Master Response 3 Hydrology and Hydrologic Modeling

Overview

Commenters raised concerns about hydrology, the hydrologic model, and the hydrologic modeling results. Topics of discussion in this master response that address recurring commenter topics and themes related to hydrology and hydrologic modeling include but are not limited to the following.

- Modeling modifications and revised modeling results.
- Hydrology and modeling of the No Project Alternative.
- Modeling period.
- Hydrologic model description and use of CALSIM II.
- Modeling time step.
- Presentation of results.

This master response includes, for ease of reference, a table of contents on the following page to help guide readers in finding where their topics of concern are addressed. The table of contents is based on general recurring and common themes found in the comments that were received.

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Modeling Modifications

Several adjustments were made in the CALSIM II modeling between the RDEIR/SDEIS and the Final EIR/EIS to allow updated modeling and to represent real-time operations. These modifications are related to different parameters represented by the model and are described below.

Baseline—The CALSIM II baseline was updated to match the most recent Bureau of Reclamation (Reclamation) and California Department of Water Resources (DWR) baseline study, which is Reclamation's November 17, 2021, benchmark study. Part of the update includes an increase in the Central Valley Project (CVP) water allocation assumed for north-of-Delta Storage Partners. As a result, less water from Sites Reservoir may be needed by north-of-Delta CVP Storage Partners, allowing more water to be transferred south to contribute to Delta carriage water or to remain in Sites Reservoir.

Shasta Lake Operations—The CALSIM II modeling of Sites-Shasta exchanges now supports Shasta Lake cold-water pool management, fall flow stability, and spring pulse flow actions. Previously, Sites-Shasta exchanges focused on improving Shasta Lake cold-water pool management and incidentally improved fall flow stability. CVP operational flexibility now supports Shasta Lake cold-water pool management, fall flow stability, and CVP deliveries. Previously, CVP operational flexibility focused on improving just Shasta Lake cold-water pool management and CVP deliveries. These refinements to the modeling did not change the impact determinations for the Project.

Dead Pool Volume—The CALSIM II model now considers a smaller dead pool volume, reducing from 120 TAF to 60 TAF. The reduction in dead pool volume means that more Sites storage is actively utilized. These refinements to the modeling did not change the impact determinations for the Project.

Delta Salinity Accounting—CALSIM II modeling of carriage water requirements for Delta salinity objectives was improved based on recommendations from DWR. This change resulted in an overall small decrease in carriage water requirements and increase in south-of-Delta deliveries, with seasonal variability in effect.

South-of-Delta Refuges—The CALSIM II modeling has been modified to allow Delta exports to refuges to occur at both Banks and Jones Pumping Plants. Previously, diversions occurred only at Banks Pumping Plant. This modification has minimal effect on modeling results, and most of the conveyance of refuge water still occurs at Banks Pumping Plant.

Period of Diversion to Sites Storage—In CALSIM II, diversions to Sites storage are now restricted to September 1 through June 14. This change was made to restrict diversions to the period when Sacramento River flows are not fully appropriated. Previously, CALSIM II diversions were allowed to occur year-round. However, June 15 through August 31 diversions had been minimal due to lack of diversion criteria being met during this period, and therefore this change has little effect on modeling results.

Period of Releases to Sacramento River—When Sacramento River flow is high (i.e., flow at Wilkins Slough is greater than 15,000 cubic feet per second [cfs]), the flap gates at the Knights Landing Outflow Gates are closed to prevent Sacramento River water from entering Colusa Basin Drain. To reflect this reality, CALSIM II operations have been modified to prevent discharge of water from Sites Reservoir to the Sacramento River when the river flow is greater than 15,000 cfs. This has minimal effect on modeling results because Sites releases during periods of high flow in the Sacramento River would be rare.

The CALSIM II model also includes updates to the Sites diversion criteria, described in Master Response 2, *Alternatives Description and Baseline*. Considering the refinements to the models, results of the revised modeling fall within the range of impacts evaluated in the RDEIR/SDEIS. Overall, the modeling for the Final EIR/EIS includes more protective diversion criteria, leading to less diversions and lesser potential for impact.

Hydrology Used for Modeling of Alternatives

Some commenters questioned the development of the hydrologic boundary conditions to the CALSIM II model or suggested that climate change has already affected hydrologic conditions in a manner that is not reflected in the 82-year (water years 1922–2003) CALSIM II simulation period used to simulate the No Project Alternative. The next sections provide detail regarding those subjects.

Hydrologic Data Development

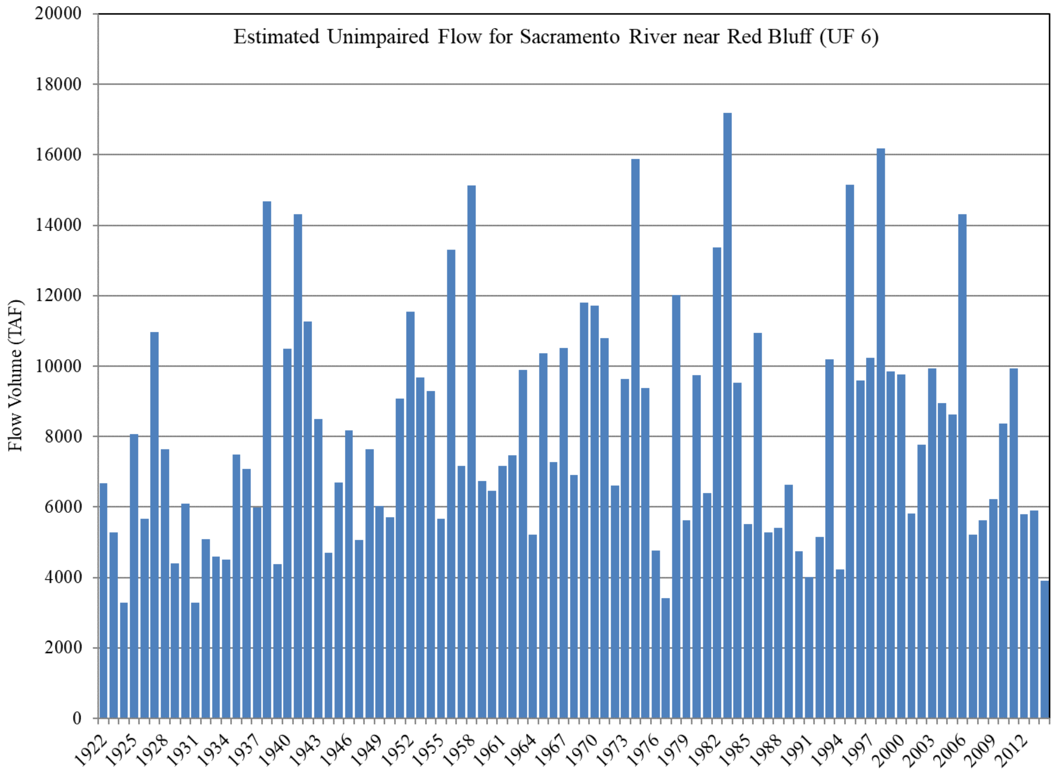
The CALSIM II model includes hydrology developed jointly by DWR and Reclamation. Water diversion requirements (demands), stream accretions and depletions, rim basin inflows, irrigation efficiency, return flows, non-recoverable losses, and groundwater operation are all considered in the development of the CALSIM II hydrology. In the development of the CALSIM II model, historical runs of CALSIM II were conducted to account for sources of uncertainty, such as gaps in observed data sets (Close et al. 2003).

Modeling Period, Hydrology and Climate Change

The planning simulation period reflects 82 years of historical hydrology spanning from water years 1922 through 2003. This period considers a wide range of hydrologic conditions, from extended droughts (e.g., 1928–1934) to very wet years (e.g., 1997). These wet and dry year sequences are essential parts of modeling, results, and the resource impact analyses. Throughout the 82-year period, several cycles of drought and wetter conditions are realized. Figure MR3-1 (figure developed with data from DWR [California Department of Water Resources 2016]) demonstrates that the range of hydrology observed at the proposed upstream diversion location on the Sacramento River during the 1922 through 2003 period is representative of the range and variability of hydrology observed in the 1922 through 2014 period. As such, the resource impact analyses in Chapters 5 through 27 use 82 years of hydrologic conditions that provide a robust representation of the wide variability observed in California between 1922 and 2003.

As described in Chapter 28, *Climate Change*, in northern California, climate change is expected to result in warmer temperatures, reduced snowpack, increased hydrologic variability, and increased and earlier runoff. These changes have already commenced in the 82-year CALSIM II hydrology, but the environmental baseline only reflects changes incurred during the simulation period. Details of potential effects of climate change on future hydrologic conditions are reflected in the 2035 CT and WSIP 2070 results contained in Appendix 28A, *Climate Change*.

Although the incipient effects of climate change are not incorporated in the full sequence of years evaluated in the environmental baseline, attempting to modify this historical hydrologic record to mimic recent hydrologic variability would not change the conclusions described in the resource chapters. The wide variability of hydrologic conditions represented in the 82-year modeling period captures minimum and maximum annual runoff and the interannual changes to flow (shifting between wet and dry years) in the 1922 through 2014 period.



Note: Developed with data from California Department of Water Resources 2016.
TAF = thousand acre-feet.

Figure MR3-1. Estimated Unimpaired Flow for Sacramento River near Red Bluff

Hydrologic Model Description

Commenters stated the selection or use of CALSIM II was not appropriate and CALSIM II is not the best available tool, and some commenters stated concerns regarding some of the CALSIM II model parameters. The sections below describe the CALSIM II model and provide an overview of model parameters noted by commenters.

Use of CALSIM II

CALSIM II is a reservoir-river basin simulation model that allows for specification and achievement of user-specified allocation targets, or goals (Draper et al. 2004). CALSIM II has been consistently utilized for evaluating long-term planning efforts for the CVP and State Water Project (SWP). The most recent planning documents for CVP and SWP operations (2019 U.S. Fish and Wildlife Service and National Marine Fisheries Service [NMFS] biological opinions [BiOps], 2020 Record of Decision, and 2020 SWP incidental take permit) relied on CALSIM II for the analysis (U.S. Fish and Wildlife Service 2019; National Marine Fisheries Service 2019; Bureau of Reclamation 2020; California Department of Fish and Wildlife 2020).

When the Notice of Preparation was published for the RDEIR/SDEIS (2017) and, in 2020, when the modeling analysis was conducted for the RDEIR/SDEIS, CALSIM II was the only systems operation model that was jointly supported by DWR and Reclamation. As such, at the time of analysis, CALSIM II was the best tool available to evaluate Sites operations in the CVP and SWP systems. Since publication of the RDEIR/SDEIS, a jointly supported CALSIM 3 model has become available. For a discussion of the selection of CALSIM II and the modeling assumptions and baseline, please refer to Chapter 3, *Environmental Analysis.*

Selection of CALSIM II Versus CALSIM 3

There are two active versions of CALSIM, a model that supports analyses of the operation of the CVP and SWP in California: CALSIM II and CALSIM 3. CALSIM II is a well-established and peer-reviewed model that simulates major reservoirs, rivers, and canals in the Central Valley and has been used and maintained over the last 20 years. CALSIM 3 is a more recent model that implements higher spatial resolution and extent, an extended hydrology timeseries, and dynamic groundwater–surface water interactions.

CALSIM 3 was first released jointly by Reclamation, who operates the CVP, and DWR, who operates the SWP, in 2021 as part of the CALSIM Model Maintenance Management (CM3) program. Reclamation did not intend to use the CALSIM 3 model released from CM3 as a baseline in planning or permitting efforts at that time. The first application of CALSIM 3 in a planning document was the Delta Conveyance Project Draft Environmental Impact Report (DCP EIR) (California Department of Water Resources 2022) and Environmental Impact Statement (DCP EIS) (U.S. Army Corps of Engineers 2022) in 2022. It should be noted that DWR was the lead agency in the preparation of the DCP EIR, and U.S. Army Corps of Engineers was the lead agency in the preparation of the DCP EIS. To date, Reclamation, the lead agency under National Environmental Policy Act for this EIR/EIS, has not released a CALSIM 3 study that reflects the operations of the CVP.

CALSIM II has a long history and has been used on numerous projects, including being used extensively in the planning and permitting for the CVP and SWP, as described above. The Sites Reservoir Project Final EIR/EIS was developed using CALSIM II. As described in Chapter 3, *Environmental Analysis*, incorporating the Project into CALSIM II required a tremendous effort to develop Project facilities, diversion criteria, and participant operations and to track Project water through the numerous components of the model. This effort required several months of focused work conducted by subject matter experts.

Although both represent the CVP and SWP, CALSIM II and CALSIM 3 use different parameter names and operational structure. Transitioning the Project into CALSIM 3 would not be a "plug-and-play" operation. Instead, it would require substantial coding, testing, and review. Additionally, secondary models, used for water quality, economics, and fisheries effects analyses would need to be updated to retrieve and process results from CALSIM 3. Transitioning the Project into the newly available CALSIM 3 model and updating secondary models necessary for effects analyses is estimated to take approximately 1 year of effort or longer, which is generally consistent with the substantial amount of time and effort required to integrate the Project with the existing CALSIM II model before CALSIM 3 was released. While the CALSIM 3 model results represent a higher spatial resolution and extent of changes in the system (i.e., there are more model nodes to report out on changes), the overall results of the Project and its changes in the physical environment are not expected to be substantially different when modelled in CALSIM 3 as compared to CALSIM II. Although CALSIM 3 considers a higher spatial resolution and extent (additional points at which data can be reported), extended hydrology timeseries, and dynamic surface water–groundwater interactions, California's major water projects (CVP and SWP) facilities, operating criteria, and demands remain unchanged. Additionally, major inputs to the CALSIM 3 model, such as inflow hydrology, level of development, and regulatory conditions, are similar to CALSIM II (minor differences arise due to change in spatial resolution). Both CALSIM II and CALSIM 3 use a mixed integer linear programming solver (i.e., they apply the same logic for computing results). The Authority intends to develop a CALSIM 3 model with Sites operations, but it will take a substantial amount of time and effort to integrate the Project into the new CALSIM 3 model, and it is not feasible to do so for this EIR/EIS.

Model Parameters

The following sub-sections detail loss parameters (seepage, evaporation, and conveyance loss), river flows, and mass balance calculations as represented by the hydrologic model.

Seepage, Evaporation and Conveyance Losses

The CALSIM II model considers losses due to net evaporation at its reservoirs. For the Final EIR/EIS Alternative 3, the long-term average evaporative losses are 27 TAF per year. These evaporative losses are roughly 10% of the long-term average annual diversion volume. Seepage at Sites Reservoir is not considered in the CALSIM II model. However, local seepage is evaluated in Appendix 8B, *Groundwater Modeling*. According to Appendix 8B, seepage losses would be roughly 2,150 gallons per minute, or 3.5 TAF per year, under the larger (1.8 MAF) configurations of Sites Reservoir presented in the 2017 Draft EIR/EIS. Considering that seepage would decrease under the alternatives presented in the RDEIR/SDEIS, the volume of loss to seepage is within 1–2% of the long-term average annual diversions.

The CALSIM II model considers conveyance losses along the canals between diversion facilities at Red Bluff and Hamilton City and Sites Reservoir. The assumed conveyance losses are presented in Table MR3-1.

Table MR3-1. CALSIM II Conveyance Loss Assumptions

Diversion Facility	Season	Max Sites Fill (cfs)	Assumed Losses	Max Diversion from Sacramento River (cfs)
Red Bluff	Year-round	2,100	1%	2,121
Hamilton City	Nov–Mar	1,800	2%	1,837
	Apr–Oct	1,800	13%	2,069

cfs = cubic feet per second

Mass Balance in the Sacramento River Basin

The following sentences detail the model's representation of water routing through the Sacramento River and various other locations within the system, including spills over multiple weirs, depending on multiple variables, including hydrologic conditions and diversions. The modeling results show the Project's effect on flow along the Sacramento River varies, depending on location. The modeling results show Project diversions have the greatest in-river change to flow immediately downstream of the two diversion facilities (Red Bluff and Hamilton City), which would be expected under Project conditions. Downstream of Hamilton City, there are several weirs allowing flow to enter the Sutter Bypass and Yolo Bypass. Between Hamilton City and Wilkins Slough, there are four weirs over which Sacramento River water may spill into the Sutter Bypass: Ord Ferry, Moulton Weir, Colusa Weir, and Tisdale Weir. When Sacramento River flow is lower, less water is spilled into Sutter Bypass. As such, the reduction in flow between Hamilton City and Wilkins Slough associated with Project operation is associated with a reduction in spills into Sutter Bypass. Furthermore, the same phenomenon occurs with spills over the Fremont Weir and over the Sacramento Weir into the Yolo Bypass.

Exchanges

Summary of Lake Oroville Exchange Operation

The Lake Oroville exchange is designed to augment delivery of Sites water to south-of-Delta Storage Partners during the transfer window. In June and July of Lake Oroville exchange years, a portion of SWP-obligated releases would come from Sites in lieu of Lake Oroville, reducing releases from Lake Oroville. Therefore, Lake Oroville storage would be preserved through the end of July. In the late summer and fall (August–November), the preserved water, or exchange volume, would augment Lake Oroville releases, provide deliveries to Sites Storage Partners, and support Lake Oroville cold-water pool management.

Lake Oroville Exchange Operational Criteria

Assumptions of Lake Oroville exchange operational criteria are detailed below.

Exchange Period

Lake Oroville exchange volume is estimated in June and July as a fraction of the forecasted delivery volume from Sites Reservoir to south-of-Delta Storage Partners in August through November. If the Lake Oroville exchange volume overestimates the ability of Sites Reservoir to deliver water to south-of-Delta Storage Partners, a portion of Sites exchange water would remain in Lake Oroville. This remaining exchange water would be subject to spill.

The Lake Oroville exchange period would be limited to June and July. This exchange period would start in June due to the high degree of uncertainty in forecasting south-of-Delta deliveries during spring months. Forecasting south-of-Delta deliveries any earlier than June would pose a substantial risk to losing Sites water via spills from Lake Oroville. The exchange period would end in July to protect green sturgeon (*Acipenser medirostris*) habitat in August (California Department of Water Resources 2008).

In Wet and Above Normal Water Years, Sites transfers to south-of-Delta Storage Partners would be limited. As such, Lake Oroville exchanges would occur in Below Normal, Dry, and Critically Dry Water Year types.

Release Period

Releases to south-of-Delta participants may occur in all years and would occur between July 1 and November 30. The majority of exchange water held in Lake Oroville would be released in August and September because releases during October and November would be required to consider Feather River fall stability flow targets. Per fall stability flow requirements, total Lake Oroville releases are limited to 2,500 cfs from October 16 through November 30 (California Department of Water Resources 2008). All exchange water must be released between August 1 and November 30. If exchange water is not released by November 30, it would be subject to spill.

Summary of Shasta Lake Exchange Operation

Shasta Lake Exchange is designed to support the Cold Water Pool Management and Fall and Winter Refill and Redd Maintenance Actions in the 2019 NMFS BiOp (National Marine Fisheries Service 2019). As noted in the *Modeling Modifications* section of this master response, Shasta Lake Exchange operations have been adjusted between the RDEIR/SDEIS and the Final EIR/EIS. The Shasta Lake Exchange criteria for temperature management are described below and are summarized in Table MR3-2. Additional exchange operations, in October through February and May, are described in Appendix 5A1, *Model Assumptions*.

In the spring of Shasta Lake Exchange years, Sites would release water for CVP uses in lieu of Shasta Lake. As Sites is releasing for CVP uses, Shasta Lake releases would be reduced, preserving Shasta Lake storage and its cold-water pool through the spring (April 1–June 30).

The volume of delivered water would be equivalent to the exchange volume preserved in Shasta Lake. The exchange volume would sustain Shasta Lake cold-water pool for use during the critical months of the cold-water pool management season (August and September) and may support Fall and Winter Refill and Redd Maintenance Actions in October through February. In late summer and fall (August–November), the exchange volume would augment releases from Shasta Lake with cooler water and provide deliveries to Sites Storage Partners. In late fall and winter (December–February), the remaining exchange volume would augment fall stability flows under the Fall and Winter Refill and Redd Maintenance Actions.

All exchange water must be released between August 1 and February 28. If exchange water is not released by the end of February, it would be subject to spill. Release of exchange water would support the Cold Water Pool Management Action and fall stability flows aspect of the Fall and Winter Refill and Redd Maintenance Action in the 2019 BiOps. As such, Shasta Lake Exchanges would occur in years when forecasted temperature-dependent mortality of early life stage winter-run Chinook salmon (*Oncorhynchus tshawytscha*) would be reduced by a Shasta Lake Exchange.

Table MR3-2. Shasta Exchange Criteria

Parameter	Modeled Criteria
Exchange Period	April–June
Exchange Constraints	–
Water Year Types	Dry and Critically Dry Water Years
Temperature Management Tier[1]	Tier 3 and 4 years
Sacramento Valley Conditions[2]	Only during balanced conditions
Release Period	August–February

[1] Described in the Cold Water Pool Management Section of the 2019 BiOps (National Marine Fisheries Service 2019)
[2] As defined by the Coordinated Operation Agreement (Bureau of Reclamation and California Department of Water Resources 1986)

In-Lieu Exchanges

Sites Reservoir may release water via an in-lieu exchange with GCID. Instead of pumping water from the Sacramento River, GCID would receive its CVP allocations via Sites. The water released from Shasta Reservoir that would normally be used to meet the CVP allocations to GCID would instead serve as Sites releases to other Storage Partners.

Folsom Lake Exchanges

Sites Reservoir exchanges with Folsom Lake were considered in the RDEIR/SDEIS as a potential benefit but were not included in the CALSIM modeling. Therefore, the Folsom Lake exchanges were removed from the Project description in the Final EIR/EIS, and modeling results have not changed.

Diversions

CALSIM II demand inputs are a preprocessed monthly time series for a specified level of development (e.g., 2020) and according to hydrologic conditions. The CALSIM II level of development reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Demands are classified as CVP, SWP, local project, or non-project. CVP and SWP demands are separated into different classes based on the contract type. A description of various demands and classifications included in CALSIM II is provided in Appendix D of the 2008 *Operations Criteria and Plan Biological Assessment* (Bureau of Reclamation 2008). The detailed listing of CVP and SWP contract amounts and other water rights assumptions are included in the delivery specification tables in Appendix 5A5, *CALSIM II Model Delivery Specifications*.

Modeling Time Step

Some commenters expressed concerns regarding the use of the modeling time step and the use of a monthly time step in CALSIM II.

Monthly Time Step

As noted in Appendix 5B, *Water Resources Modeling System*, the CALSIM II model uses a monthly time step. Although daily hydrology may fluctuate in a given month, the resultant monthly average flow will: (1) reflect the overall conditions of the system (e.g., whether a hydrologic drought is occurring); (2) capture operational rules that rely on (hydrologic) system conditions; and (3) fulfill mass balance calculations for reservoir storage, volumes of river flows, and Delta outflow. The monthly operational time steps support more detailed analyses, where diurnal temperature range, maximum daily temperature, minimum daily temperature, and tidal influences are considered. This suite of quantitative modeling tools represents the best available science for conducting long-term planning analyses.

CALSIM II and Upper Sacramento River Daily Operations Model

Because some Sites diversion criteria rely on information at a sub-monthly time step, the Upper Sacramento River Daily Operations Model (USRDOM) of the No Action Alternative was used to estimate diversions that could be made for Sites storage under the alternatives. These diversion estimates were then used in CALSIM II to simulate the alternatives. The CALSIM II simulations of the alternatives were then downscaled back to USRDOM for daily simulation of some parameters. This integrated modeling using CALSIM II and USRDOM models is described in detail in Appendix 5C, *Upper Sacramento River Daily River Flow and Operations Model*. Additionally, hydrologic inputs, stream routing, and reservoir operations of the USRDOM have been calibrated and verified. For example, across the verification period (1964–2003), the ratio of residual (difference between historical simulated and observed) to observed data is -1.62% in the months of October through March and 0.03% in the months of April through September at the Sacramento River at Bend Bridge. The development, calibration, and verification of daily hydrology, stream routing, and reservoir operations are described in *USRDOM Development, Calibration, and Application* (CH2M HILL 2011). This includes detailed statistics and plots comparing USRDOM results to observed data at several additional locations on the Sacramento River.

In the downscaling of CALSIM II boundary condition flows for use in the USRDOM simulations, diversions at Red Bluff and Hamilton City are smoothed from monthly to daily time steps. In this smoothing operation, to conserve volume and have a gradual change in diversion flows (as opposed to sharp changes at monthly or other time scale boundaries), there are some days in which diversions are represented in the USRDOM at flow rates that may exceed the sustainable rate of the physical capacity of these facilities. It should be noted that CALSIM II does not allow diversions to exceed the sustainable rate of the physical capacity of these facilities, and therefore does not overestimate diversions. It is recommended that any assessment of flows or other parameters linked to the peak flow rate of these diversions use monthly average values rather than daily or other sub-monthly average values.

The CALSIM II model is used to establish system operational conditions, and USRDOM is used to interpret these on a daily time step. All residuals and inconsistencies between the CALSIM II and USRDOM models accumulate in storage facilities modeled, including Sites Reservoir; the Sites Reservoir storage in the USRDOM sometimes exceeds physical capacity slightly due to this inconsistency between the models. Despite these limitations, the USRDOM simulates daily flow conditions in the Sacramento River, based on operations specified by CALSIM II, to establish operating criteria and support fisheries analyses.

CALSIM II and Real-Time Operations

CALSIM II is intended to be used in a comparative mode. The results from a "with Project" alternative simulation are compared to the results of a "base" simulation to determine the incremental effects of a project. The results from a single simulation may not necessarily represent the exact operations for a specific month or year but reflect long-term trends. Reclamation and DWR operators work in real time to satisfy legal and contractual obligations based on observed data (e.g., flow, water quality). The model should be used with caution to prescribe operations, predict flows, or prescribe water deliveries for any real-time operations.

The models used in planning analysis are not predictive models, and therefore the results cannot be considered as absolute with a quantifiable confidence interval. The modeling results are only useful in a comparative analysis and can only serve as an indicator of condition (e.g., compliance with a standard) and of trend (e.g., generalized impacts).

Presentation of Results

CALSIM II modeling results are presented in Appendix 5B1, *Project Operations*; Appendix 5B2, *River Operations*; Appendix 5B3, *Delta Operations*; Appendix 5B4, *Regional Deliveries*; and Appendix 5B5, *Water Supply*. Modeled results are presented with monthly tables, monthly pattern charts, and monthly exceedance charts. Monthly tables compare an alternative against the No Action Alternative (exceedance values, long-term average, and average by water year type). Monthly pattern charts (long-term average and average by water year type) present all alternatives. Monthly exceedance charts (all months) present all alternatives.

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