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APPENDIX 5A, SECTION A
MODELING TECHNICAL APPENDIX –
MODELING OVERVIEW

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Appendix 5A, Section A

Modeling Technical Appendix – Modeling Overview

A.1 Introduction

This section of Appendix 5A, *Modeling Technical Appendix*, provides an overview of the numerical models and supporting assumptions used for the Delta Conveyance Project Final Environmental Impact Report (EIR). It describes the overall analytical framework and contains descriptions of the key analytical tools and approaches used in the quantitative evaluation of existing conditions, No Project Alternative (2040), proposed project, and project alternatives.

The Delta Conveyance Project (project) includes several main components that will significantly change operations of the State Water Project (SWP) and Central Valley Project (CVP). Most of the alternatives include construction and operation of new north Delta intakes and associated conveyance and changes to the operation of the existing SWP and CVP south Delta export facilities.

For modeling purposes, the Proposed Project and Project Alternatives are simulated at two time horizons or levels of development. First, the Proposed Project and Project Alternatives are imposed on existing conditions—the conditions that existed in year 2020 at the date of issue of the Notice of Preparation (NOP). Second, the Proposed Project and Project Alternatives are imposed on projected year 2040 conditions, i.e., the No Project Alternative (2040). Simulation of future 2040 conditions include the projected effects of climate change, sea level rise, land use change and population growth, and associated changes in water demands and water use.

A.2 Geographical Scope of Analysis

The zone of influence for the technical analysis for the EIR includes:

- The Trinity River above the USGS gage at Lewiston (USGS 11525500).
- The Sacramento River and its tributaries from Shasta Dam to its confluence with the San Joaquin River near Collinsville.
- The Feather River from Oroville Dam to the river's confluence with the Sacramento River.
- The American River from Folsom Dam to the river's confluence with the Sacramento River.
- The Sacramento–San Joaquin Delta (Delta), Suisun Marsh and Bay.
- The SWP service area north of the Delta, as supplied from Barker Slough Pumping Plant.
- The SWP service area south of the Delta, as supplied from Banks Pumping Plant.
- The CVP service area north of the Delta.
- The CVP service area south of the Delta, as supplied from Jones and Banks pumping plants.

A.3 Existing Conditions

For modeling purposes, existing conditions are characterized by the following: (1) current regulatory environment; (2) current facilities, programs, and operational criteria; (3) current water demands and water use; (4) runoff from the mountain and foothill watersheds derived from historical streamflow records; and (5) valley floor surface and subsurface hydrology for current land use. Model assumptions and input data are based on conditions that existed in 2020. Details on these assumptions are contained in Appendix 5A, Section B, *Hydrology and Systems Operations Modeling*.

A.4 No Project Alternative (2040)

For modeling purposes, the No Project Alternative (2040) includes the same facilities and programs that are represented under existing conditions, except that the Yolo Bypass Salmonid Habitat Restoration and Fish Passage Project is added and there are some changes to assumed FERC regulatory requirements for some hydropower projects located in the Sierra Nevada. Surface hydrology, water demands, and Delta conditions are substantially different from existing conditions. They represent changes in land use and urban growth, climate change and sea level rise, as projected to occur by year 2040. Details on these assumptions are contained in Appendix 5A, Section B.

A.5 Proposed Project and Project Alternatives

Model simulations for the proposed project and project alternatives include simulation of intake facilities on the lower Sacramento River, water conveyance through tunnels and forebays, and connection to south Delta SWP and CVP export facilities. Model simulations are characterized by the capacity of the north Delta diversion intakes, SWP and CVP access to the new conveyance, and the connection to existing south-of-Delta facilities, as follows

- Alternatives 1/3: central/eastern alignment, 6,000 cfs, Intakes B and C, SWP only.
- Alternatives 2a/4a: central/eastern alignment, 7,500 cfs, Intakes A, B, and C, SWP 6,000 cfs, CVP 1,500 cfs.
- Alternatives 2b/4b: central/eastern alignment, 3,000 cfs, Intake C, SWP only.
- Alternatives 2c/4c: central alignment, 4,500 cfs, Intakes B and C, SWP only.
- Alternative 5: Bethany Reservoir alignment, 6,000 cfs, Intakes B and C, SWP only.

Alternative 5 is the proposed project. The analysis of water conditions is not affected by the alignment of the proposed project. Therefore, a single model simulation may represent two alternatives that differ only in alignment.

A.6 Overview of Modeling Approach

A suite of numerical modeling tools was developed to support the quantitative assessment of existing conditions, No Project Alternative (2040), proposed project, and project alternatives. To provide a holistic assessment of regional and local project effects, model inputs and outputs were linked through a multi-objective and multi-model framework. Figure 5A-A.1 depicts this modeling framework, highlighting the primary models and flow of data and information between them.

Subsequent sections of Appendix 5A describe each of these models, their major underlying assumptions, and any additional modeled relationships, validation, and calibration that was carried out to adapt the model to the project. Summaries of the models and modeling processes are presented in the sections below. More detailed descriptions are presented in Appendix 5A, Sections B through E.

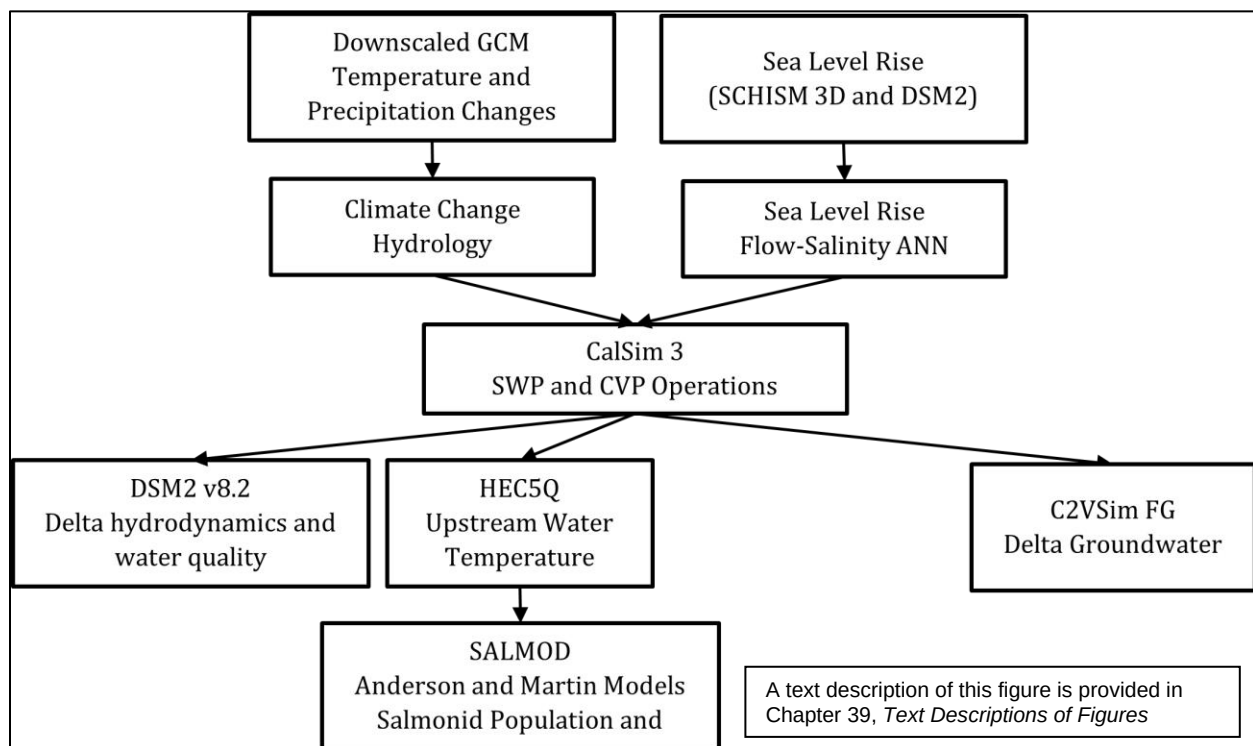


Figure 5A-A.1. Modeling Framework Used to Assess Impacts of the Proposed Project and Project Alternatives

A.7 CalSim 3

The California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) jointly developed CalSim 3 as a planning model to simulate operations of the SWP and CVP over a range of hydrologic conditions. The model represents the best available planning-level analytical tool for SWP and CVP system operations and is an improved and expanded version of CalSim II, which has been the standard planning model for system operations since the early 2000s. The use of CalSim 3 for the EIR is the first application of the new model for environmental

review purposes. A description of CalSim 3 is available from DWR (California Department of Water Resources 2017, 2021a).

Inputs to CalSim 3 include unimpaired inflows and rainfall runoff, agricultural, urban, and wetland water demands, return flows, and groundwater recharge from precipitation and irrigation. Sacramento and San Joaquin Valley and tributary rim basin hydrology are developed using a process designed to adjust the historical sequence of monthly stream flows over a 94-year period (1922–2015) to represent a sequence of flows at existing and future levels of development.

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

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

A.8 Delta Simulation Model 2

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

DSM2 model has three separate components or modules that are run sequentially: HYDRO, QUAL, and PTM. HYDRO simulates velocities and water surface elevations and provides the flow input for QUAL and PTM. HYDRO outputs are used to predict changes in flow rates and depths, and their effects resulting from the proposed project and project alternatives.

QUAL simulates fate and transport of conservative and non-conservative water quality constituents, including salts, given a flow field simulated by HYDRO. Outputs are used to estimate changes in salinity, and their effects resulting from the proposed project and project alternatives.

PTM simulates pseudo three-dimensional transport and fate of neutrally buoyant particles traveling throughout the Delta. The model uses velocity, flow, and stage output from HYDRO to monitor the location of each individual particle using assumed vertical and lateral velocity profiles and specified random movement to simulate mixing. PTM has multiple applications ranging from visualization of flow patterns to simulation of discrete organisms such as fish eggs and larvae. Additional information on DSM2 is available from DWR (California Department of Water Resources 2021b).

A.9 HEC-5Q Temperature Model

HEC-5Q is a generalized FORTRAN-based code that simulates reservoir and river water temperatures based on input storage, flow, and meteorological data. HEC-5Q consists of two model components, HEC-5 and HEC-5Q. HEC-5 is the daily flow simulation component of the model, whereby daily storage and flows are simulated at specific nodes (U.S. Army Corps of Engineers,

Hydrologic Engineering Center 1998). HEC-5Q is the temperature simulation component of the model, where 6-hour input meteorological data (equilibrium temperatures, exchange rates, shortwave radiation, and wind speed) are applied to the simulated storage and flows from the HEC-5 model to simulate water temperatures at specified locations (RMA 1998).

The Trinity-Sacramento River and American River HEC-5Q models used for the project and described below are specific implementations of the general HEC-5Q model described above. Both use (1) inputs derived from CalSim 3 outputs that have been temporally downscaled to daily timeseries, and (2) 6-hour meteorological data derived from observed data. These models were previously used in Reclamation's Biological Assessment for the 2019 Reinitiation of Consultation on the Coordinated Long-Term Operation of the CVP and SWP (Bureau of Reclamation 2019) but have been updated to use CalSim 3 outputs and simulate the same 94-year period as CalSim 3.

A.9.1 Trinity-Sacramento River HEC-5Q Model

The Trinity-Sacramento River HEC-5Q model simulates water temperatures in major reservoirs and river segments on the Trinity River, Clear Creek, the Upper Sacramento River, Stony Creek, and the Sutter Bypass. The model has the capability of simulating the selective withdrawal operations at Shasta Dam and Trinity Dam in order to meet specified tailwater temperature targets. It is the standard planning-level model used for assessing the water temperature effects of CalSim simulated operations on the Sacramento and Trinity rivers.

A.9.2 American River HEC-5Q Model

The American River HEC-5Q model simulates water temperatures for the lower American River from Folsom Dam to the confluence with the Sacramento River. The model has the capability of simulating the selective withdrawal operations at Folsom Dam in order to meet specified tailwater temperature targets. It is the standard planning-level model used for assessing the temperature effects of CalSim simulated operations on the American River.

A.10 Power and Energy Modeling

A.10.1 SWP Power

SWP Power is a spreadsheet-based model that uses output from CalSim 3 to evaluate the effects of the proposed project and project alternatives on power and energy use and power generation at SWP facilities. Energy use is determined using empirical energy factors provided by DWR's Operations Control Office (OCO). Energy generation at SWP facilities is also determined using empirical energy factors provided by the OCO. The model has previously been used to support effects analysis for various projects and programs (Bureau of Reclamation 2019).

A.10.2 LTGen

LTGen is a spreadsheet-based model that uses output from CalSim 3 to evaluate the effects of the proposed project and project alternatives on power and energy use and power generation at CVP facilities. Energy use is determined using empirical energy factors provided by the Western Area Power Authority (WAPA). Similarly, energy generation at CVP facilities is determined using

empirical energy factors provided by WAPA. The model has previously been used to support effects analysis for various projects and programs (Bureau of Reclamation 2019).

A.11 Salmonid Population and Mortality Modeling

A.11.1 SALMOD

SALMOD simulates the dynamics of freshwater salmonid populations, both anadromous and resident. The model is described in Bartholow (2003). The specific SALMOD model application used for the project simulates the life-stage dynamics of fall-run, late fall-run, spring-run, and winter-run Chinook Salmon populations within the Sacramento River, from below Keswick Dam to the decommissioned Red Bluff Diversion Dam. The model uses daily flow and temperature data from the Trinity-Sacramento River HEC-5Q model to simulate the annual growth, movement, and mortality of the various riverine life stages of the four Chinook Salmon populations based on an initial annual adult population that resets each biological year. The dynamics simulated are based on assumptions and relations specified in the model. The final outputs from SALMOD used in the effects analysis are annual production (number of surviving members of each life-stage) and annual mortality based on a variety of factors, including temperature and habitat (flow) based mortality.

A.11.2 Martin and Anderson Egg Mortality Models

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

A.12 Delta Groundwater Model

To facilitate quantitative groundwater analyses, a new integrated groundwater-surface water model, called the Delta Groundwater (DeltaGW) model, was developed. The new model was used to evaluate the potential effects of the proposed project and project alternatives on the groundwater resources in the Delta region.

The DeltaGW model is built on DWR's Integrated Water Flow Model platform (California Department of Water Resources 2020) and simulates land surface processes, groundwater flows, surface water flows, and stream aquifer interactions in response to stresses from water use, land use, and hydrologic variability. The model uses the same model grid structure as the California Central Valley Simulation Fine Grid (C2VSim-FG) model but covers a smaller model domain, which includes the Delta and surrounding areas. Boundary conditions for the DeltaGW model are from

CalSim 3. A detailed description of model development and calibration is provided in Appendix 8A, *Delta Groundwater Model: Development and Calibration*.

A.13 SCHISM

The Bay-Delta SCHISM is a 3-dimensional hydrodynamic model of the San Francisco Bay and Delta. The model was applied for the EIR to investigate the long-term effects of climate change and associated sea level rise on Delta salinity and on Delta outflow needed to comply with current regulatory objectives.

A.14 Data Connections between Models

CalSim 3 outputs are used as inputs to DSM2, HEC-5Q, LTGEN and SWP Power, and DeltaGW. HEC5Q outputs are used as inputs to SALMOD and the Martin and Anderson models. SCHISM is used to develop downstream boundary conditions for DSM2. The goal in each case is for the model receiving the input data to further simulate the environmental consequences of the operation in the model providing the inputs. For example, DSM2 simulates the same Delta inflow and outflow, Delta exports, and Vernalis salinity as CalSim 3 for each month, but generates more spatially and temporally detailed hydrodynamic results for the Delta. Similarly, HEC-5Q uses CalSim 3 outputs for monthly reservoir storage and monthly flows but simulates water temperatures on a 6-hour timestep in order to capture the effects of finer-scale variations in meteorology. The data transfer process generally involves reading CalSim 3 outputs into the following model directly, manually converting those data to a new format needed for inputs, or, in the case of HEC-5Q, using an automated pre-processor to convert CalSim 3 outputs to the proper format and timestep. Some models compute output at a finer time-step than monthly. However, all of the data used are ultimately derived from monthly outputs from CalSim 3, therefore, final results should be aggregated back to a monthly timestep for reporting purposes.

A.15 Appropriate Use of Modeling Results

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

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

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

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

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

A.16 Modeling Limitations

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

A.17 Appendix Organization

Appendix 5A, *Modeling Technical Appendix*, is organized as follows:

- Section A, *Modeling Overview*, (this section) provides an overview of the numerical modeling tools described in this appendix.
- Section B, *Hydrology and Systems Operations Modeling*, describes the CalSim 3 model, its simulation of SWP and CVP operations, and its assumptions, including climate change. It includes five attachments:
 - Attachment 1, *CalSim 3 State Water Project and Central Valley Project Contract Assumptions*
 - Attachment 2, *CalSim 3 Regulatory Assumptions and State Water Project/Central Valley Project Operations Criteria*
 - Attachment 3, *CalSim 3 Model Results for Existing Condition and Alternatives at 2020*
 - Attachment 4, *Climate Change Development for Delta Conveyance Project*
 - Attachment 5, *CalSim 3 Model Results for No Project Alternative and Alternatives at 2040*
- Section C, *DSM2 One-Dimensional Delta Hydrodynamics and Water Quality Modeling Results*, describes the DSM2 model, application of its three modules, and its assumptions.
 - Attachment 1, *DSM2 Model Results for Existing Condition and Alternatives at 2020*
 - Attachment 2, *DSM2 Model Results for No Project Alternative and Alternatives at 2040*

- Section D, *Water Temperature Modeling Results*, describes the HEC-5Q Trinity-Sacramento and American models, major assumptions and inputs, and the simulation methods for water temperatures. Results are included in two attachments:
 - Attachment 1, *HEC-5Q Model Results for Existing Condition and Alternatives at 2020*
 - Attachment 2, *HEC-5Q Model Results for No Project Alternative and Alternatives at 2040*
- Section E, *SALMOD and Egg Mortality Models*, describes the SALMOD model and the Martin and Anderson salmonid mortality models, including assumptions and modeling equations. Results are included in four attachments:
 - Attachment 1, *SALMOD Model Results for Existing Condition and Alternatives at 2020*
 - Attachment 2, *Martin and Anderson Model Results for Existing Condition and Alternatives at 2020*
 - Attachment 3, *SALMOD Model Results for No Project Alternative and Alternatives at 2040*
 - Attachment 4, *Martin and Anderson Model Results for No Project Alternative and Alternatives at 2040*
- Section F, *Sea Level Rise and Delta Water Quality Modeling*, describes an investigation of Delta water quality response to an ensemble of seven sea level rise using the SCHISM model.

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