	14-06-200-1086Y	Short	08S_SA1	SAC159	89.2	144.7	5	12	7	19
King, Laura	14-06-200-1086Z	Short	08S_SA1	SAC159	89.2	144.7	6	13	13	26
Wisler, John W., Jr.	14-06-200-5215A	Short	08S_SA1	SAC159	88.0	144.6	18	8	27	35
Empire Group, LLC	14-06-200-2145A	Short	08S_SA1	SAC159	87.7	144.0	65	164	16	180
Steidlmayer, Anthony E. et al.	874A	Short	Not renewed	SAC159	83.0	139.0	168	0	0	0
Sycamore MWC	**14-06-200-2146A**	**Long**	**08S_SA1**	**SAC159**	**77.8, 78.15, 78.75, 78.8**	**135.5**		**22,000**	**9,800**	**31,800**
Subtotal										***53,581***
Glenn-Colusa ID [8]	**14-06-200-855A**	**District**	**08S_SA2**	**SAC207**	**154.8**	**206.6**		**324,000**	**47,250**	**371,250**
Subtotal										***371,250***
Jansen, Peter and Sandy	14-06-200-1426A	Short	08S_SA3	SAC121	70.4	128.1	61	150	40	190
Gillaspy, William F., Trustee	14-06-200-8117A	Short	08S_SA3	SAC121	70.4	128.1	64	120	90	210
Charter, Kristine	14-06-200-8118A	Short	08S_SA3	SAC121	70.4	128.1	92	165	135	300
Driver, Gary, et al.	14-06-200-8585A	Short	08S_SA3	SAC121	69.2	127.0	10	8	22	30
Reclamation District 108	**14-06-200-876A**	**District**	**08S_SA3**	**SAC121**	**43.1, 43.3, 51.1, 56.4, 59.15, 61.05 61.2, 62.3, 63.2, 70.4**	**120.9**		**199,000**	**33,000**	**232,000**
River Garden Farms Company	**14-06-200-878A**	**Long**	**08S_SA3**	**SAC109**	**34.5, 41.0, 43.1**	**101.5**		**29,300**	**500**	**29,800**
Driver, John A. & Clare M., Trustees	14-06-200-1314A	Short	08S_SA3	SAC109	36.45	95.2	84	150	80	230
Driver, John A. & Clare M., Trustees	14-06-200-2398A	Short	08S_SA3	SAC109	36.45	95.2	6	6	10	16
Subtotal										***262,776***

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile[13]	Size (acres)	Base	Project	Total
WATER BUDGET AREA 09: SACRAMENTO RIVER LEFT BANK, RM 140.6 – RM 195.7										
Pacific Realty Associates, L.P. (M&T Chico Ranch)	**14-06-200-940A**	**Long**	**09_SA1**	**SAC196**	**140.8, 141.5**	**195.6**		**16,980**	**976**	**17,956**
Subtotal										***17,956***
Reclamation District 1004	**14-06-200-890A**	**District**	**09_SA2**	**SAC162**	**84.28, 85.3, 89.12, 111.8**	**164.8**		**56,400**	**15,000**	**71,400**
Spence, Ruthann (Spence Farms)	4829A	Long	Not renewed	SAC162	104.8	160.4	209	0	0	0
Anderson, Arthur L. et al.	14-06-200-3591A	Short	09_SA2	SAC162	102.5	158.1	200	445	45	490
Carter Mutual Water Company	14-06-200-2401A	District	09_SA2	SAC162	99.25, 101.8,102.9	158.1		6,450	672	7,122
Forry, Laurie and Adams, Louise	14-06-200-7691A	Long	09_SA2	SAC162	99.8	154.8	506	2,285	0	2,285
Otterson, Mike, Trustee	14-06-200-2896A	Long	09_SA2	SAC162	98.9	154.7	422	1,515	300	1,815
T&P Farms	14-06-200-2993A	Long	09_SA2	SAC162	98.6	153.7	409	1,360	200	1,560
Griffin, Joseph and Prater, Sharon	14-06-200-2895A	Long	09_SA2	SAC162	95.8	151.3	552	1,610	1,150	2,760
Baber, Jack W. et al.	14-06-200-1604A	Long	09_SA2	SAC162	95.6	151.1	1,068	3,630	2,630	6,260
Eastside Mutual Water Company	14-06-200-1053A	District	09_SA2	SAC162	95.25	150.8	1,006	2,170	634	2,804
Zelmar Ranch, Inc.	14-06-200-1827A	Short	09_SA2	SAC162	92.5	148.7	120	112	52	164
Gomes, Judith A., Trustee	14-06-200-1827X	Short	09_SA2	SAC162	92.5	149.7	72	168	78	246
Butte Creek Farms, Inc.	14-06-200-2851A	Short	09_SA2	SAC162	89.26	145.7	17	20	16	36
Butte Creek Farms, Inc.	14-06-200-5206A	Short	09_SA2	SAC162	89.24	145.6	36	40	55	95
Butte Creek Farms, Inc.	14-06-200-1976A	Short	09_SA2	SAC162	88.7	145.2	114	196	8	204
Butte Creek Farms, Inc.	14-06-200-7744X	Short	09_SA2	SAC162	88.7	145.2	180	300	340	640
Howard, Theodore W. and Linda M.	14-06-200-1976X	Short	09_SA2	SAC162	88.7	145.2	31	74	2	76
Locvich, Loyd	1945A	Short	Not renewed	SAC162	88.2	144.7	160	0	0	0
Ehrke, Allen A. and Bonnie E.	14-06-200-8330A	Short	09_SA2	SAC162	86.8	143.3	165	220	160	380
Subtotal										***98,337***
WATER BUDGET AREA 18: SACRAMENTO RIVER LEFT BANK, RM 121.8 – RM 140.6										
Fedora, Sibley G. and Margaret L., Trustees	14-60-200-2916A	Short	18_SA	SAC136	82.7	139.3	86	190	20	210
Reische, Laverne C. et al.	14-06-200-1150A	Short	18_SA	SAC136	82.5	139.1	104	183	267	450
Reische, Eric L.	14-06-200-1150X	Short	18_SA	SAC136	82.5	139.1	18	37	53	90
Tarke, Stephen E. and D.F., Trustees	14-06-200-1949A	Long	18_SA	SAC136	81.5	138.1	492	1,700	1,000	2,700
Meridian Farms Water Company	**14-06-200-838A**	**District**	**18_SA**	**SAC136**	**71.1, 74.8, 80.0**	**136.5**		**23,000**	**12,000**	**35,000**
Churkin, Michael Jr. et al.	14-06-200-7227A	Short	18_SA	SAC136	79.5	135.8	49	75	55	130
Eggleston, Ronald H. et ux.	14-06-200-7339A	Short	18_SA	SAC136	79.0	135.3	28	53	12	65
Hale, Judith A. and Marks, Alice K.	14-06-200-7572A	Short	18_SA	SAC136	79.0	135.3	54	117	13	130
Hale, Judith A. and Marks, Alice K.	14-06-200-1638A	Short	18_SA	SAC136	79.0	135.3	31	58	17	75

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile [13]	Size (acres)	Base	Project	Total
Pires, Lawrence and Beverly	7744A	Short	Not renewed	SAC136	77.9	134.6	111	0	0	0
Davis, Ina M.	14-06-200-1851A	Short	18_SA	SAC136	76.2	132.5	34	71	14	85
Chesney, Adona, Trustee	14-06-200-930A	Short	18_SA	SAC136	76.15	132.5	149	310	390	700
Andreotti, Beverly F. et al.	14-06-200-1898A	Long	18_SA	SAC136	72.1	128.8	462	2,060	1,560	3,620
Mclaughlin, Jack E. and Margery L.	2514A	Short	Not renewed	SAC136	72.0	128.7	142	0	0	0
Lomo Cold Storage and Micheli, Justin J.	14-06-200-931A	Long	18_SA	SAC136	67.5	125.1		6,410	700	7,110
Anderson R. and J., Properties, LP	14-06-200-1726A	Short	18_SA	SAC136	67.1	124.7	95	149	88	237
Lonon, Michael E.	14-06-200-8658A	Short	18_SA	SAC136	67.1	124.7	260	715	440	1,155
Tisdale Irrigation and Drainage Company	14-06-200-2781A	District	18_SA	SAC136	64.4, 67.1	124.3		7,900	2,000	9,900
Sutter MWC [9]	**14-06-200-815A**	**District**	**18_SA**	**SAC136**	**63.75**	**121.2**		**10,170**	**3,390**	**13,560**
Subtotal										***75,217***
WATER BUDGET AREA 19: SACRAMENTO RIVER LEFT BANK, RM 87.5 – RM 121.8										
Oji Brothers Farm, Inc.	14-06-200-3753A	Long	19_SA	SAC122	63.9	121.3		1,340	1,860	3,200
Sutter MWC [10]	**14-06-200-815A**	**District**	**19_SA**	**SAC091, SAC099, SAC122**	**32.4, 40.6, 63.75**	**121.2**		**159,330**	**53,110**	**212,440**
Young, Troy Brady and Susan Elizabeth	14-06-200-2552A	Short	19_SA	SAC122	63.3	121.1	4	2	8	10
Sekhon, Arjinderpal and Daljit	W0001	Short	Not renewed	SAC115	62.3	119.8	155	0	0	0
Butler, Dianne E., Trust	14-06-200-2365A	Short	19_SA	SAC115	60.5, 61.8	119.4	142	180	280	434
Hatfield, Paul and Crystal	14-06-200-2365X	Short	19_SA	SAC115						26
Howald Farms, Inc.	14-06-200-1042A	Long	19_SA	SAC115	60.4	118.9	512	1,350	1,410	2,760
Kary, Carol Trustee	14-06-200-2520A	Short	19_SA	SAC115	59.8	117.4	280	400	600	1,000
Wallace, Joseph V., and Janice C.	14-06-200-5200A	Short	19_SA	SAC115	58.9	116.7	80	295	60	355
Lockett, William P. and Jean B.	14-06-200-4105A	Short	19_SA	SAC115	58.3	116.8	490	370	47	417
O'Brien, Frank J., and Janice C.	14-06-200-4105X	Long	19_SA	SAC115	58.3	116.0	290	550	289	839
Dyer, Jeffrey E., and Wing-Dyer, Jan	14-06-200-2486A	Short	19_SA	SAC115	57.75	115.6	120	180	340	520
Pelger Mutual Water Company	14-06-200-2073A	District	19_SA	SAC115	56.96	114.8		7,110	1,750	8,860
Bardis, Cristo D. et al.	**14-06-200-1286A**	**Long**	**19_SA**	**SAC109**	**55.1**	**112.8**	**2,055**	**8,070**	**2,000**	**10,070**
Van Ruiten Brothers	14-06-200-1415A	Short	19_SA	SAC109			164	50	275	325
Van Ruiten Brothers	14-06-200-5200X	Short	19_SA	SAC109	52.3	110.3	80	25	135	160
Nelson, Henry E., Trustee	14-06-200-1954A	Short	19_SA	SAC109	52.0	110.0	43	38	98	136
Saeed, Faraz A.	8-07-20-W0117	Long	19_SA	SAC109	50.0	108.0	483	2,450	710	3,160
Van Ruiten Brothers	14-06-200-880A	Long	19_SA	SAC109	49.0, 49.7	107.5	375	947	538	1,485
Van Ruiten Brothers	14-06-200-880X	Long	19_SA	SAC109	49.0	106.8		372	212	584
Oji, Mitsue, Family Partnership et al.	14-06-200-2427A	Long	19_SA	SAC109	48.7	106.8		3,430	1,310	4,740

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile [13]	Size (acres)	Base	Project	Total
Henle, Thomas N., Trustee	14-06-200-932A	Long	19_SA	SAC109	46.5	105.6	393	935	0	935
Windswept Land and Livestock Company	14-06-200-2045A	Long	19_SA	SAC109	44.2, 45.6, 46.45	105.1	738	4,040	0	4,040
Knights Landing Properties, LLC	14-06-200-889A	Short	19_SA	SAC099	38.8	97.3	112	180	20	200
Sooch, Jagar S., et al.	14-06-200-7049A	Short	19_SA	SAC099	37.75	96.4	78	70	85	155
KLSY LLC	14-06-200-7556A	Short	19_SA	SAC099	37.2	95.8	63	80	90	170
Quad-H Ranches, Inc.	14-06-200-2153A	Short	19_SA	SAC099	36.2	94.9	74	190	310	500
Giusti, Richard J. and Sandra A., Trustees	14-06-200-4076A	Short	19_SA	SAC099	36.2	95.0	304	850	760	1,610
Drew, Jerry	2250A	Short	Not renewed	SAC099	35.85	94.4	9	0	0	0
Jaeger, William L. and Patricia A.	7-07-20-W0002	Short	19_SA	SAC091	Sutter Bypass		112	385	485	870
Morehead, Joseph A. and Brenda	14-06-200-5789A	Short	19_SA	SAC091	Sutter Bypass		48	115	140	255
Heidrick & McGinnis Properties, LP	14-06-200-1176A	Short	19_SA	SAC091	33.75	92.4	72	360	200	560
B&D Family Partnership	14-06-200-4178A	Short	19_SA	SAC091	33.75	92.4	14	36	24	60
MCM Properties, Inc.	14-06-200-7827A	Long	19_SA	SAC091	33.75	91.8	201	860	610	1,470
Richter, Henry D. et al.	14-06-200-4362A	Long	19_SA	SAC091	33.2	92.0	583	1,750	1,030	2,780
Furlan, Emile and Simone, Family Trust	14-06-200-1175A	Short	19_SA	SAC091	32.5	90.9	195	23	30	53
Wallace, Kenneth L. Living Trust	14-06-200-1175A-X	Short	19_SA	SAC091	32.5, 33.2	91.6	195	547	320	867
Byrd, Anna C., and Osborne, Jane [12]	14-06-200-1595A	Long	19_SA	SAC091	26.8, 30.5	89.6	316	1,065	200	1,265
Subtotal										***267,311***
WATER BUDGET AREA 21: SACRAMENTO RIVER RIGHT BANK, RM 62.1 – RM 92.8										
Edson, Wallace L. and Mary O.	906A	Short	Not renewed	SAC083	33.85	92.5	25	0	0	0
Driver, William A., et al.	14-06-200-939A-1	Short	21_SA	SAC083	32.5	91.2	82	54	106	160
Driver, Gregory E.	14-06-200-939A-2	Short	21_SA	SAC083	32.5	91.2	80	6	14	20
Giovannetti, Emil Joseph	14-06-200-991A	Short	21_SA	SAC083	31.5	90.5	150	470	50	520
Heidrick, James E. and Terry E., Trustee	14-06-200-1616A	Short	21_SA	SAC083	30.6	89.5	42	69	16	85
Knights Landing Investors, LLC	14-06-200-4604A	Long	21_SA	SAC083	32.1, 30.7, 29.7	88.6	820	2,680	960	3,640
Heidrick, James E. and Terry E., Trustee	14-06-200-8322A	Short	21_SA	SAC083	29.2, 30.3	89.6	204	370	60	430
Hershey Land Company	7972A	Long	Not renewed	SAC083	28.1	87.2	727	0	0	0
Sacramento River Ranch LLC	14-06-200-2149A	Long	21_SA	SAC083	16.6, 17.0, 22.5	84.5		4,000	0	4,000
Yolo Land Trust	14-06-200-2148A	Long	21_SA	SAC083	16.1	78.1		630	0	630
Conaway Preservation Group	**14-06-200-7422A**	**Long**	**21_SA**	**SAC074**	**12.0**	**73.6**		**40,190**	**672**	**40,862**
Woodland-Davis Clean Water Agency	**14-06-200-7422X**	**Long**	**21_SA**	**SAC074**	**12.0**	**73.6**		**10,000**	**0**	**10,000**
Wilson Ranch Partnership	14-06-200-4520A	Long	21_SA	SAC074	11.1	72.9		370	0	370
Reclamation District 900 and 1000	14-06-200-1779A	Short	21_SA	SAC074	9.35	71.1	142	281	123	404

Central Valley Project Settlement Contractor	Contract		CalSim 3 Representation		Geographic Location			Contract Amount (AF/year)		
	Number	Form	Demand Unit	Diversion Node	Contract River Mile	Adjusted River Mile [13]	Size (acres)	Base	Project	Total
McClatchy Partners, LLC and Riveryby LLC	14-06-200-934A	Short	21_SA	SAC074	5.25	66.9	177	470	30	500
Subtotal										***61,621***
WATER BUDGET AREA 17: SACRAMENTO RIVER LEFT BANK, RM 82.7 – RM 87.5										
Byrd, Anna C., and Osborne, Jane [12]	14-06-200-1595A	Long						0	0	0
Subtotal										***0***
WATER BUDGET AREA 22: SACRAMENTO RIVER LEFT BANK, RM 64.9 – RM 82.7										
Pleasant Grove-Verona MWC [11]	**14-06-200-5520A**	**District**	**22_SA1**	**SAC082**	**19.6**	**81.7**		**23,790**	**2,500**	**26,290**
Natomas Central MWC [11]	**14-06-200-885A**	**Long**	**22_SA1**	**SAC082**	**2.15,6.1,7.5, 4.1,16.0,19.6**	**81.5**		**98,200**	**22,000**	**120,200**
Odysseus Farms Partnership	14-06-200-8574A	Short	22_SA1	SAC076	19.6	81.7	121	220	410	630
Cummings, William C.	7-07-20-W0054	Short	22_SA1	SAC076	18.7	81.0	130	180	120	300
Lauppe, Burton H., and Kathryn L.	14-06-200-1289A	Short	22_SA1	SAC076	18.45	80.6	264	720	230	950
Natomas Basin Conservancy	14-06-200-1364A	Short	22_SA1	SAC076	18.2	80.2	271	221	269	490
Lauppe, Alan, Joan Johnson, and Warren Lauppe	14-06-200-1364Y	Short	22_SA1	SAC076	18.2	80.2	12	6	14	20
Lauppe, Burton H., and Kathryn L.	14-06-200-1364X	Short	22_SA1	SAC076	18.2	80.2	110	153	197	350
Siddiqui, Javed and Amna	2065A	Short	Not renewed	SAC076	10.75	72.5	88	0	0	0
Willey, Edwin A. and Marjorie E.	14-06-200-3556A	Short	22_SA1	SAC076	10.75	72.5	46	75	20	95
Siddiqui, Javed and Amna	7941A	Long	Not renewed	SAC076	10.25	71.8	280	0	0	0
Sacramento, County of	14-06-200-2404A	Short	22_SA1	SAC076	9.3	71.2	250	520	230	750
Subtotal										***150,075***
TOTAL								**1,761,376**	**330,182**	**2,091,558**

AF = acre-feet; CVP = Central Valley Project; GIS = geographical information system; ID = Irrigation District; LLC = Limited Liability Company; LP = Limited Partnership; MWC = Mutual Water Company; RM = river mile; WBA = Water Budget Area.

[1] Contract for City of Redding estimated as 50% of 21,000 AF based on Census 2000 population located within Foothill, Hill 900 and Cascade pressure zones.

[2] Contract for City of Redding estimated as 50% of 21,000 AF based on Census 2000 population located within Enterprise Zone.

[3] Contract for Anderson-Cottonwood ID estimated as 85% of 125,000 AF based on historical delivery data. Additional 85% of 3,000 AF water rights.

[4] Contract for Anderson-Cottonwood ID estimated as 15% of 125,000 AF based on historical delivery data. Additional 15% of 3,000 AF water rights.

[5] Contract for Maxwell ID estimated as 5% of 18,000 AF based on GIS land-use surveys of cropped area.

[6] Contract for Maxwell ID estimated as 95% of 18,000 AF based on GIS land-use surveys of cropped area.

[7] Contract for Glenn-Colusa ID estimated as 55% of 825,000 AF based on GIS land-use surveys of cropped area.

[8] Contract for Glenn-Colusa ID estimated as 45% of 825,000 AF based on GIS land-use surveys of cropped area.

[9] Contract for Sutter MWC estimated as 94% of 226,000 AF based on GIS land-use surveys of cropped area. Diversion from Tisdale Pumping Plant.

[10] Contract for Sutter MWC estimated as 6% of 226,000 AF based on GIS land-use surveys of cropped area.

[11] Pleasant Grove-Verona MWC and Natomas Central MWC also divert water from the Natomas Cross Canal.

[12] Contractor located in WBA 17S and WBA 19. For modeling purposes, land assumed to be in WBA 19

[13] CalSim 3 river mile refers to most upstream diversion point. RM 61.7 corresponds to the I Street Bridge in the City of Sacramento. This is RM 0.0 for Reclamation contract river miles.

Table F.3-2. CVP San Joaquin River Exchange Contracts

Central Valley Project Exchange Contractor	Contract Number	CalSim 3 Representation		Point of Diversion	Contract Amount (AF/year)
		Demand Unit	Diversion Node		
Columbia CC	I1r-1144	64_XA	MDOTA	Mendota Pool	59,000
San Luis CC	I1r-1144	72_XA1	SJR180, ARY010	San Joaquin River at Sack Dam via Arroyo Canal	163,600
Central California ID (north) [1]	I1r-1144	72_XA3	XCC055	Delta-Mendota Canal via Wolfson Bypass and Outside and Main canals	140,000
Central California ID (South)	I1r-1144	72_XA2	MDOTA, XCC010	Mendota Pool via Outside and Main canals	392,400
Firebaugh CC	I1r-1144	73_XA	DMC111, MDOTA	Delta-Mendota Canal, Check 20 and Mendota Pool	85,000

AF = acre-feet; CC = Canal Company; CVP = Central Valley Project; ID = Irrigation District.

[1] Under an exchange agreement with Reclamation (contract 9-07-20-W0812), Central California ID makes available up to 2,500 AF of exchange water to be delivered by Reclamation from the California Aqueduct (MP 89.7) to the Dos Palos Area Joint Powers Authority (JPA).

Table F.3-3. CVP Schedule 2 Water Rights and Contract Amounts

Central Valley Project Schedule 2 Contractor [1]	Contract Number	CalSim 3 Representation		Point of Diversion	Contract Amount (AF/year)	
		Demand Unit	Diversion Node		Irrigation	Schedule 2
Dudley & Indart/Coelho/Hansen	14-06-200-4448A	91_PA	MDOTA	Fresno Slough	-	2,280
Fresno Slough WD	14-06-200-4019A	91_PA	MDOTA	Fresno Slough	4,000	866
James ID	14-06-200-700A	91_PA	MDOTA	Fresno Slough	35,300	9,700
Meyers Farms Family Trust	9-07-20-W1608	91_PA	MDOTA	Fresno Slough	-	210
Kenneth and Karen Carvalho Revocable Trust	11-WC-20-0026	91_PA	MDOTA	Fresno Slough	-	600
Reclamation District 1606	14-06-200-3802A	91_PA	MDOTA	Fresno Slough	228	342
Terra Linda Farms	14-06-200-7859A	91_PA	MDOTA	Fresno Slough	2,080	1,332
Tranquility ID	14-06-200-701A	91_PA	MDOTA	Fresno Slough	13,800	20,200
Tranquility PUD	14-06-200-3537A	91_PA	MDOTA	Fresno Slough	70	93
TOTAL					**55,478**	**35,623**

AF = acre-feet; CVP = Central Valley Project; ID = Irrigation District; PUD = Public Utility District; WD = Water District.

[1] Schedule 2 water is all water delivered without charge under the authority of Section 14 of the Reclamation Project Act of 1939, as a permanent adjustment and settlement of a district's asserted claims to water in the Fresno Slough tributary to the San Joaquin River in fulfillment of such rights pursuant to Contract No. I7R-1145, "Contract for Purchaser of Miller & Lux Water Rights," dated July 27, 1939.

[2] Formerly Coelho Family Trust

Table F.3-4. CVP Water Service Contracts for Service Areas North of Delta

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
SACRAMENTO AND TRINITY RIVER DIVISIONS [4]					
Clear Creek CSD	489-A	02_PA	WKYTN	7,300 [1]	-
Centerville CSD	14-06-200-3367X	02_PU	WKYTN	-	2,900 [3]
Clear Creek CSD	14-06-200-489-A		WKYTN	-	8,000 [1]
Shasta CSD	14-06-200-862A		WKYTN	-	1,000
Shasta County WA	14-06-200-3367A		WKYTN	-	332 [2]
Keswick CSA	N/A		WKYTN	-	400 [2]
Bella Vista WD	14-06-200-851A	03_PA	SAC294	18,000 [8]	-
Bella Vista WD	14-06-200-851A	03_PU2	SAC294	-	6,578 [8]
City of Shasta Lake	4-07-20-W1134	03_PU1	SHSTA	-	4,400
Mountain Gate CSD	14-06-200-6998		SHSTA	-	1,350
Jones Valley CSA	N/A		SHSTA	-	290 [2]
Redding, City of (Buckeye WTP)	14-06-200-5272A	03_PU3	WKYTN	-	6,140
Subtotal				***25,300***	***31,390***
CORNING CANAL UNIT					
Corning WD	14-06-200-6575	04_PA1	CCL005	20,000	-
Proberta WD	14-06-200-7311			3,500	-
Thomes Creek WD	14-06-200-5271A			6,400	-
Subtotal				***29,900***	***0***
TEHAMA-COLUSA CANAL UNIT					
Kirkwood WD	7-07-20-W0056	04_PA2	TCC022	2,100	-
Glide WD	W0040	07N_PA	TCC036	10,500	-
Kanawha WD	466-A			45,000	-
Orland-Artois WD	14-06-200-8382A			53,000	-
Colusa, County of					
Holthouse WD (65%) (assigned)	1-07-20-W0224			1,513	-
Colusa, County of	14-06-200-8310A	07S_PA	TCC081 TCC111	[10]	-
4-M WD (assigned)	0-07-20-W0183			5,415	-
Colusa County WD (assigned)	1-07-20-W0220			5,667	-
Cortina WD (assigned)	0-07-20-W0206			1,615	-
Glenn Valley WD (assigned)	1-07-20-W0219			1,730	-
Holthouse WD (35%) (assigned)	1-07-20-W0224			814	-
La Grande WD (assigned)	0-07-20-W0190			2,090	-
Myers-Marsh MWC (assigned)	1-07-20-W0225			242	-

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
Colusa County WD	14-06-200-304-A			62,200	-
Colusa, County of	14-06-200-8310A			914	
Davis WD	14-06-200-6001A			4,000	-
Dunnigan WD	14-06-200-399-A			19,000	-
La Grande WD	7-07-20-W0022			5,000	-
Westside WD	14-06-200-8222			65,000	-
Subtotal				***285,800***	***0***
BLACK BUTTE UNIT					
4-E WD	3-07-20-W0312	N/A	N/A	35	-
Elk Creek CSD	3-07-20-W0312				100
Stony Creek WD	2-07-20-W0261	SCKWD	EPARK		3,345
U.S. Forest Service (Salt Creek)	14-06-200-3621A	N/A	N/A		45
Whitney Construction, Inc.	14-06-200-5749A	N/A	N/A		25
U.S. Forest Service	14-06-200-3464A	N/A	N/A		10
Colusa, County of (Stonyford)	4-07-20-W0348	N/A	N/A		40
Subtotal				***35***	***3,565***
COLUSA BASIN DRAIN					
Colusa Drain MWC [5]	8-07-20-W0693	08N_PA	CBD049	5,600	-
Colusa Drain MWC [5]	8-07-20-W0693	08S_PA	CBD028	49,000	-
Colusa Drain MWC [5]	8-07-20-W0693	21_PA	KLR005	15,400	-
Subtotal				***70,000***	***0***
AMERICAN RIVER DIVISION					
El Dorado ID	14-06-200-1357A	ELDID	FOLSM	-	7,550
El Dorado County Water Agency [11]	07-WC-20-3534	ELDID	FOLSM		15,000
City of Roseville	14-06-200-3474A	26N_PU1	FOLSM	-	32,000
Sacramento County WA	6-07-20-W1372	26S_PU4, 26S_PU6	SAC052, SAC062	-	22,000
San Juan WD	6-07-20-W1373	26N_PU2, 26N_PU3	FOLSM	-	24,200
East Bay MUD	14-06-200-5183A	EBMUD	FOLSM	-	133,000
SMUD	14-06-200-5198A	60N_PU	FOLSM	-	30,000
Sacramento County WA (SMUD assignment)	N/A	26S_PU4, 26S_PU6	SAC052, SAC062	-	30,000
Placer County WA	14-06-200-5082A	[6]	FOLSM	-	35,000
Subtotal				***0***	***328,750***
DELTA DIVISION					
Contra Costa WD	I75r-3401A	CCWD	RSL004, OMR021, VCT002	-	195,000
Subtotal				***0***	***195,000***

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
OTHER					
Feather WD	14-06-200-171-A	16_PA	FTR020	20,000	
City of West Sacramento [7,9]	0-07-20-W0187	21_PU	SAC066		23,600
Subtotal				***20,000***	***23,600***
TOTAL				**431,035**	**582,305**

AF = acre-feet; CSA = County Service Area; CSD = Community Service District; CVP = Central Valley Project; ID = Irrigation District; M&I = municipal and industrial; MUD = Municipal Utility District; MWC = Mutual Water Company; N/A = not applicable; SMUD = Sacramento Municipal Utility District; WA = Water Agency; WD = Water District; WTP = water treatment plant.

[1] Split between irrigation and M&I use based on an urban demand of 8,000 AF/year.

[2] Shasta County WA provides water to water purveyors in Shasta County, including 500 AF to Keswick CSA, 190 AF to Jones Valley CSA, and 332 AF elsewhere. For modeling purposes, it is assumed that 332 AF are made available to contractors in 02_PU. Under a 2008 transfer agreement, 100 AF of Shasta County WA water were transferred from Keswick CSA to Jones Valley CSA.

[3] Centerville Community Services District as part of the liquidation of the Townsend Flat Water Ditch Company's pre-1914 water rights holdings on Clear Creek has secured 900 AF of CVP supplies in addition to the 2,900 AF. These quantities of supply are not subject to cutbacks, and the water may be transferred to any other purveyor in the Redding Basin.

[4] The McConnell Foundation as part of the liquidation of the Townsend Flat Water Ditch Company's pre-1914 water rights holdings on Clear Creek, has secured 5,100 AF of CVP supplies. These quantities of supply are not subject to cutbacks, and the water may be transferred to any other purveyor in the Redding Basin. For modeling purposes, it is assumed that this water is available to urban municipalities.

[5] Division of the 70,000 AF/year contract for the Colusa Drain MWC is based on GIS land use (irrigated area) and split 8%, 70%, and 22% among the 3 demand units 08N_PA, 08S_PA, and 21_PA.

[6] Placer County WA currently has no facilities to take delivery of CVP water from Folsom Lake.

[7] Contract amount for West Sacramento includes water right water and CVP project water.

[8] Split between irrigation and M&I use for Bella Vista WD based on Reclamation delivery data for water years 2000 – 2009.

[9] The City of West Sacramento also could be categorized as a CVP settlement contractor.

[10] Seven districts have assigned a total of 20,000 AF to Colusa County Water District.

[11] For modeling purposes, it is assumed that 7,500 AF of El Dorado County Water Agency CVP contract water would be available to El Dorado Irrigation District for diversion at Folsom Lake.

Table F.3-5. CVP Contract Amounts for Service Areas South of Delta

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
UPPER DELTA-MENDOTA CANAL					
Byron-Bethany ID [6]	14-06-200-785	71_PA8	DMC011	20,600	-
Tracy, City of	14-06-200-7858A	50_PU	DMC016	-	10,000
Tracy, City of (from Banta-Carbona ID)	14-06-200-4305A-B			-	5,000
Tracy, City of (from West Side ID)	7-07-20-W0045-B			-	5,000
Banta-Carbona ID	14-06-200-4305A	50_PA1	DMC021	20,000	-
West Side ID	7-07-20-W0045			5,000	-
Hospital WD	14-06-200-922	71_PA1	DMC030	34,105	-
West Stanislaus ID	14-06-200-1072	71_PA2	DMC034	50,000	-
Kern Canon WD	14-06-200-922	71_PA3	DMC034	7,700	-
Patterson ID [1]	14-06-200-3598A	71_PA4	DMC044	22,500	-
Del Puerto WD	14-06-200-922	71_PA5	DMC044	12,060	-
Salado WD	14-06-200-922		DMC044	9,130	-

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
Orestimba WD	14-06-200-922		DMC044	15,860	-
Sunflower WD	14-06-200-922		DMC044	16,625	-
Davis WD	14-06-200-922	71_PA6	DMC064	5,400	-
Foothill WD	14-06-200-922		DMC064	10,840	-
Mustang WD	14-06-200-922		DMC064	14,680	-
Quinto WD	14-06-200-922		DMC064	8,620	-
Romero WD	14-06-200-922		DMC064	5,190	-
Subtotal				***258,310***	***20,000***
LOWER DELTA-MENDOTA CANAL, VOLTA WASTEWAY, MENDOTA POOL					
Laguna WD	2-07-20-W0266	72_PA	XCC025	800	-
San Luis WD (north) [2]	14-06-200-7773A (part)	73_PA1	DMC070	62,540	-
Eagle Field WD	14-06-200-7754	73_PA2	DMC105	4,550	-
Mercy Springs WD	14-06-200-3365A		DMC105	2,842	-
Oro Loma WD	14-06-200-7823		DMC105	600	-
Panoche WD [3]	14-06-200-7864A (part)	73_PA3	DMC091	27,000	-
Westlands WD (from Broadview WD)	14-06-200-8092	90_PA1		27,000	-
Westlands WD DD No.2 (from Mercy Springs WD)	14-06-200-3365A-C			4,198	-
Westlands WD DD No. 1 (from Widren WD)	14-06-200-8018-B		COC001	2,990	-
Westlands WD DD No. 1 (from Centinella WD)	7-07-20-W0055-B			2,500	-
Westlands WD DD No. 1 (from Oro Lomo WD)	14-06-200-7823			4,000	
Subtotal				***139,020***	***0***
SAN FELIPE DIVISION					
San Benito County WD	8-07-20-W0130	N/A	SLUIS	35,550	8,250
Santa Clara Valley WD	7-07-20-W0023	N/A	SLUIS	33,100	119,400
Pajaro Valley WD	14-06-200-3365A-B	N/A	SLUIS	6,260	
State of California	14-06-200-8033A	N/A	SLUIS	-	10
Subtotal				***74,910***	***127,660***
CALIFORNIA AQUEDUCT					
U.S. Department of Veteran Affairs	3-07-20-W1124	71_PU2	CAA066	-	850
California State Parks and Recreation [4]	14-06-200-4353A		CAA071	2,250	-
Los Banos Gravel Company	8-07-20-W0151		CAA071	250	-

Central Valley Project Water Service Contractor	Contract Number	CalSim 3 Representation		Contract (AF/year)	
		Demand Unit	Diversion Node	Irrigation	M&I
San Luis WD (south) [2]	14-06-200-7773A (part)	73_PA3	CAA087	62,540	-
Panoche WD [3]	14-06-200-7864A (part)		CAA109	67,000	-
Pacheco WD	6-07-20-W0469		CAA109	10,080	-
Westlands WD, CA Joint Reach 4	14-06-200-495A	90_PA1, 90_PA2	CAA109	219,000	-
Westlands WD, CA Joint Reach 5			CAA143, COC001	570,000	-
Westlands WD, CA Joint Reach 6			CAA155	219,000	-
Westlands WD, CA Joint Reach 7			CAA172	142,000	-
Avenal, City of	14-06-200-4619A	90_PU	CAA165	-	3,500
Coalinga, City of	14-06-200-4173A		COC001	-	10,000
Huron, City of	14-06-200-7081A		CAA156	-	3,000
Subtotal				***1,292,120***	***17,350***
EASTSIDE DIVISION [7]					
Central San Joaquin WCD	4-07-20-W0330			80,000	
Stockton East WD	4-07-20-W0329			75,000	
Subtotal				***155,000***	
CROSS VALLEY CANAL					
Fresno, County of	14-06-200-8292A	N/A	D855	3,000	-
Hills Valley ID	14-06-200-8466A	N/A		3,346	-
Kern-Tulare WD	14-06-200-8601A	N/A		40,000	-
Lower Tule River ID	14-06-200-8237A	N/A		31,102	-
Pixley ID	14-06-200-8238A	N/A		31,102	-
Kern-Tulare WD	14-06-200-8367A	N/A		13,300	-
Tri-Valley WD	14-06-200-8565A	N/A		1,142	-
Fresno, County of	14-06-200-8293A	N/A		5,308	-
Subtotal				***128,300***	***0***

AF = acre-feet; CVP = Central Valley Project; DD = Distribution District; ID = Irrigation District; M&I = municipal and industrial; N/A = not applicable; WD = Water District.

[1] Patterson ID contract includes 6,000 AF/year of water furnished at no cost to replace for San Joaquin River water rights water.

[2] The total contract amount for San Luis WD is 125,080 AF. This is split between CalSim 3 demand units 73_PA1 and 73_PA3, based on a GIS analysis of land area, in proportions 50% and 50%.

[3] The contract amount for Panoche WD is split between the Delta-Mendota Canal and Joint Reach of the California Aqueduct based on information received from the San Luis and Delta-Mendota Authority.

[4] The contract with California State Parks and Recreation states that 5,000 AF of water will be provided for use in parks adjacent to San Luis Reservoir and that Reclamation shall provide 45% and DWR shall provide 55%.

[5] Byron-Bethany ID diverts up to 5,000 AF/year under pre-1914 water rights water pumped from Clifton Court Forebay and the California Aqueduct upstream from Banks Pumping Plant.

[6] Under a contract between Byron-Bethany ID and Musco Olive, the district may provide up to 800 AF/year of its CVP water to Musco Olive, which is represented by demand unit 71_PU1.

[7] Under the 1988 Stipulation and Agreement, Oakdale ID and South San Joaquin ID may receive the annual inflow to New Melones Reservoir, up to a maximum of 600,000 AF/year. Reclamation is obligated to make up 33% of any deficiency below 600,000 AF/year with withdrawals from storage.

Table F.3-6. Refuge Level 2 and Level 4 Amounts per Exhibit B of Water Service Contracts

Wildlife Refuge Area	Contract Number	CalSim 3 Representation		Point of Diversion	Water Supply Contract Amounts (AF/year) [8]			
		Demand Unit	Diversion Node		Level 2 Amount [1]	Incremental Level 4	Replacement Water [2]	Total Level 4 Amount
SACRAMENTO RIVER HYDROLOGIC REGION								
Sacramento NWR	01-WC-20-1757	08N_PR [1]	GCC027	Glenn-Colusa Canal	46,400	3,600	–	50,000
Delevan NWR	01-WC-20-1757	08N_PR [2]	GCC039	Glenn-Colusa Canal	20,950	9,050	–	30,000
Colusa NWR	01-WC-20-1757	08S_PR	GCC056, CBD037	Glenn-Colusa Canal, Colusa Basin Drain	25,000	–	–	25,000
Sutter NWR [5]	01-WC-20-1757	17S_PR	SBP028, SEC009	Sutter Bypass, Sutter Extension Canal	23,500 [6]	6,500	–	30,000
Gray Lodge WA [5]	01-WC-20-1755	17N_PR	JBC002	Joint Board Canal	35,400 [7]	8,600	–	44,000
Subtotal					***151,250***	***27,750***	***0***	***179,000***
SAN JOAQUIN RIVER AND TULARE LAKE HYDROLOGIC REGIONS								
Merced NWR [4]	01-WC-20-1756	63_PR [2]	DED010	Deadman Creek	13,500	2,500	–	16,000
San Luis NWR – East Bear Creek Unit [5]	01-WC-20-1756	63_PR [3]	EBP048	Eastside Bypass	8,863	4,432	–	13,295
Volta WA	01-WC-20-1756	72_PR [1]	VLW008	Volta Wasteway	13,000 [3]	3,000	3,000	16,000
San Luis NWR – Kesterson Unit	01-WC-20-1758	72_PR [2]	XCC033	Main and Outside canals	10,000 [3]	–	6,500	10,000
San Luis NWR – Freitas Unit	01-WC-20-1758				5,290 [3]	–	1,763	5,290
San Luis NWR – San Luis Unit	01-WC-20-1758	72_PR [3]	ARY010	Arroyo Canal	19,000 [3]	–	5,650	19,000
San Luis NWR – West Bear Creek Unit	01-WC-20-1758				7,207	3,603	–	10,810
Los Banos WA	01-WC-20-1756	72_PR [4]	XCC033	Main and Outside canals	16,670	8,330	–	25,000
North Grasslands WA – Salt Slough Unit	01-WC-20-1756		ARY010, XCC033	Arroyo Canal, Main and Outside canals	6,680	3,340	–	10,020
North Grasslands WA – China Island Unit	01-WC-20-1756				6,967	3,483	–	10,450
Grassland RCD (north)	01-WC-20-1754	72_PR [5]	LBN012, XCC054	Los Banos Creek, Main and Outside canals	125,000	55,000	–	180,000
Grassland RCD (south)	01-WC-20-1754	72_PR [6]	ARY013, XCC025	Arroyo Canal, Main and Outside canals				
Mendota WA [5]	01-WC-20-1756	91_PR	MDOTA	Mendota Pool	27,594 [3]	2,056	9,094	29,650
Kern NWR [5]	01-WC-20-1758	N/A	D856	California Aqueduct	9,950	15,050	–	25,000
Pixley NWR [5]	01-WC-20-1758	N/A	D856	California Aqueduct	1,280	4,720	–	6,000
Subtotal					***271,001***	***105,514***	***26,007***	***376,515***
TOTAL					**422,251**	**133,264**	**26,007**	**555,515**

"– " = No contract or water right; AF = acre-feet; CVP = Central Valley Project; CVPIA = Central Valley project Improvement Act; ID = Irrigation District; NWR = National Wildlife Refuge; RCD = Resource Conservation District; Reclamation = U.S. Department of the Interior, Bureau of Reclamation; SWP = State Water Project; WA = Wildlife Area or Wildlife Management Area; WD = Water District.

[1] Level 2 amounts do not include conveyance losses.

[2] Replacement water is water that Reclamation provides from CVP yield to certain CVPIA refuges through contracts with management agencies executed before the passage of the CVPIA. It is to be replaced to the CVP when water can be acquired from willing sellers.

[3] Contract amounts include replacement water. Without replacement water the contract amounts are as follows: San Luis Unit, 13,350 AF; Kesterson Unit, 3,500 AF; Freitas Unit, 3,527 AF; Mendota WA, 18,500 AF, and Volta WA, 10,000 AF.

[4] Merced NWR receives 15,000 AF of mitigation water from Merced ID in accordance with Article 45 of its 1964 Federal Energy Regulatory Commission (FERC) license, which expires 2/28/2014. An additional 1,000 AF is met through groundwater pumping.

[5] Deliveries of Level 2 water are limited by conveyance constraints.

[6] Includes 3,000 AF of non-CVP water to be delivered from Sutter Extension WD

[7] Includes 18,841 AF of non-CVP water to be delivered by Biggs-West Gridley WD and SWP. Biggs-West Gridley WD delivers up to 6,949 AF to primary lands and up to 3,936 AF to secondary lands within the district. The SWP delivers up to 5,079 AF of surplus water to primary lands and 2,877 AF of surplus water to secondary lands

[8] Level 2 and incremental Level 4 amounts differ from Reclamation 1989 reports because of inclusion of replacement water. Level 2 water under the water supply contracts includes 26,007 AF of Replacement water. Under the water supply contracts, incremental Level 4 amounts have been reduced by the same amount.

Table F.3-7. Maximum Annual State Water Project Table A Amounts

State Water Project Long-term Contractors	**CalSim 3 Representation**		**Maximum Table A Amount (AF/year)**
	Demand Unit	**Diversion Node(s)**	
FEATHER RIVER			
County of Butte [1]	N/A	N/A	27,500
Plumas County FC&WCD	PLMAS	BGC002	2,700
City of Yuba City	16_PU	FTR031	9,600
Total for Feather River			***39,800***
NORTH BAY			
Napa County FC&WCD	NAPA	BKR004	29,025
Solano County WA	N/A	BKR004	47,756
Total for North Bay			***76,781***
SOUTH BAY			
Alameda County FC&WCD, Zone 7	N/A	SBA009,SBA020	80,619
Alameda County WD	N/A	SBA029	42,000
Santa Clara Valley WD	N/A	SBA036	100,000
Total for South Bay Aqueduct			***222,619***
SAN JOAQUIN VALLEY			
Oak Flat WD	71_PA7	CAA046	5,700
County of Kings	N/A	CAA181	9,305
Dudley Ridge WD	N/A	CAA184	41,350
Empire West Side ID	N/A	CAA173	3,000
Kern County WA	N/A	Multiple nodes	982,730
Tulare Lake Basin WSD	N/A	CAA183	87,471
Total for San Joaquin Valley			***1,129,556***
CENTRAL COAST			
San Luis Obispo County FC&WCD	N/A	CSB103	25,000
Santa Barbara County FC&WCD	N/A	CSB115	45,486
Total for Central Coast			***70,486***
SOUTHERN CALIFORNIA			
Antelope Valley-East Kern WA	N/A	ESB324	144,844
Santa Clarita Valley	N/A	CSTIC	95,200
Coachella Valley WD	N/A	ESB407	138,350
Crestline-Lake Arrowhead WA	N/A	SVWRD	5,800
Desert WA	N/A	ESB408	55,750
Littlerock Creek ID	N/A	ESB355	2,300
Mojave WA	N/A	ESB403	89,800

State Water Project Long-term Contractors	CalSim 3 Representation		Maximum Table A Amount (AF/year)
	Demand Unit	Diversion Node(s)	
Metropolitan WD	N/A	Multiple nodes	1,911,500
Palmdale WD	N/A	ESB347	21,300
San Bernardino Valley MWD	N/A	ESB414	102,600
San Gabriel Valley MWD	N/A	ESB415	28,800
San Gorgonio Pass WA	N/A	ESB420	17,300
Ventura County FCD	N/A	CSTIC	20,000
Total for Southern California			***2,633,544***
TABLE A TOTAL			**4,172,786**

AF = acre-feet; FC&WCD = Flood Control and Water Conservation District; FCD = Flood Control District; ID = Irrigation District; MWD = Metropolitan Water District of Southern California; N/A = not applicable; WA = Water Agency; WD = Water District; WSD = Water Storage District.

[1] County of Butte wholesales water to municipal and industrial water purveyors in the county. In CalSim 3, water from the county is available for demand units 11_NU1 (California Water Service Company – Oroville), 12_NU1 (Thermalito ID), and 16_PU (City of Yuba City).

Table F.3-8. Feather River Service Area Contracts and Water Rights

Water Purveyor	Point of Diversion	CalSim 3 Representation		Contract Amount (AF/year)			Contract Period of Diversion
		Demand Unit	Diversion Node	Table A	Settlement Contract	Water Right	
Western Canal WD	Thermalito Afterbay	11_SA1	THRMA	–	150,000	145,000	Mar–Oct
Richvale ID [1]		11_SA2		–	148,500	1,350	Apr–Oct
Biggs-West Gridley WD [1]		11_SA3		–	160,000	1,000	
Butte WD [1]				–	131,500	1,650	
Sutter Extension WD [1]	Thermalito Afterbay	11_SA4	THRMA	–	110,000	1,000	
	Sunset Pumps		FTR039	–	50,000 [5]	–	
Butte County	N/A	N/A	N/A	27,500	–	–	Jan–Dec
Thermalito ID	Power Canal	11_NU1	PCL000	–	–	8,000 [2]	Jan–Dec
South Feather Water and Power Agency	Lake Oroville	13_NU1	OROVL	–	–	17,555 [3]	Jan–Dec
Plumas MWC	Feather River	15S_SA	FTR018	–	8,000	6,000	Jan–Dec
Garden Highway MWC		16_SA	FTR014	–	12,870	5,130	Apr–Oct
Oswald WD			FTR021	–	2,850	150	Apr–Oct
Tudor MWC			FTR018	–	4,790	210	Jan–Dec
City of Yuba City		16_PU	FTR031	9,600	–	–	Jan–Dec
Subtotal				***37,100***	***778,510***	***187,045***	
Miscellaneous diverters [6]	Feather River		N/A		26,650		
Feather WD [7]	Feather River	16_PA	FTR021		20,000		
TOTAL					**1,015,555**		

"–" = No contract or water right; AF = acre-feet; CVP = Central Valley Project; DWR = California Department of Water Resources; ID = Irrigation District; MWC = Mutual Water Company; WD = Water District.

[1] The Joint WD Board includes Biggs-West Gridley WD, Butte WD, Richvale ID, and Sutter Extension WD. The Joint WD Board signed a settlement agreement with DWR for 550,000 AF of water, subject to deficiencies (settlement water), and 5,000 AF of water, not subject to deficiencies, in dry years. These amounts are shared among the member districts, for modeling purposes, as shown in the table. Additionally, the districts have the right to divert up to 10,000 AF of carriage water during the irrigation season, if it is returned to the Feather River above the City of Yuba City as operational spills.

[2] The amount of water available to Thermalito ID depends on the water supply at Lake Wilenor. The maximum entitlement is 8,000 AF/year represented in CalSim 3.

[3] The amount of water available to South Feather Water and Power Agency depends on the water supply at Ponderosa Reservoir. The maximum entitlement is 17,555 AF/year.

[4] DWR has additional agreements with Last Chance Creek WD, which claims pre-1914 water rights on the Middle Fork of the Feather River.

[5] The amount of water that may be diverted at the Sunset Pumps is increased to 65,000 AF when the unimpaired runoff to Lake Oroville for the period April 1 through July 31, as forecasted by DWR on May 10, is equal to or exceeds 1,500,000 AF, or when such forecasted runoff when added to the previous year's April 1 to July 31 runoff into Lake Oroville is equal to or exceeds 3,000,000 AF.

[6] These include minor diverters who hold riparian and appropriative water rights.

[7] Feather WD is a CVP contractor but is included here to show the total demands on Lake Oroville.

Appendix F, Modeling

Attachment F.1-1 Climate Change

F.1-1.1 Objective

The project team has developed model simulations to support analysis of the Central Valley Project (CVP) and State Water Project (SWP) long-term operations as part of reviewing proposed operations under the 2021 Reinitiation of Consultation on the Coordinated Long-Term Operation (2021 LTO) of the CVP and SWP. This attachment describes the overall analytical framework to consider climate change under future climate conditions and contains descriptions of the key analytical tools and approaches used.

F.1-1.2 Climate Change

In California, hydrology, regulations, and demands affect the operation of the Central Valley Project (CVP) and State Water Project (SWP). Climate change poses a significant challenge to Reclamation's operation of the CVP. Climate analyses can provide valuable insight into the projected conditions that may result from climate change. The effects of climate change on water management in California were analyzed as part of the 2021 LTO of the CVP and SWP.

Climate change effects representing 2022±15 climate conditions were analyzed by updating CalSim 3 meteorologic and hydrologic boundary conditions for 2021 LTO. The future climate condition was developed with 40 Coupled Model Intercomparison Project Phase 5 (CMIP5) global climate projections, selected for LTO as briefly described in Section F.1-1.2.2.2, *Global Climate Model Selections*. The main analysis was based on the 2022±15 median climate change scenario. A set of different scenarios, to review range of uncertainty, were developed representing 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median conditions.

The integrated daily historical Livneh data (Livneh et al. 2013 and updated thereafter) and Parameter-elevation Regressions on Independent Slopes Model (PRISM) dataset (Daly et al. 1994), were processed and then perturbed using the differences observed in the ensemble of the 40 selected global climate projections. Historical and perturbed meteorological data were used for simulating projected surface runoff, baseflow, surface water evaporation, and potential evapotranspiration variables for future period using the Variable Infiltration Capacity (VIC) model. The differences between simulated historical and projected variables were applied to the historical CalSim 3 boundary conditions to represent the future climate scenarios.

F.1-1.2.1 Introduction

The details of the methodology used in developing hydroclimate boundary conditions for the CalSim 3 models to represent 2022±15 conditions are outlined in this document. The main analysis was based on the 2022±15 median climate change scenario. A set of additional climate scenarios to review the range of uncertainty was developed. This set of climate scenarios is described in Section F.1-1.2.7, *Climate Change Scenarios for Sensitivity*. Figure F.1-1-1 illustrates the overall dataset development and modeling sequence used for the analysis. Table F.1-1-1 shows the various datasets used for perturbing different variables of CalSim 3 model to represent future climate conditions.

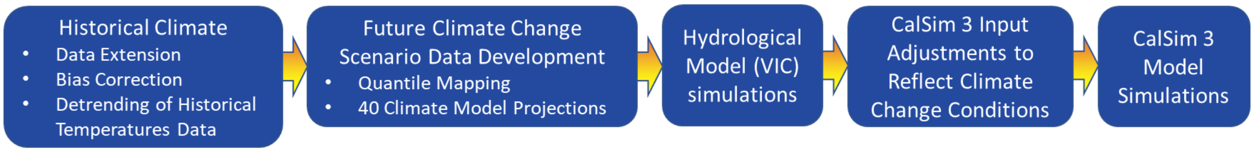

Figure F.1-1-1. Dataset Development and Modeling Sequence

Table F.1-1-1. Summary of the Principal Data Sources Used in the Climate Change Analysis

Data	Use in Climate Change Analysis	Spatial and Temporal Resolution	Source
Daily Gridded Historical Climate Data (Livneh et al. 2013 and updated thereafter)	Used in VIC model simulations and developing climate change scenarios	Daily data at 1/16-degree (~6 km) spatial resolution over the period 1915-2015	Surface Water Modeling Group at the University of Washington (http://www.hydro.washington.edu)
Daily Historical Gridded Climate Data (PRISM)	Used in extending Livneh et al. daily gridded historical climate data	Daily data at ~800-m spatial resolution over the period 2016-2020 and ~4-km spatial resolution for 2021	PRISM Climate Group at Oregon State University (http://www.prism.oregonstate.edu/)
Monthly Historical Gridded Climate Data (PRISM)	Used in adjusting the extended Livneh et al. daily gridded historical climate data	Monthly data at ~800-m spatial resolution over the period 1895-2020 and ~4-km spatial resolution for 2021	PRISM Climate Group at Oregon State University (http://www.prism.oregonstate.edu/)
CMIP5 Downscaled Climate Projections (LOCA method)	Used in developing climate change scenarios	Daily data at 1/16-degree (~6 km) spatial resolution over the period 1950-2099	Scripps Institution of Oceanography

F.1-1.2.2 Climate Change Scenario Development

F.1-1.2.2.1 Historical Observed Meteorology Data and processing

Livneh et al. (2013, updated thereafter) daily historical meteorology data at 1/16th degree (~6 km or ~3.75 miles) spatial resolution over the period 1915 through 2015 was extended using the PRISM daily historical meteorology data from 2016 to 2021. Livneh et al. (2013, updated thereafter) was gridded from observations of precipitation and minimum and maximum daily temperature at National Climatic Data Center (NCDC) Cooperative Observer (COOP) stations across the conterminous United States using the synergraphic mapping system algorithm. Wind data were linearly interpolated from a larger NCEP–NCAR reanalysis grid (Kalnay et al. 1996).

This extended daily historical precipitation, minimum and maximum temperatures data were adjusted based on PRISM monthly data (Daly et al. 1994) to correct biases found in the period of interest. The bias corrected minimum (T_{min}), and maximum (T_{max}) temperature were detrended using the Linear Trend Removing Technique to represent the current climate condition (Zhang et al., 2011). The temperature detrending was performed by removing the month-specific trends and adding the daily residuals of 1915-2021 to the monthly climatology for 1991–2020. The approach was followed for detrending T_{max} and daily temperature range (DTR), while detrended T_{min} was estimated as the difference between detrended T_{max} and DTR. The anchor period used for the temperature detrending was over the period 1991-2020, consistent with the National Oceanic and Atmospheric Administration (NOAA) climatological normal period.

The extended daily historical meteorological data was used for historical VIC simulation. Bias corrected daily precipitation and detrended daily temperature were used for the development of the future climate change scenarios dataset using Global Climate Models (GCMs).

F.1-1.2.2.2 Global Climate Model Selections

The 2022±15 median climate change scenario and various sensitivity scenarios were developed using 40 Coupled Model Intercomparison Project 5 (CMIP5) global climate model (GCM) projections. These projections were downscaled using the localized constructed analog (LOCA) method at 1/16th degree spatial resolution (Pierce et al. 2014). The LOCA method is a statistical scheme that uses future climate projections combined with historical analog events to produce daily downscaled precipitation, and maximum and minimum temperature time series data. More details on the LOCA downscaling can be found in Pierce et al. (2014).

The 40 CMIP5 global climate model projections were selected by LTO as the most appropriate projections for Central Valley Project (CVP) and State Water Project (SWP) long-term operations. The 40 climate projections were generated with 20 global climate models and two emission scenarios, one optimistic (Representative Concentration Pathway [RCP] 4.5) and one pessimistic (RCP 8.5) (Table F.1-1-2).

The selection of the climate models for likely representation of future climate conditions within California was made by evaluating the accuracy of the GCMs over the historical period (1950–2005) in comparison to observationally informed datasets (PRISM). Downscaled GCM performance was evaluated using metrics of temporal skill, spatial skill, and interannual variability over the historical period produced using an updated climate change understanding. Differences in temporal and spatial skill were insufficient to identify GCMs that did not accurately represent climate conditions. Instead, the representation of interannual variability representation was used to eliminate GCMs that least accurately replicated California during the historical period. Out of the initial set of 32 GCMs from CMIP5, 20 GCMs were selected for the climate change analysis based on California-specific water management metrics.

Table F.1-1-2. Recommended Global Climate Models

Model Number	Model Name	Model Institution
1	ACCESS1-0	Commonwealth Scientific and Industrial Research Organization and Bureau of Meteorology
2	ACCESS1-3	Commonwealth Scientific and Industrial Research Organization and Bureau of Meteorology
3	bcc-csm1-1	Beijing Climate Center, China Meteorological Administration
4	CESM1-BGC	National Science Foundation, Department of Energy, National Center for Atmospheric Research
5	CESM1-CAM5	National Center for Atmospheric Research
6	CMCC-CM	Centro Euro-Mediterraneo per I Cambiamenti Climatici
7	CNRM-CM5	Centre National de Recherches Météorologiques, Centre Européen de Recherche et Formation Avancées en Calcul Scientifique
8	CSIRO-Mk3.6.0	Commonwealth Scientific and Industrial Research Organization/Queensland Climate Change Centre of Excellence
9	GFDL-ESM2G	Geophysical Fluid Dynamics Laboratory
10	GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory
11	GISS-E2-H	NASA Goddard Institute for Space Studies
12	GISS-E2-R	NASA Goddard Institute for Space Studies
13	HadGEM2-AO	National Institute of Meteorological Research/Korea Meteorological Administration
14	HadGEM2-ES	Met Office Hadley Centre; additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais
15	INM-CM4	Institute for Numerical Mathematics
16	IPSL-CM5A-MR	Institute Pierre-Simon Laplace
17	MIROC5	Atmosphere and Ocean Research Institute at the University of Tokyo, National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
18	MPI-ESM-LR	Max Planck Institute for Meteorology
19	MPI-ESM-MR	Max Planck Institute for Meteorology
20	NorESM1-M	Norwegian Climate Center

Notes: Models are listed alphabetically.

F.1-1.2.2.3 Future Climate Change Scenario

Future climate change scenario (2022±15 median climate condition) was developed over the bias corrected daily precipitation and detrended daily temperature using the quantile mapping approach based on selected 40 global climate model projections. Adjustments to temperature and precipitation were calculated with cumulative distribution functions, mapped with the 40 downscaled CMIP5 GCM projections (Taylor et al. 2012). The quantile mapping approach involves the following steps:

- A 30-year slice of climate model data (precipitation, and maximum and minimum temperatures) was extracted from each of the 40 downscaled climate model simulations centered on the model-simulated reference period (1995: 1981–2010) and future period (2022: 2008–2037).
- For each calendar month (e.g., January) of the model simulated reference period, the CDF for each climate model projection of temperature and precipitation at each grid cell was determined separately. 50th percentile value for each quantile of the 40 CDFs was computed to form a model simulated reference period CDF.
- For each calendar month of the future period, the CDF for each climate model projection of temperature and precipitation at each grid cell was determined separately. 50th percentile value for each quantile of the 40 CDFs was computed to form a model simulated future period CDF.
- The change was computed as the ratio (future period divided by reference period) for precipitation and 'deltas' (future period minus reference period) for temperature at each quantile from the reference and future period CDFs.
- These ratios and deltas were applied to historical precipitation and detrended temperature data to develop a monthly time series of temperature and precipitation at 1/16th degree over 1915-2021 that incorporates the future climate shift.
- Monthly time series was converted to a daily time series by scaling monthly values to daily sequence found in the observed record.

Figure F.1-1-2 shows the projected change in long-term average annual temperature for the major watersheds in the Sacramento and San Joaquin River Basins under 2022±15 median climate change scenario. The temperature is projected to increase by 1.6°C across major watersheds with a minimum increase of 1.4°C under 2022±15 median condition with respect to the historical reference period (1995). The highest temperature increases are projected for Feather River (1.7°C) watershed in the Sacramento River Basin and Merced River (1.7°C) watershed in the San Joaquin River Basin. As reflected in Figure F.1-1-3, average annual temperature increases are nearly uniform across the domain.

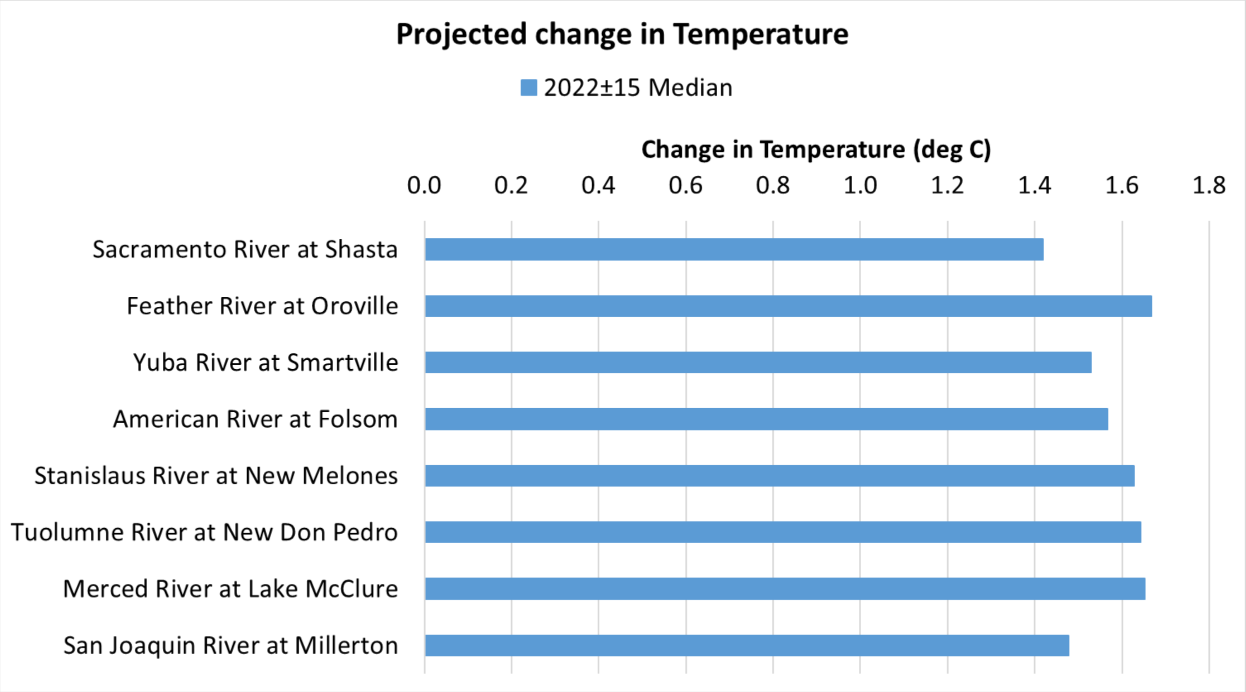

Figure F.1-1-2. Projected Changes in Average Annual Temperature for Major Watersheds in the Sacramento and San Joaquin River Basins under 2022±15 Median Climate Change Scenario

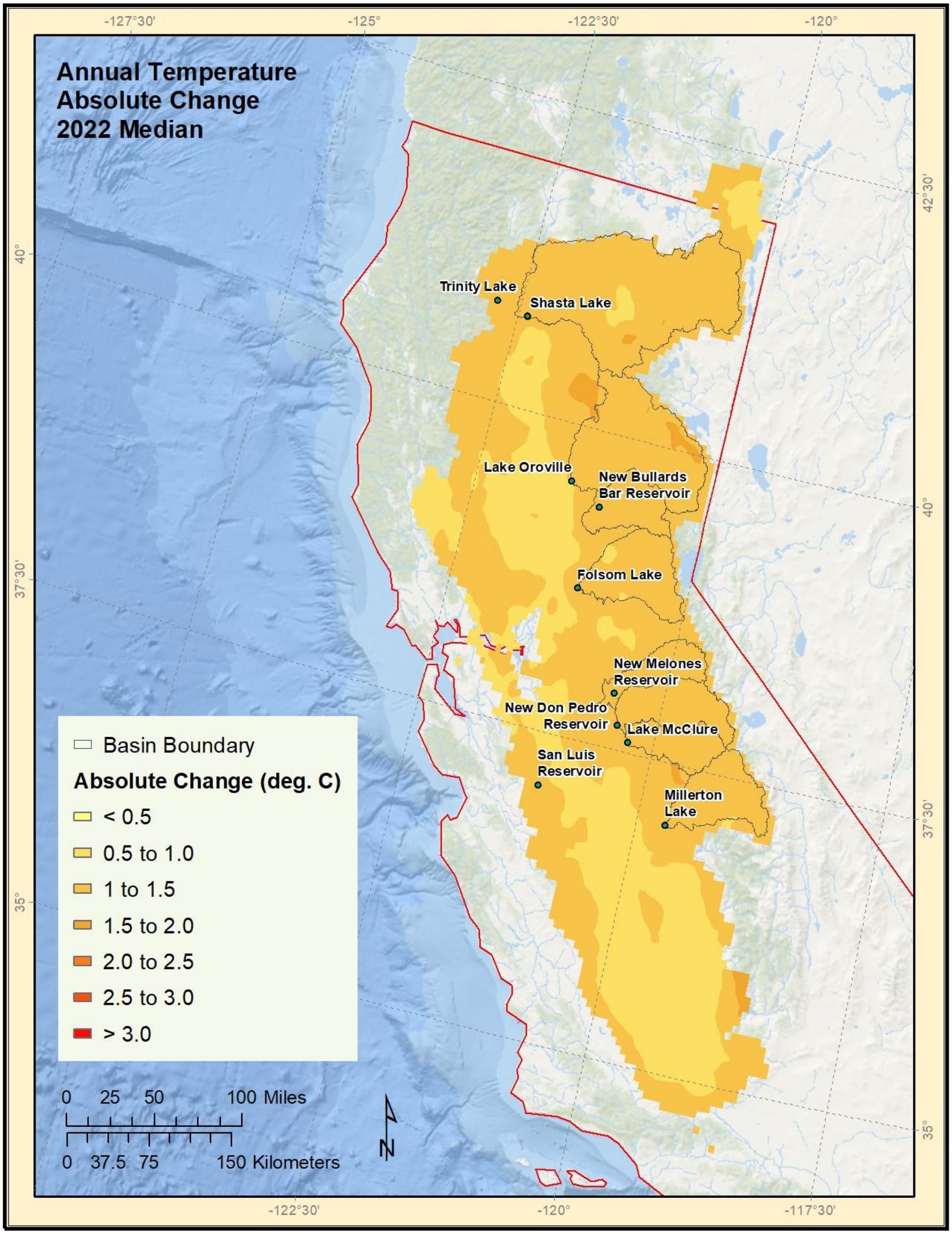

Figure F.1-1-3. Projected Absolute Changes in Average Annual Temperature under 2022±15 Median Climate Change Scenario

Projected change in long-term average annual precipitation for major watersheds in the Sacramento and San Joaquin River Basins are presented in Figure F.1-1-4. Overall, all major watersheds are projected to be wetter under 2022±15 median condition, with average increases from 0.9% to 2%. Sacramento River Basin is projected to experience a higher increase in long-term average annual precipitation than the San Joaquin River Basin (Figure F.1-1-4 and Figure F.1-1-5).

The Snow Water Equivalent (SWE) for the major watersheds in the Sacramento and San Joaquin River Basins is projected to decrease under 2022±15 median climate conditions. The projected reduction in the snowpack volume and earlier snowmelt due to the rise in temperature will shift unregulated streamflow volume to earlier in the year. More information on projected changes in SWE and snowpack is provided in Section F.1-1.2.5, *Use of Fractional Changes for HydroClimate Data*.

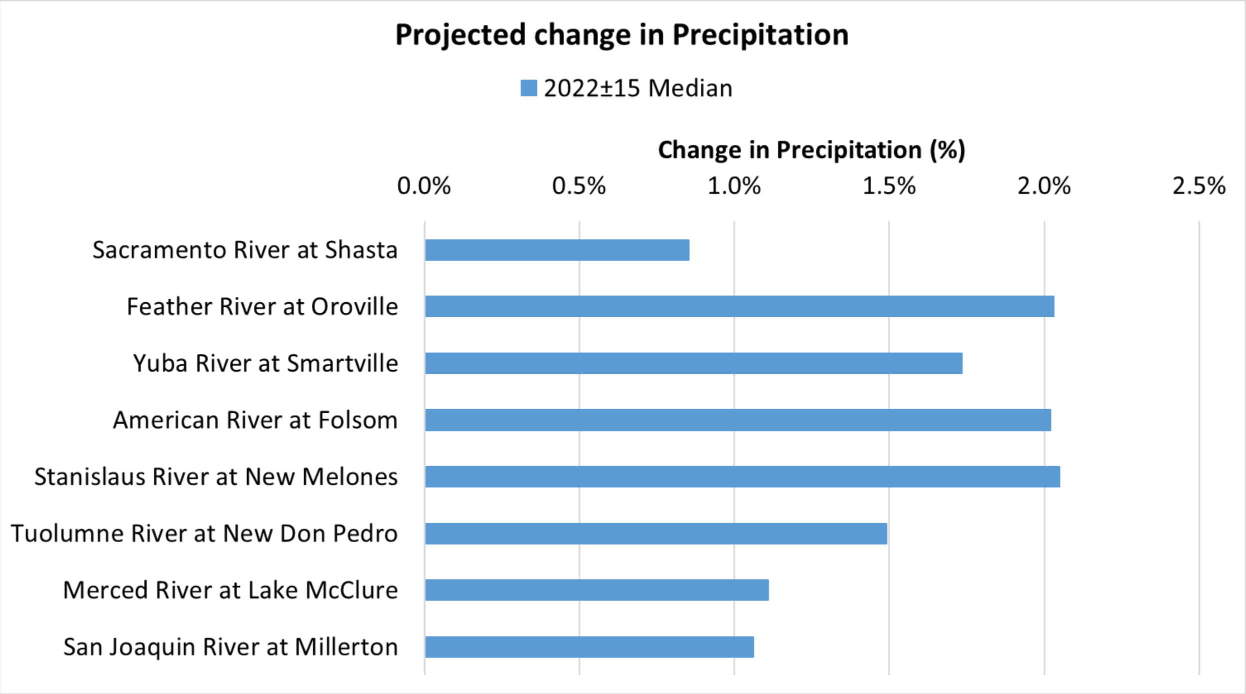

Figure F.1-1-4. Projected Changes in Annual Precipitation for Major Watersheds in the Sacramento and San Joaquin River Basins under 2022±15 Median Climate Change Scenario

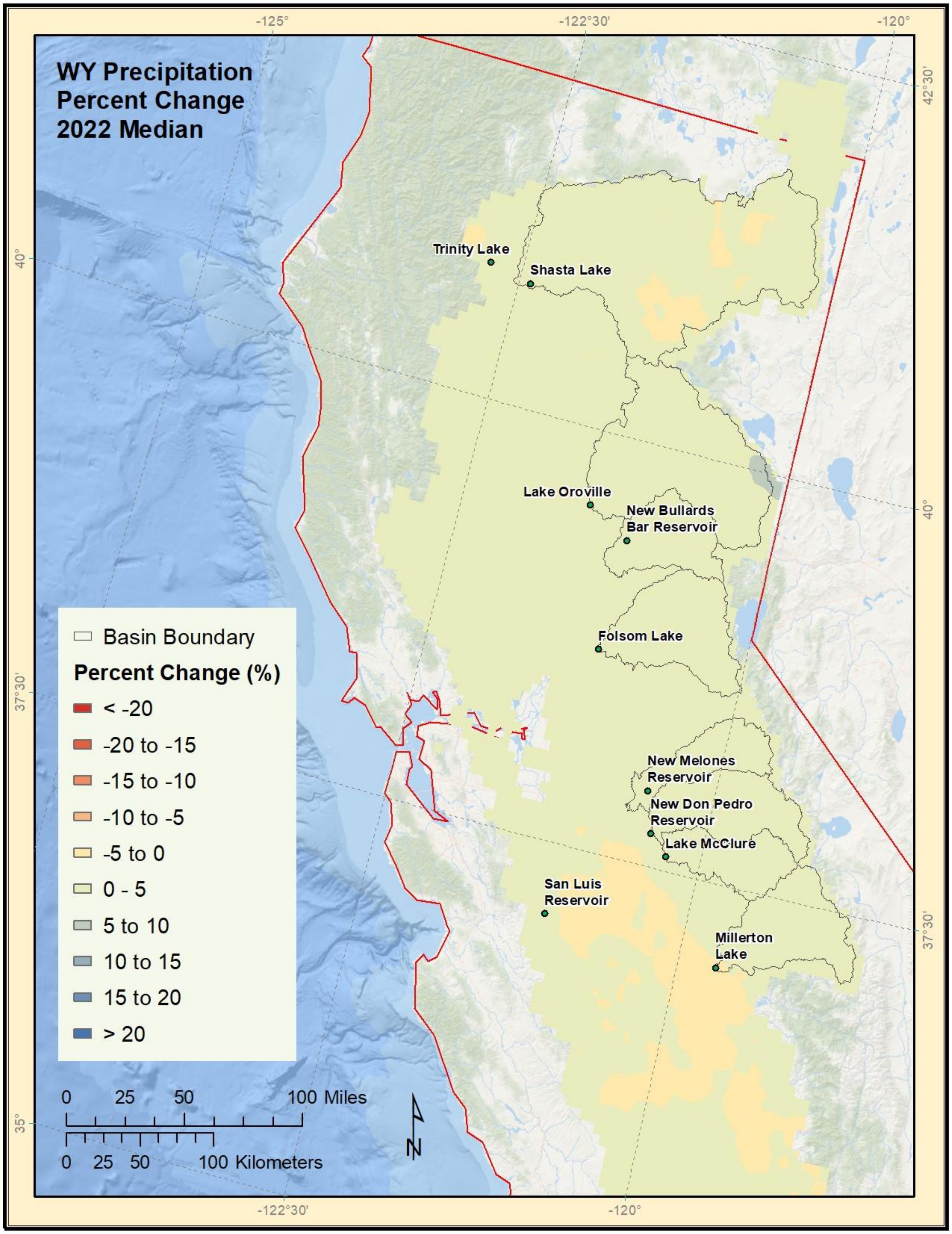

Figure F.1-1-5. Projected Change in Annual Precipitation under 2022±15 Median Climate Change Scenario

F.1-1.2.3 VIC Model Simulations

Variable Infiltration Capacity (VIC, Liang et al. 1996; Nijssen et al. 1997) model was used for simulating the daily historical and projected surface runoff, baseflow, surface water evaporation and potential evapotranspiration at 1/16th degree by inputting historical and projected meteorological data under different climate change scenarios. The VIC model simulates land-surface-atmosphere exchanges of moisture and energy at each model grid cell. The model incorporates spatially distributed parameters describing topography, soils, land use, and vegetation classes.

The comparison of VIC model simulated fluxes between historical and future conditions were used to perturb CalSim 3 boundary conditions. Surface runoff and baseflow were used to produce total runoff at all locations that correspond to CalSim 3 rim inflows and unimpaired flow. Potential evapotranspiration was used to estimate crop evapotranspiration throughout the Sacramento and San Joaquin Valleys. Surface water evaporation was used to estimate evaporation rates at reservoirs within the CalSim 3 model domain.

F.1-1.2.4 CalSim 3 Inputs Development

CalSim 3 projected hydroclimate input data under different climate change scenario was developed using the following methods:

- For all watersheds, simulated changes in streamflows (simulated future streamflows divided by historical simulated streamflows) were applied to the CalSim 3 inflows. These fractional changes were first applied for every month of the 106-water year period (1915–2021) consistent with the VIC model simulated patterns. A second order correction was then applied to confirm that the annual shifts in runoff at each location were consistent with the shifts observed in the VIC model.
- Total flows of major watersheds were perturbed with the two-step process described above. Then, the perturbed runoff of each contributing watershed was adjusted to match the perturbed total flow in the watershed.
- For watersheds where streamflows are heavily impaired, a process was implemented by calculating historical impairment based on observed data and adding that impairment back onto the VIC model simulated flows at a location upstream of the impairment.
- Similarly, fractional changes (described in the first bullet) were also used to simulate changes in precipitation, temperature, surface water evaporation and evapotranspiration as needed for calculation of certain parameters used in CalSim 3.

F.1-1.2.5 Use of Fractional Changes for HydroClimate Data

Fractional changes (simulated future data divided by historical simulated data) were applied to the CalSim 3 inflow, precipitation, surface water evaporation, and evapotranspiration boundary conditions. Absolute changes (difference in simulated future data and historical simulated data) were applied to CalSim 3 temperature boundary conditions. For the CalSim 3 boundary conditions, climate variables and perturbation methods used are further detailed below.

F.1-1.2.5.1 Rim Inflows

Rim inflows, or inflows from the "rim" of the California watershed, routing through a system of reservoirs, channels, and diversions is simulated by CalSim3 model. Perturbation of CalSim 3 inflow boundary conditions were based on VIC simulated watershed area-weighted total runoff (surface runoff plus baseflow). The following steps were used to perturb CalSim 3 rim inflows and major watershed flows:

- Monthly change factors were calculated for every month in the simulation period from WY 1922 to 2021 using VIC historical and 2022±15 median condition simulated total runoff.
- Monthly CalSim 3 historical rim inflows were perturbed using the monthly change factors from the previous step.
- Annual perturbation, based on water year, was applied to the monthly perturbed CalSim 3 flows. These water year change factors were calculated as the ratio between the water year change factors of the VIC simulated (2022±15 median and historical) total runoff and the water year change factors of the monthly perturbed historical CalSim 3 flow and observed historical CalSim 3 flow.
- A correction factor was applied to major watershed flow locations by calculating the difference between perturbed CalSim 3 flow at the major flow location and the sum of perturbed CalSim 3 flow from all contributing watersheds at that major flow location. Major watershed flow locations and the number of contributing watersheds to each location are tabulated in 3.
- The calculated difference (step above) was applied to the perturbed CalSim 3 flow at the contributing watersheds. At each time step, the difference is proportionally distributed to perturbed CalSim 3 flow. The proportion of error distribution is based on the ratio of the perturbed CalSim 3 flow magnitude from an individual watershed to the total CalSim 3 flow magnitude from all contributing watersheds.

Table F.1-1-3. Major Watershed Flow Locations in CalSim 3

Basin Name	Flow Location	No. Contributing Watersheds
Feather River	Total Inflow to Lake Oroville	21
Yuba River	Yuba River at Smartville	18
Bear River	Bear River at Confluence with Feather River	5
American River	Total Inflow to Folsom Lake	46
Mokelumne River	Total Inflow to Pardee Reservoir	9
Stanislaus River	Total Inflow to New Melones Lake	21
Tuolumne River	Total Inflow to New Don Pedro Reservoir	4

Eight River Index (8RI) is the sum of the rivers included in the Sacramento Valley (SAC-4) and San Joaquin Valley (SJR-4) 4 Rivers Indices. The Sacramento Valley Four Rivers Index (SAC-4) is the sum of runoff at the following locations: Sacramento River above Bend Bridge, Feather River inflow at Lake Oroville, Yuba River at Smartville, and American River inflow to Folsom Lake. The San Joaquin Valley Four Rivers Index (SJR-4) is the sum of runoff at the following locations: Stanislaus River inflow to New Melones Lake, Tuolumne River inflow to New Don Pedro River, Merced River inflow to Lake McClure, and San Joaquin River inflow to Millerton Lake.

Projected change in the Eight River Index (8RI), Sacramento Valley Four Rivers Index (SAC-4), San Joaquin Valley Four Rivers Index (SJR-4), and runoff at eight major rivers under 2022±15 median climate conditions is provided in Figure F.1-1-6. 8RI runoff change is dominated by the change in the Sacramento Valley runoff and projected to increase. The runoff in the Sacramento Valley is projected to increase by 0.3%, while San Joaquin Valley runoff is projected to reduce by 0.6%. Runoff increases in all major basins except for the San Joaquin River at Millerton and Merced River at Lake McClure, where runoff decreases by more than 1%. The San Joaquin River at Millerton, Merced River at Lake McClure, and Sacramento River at Shasta basins are projected to receive the least increase in the precipitation as compared to other basins. In the San Joaquin River at Millerton and Merced River at Lake McClure basins, projected increases to actual evapotranspiration are greater than the increase to precipitation, resulting in a projected decrease in runoff. However, in the Sacramento River at Shasta basin, the runoff is projected to slightly increase because the projected increase in actual evapotranspiration is less than the projected increase to precipitation.

The April 1st Snow Water Equivalent (SWE) for the major basins in the Sacramento and San Joaquin is projected to decrease by 20% to 75% under 2022±15 median climate conditions (Figure F.1-1-7). The reduction in the SWE for all the major basins is caused by the rise in temperature and occurs even if the amount of precipitation remains relatively stable over the central and northern California region (Pierce et al. 2018; Bedsworth et al. 2018). The variation in the decrease in the SWE among the basins is attributed to the elevation of the watersheds.

Long-term average monthly flows of SAC-4 and SJR-4 are presented in Figure F.1-1-8. As compared to historical runoff, increased precipitation under 2022±15 median climate conditions lead to a higher peak in SAC-4 peak runoff. 2022±15 median climate SJR-4 peak runoff volume and timing remain similar to historical runoff. In both basins, runoff increases in winter and decreases in spring and summer. Increased winter temperatures lead to a higher portion of precipitation that directly results in runoff, as opposed to snowpack. Similarly, with decreased snowpack, runoff during the summer, when the majority of runoff is snowmelt under historical conditions, decreases. A map of projected changes in annual rim inflows under 2022±15 median climate change scenario is presented in Figure F.1-1-9.

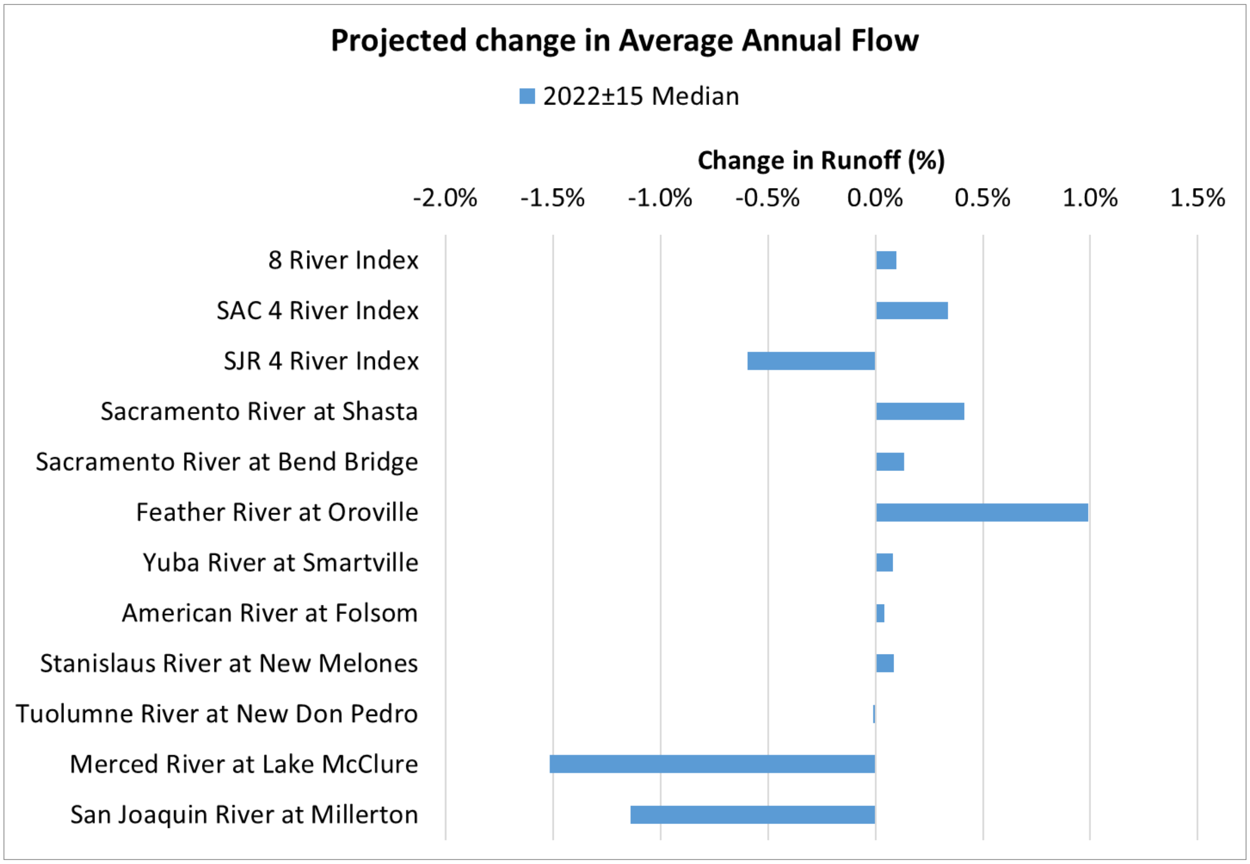

Figure F.1-1-6. Projected Changes in Runoff for Major Watersheds in the Sacramento and San Joaquin River Basins for 2022±15 Median Climate Change Scenario

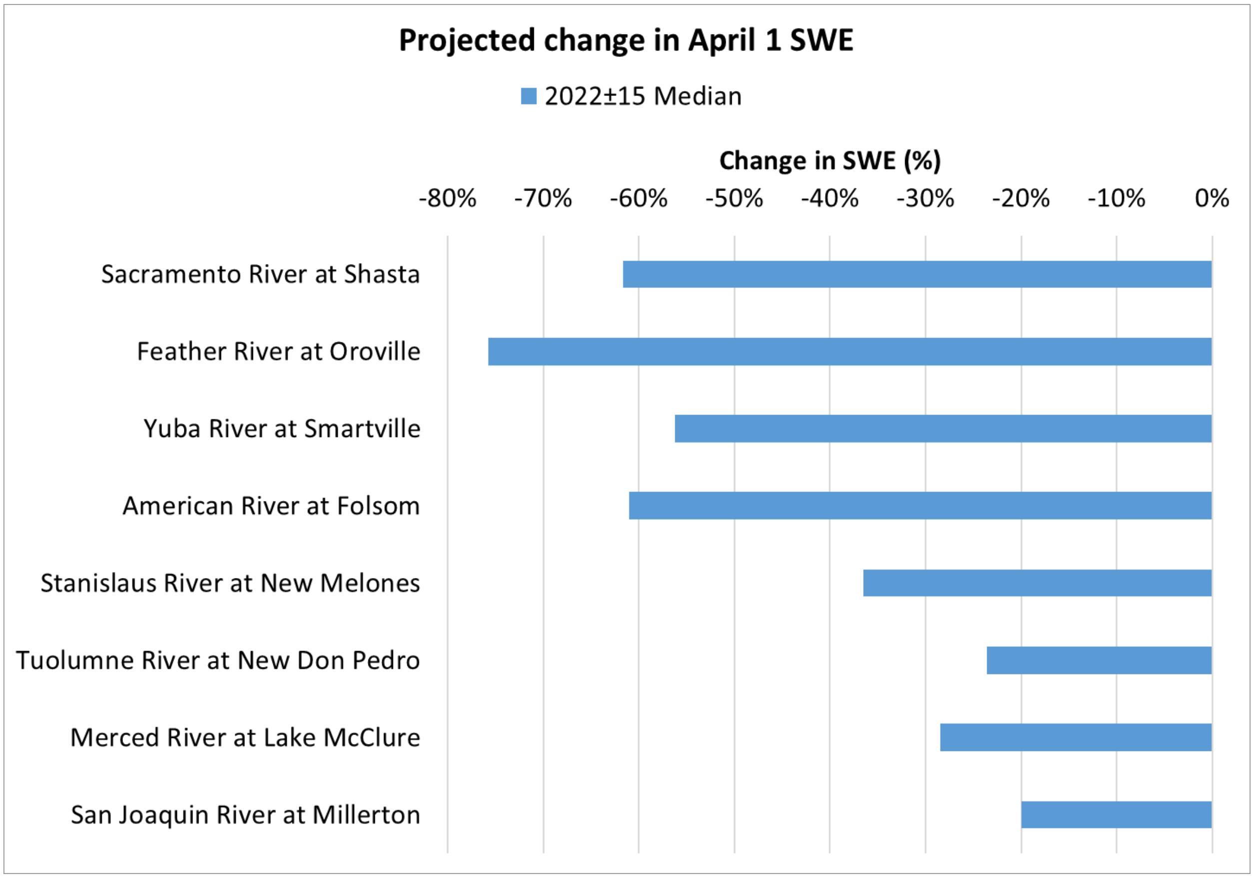

Figure F.1-1-7. Projected Changes in April 1 Snow Water Equivalent (SWE) in the Sacramento and San Joaquin River Basins for 2022±15 Median Climate Change Scenario

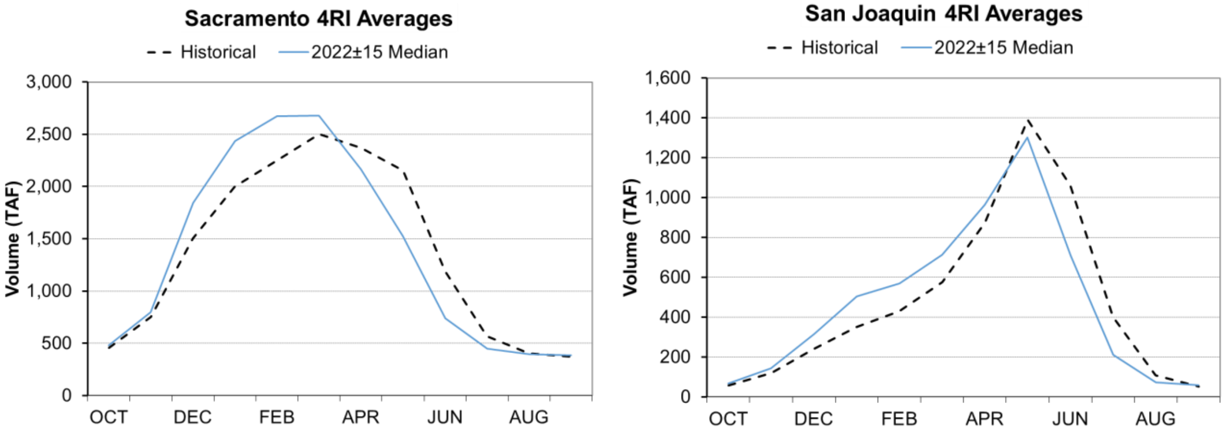

Figure F.1-1-8. Projected Changes in Monthly Pattern of Runoff for the Sacramento Basin (left) and San Joaquin Basin (right) for 2022±15 Median Climate Change Scenario.

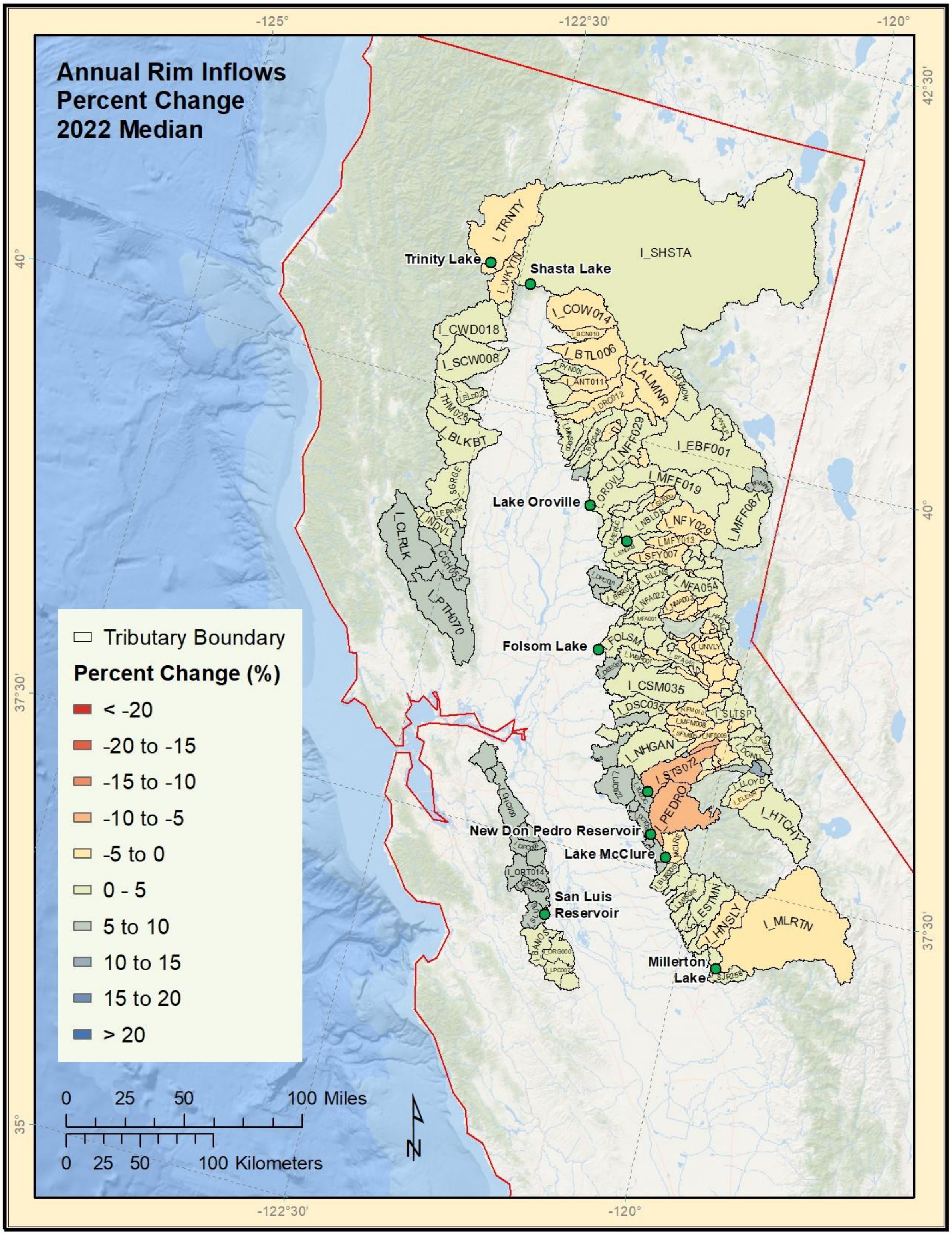

Figure F.1-1-9. Projected Changes in Annual Rim Inflows under 2022±15 Median Climate Change Scenario

F.1-1.2.5.2 Valley Floor Flows

CalSimHydro is a surface water hydrologic model that estimates CalSim 3 boundary conditions in the Sacramento and San Joaquin Valleys. A map of its spatial domain is provided in Figure F.1-1-10. The CalSimHydro model estimates applied crop water, surface runoff, return flow and deep percolation data for use in CalSim 3. The input variables to the CalSimHydro model include daily precipitation, crop evapotranspiration (ET), reference evapotranspiration, pan evaporation, land use area, and urban demand. More details regarding the CalSimHydro model are available at CalSimHydro Reference Manual (California Department of Water Resources 2019).

Figure F.1-1-10. Water Budget Areas in the CalSim 3 and CalSimHydro Models

The following steps were used to perturb CalSimHydro input variables:

- Monthly change factors were calculated for every month in the simulation period from WY 1922 to 2021 using VIC historical and 2022±15 median condition simulated data.
- Monthly historical data were perturbed using the monthly change factors from the previous step.
- Annual perturbation, based on water year, was applied to the monthly perturbed data. These water year change factors were calculated as the ratio between the water year change factors of the VIC simulated (2022±15 median and historical) data and the water year change factors of the monthly perturbed historical data and observed historical data.

Figure F.1-1-11 shows the projected change to applied crop water, surface runoff, tail water and deep percolation in the Sacramento and San Joaquin Valleys, as estimated with the CalSimHydro model under 2022±15 median condition. Applied water increases in both valleys due to increased evapotranspiration, a result of increased temperature (Figure F.1-1-2). As estimated with CalSimHydro, changes to pattern and magnitude of precipitation (Figure F.1-1-4) result in small increases to surface runoff and return flow. But the deep percolation decreases for Sacramento Valley and increases for San Joaquin Valley.

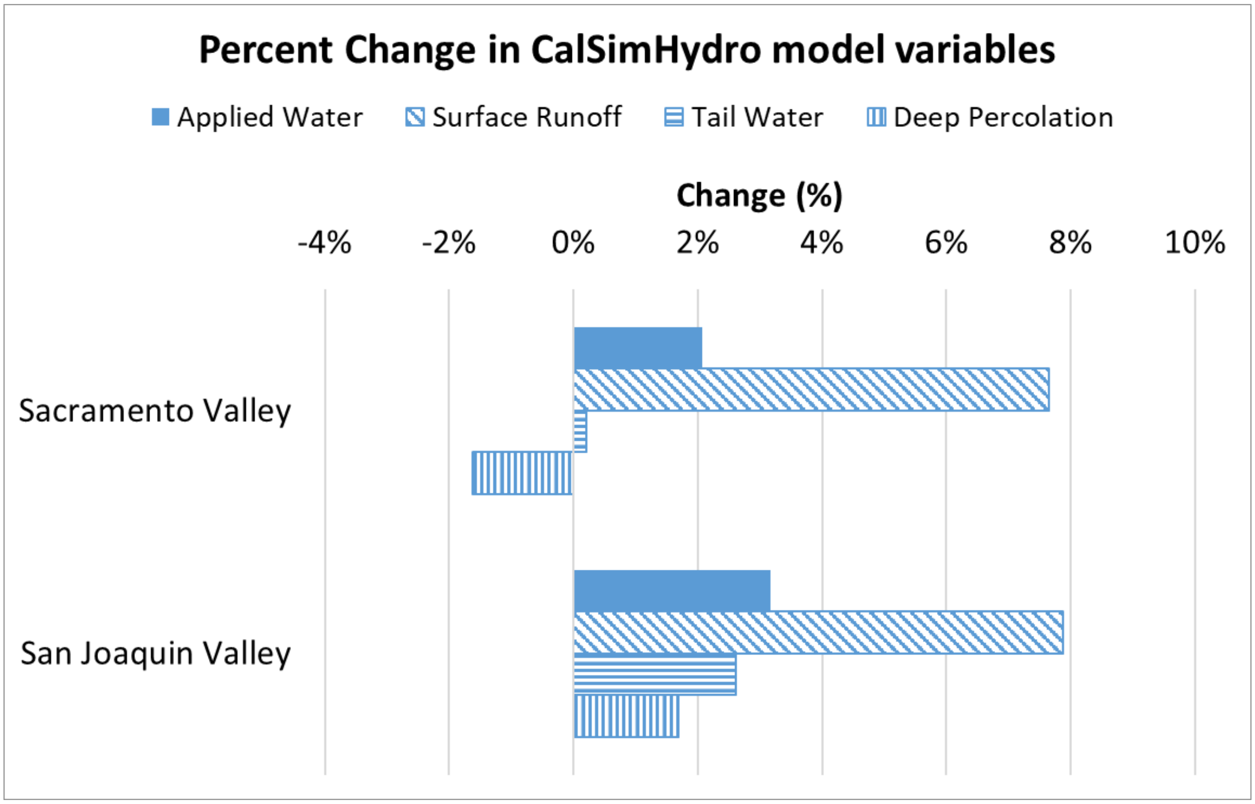

Figure F.1-1-11. Projected Changes in Applied Water, Surface Runoff, Tail Water, and Deep Percolation for Sacramento and San Joaquin for 2022±15 Median Climate Change Scenarios

F.1-1.2.5.3 Delta Channel Depletion

The Delta Channel Depletion (DCD) model was used to estimate CalSim 3 irrigation, drainage, and seepage in the Sacramento–San Joaquin River. The DCD model depends on the Delta Evapotranspiration of Applied Water (DETAW) model to estimate Delta crop evapotranspiration. Inputs to the DCD model include daily timeseries of precipitation and temperature at several locations throughout the Delta. More details regarding the DCD model are available at Methodology for Flow and Salinity Estimates in the Sacramento–San Joaquin Delta and Suisun Marsh, Chapter 2: Calibrating and Validating Delta Channel Depletion Estimates (California Department of Water Resources 2018).

Perturbation of the precipitation data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.2, *Valley Floor Flows*. Daily maximum and minimum temperature boundary conditions are referenced to estimate Delta evapotranspiration. The following steps were used to perturb temperature data:

- Monthly absolute differences, or deltas, were calculated for every month in the simulation period from WY 1922 to 2021 using historical and 2022±15 median condition temperature data.
- Daily historical minimum and maximum temperature data were perturbed using the monthly absolute differences from the previous step.

Figure F.1-1-12 shows the projected change to Sacramento–San Joaquin River Delta irrigation, drainage, and seepage under 2022±15 median condition as estimated with the DCD model. Irrigation and seepage increase due to increased evapotranspiration, a result of increased temperature (Figure F.1-1-2). As estimated with DCD, changes to pattern and magnitude of precipitation (Figure F.1-1-4) and increased irrigation result in a small increase to Delta Island drainage. The projected increase in the Net Delta Island Consumptive Use (DICU) is 1.6% under 2022±15 median climate change scenario. Net DICU refers to the total island monthly consumptive uses. It represents the sum of irrigation withdrawal and levee seepage minus the return volume, or drainage.

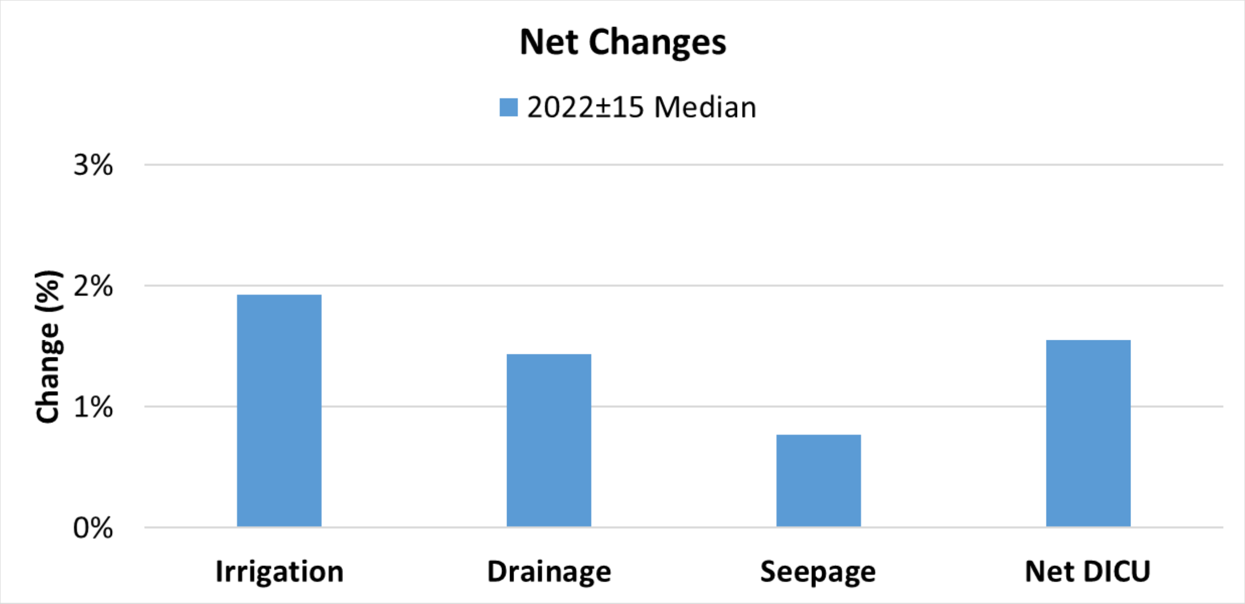

Figure F.1-1-12. Projected Changes in Delta Island Consumptive Use for 2022±15 Median Climate Change Scenario

F.1-1.2.5.4 Reservoir Evaporation

Evaporation rate boundary conditions are applied to all reservoirs in the CalSim 3 spatial domain. Gross evaporation rates were applied at most reservoirs. Net evaporation rates (evaporation rate minus precipitation) were applied at terminal reservoirs, or reservoirs without natural inflow.

Gross evaporation and precipitation data were perturbed separately to develop net evaporation at 2022±15 median conditions. Perturbation of the surface water evaporation and precipitation data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.2.

Figure F.1-1-13 shows the projected change in evaporation rate at major reservoirs under 2022±15 median conditions. The evaporation rates of the reservoirs are projected to increase due to the increase in temperature and diurnal temperature range.

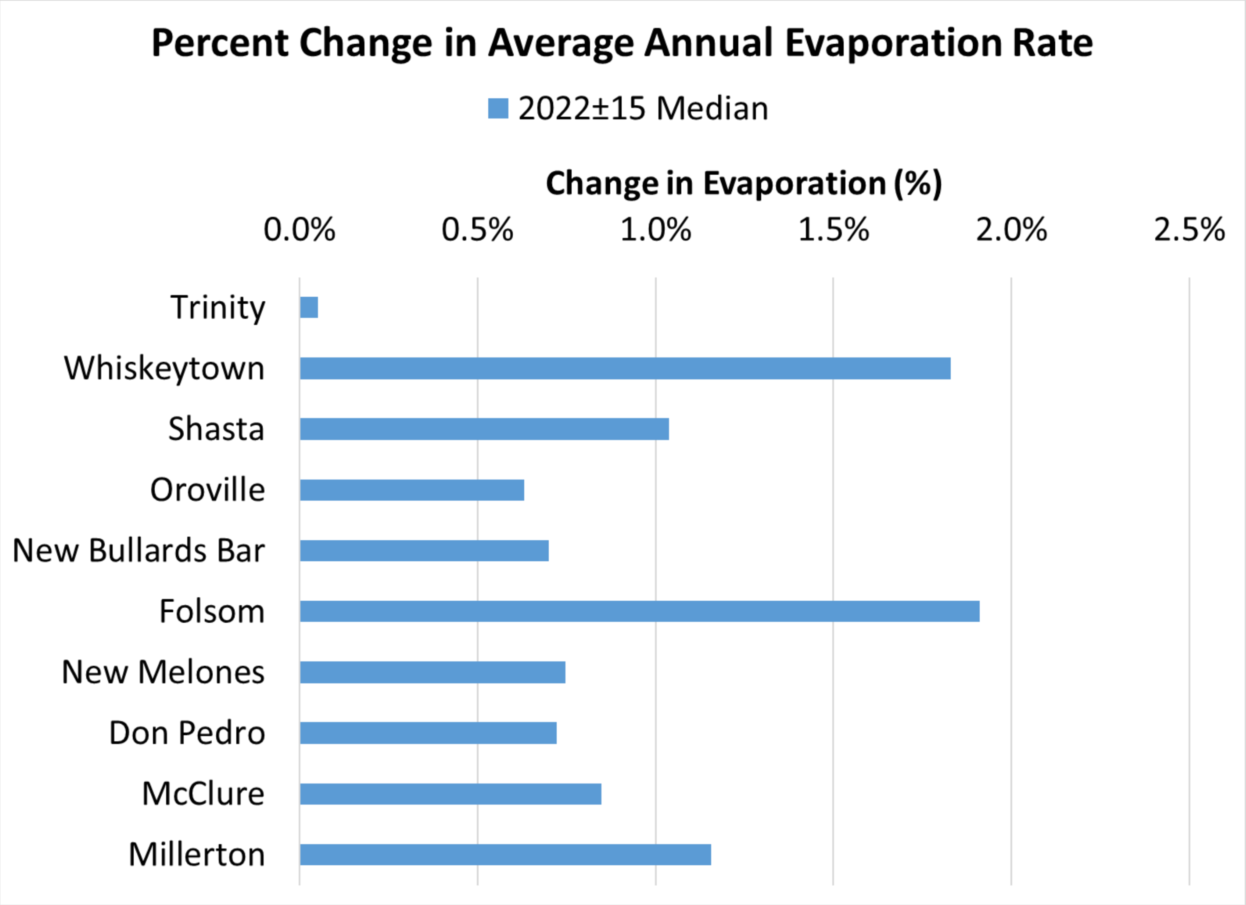

Figure F.1-1-13. Projected Changes in Evaporation Rate at Major Reservoirs for 2022±15 Median Climate Change Scenario

F.1-1.2.5.5 Inputs for Lookup Tables

CalSim 3 operations decisions are based upon meteorologic and hydrologic indices. CalSim 3 calculates these indices based on unimpaired runoff at 10 distinct locations Table F.1-1-4. Additionally, CalSim 3 requires input basin average and point precipitation data to forecast runoff in several river basins, including the eight major river basins, and reservoir operations.

Table F.1-1-4. Unimpaired Flow Inputs to CalSim 3

CDEC Station Name	Station Description
AMF	American River at Folsom
MRC	Merced River at Exchequer Reservoir
ORO	Feather River at Oroville
SIS	Sacramento River inflow to Shasta
SJF	San Joaquin River at Millerton
SBB	Sacramento River above Bend Bridge
SNS	Stanislaus River at New Melones
TNL	Trinity River at Lewiston
TLG	Tuolumne River at New Don Pedro
YRS	Yuba River near Smartville

Perturbation of the precipitation and unimpaired runoff data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.2. For perturbation of the precipitation data, the following steps were taken:

- Basin-wide average precipitation or point precipitation at a given station were estimated for historical and 2022±15 median conditions.
- Sensitivity factors, based on simulated historical and 2022±15 median conditions, for precipitation were calculated and applied to historical data.

Point and basin average precipitation are projected to change similarly as for the major watersheds in the Sacramento and San Joaquin River basins under 2022±15 median climate change scenario as shown in Figure F.1-1-4. Figure F.1-1-14 shows projected change in unimpaired runoff at 10 distinct locations under 2022±15 median conditions. Also, the projected change in unimpaired flows is similar to the rim inflows changes for major watersheds (Figure F.1-1-6). The projected change in unimpaired flows varies from -1.5% to +1% under 2022±15 median climate change scenario.

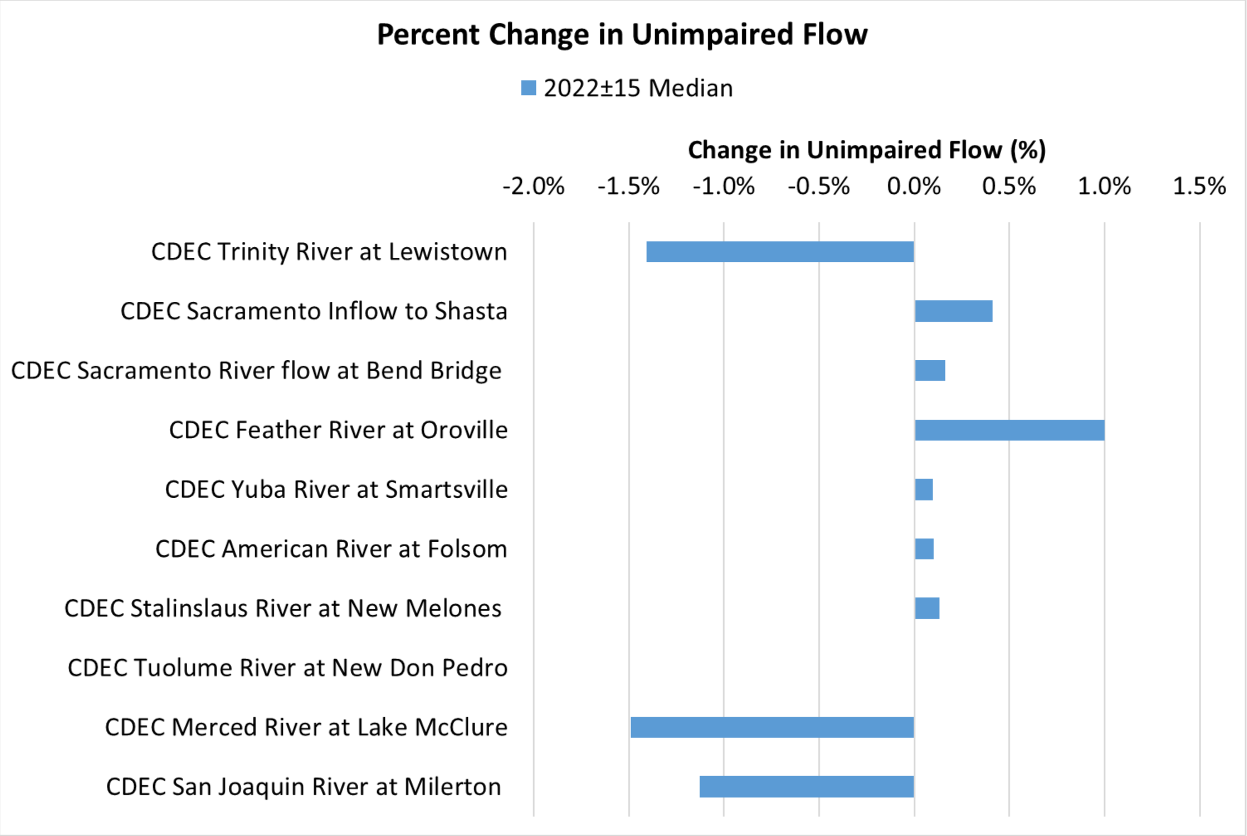

Figure F.1-1-14. Projected Changes in Unimpaired Flow for 2022±15 Median Climate Change Scenario

F.1-1.2.5.6 Groundwater

CalSim 3 requires two types of groundwater boundary conditions along the edges of its spatial domain: (1) deep percolation and (2) lateral flows. Deep percolation and lateral flow boundary conditions are developed by the CalSimHydroEE and SmallWatersheds models, respectively. Both models estimate groundwater flow with assumptions consistent to the CalSimHydro model. These models are described in Chapter 15 of the CalSim 3.0 Draft Report (California Department of Water Resources 2017).

CalSimHydroEE and SmallWatersheds models use precipitation and evapotranspiration data for estimating rainfall-runoff, evapotranspiration, and percolation. Perturbation of the precipitation and evapotranspiration data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.2.

Figure F.1-1-15 shows the projected change in average annual deep percolation, and lateral flows under 2022±15 median climate conditions. Perturbed deep percolation and lateral flow input boundary conditions decrease under 2022±15 median climate change scenario. However, relative to all of the other CalSim 3 boundary conditions, these changes are negligible.

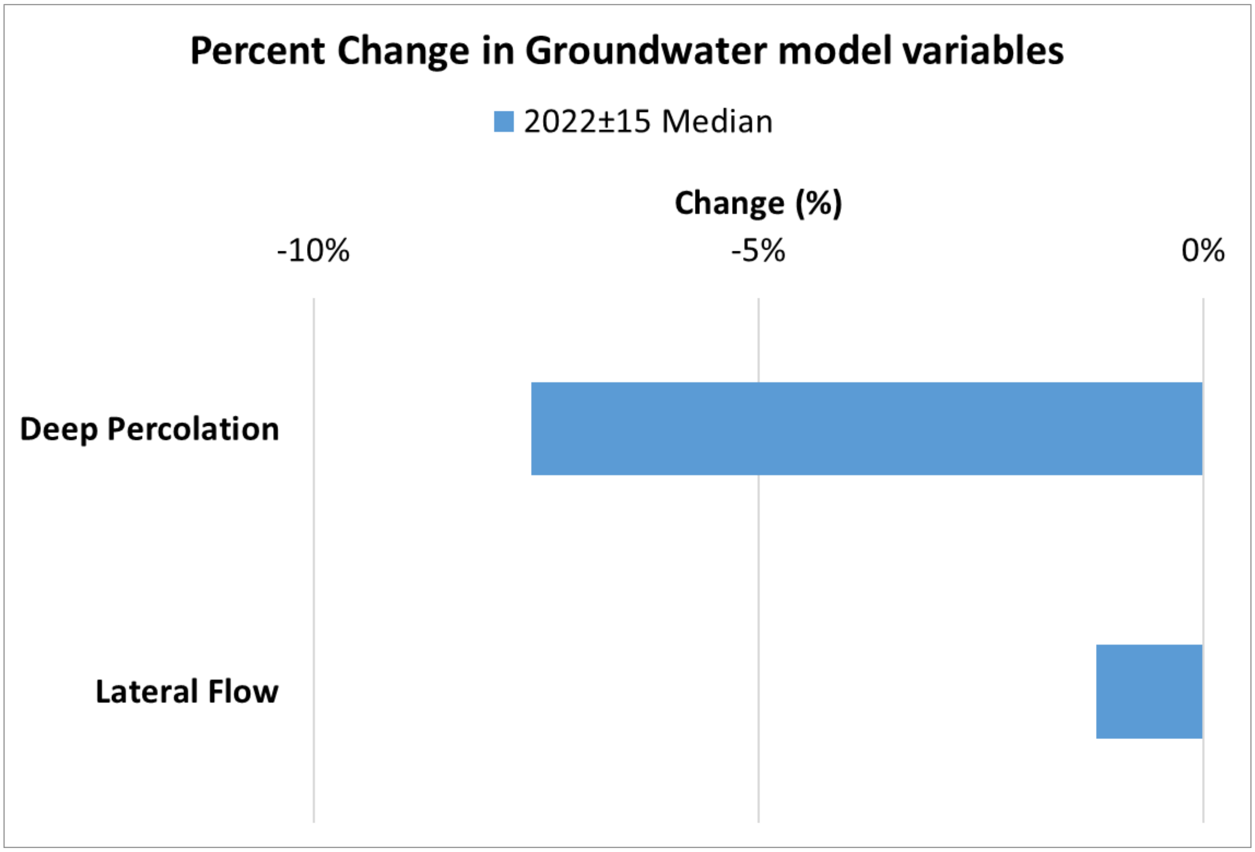

Figure F.1-1-15. Projected Changes in Average Annual Deep Percolation and Lateral Flow under 2022±15 Median Climate Change Scenario

F.1-1.2.6 Use of Projected Runoff from the VIC Model for Impaired Streamflows

Impaired rim inflows in the upper San Joaquin of CalSim 3 were unimpaired before perturbation process. The rim inflows were “re-impaired” after perturbing the unimpaired inflows to represent future climate conditions. As information on specific local project operations (impairment) at these locations was not available, impairment was calculated as the difference between the unimpaired historical flow and the CalSim 3 inflow time series. This method assumes the local project operations will be the same in future climate conditions and does not account for any adaptation in local project operations. This method was applied to 2022±15 median climate condition.

F.1-1.2.7 Climate Change Scenarios for Sensitivity

In addition to 2022±15 median condition, the datasets were also developed for three sensitivity scenarios: 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions. The climate change scenarios differ based on centered-future period and quantile value across all climate model projections used for the development of precipitation and temperature future climate data (Table F.1-1-5).

Table F.1-1-5. Details of the Climate Change Scenarios

Climate Change Scenario	Centered-Future Period	Quantile of Temperature	Quantile of Precipitation
2022±15 Median	2022 (2008–2037)	50th percentile	50th percentile
2022±15 Hot-Dry	2022 (2008–2037)	75th percentile	25th percentile
2022±15 Warm-Wet	2022 (2008–2037)	25th percentile	75th percentile
2040±15 Median	2040 (2026–2055)	50th percentile	50th percentile

Similar to 2022±15 median climate change condition, historical detrended temperature and bias corrected precipitation were adjusted based on quantile mapping approach to represent three sensitivity scenarios. The quantile mapping approach for developing the sensitivity scenarios was implemented with future periods and quantile values for temperature and precipitation as outlined in Table F.1-1-5.

Figure F.1-1-16 shows the projected change in long-term average annual temperature for the major watersheds in the Sacramento and San Joaquin River Basins under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions. The average annual temperature across major watersheds is projected to increase by 2.1°C, 1.1°C, and 2.3°C under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median conditions, respectively.

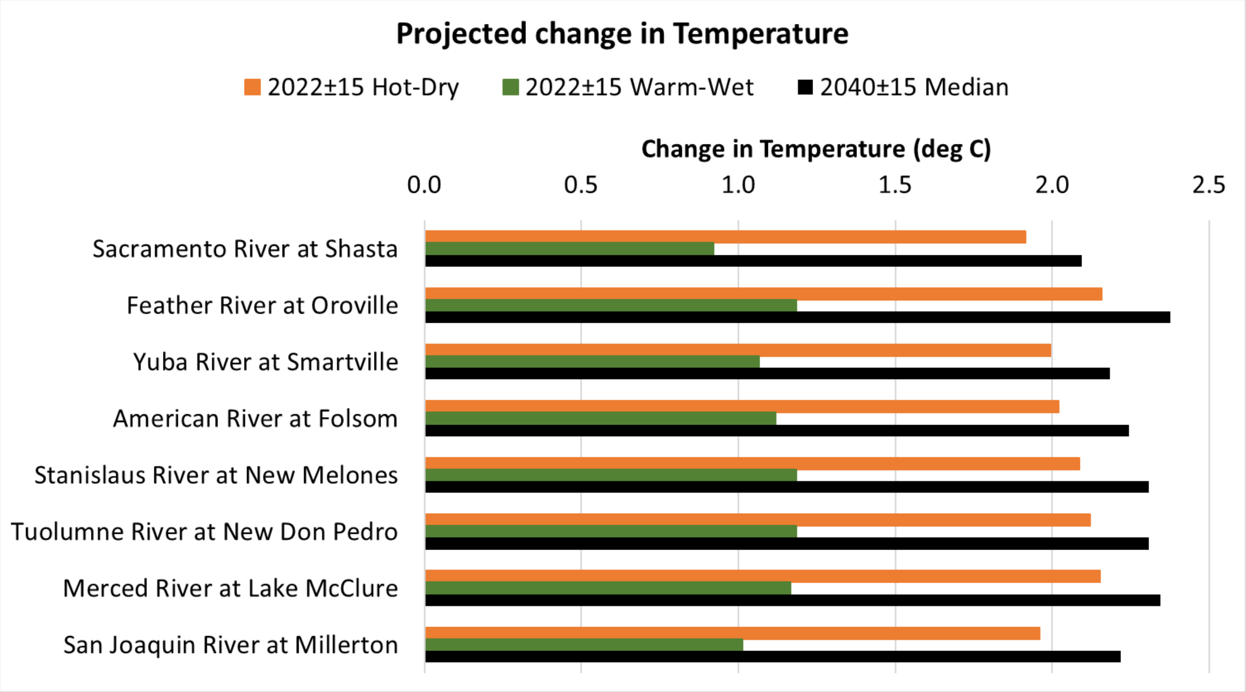

Figure F.1-1-16. Projected Changes in Average Annual Temperature for Major Watersheds in the Sacramento and San Joaquin River Basins under 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

Projected change in long-term average annual precipitation for major watersheds in the Sacramento and San Joaquin River Basins under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions are presented in Figure F.1-1-17. Overall, all major watersheds are projected to be drier under 2022±15 hot-dry climate condition and wetter under 2022±15 warm-wet, and 2040±15 median climate conditions. On an average, long-term average annual precipitation is projected to change by -13.2%, +17.8%, and +1.6% under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median conditions, respectively.

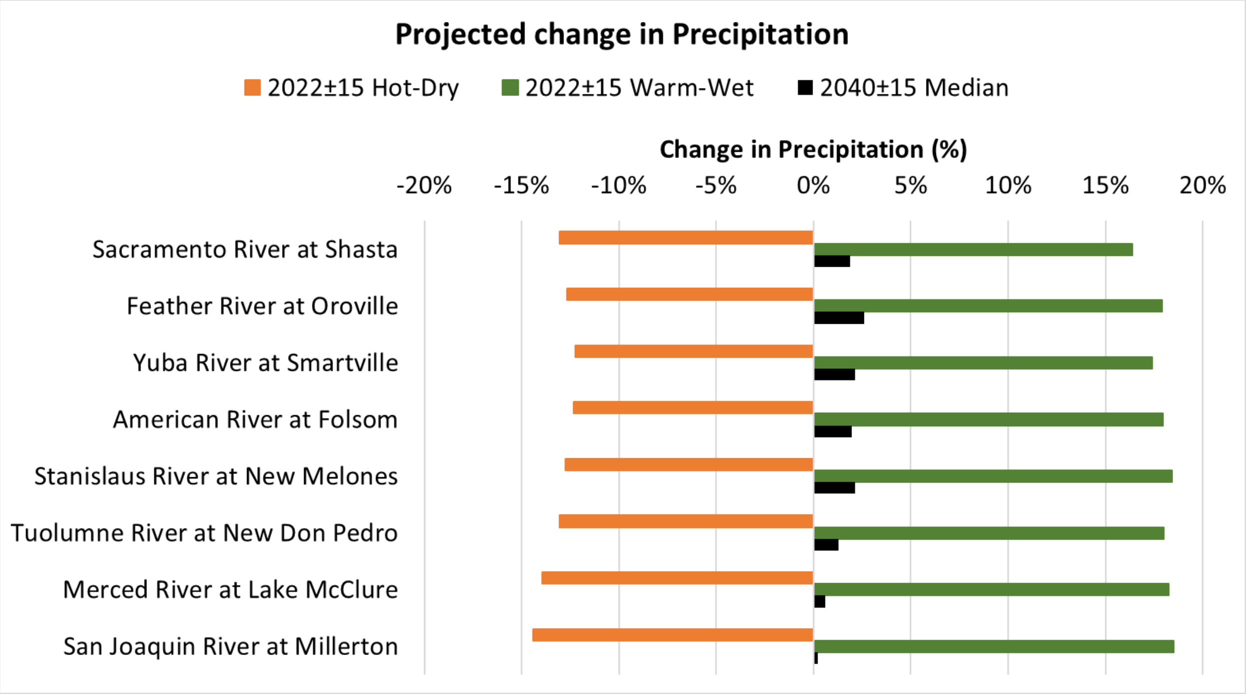

Figure F.1-1-17. Projected Changes in Annual Precipitation for Major Watersheds in the Sacramento and San Joaquin River Basins under 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8 Use of Fractional Changes for Sensitivity Analysis

CalSim 3 boundary conditions for sensitivity scenarios were developed using similar climate variables and perturbation methods as 2022±15 median climate change scenario. Fractional changes were applied to the CalSim 3 inflow, precipitation, surface water evaporation, and evapotranspiration boundary conditions. Absolute were applied to CalSim 3 temperature boundary conditions.

F.1-1.2.8.1 Rim Inflows

Perturbation of CalSim 3 inflow boundary conditions was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.1, *Rim Inflows*. CalSim 3 rim inflows and major watershed flows were perturb separately for the three sensitivity climate change scenarios similar to 2022±15 median climate change scenario.

Projected change in the Eight River Index (8RI), Sacramento Valley Four Rivers Index (SAC-4), San Joaquin Valley Four Rivers Index (SJR-4), and runoff at eight major rivers under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions is provided in Figure F.1-1-18. As compared to 0.1% increase for 2022±15 median climate conditions, the average annual 8RI varies between -23% and 26% under sensitivity climate change scenarios. Runoff decreases in all major basins for 2022±15 hot-dry climate conditions, while the increase is projected under 2022±15 warm-wet climate conditions.

Long-term average monthly flows of SAC-4 and SJR-4 under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions are presented in Figure F.1-1-19. Similar to 2022±15 median climate conditions, runoff increases in winter and decreases in spring and summer in both basins under the sensitivity climate scenarios. As compared to historical runoff, change in precipitation lead to a reduced peak for 2022±15 hot-dry and higher peak for SAC-4 and SJR-4 under 2022±15 warm-wet, and 2040±15 median climate conditions.

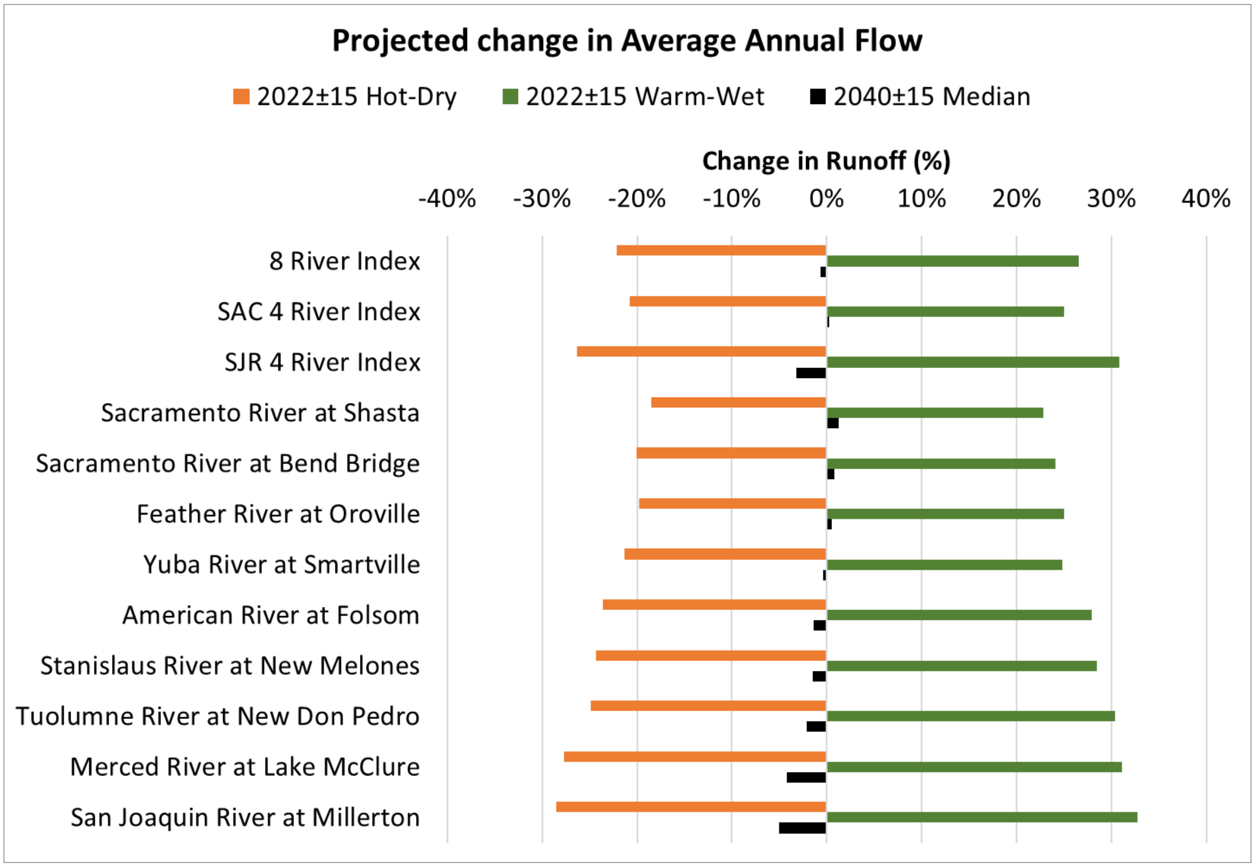

Figure F.1-1-18. Projected Changes in Runoff for Major Watersheds in the Sacramento and San Joaquin River Basins for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

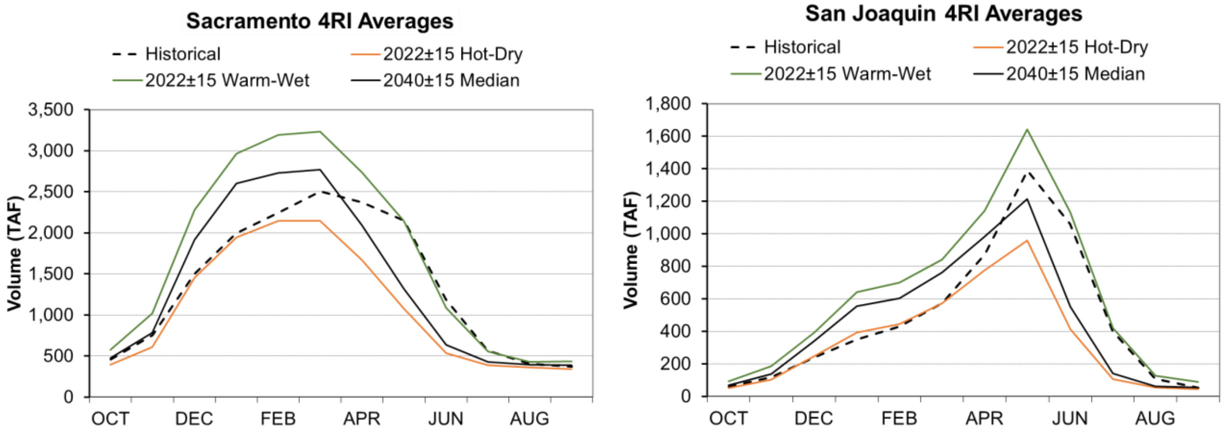

Figure F.1-1-19. Projected Changes in Monthly Pattern of Runoff for the Sacramento Basin for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8.2 Valley Floor Flows

Perturbation of CalSim 3 boundary conditions was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.2. CalSimHydro input variables were perturb separately for the three sensitivity climate change scenarios similar to 2022±15 median climate change scenario.

Figure F.1-1-20 shows the projected change to applied crop water in the Sacramento and San Joaquin Valleys, as estimated with the CalSimHydro model under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate conditions. Under the sensitivity climate scenarios, the applied water varies from -1.3% to +5.4% in Sacramento Valley and from -2.7% to +9.1% in San Joaquin Valley. As estimated with CalSimHydro, changes to pattern and magnitude of precipitation (Figure F.1-1-17) result in small increases to surface runoff, return flow, and deep percolation. The projected change to surface runoff, tail water and deep percolation in the Sacramento and San Joaquin Valleys under sensitivity climate change scenarios are shown in Figures F.1-1-21, F.1-1-22, and F.1-1-23, respectively. The surface runoff is projected to vary from -20% to +40% in Sacramento Valley and from -30% to +60% in San Joaquin Valley, while the tail water varies from -0.5% to 1% in Sacramento Valley and from -2.2% to +7.5% in San Joaquin Valley under the sensitivity climate scenarios. The deep percolation varies from -13% to +13% in Sacramento Valley and from +0.8% to +5.5% in San Joaquin Valley.

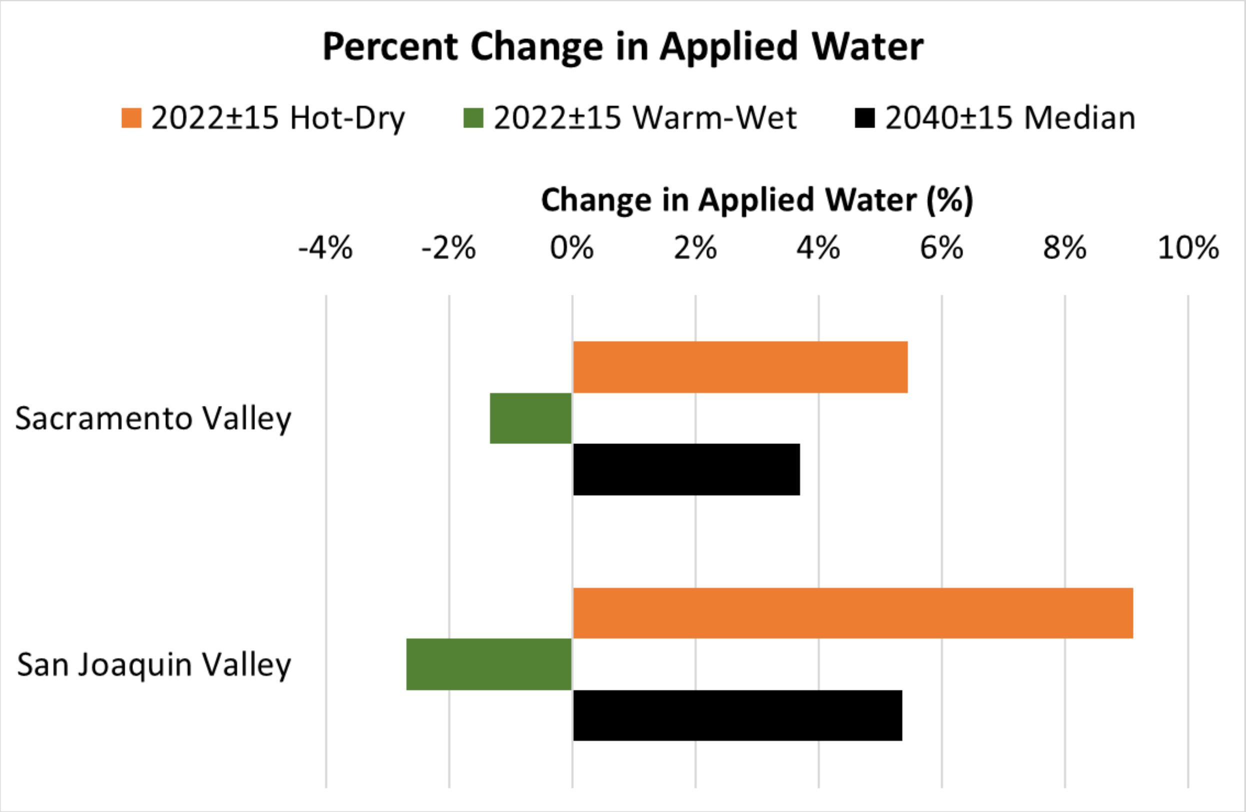

Figure F.1-1-20. Projected Changes in Applied Water for Sacramento and San Joaquin for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

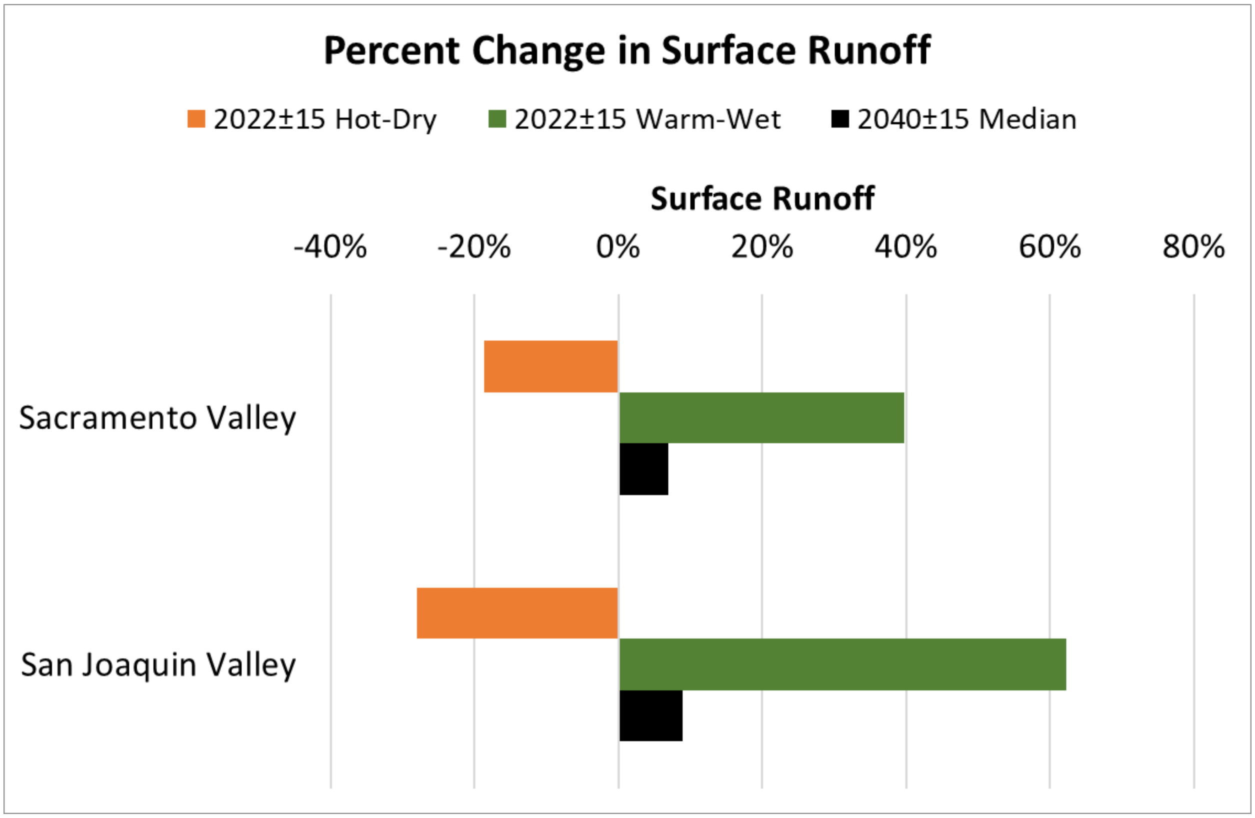

Figure F.1-1-21. Projected Changes in Surface Runoff for Sacramento and San Joaquin for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

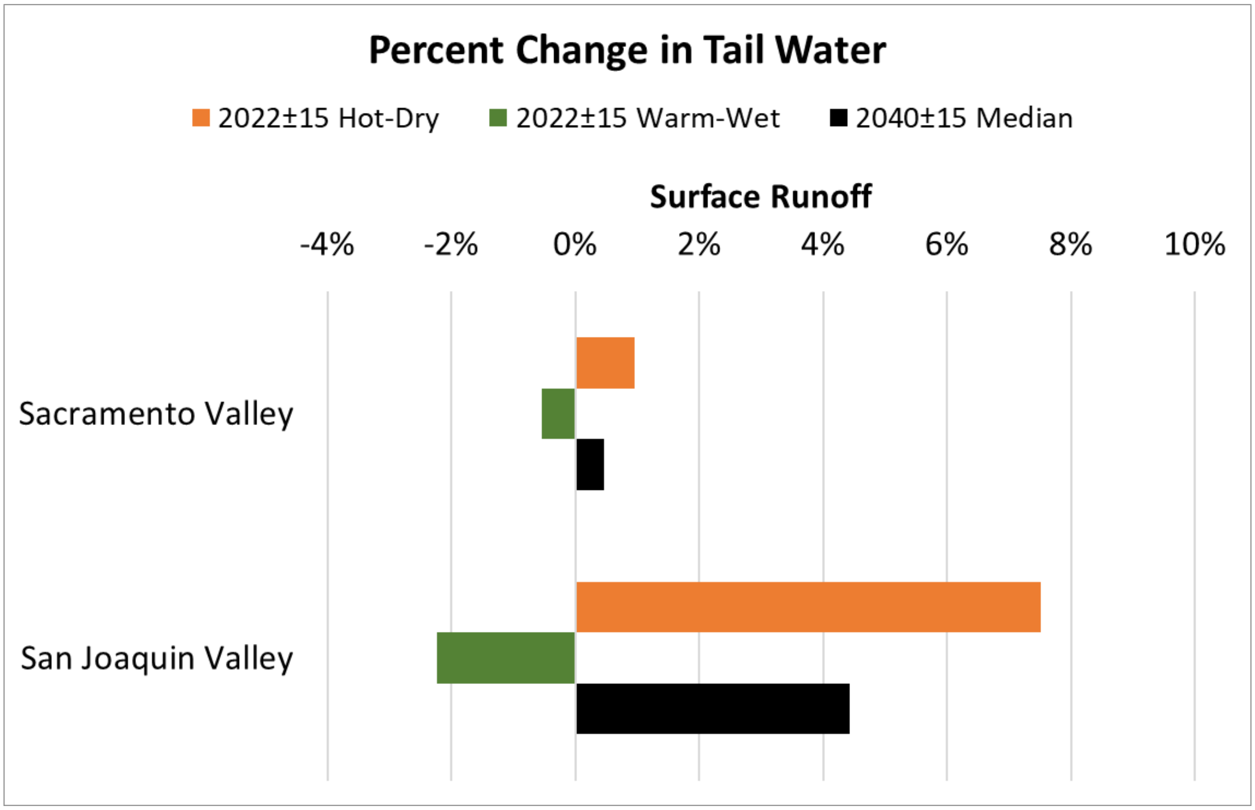

Figure F.1-1-22. Projected Changes in Tail Water for Sacramento and San Joaquin for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

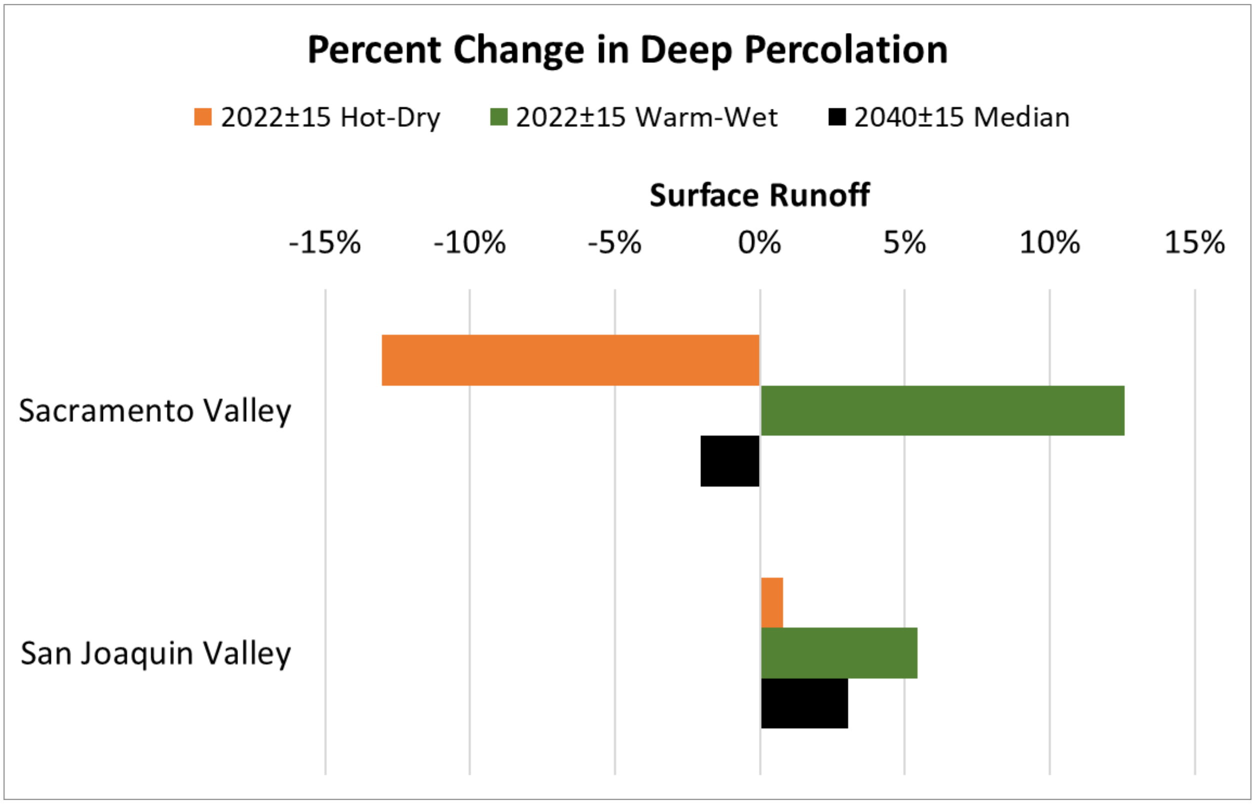

Figure F.1-1-23. Projected Changes in Tail Water for Sacramento and San Joaquin for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8.3 Delta Channel Depletion

Perturbation of CalSim 3 delta evaporation boundary conditions was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.3, *Delta Channel Depletion*. Precipitation and daily maximum and minimum temperature were perturbed separately for the three sensitivity climate change scenarios similar to 2022±15 median climate change scenario.

Figure F.1-1-24 shows the projected change to Sacramento–San Joaquin River Delta irrigation, drainage, and seepage under 2022±15 hot-dry, 2022 ±15 warm-wet, and 2040±15 median climate conditions as estimated with the DCD model. Irrigation and seepage increase due to increased evapotranspiration, a result of increased temperature for 2022±15 hot-dry, and 2040±15 median climate conditions (Figure F.1-1-16). As estimated with DCD, changes to pattern and magnitude of precipitation (Figure F.1-1-17) and irrigation result in a small change to Delta Island drainage. The change in the Net Delta Island Consumptive Use (DICU) ranges from -8.6% to +10.6% under three sensitivity climate change scenarios. DICU refers to the island monthly consumptive uses, corresponding island water supplies, and the channel diversion, seepage and return volumes over the islands in islands in the Sacramento-San Joaquin Delta.

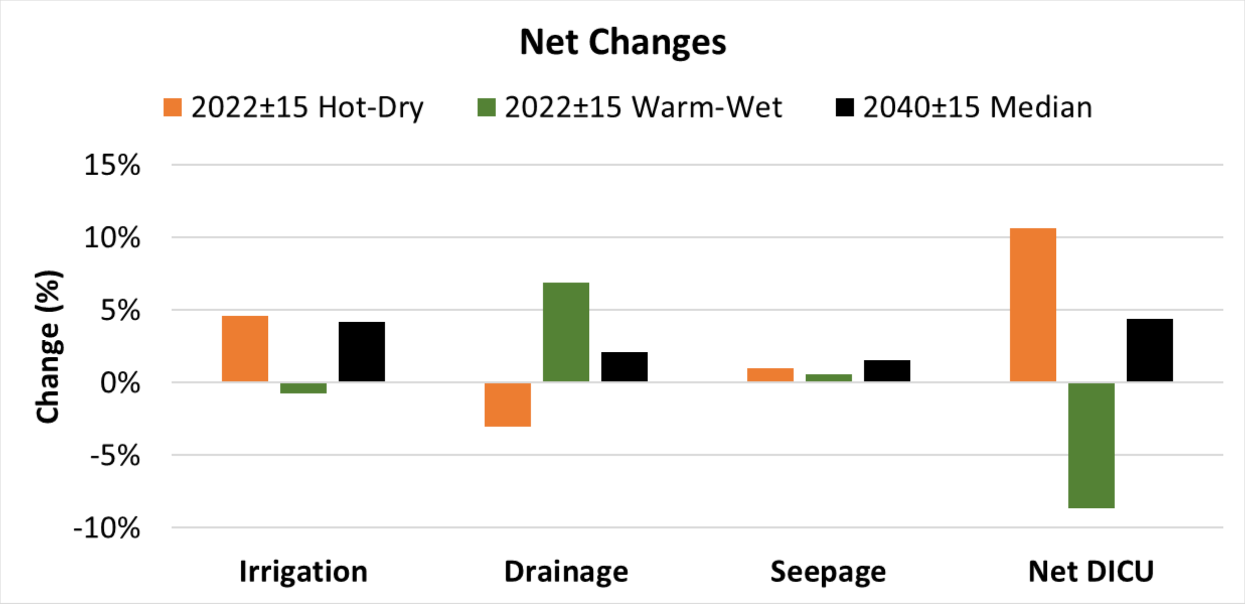

Figure F.1-1-24. Projected Changes in Delta Island Consumptive Use for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8.4 Reservoir Evaporation

Perturbation of surface water evaporation and precipitation was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.3. Gross evaporation and precipitation were perturbed separately for the three sensitivity climate change scenarios similar to 2022±15 median climate change scenario.

Figure F.1-1-25 shows the projected change in evaporation rate at major reservoirs under 2022±15 hot-dry, 2022 ±15 warm-wet, and 2040±15 median climate conditions. The evaporation rates for all the major reservoirs are expected to increase due to rise in temperature under 2022±15 hot-dry and 2040±15 median climate conditions. For 2022±15 warm-wet climate change scenario, the evaporation rate is projected to reduce for most of the reservoirs due to relatively less rise in temperature and increase in precipitation as compared to other climate change scenarios. The water surface evaporation is decreases due to increase in cloud cover and relative humidity caused by wetter condition. Along with the average temperature, the evaporation rates of the reservoirs are also positively correlated to diurnal temperature range (DTR). The DTR decreases most for 2022±15 warm-wet climate change scenario and least for 2022±15 hot-dry climate change scenario.

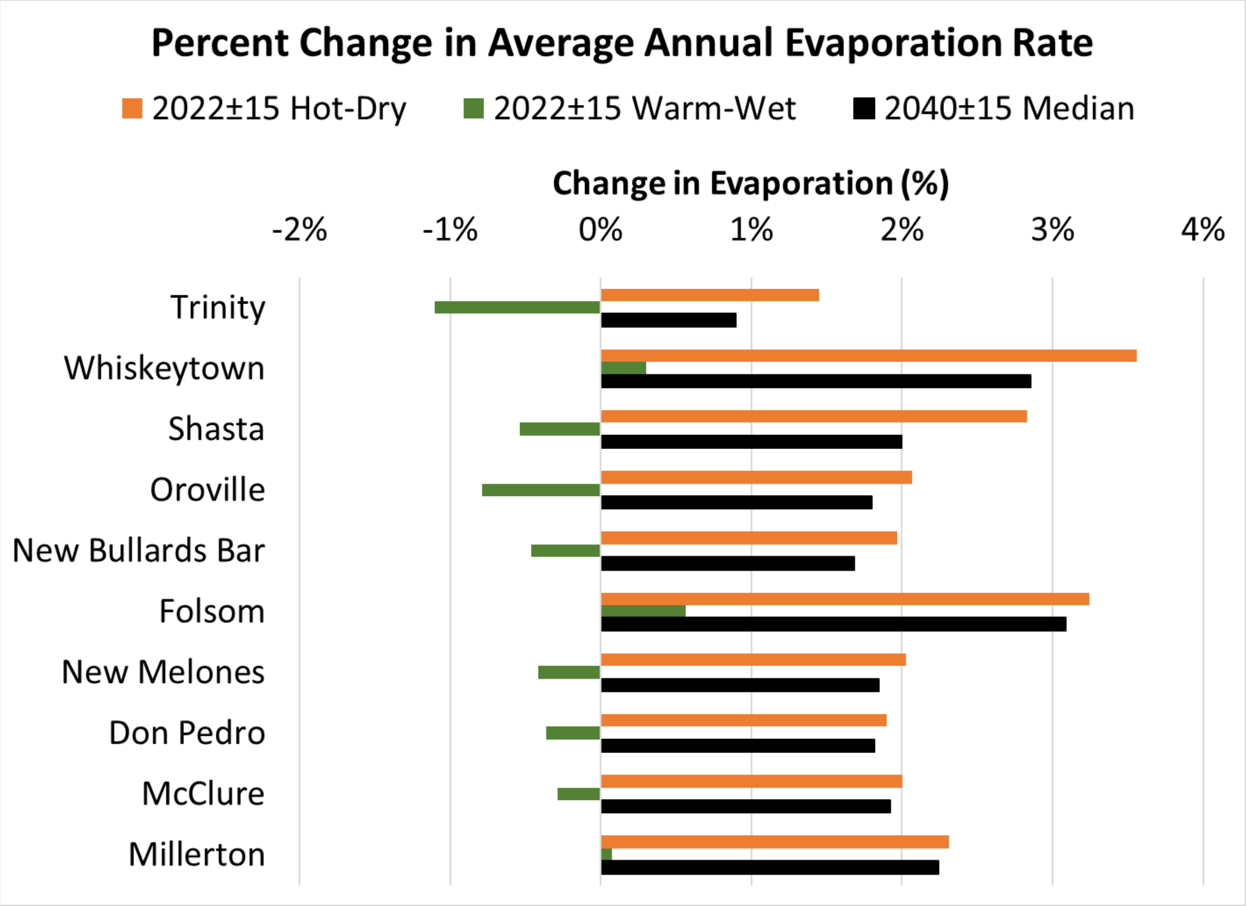

Figure F.1-1-25. Projected Changes in Evaporation Rate at Major Reservoirs for 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8.5 Inputs for Lookup Tables

Perturbation of the precipitation and unimpaired runoff data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.5, *Inputs for Lookup Tables*. Data were perturbed separately for the three sensitivity climate change scenarios similar to 2022±15 median climate change scenario.

Point and basin average precipitation are projected to change similarly as for the major watersheds in the Sacramento and San Joaquin River basins under 2022±15 hot-dry, 2022±15 warm-wet, and 2040±15 median climate change scenarios as shown in Figure F.1-1-17. Figure F.1-1-26 shows projected change in unimpaired runoff at 10 distinct locations under 2022±15 hot-dry, 2022 ±15 warm-wet, and 2040±15 median climate conditions. Also, the projected change in unimpaired flows will be similar to the rim inflows changes for major watersheds under the sensitivity climate change scenarios (Figure F.1-1-18). The unimpaired flow is projected to decrease by 19% to 28% under 2022±15 hot-dry climate conditions and increase by 23% to 33% under 2022 ±15 warm-wet climate conditions. Under 2040±15 median climate conditions, the unimpaired flow varies from -5% to +1.2%.

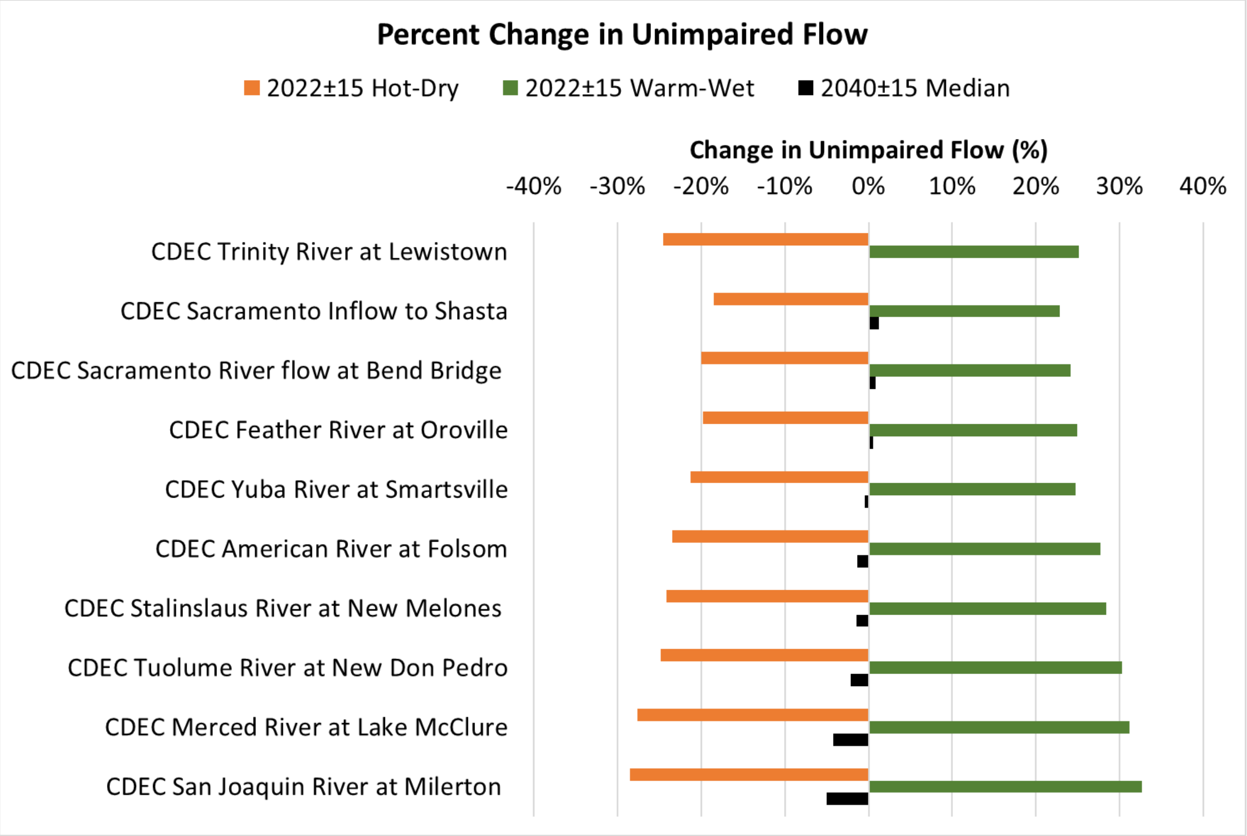

Figure F.1-1-26. Projected Changes in Unimpaired Flow under 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.8.6 Groundwater

Deep percolation and lateral flow boundary conditions are developed by the CalSimHydroEE and SmallWatersheds models, respectively, using precipitation and evapotranspiration data. Perturbation of the precipitation and evapotranspiration data was performed using the monthly and water year climate change rate-based approach as described in Section F.1-1.2.5.6, *Groundwater*.

Figure F.1-1-27 shows the projected change in average annual deep percolation and lateral flow under 2022±15 hot-dry, 2022 ±15 warm-wet, and 2040±15 median climate conditions. Perturbed deep percolation and lateral flow input boundary conditions change under sensitivity scenarios were dominated by precipitation change. Deep percolation is projected to change between -38% and +33% under three sensitivity climate change scenarios.

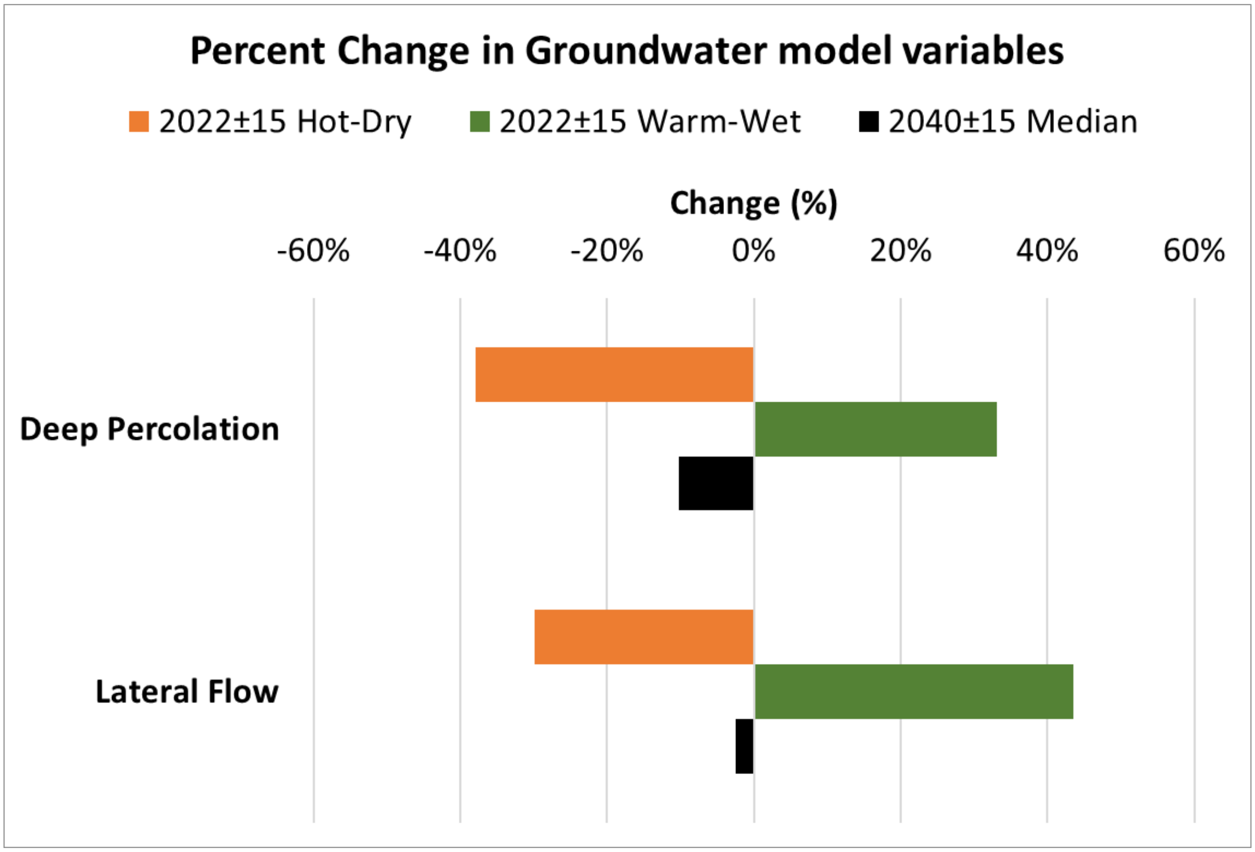

Figure F.1-1-27. Projected Changes in Average Annual Deep Percolation and Lateral Flow under 2022±15 Hot-Dry, 2022±15 Warm-Wet, and 2040±15 Median Climate Change Scenarios

F.1-1.2.9 Use of Projected Runoff from the VIC Model for Impaired Streamflows

Impaired rim inflows in the upper San Joaquin of CalSim 3 were unimpaired before perturbation process. The rim inflows were “re-impaired” after perturbing the unimpaired inflows to represent future climate conditions. As information on specific local project operations (impairment) at these locations was not available, impairment was calculated as the difference between the unimpaired historical flow and the CalSim 3 inflow time series. This method assumes the local project operations will be the same in future climate conditions and does not account for any adaptation in local project operations. This method was applied to 2022±15 hot-dry, 2022 ±15 warm-wet, and 2040±15 median climate conditions.

F.1-1.2.10 Limitations and Appropriate Use of Results

Daily gridded windspeed data was used in simulating the VIC hydrologic model. Observational data for wind are generally sparce but several reanalysis datasets exist for historical data. In this study, climatological averages of daily reanalysis data over the period 1948–2015 is used as a repeating annual signal in both baseline and all future climate scenarios because of a lack of available data prior to 1948, after 2015, and for future climate scenarios. Windspeed can have impacts on evapotranspiration, surface water evaporation, snow ablation, soil moisture, and other important hydroclimate variables. However, previous analysis (https://loca.ucsd.edu/loca-vic-runs/) has shown that VIC has a modest sensitivity to windspeed.

Temperature detrending was performed to represent recent climate conditions but the precipitation was not detrended as the trends are statistically insignificant. During the bias correction process, negative daily temperature range (DTR) was observed in the time series, which further amplified during the temperature detrending process. However, the frequency if occurrence of negative DTR was less than 0.2% annually. Spatial variation of the hydrological parameter at grid level and watershed averaged hydrology at seasonal and monthly scale are negligible (<0.5%) affected by negative DTR. Projected changes in temperatures remain unaffected by negative DTR under future climate change conditions.

Future climate change scenarios are developed based on historical meteorology (Livneh et al. and PRISM datasets), historical hydrology, and projected changes simulated by global climate models (GCMs). The refinements in historical meteorological, historical hydrological datasets, and GCM projections may affect the future climate scenarios. There is considerable uncertainty in GCM projections embedded in characterizing extremely complicated systems using climate modeling. Development of a climate change scenario requires the application of various tools and approaches, such as emission scenarios (RCPs and Shared Socioeconomic Pathways (SSPs)), GCMs (CMIP5 and CMIP6), downscaling approach, climate change scenarios development approach (scenario-based approaches and decision-scaling approaches) and climate impact models. Each tool and approach come with varying degrees of uncertainty, which accumulates as they are implemented together in the full development of a climate change scenario.

The limitations of the numerical models include generalized and simplified representations of a complex water resources system and reporting the model results at monthly timesteps. Statistics computed based on long-term and water year-type averages are an appropriate use of model results. It is necessary to understand these limitations to correctly interpret results. Please see Appendix F, *Modeling*, Section F.14, *Model Limitations and Appropriate Use of Model Results*, for more details.

F.1-1.3 References

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Appendix F, Modeling

Attachment F.1-2 Modeled Representation of Old and Middle River Actions

Calculations of the Net Tidal Flow in Old and Middle River (OMR) have been used in recent years as a surrogate for determining the relative influence of water project export rates on Bay-Delta aquatic species listed for Endangered Species Act protection under both Federal and State law.

F.1-2.1 Proposed Approach

As part of assumptions development for Alternative 2, previous assumptions that were developed under the 2019 BiOps and 2020 ITP for the Exiting Conditions, were reevaluated for consistency with current understanding of OMR management. This review is especially necessary considering data availability. 2010–2022 data was used to determine new assumptions for Alternative 2 and update assumptions for the No Action Alternative (NAA).

The historical data was used to determine what percentage of the historical month an OMR action would have triggered, herein referred to as the historical percentage of month method. Table F.1-2-1 is a hypothetical table for 2010–2022 OMR percentages.

Table F.1-2-1. 2010–2022 Hypothetical OMR Percentage

Year	Jan	Feb	Mar	Apr	May	Jun
2010	0%	4%	93%	18%	13%	0%
2011	0%	39%	93%	93%	93%	0%
2012	0%	0%	47%	93%	93%	0%
2013	0%	0%	64%	63%	93%	0%
2014	0%	0%	0%	0%	0%	0%
2015	0%	14%	93%	68%	33%	0%
2016	0%	39%	93%	68%	93%	0%
2017	0%	0%	43%	93%	93%	0%
2018	0%	0%	93%	93%	93%	0%
2019	0%	72%	93%	0%	58%	0%
2020	0%	0%	0%	0%	0%	0%
2021	0%	0%	0%	0%	0%	0%
2022	0%	0%	0%	0%	0%	0%

Table F.1-2-1 was then averaged by water year type. The historical 50% exceedance forecast was used for the water year type for each month. Table F.1-2-2 below shows the historical 50% exceedance forecasted water year types by year and month.

Table F.1-2-2. 2010–2022 Historical Water Year Type

Year	Jan	Feb	Mar	Apr	May	Jun
2010	D	BN	D	D	BN	BN
2011	AN	AN	BN	W	W	W
2012	BN	D	D	D	BN	BN
2013	W	BN	D	D	D	D
2014	C	C	C	C	C	C
2015	BN	C	C	C	C	C
2016	D	D	D	BN	BN	BN
2017	AN	W	W	W	W	W
2018	AN	BN	D	BN	BN	BN
2019	BN	BN	W	W	W	W
2020	BN	BN	D	D	D	D
2021	C	C	C	C	C	C
2022	BN	D	C	C	C	C

A breakdown of the data in Table F.1-2-2 by water year type is shown in Table F.1-2-3.

Table F.1-2-3. 2010–2022 Historical Water Year Type Summary

WY Type	Jan	Feb	Mar	Apr	May	Jun
C	2	3	4	4	4	4
D	2	3	6	4	2	2
BN	5	5	1	2	4	4
AN	3	1	0	0	0	0
W	1	1	2	3	3	3

Table F.1-2-1 and Table F.1-2-2 were used to determine the average OMR percentage by water year type and month for input into CalSim 3. For example, there are three (3) February D years in the 2010–2022 data: 2012, 2016, and 2022. The OMR percentages from Table F.1-2-1 are 0%, 39%, and 0% for 2012, 2016, and 2022, respectively. These numbers are averaged to get the D year OMR % for use in CalSim 3 (13%). There are zero AN water year types for the months of March through June as shown in Table F.1-2-3, therefore, the average of the BN and W was used for these months. The OMR percentage by water year type and month are shown in Table F.1-2-4 for this hypothetical example.

Table F.1-2-4. 2010–2022 Historical Water Year Type Summary

WY Type	Jan	Feb	Mar	Apr	May	Jun
C	0%	5%	23%	17%	8%	0%
D	0%	13%	65%	44%	47%	0%
BN	0%	15%	93%	81%	73%	0%
AN	0%	39%	81%	71%	77%	0%
W	0%	0%	68%	62%	81%	0%

F.1-2.2 No Action Alternative

The U.S. Fish and Wildlife Service and National Marine Fisheries Service issued Biological Opinions for Delta smelt and Central Valley salmonids in 2019 (2019 BiOps) and the California Department of Fish and Wildlife (CDFW) issued the Incidental Take Permit for the State Water Project in 2020 (2020 ITP). The 2019 BiOps and the 2020 ITP included OMR restrictions to minimize potential loss of sensitive fish species due to the Project exports.

F.1-2.2.1 Integrated Early Winter Pulse Protection

In modeling the NAA, the 2019 BiOps Integrated Early Winter Pulse Protection or "First Flush" was assumed to be implemented under the following conditions:

- December when the unimpaired Sacramento River Runoff (SRR) is greater than 20,000 cfs,
- January if no First Flush occurred in December and when the SRR is greater than 20,000 cfs

The First Flush action is assumed to restrict OMR to -2,000 cfs for 14 days. Since CalSim utilizes a monthly timestep this 14 day action is implemented using a weighted average with a background level. For December the background level is -8,000 cfs and for January the background level is -5,000 cfs.

These assumptions were developed using Sacramento River at Freeport flow and turbidity data from 2008 to 2019. In addition, turbidity data from Sacramento River at Hood was used to fill-in and confirm turbidity data at Freeport. Since the first flush is limited to the December to January period, the data analyzed was also limited to this timeframe. Turbidity is a parameter that is not simulated in CalSim, and so a flow surrogate was used and consistent with past practice. The SRR represents the unimpaired flow from the major tributaries to the Sacramento River. As shown in Figure F.1-2-1 the approximate transition where Freeport flow and turbidity levels would trigger a first flush is around an SRR of about 20,000 cfs.

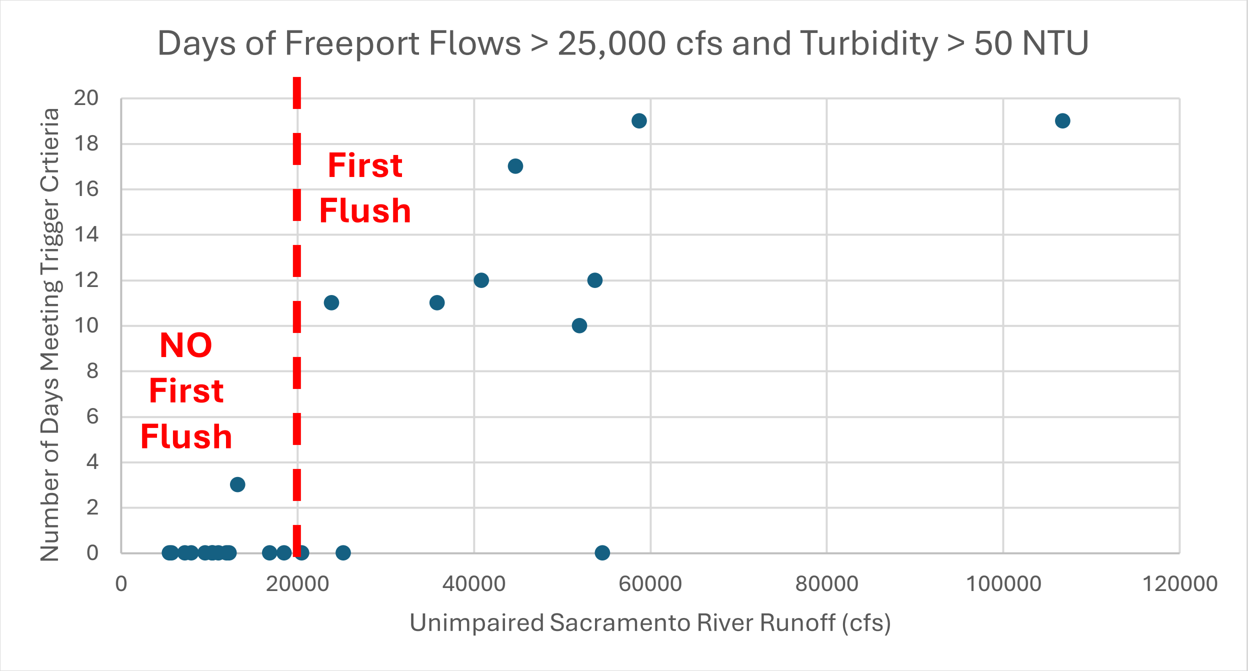


Figure F.1-2-1. Relationship between Sacramento River Runoff and the flow and turbidity at Freeport exceeding 25,000 cfs and 50 NTU.

F.1-2.2.2 Start of OMR Management

If the First Flush action does not occur in December, it is assumed in the model that the OMR management season will start at the beginning of January. Unless Storm Flex is triggered, OMR index must be greater than -5,000 cfs through the OMR Management season.

F.1-2.2.3 Turbidity Bridge Avoidance

In modeling the NAA, the turbidity bridge avoidance was assumed to apply an additional OMR requirement of -2,000 cfs for 5 days when the following conditions occur:

- Timeframe under which a turbidity avoidance action may occur
    - January–if First Flush occurs in December,
    - February–if First Flush occurs in January or not at all,
- SRR > 20,000 cfs

Like other turbidity related actions, this one requires the use of a surrogate to determine when an action is triggered. The turbidity station at Old River at Bacon Island (OBI) is in the interior Delta south of the San Joaquin River, which makes it difficult to predict with any great accuracy. However, the SRR is and has been used for other turbidity based actions. Using historical OBI data from 2008 to 2019, daily average values above 12 NTU were summed for months January and February. The resulting number of days per month exceeding 12 NTU were compared to the SRR for the same month (Figure F.1-2-2). The red line indicates the rough transition point using the SRR.

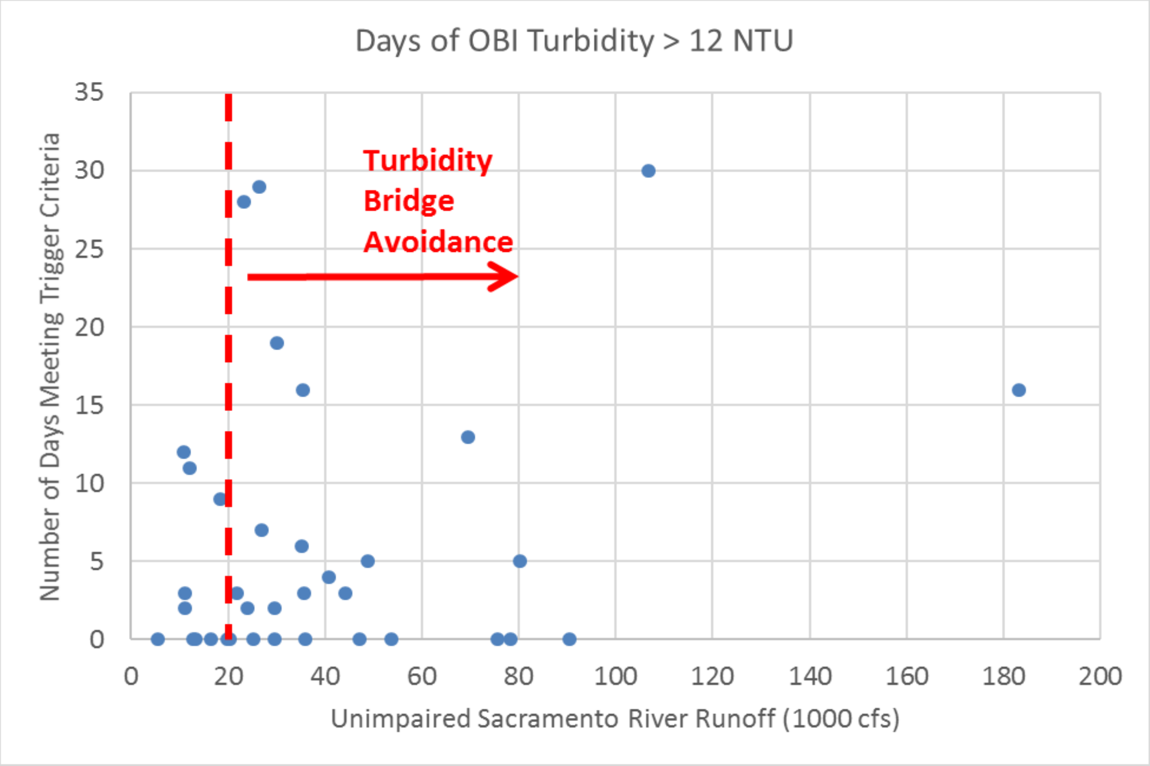


Figure F.1-2-2. Monthly Comparison of Number of Days in Month Exceeding 12 NTU at OBI and SRR

This relationship could be stronger, but it should be recognized that because of its location, OBI, is subject to many variables, including but not limited to wind driven turbidity and lower turbidity due to proactive Project operations that is embedded in the data. In general, the historic data resulted in a 72% frequency of a triggering event. Using an SRR surrogate of 20,000 cfs results in a 61% triggering frequency.

F.1-2.2.4 Salvage Loss Thresholds

The NAA included real-time OMR management actions based on the percent of Winter-Run Chinook Salmon and Central valley Steelhead salvaged relative to proposed Single Year Loss Thresholds. The salvage loss threshold OMR assumption was modified from previous analysis to ensure consistent methodology with Alternative 2, using the historical percentage of month method.

F.1-2.2.4.1 Winter-Run and Steelhead

Historic salvage data, based on the length at date Delta Model (LAD), at the fish facilities at Banks and Jones Pumping Plants for water years 2010–2022, and fish catch data at Chipps Island trawl during water years 2017–2021 were analyzed. Historic salvage data provides the potential timing of triggering the 50% levels of the proposed single year loss thresholds. For modeling purposes, it is assumed that if the 50% level is triggered then the 75% level would not be triggered. For Winter-Run loss thresholds were identified for Dec–Jun period. For steelhead, separate loss thresholds were identified for Dec–Mar and Apr–May.

Table F.1-2-5. 2010–2022 Historical Winter-Run and Steelhead Salvage Loss

Water Year	Steelhead Dec - Mar	Steelhead Apr - Jun	WR Natural	WR Hatchery
2010	10-Feb	-	-	-
2011	15-Feb	7-May	24-Feb	-
2012	22-Mar	-	10-Mar	-
2013	9-Mar	9-Apr	-	-
2014	-	-	-	-
2015	22-Feb	-	-	-
2016	15-Feb	-	-	-
2017	-	-	-	-
2018	5-Mar	6-Apr	-	-
2019	6-Feb	11-May	-	-
2020	-	-	-	-
2021	-	-	-	-
2022	-	-	-	-

The salvage data above was summarized to percent of the month the threshold would trigger. For example, the 2011 Steelhead (Dec–Mar) loss threshold triggered February 15 so the assumption is the OMR would be -3,500 from Feb 16 through the end of the February and continue through March 31. The Steelhead (Apr–Jun) was triggered May 7 so -3,500 would be assumed May 8 through May 31, and the WR was triggered March 29 so it was assumed -3,500 from May 8 through May 31. The monthly percentages for the entire 2010–2022 period are summarized in Table F.1-2-8 below.

Table F.1-2-6. 2010–2022 Historical Winter-Run and Steelhead Salvage Loss OMR Percentage

Water Year	Jan	Feb	Mar	Apr	May	Jun
2010	0%	64%	100%	23%	23%	0%
2011	0%	46%	100%	100%	100%	0%
2012	0%	0%	39%	100%	100%	0%
2013	0%	0%	71%	70%	100%	0%
2014	0%	0%	0%	0%	0%	0%
2015	0%	21%	100%	77%	23%	0%
2016	0%	46%	100%	77%	100%	0%
2017	0%	0%	52%	100%	100%	0%
2018	0%	0%	84%	80%	100%	0%
2019	0%	79%	100%	50%	65%	0%
2020	0%	0%	0%	0%	0%	0%
2021	0%	0%	0%	0%	0%	0%
2022	0%	0%	0%	0%	0%	0%

F.1-2.2.4.2 Juvenile Delta Smelt

The NAA previously assumed the Juvenile Delta Smelt was covered by the assumption made for the Winter-Run and Steelhead. However, to ensure consistency with the assumptions made for Alternative 2, the NAA assumption was updated. The historical Secchi depth data for Juvenile Delta Smelt data was analyzed and summarized by weeks when the Secchi depth is less than 100 cm. Table F.1-2-9 summarizes when the Secchi depth is less than 100 cm for Juvenile Delta Smelt and which would have triggered a potential OMR action to protect Juvenile Delta Smelt (1= trigger, 0=No trigger) during the 2010–2022 period.

Table F.1-2-7. 2010–2022 Historical Winter-Run Loss OMR Triggers

Year	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	0	0	0	0	0.5	1	1	1	1	1	1	1	1	1
2011	0	0	0	0	0	1	1	1	1	1	1	1	1	1
2012	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table F.1-2-8. 2010–2022 Historical Steelhead Loss OMR Triggers

Year	1/1–1/7	1/8–1/14	1/15–1/21	1/22–1/28	1/29–2/4	2/5–2/11	2/12–2/18	2/19–2/25	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	0	0	0	0	0	0.29	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	-
2011	0	0	0	0	0	0	0.43	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1
2012	0	0	0	0	0	0	0	0	0	0	0	0.43	1	0	0	0	0	0	0	0	0	
2013	0	0	0	0	0	0	0	0		0.29	1	1	1	0	1	1	1	1	1	1	1	1
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0.43	1	1	1	1	1	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0.43	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0		1	1	1	1	0.43	1	1	1	1	1	1	1	1
2019	0	0	0	0	-	0.86	1	1	1	1	1	1	1	0	0	0	0	0	0	1	1	1
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table F.1-2-9. 2010–2022 Juvenile Delta Smelt Loss OMR Triggers

Year	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	1	1	1	1	0	0	0	0	0	0	1	1	1	0
2011	1	1	1	0	0	0	0	0	1	0	0	0	1	0
2012	1	0	0	1	1	1	0	0	0	0	0	0	0	0
2013	0	0	0	0	1	1	0	1	1	1	1	1	1	1
2014	0	0	0	0	0	0	0	0	0	1	1	1	1	1
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	1	1	0	1	1	0	1	1	1	1	1	0	0	0
2017	0	1	1	1	1	1	0	1	1	1	1	1	1	1
2018	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2019	0	0	0	0	1	1	1	0	0	0	0	0	0	0
2020	1	1	1	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0

The data in Table F.1-2-9 was then summarized to percent of the month a trigger would occur and is shown in Table F.1-2-10 below. For example, in 2011, 2 weeks of March are marked with a “1” indicating half the month an OMR Index was needed in protecting Delta Smelt.

Table F.1-2-10. 2010–2022 Historical Juvenile Delta Smelt Loss OMR Percentage

Year	Mar	Apr	May	Jun
2010	0%	25%	20%	0%
2011	50%	25%	0%	0%
2012	25%	75%	100%	25%
2013	0%	0%	100%	75%
2014	0%	0%	0%	0%
2015	50%	75%	40%	0%
2016	50%	75%	100%	50%
2017	50%	100%	100%	100%
2018	25%	50%	0%	0%
2019	0%	0%	0%	0%
2020	0%	0%	0%	0%
2021	0%	0%	0%	0%
2022	0%	0%	0%	50%

F.1-2.2.4.3 OMR flex trigger and criteria

In modeling the NAA, OMR Flex was assumed to be -6,250 for up to 6 days under the following conditions dynamically determined in CalSim 3:

- Delta in Excess,
- X2< 81 km,
- Sacramento River Runoff < 20,000 cfs,
- Qwest > +1,000 cfs
- January and February

Historically, the Projects have not operated to the OMR Storm Flex and the criteria above only occurs a handful of times in the NAA CalSim 3 model.

F.1-2.2.4.4 Combined Coverage

Table F.1-2-6 and Table F.1-2-10 were combined into one lookup table that was used in CalSim 3. The data was summarized by water year type. Table F.1-2-11 and Table F.1-2-12 summarize the combined 2010–2022 OMR percentage and water year type lookup table that was used for CalSim 3, respectively.

Table F.1-2-11. 2010–2022 Historical Winter-Run, Steelhead, and Juvenile Delta Smelt Loss OMR Percentage

Water Year	Jan	Feb	Mar	Apr	May	Jun
2010	0%	64%	100%	25%	20%	0%
2011	0%	46%	100%	100%	100%	0%
2012	0%	0%	54%	100%	100%	0%
2013	0%	0%	71%	70%	100%	0%
2014	0%	0%	0%	0%	0%	0%
2015	0%	21%	100%	75%	40%	0%
2016	0%	46%	100%	75%	100%	0%
2017	0%	0%	50%	100%	100%	0%
2018	0%	0%	100%	100%	100%	0%
2019	0%	79%	100%	0%	65%	0%
2020	0%	0%	0%	0%	0%	0%
2021	0%	0%	0%	0%	0%	0%
2022	0%	0%	0%	0%	0%	0%

Table F.1-2-12. OMR Percentage by Water Year Type for Input Into CalSim 3

Water Year Type	Jan Avg	Feb Avg	Mar Avg	Apr Avg	May Avg	Jun Avg
C	0%	7%	25%	19%	10%	0%
D	0%	15%	71%	49%	50%	0%
BN	0%	29%	100%	88%	80%	0%
AN	0%	46%	88%	77%	84%	0%
W	0%	0%	75%	67%	88%	0%

Table F.1-2-12 was used as a lookup table in CalSim 3 and the percent shown for each month is the portion of the month operated to greater than a -3,500 OMR Index. For example, Dry March years are assumed to be at -3,500 OMR Index for 71% of the month.

F.1-2.3 Alternative 2

The following OMR criteria were implemented in the Alternative 2 CalSim 3 model.

F.1-2.3.1 Winter-Run Early Season Migration

In modeling Alternative 2, the Winter-Run Early Season Migration not modeled as historical data indicated it did not trigger and there was not enough data to develop an assumption for CalSim 3.

Table F.1-2-13. 2010–2022 Winter-Run Early Season Migration Loss and Trigger

WR WY	Nov-ember Loss	RB Juvenile Total	Limit	Trigger	Year	WYT	Dec-ember Loss	RB Juvenile Total	Limit	Trigger
2010	0.00	4237821	559	0	2010	BN	3.78	4302153	1140	0
2011	0.00	1102840	146	0	2011	W	25.21	1234434	327	0
2012	0.00	605098	80	0	2012	BN	0.00	715359	190	0
2013	0.00	628082	83	0	2013	D	4.93	866852	230	0
2014	0.00	636764	84	0	2014	C	0.00	1249821	331	0
2015	0.00	279954	37	0	2015	C	0.00	354876	94	0
2016	0.00	217489	29	0	2016	BN	0.00	252675	67	0
2017	0.00	363832	48	0	2017	W	0.00	484841	128	0
2018	0.00	283674	37	0	2018	BN	0.00	407410	108	0
2019	0.00	707433	93	0	2019	W	0.00	884916	235	0
2020	0.00	3217093	425	0	2020	D	0.00	3684857	976	0
2021	0.00	1467024	194	0	2021	C	0.00	1759210	466	0
2022	0.00	434371	57	0	2022	C	0.00	544541	144	0

F.1-2.3.2 OMR Management Season

In modeling Alternative 2, the OMR management begins in December and ends in June with the OMR index no more negative than -5,000 cfs unless Storm Flex is initiated.

F.1-2.3.2.1 First Flush

Like in the NAA, the First Flush action for Alternative 2 is assumed to restrict OMR to -2,000 cfs for 14 days when SRR > 20,000 cfs, and triggering First Flush starts the OMR Management season. The modeling assumptions for First Flush in Alternative 2 differ from the NAA in the following ways:

- First Flush can occur in February in addition to December and January, and
- There is a high-flow offramp that is dynamically triggered in CalSim 3 when flow at Rio Vista is greater than 55,000 cfs or flow at Vernalis is greater than 8,000 cfs.

F.1-2.3.2.2 Start of OMR Management

If First Flush is not triggered in December, it is assumed that the OMR Management season will begin on January 1st.

F.1-2.3.2.3 End of OMR Management

End of OMR Management Season was evaluated by looking at (1) the historical 3-day average water temperature at Clifton Court Forebay (CLC) being 25° C or higher for Delta Smelt and (2) historical daily water temperature at Mossdale (MSD) and Prisoner's Point (PPT) exceeds 22.2° C for 7 non-consecutive days for Salmonids. Table F.1-2-14 shows that most of these temperature thresholds are met towards the end of June, therefore, the OMR management season goes through June in the CalSim 3 model.

Table F.1-2-14. 2010–2022 Water Temperature Data for Delta Smelt (CLC) and Salmonids (MSD and PPT)

Year	Clifton Court Forebay (CLC)	Mossdale (MSD)	Prisoner's Point (PPT)
2010	30-Jun	-	-
2011	30-Jun	30-Jun	-
2012	30-Jun	30-Jun	-
2013	30-Jun	30-Jun	-
2014	9-Jun	30-Jun	-
2015	11-Jun	30-Jun	-
2016	5-Jun	30-Jun	-
2017	23-Jun	30-Jun	-
2018	25-Jun	30-Jun	-
2019	30-Jun	30-Jun	-
2020	26-Jun	30-Jun	2-Jun
2021	21-Jun	30-Jun	7-Jun
2022	27-Jun	30-Jun	22-Jun

F.1-2.3.3 Real-Time Adjustments

F.1-2.3.3.1 Adult Delta Smelt Entrainment Protection Action

In modeling Alternative 2, the turbidity bridge avoidance was assumed to apply an additional OMR requirement of -3,500 cfs for 10 days when the following conditions occur:

- Timeframe under which a turbidity avoidance action may occur
    - January–if First Flush occurs in December,
    - February–if First Flush occurs in January or not at all,
- SRR > 20,000 cfs
- Highflow Offramp when Vernalis flows above 10,000 cfs

Like other turbidity related actions, this requires the use of a surrogate to determine when an action is triggered. Like the NAA, Alternative 2 looks at the turbidity station at Old River at Bacon Island (OBI) but also, Holland Cut (HOL) and Old River at Highway 4 (OH4). Using historical OBI, HOL, and OH4 data from 2009 to 2023, daily average values above 12 NTU for all three stations were summed for the months of January and February. The resulting number of days per month exceeding 12 NTU at OBI, HOL, and OH4 were compared to the SRR for the same month (Figure F.1-2-3). The red line indicates the rough transition point using the SRR. The average days for the points that met the trigger is 10 days.

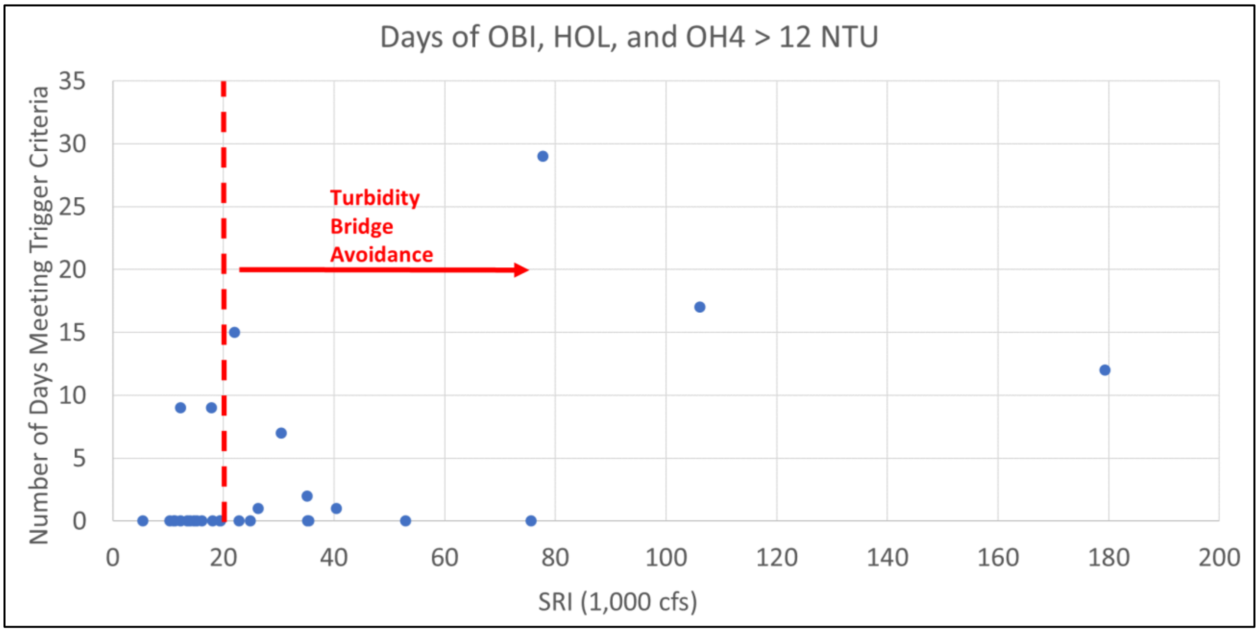


Figure F.1-2-3. Monthly Comparison of Number of Days in Month Exceeding 12 NTU at OBI, HOL, and OH4 and SRR

This relationship could be stronger, but it should be recognized that because of its location, OBI, HOL, and OH4, is subject to many variables, including but not limited to wind driven turbidity and lower turbidity due to proactive Project operations that is embedded in the data.

F.1-2.3.3.2 Adult Longfin Entrainment Protection Action

In modeling Alternative 2, the Adult Longfin Smelt OMR assumption was based on observed salvage of Longfin Smelt greater or equal to 60 mm at both the CVP and SWP fish salvage facilities. OMR action was triggered in weeks where this observed salvage exceeded the salvage threshold determined by the San Francisco Bay Study Longfin Smelt Index.

Table F.1-2-15 summarizes the sampling data for the Adult Longfin Smelt which would have triggered a potential OMR action (1= trigger, 0=No trigger) during the 2010–2022 period.

Table F.1-2-15. 2010–2022 Historical Adult Longfin Smelt Trigger

Year	**1/1–1/7**	**1/8–1/14**	**1/15–1/21**	**1/22–1/28**	**1/29–2/4**	**2/5–2/11**	**2/12–2/18**	**2/19–2/25**	**2/26–3/4**	**3/5–3/11**	**3/12–3/18**	**3/19–3/25**	**3/26–4/1**
2010	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	1	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0

F.1-2.3.3.3 Larval and Juvenile Delta Smelt Protection Action

In modeling Alternative 2, the Juvenile Delta Smelt OMR assumption was the same as the NAA. This action also includes a highflow offramp when Rio Vista flows above 55,000 cfs or Vernalis flows above 8,000 cfs.

Table F.1-2-16. 2010–2022 Historical Larval Delta Smelt Trigger

Year	**2/26–3/4**	**3/5–3/11**	**3/12–3/18**	**3/19–3/25**	**3/26–4/1**	**4/2–4/8**	**4/9–4/15**	**4/16–4/22**	**4/23–4/29**	**4/30–5/6**	**5/7–5/13**	**5/14–5/20**	**5/21–5/27**	**5/28–6/03**	**6/04–6/10**	**6/11–6/17**	**6/18–6/24**	**6/25–7/1**
2010	1	1	1	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0
2011	1	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	1	1	0	1	1	1	1	1	1	1	1	0	0	0
2013	0	0	0	0	0	0	0	0	0	1	1	1	1	1	0	1	1	1
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	1	1	0	1	1	0	1	1	1	1	1	0	0	0	0	0	0	0
2016	0	1	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1
2017	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2018	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0
2019	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1

F.1-2.3.3.4 Larval and Juvenile Longfin Smelt Protection Action

In modeling Alternative 2, the Juvenile Longfin Smelt OMR assumption was based on the historical SLS or 20mm survey at stations 809 and 812 exceeding the threshold set by the San Francisco Bay Study Longfin Smelt Index. Table F.1-2-17 summarizes when the surveys would have triggered a potential OMR action to protect Juvenile Longfin Smelt (1= trigger, 0=No trigger) during the 2010–2022 period. This action also includes a highflow offramp when Rio Vista flows above 55,000 cfs or Vernalis flows above 8,000 cfs.

Table F.1-2-17. 2010–2022 Historical Larval Longfin Smelt Trigger

Year	1/1–1/7	1/8–1/14	1/15–1/21	1/22–1/28	1/29–2/4	2/5–2/11	2/12–2/18	2/19–2/25	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	1	1	1	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	1	0	1	1	1	0	0	0	1	0	1	0	0	0	1	0	0	0
2014	1	0	0	1	1	1	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	0
2016	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	1	0	1	0	1	0	1	1	1	1	1	0	1	0	0	0	0	0	0

F.1-2.3.3.5 Winter-Run Chinook Salmon Annual Loss Threshold

In modeling Alternative 2, the Winter-Run Chinook Salmon Annual Loss Threshold OMR assumption was the same as the NAA. Table F.1-2-18 summarizes when the loss threshold would have triggered a potential OMR action to protect Winter-Run Chinook Salmon (1= trigger, 0=No trigger) during the 2010–2022 period.

Table F.1-2-18. 2010–2022 Historical Winter-Run Chinook Salmon Annual Loss Threshold Trigger

Year	1/1–1/7	1/8–1/14	1/15–1/21	1/22–1/28	1/29–2/4	2/5–2/11	2/12–2/18	2/19–2/25	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2011	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

F.1-2.3.3.6 Winter-Run Chinook Salmon Weekly Distributed Loss Threshold

In modeling Alternative 2, the Winter-Run Chinook Salmon Weekly Loss Threshold OMR assumption was based on historical loss data of genetically confirmed natural origin juvenile winter-run Chinook salmon and for water year 2022, loss of two LAD juvenile winter-run samples that failed during the analysis process. Table F.1-2-19 summarizes when the loss threshold would have triggered a potential OMR action to protect Winter-Run Chinook Salmon (1= trigger, 0=No trigger) during the 2010–2022 period.

Table F.1-2-19. 2010–2022 Historical Winter-Run Chinook Salmon Weekly Loss Threshold Trigger

Year	1/1–1/7	1/8–1/14	1/15–1/21	1/22–1/28	1/29–2/4	2/5–2/11	2/12–2/18	2/19–2/25	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	0	0	0	1	0	0	0	0	1	1	0	0	1	1	0	0	0	0	0	0	0	0
2011	1	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	1	1	0	1	1	1	0	0	0	0	0	0	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0
2019	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0

F.1-2.3.3.7 Steelhead Annual Loss Threshold

In modeling Alternative 2, the Steelhead Annual Loss Threshold OMR assumption was not modeled as it was assumed the annual loss threshold was covered by the Steelhead Weekly loss threshold.

F.1-2.3.3.8 Steelhead Weekly Distributed Loss Threshold

In modeling Alternative 2, the Steelhead Weekly Loss Threshold OMR assumption was based on historical loss data from the CVP and SWP fish protection facilities for Water Years 2010–2022. The threshold was set as a rolling cumulative 7-day loss of 120 or more fish. Table F.1-2-20 summarizes when the loss threshold would have triggered a potential OMR action to protect Steelhead (1= trigger, 0=No trigger) during the 2010–2022 period.

Table F.1-2-20. 2010–2022 Historical Steelhead Weekly Loss Threshold Trigger

Year	1/1–1/7	1/8–1/14	1/15–1/21	1/22–1/28	1/29–2/4	2/5–2/11	2/12–2/18	2/19–2/25	2/26–3/4	3/5–3/11	3/12–3/18	3/19–3/25	3/26–4/1	4/2–4/8	4/9–4/15	4/16–4/22	4/23–4/29	4/30–5/6	5/7–5/13	5/14–5/20	5/21–5/27	5/28–6/03
2010	0	0	0	0	1	1	1	0	0	1	0	1	1	0	0	0	0	0	0	0	0	1
2011	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2012	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	1	1	0	0	1	0	0
2013	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0
2014	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2015	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2016	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2017	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2018	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1	1	1
2019	0	0	0	0	0	1	1	1	1	1	0	0	1	1	0	0	0	0	0	0	0	0
2020	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
2021	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2022	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

F.1-2.3.3.9 Spring-Run Chinook Salmon and Surrogate Threshold

In modeling Alternative 2, the Spring-Run Chinook Salmon was not modeled as it was assumed it is covered by other actions.

F.1-2.3.3.10 Combined Coverage

Table F.1-2-15 through Table F.1-2-20 were combined into one weekly table that can be used in CalSim 3 for the No Highflow Offramp conditions. Table F.1-2-15, Table F.1-2-18, Table F.1-2-19, and Table F.1-2-20 were combined into one weekly table that can be used in CalSim 3 for the With Highflow Offramp conditions. For a week where multiple species would have triggered an OMR action, it was counted as only a single occurrence of triggering an action to ensure these actions weren't double counted while the effects of the actions would overlap. Table F.1-2-21 and Table F.1-2-22 summarize the combined 2010–2022 OMR percentage for the No Highflow Offramp and With Highflow Offramp conditions, respectively and Table F.1-2-23 and Table F.1-2-24 summarize by water year the OMR percentages for the No Highflow Offramp and With Highflow Offramp conditions, respectively, based on Table F.1-2-21 and Table F.1-2-22, respectively.

Table F.1-2-21. 2010–2022 Historical Delta Smelt, Longfin, Winter-Run, and Steelhead OMR Percentage, No Highflow Offramp

Water Year	Jan	Feb	Mar	Apr	May	Jun
2010	100%	75%	100%	50%	25%	20%
2011	25%	75%	100%	25%	0%	0%
2012	50%	50%	100%	75%	100%	40%
2013	0%	75%	60%	100%	100%	80%
2014	50%	75%	20%	0%	0%	0%
2015	0%	0%	80%	75%	50%	0%
2016	25%	25%	80%	75%	100%	60%
2017	0%	0%	100%	100%	100%	100%
2018	0%	0%	60%	75%	50%	20%
2019	0%	75%	80%	50%	0%	0%
2020	0%	0%	60%	75%	0%	0%
2021	0%	0%	0%	0%	0%	0%
2022	25%	50%	80%	75%	0%	40%

Table F.1-2-22. 2010–2022 Historical Delta Smelt, Longfin, Winter-Run, and Steelhead OMR Percentage, With Highflow Offramp

Water Year	Jan	Feb	Mar	Apr	May	Jun
2010	25%	75%	80%	25%	0%	20%
2011	25%	0%	80%	0%	0%	0%
2012	0%	0%	100%	75%	25%	0%
2013	0%	0%	40%	100%	50%	0%
2014	0%	0%	0%	0%	0%	0%
2015	0%	0%	0%	0%	0%	0%
2016	25%	0%	0%	0%	0%	0%
2017	0%	0%	0%	0%	0%	0%
2018	0%	0%	60%	75%	50%	20%
2019	0%	75%	60%	50%	0%	0%
2020	0%	0%	20%	75%	0%	0%
2021	0%	0%	0%	0%	0%	0%
2022	25%	0%	0%	25%	0%	0%

Table F.1-2-23. OMR Percentage by Water Year Type for Input Into CalSim 3, No Highflow Offramp

Water Year Type	Jan Avg	Feb Avg	Mar Avg	Apr Avg	May Avg	Jun Avg
C	25%	25%	45%	38%	13%	10%
D	63%	42%	77%	75%	50%	40%
BN	15%	45%	100%	75%	69%	35%
AN	8%	75%	95%	67%	51%	34%
W	0%	0%	90%	58%	33%	33%

Table F.1-2-24. OMR Percentage by Water Year Type for Input Into CalSim 3, With Highflow Offramp

Water Year Type	Jan Avg	Feb Avg	Mar Avg	Apr Avg	May Avg	Jun Avg
C	0%	0%	0%	6%	0%	0%
D	25%	0%	50%	69%	25%	0%
BN	5%	30%	80%	38%	19%	10%
AN	8%	0%	55%	27%	9%	5%
W	0%	0%	30%	17%	0%	0%

Table F.1-2-23 and Table F.1-2-24 were used as a lookup table in CalSim 3 and it was assumed the percent shown for each month is the portion of the month operated to greater than a -3,500 OMR Index. For example, from Table F.1-2-24, Dry March years was assumed to be at a -3,500 OMR Index for half the month (50%).

F.1-2.3.3.11 Storm-Flex

In modeling Alternative 2, OMR Flex was assumed to be the same as the NAA, except that QWEST flow must exceed 1,500 cfs instead of 1,000 cfs.

Appendix F, Modeling
Attachment F.1-3 Model Updates

F.1-3.1 CalSim 3 Model Updates

Through the LTO and other concurrent processes, the CalSim 3 model has undergone multiple updates since the CalSim 3 Report (California Department of Water Resources and U.S. Bureau of Reclamation 2022) was published.

F.1-3.1.1 Extension through WY 2021

F.1-3.1.1.1 Rim Inflows

The physical hydrology components of CalSim 3 are based on two assumptions for classifying watersheds. The first assumption is that the foothill and mountainous ‘rim’ watersheds that surround the Central Valley are relatively undeveloped, and changes in land use over time have not significantly affected the natural outflow from these watersheds. Rim watersheds typically are characterized by complex topography, steep slopes, shallow soils, and limited groundwater aquifer systems. Runoff at higher elevations is largely determined by the snowfall and snowmelt cycle. Precipitation percolating to groundwater quickly returns to streams as baseflow. Groundwater in these upland watersheds is not extensively used as a source of water supply.

The second assumption is that the ‘valley floor’ watersheds have been extensively developed for agriculture and contain significant urban areas. The valley watersheds cover the same domain as the Water Budget Areas (WBA), but are delineated according to drainage lines, rather than water supply and water use. For these watersheds, the timing and volume of runoff is strongly influenced by human impacts on the environment. Deep percolation from precipitation and irrigation recharges the underlying aquifer, which is hydraulically linked to the stream system. Groundwater is an important source of water both for agricultural and urban uses. Significant changes in groundwater storage occur.

CalSim 3 represents the hydrology of the rim watersheds as preprocessed time series of unimpaired runoff. This runoff either enters the boundary of the model domain as inflow to the valley floor stream network, or where management of water control infrastructure in the rim watersheds is dynamically simulated, the runoff enters the stream network of the upper watersheds.

Currently, CalSim 3 assumes that the historical flow record can be used to characterize existing conditions, in terms of the magnitude and frequency of wet and dry years and the monthly distribution of runoff. Upper watershed unimpaired runoff used in CalSim 3 represent the flows that would occur under a repeat of historical weather conditions. CalSim 3 inflows are based on streamflow records adjusted for any upstream storage regulation and associated evaporation, imports, and exports.

All available historical gage data were unimpaired for upstream water management (storage regulation, reservoir evaporation, imports, exports, stream diversions and return flows) and extended till 2021 in the latest CalSim 3 update. Subsequently, unimpaired outflows from each rim watershed were determined as follows:

- **Complete record:** Stream gage data or reservoir release records exist at the watershed outflow point for water years 1922 through 2021.
- **Streamflow correlation:** Streamflow data exist at the watershed outflow point for only a limited period between water years 1922 and 2021. These data were extended through linear correlation with streamflow records from adjacent watersheds, assuming statistical relationships between (unimpaired) streamflows in adjacent watersheds are constant. Double mass plots of monthly flows were used to check that a constant (and linear) relationship exists between the dependent and independent variables.
- **Proportionality:** No gage data exist for the watershed. It is assumed that runoff is proportional to the product of drainage area and average annual precipitation depth over the watershed. Outflow was determined through association of the watershed with a similar but gaged watershed and the use of multiplicative factors representing the ratio of watershed areas and the ratio of precipitation depths. Similar to streamflow correlation, it is assumed that no significant land use change has occurred during the historical period.

F.1-3.1.1.2 Reservoir Evaporation Rates

Reservoir evaporation serves two purposes in CalSim 3. First, estimates of historical evaporation, coupled with reservoir storage and release data, are used to develop reservoir inflows from CalSim 3 rim watersheds. Inflow data are preprocessed, stored in the CalSim 3 input file, and read at run-time. Second, evaporation rates for reservoirs represented in CalSim 3 are used to dynamically compute reservoir evaporative losses at model run time. Reservoir evaporation is calculated as the product of a monthly evaporation rate and reservoir surface area. The area-capacity curve is linearized centered on the beginning-of-period storage so that evaporation is a linear function of storage.

As evaporation data is incomplete it is necessary to develop a standard method of estimating reservoir evaporation rates beginning October 1921. For CalSim 3, the Hargreeves-Samani equation was modified to determine open water evaporation as a function of monthly average maximum and average minimum temperatures and extraterrestrial solar radiation (Eqn 9-10, California Department of Water Resources and Bureau of Reclamation 2022).

$$E_o = [0.0023.a.(T_{max} - T_{min})^{0.5}. (T_m + 17.8) + b].n_d / 25.4.f(z)$$

where n_d = the number of days of the month and 1/25.4 is the conversion factor from millimeters to inches.

Updates to the method for the 2021 CalSim3 data extension are described below:

- **Pan Evaporation Data:** Evaporation from open water is rarely measured directly, therefore, a number of techniques have been developed to indirectly measure or estimate evaporative losses from open water. These techniques are reviewed by Jensen (2010). In California, pan evaporation data are commonly used to estimate evaporative losses from open water. Historical daily pan evaporation records exist for many larger reservoirs in California, particularly for reservoirs operated by CVP, SWP, or USACE. *No historical daily pan evaporation data was added for the 2021 CalSim3 data extension.*
- **Historical Temperature Data:** Historical temperature data was obtained from the PRISM Climate Group at Oregon State University (2020). PRISM data include estimates of historical maximum and minimum monthly temperatures and dew point available on a 30-arcsecond grid beginning January 1890. *PRISM temperature data were downloaded for the extended period of simulation and updated in calculations.* Grids of 30-year average (January 1991–December 2020) monthly maximum and minimum temperatures are also available. These grids are referred to as climate "normals." T*he climate normal data was updated for the CalSim3 2021 data extension using the most up-to-date climate normal (January 1991–December 2020).*
- **Extraterrestrial Radiation:** Monthly estimates of extraterrestrial radiation (R_a) as a function of latitude were determined using equations published by Allen et al. (1998). Values are also given by Samani (2000). *Monthly estimates of extraterrestrial radiation did not require updates.*
- **Calibration**: For each reservoir, the slope (a) and intercept (b) in Equation 9-10 were determined by the least squares estimator line between observed evaporation data and estimated evaporation rate obtained using the modified Hargreaves-Samani equation. For each reservoir 12 sets of coefficients were determined, one set for each month. Values for the coefficient of determination (R^2) typically range from 0.87 to 0.98. Where historical evaporation data were not available for a particular reservoir, calibration coefficients from a reservoir most similar in characteristics (latitude, altitude, size) were used. *The calibration factors (slope, intercept values) were updated as historical temperature data was updated.* Time series of evaporation rates were generated for the 40 reservoirs that are dynamically simulated in CalSim 3 from September 1921 to October 2021.

F.1-3.1.1.3 CalSim Hydro, Land Use, and Closure Terms

CalSim Hydro

CalSim 3's catchment area is delineated into three categories: rim watersheds, valley floor WBAs, and Delta subregions for surface hydrology simulations. CalSimHydro is the surface hydrologic modeling system for the CalSim 3 valley floor WBAs. It automates various steps in the computation of hydrologic inputs for CalSim 3.0. CalSimHydro uses a Microsoft Windows batch file as a wrapper, which runs the individual models in succession, passing information from one model to the next and aggregating data as required by each model. It consists of four hydrologic models, a CalSim 3.0 state variable (SV) input file generator, and a diagnose tool, which are all written in Fortran and complied into executable files. The four hydrologic models are Daily Curve Number (CN) Runoff model, the Integrated Demand Calculator for CalSim 3

(IDCv2.1), the Rice Water Use model (RWUM), and Refuge Water- use model. The final product is an SV input file in the Hydrologic Engineering Center (HEC) Data Storage System (DSS) format. The diagnose tool, named as Hydrologic Water Balance Diagnose Utility program (HydroDU), does not generate data for CalSim 3.0, but it diagnoses the models using water balance calculations. More information about models included in CalSimHydro can be found in the CalSim 3 Report (California Department of Water Resources and Bureau of Reclamation 2022) and in the CalSimHydro Reference Manual (California Department of Water Resources and Bureau of Reclamation 2017).

CalSim 3 is not dynamically linked with CalSimHydro. Instead, CalSimHydro is run before any CalSim 3 simulation to provide preprocessed hydrologic inputs for CalSim 3. The input time series data for CalSim 3 generated using CalSimHydro includes:

- Surface runoff (SR) from precipitation
- Applied water demand for rice (AWr)
- Applied water demand for other agricultural crops (AWo)
- Applied water demand for permanent, semi-permanent, and seasonal wetlands (AWw)
- Urban demand (UD), combining indoor and outdoor components
- Tailwater (TW) from irrigated agricultural land
- Wastewater (WW) return flows from wastewater treatment plants
- Deep percolation (DP) from all land-use classes

All input timeseries including Land Use, Precipitation and ET for CalSimHydro were extended through September 2021 and the CalSimHydro engine was modified to run through 2021 as part of the most recent update. Precipitation and temperature data were extended using the PRISM Database (Daly et al. 2008). Land Use data was extended as explained in the previous section. Temperature data from the PRISM database used for the ET data computation has changed for the period-of-record, therefore the extension exercise updated the ET data for the entire simulation period (1922-2021).

Land Use Assumptions

Planning models for managing California's water resources typically simulate water-related operations using a fixed level of development. The level of development describes conditions, including facilities, population, and land use at a point in time or planning horizon.1 This section describes the calculation of land use for CalSim 3 for both historical and year 2020 conditions. Results are presented by WBA and by Demand Unit (DU).

Four broad categories of land use are considered in CalSim 3: agricultural, urban, managed wetlands, and native vegetation. The agricultural category is further divided into 20 subcategories. Managed wetlands are divided into 3 main subcategories. Land use data are required both for historical conditions and for year 2020, which was selected to represent existing conditions.

Historical and 2020 level land uses for CalSim 3 are developed from three data sources:

- DWR Consumptive Use (CU) computer program, which provides annual historical land use for DWR-defined DSAs beginning in 1922.
- DWR county land-use surveys, which provide geospatial land-use data beginning in the 1950s.
- DWR California land and water-use database, which provides land-use data by DWR-defined DAUs.

Additionally, beginning in 2014, DWR has partnered with Land IQ to develop satellite-based land-use data for the State of California (State).

DWR county land-use data contains over 160 separate land cover classes, including over 70 classes for agriculture. For CalSim 3, these land cover designations need to be aggregated to a more limited number of classes to be practical, while maintaining sufficient resolution to distinguish between classes that have significantly different water demands, or different soil and land cover characteristics that lead to significantly different surface runoff amounts. Based on an analysis of the relative areas of each land-use type described in county land-use surveys, irrigated agricultural classes have been aggregated according to the 20 land-use categories used for California Water Plan. For CalSim 3, all idle land and semi-agricultural land was reassigned to a native vegetation category. The reassignment of semi-agricultural land to a non-irrigated class results in an underestimate of water demands. However, these land areas are small compared with the total area of the 20 irrigated agriculture categories. Over 50 percent of the land is not designated to subclasses within the urban class. Consequently, for CalSim 3, no attempt was made to explicitly represent different urban land-use classes to improve estimates of surface runoff from these lands.

For CalSim 3 2020 level Land Use, which is subsequently used in the extension of Land Use data till 2021, agricultural land use is based on the average irrigated crop area for the 10-year period from 2004 through 2013. DAU tabular agricultural land use acreages were distributed among agricultural demand units using the GIS land-use survey mosaic and DAU and demand unit boundaries. Crop-specific land-use adjustment factors were calculated for each DAU as the ratio of crop area within the DAU from the county land-use surveys to the crop area from land-use database (non-spatial). Subsequently, a data field of adjusted land use was created by multiplying the GIS survey acreage by these crop-specific and DAU-specific factors. The adjusted land-use data derived from GIS, when aggregated by DAU, matches the DAU tabular land-use data (calculated as the average of years 2004 through 2013). The adjusted land-use data were used to derive agricultural land use for each demand unit. Agricultural land located within an urban demand unit (e.g., within the City of Redding's planning area boundary) was reassigned to an agricultural demand unit. Agricultural land located within the boundary of a managed wetland demand unit was considered part of total refuge water demands.

CalSim 3 land use is based on irrigated crop area rather than irrigated land area. A unit of land that is double cropped is treated as two separate units of land in the model. To maintain the correct total land area for each demand unit, a unit of native vegetation is reclassified as irrigated land. This approach provides reasonable estimates of crop water requirements but may result in small errors due to incorrect antecedent soil moisture conditions before planting and errors in surface runoff. However, these inaccuracies are considered minor given the relatively low intensity of double cropping in the Central Valley.

Urban lands, which include roads, railways, and other types of infrastructure, are located in all three demand unit types (agricultural urban, managed wetland). Urban water demands are not land-use based so this does not create problems in accounting for water demands; urban land use only affects the calculation of surface runoff. The areas of urban lands were developed from the GIS mosaic of DWR county land-use surveys.

Managed seasonal and permanent wetlands are designated NR4 and NR5, respectively, in DWR county land-use surveys. These wetlands are typically located in Federal and State refuges; however, significant areas of private wetlands exist within agricultural demand units. The areas of seasonal and permanent ponds on private lands are taken from DWR's water balances for the water year 2000. The areas of seasonal and permanent ponds in Federal and State refuges are based on the 2010 refuge water management plans (Bureau of Reclamation 2022) and DWR's water balances for the water year 2000.

For the purposes of CalSim 3, the native vegetation designation applies to all areas of the Central Valley, external to the rim Valley watersheds that are not designated as agricultural, urban, or managed wetland land classes. It includes open water, riparian vegetation, and grasslands. For each demand unit, the area of native vegetation is calculated as the area remaining after areas of the other three land-use classes have been subtracted.

Land-Use data was extended using DWR Atlas database till 2021. Land use data was only available for 2016, 2018 and 2019 for this exercise.

Miscellaneous Timeseries Input Data

Approximately 600 other SV input timeseries were updated and extended for the 2021 CalSim3 data extension. Description of updating and extending these timeseries is provided below.

- **DCD Model:** Coordination with DWR to develop pre-processed timeseries for the extended period of simulation.
- **DSM2 Model:** Coordination with DWR to develop pre-processed timeseries for the extended period of simulation.
- **Groundwater Models (Foothill Small Watershed Model, C2VSIM FG – Tulare Basin Tool, CalSimHydroEE Model):** Coordination with Reclamation to develop pre-processed timeseries for the extended period of simulation.
- **CS3 Upper Watershed Preprocessed Timeseries (Lower Yuba, Upper Yuba Bear, Upper American, Upper Feather, Upper Stanislaus, Upper Tuolumne, Upper Mokelumne):** Independent upper watershed models were developed and run independently to develop pre-processed timeseries for the extended period of simulation.

- **Historical Data:** CDEC, PRISM, and other data repositories were used to update historical data for the extended period of simulation. Some of this data is directly inputted into the CS3 model as timeseries data and other data is used in historical data workbooks to subsequently develop input timeseries for the CS3 model.
- **Other data sources (Bulletin 120, water management plans, etc.):** The majority of these timeseries could be updated due to updates in source material or as repeating 12-month timeseries, given they were already 12-month repeating timeseries.
- **Missing data sources:** For timeseries where sources could not be verified and did not have a discernable pattern, a water year type approach whereby repeating monthly averages by water year type was used to extend timeseries data.

Method of extending timeseries data and location of the source material was recorded in a source documentation inventory spreadsheet.

Closure Terms

Four types of water supply are represented in CalSim 3: rim inflows from mountain and foothill watersheds, surface runoff from the valley floor, deep percolation to groundwater from precipitation and irrigation within the valley floor, and subsurface boundary inflows to the Central Valley groundwater aquifer. These water supplies are exogenous to the model, are predetermined, and are represented by monthly time series input data.

CalSim 3 uses historically observed hydrology to study how existing or planned facilities may be operated to meet competing demands for water under a wide range of hydrologic conditions. Historical surface water supplies consisted of inflows from the rim watersheds, supplemented by runoff from the valley floor and groundwater accretions to the stream system. Historical streamflows were depleted through diversions and augmented by return flows. The net effects of all these processes were integrated into the observed gauged flows on the valley floor. As part of CalSim 3 hydrology development, a set of monthly historical water budgets were developed. Water budgets can be calculated along river reaches where reliable gauge data exist for the entire period of simulation at both upstream and downstream ends of the reach. These key gauge locations are referred to as “control” points; flows at these locations are used to correct the CalSim 3 surface water hydrology.

CalSim 3 uses ‘closure terms’ to adjust surface water supplies using historical streamflow data as a reference or control. These terms can be regarded as a bias correction of rim inflows and/or rainfall runoff so that simulated and recent observed streamflow data are more consistent. Data has been developed in a set of Excel workbooks, one for each closure term. *These data were extended to include October 2015 – September 2021.*

CalSim 3 closure terms correct hydrology components that are exogenous to the model (i.e., rim inflows and surface runoff on the valley floor). They do not correct for errors in components that are dynamically simulated in CalSim 3 (i.e., surface water diversions, return flows, and groundwater inflow to the stream system). These latter components may be adjusted and refined through water use parameters included in the WRESL code and lookup tables, or through further calibration of the CalSim 3 groundwater module.

Types of Closure Terms used in CalSim:

1. **Rim Inflow Corrections**

   Historical inflows from the rim watersheds typically are from direct gauge measurement. Where necessary, historical gauge data are extended to cover the entire period of simulation through correlation of annual observed flows with annual flows from adjacent gauged watersheds. For ungauged watersheds, monthly flows are derived by scaling flows from a similar, but gauged watershed, by the ratio of drainage areas and the ratio of average annual precipitation depth. Both of these approaches tend to increase flow correlation between the two watersheds.

   Derived or synthetic streamflows may significantly depart from historical flows. Stream gauges located on the valley floor, downstream from the rim watersheds, provide a control for validating derived streamflow data for the upstream rim watersheds and making flow corrections. Once calculated, flow corrections based on a downstream control gauge could be redistributed among upstream rim watersheds. However, for CalSim 3, flow corrections were not redistributed because a single flow adjustment at the downstream control location provides greater transparency of model accuracy.

   The following control gauges are located on major river system downstream from CalSim 3's rim watersheds and are used to calculate closure terms to correct errors in the upstream rim inflows:

   - Yuba River at Smartville (USGS 11419000)
   - Feather River at Oroville (USGS 11407000)
   - Bear River near Wheatland (USGS 11424000)
   - American River at Fair Oaks (USGS 1146500)
   - Tuolumne River below La Grange Dam (USGS 11289650)
   - Stanislaus River below Goodwin Dam (USGS 11302000)

2. **Rainfall Runoff Corrections**

   Surface runoff for CalSim 3 is calculated using the SCS Curve Number method (SCS method) in a continuous simulation on a daily time step. The method is described in Chapter 10 (Valley Surface Runoff). Curve numbers for different soil types and land cover were taken from typical values published by the NRCS, although a limited model validation was undertaken. Long-term average annual volumes of simulated runoff may match historical average annual volumes reasonably well. However, correlation of monthly simulated runoff with monthly stream gauge data is generally poor. Similar to rim watersheds, stream gauges located on the valley floor can be used to correct poor simulation of surface runoff in CalSim 3. Closure terms partly correct for errors in the surface runoff because the rainfall-runoff model used to estimate historical flows for the water balance is used to estimate existing level flows for the CalSim 3 simulation; only the land use is different. In addition to the four control gauges described in the previous section, the following control gauges are used to calculate closure terms to correct errors in surface runoff from upstream watersheds:

- Sacramento River below Wilkins Slough (USGS 11390500)
- Sacramento River at Verona (USGS 11425500)
- Sacramento River at Freeport (USGS 11447650)
- San Joaquin River near Stevinson (USGS 11260815)
- San Joaquin River at Gravelly Ford
- Salt Slough at Highway 165 (USGS 11261100)
- Mud Slough near Gustine (USGS 11262900)
- Merced River near Stevinson (USGS 11272500)
- Tuolumne River at Modesto (USGS 11290000)
- Stanislaus River at Ripon (USGS 11303000)
- San Joaquin River near Vernalis (USGS 11203500)

Flows at these locations are strongly influenced not only by surface runoff from rainfall, but also groundwater inflow, irrigation diversions, and return flows. In months of low or no precipitation, non-zero closure terms from a historical water balance are caused by a combination of gauge errors, inaccurate records of historical stream diversions, poor estimates of historical inflow from groundwater, and approximate estimates of historical irrigation return flows. These flow components are dynamically calculated in CalSim 3; errors in the historical values of these terms should not be added to the model. In contrast, in months of high precipitation, non-zero closure terms are probably predominantly caused by poor estimates of surface runoff. In these cases, including the closure term in CalSim 3 as a correction to the surface runoff is likely to improve model accuracy. For the locations listed above, closure terms derived from historical flow balances are not included in CalSim 3 for the months of April through October; for these months' precipitation is generally low and irrigation return flows are a significant fraction of the total stream flow.

3. Combined Rim Inflow and Rainfall-Runoff Corrections

For six water balances, flow components include both inflows from rim watersheds and inflows from rainfall-runoff. The associated downstream control points are as follows:

- Sacramento River above Bend Bridge (USGS 11377100)
- Sacramento River at Butte City (USGS 11389000)
- Feather River at Nicolaus (USGS 1142500)

Closure terms associated with these locations are applied year-round or only during the non- irrigation season, depending on the relative magnitude of rim inflows to irrigation diversions and return flows, and the degree of confidence in the historical data.

Data used for closure term computations include:

- *Inflows:* flows at upstream control locations.
- *Groundwater inflows:* accretions to the stream system from the groundwater aquifer.
- *Return flows:* combined irrigation return-flows and treated wastewater return flows.
- *Rim inflows:* flows from one or more of the 60 rim watersheds described in Chapter 5.
- *Runoff:* surface runoff from precipitation as simulated by CalSim Hydro for the historical land use.
- *Imports:* canal imports from stream systems that are part of other flow balances.
- *Storage gain:* increase in storage in surface water reservoirs.
- *Evaporation:* open water evaporation from lakes and reservoirs.
- *Outflows:* flows at the downstream control location(s).
- *Diversions:* stream diversions for agricultural, municipal, and environmental (wetlands) purposes.
- *Exports:* canal exports to stream systems that are part of other flow balances.

In the recent CalSim 3 update, closure terms were extended to September 2021. Following is a brief description of the methodology used for Sacramento Valley and San Joaquin Valley Closure Term computation.

4. Sacramento Valley Closure Terms

Sacramento Valley closure terms were computed using the methodology described in CalSim 3 Report (California Department of Water Resources and Bureau of Reclamation 2022) and extended till 2021. The data extension effort till 2021 included minor updates to historical rim and reservoir inflow terms and updates to the groundwater data using C2VSIM fine grid data.

5. San Joaquin Valley Closure Terms

Sacramento Valley closure terms were computed using the methodology described in CalSim 3 Report (California Department of Water Resources and Bureau of Reclamation 2022) and extended till 2021. The data extension effort till 2021 included minor updates to historical rim and reservoir inflow terms and updates to the groundwater data. Large inconsistencies were observed between groundwater inflows and outflows in C2VSIM and Groundwater DLL module used I CalSim 3. To remove these errors from the closure term computations, Groundwater DLL was needed to be run for historical operations. Since a CalSim model simulating historical operations is not available, operations in CalSim were fixed to historical gauge data for rim inflows, reservoir releases and diversions in the San Joaquin Valley. Thereafter the model was run for October 1996 – September 2021. Groundwater seepage and tile drain data from groundwater DLL using this model run was used for the closure term computations. For the San Joaquin Valley closure terms, no correlation was observed between water year type and the values of closure term/bias computed. Therefore, monthly average values from 1996-2021 were used as repeating timeseries for the entire simulation period (1922 – 2021).

F.1-3.1.2 Upstream Operations

Separate modules along with detailed documentation have been developed for:

1. Upper American River above Folsom Lake (Bureau of Reclamation 2020)
2. Upper Feather River above Lake Oroville
3. Upper Mokelumne River above Pardee Reservoir
4. Upper Stanislaus above New Melones Reservoir
5. Upper Tuolumne above New Don Pedro Reservoir
6. Upper San Joaquin above Millerton Reservoir

F.1-3.2 DSM2 Updates

F.1-3.2.1 Development of ANN

The representation of Delta hydrodynamics in CalSim 3 is simplified. Simulated Delta channel flows represent tidally averaged or freshwater flow averaged over a monthly timestep. Salinity in the Delta cannot be modeled accurately by the simple mass balance routing and coarse timestep used in CalSim 3. Salinity variation in the western Delta (represented by X2 location in the model) is affected by seawater intrusion. Delta salinity is also influenced by boundary inflows, operation of the Delta Cross Channel Gates, salinity of the San Joaquin River at Vernalis, export pumping, and SMSCG operations. Agricultural drainage and M&I wastewater discharges also can affect local salinity conditions. CalSim 3 uses an Artificial Neural Network (ANN) algorithm developed by DWR to translate water quality standards into flow equivalents that are to be met through SWP and CVP simulated operations (Sandhu et al. 1999). The ANN mimics the flow-salinity relationships as simulated in DSM2 and provides a rapid transformation of this information into a form usable by CalSim 3 operations. The ANN references DSM2 because it represents the best available planning model for Delta tidal hydraulic and salinity modeling. It is appropriate for describing the existing conditions in the Delta, as well as performing simulations for the assessment of incremental environmental impacts caused by future facilities and operations (Bureau of Reclamation 2015). It has been calibrated and validated to historical, observed flow, stage and electrical conductivity (EC) data (California Department of Water Resources 2021b).

The ANN is trained based on the flow-salinity relationships of DWR's hydrodynamic and water quality model, DSM2. To estimate the flow equivalents for the water quality standards, the ANN relies upon the seven inputs listed below:

1. Northern flow (Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, and Calaveras River inflow)
2. San Joaquin River inflow
3. Exports (Banks, Jones, and Contra Costa Pumping Plants)
4. Delta cross-channel gate operation
5. Net Delta Channel Depletion
6. Tidal energy (daily maximum – daily minimum of astronomical tides)
7. SMSCG gate operation (this modification was added to ANN after Jayasundara et al, 2020)

A more detailed description of the use of ANNs in the CalSim model is provided in Wilbur and Munévar (2001). For more details regarding the implementation of the ANN in CalSim 3, please refer to Chapter 17, Sacramento – San Joaquin Delta in the CalSim 3 Report (California Department of Water Resources 2022).

F.1-3.2.2 15 cm of Sea Level Rise

The DSM2 models assume a 15 cm increase in sea level rise. The Martinez electrical conductivity (EC) boundary condition is modified to account for the salinity changes related to the sea level rise using the regression equation derived based on the three-dimensional (SCHISM) modeling of the Bay-Delta under the future conditions with 15 centimeters (0.5 feet) sea level rise.

The hydrodynamics and salinity changes in the Delta due to sea level rise were determined from the SCHISM three-dimensional Bay-Delta model simulations based on 2009 through 2010 historical hydrology. SCHISM results for changes of stage at Martinez were dominated by a scalar shift of about 0.5 feet.

SCHISM results also indicated that there would be a very small phase shift (2 to 3 minutes) with the assumed sea level rise, with the tides arriving slightly earlier due to faster propagation in deeper water. Given that the magnitude of the phase shift is very small relative to the DSM2 timestep, it was assumed that 0.5 feet sea level rise would lead to 0.5 feet incremental change at Martinez with no phase shift.

A regression equation was developed to estimate the incremental change in EC at Martinez due to the assumed sea level rise as shown below:

$$\text{Change in EC at Martinez (for 0.5 ft sea level rise)} = \\ -0.0155 * \text{EC (at 0 cm sea level rise)} - 28.9 * \text{TE} + 596$$

Where:

- EC is the filtered EC using is the cosine-lanczos squared filter, and
- TE is the tidal energy measure defined as the cosine-lanczos of the residual tide squared (tide minus filtered tide squared)

DSM2 model results were corroborated for the assumed sea level rise using SCHISM results. DSM2 results indicated a stronger salinity response mostly along the San Joaquin River. In order to obtain a better corroboration between the two models, changes were introduced in the dispersion coefficients in some DSM2 channels. These changes were mostly along the San Joaquin River, to ensure that the incremental changes in salinity at key locations in the Delta due to the assumed 0.5 feet of sea level rise predicted by the two models are similar.

F.1-3.2.3 7-7 SMSCG operations

The SMSCG are located approximately 2 miles downstream from the confluence of the Sacramento and San Joaquin Rivers, on Montezuma Slough. The operation of the SMSCG aims to lower salinity in Montezuma Slough by restricting the flow of higher salinity water from Grizzly Bay into Montezuma Slough during incoming tides and retaining lower salinity Sacramento River water from the previous ebb tide.

Some alternatives include measures to operate SMSCG in September through May to meet water quality objectives in the Marsh, and in June through October for the Summer-Fall Habitat Action (State Water Contractors 2017). Per the Summer-Fall Habitat Action in the No Action Alternative, SMSCP will operate for up to 60 days in June – October of above normal years, below normal years, and dry years following wet, above normal, or below normal years. Instead of operating the SMSCG continuously (as done in the No Action Alternative) for the Summer-Fall Habitat Action, the SMSCG cycle between tidal operations for 7 days and remaining open for 7 days, or a 7 on, 7 off schedule, in Alternative 2. For more details regarding this action, see the Alternative 2 description.

SMSCG operations reduce the effective Delta outflow through tidal pumping of Sacramento River waters through the Montezuma Slough. The degree to which effective Delta outflow changes is affected by the operational schedule of the SMSCG (continuous vs 7 on, 7 off). As such, the ANN was retrained to reflect the continuous and 7 on, 7 off operational schedules for the SMSCG.

F.1-3.3 Temperature Model Updates

Temperature model updates were conducted to support the CalSim 3 extended simulation period, to more closely match model behavior to real-world operations, and to improve throughput/documentability of the modeling workflow. The following sections detail the changes within the 2021 LTO to the temperature modeling workflow.

F.1-3.3.1 Toolkit Revisions

F.1-3.3.1.1 Preprocessor Updates

The temperature preprocessor is utilized across the Sacramento, American, and Stanislaus models to prepare CalSim outputs for use in the HEC5Q temperature models. The preprocessor aggregates various CalSim timeseries as well as interpolates the timeseries, as needed, from monthly to daily values. The 2021 LTO inherited a legacy version of the preprocessor that was used in combination with the CalSim II model. With the transition to CalSim 3, the temperature preprocessor required updating for the extended simulation period. However, the source code for the legacy temperature preprocessor is written in Fortran and compiled. Given the complexity of the modification in Fortran and the lack the original compilation solution which has the potential to greatly alter post-compilation performance, Reclamation undertook a modernization of the temperature preprocessor to improve the code transparency, understandability, and maintainability.

The revised preprocessor is written in Python to broadly conform with the logic from the legacy preprocessor, with improvements to the handling of interpolation edge cases. The preprocessors use the XX_CS.dat file from the legacy preprocessor with modification to read CalSim 3 outputs (as outlined in Section F.1-3.3.2, *Conversion of American/Stanislaus Models to CalSim 3*), where XX is replaced by the two letter characters that designate the base (i.e. SR for the Sacramento River). Mirroring the legacy preprocessor, the revised preprocessor reads the *get* lines and extracts those fields from the CalSim SV and DV files. The preprocessor then parses the *ZR* lines which indicate how the CalSim inputs will be renamed to the HEC5Q inputs and aggregated. Based on the sign of the CalSim inputs, the revised temperature preprocessor adds or subtracts the CalSim timeseries. The outputs are written in a CalSimII_HEC5Q.DSS file that is ready for use within HEC5Q. The preprocessor therefore also acts as a converter from the CalSim 3 to CalSim II to maintain compatibility with HEC5Q.

The revised preprocessor differs from the legacy version in how the timeseries interpolation is accomplished. Several timeseries within each basin model require disaggregation from the monthly CalSim inputs to a daily timeseries. This is done to estimate the daily temperatures more accurately than what would otherwise be possible from the monthly averages. The temporal downscaling is done by applying a spline interpolation to the monthly magnitudes timeseries. The legacy temperature preprocessor is believed to utilize a cubic polynomial procedure that computes the tangent through the monthly values. To minimize the sharp transition between months, a five-day linear interpolation is conducted across the splined values centered on the first day of the month. If values from the fit are less than one cfs, the values are set to one cfs as a floor value. It is understood that there is a mechanism that preserves the monthly averages of the time series, but it is unclear the mechanism by which this is implemented from reviewing the source code.

The revised preprocessor utilizes the PchipInterpolator from the Python Scipy library to perform the spline interpolation (Virtanen et al. 2020). This generally conforms with the process from the legacy temperature preprocessor in preserving the timeseries shape. However, by itself, the PchipInterpolator does not preserve the monthly volumes. Volume was enforced through a preconditioning operation that incrementally adjusts the maximum monthly magnitude until the average value of the spline matches the CalSim monthly value. To prevent an unphysically realistic trough prior to large increases in magnitude, the code shifts the date of the maximum monthly magnitude backwards in time if the months differ in magnitude by more than a factor of two. This results is a continuous timeseries that is more smooth and representative of the CalSim monthly timeseries than would otherwise be produced by PchipInterpolator with the maximum flow occurring mid-month. The maximum monthly flow is limited to occurring five days before the end of the month.

An additional volume criterion is imposed after the spline fit to adjust for any residual volume discrepancies between the monthly and daily timeseries. The monthly volume was enforced by first setting any flows less than 0.2 cfs to 0.2 cfs and calculating the difference between the monthly volume and the average of the fit daily series. The difference was then averaged over the month and applied as a adjustment factor. Any values less than 0.2 cfs after the adjustment were again reset to 0.2 cfs. Given the initial performance of the preconditioning operation, the required secondary adjustments were relatively small and did not result in a large enough discontinuity require a linear interpolation between months.

F.1-3.3.1.2 Shutter Lock

The Sacramento HEC5Q incorporates the movement of the Temperature Control Device (TCD) shutters to describe the selective withdrawal used to manage river temperatures throughout the year. During normal real-world temperature operations, the shutters are raised in a predictable sequence throughout the year, beginning at the highest elevations and moving downward to access cooler water. At the end of the temperature management season, the shutters are lowered as the reservoir refills with cold water.

The Sacramento HEC5Q model incorporates the shutter logic in a more simplistic fashion to approximate real-world temperature operations. For each day, the model assesses the stratification of the cold-water pool from the previous day. Starting from the highest elevation shutter, it determines if the water is cold enough to meet the downstream temperature requirement. If the highest shutter is too warm, it looks to use the next shutter elevation. If the release temperature is between the water temperatures available at two shutter elevations, the HEC5Q model will utilize both shutters and blend the flow between them to obtain the desired temperature. When the HEC5Q model reaches the lowest shutter, it accepts that temperature as the only available outlet temperature regardless of the target temperature.

This blend order results in the shutters moving out-of-sequence with real-world operations to obtain unrealistically good temperature performance. Whereas in normal real-world operations an operator would typically not move back upward in the shutter sequence once moving downward, the model may do so to save cool water. Additionally, the HEC5Q model may move shutters earlier than the operator if a short duration increase in temperature is experienced. Because of these discrepancies, it was sought to bring the model more closely into agreement with actual operations to better estimate temperature performance.

Several methods were evaluated for enforcing the shutter movement in collaboration with Reclamation operators, with the preferred logic of a three-day shutter lock implemented within the model engine. The most straightforward and realistic approach would be to constrain the model to only move downward until a given date or reservoir elevation, at which point the model would be allowed to move upward. However, this was determined not to be possible as the internal logic of the HEC5Q model uses a Julian date scheme from the model start date. To be robust to the model being initialized at various dates, it is it not possible to utilize the Julian date in the logic as the same Julian dates may correspond to varying calendar dates. The shutter lock approach introduced a counter into the HEC5Q logic to count the days from the last shutter change. If within the specified target duration, the model is required to maintain the same shutter configuration regardless of the pool stratification. If the duration is exceeded, the model may choose to retain the same shutters configuration or move to another shutter configuration if the pool stratification has changed.

The shutter lock approach has the advantage of introducing the target shutter lock duration as a parameter that can be adjusted. In consultation with Shasta operators reviewing output from the HEC5Q model, a three-day shutter lock duration was selected for the model based on multiple considerations. The foremost is that, while an upward movement in shutters is not typically utilized in real-world operations, there is no conceptual limitation against an upward shutter movement were the operators to think it beneficial for temperature management. There is however, a soft limitation of approximately three days for the operators to issue the order, for the shutters to be moved to the new configuration, and to recognize the effect of the change downstream. Additionally, despite there being some physically realistic shutter motion, the temperatures from the three-day lock were thought to be most representative of the anticipated downstream temperatures.

The three-day shutter lock is currently only applied to the Shasta version of the HEC5Q model.

F.1-3.3.1.3 Converged Temperature Operations

Previous implementations of the Sacramento and American HEC5Q models included some limited manual iteration between the performance of the downstream river compliance temperatures and the release temperatures at the dam, the latter of which is controlled as an input into HEC5Q model. If the temperatures at the compliance point were below the target temperature, the dam release temperature would be increased to save cold water pool (CWP); if the temperatures at the compliant point were above the target temperature, the dam release temperature would be decreased if CWP were available to bring the system into compliance. The intent of the model iteration was to utilize the CWP most effectively. While the manual process was effective, the procedure relied on skill of the user and was challenging to generalize across temperature operation logics.

The iteration between downstream and dam release temperatures was automated within the 2021 LTO through a procedure known as converged temperature operations. This formalized the manual iteration procedure by wrapping the HEC5Q modeling engine in Python to control the dam release temperature. While the HEC5Q model is Fortran based, a Python wrapper was utilized to strongly separate the temperature target logic from the hydrodynamics. Additionally, use of Python allowed for code optimizations to accelerate model solutions when considering complex temperature logics that could account for the DSS output format not being thread safe.

While the numeric implementation of the converged temperature logic is specific to each temperature target formulation, the implementations have a broadly similar scheme. The Python wrapper begins by taking the desired compliance temperature as the dam release temperature. To accelerate convergence and to improve temperature performance, the initial compliance temperature timeseries is reduced by 5°F. This forces the model to converge toward the compliance temperature timeseries from a cold bias rather than a warm bias, which generally reduced the number of model evaluations required. With each HEC5Q evaluation, the compliance timeseries was calculated with a rolling three-day average to mimic real-time operations. The amount the previous three-day average was above or below the compliance temperature at the compliance location was then added to the dam release timeseries. The release temperature adjustment was repeated until the compliance temperatures converged to the specified tolerance.

Convergence is done calendar year by calendar year with exception for the first and last years that adjust for the period of record start and end dates. The release targets from each year are combined into a single timeseries for the period of record, and the full period of record is simulated twice. Temperature convergence is done year by year to reduce the total compute time. The CWP of the next year is initialized with the ending CWP of the previous year. Because application of the CWP initial condition has some numerical error, the two full period of record runs are done to remove any numerical artifacts in the temperature output or the specified temperature target. Full convergence of the period of record is not done to minimize computational requirements and is not required as the temperature target is largely stable and the blend differences between the annual and period of record runs are generally small.

The tolerance was determined to balance temperature performance with the movement of the shutters. As the temperature tolerance is decreased, the model becomes more aggressive in determining both the shutter position and blend of water through them. This can lead to the HEC5Q model unrealistically both moving the shutters very frequently and blending to the exact value of the compliance temperature timeseries, neither of which is achievable in real operations. However, at high tolerances, the model is not sufficiently aggressive in utilizing the CWP which can adversely affect temperature compliance and would also not mimic real operations. A tolerance must therefore be selected that balances being sufficiently aggressive in utilizing the CWP with not being overly aggressive in the shutter movement and blending. This can be further complicated by the tolerance performance varying by water year.

Utilizing the Shasta HEC5Q model with the three-day shutter lock, the modeling team selected a convergence tolerance of 0.1% in consultation with the operators to balance the shutter motion and blending with the use of the CWP. The 0.1% tolerance was then applied to the American model as well. Upon inspection, the 0.1% tolerance balanced use of the CWP with minimizing shutter motions across the majority of the period of record. While there were outlier years where the shutter motion in the models was too frequent, the temperature performance in those years was thought to be more representative of operations as compared to larger tolerances. Additionally, the 0.1% tolerance fully utilized the CWP in most years with at most a residual fraction remaining, the exact volume differing based on the temperature logic and hydrology. The operators thought this residual CWP correctly reflected operations as some limited CWP volume is retained to be dispatched in the late season were unexpected heating to occur.

F.1-3.3.2 Conversion of American/Stanislaus Models to CalSim 3

The HEC5Q temperature models were converted from using CalSim II outputs to CalSim 3 outputs as part of the 2021 LTO. Conversion of the CalSim outputs rather than the HEC5Q inputs facilitated use of the existing HEC5Q model without modification. Development of the

Sacramento River conversion was not required as this was previously completed by Jacobs Engineering.

The American basin model uses a vscript that extracts the required data set from the CalSim 3 output and renames the data set with the equivalent CalSim II parameter names. In the CalSim 3 model there is a closure term, CT_FAIROAKS, that does not exist in the CalSim II model. A term, D0, was added to the AR_CS.dat file and was mapped to the closure term CT_FAIROAKS. The DSS file created is then used in the updated preprocessor. The mapping between CalSim II and CalSim 3 variables is given in Table F.1-3-1.

Table F.1-3-1. American River parameter name mapping from CalSim II to CalSim 3

CalSim II Parameter Name	**CalSim 3 Parameter Name/Formula**
I8	I_FOLSM
I300	I_NFA022
S8	S_FOLSM
S9	S_NTOMA
D8	D_FOLSM_26S_PU3 + D_FOLSM_26S_NU4 + D_FOLSM_WTPRSV + D_FOLSM_WTPSJP + D_FOLSM_WTPFOL + D_FOLSM_WTPEDH + D_FOLSM_EDCOCA + D_FOLSM_24_NU2_CVP + D_FOLSM_24_NA3_CVP
E8	E_FOLSOM
D9	D_NTOMA_FSC003 + SG375_NTOMA_66
E9	E_NTOMA
C300	S_SFA011 + C_NFA011
C8	C_FOLSM
F8	F_FOLSM
D302	D_AMR007_WTPFBN + D_AMR017_WTPBJM
GS66	SG374_FOLSM_66
I9	SR_26N_NTOMA + SR_26S_NTOMA
I302	SR_26S_AMR007 + SR_26N_AMR004
C301	C_AMR020
D0	CT_FAIROAKS

The Stanislaus basin model uses an updated StanR_CS.dat file in which the CalSim II parameter names were replaced with equivalent CalSim 3 parameter names. In the CalSim II model there is a spill term, F10, that does not exist in the CalSim 3 model. The term F10 was removed from the StanR_CS.dat file. In the CalSim 3 model there is a closure term, CT_MELON, that does not exist in the CalSim II model. This term was added to the StanR_CS.dat file. The updated preprocessor uses the updated StanR_CS.dat file. The mapping between CalSim II and CalSim 3 variables is given in Table F.1-3-2.

Table F.1-3-2. Stanislaus parameter name mapping from CalSim II to CalSim 3

CalSim II Parameter Name	CalSim 3 Parameter Name/Formula
I10	C_STS072
I76	I_TULOC
I520	I_STS059
S10	S_MELON
S76	S_TULOC
E10	E_MELON
E76	E_TULOC
C10	C_MELON
C76	C_TULOC
C520	C_STS059
C528	C_STS004
C545	C_TUO003
C620	C_SJR082
C644	C_SJR056

F.1-3.3.3 Temperature Target Logics and Schedules

Temperature logics exist independently from operations logic and may be applied to any CalSim scenario. The temperature target logic determines how the limited cold-water pool (CWP) is allocated through the temperature management season, with colder temperatures using the CWP more aggressively than warmer temperatures. CWP is defined as Shasta storage less than 52°F. By changing the compliance locations and compliance temperatures based on variables such as the CWP volume, year type, or bin types, a temperature target logic seeks to minimize river temperatures across different hydrology and meteorology conditions. It is important to recognize that within the same CalSim operations scenario, temperature performance can vary greatly based on the utilized temperature target logic. Table F.1-3-4 provides a summary of each temperature logic.

The Shasta 2019 Temperature Tiers (2019 tiers) temperature logic was developed as part of the 2019 BiOps. There is a 60°F temperature target for the shoulder period of January 1st through May 15th. The strategy consists of four temperature tiers based on Shasta CWP. Tiers 2 and 3 have sub tiers that are selected based on the coolest temperatures that can be maintained with the CWP. Tier 1 is selected when Shasta cold water pool is greater than 3,800 TAF. This tier transition is shifted from the 2019 BiOps based on operator feedback. Tier 2 is selected when Shasta cold water pool is greater than 2,800 TAF and less than or equal to 3,800 TAF. Tier 2 has two sub tiers. Tier 3 is selected when Shasta cold water pool is greater than 2,500 TAF and less than or equal to 2,800 TAF. Tier 3 has three sub tiers. Tier 4 is selected when Shasta cold water pool is less than or equal to 2,500 TAF. The tier structure and temperature targets for the 2019 Tiers is shown in Table F.1-3-3.

Table F.1-3-3. 2019 Tiers structure description

Tier	**CWP Description**	**Temperature Targets**
Tier 1	greater than 3,800 TAF	53.5°F May 16th–December 31st
Tier 2.1	greater than 2,800 TAF and less than or equal to 3,800 TAF	56°F May 16th–May 31st 53.5°F June 1st–December 31st
Tier 2.2	greater than 2,800 TAF and less than or equal to 3,800 TAF	56°F May 16th–June 15th 53.5°F June 16th–December 31st
Tier 3.1	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16th–June 15th 54°F June 16th–December 31st
Tier 3.2	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16th–June 15th 54.5°F June 16th–December 31st
Tier 3.3	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16th–June 15th 55°F June 16th–December 31st
Tier 4	less than or equal to 2,500 TAF	56°F May 16th–December 31st

The Mixed Compliance Location (mixed) temperature logic has a 60°F temperature target for the shoulder period of January 1st through May 15th. The strategy consists of a constant 53.5°F temperature target and adjusts the compliance location based on the Shasta bin type. For a Shasta bin type of 1, the compliance location is Airport Road. For a Shasta bin type of 2, the compliance location is Clear Creek. For a Shasta bin type of 3, the compliance location is Hwy 44.

The Water Year Type Target (NGO) temperature logic has a 61°F temperature target for the shoulder period of January 1st through May 15th. The strategy consists of a 53.5°F temperature target at Clear Creek unless the water year type is critically dry. When the water year type is critically dry, the temperature target is relaxed to 54.5°F. In addition to the temperature target at Clear Creek, the 7-day average of daily maximum temperatures must be less than 61°F for the days of May 1st to May 15th.

The Carryover Based Target (carryover) temperature logic has a 60°F temperature target for the shoulder period of December 1st through May 15th. The strategy consists of a first tier with a 53.5°F temperature target at Clear Creek while preserving a project end of September CWP of 400 TAF. If the projected end of September CWP is less than 400 TAF while using the first tier, the model will shift into the second tier which will relax the temperature target to 56°F for May 16th through June 15th. If the projected end of September cold water pool is less than 400 TAF while using the second tier, the model will shift into the third tier which will relax the temperature target to 54°F for June 16th through November 30th. If the projected end of September cold water pool is less than 400 TAF while using the third tier, the model will shift into the fourth tier which will reduce the end of September cold water pool target to 200 TAF. If the projected end of September cold water pool is less than 200 TAF while using the fourth tier, the model will shift into the fifth tier which will relax the temperature target to 56°F for October 1st to November 30th. If the projected end of September cold water pool is less than 200 TAF, the model will relax the temperature target from 54°F to 56°F in monthly steps until the temperature target is 56°F for May 16th through November 30th. If the storage target is still not met, the model accepts the performance at the 56°F temperature target.

The Shasta 2021 Temperature tiers (2021 tiers) were developed as a revision to the 2019 temperature tiers. The revision was informed by corporate lessons learned through Shasta temperature tier optimization and were done to balance complexity with operational feasibility. There is a 60°F temperature target for the shoulder period of January 1st through May 15th. The strategy consists of three temperature tiers based on Shasta CWP. The first tier is selected when Shasta CWP is greater than 3.0 MAF. The temperature target for the first tier is 53.5°F. The second tier is selected when Shasta CWP is between 1.5 MAF and 3.0 MAF. The temperature target for the second tier is 54°F. The third tier is selected is selected when Shasta CWP is less than 1.5 MAF. The temperature target for the third tier is 56°F.

Table F.1-3-4. Temperature logic used within HEC5Q for the alternatives

Target Logic Name	Target Logic Description
Shasta 2019 Temperature Tiers (2019 tiers)	• Clear Creek compliance location • Primary tier selected based on Shasta cold water pool • Includes 53.5°F, 54°F, 54.5°F, 55°F, and 56°F periods depending on tier and time • 60°F shoulder Jan 1st-May 15th

Mixed Compliance Location (mixed)	• Changing compliance location based on Shasta bin type
	  • Type 1 –Airport Road
	  • Type 2 –Clear Creek
	  • Type 3 –Hwy 44
	• Temperature target of 53.5°F
	• 60°F shoulder Jan 1st-May 15th

Water Year Type Target (NGO)	• Clear Creek compliance location
	• Temperature target of 53.5°F unless critically dry
	  • 54.5°F temperature target when critically dry
	• 61°F shoulder from Jan 1st–May 15th
	• Additional target at Jelly's Ferry March 1st–May 15th
	  • 7-day average of daily maximum temperatures less than 61°F

Carryover Based Target (carryover)	• Clear Creek compliance location
	• Targets end of September cold water pool volume
	  • 400,000 AF after unless 54°F cannot be maintained at Clear Creek
	  • Reduce to 200,000 AF, targeting coldest temperatures that meet storage targets
	  • Increases temperatures from 54°F to 56°F in monthly steps
	• 60°F shoulder Dec 1st–May 15th

Shasta 2021 Temperature Tiers (2021 tiers)	• April cold water pool volume determines target
	  • Less than 1.5 MAF: 56°F
	  • Between 1.5 MAF and 3.0 MAF: 54°F
	  • Greater than 3 MAF: 53.5°F
	• 60°F shoulder Jan 1st–May/June 15th

F.1-3.3.4 Meteorologic Data Extension

The meteorologic inputs for the HEC5Q temperature models were extended as part of the 2021 LTO. The initial period of record for the HEC5Q basin models was 1921 through 2015, having been extended beyond the CalSim II period of record as part of the DWR Delivery Capability Report (DCR) effort. The Stanislaus was not included in the DCR effort and therefore had an initial period through 2010. The period of record for all models was extended through the end of calendar year 2022 to provide full coverage for the CalSim 3 period of records.

The HEC5Q basin models utilize input meteorology at the Gerber, Nicolaus, and Modesto California Irrigation Management Information System (CIMIS) stations. Four properties are calculated from each station – solar radiation, equilibrium temperature, the heat transfer coefficient, and wind – as hourly timeseries. These are then converted into a DSS file and included in the CalSimII_HEC5Q.DSS input file. Because CIMIS information does not provide coverage back to 1921, the period CIMIS data has been augmented based on water year types to backfill for the full CalSim period. In addition, the HEC5Q model had been calibrated by manually adjusting the CIMIS data Resource Management Associates 2003).

Initial review of the CIMIS station output indicated significant discrepancies between the CIMIS station information and the HEC5Q meteorologic data over the period which the Gerber, Nicolaus, and Modesto stations provided coverage. Solar radiation, the primary variable used to calculate equilibrium temperature and the heat transfer coefficient, and the wind speeds were markedly different in both trend and magnitude between the CIMIS values and the existing HEC5Q meteorology. This triggered a Reclamation review of the scripting used to previously generate HEC5Q temperature inputs and subsequent revision to the workflow used by Resource Management Associates (RMA) to develop HEC5Q meteorologic inputs.

A primary finding of the Reclamation review was that total solar radiation as measured at the CIMIS station was not being utilized in favor of top of atmosphere short wave radiation. The RMA workflow applied a correction factor to account for latitude and seasonal tilt of the earth with an additional ad hoc adjustment factor to increase the short-wave radiation magnitude to account for long wave radiation forcing. These geometric correction factors were not correct in the RMA analysis; when Reclamation adjusted the factors, the radiative forcing differed significantly from that previously utilized. Furthermore, the RMA solar radiation logic applied several reduction factors that could not be replicated. These reduction factors should have lowered top of atmosphere short wave radiation forcing from 1800 W/m^2 to approximately 250 W/m^2 on the surface; however, total radiative forcing on the surface remained approximately 1800 W/m^2 after the reduction factors. The discrepancy in short wave radiation carried through to alter the equilibrium temperature and heat transfer coefficient calculations as well. Wind speed was also lower at the CIMIS stations than what was reported in the existing HEC5Q meteorology by approximately 50% peak magnitudes.

The differences between the CIMIS station information and the existing HEC5Q meteorology were significant enough to warrant additional consideration during the present extension. While some of the differences can be explained by adjustments during previous calibration, the difference due to geometric factors and wind speed could not be satisfactorily resolved. However, given the previous calibration of the model, significant deviation from the previous approach were not desirable as it may reduce the accuracy of the HEC5Q model estimates.

To balance these concerns, a hybrid approach was utilized. Revised geometric correction factors were applied to the top of atmosphere solar radiation estimates and the reduction factors were eliminated. The resulting solar radiation, equilibrium temperatures, and heat transfer coefficients were bias corrected from their revised values to agree in magnitude with the previous existing HEC5Q meteorology. For the Gerber and Nicolaus locations, manual bias correction was done using the DCR period as a reference period to adjust the magnitudes for the more recent period. For the Modesto station that lacked the DCR reference period, manual bias correction was done such that the period before 2010 and after 2010 did not have significant seasonal magnitude discontinuities. In addition to the manual bias correction, an automated linear bias correction was applied between the existing and revised station values to remove any residual bias. Given the variability of the data, the affect of the linear bias correction was small and motivation for the initial manual bias correction. The effectiveness of the bias correction was determined qualitatively by reviewing the timeseries for each station.

Wind speed was retained as the values reported by the CIMIS station as no clear pattern in values was evident to perform a bias correction or physical process that would otherwise justify an adjustment.

To create a full period of record for the Gerber and Nicolaus stations, several stations needed to be combined as the HEC5Q reference CIMIS stations have varying period of records. The bias correction for the methodology revisions had the additional benefit of compensating for differences in the model locations. The Gerber station was combined with the Gerber South station to provide full coverage. The Nicolaus station was combined initially with the Woodland station and then with the Verona station when the latter came online. Stations for transposition were selected based on proximity to the reference station and topographic similarity. The Modesto station was active over the full period and did not require any combination. Across the considered stations, a data cleanup process was utilized to remove unrealistic values, interpolate for small gaps, and backfill from adjacent stations. The procedure is documented within Python scripts that allow for a repeatable, transparent process for creating HEC5Q meteorologic inputs.

The extended meteorologic timeseries were applied within test model scenarios to verify that no temperature discontinuities existed between the previously existing inputs and the extended meteorologic period.

F.1-3.4 Modeling of EXP1

Modeling of the EXP1 scenario within the HEC5Q basin models presents a numerical challenge. The scenario is characterized by very low storages, often going beyond dead pool to actual zero total storage within the CalSim 3 simulations. These very low storages utilize the HEC5Q basin models outside of their intended range of inputs, leading to numerical issues that are challenging to resolve. These issues are present in each of the Sacramento, American, and Stanislaus model domains and were isolated to the model output after the preprocessor was completed.

When the EXP1 CalSim 3 outputs are utilized in the temperature workflow, the primary resulting issue is that the storages in the models no longer agree with the CalSim 3 values, deviating by hundreds of thousands of acre-feet over the full period of record. Because the storages are not accurate, the primary affect will be reservoir temperatures not being calculated correctly with additional secondary affects throughout the model, such as the release temperatures. This issue is believed to be a result of how the numerics are implemented within the HEC5Q model engine. When the storages fall below the values expected by the HEC5Q model engine, because the Fortran language is not memory safe, the model engine is able to access random values in memory. This replaces correct values with random, garbage values that may propagate in unexpected and unknown ways throughout the rest of the model. While it is possible to adjust reservoir storages with a compensating timeseries, this may further alter the internal model numerics or otherwise skew temperature estimates.

The only definitive method to fully resolve the HEC5Q numerical issues under the EXP1 operations logic would be to rearchitect the HEC5Q model engine itself to correct the problematic algorithms. Such an undertaking is not within the scope of the 2021 LTO and would require full revalidation/recalibration of the HEC5Q basin models. It was therefore decided to utilize an approach to minimize the numerical issues within the current HEC5Q model engine.

The errors present in the HEC5Q basin models were cumulative over the period of record, beginning small at the start of the record and growing over time. To minimize the accumulation of error in the model, the full period of record simulations were discarded in favor of the single year analyses that were combined together to form the period of record. Use of the single year simulations resulting from the converged temperature operations minimized the accumulation of numerical error within the models. When a HEC5Q model is initialized, it reads the initial condition from the CalSimII_HEC5Q.DSS file which is accurate. The model then simulates for the year from that accurate initial condition, accumulating some amount of error through the end of the simulation. When the simulation window completes, the model state is updated from the CalSimII_HEC5Q.DSS file, eliminating the accumulation of error from the previous period. While the pool stratification is transferred between years, because the transition between simulation windows is done in the winter, the pool generally becomes isothermal which minimizes any accumulated error in the reservoir temperature profile. The year-by-year analysis has error accumulate within each annual simulation window, but effectively resets the error when each simulation window begins.

The single year approach is intended to recognize the numerical limitations of the HEC5Q model engine while not compounding the numerical errors with compensations that would not fully resolve the numerical issues. It should be recognized that any approach for simulating the EXP1 logic with the exiting HEC5Q model engine introduces significant uncertainty into the temperature estimates.

F.1-3.5 Temperature Dependent Mortality (TDM) Updates

To convert temperature performance into biologic outcomes, the Martin and Anderson temperature dependent egg mortality (TDM) models for the Sacramento River had previously been codified within a Python script that was callable from the HEC5Q Python wrapper (Anderson 2018; Martin et al. 2017). This code was utilized within the 2021 LTO to estimate TDM under varying operations scenarios.

While both the Anderson and Martin models were utilized, the Martin model was of primary focus as it is the preferred model by Reclamation interested parties. TDM outcomes in the Martin are highly sensitive to the parameterization used in the model. Table F.1-3-5 provides the assumed values which were selected in consultation with Reclamation fish biologists. These parameters were utilized across all operations and temperature logics to allow relative performance of the scenarios to be ascertained.

The TDM models require a spatial distribution of redds in river to estimate temperature affects. Given that this an unknown and redd placement can vary significantly even within similar water years, a conservative approach was taken to estimate the affect of the spatial distribution. Twenty-one years of redd distributions from 2001 through 2021 were applied for each simulated temperature season, and the 80th percentile ordered low to high from the spatial distributions was reported as the mortality for that season. The 80th percentile utilizes values that are larger than the median TDM and is likely to over estimate TDM in most years. Higher TDM percentiles were not utilized as these can be constrained by more unrealistic scenarios, such as redds very far downstream in critical dry years when there is some tendency for redds to be located closer to Keswick Dam.

Table F.1-3-5. Coefficients used in the Martin and Anderson TDM models, where the *m* and *a* subscripts indicate the Martin and Anderson values, respectively

Parameter	**Value**
ATU_a	487°C-Days
ATU_b	958°C-Days
$b_{T,a}$	1.17 (°C-Days)$^{-1}$
$b_{T,m}$	0.026 (°C-Days)$^{-1}$
$T_{crit,a}$	12.056°C
$T_{crit,m}$	12.056°C
$Critial\ Days_a$	3 days

F.1-3.6 USRDOM Updates

The Upper Sacramento River Daily Operations Model (USRDOM) simulates daily flows and related operations from Water Years (WYs) 1921 through 2021 based on CalSim outputs and/or historic information. The model includes the streams and facilities in the upper portion of the Sacramento River from Shasta Reservoir to Knights Landing and the Trinity River portion of the Central Valley Project (CVP).

USRDOM was originally developed in 2010 to support the Bureau of Reclamation (Reclamation) and California Department of Water Resource (DWR) in evaluating hydrologic, regulatory, and operational conditions on a daily timestep. It included the capability to downscale CalSim II operations from monthly to daily timesteps over the 82-year planning period (WY 1921-2003).

In 2022, USRDOM was updated to be compatible with the CalSim 3 models developed for the 2021 LTO. This update included accounting for the increased number of CalSim 3 outputs (tributary contributions, return flows, stream and groundwater interactions, and closure terms) and extending the period of record to WY 2021.

Updates that have been implemented to USRDOM to be compatible with CalSim 3 and used for 2021 LTO modeling are described in the following sections.

F.1-3.6.1 Historical Data Extension

A historical dataset was assembled to aid in developing the hydrology for the upper Sacramento River and in verifying the operations and routing capabilities of USRDOM. The dataset contains daily average Sacramento River flows and its tributary inflows where gaged.

Table F.1-3-6 includes the eleven tributaries that are modeled specifically along the Upper Sacramento River. The datasets for the first six tributaries listed in this table were extended through WY 2021. Gaged data is unavailable for the following five tributaries in recent years. Synthesized flow was developed for missing gaged records using the methodology described in Section 2.4 of the USRDOM Development, Calibration, and Application document (CH2M 2011).

Table F.1-3-6. Gaged and Synthesized Tributary Flows in USRDOM.

Location	Agency/ID	Parameter	Timestep	Period Available
Deer Creek near Vina	USGS/11383500	Flow	Daily	10/01/1911–09/30/2021
Mill Creek near Los Molinos	USGS/11381500	Flow	Daily	10/01/1928–09/30/2021
Battle Creek near Cottonwood	USGS/11376550	Flow	Daily	10/01/1940–09/30/2021
Elder Creek near Paskenta	USGS/11379500	Flow	Daily	10/01/1948–09/30/2021
Cottonwood Creek near Cottonwood	USGS/11376000	Flow	Daily	10/01/1940–09/30/2021
Cow Creek near Millville	USGS/11374000	Flow	Daily	10/01/1949–09/30/2021
Antelope Creek	USGS/11379000	Flow	Daily	10/01/1940–09/29/1982
Big Chico Creek	USGS/11384000	Flow	Daily	10/01/1930–09/29/1986
Paynes Creek	USGS/11377500	Flow	Daily	10/01/1949–10/31/1966
Red Bank	USGS/11378860	Flow	Daily	10/01/1959–09/29/1967
Thomes Creek	USGS/11382000	Flow	Daily	10/01/1920–09/30/1969

F.1-3.6.2 USRDOM Inputs using CAL2DOM

CAL2DOM is the utility that translates data from CalSim to USRDOM, including conversions from monthly to daily operations and the disaggregation and consolidation of flow data. More information on CAL2DOM is provided in Section 5.2 of the USRDOM Development, Calibration, and Application document (CH2M 2011).

CAL2DOM has been updated to be compatible with inputs and outputs from CalSim 3. The inputs included in the updated model are included in Table F.1-3-7.

Table F.1-3-7. USRDOM Inputs Based on CalSim 3 Data Using CAL2DOM.

Input Type	USRDOM Inputs	USRDOM ID
Minimum Reservoir Releases	Trinity Reservoir	MR340
	Whiskeytown Reservoir	QD214
	Shasta Reservoir	MR220
Minimum In-stream Flows	Trinity River flow downstream of Lewiston	QD244
	Sacramento River downstream of Red Bluff Diversion Dam	MR175
	Sacramento River downstream of GCC diversion	MR150
	Sacramento River downstream of Wilkins Slough	MR110
	Sacramento River downstream of Knights Landing	MR105
Diversions	ACID and other lumped upper segment diversions	QD197
	Tehama-Colusa Canal and Corning Canal diversions	QD175
	Lumped diversions in middle segment (Elder Creek, Thomes Creek, Antelope Creek, Mill Creek, Deer Creek)	QD155
	Stony Creek Diversions	QD1135
	Stony Creek - TCC Intertie Flow	QD1134
	Glenn-Colusa Canal diversion	QD150
	Sac R diversions between Butte City and Colusa Weir	QD135
	Sac R diversions between Colusa Weir to Tisdale Weir	QD117
	Sac R diversions to Tisdale and Wilkins Slough Pumping Plants	QD110
Closure Terms	Upper Reach Distributed Accretions and Closure Adjustment	IN182
	Middle Reach Distributed Accretions and Closure Adjustment	IN142
	Lower Reach Distributed Accretions and Closure Adjustment	IN110
Evaporation Rate	Trinity Reservoir	EV340
	Whiskeytown Reservoir	EV240
	Shasta Reservoir	EV220
	Black Butte Reservoir	EV1136
Reservoir Outflow	Black Butte Reservoir	QA1136
Reservoir Inflow	Black Butte Reservoir	IN1136

F.1-3.6.3 CAL2DOM Operational Controls

CAL2DOM identifies the operational controls for the storage release requirements for Trinity and Shasta Reservoir in CalSim 3 for each month. It uses these controls to determine the minimum in-stream flow requirements and minimum reservoir release requirements in USRDOM. Table F.1-3-8 shows the list of operational controls computed in CAL2DOM. CalSim 3 operational (simulated) and control variables (requirements) are listed in separate columns.

Table F.1-3-8. CalSim 3 Operational Controls in CAL2DOM.

Description	**CAL2DOM Ops Controls (Result)**	**CALSIM 3**		**Method used to determine the control**
		Control	**Operation**	
Trinity River Minimum Flow	C_LWSTN_CTRL	C_LWSTN_MIF	C_LWSTN	C_LWSTN _CTRL is 1 if C_LWSTN = C_LWSTN _MIF, otherwise is 0
Clear Creek Minimum Flow	C_WKYTN_CTRL	C_WKYTN_MIF	C_WKYTN	C_WKYTN_CTRL is 1 if C_WKYTN = C_WKYTN_MIF, otherwise 0
Sacramento River at Keswick Reservoir Minimum Flow	C_KSWCK_CTRL	C_KSWCK_MIF	C_KSWCK	C_KSWCK_CTRL is 1 if C_KSWCK = C_KSWCK_MIF, otherwise 0
Red Bluff Diversion Dam Bypass Flow	C_SAC240_CTRL	C_SAC240_MIF	C_SAC240	C_SAC240_CTRL is 1 if C_SAC240 = C_SAC240_MIF, otherwise 0
Glenn-Colusa Canal Diversion Bypass Flow	C_SAC201_CTRL	C_SAC201_MIF	C_SAC201	C_SAC201_CTRL is 1 if C_SAC201 = C_SAC201_MIF, otherwise 0
Sacramento River at Wilkins Slough (NCP) Flow Objective	C_SAC120_CTRL	C_SAC120_MIF	C_SAC120	C_SAC120_CTRL is 1 if C_SAC120 = C_SAC120_MIF, otherwise 0
Sacramento River at Rio Vista Minimum Flow	C_SAC017_CTRL	C_SAC017_MIF	C_SAC017	C_SAC017_CTRL is 1 if C_SAC017 = C_SAC017_MIF, otherwise 0
Delta Inflow needed for Delta Export for ANN compliance	C_SAC041_ANN_CTRL	C_SAC041_MIF	C_SAC041_ANN	C_SAC041_ANN_CTRL is 1 if C_SAC041_ANN= C_SAC041_ANN_MIF, otherwise is 0

Description	CAL2DOM Ops Controls (Result)	CALSIM 3		Method used to determine the control
		Control	Operation	
Delta Outflow needed to comply with Jersey Point salinity standards	JP_CTRL	JP_MRDO	NDOI_ADD, NDOI_MIN	JP_CTRL is 1 if JP_MRDO >= NDOI_ADD + NDOI_MIN, otherwise is 0
Delta Outflow needed to comply with Emmaton salinity standards	EM_CTRL	EM_MRDO	NDOI_ADD, NDOI_MIN	EM_CTRL is 1 if EM_MRDO >= NDOI_ADD + NDOI_MIN, otherwise is 0
Delta Outflow needed to comply with Rock Slough salinity standards	RS_CTRL_1	RS_MRDO_1	NDOI_ADD, NDOI_MIN	RS_CTRL_1 is 1 if RS_MRDO_1 >= NDOI_ADD + NDOI_MIN, otherwise is 0
Delta Outflow needed to comply with Rock Slough salinity standards	RS_CTRL_2	RS_MRDO_2	NDOI_ADD, NDOI_MIN	RS_CTRL_2 is 1 if RS_MRDO_2 >= NDOI_ADD + NDOI_MIN, otherwise is 0
Delta Outflow needed to comply with Rock Slough salinity standards	RS_CTRL_3	RS_MRDO_3	NDOI_ADD, NDOI_MIN	RS_CTRL_3 is 1 if RS_MRDO_3 >= NDOI_ADD + NDOI_MIN, otherwise is 0
Delta Outflow needed to comply with Collinsville salinity standards	CO_CTRL	CO_MRDO	NDOI_ADD, NDOI_MIN	CO_CTRL is 1 if CO_MRDO >= NDOI_ADD + NDOI_MIN, otherwise is 0
Sacramento and San Joaquin River Delta Outflow	NDOI_ADD _CTRL	0	NDOI_ADD	C407_CTRL is 1 if NDOI_ADD = 0., otherwise is 0
Delta Inflow needed to maintain Delta Export/Inflow Ratio	EI_CTRL	EIExpCtrl	C_DMC003, C_CAA003	EI_CTRL is 1 if EIExpCtrl <= C_DMC003 + C_CAA003, otherwise is 0
Status of COA Sharing (UWFE or IBU conditions)	IBU_TRUE	0	UWFE_TRUE	IBU_TRUE is 1 if UWFE_TRUE = 0., otherwise is 0

Description	CAL2DOM Ops Controls (Result)	CALSIM 3		Method used to determine the control
		Control	Operation	
Shasta Reservoir is in Flood Control	S_SHSTA_FLD_CTRL	S_SHSTALEVEL5	S_SHSTA	S4_FLD_CTRL is 1 if S_SHSTALEVEL5 <= S_SHSTA, otherwise is 0
Cumulative Sacramento River Control	SACR_CTRL	C_KSWCK_CTRL, C_SAC240_CTRL, C_SAC201_CTRL, C_ SAC120_CTRL	N/A	Take the maximum of all CTRL values
Cumulative Sacramento/San Joaquin Delta Control	DELTA_CTRL	C_SAC041_ANN_CTRL, JP_CTRL, EM_CTRL, RS_CTRL_1, RS_CTRL_2, RS_CTRL_3, CO_CTRL, NDOI_ADD_CTRL, EI_CTRL	N/A	Take the maximum of all CTRL values
Set Trinity Reservoir Release Trigger	TRIN_TRUE	1, S_SHSTA_FLD_CTRL, JUNOCT_TRUE, SACR_CTRL	N/A	Maintain Trinity Reservoir releases if Shasta Reservoir is NOT in flood control (S_SHSTA_FLD_CTRL is subtracted from the value of 1) or if it is June through October or if Sacramento River controls are in effect
Set Shasta Reservoir Release Trigger (Option A)	SHASTA_TRUE	JUNOCT_TRUE, IBU_TRUE, DELTA_CTRL, SACR_CTRL	N/A	Maintain Shasta Reservoir releases if it is June through October, IBU conditions exist, and Sacramento/San Joaquin Delta controls or Sacramento River controls are in effect

Description	CAL2DOM Ops Controls (Result)	CALSIM 3		Method used to determine the control
		Control	Operation	
Set Shasta Reservoir Release Trigger (Option B)	SHASTA_TRUE	JUNOCT_TRUE, IBU_TRUE, DELTA_CTRL	N/A	Maintain Shasta Reservoir releases if it is June through October, IBU conditions exist, or Sacramento/San Joaquin Delta controls are in effect (Sacramento River controls are implemented as flow checks)

Notes:
ANN = artificial neural network
N/A = not applicable
NCP = navigation control point
UWFE = unstored water for export

F.1-3.6.4 CAL2DOM Minimum In-stream Flows

Table F.1-3-9 includes the CalSim 3 variables and the methodology used in CAL2DOM to compute various minimum in-stream flow requirements used in USRDOM. Minimum in-stream requirements in USRDOM are specified at four Sacramento River locations: Red Bluff Diversion Dam, GCC diversion, Wilkins Slough, and Knights Landing. The minimum in-stream flow requirement for Trinity River is specified as a diversion at the Lewiston Reservoir.

Table F.1-3-9. Computation of Minimum In-stream Flow Requirements in CAL2DOM.

USRDOM Inputs	USRDOM ID	CALSIM 3 Variables	CAL2DOM Translation
Trinity River flow downstream of Lewiston	QD244	N/A	Estimated based on the Trinity River Flow Evaluation Final Report (U.S. Fish and Wildlife Service and Hoopa Valley Tribe 1999) recommendation
Sacramento River downstream of Red Bluff Diversion Dam	MR175	C_SAC240_MIF	Converted to daily, ramped 2 days going up and saved the result as average weekly values
Sacramento River downstream of GCC diversion	MR150	C_SAC201_MIF	Converted to daily, ramped 3 days going up and saved the result as average weekly values

USRDOM Inputs	USRDOM ID	CALSIM 3 Variables	CAL2DOM Translation
Sacramento River downstream of Wilkins Slough	MR110	C_SAC120_MIF	Converted to daily, ramped 6 days going up and saved the result as average weekly values
Sacramento River downstream of Knights Landing	MR105	C_SAC093	If Shasta Reservoir release trigger, SHASTA_TRUE (described in Table F.1-3-8), is 1, then C134 value is used. Checked to make sure at least 3,000 cfs of flow exists, ramped 6 days going up and saved the result as average weekly values.

F.1-3.6.5 CAL2DOM Diversions

Table F.1-3-10 lists the diversions explicitly modeled in USRDOM, along with the CalSim 3 variables and the methodology used by CAL2DOM to compute them.

Table F.1-3-10. Diversions in CAL2DOM.

Description	USRDOM (Result)	CALSIM 3	Comment
ACID Diversion	QD197	D_SAC289_03_SA, D_SAC296_02_SA, D_SAC296_WTPFTH	Limited to a maximum of 315 cfs (used the remainder, D_ACID_REM for estimating upper segment closure term, IN182). Converted to daily and smoothed over 9-day period without conserving the monthly volume and saved as average weekly values
Red Bluff Diversion Dam Diversion (Tehama-Colusa and Corning Canals)	QD175	D_SAC240_TCC001	Converted monthly to daily and smoothed over 21 days while conserving monthly volume and saved as average weekly values
Middle Reach Miscellaneous Diversions	QD155	D_ELD012_04_NA, D_THM012_04_NA, D_SAC224_04_NA, D_ANT010_05_NA, D_MLC006_05_NA, D_DRC010_05_NA, D_DRC005_05_NA, D_SAC240_05_NA	Converting the sum of the monthly CALSIM 3 diversions to daily, smoothed over 21 days while conserving monthly volume and saved as average weekly values
Stony Creek WBA6 Diversions	QD1135	D_STN026, D_STN021, D_STN004_GCC007, SG263_STN026_49, SG264_STN021_49,	Summing of the monthly CALSIM 3 diversions and subtracting the return flows and stream gains from groundwater terms. Converting the result from monthly to daily, smoothed over 21 days while

Description	USRDOM (Result)	CALSIM 3	Comment
		SG265_STN014_49, SG266_STN009_49, SG267_STN004_49, SG268_STN004_49, R_06_PA_STN009	conserving monthly volume and saved a as average weekly values
Stony Creek - TCC Intertie Flow	QD1134	D_STN014_TCC031	Converting monthly to daily values and smoothed over 9 days without conserving monthly volume
Middle Segment Diversions Butte City to Colusa Weir)	QD135	D_SAC178_08N_SA1, D_SAC162_09_SA2, D_SAC159_08N_SA1, D_SAC159_08S_SA1, SG277_SAC178_51, SG278_SAC174_51, SG279_SAC168_51, SG280_SAC162_51, SG281_SAC154_51, SG282_SAC148_51, SG293_SAC148_53, SR_08N_SAC154	Summing five monthly CALSIM 3 diversions and subtracting them from return flows and stream gains grom groundwater terms. Converting the results from monthly to daily, smoothed over 21 days while conserving monthly volume and saved as average weekly values
Diversions to Tisdale and Wilkins Slough Pumping Plants	QD110	D_SAC122_19_SA, D_SAC121_08S_SA3	Converted the sum of two monthly CALSIM 3 diversions to daily, smoothed over 21 days while conserving monthly volume and saved as average weekly values

F.1-3.6.6 Closure Terms

CAL2DOM computes closure terms for three river segments in USRDOM: Upper Segment (downstream of Clear Creek inflow to Bend Bridge), Middle Segment (downstream of Bend Bridge to Butte City), and Lower Segments (downstream of Butte City to Wilkins Slough). In previous iterations of USRDOM, the closure terms for the projected conditions simulation were mainly comprised of ungagged tributary flows, accretions or gains, and depletions within the river segment. The latest USRDOM model relies on CalSim 3 closure terms to determine closure in the Upper segment, middle segment, and lower segment. Table F.1-3-11 includes the variables used and the methods used in computing the three closure terms.

Table F.1-3-11. Closure Terms in CAL2DOM.

Description	USRDOM (Result)	CALSIM 3	Methodology used to determine Closure Adjustments
Upper Reach Distributed Accretions	IN182	CT_BENDBRIDGE, R_03_PA_SAC287, R_CCWWTP_SAC287, R_02_NU_SAC281, R_03_SA_SAC281, R_SWWWTP_SAC281,	IN182 is distributed to USRDOM node 182; adjustments smoothed

Description	USRDOM (Result)	CALSIM 3	Methodology used to determine Closure Adjustments
and Closure Adjustment		SR_03_SAC277, R_02_SA_SAC273, R_02_PA_SAC273, SR_02_SAC271, R_03_NA_SAC269, SR_03_SAC265, SR_02_SAC257, R_04_NU1_SAC240, R_04_NU1_SAC240, SG206_SAC294_32, SG207_SAC289_32, SG208_SAC287_32, SG209_SAC281_32, SG210_SAC277_32, SG215_SAC277_34, SG216_SAC275_34, SG217_SAC269_34, SG222_SAC269_37, SG223_SAC265_37, SG224_SAC259_37, SG227_SAC259_39, SG228_SAC254_39, SG229_SAC250_39, SG230_SAC247_39, SG231_SAC240_39, D_SAC289_03_SA, D_SAC296_02_SA, D_SAC296_WTPFTH, D_SAC294_03_PA, D_SAC294_WTPBLV, D_SAC281_02_NA	over 21 days; conserving monthly volume
Middle Reach Distributed Accretions and Closure Adjustment	IN142	CT_BUTTE, R_04_NU2_SAC217, SR_04_SAC217, SR_05_SAC217, SR_05_SAC201, SG261_SAC207_48, SG260_SAC214_48, R_04_NA_SAC207, SR_04_SAC207, R_04_PA2_SAC207, SR_06_SAC185, SR_07N_SAC185, SR_08N_SAC185, SR_09_SAC185 SG276_SAC182_51	IN142 is distributed to USRDOM node 142; adjustments smoothed over 21 days; conserving monthly volume
Lower Reach Distributed Accretions and Closure Adjustment	IN110	CT_WILKINSSL, SG298_SAC115_53, SG299_SAC106_53, SG300_SAC097_53	IN110 is distributed to USRDOM node 110; adjustments smoothed over 21 days; conserving monthly volume

F.1-3.7 C2VSim

The Reclamation, 2021 LTO project team, has developed groundwater model simulations to support quantitative analysis of CVP and SWP long-term operations as part of NEPA document.

The California Department of Water Resources (DWR) Fine Grid California Central Valley Groundwater-Surface Water Simulation Model (C2VSimFG) Version 1.01 has been identified as the model to be used in assessing groundwater impacts in the Central Valley. A set of preprocessing utilities, and base model files have been established to assist in incorporating changes in CVP and SWP operations in C2VSimFG predictive simulations.

The purpose of this document is to provide details on the modifications made to C2VSimFG input files for comparative simulations under the 2021 LTO project. Please refer to the

C2VSimFG release package for more detailed documentation of the C2VSimFG model (California Department of Water Resources 2021a).

F.1-3.7.1 C2VSim Simulation Assumptions

To evaluate potential impacts on Central Valley groundwater conditions, a toolset was developed to incorporate changes in precipitation, evapotranspiration, land use, streamflow, and diversions in the C2VSimFG model. Climate and hydrologic conditions that serve as input to the toolset are based on CalSim 3 simulations of the CVP & SWP system under project related alternatives. Input and output data associated with CalSim 3 are processed and incorporated into new C2VSimFG input files that can be used to simulate groundwater conditions in the Central Valley. The following sections describe in detail the assumptions associated with processing CalSim 3 data into C2VSimFG model input.

F.1-3.7.1.1 C2VSim Simulation Period

The 42-year period used to present results from C2VSimFG represents more recent hydrologic conditions experienced in the Central Valley. This period represents climate conditions that have changed since those of the early- to mid-portion of the 1900s. The period 1974-2021 contains the driest year on record (WY 1977) as well as the wettest on record (WY 1983). This more recent period also contains multiple sequential drier years (WY in late 1980s and early 1990s), as well as the more recent drought years since the mid-2010s. The distribution of water year types for the longer and shorter periods is similar for the Sacramento Valley. The shorter record contains a slightly higher proportion of Dry and Critical years versus the longer record (45% versus 36%, respectively). In the San Joaquin Valley index, the shorter period also contains a higher portion of Dry and Critical years as compared to the longer record (49% versus 34%, respectively). The higher portion of drier years in the record may result in a more pronounced affect to groundwater resources.

F.1-3.7.1.2 Precipitation

Monthly precipitation timeseries data for CalSim 3 are defined as monthly inputs to the CalSimHydro model for each Water Balance Area (WBA). C2VSimFG specified monthly precipitation on a per element basis. An approach was developed to translate WBA precipitation to C2VSimFG elemental precipitation based on the spatial extents of these two boundaries. Figure F.1-3-1 shows an example overlay of WBA polygons and C2VSimFG model elements for the northern Sacramento Valley. C2VSimFG elements tend to overlap one or more WBAs, or in some cases may fall completely outside of a WBA. Where C2vSimFG elements and WBAs overlap, area fractions relating the intersected element area and the WBA area are used to evenly weight WBA precipitation across elements. Where C2VSimFG elements fall outside of a WBA, the historical C2VSimFG precipitation is retained for the CalSim 3 simulation. Additionally, WBAs often extend to watershed boundaries that are not part of the C2VSimFG model domain. In the portions of WBAs outside of the C2VSimFG model domain, the precipitation associated with these areas are ignored and not incorporated in the C2VSimFG simulation.

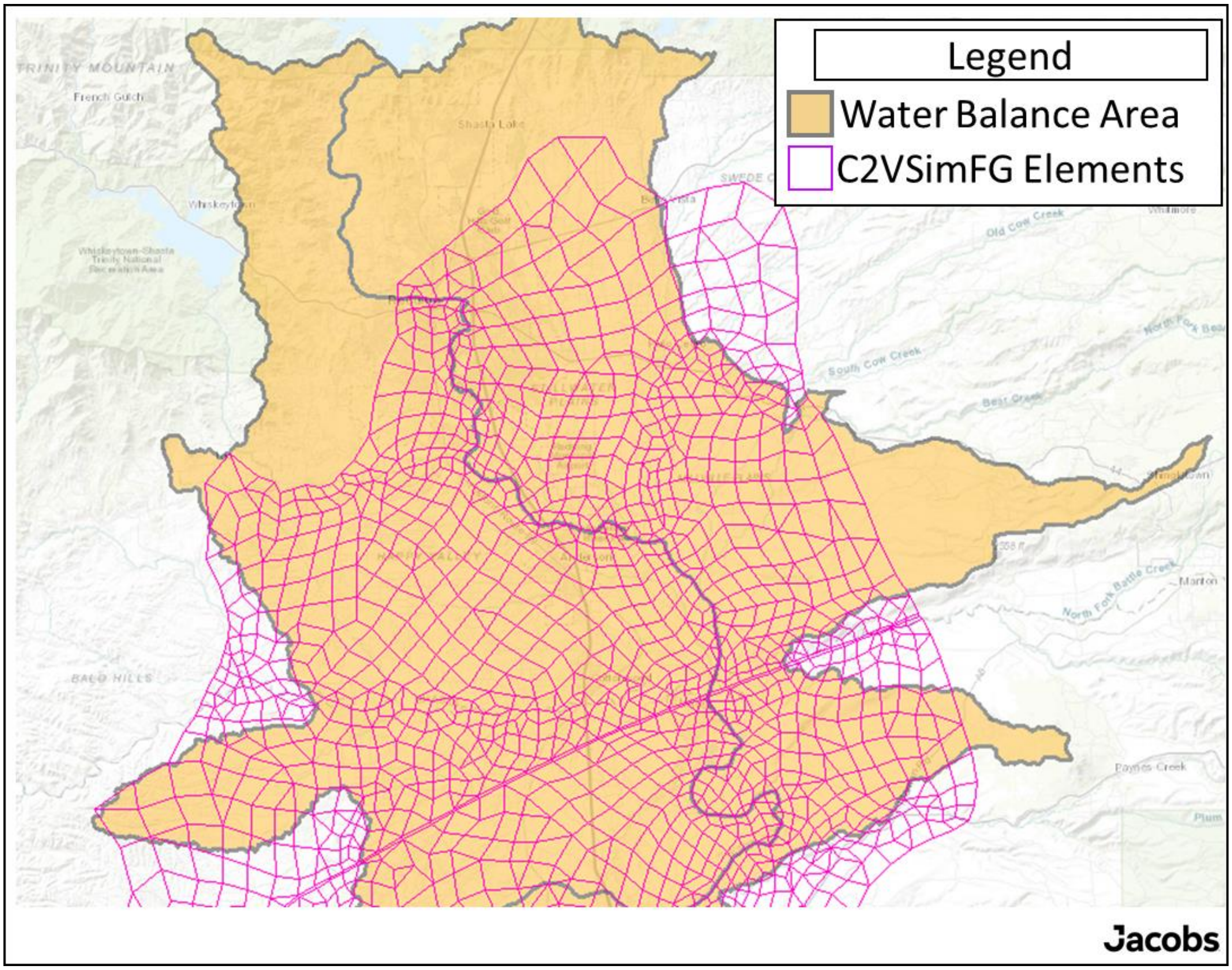
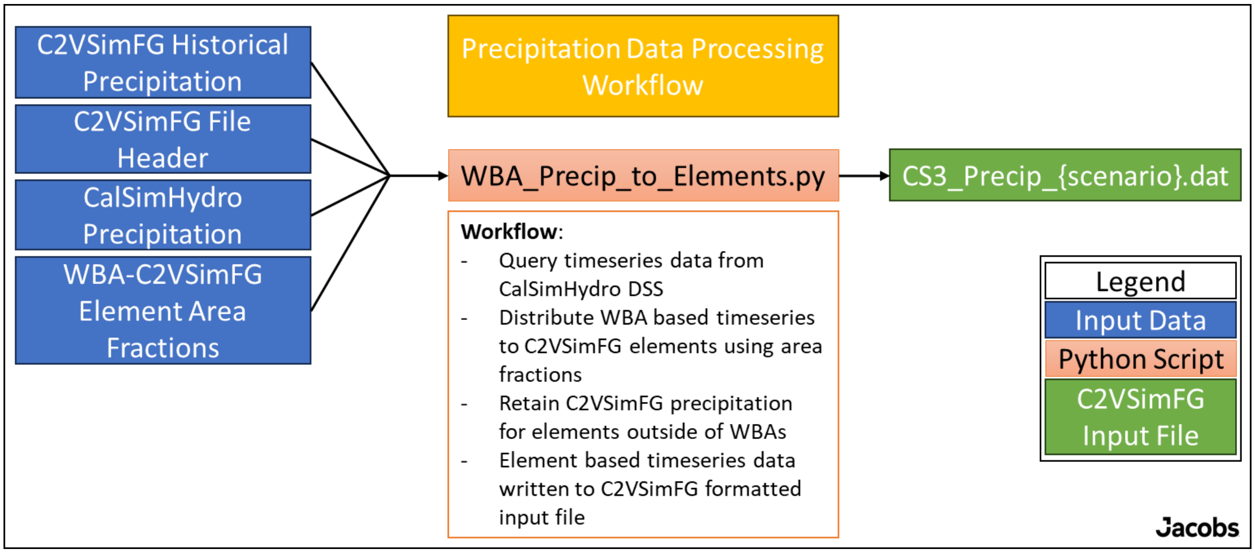


Figure F.1-3-1. Comparison of Water Balance Areas and C2VSimFG Elements

Figure F.1-3-2 provides an overview of the data processing workflow that is used to translate CalSimHydro WBA precipitation into distributed C2VSimFG elemental precipitation. A single Python script was developed that implements the approach described earlier in this section. Input data to the Python script include the C2VSimFG historical precipitation data as published in the C2VSimFG model, a header file containing necessary information for generating a new C2VSimFG input file, the CalSimHydro precipitation data which is housed in a DSS file, and the area fractions used to area-weight the WBA precipitation to C2VSimFG model elements. The Python script generates a single file that serves as input to a C2VSimFG simulation.



Workflow:
- Query timeseries data from CalSimHydro DSS
- Distribute WBA based timeseries to C2VSimFG elements using area fractions
- Retain C2VSimFG precipitation for elements outside of WBAs
- Element based timeseries data written to C2VSimFG formatted input file

Figure F.1-3-2. CalSimHydro to C2VSimFG Precipitation Processing Workflow

F.1-3.7.1.3 Evapotranspiration

Monthly evapotranspiration data for CalSim 3 is specified in CalSimHydro by WBA and crop category to account for spatial variability in crop specific evapotranspiration. Evapotranspiration rates are specified as linear rates and are used in conjunction with land use area classifications to determine volumetric rates of evapotranspiration on a per crop basis. Within C2VSimFG, crop specific evapotranspiration is specified on a pre-defined subregion basis, where a subregion is made up of a selection of elements (herein referred to as the C2VSimFG Subregions). Figure F.1-3-3 shows an overlay of the C2VSimFG Subregions and the WBAs for the northern Sacramento Valley. For the purposes of translating WBA evapotranspiration to C2VSimFG Subregions, an area weighting approach was used to weight the WBA evapotranspiration by the fraction of the C2VSimFG Subregion that intersects the WBA.

Crop categories from CalSimHydro were mapped to the C2VSimFG crop categories to translate crop evapotranspiration. The CalSimHydro model contains 23 crop categories while the C2VSimFG model contains 25 different crop categories. Aside from two crop categories in C2VSimFG not simulated in CalSimHydro, the mapping of crop categories between the two models was straightforward, where all categories between the two models represented the same crop but used slightly different nomenclature to describe the categories. The two crop categories in C2VSimFG that are not simulated by CalSimHydro are idle and riparian vegetation. For the purposes of simulating project operations as simulated by CalSim 3 any idle and riparian vegetation areas were assumed to be zero in the C2VSimFG simulations.

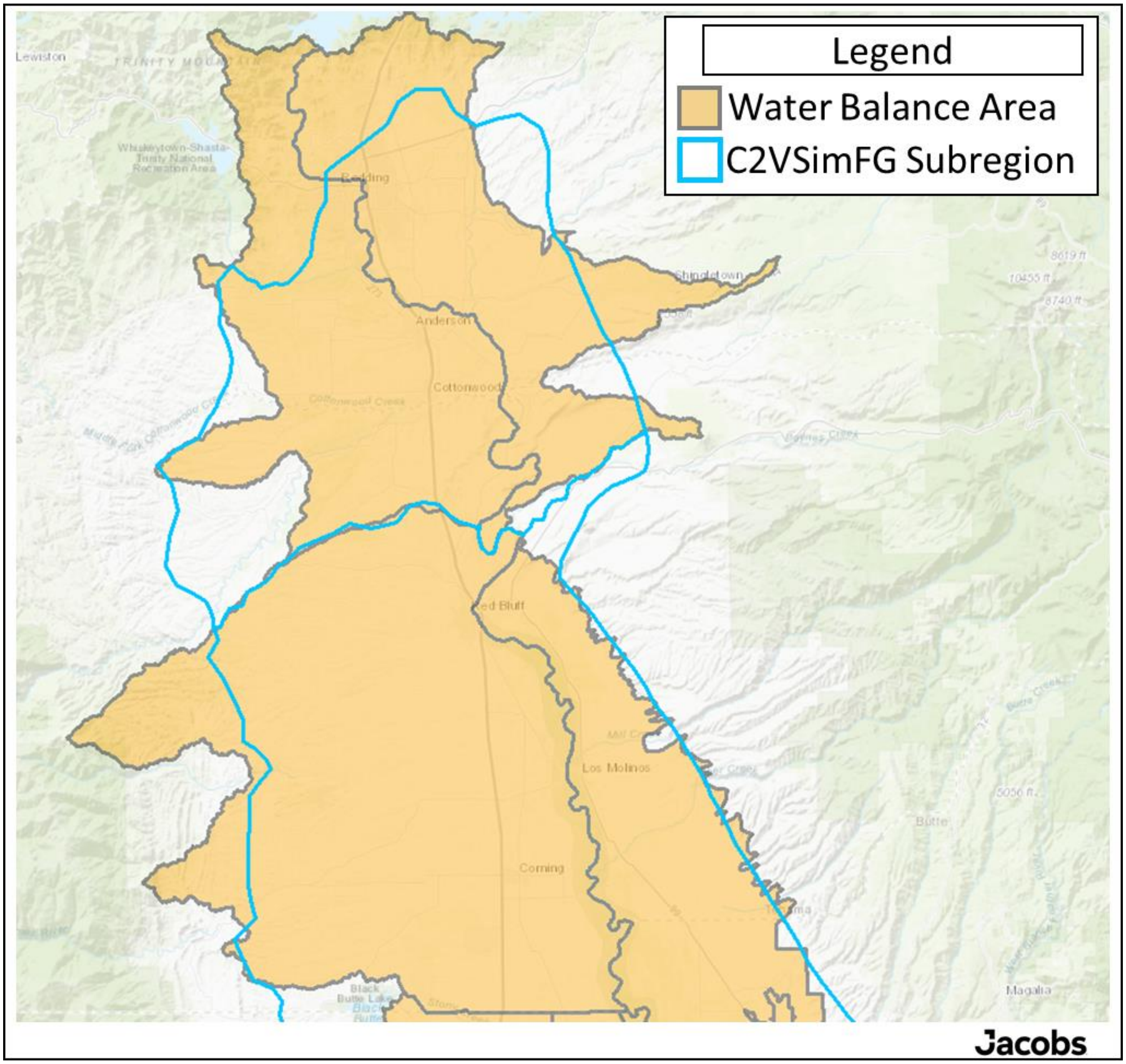
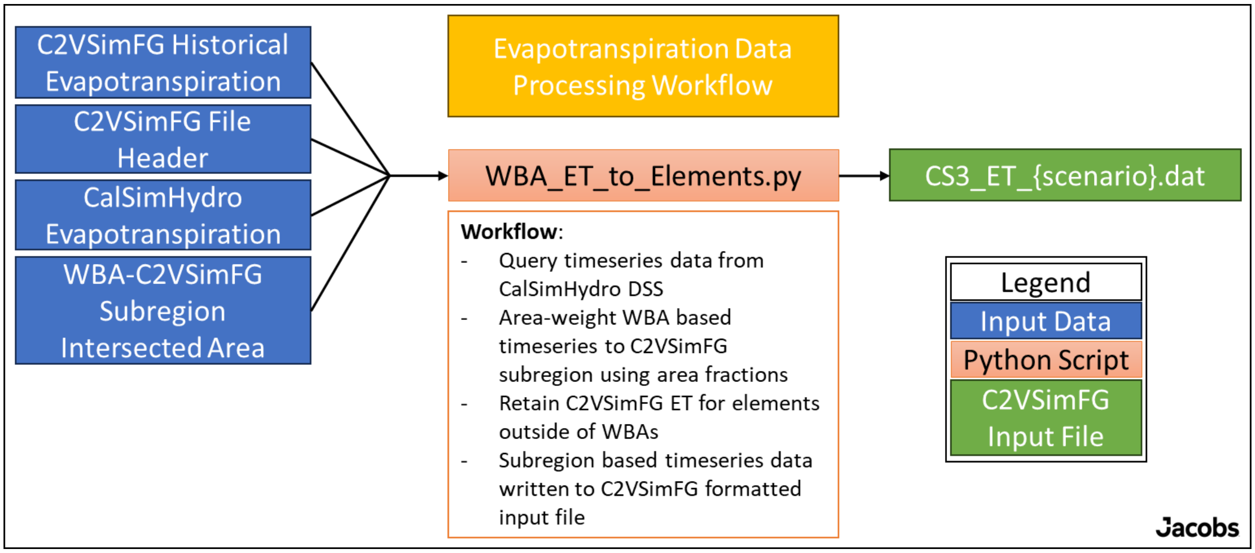


Figure F.1-3-3. Comparison of Water Balance Areas and C2VSimFG Subregions

Figure F.1-3-4 provides an overview of the data processing workflow that is used to translate CalSimHydro WBA evapotranspiration into C2VSimFG Subregion evapotranspiration. A single Python script was developed that implements the approach described earlier in this section. Input data to the Python script include the historical C2VSimFG evapotranspiration, a C2VSimFG header file used to establish the required format of the C2VSimFG input file, the CalSimHydro evapotranspiration data, and the WBA to C2VSimFG area weighting fraction information. The Python script generates a single file that serves as input to a C2VSimFG simulation.



Workflow:

- Query timeseries data from CalSimHydro DSS
- Area-weight WBA based timeseries to C2VSimFG subregion using area fractions
- Retain C2VSimFG ET for elements outside of WBAs
- Subregion based timeseries data written to C2VSimFG formatted input file

Figure F.1-3-4. CalSimHydro to C2VSimFG Evapotranspiration Processing Workflow

F.1-3.7.1.4 Agricultural Applied Water Demands

Given the complexity of water rights and contract limits associated with water use throughout the Central Valley, agricultural applied water demands at the Demand Unit (DU) scale were utilized as direct input to the C2VSimFG model from CalSim 3. Agricultural applied water demands replace the C2VSimFG internal calculation of agricultural supply requirement, as determined by land use and crop evapotranspiration, to determine how much surface water and supplemental groundwater is required to meet agricultural applied water demands, The calculation of agricultural supply requirement using specified agricultural applied water demands is facilitated through the inclusion of the water supply requirement input file which includes applied water timeseries data for each demand unit. Agricultural applied water demands were initially determined using the CalSimHydro model based on land use and crop ET, however, some scaling of agricultural applied water demands occur due to deficiencies in land use and crop ET data that do not accurately reflect actual water use based on contractual limits. Thus, the CalSim 3 to C2VSimFG linkage utility aims to incorporate agricultural applied water demands as simulated by CalSim 3.

Demand unit agricultural applied water demands were queried from the CalSim 3 SV DSS file. There are three categories of agricultural applied water demands simulated in the CalSim 3 model representing other crops, rice, and wetland. Each applied water demand category term is incorporated through linkages with either the C2VSimFG non-ponded crop or ponded crop input files. Linkages to the agricultural applied water demand time series were added to the non-ponded and ponded crop input files for elements where agricultural applied water demands are to be specified. Elements where agricultural applied water demands are specified directly were determined by relating the centroid of each C2VSimFG element to a DU. Agricultural applied water timeseries data were then scaled based on the number of C2VSimFG elements that relate to a DU and by the number of crops simulated by C2VSimFG and by the fraction of the DU area that is within the C2VSimFG domain. Scaling the agricultural applied water demand timeseries data in this manner essentially distributes the agricultural applied water demand evenly across all elements and crops that make up the DU and ensures that the simulated applied water demands do not reflect areas of a DU that are outside of the C2VSimFG model domain.

Figure F.1-3-5 shows the workflow for processing CalSim 3 agricultural applied water demands. A single Python script was developed that implements the approach described earlier in this section. Input data to the Python script includes a C2VSimFG header file used to establish the required format of the C2VSimFG input file, the CalSim 3 SV DSS file containing agricultural applied water demands, a lookup table containing the number of elements and number of crops relevant to each DU, and a lookup table containing the fraction of the DU area that is within the C2VSimFG model domain. The Python script generates a single file that serves as input to C2VSimFG simulation.

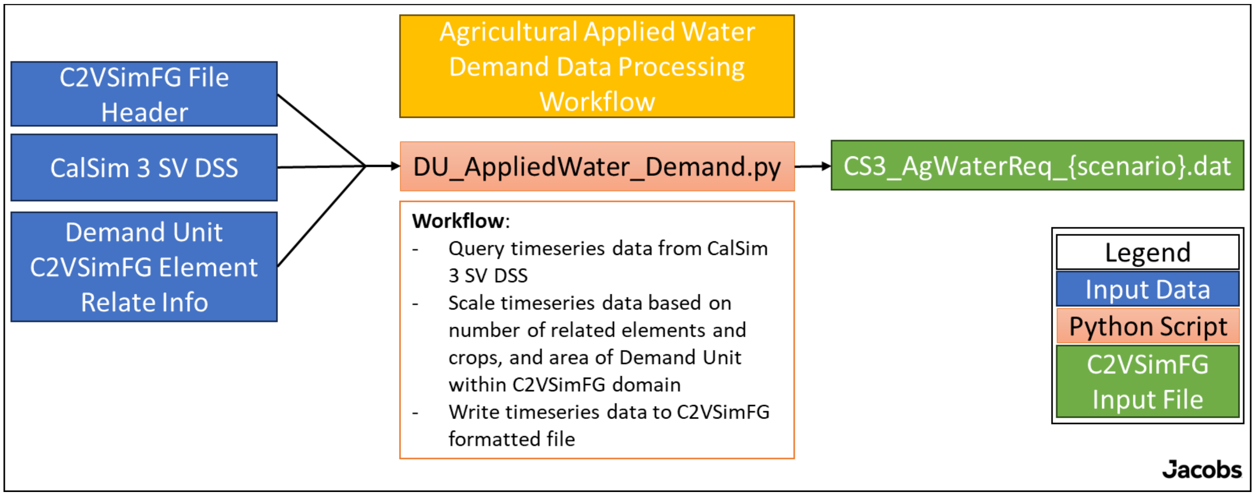


Figure F.1-3-5. CalSim 3 to C2VSimFG Agricultural Applied Water Demand Processing Workflow

F.1-3.7.1.5 Land Use

CalSim 3 simulates land use conditions that represent "current" level of development defined at the WBA scale. Considering the inclusion of the direct specification of agricultural applied water demands, as described in Section F.1-3.7.1.4, *Agricultural Applied Water Demands*, replaces the need for land use in determining agricultural supply requirements. However, the land use conditions are still necessary for determining target soil moisture conditions based on crop category and the resulting land and water use budget simulated in C2VSimFG.

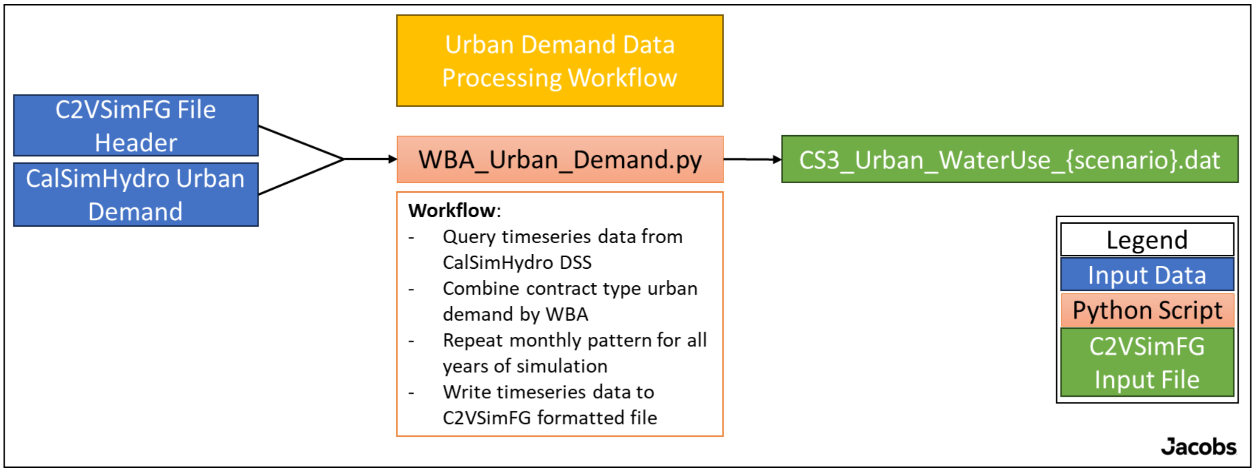
Given the secondary importance of having land use conditions reflect CalSim 3 assumption, rather than devise an approach to translate WBA based land use conditions to distributed C2VSimFG the latest land use conditions, representing 2015 conditions, in the C2VSimFG v1.01 model was retained for all areas of the C2VSimFG model domain. The 2015 land use conditions are held constant throughout the simulation period of a CalSim 3 scenario. The 2015 land use condition will more accurately reflect "current" day distribution of agricultural conditions and any supplementary pumping that may occur due to deficiencies in surface water supplies, creating a better representation of actual pumping conditions throughout the C2VSimFG model domain.

F.1-3.7.1.6 Urban Demand

CalSim 3 urban demands are simulated through CalSimHydro by WBA and contract type. Contract types represent the water right or water contract associated with the supply used to meet the urban demand. These demands are specified as a monthly volume that are uniform across all years of the simulation. For simulating CalSim3 conditions in C2VSimFG, urban demand by contract type were combined into a single urban demand by WBA to simplify the representation of urban demands. The monthly urban demand pattern is replicated for each year of the C2VSimFG simulation.

The historical version of C2VSimFG is configured such that a per capita water use rate and population are specified to establish a total volumetric urban demand which is then distributed based on the presence of urban areas in each C2VSimFG element. Since the urban demands from CalSimHydro represent a total volume, the population entry in C2VSimFG is set to a value of 1, since the demand volume already incorporates an assumption on urban population. Additionally, the C2VSimFG historical land use conditions (2015) for urban areas are retained to ensure that the spatial distribution of urban demands in C2VSimFG is the same as the historical C2VSimFG simulation (urban expansion assumed to be negligible). This ensures that the supply to water use relationship configured in C2VSimFG are retained for CalSim 3 simulations.

Figure F.1-3-6 CA single Python script was developed that implements the approach described earlier in this section. Input data to the Python script includes a C2VSimFG header file used to establish the required format of the C2VSimFG input file, and CalSimHydro urban demand data. The Python script generates a single file that serves as input to a C2VSimFG simulation.



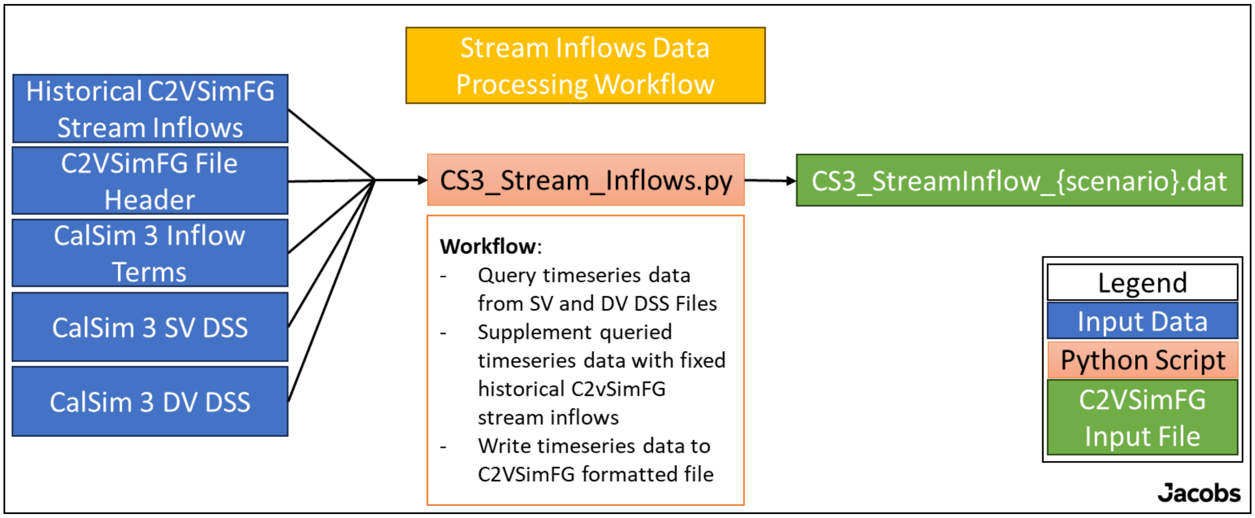
Workflow:
- Query timeseries data from CalSimHydro DSS
- Combine contract type urban demand by WBA
- Repeat monthly pattern for all years of simulation
- Write timeseries data to C2VSimFG formatted file

Figure F.1-3-6. CalSimHydro to C2VSimFG Urban Demand Processing Workflow

F.1-3.7.1.7 Stream Inflows

The historical C2VSimFG model uses specified flux boundary conditions to represent major stream inflows to surface water features within the C2VSimFG model domain. C2VSimFG includes a total of 58 stream inflows that represent reservoir releases and surface water inflows to larger creeks and rivers. An effort was undertaken to map equivalent CalSim 3 terms to each stream inflow included in C2VSimFG. Table F.1-3-12 presents a description of each C2VSimFG stream inflow and the associated CalSim 3 term that will be used to represent the stream inflow. There are numerous C2VSimFG stream inflows in the Tulare Basin region of the Central Valley that are not explicitly simulated in the CalSim 3 model. For Tulare Basin stream inflows, the C2VSimFG historical timeseries are retained for each C2VSimFG simulation.

Figure F.1-3-7 shows the workflow for processing CalSim 3 stream inflows. A single Python script was developed that implements the approach described earlier in this section. Input data to the Python script include the historical C2VSimFG stream inflows, a C2VSimFG header file used to establish the required format of the C2VSimFG input file, a list of the CalSim 3 stream inflow terms, and the CalSim 3 state variables (SV) and decision variables (DV) DSS files. The Python script generates a single file that serves as input to a C2VSimFG simulation.



Workflow:
- Query timeseries data from SV and DV DSS Files
- Supplement queried timeseries data with fixed historical C2vSimFG stream inflows
- Write timeseries data to C2VSimFG formatted file

Figure F.1-3-7. CalSim 3 to C2VSimFG Stream Inflows Processing Workflow

Table F.1-3-12. C2VSimFG Stream Inflow to CalSim 3 Mapping Table

C2VSimFG Stream Inflow	Mapped CalSim 3 Term
Sacramento River	C_KSWCK
Clear Creek	C_CLR011
Cow Creek	C_COW007
Battle Creek	I_BTL006
NF Cottonwood Creek	I_CWD018
MF Cottonwood Creek	I_CWD018

C2VSimFG Stream Inflow	Mapped CalSim 3 Term
SF Cottonwood Creek	I_SCW008
Paynes and Sevenmile Creek	I_PYN001
Antelope Creek Group	I_ANT011
Mill Creek	I_MLC006
Elder Creek	I_ELD027
Thomes Creek	I_THM028
Deer Creek Group	I_DRC012
Black Butte Release to Stony Creek	C_BLKBT
Stony Creek North Fork	I_BLKBT
Stony Creek South Fork	I_SGRGE
Big Chico Creek	I_BCC014
Butte and Little Chico Creeks	I_BTC048 + I_LCC038
Feather River	CFTR068 + C_THRMA
Honcut Creek North Fork	I_HON021
Honcut Creek South Fork	I_HON021
Yuba River	C_YUB002
Bear River	C_BRR011
Cache Above Rumsey	C_CCH058
Cache Creek below Diversion Dam	C_CCH030
American River	C_NTOMA
Putah Creek	C_BRYSA + D_PTH024_PSC003
Cosumnes River	C_CSM035
Dry Creek	I_DSC035
Mokelumne River	C_CMCHE
Calaveras River	C_NHGAN
Stanislaus River	C_STS059
Tuolumne River	C_TUO054
Orestimba Creek	I_ORT014
Merced River	C_MCD055
Bear Creek Group	I_BCK040
Deadman's Creek	I_DED044
Chowchilla River	C_ESTMN
Fresno River	C_HNSLY
San Joaquin River	C_SJR265

C2VSimFG Stream Inflow	Mapped CalSim 3 Term
Little Panoche Creek	I_LPC007
Panoche Creek North Fork	Retain C2VSimFG Historical
Panoche Creek South Fork	Retain C2VSimFG Historical
Cantua Creek	Retain C2VSimFG Historical
Los Gatos Creek	Retain C2VSimFG Historical
Zapata Chino Creek	Retain C2VSimFG Historical
Kings River	Retain C2VSimFG Historical
Kaweah River	Retain C2VSimFG Historical
Tule River	Retain C2VSimFG Historical
Deer Creek	Retain C2VSimFG Historical
White River	Retain C2VSimFG Historical
Poso Creek	Retain C2VSimFG Historical
Kern River	Retain C2VSimFG Historical
FKC Wasteway Deliveries to Kings River	Retain C2VSimFG Historical
FKC Wasteway Deliveries to Tule River	Retain C2VSimFG Historical
FKC Wasteway Deliveries to Kaweah River	Retain C2VSimFG Historical
Cross-Valley Canal deliveries to Kern River	Retain C2VSimFG Historical
Friant-Kern Canal deliveries to Kern River	Retain C2VSimFG Historical

F.1-3.7.1.8 Groundwater Inflows

CalSim 3 incorporates estimates of surface water inflows from small watersheds using an external small watersheds model. The small watersheds model represents watersheds that tend to be smaller unimpaired watersheds not controlled by a major SWP or CVP reservoir. The historical C2VSimFG model explicitly simulates its own set of small watersheds, however, the extent of the C2VSimFG small watersheds is different from the version simulated for input to CalSim 3. Due to this inconsistency, the small watersheds module that is part of the historical C2VSimFG simulation has been disconnected for all CalSim 3 based simulations of C2VSimFG. Water budget terms from the CalSim 3 small watersheds model will be adapted and incorporated into each C2VSimFG simulation. One such water budget term represents groundwater inflow or mountain front recharge from small watersheds. This recharge term from the small watersheds model is incorporated into C2VSimFG through simulation of a specified flux boundary condition along the margins of the C2VSimFG model boundary.

Figure F.1-3-8 shows an example of the CalSim 3 small watershed boundaries and the C2VSimFG boundary nodes that were evaluated to incorporate the CalSim 3 small watersheds groundwater inflows. Groundwater inflow timeseries from the CalSim 3 small watersheds model were extracted for each small watershed. C2VSimFG boundary nodes were then assigned to each small watershed where the groundwater inflows timeseries is distributed evenly across each assigned boundary node. Small watershed groundwater inflows are simulated in C2VSimFG as specified flux inflows at each of the assigned boundary nodes through the timeseries boundary condition package of C2VSimFG. The historical C2VSimFG model includes an existing set of constant head timeseries data used to simulate a constant head boundary condition. To prevent alteration of this boundary condition, as it is not relevant to the CalSim 3 simulation, the small watershed groundwater inflow timeseries are appended to the constant head timeseries dataset to maintain the structure of the existing constant head boundary condition.

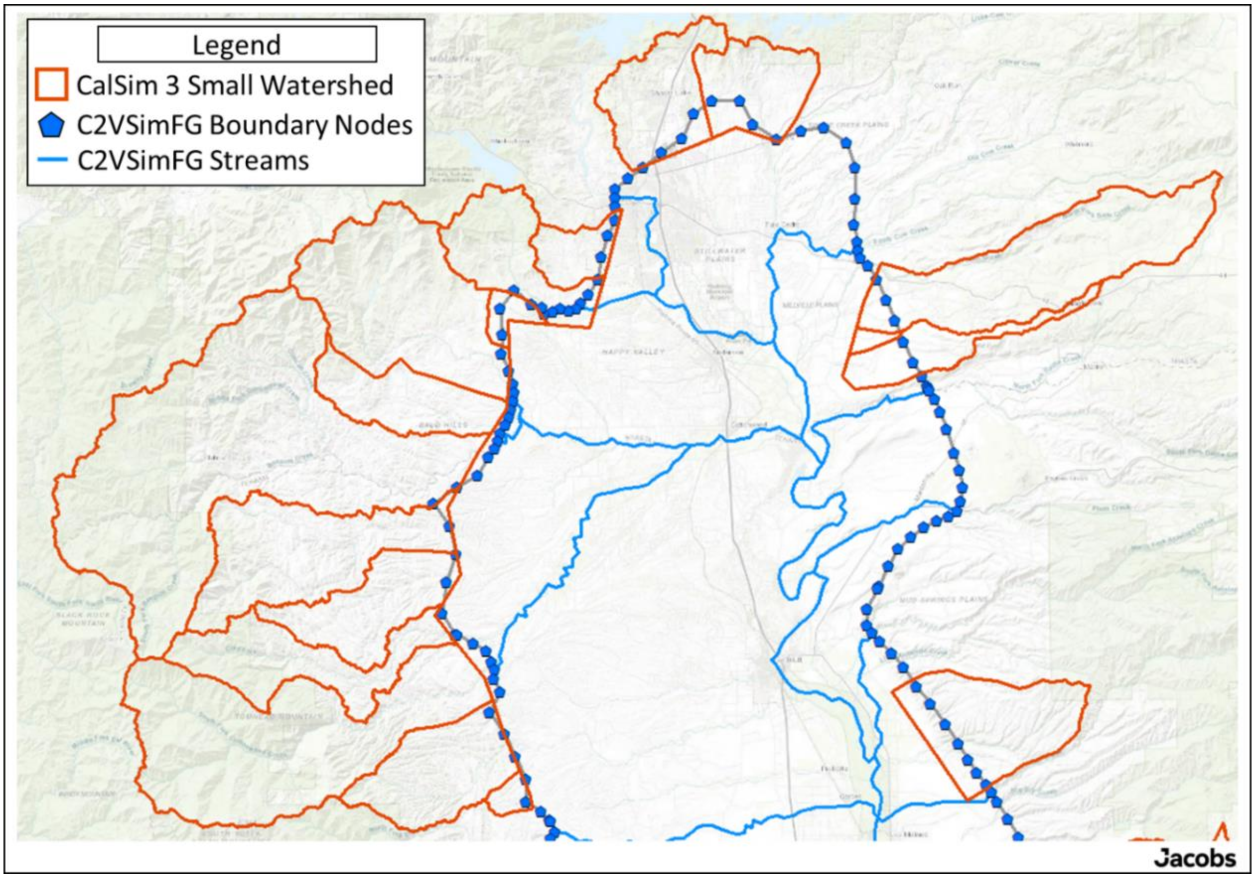


Figure F.1-3-8. CalSim 3 Small Watersheds and Neighboring C2VSimFG Groundwater Boundary Nodes

Figure F.1-3-9 shows the workflow implemented to translate the CalSim 3 small watersheds groundwater inflow into C2VSimFG specified flux input. A single Python script was developed that implements the approach described earlier in this section. Input data to the Python script include the historical C2VSimFG constant head timeseries data, a C2VSimFG header file used to establish the required format of the C2VSimFG input file, and the CalSim 3 small watershed DSS file. The script generates a single file that serves as input to a C2VSimFG simulation.

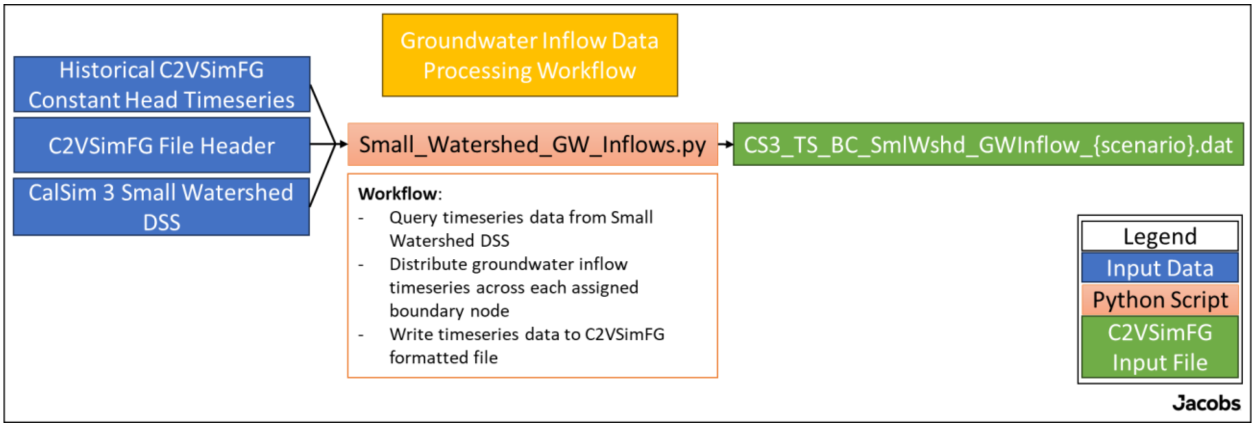
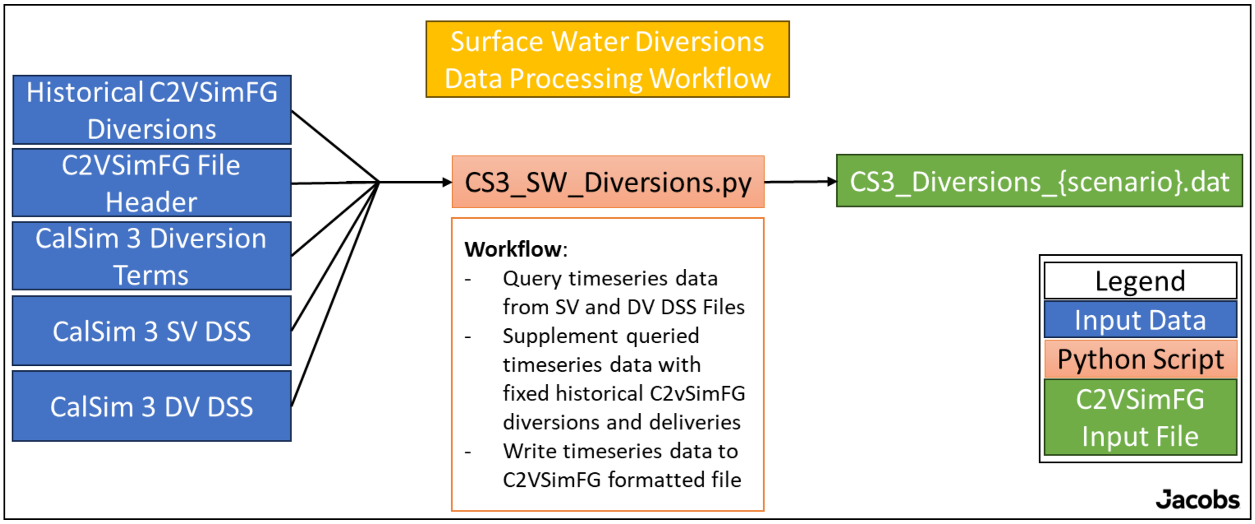


Figure F.1-3-9. CalSim 3 Small Watershed Groundwater Inflow to C2VSimFG Workflow

F.1-3.7.1.9 Surface Water Diversions

CalSim 3 simulations represent operations of the SWP and CVP to supply water to user groups throughout the Central Valley. To meet these demands, CalSim 3 determines the amount of surface water diversions that can be made available for delivery to user groups based on hydrologic conditions, water rights, and other beneficial use constraints. C2VSimFG explicitly simulates diversions and deliveries either as outflows from simulated streams or as imports to the C2VSimFG domain. The historical C2VSimFG model is configured to account for where the deliveries of water are used, either as applied water for irrigation or for urban indoor and outdoor use. An effort was undertaken to map the list of C2VSimFG diversions to CalSim 3 diversions. In some instances, a unique C2VSimFG diversion is not explicitly represented in CalSim 3, either because the term simply does not exist or because the diversion occurs within the Tulare Lake Basin which is outside the domain of CalSim 3. For these diversions, the historical C2VSimFG diversion timeseries data was retained for all C2VSimFG simulations. Additionally, there are instances where a single CalSim 3 diversion is represented by multiple diversions in C2VSimFG. In this case, the single CalSim 3 diversion is split evenly amongst the relevant C2VSimFG diversions.

Figure F.1-3-10 provides an overview of the CalSim 3 surface water diversion processing workflow. A single python script was developed to implement the approach described earlier in this section. Input data to the Python script includes the historical C2VSimFG diversion timeseries data, a C2VSimFG header file used to establish the required format of the C2VSimFG input file, a list of CalSim 3 diversion terms, and the CalSim 3 SV and DV DSS files. The Python script generates a single file that serves as input to a C2VSimFG simulation.



Workflow:

- Query timeseries data from SV and DV DSS Files
- Supplement queried timeseries data with fixed historical C2vSimFG diversions and deliveries
- Write timeseries data to C2VSimFG formatted file

Figure F.1-3-10. CalSim 3 Diversions to C2VSimFG Workflow

The diversion specifications file defines how surface water diversions are configured within C2VSimFG, defining losses and delivery locations associated with each diversion term. Factors are used to determine how much of the total diversion contributes to recoverable and non-recoverable losses, and the actual water delivered to agricultural fields. The inclusion of these factors is intended to represent inefficiencies associated with conveyance of water from streams to agricultural fields where the water is used.

CalSim 3 incorporates similar dynamics that account for potential losses and inefficiencies associated with conveyance of water. Loss terms within CalSim 3 are defined at the DU scale. Relevant loss terms are defined as evaporative loss, lateral flow loss, spill loss, and deep percolation. These terms along with the gross delivery term, were queried for each demand unit from which factors for recoverable loss, non-recoverable loss, and actual delivery were calculated for each DU. The recoverable loss factor was calculated as the sum of the lateral flow loss, spill loss, and deep percolation divided by the gross delivery term, The non-recoverable loss factor was calculated as the evaporative loss divided by the gross delivery term. The remaining water associated with the gross delivery was assumed to be made available for actual delivery. Thus, the sum of the three factors should equal a value of 1.0. Each C2VSimFG diversion was then related to a specific DU from which the relevant factors are used to define the specifications of that diversion. In some instances, a term was missing from CalSim 3 to perform the appropriate factor calculation. In these instances, the factors published in C2VSimFG v1.01 were used in place of values from CalSim 3.

F.1-3.7.2 Limitations

The linkage between CalSim 3 and C2VSimFG was designed solely to support the analysis of changing conditions between project alternatives. The translation of CalSim 3 data to C2VSimFG should be performed in the same manner for all project alternatives such that any differences in C2VSimFG input data solely reflect changes in CalSim 3 simulations.

Any limitations associated with the published version of C2VSimFG model have not been addressed through this model linkage utility. Further evaluation of the published C2vSimFG model structure and the linkage approach may need to occur to ensure that the simulated changes in groundwater conditions accurately reflect the differences in project alternatives as defined by CalSim 3 simulations. For example, the linkage between C2VSimFG surface water diversions and the group of model elements where the diversion is delivered to, is based solely on the configuration outlined in the published version of the C2VSimFG model. These areas of use have not been modified or evaluated for accuracy.

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