2. Modeling Methodology Overview

The potential effects of the FRWP and alternatives on California's surface water system were evaluated using a suite of state-of-the-art computer simulation models. This section provides an introduction to how these simulations were performed. In-depth discussion of each modeling tool, including assumptions and results, is provided in the following sections of this appendix.

The operation of the simulation models used for the FRWP analyses were linked through the exchange of information between the models. Figure 2-1 displays in a general sense how the models interacted. The appendix section containing detail for each model is also indicated.

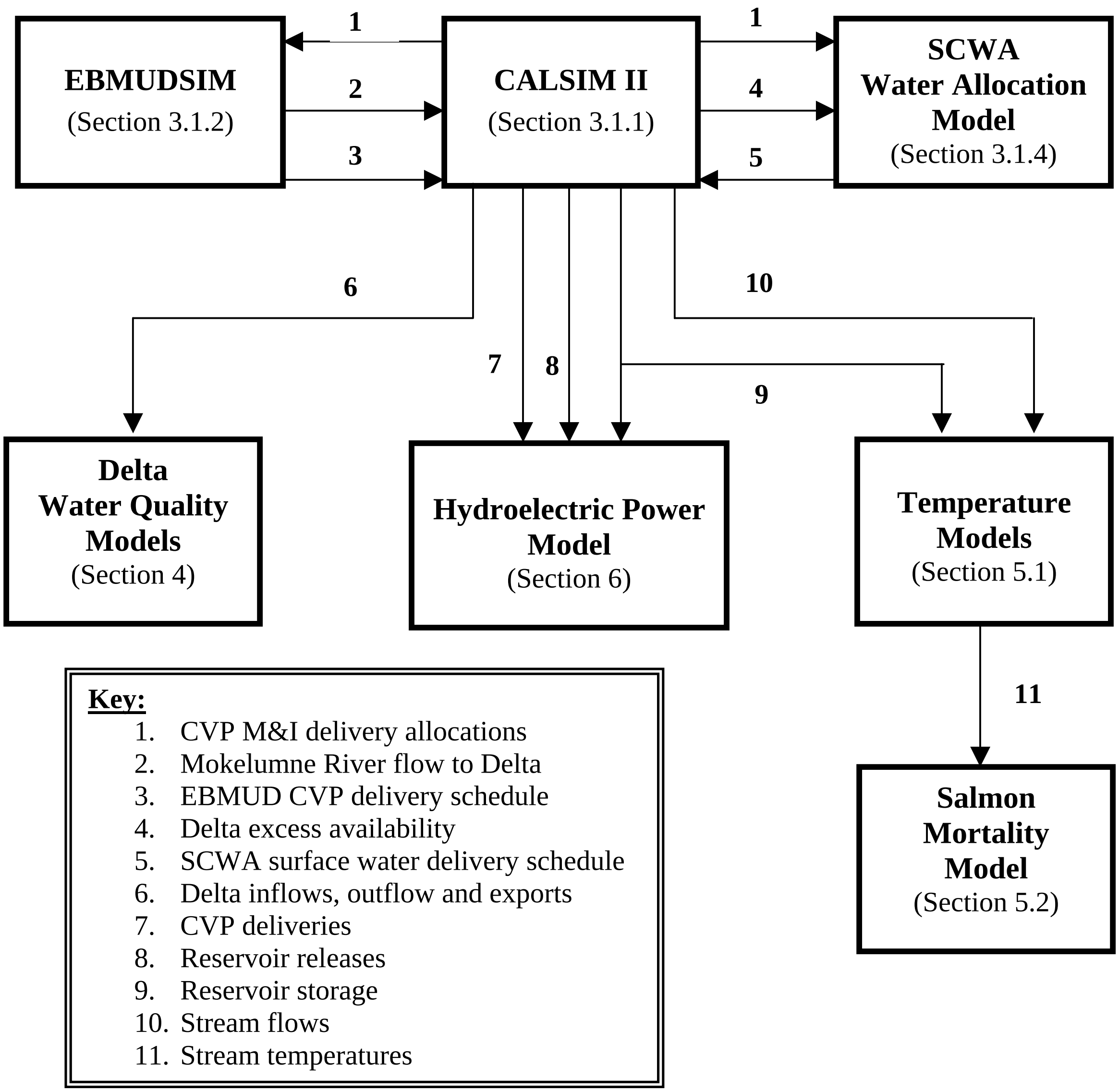

Figure 2-1   Information Exchange Between FRWP Simulation Models

2.1 SURFACE WATER AND RESERVOIR OPERATIONS MODELING

The first modeling step was to simulate the hydrologic effects of the proposed project and alternatives on the surface water system. This system is composed of both natural water bodies (rivers and streams) and constructed facilities (reservoirs and diversions). Hydrologic effects include changes in stream flow, reservoir levels, and water deliveries. Water is a highly valued resource in California. Consequently the hydrologic system within the potential zone of influence of the FRWP is managed carefully to provide for multiple beneficial uses of water; including aquatic habitat, water supply, power production, and recreation. Therefore the hydrologic models used for this analysis must take into account and integrate many water supply priorities and constraints.

2.1.1 CVP/SWP System

The Central Valley Project (CVP) operated by the US Bureau of Reclamation (USBR) and the State Water Project (SWP) operated by the California Department of Water Resources (DWR) constitute the bulk of the water supply in California and have the most significance on surface-water-related environmental considerations.

The current planning model used by DWR and USBR is CALSIM II, a general-purpose simulation model of the combined CVP/SWP systems, as well as a host of smaller water supply entities with which the CVP/SWP systems interact. A geographically comprehensive model, CALSIM II includes the Sacramento River basin, the San Joaquin River basin, and the Delta, as well as portions of the Tulare Basin and Southern California. The model was developed jointly by DWR and USBR, and replaces DWRSIM and PROSIM, earlier hydrologic planning models for the CVP/SWP systems. CALSIM II provides a platform for assessing changes in Delta water quality and water supply operations of the CVP and SWP projects.

2.1.2 EBMUD System

The East Bay Municipal Utilities District (EBMUD) currently owns two reservoirs within the Mokelumne River watershed (Pardee and Camanche Reservoirs) and operates them to provide on average 95% of its current water supply, as well as meet downstream environmental and water supply requirements. To increase the dry-year supply reliability of its water supply system and provide greater operational flexibility, EBMUD is proposing to enhance this system by accessing CVP contract water from the Sacramento River through a diversion at Freeport. As an alternative to this approach, the modeling explores enlarging Pardee Reservoir to increase the yield of EBMUD's Mokelumne River water supply.

EBMUDSIM is the planning model used by EBMUD for simulating its Mokelumne River system (i.e. operational decisions and constraints for Pardee Reservoir, Camanche Reservoir, the Mokelumne River, and the Mokelumne Aqueduct; as well as EBMUD demands). Because it allows for more detailed analysis of Mokelumne system operations, EBMUDSIM was used to model the Mokelumne River system for the FRWP studies, instead of the more generalized representation of the system in CALSIM II. EBMUDSIM was also used to determine the timing of EBMUD's diversions at Freeport, taking into account the provisions of EBMUD's amendatory

CVP water supply contract. Interactions between EBMUDSIM and CALSIM II are outlined in a later section of this appendix.

A separate model of Pardee and Camanche Reservoir operations was used to assist in the evaluation of project alternatives that involved enlargement of either reservoir. This spreadsheet model, developed by Jones & Stokes, uses a daily time step. The daily model was not integrated with CALSIM II studies, but was useful for feasibility analyses and to refine operating rules.

2.1.3 SCWA System

The Sacramento County Water Agency (SCWA) currently relies on a combination of groundwater supplies and CVP contract water from the Sacramento River, which it diverts at the City of Sacramento's water treatment facility immediately downstream of the American River confluence. SCWA is seeking to increase surface water supplies from several sources to both meet increasing water demands within its jurisdiction and to ensure sustainable groundwater yields in the future. SCWA proposes to accomplish this goal by adding a diversion at Freeport on the Sacramento River. SCWA's ability to operate its surface water and groundwater supplies conjunctively will give SCWA the flexibility to divert more of its surface water in wet years when impacts to other water users and environmental interests are minimized.

Utilizing a diversion at Freeport offers SCWA access to the remainder of its current CVP "Fazio" contract amount (15 TAF/yr), presently limited by the existing biological opinion. CVP contract water reassigned from the Sacramento Municipal Utility District, up to an additional 30 TAF/yr, would also be diverted at Freeport.

A second potential supply source for SCWA is appropriative rights to natural flows that are available when excess water conditions exist. Excess water conditions exist when releases from upstream reservoirs plus unregulated flow exceed existing legal uses of water in the Sacramento Basin, including water required to meet Sacramento-San Joaquin Delta water quality standards, plus exports.

A third SCWA surface water supply source is "Other Water" obtained through transfers or an additional appropriation of water. In the CALSIM II model, "Other Water" is not limited to appropriations when excess water conditions exist, but also includes diversions of unregulated flow when there are balanced water conditions. Balanced water conditions exist when releases from upstream reservoirs plus unregulated flow approximately equal the water supply needed to meet legal uses of water in the Sacramento Basin, plus exports. Treating "Other Water" in this manner provides a "worst-case" estimate of the impact of SCWA "Other Water" diversions on the state water resources system, since such diversions have the potential to impact CVP/SWP operations and supplies.

A spreadsheet model developed for SCWA was utilized to determine the mix of the various surface water supplies and groundwater, based upon diversion capacities at the two diversion points on the Sacramento River, CVP contract allocations, and Delta Excess water availability. These diversion patterns were then used in CALSIM II to estimate system changes.

2.1.4 Modeling Framework

The surface water analysis for the FRWP involves the interaction of the three principal models listed above. A description of the modeling methodology used for the FRWP analyses can be found in Section 3 of this appendix. Section 3.3 specifically addresses interaction of the surface water models.

Although CALSIM II includes a simplified representation of the Mokelumne River system, EBMUDSIM provides more detailed analysis of the effects of Mokelumne River operations on the Delta and upstream users, and captures the dynamic nature of EBMUD's operation of the proposed FRWP diversion and the Mokelumne River system. CALSIM II and EBMUDSIM interact in two locations, as shown in Figure 2.1.4-1. Mokelumne River flows into the Delta, determined using EBMUDSIM, are modeled as an inflow time series in CALSIM II. The schedule of Freeport diversions for EBMUD is also generated by EBMUDSIM, utilizing CVP delivery allocations determined using CALSIM II. Diversions for EBMUD at Freeport, modeled as an EBMUD demand pattern in CALSIM II, are conveyed to the Mokelumne Aqueducts via the Folsom South Canal. While these deliveries may affect Mokelumne River flows into the Delta, as determined using EBMUDSIM, there are no direct return flows to the Sacramento River from EBMUD surface diversions at Freeport.

The SCWA allocation model provides a level of detail and control in SCWA operations that would be difficult to obtain by modeling SCWA demands and diversion patterns directly in CALSIM II. Similar to the CALSIM II/EBMUDSIM interaction, output from the SCWA model is input into CALSIM II as CVP and “Other Water” diversion patterns, based upon estimated Delta Excess availability from previous CALSIM II results. CALSIM II is structured to divert Excess water, subject to availability and diversion capacity, to meet surface water demands unmet by SCWA CVP and “Other Water”. Return flows associated with SCWA diversions are calculated by CALSIM II and re-enter the river downstream of the Freeport diversion.

Due to the interactions of CALSIM II and the EBMUD and SCWA system models, iterations of modeling were required for each modeling case, until the values shared by the models closed.

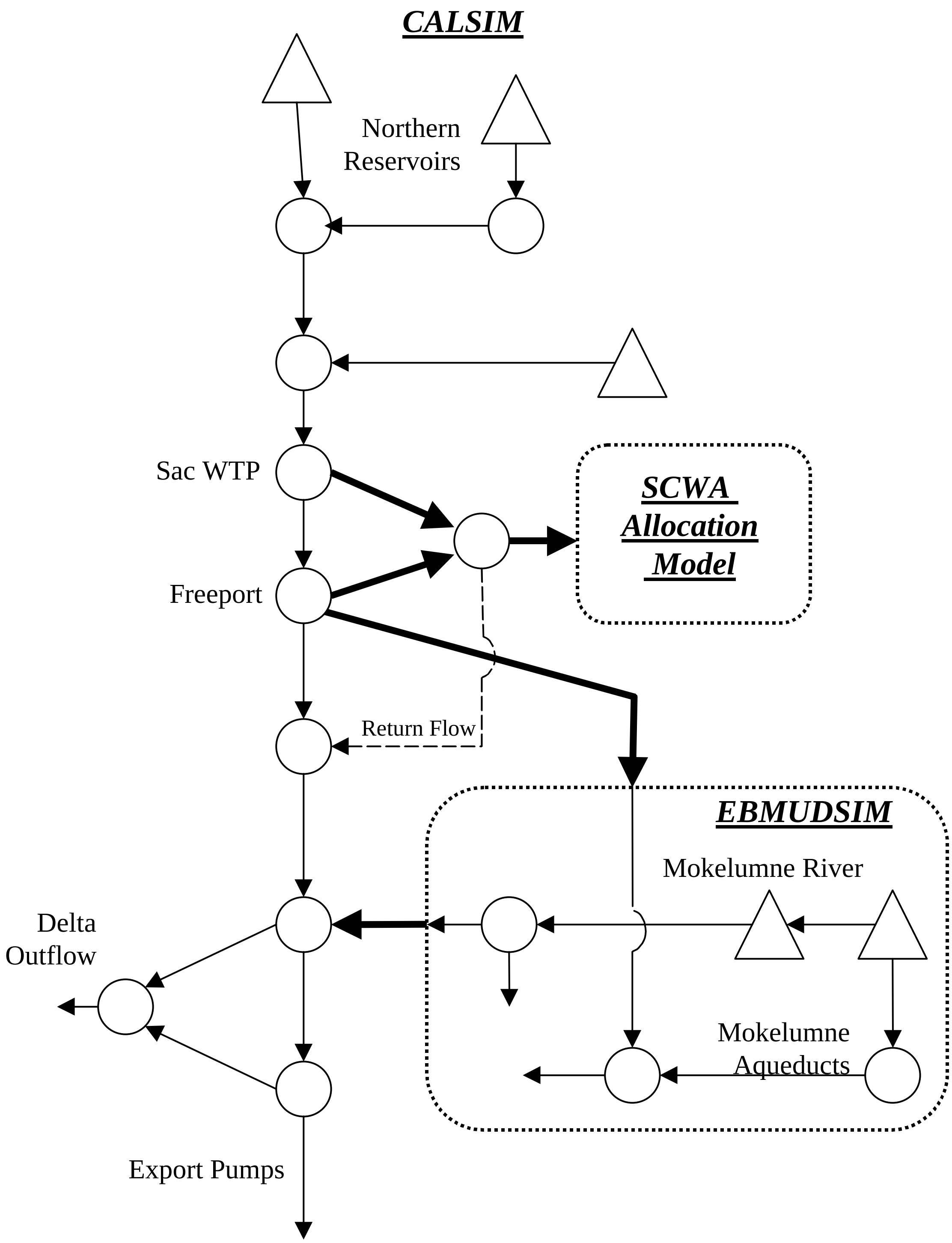

Figure 2.1.4-1 FRWP Surface Water and Reservoir Operations Model Interactions

2.2 WATER QUALITY MODELING FOR THE SACRAMENTO-SAN JOAQUIN DELTA

Five water quality models were utilized to simulate potential salinity changes in the Sacramento-San Joaquin Delta. These models, listed in order of complexity, are:

- Outflow-X2 model of Kimmerer and Monismith
- Outflow-salinity model of the Contra Costa Water District (the "G-model")
- Artificial Neural Network (ANN) Algorithm of the Department of Water Resources
- Fischer Delta Model (Hugo B. Fischer, Inc.)
- Delta Simulation Model II (DSM2) of the Department of Water Resources

The X2 model and the Artificial Neural Network are incorporated in CALSIM II. The other models were run separately, utilizing hydrologic output from the FRWP CALSIM II studies.

Potential impacts of salinity on disinfection byproducts formation were estimated using two empirical relationships based on regression of data from a pilot treatment plant.

2.3 TEMPERATURE AND SALMON MORTALITY MODELING

River flow and reservoir storage results from the hydrologic modeling, as well as historic climatic data, were input into USBR's temperature models for the Sacramento, Feather and American Rivers. These models simulated monthly mean temperatures in key reservoirs and each of the rivers at several locations. The temperature model utilized for the FRWP analysis is identical to the version used by USBR for its OCAP.

Results from the temperature modeling were used by USBR's salmon mortality model. This modeling simulated the effects of the FRWP alternatives on egg survival and early life stages of chinook salmon.

2.4 HYDROELECTRIC POWER MODELING

Hydroelectric power generated and utilized by the CVP was simulated using LongTermGen, a spreadsheet model recently developed by the Western Area Power Administration. This model utilizes output from CALSIM II to simulate power generation at 11 hydroelectric power plants directly affected by operation of the CVP. The model takes into account transmission losses and utilization of power to operate the CVP to estimate net power available for sale. USBR Central Valley Operations has reviewed LongTermGen and approved of its use.

2.5 REVERSE FLOW MODELING FOR THE SACRAMENTO RIVER

To support screening of possible FRWP intake locations and to refine planning for project operations, a river transport model for the Sacramento River near Freeport was utilized. The focus of this modeling was on two representative "worst case" reverse flow periods. The model used was originally developed for use in the Sacramento Regional Wastewater Treatment Plant Expansion DEIR.

Results of the reverse flow modeling included the percentage of wastewater effluent that could be present at the FRWP intake location during the severe reverse flow events simulated, as well as the duration of the reverse flow events.

2.6 MODELING SCENARIOS EVALUATED FOR THE FREEPORT REGIONAL WATER PROJECT

As described in the FRWP DEIR/EIS report, three modeling scenarios were considered in the impact analysis. Each scenario was modeled for existing and future conditions. In combination, this resulted in six sets of modeling studies.

2.6.1 Alternatives

The FRWP EIR/EIS evaluates six primary alternatives. For the purposes of modeling, this required the following three modeling cases:

Alternative 1, the "No Action" alternative, does not include the FRWP and thus represents the state of both the EBMUD/Mokelumne and the CVP/SWP systems without operation of the FRWP. SCWA diversions under this scenario are limited to those made at the Sacramento River Water Treatment Plant, subject to the limitations of SCWA's current Biological Opinion for its "Fazio" CVP contract. Alternative 1 provides a basis for comparison with the "Action" alternatives. Alternative 1 modeling for existing conditions is identical to the OCAP "Today" studies.

Alternatives 2-5 are the Joint Project alternatives, representing joint operations of EBMUD and SCWA at the Freeport diversion. As described in Chapter 2 of the FRWP DEIR/EIS, Alternatives 2, 3, 4 and 5 differ only in the pipeline alignment they include. Operation of these four alternatives is identical, so a single modeling scenario can cover them all. In this modeling case, EBMUD diverts CVP water when its forecasted reservoir storage is below the trigger set in its amendatory CVP water supply contract. In the modeling studies for Alternatives 2-5, it has been assumed that EBMUD diversions will be taken as early as allowable (starting on March 1, the first day of the CVP contract year, March 1) and at the full rate allocated to EBMUD (100 mgd). SCWA annual diversions fluctuate based on CVP contract allocations, available excess flows, and "Other Water" needs.

Alternative 6 is the SCWA Freeport/Enlarged Pardee alternative. In this alternative EBMUD does not divert water at Freeport, but instead obtains greater supply reliability through enlarging the capacity of Pardee Reservoir from 190 TAF to 360 TAF and by modifying Mokelumne River release operations. SCWA operations at Freeport for this alternative are assumed to be identical to Alternatives 2-5.

More detailed discussion of modeling assumptions for each alternative is contained in Section 3 of this appendix, particularly Section 3.2.

2.6.2 Level of Development

In order to assess system-wide effects of the FRWP alternatives under existing and future conditions, each alternative was modeled at both 2001 and 2020 levels of development, under demands and hydrology as determined by the California Department of Water Resources Bulletin 160-98. The 2001 level-of-development studies were the primary studies used for impact assessment in the EIR/EIS. The 2020 level-of-development studies were used for the cumulative impact analysis.

The following table describes how the levels of development and demand were structured for each of the studies.

Table 2.6.2-1. Level of Development and Demands for FRWP Modeling Analyses

Study	Existing Condition	Future Condition
Alternative 1 (No Action)	**CVP/SWP system and Mokelumne River watershed**: 2001 Level of Development[1] **EBMUD:** 2001 demand level[2], no Freeport diversion **SCWA:** 2001 demand level[3], no Freeport diversion	**CVP/SWP system and Mokelumne River watershed**: 2020 Level of Development[1] **EBMUD:** 2020 demand level[2], no Freeport diversion **SCWA**: 2020 demand level[3], no Freeport diversion
Alternatives 2-5 (Joint Project)	**CVP/SWP system and Mokelumne River watershed**: 2001 Level of Development **EBMUD:** 2020 demand level[2], Freeport diversion **SCWA**: "Build-Out" demand level[3], Freeport diversion	**CVP/SWP system and Mokelumne River watershed**: 2020 Level of Development **EBMUD:** 2020 demand level[2], Freeport diversion **SCWA**: "Build-Out" demand level[3], Freeport diversion
Alternative 6 (SCWA at Freeport, Enlarged Pardee Reservoir)	**CVP/SWP system and Mokelumne River watershed**: 2001 Level of Development **EBMUD:** 2020 demand level[2], no Freeport diversion **SCWA:** "Build-Out" demand level[3], Freeport diversion	**CVP/SWP system and Mokelumne River watershed**: 2020 Level of Development **EBMUD:** 2020 demand level[2], no Freeport diversion **SCWA**: "Build-Out" demand level[3], Freeport diversion

[1] Bulletin 160-98 (DWR 1998)
[2] Urban Water Management Plan 2000 (EBMUD 2001)
[3] Draft Zone 40 Water Supply Master Plan (SCWA 2002)

The FRWA member agencies were conservative in estimating impacts by assuming future demand levels in the existing condition modeling studies for the action alternatives (Alternatives 2-5 and Alternative 6).

EBMUD's average annual current customer demand was assumed to be 220 mgd (196 TAF/yr). This demand level was applied only to the Alternative 1 existing condition study. For all other studies, the average annual demand for EBMUD was assumed to be 228 mgd (255 TAF/yr), EBMUD's projected demand in 2020.

Current surface water demand for SCWA was assumed to be 5.7 mgd (6.3 TAF/yr). SCWA future, or "Build Out" total potable water demand, has been estimated to be 98 mgd (109.5 TAF/yr). Annual average surface water diversions of at least 68.5 TAF/yr are needed to prevent annual long-term average groundwater pumping from exceeding a sustainable yield of 41

TAF/yr. SCWA's build out demand is expected to occur sometime between 2030 and 2050, depending on the rate of growth in SCWA's service area.

Use of future project demands with existing level of development by others is appropriate for the EIR/EIS impact assessment because it provides for analysis of the full project against existing conditions, thereby fully analyzing the environmental effects of the entire project without including major (and likely speculative) assumptions about what other projects and water uses may be developed in the future.

2.6.3 Simulation period hydrology

A hydrologic sequence based on historical hydrology developed by DWR is utilized for these analyses. This hydrology is adjusted to a projected 2001 and 2020 level of development and extends from Water Year 1922 through 1994. (Water Year begins on October 1.) The sequence of hydrologic events in the adjusted historic record is considered to be representative of conditions the system might encounter currently or in the future. This method is preferred over an explicitly stochastic modeling approach, since such an approach would be highly data-intensive and complex for such a large-scale system.

This 73-year period encompasses several drought periods, including WY 1928-1934, WY 1977-1978, and WY 1987-1992. In most cases, dry-year results reported in later sections of this appendix are extracted from the WY 1928-1934 period, since this dry period is one of the longest on record, and wet conditions preceding WY 1928 result in full reservoirs at the beginning of the period, eliminating operational effects from previous years. Results for other dry periods are also presented in this appendix for particular parameters.

2.7 APPLICATION AND LIMITATIONS OF MODELING RESULTS TO ESTIMATES OF IMPACTS ON BENEFICIAL USES

The FRWP EIR/EIS assesses the potential impacts of the FRWP on a wide variety of environmental considerations. Due to the complexity and integration of water supply and quality considerations in California and their ramifications on target fish populations, appropriate hydrologic and water quality models are important for quantifying the potential effects of the FRWP. This approach provides a more rigorous assessment than qualitative impact estimates.

CALSIM II, EBMUDSIM, the SCWA Water Allocation Model, and the various water quality models utilized for the FRWP modeling analysis are state-of-the-art planning models that provide generalized insight on project and environmental effects as a result of the FRWP alternatives. Though providing quantitative insights, planning models differ from actual project operations in several ways (as outlined in the following paragraphs). Proper interpretation of planning model results presented in this appendix therefore requires exercise of professional experience and judgment.

Because of the difficulty of incorporating complex operating criteria into long-term planning scenarios, CALSIM II, EBMUDSIM, and the SCWA Water Allocation models, as is typical of planning models in general, use a monthly time step and simplified system representations. The models used in this analysis use a monthly time step, whereas actual operational decisions may be formulated on weekly, daily, or hourly time steps. Operational adjustments on time steps less than one month, such as flood control spills or diurnal hydropower operations, are assumed to be included in monthly averaged storages, releases, and streamflows. Inputs and results are therefore monthly averages. Operations and calculations in these models are based on generalized monthly operational rules. Interpretation of results from planning models must therefore consider this lower "resolution" and conclusions must remain generalized in nature.

CALSIM II assumes average monthly flows to meet instream flow requirements and contract demands. If streamflows vary during the month, some daily and weekly flows will exceed the minimum requirements/demands and others will not meet the minimum requirements/demands. In actuality, additional water may need to be released to meet minimum requirements/demands if the streamflow fluctuations are due to uncontrolled events (e.g. as flood releases from a reservoir and local accretions due to precipitation).

As a monthly model, CALSIM II does not account for the travel time associated with reservoir releases for downstream requirements. In actuality, reservoir releases must be made hours or days in advance of a downstream requirement. If it rains before the released water reaches the required location and the resultant streamflows increase, more water than necessary may have been released to meet the requirement. CALSIM II uses perfect foresight on a monthly basis and therefore may underestimate the water volume that would be spent during a month trying to maintain a minimum flow requirement.

The simplified representation of allocation procedures in CALSIM II does not explicitly consider many policies regarding storage targets and pumping limitations. This results in situations where allocations may use supplies more efficiently than forecast uncertainty and operational policies may actually allow. Conversely, because of loss of detail, local and specific conditions may not be recognized.

Unlike operations models, which would be infeasible to simulate long-term periods, planning models do not describe operations in absolute terms. Results from a single study, therefore, should not be presented as "stand alone" output, e.g. model output should always be presented in comparison with output from other studies. As such, CALSIM II is not designed to *predict* system river, reservoir, or water quality conditions based upon simulated operational decisions, but instead provides relative magnitudes and timing of "with FRWP" effects compared to "without FRWP".

Since CALSIM II is not designed to predict operations and flows, results from individual months should be considered only in the context of overall trends and averages. CALSIM II represents operational or regulatory thresholds through the use of step functions. Due to CALSIM II's dynamic responses to system conditions, slight changes in model inputs or operations could trigger responses which may significantly vary on an individual monthly basis from the ”No-Action” simulation to the “With Project” alternative simulation. These dynamic responses, however, often average out over longer time periods. It is these longer-term trends that are useful in determining potential impacts of the FRWP on the SWP/CVP system. Therefore, it is most appropriate to interpret results of CALSIM II and the models utilizing those results by evaluating averages over a suitable period (season, year, drought) or exceedence, rather than focusing on a single monthly value.

CALSIM II, in conjunction with EBMUDSIM, the SCWA Water Allocation Model, the Delta water quality models, the temperature models, the salmon mortality model, and the hydroelectric generation model provide indices for:

- FRWP water supply reliability
- Reservoir storage
- River flows and temperatures
- Delta water quality and exports
- Water supply reliability for other CVP/SWP users
- Hydroelectric power generation

The models utilized in the FRWP analysis represent the best tools and information available for hydrologic and water quality impact assessments for both the EBMUD and SCWA systems, as well as the integrated CVP/SWP systems.