Appendix F, Modeling

Attachment 1-3 Model Updates

1.1 CalSim 3 Model Updates

Through the LTO and other concurrent processes, the CalSim 3 model has undergone multiple updates since the CalSim 3 Report (https://data.cnra.ca.gov/dataset/2395530a-5421-487e-921e-d6e594f23ac6/resource/2d4160d7-cbe1-4e63-8cdd-98f322e74cf2/download/cs3_mainreport_updates.pdf) was published.

1.1.1 Extension through WY 2021

1.1.1.1 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.

1.1.1.2 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." **The 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.

1.1.1.3 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 chapter 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:

- California Department of Water Resources (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).

1.1.2 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

1.1.3 References

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1.2 DSM2 Updates

1.2.1 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 2021).

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).

1.2.2 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:

> Change in EC at Martinez (for 0.5 ft sea level rise) = -0.0155*EC (at 0 cm sea level rise) - 28.9*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.

1.2.3 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.

1.3 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.

1.3.1 Toolkit Revisions

1.3.1.1 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 a subsequent section), 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.

1.3.1.2 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.

1.3.1.3 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.

1.3.2 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 1.

Table 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 2.

Table 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

1.3.3 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 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 1 through May 15. 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 3.

Table 3. 2019 Tiers structure description

Tier	CWP Description	Temperature Targets
Tier 1	greater than 3,800 TAF	53.5°F May 16–December 31
Tier 2.1	greater than 2,800 TAF and less than or equal to 3,800 TAF	56°F May 16–May 31 53.5°F June 1–December 31
Tier 2.2	greater than 2,800 TAF and less than or equal to 3,800 TAF	56°F May 16–June 15 53.5°F June 16–December 31
Tier 3.1	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16–June 15 54°F June 16–December 31
Tier 3.2	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16–June 15 54.5°F June 16–December 31
Tier 3.3	greater than 2,500 TAF and less than or equal to 2,800 TAF	56°F May 16–June 15 55°F June 16–December 31
Tier 4	less than or equal to 2,500 TAF	56°F May 16–December 31

The Mixed Compliance Location (mixed) temperature logic has a 60°F temperature target for the shoulder period of January 1 through May 15. 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 1 through May 15. 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 1 to May 15.

The Carryover Based Target (carryover) temperature logic has a 60°F temperature target for the shoulder period of December 1 through May 15. 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 16 through June 15. 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 16 through November 30. 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 1 to November 30. 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 16 through November 30. 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 1 through May 15. 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 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 1-May 15

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 1-May 15

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 1–May 15
	• Additional target at Jelly’s Ferry March 1–May 15
	  • 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 1–May 15

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 1–May/June 15

1.3.4 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.

1.4 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.

1.5 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 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 80 percentile ordered low to high from the spatial distributions was reported as the mortality for that season. The 80 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 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	Parameter	Value
ATU_a	487 °C-Days	$T_{crit,a}$	12.056 °C
ATU_b	958 °C-Days	$T_{crit,m}$	12.056 °C
$b_{T,a}$	1.17 (°C-Days)$^{-1}$	$Critial\ Days_a$	3 days
$b_{T,m}$	0.026 (°C-Days)$^{-1}$		

1.6 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.

1.6.1 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 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 6. Gaged and Synthesized Tributary Flows in USRDOM.

Location		Agency/ID	Parameter	Timestep	Period Available
1	Deer Creek near Vina	USGS/11383500	Flow	Daily	10/01/1911–09/30/2021
2	Mill Creek near Los Molinos	USGS/11381500	Flow	Daily	10/01/1928-09/30/2021
3	Battle Creek near Cottonwood	USGS/11376550	Flow	Daily	10/01/1940-09/30/2021
4	Elder Creek near Paskenta	USGS/11379500	Flow	Daily	10/01/1948-09/30/2021
5	Cottonwood Creek near Cottonwood	USGS/11376000	Flow	Daily	10/01/1940-09/30/2021
6	Cow Creek near Millville	USGS/11374000	Flow	Daily	10/01/1949-09/30/2021
7	Antelope Creek	USGS/11379000	Flow	Daily	10/01/1940–09/29/1982
8	Big Chico Creek	USGS/11384000	Flow	Daily	10/01/1930–09/29/1986
9	Paynes Creek	USGS/11377500	Flow	Daily	10/01/1949–10/31/1966
10	Red Bank	USGS/11378860	Flow	Daily	10/01/1959–09/29/1967
11	Thomes Creek	USGS/11382000	Flow	Daily	10/01/1920–09/30/1969

1.6.2 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 7.

Table 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

1.6.3 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 8 shows the list of operational controls computed in CAL2DOM. CalSim 3 operational (simulated) and control variables (requirements) are listed in separate columns.

Table 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
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

Description	CAL2DOM Ops Controls (Result)	CALSIM 3		Method used to determine the control
		Control	Operation	
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
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

Description	CAL2DOM Ops Controls (Result)	CALSIM 3		Method used to determine the control
		Control	**Operation**	
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
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)

ANN = artificial neural network; N/A = not applicable; NCP = navigation control point; UWFE = unstored water for export

1.6.4 CAL2DOM Minimum In-stream Flows

Table 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 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
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 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.

1.6.5 CAL2DOM Diversions

Table 10 lists the diversions explicitly modeled in USRDOM, along with the CalSim 3 variables and the methodology used by CAL2DOM to compute them.

Table 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

Description	USRDOM (Result)	CALSIM 3	Comment
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, SG265_STN014_49, SG266_STN009_49, SG267_STN004_49, SG268_STN004_49, R_06_PA_STN009	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 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

1.6.6 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 11 includes the variables used and the methods used in computing the three closure terms.

Table 11. Closure Terms in CAL2DOM.

Description	USRDOM (Result)	CALSIM 3	Methodology used to determine Closure Adjustments
Upper Reach Distributed Accretions and Closure Adjustment	IN182	CT_BENDBRIDGE, R_03_PA_SAC287, R_CCWWTP_SAC287, R_02_NU_SAC281, R_03_SA_SAC281, R_SWWWTP_SAC281, 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	IN182 is distributed to USRDOM node 182; adjustments smoothed 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

1.7 References

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