# Chapter 9 Modeling and Assumptions

A suite of simulation models were used to analyze effects of proposed Central Valley Project (CVP) and State Water Project (SWP) operations on steelhead, coho salmon, delta smelt, green sturgeon, and winter-run and spring-run Chinook salmon. This chapter presents the modeling tools, study assumptions, sensitivity and uncertainty evaluations, and limitations. In addition, key simulated summary results are included under a range of assumed conditions.

The following simulation models were used to quantify effects:

- Hydrologic- (CalSim-II and CalLite)
- Delta Hydrodynamics - (DSM2)
- Temperature - (Reclamation Temperature, Sacramento Rivers Water Quality Management [SRWQM], and Feather River)
- Salmon Mortality, Population, and Life Cycle - (Reclamation Mortality, SALMOD, and Interactive Object-Oriented Salmon Simulation [IOS])
- Climate Change and Sea Level Rise - (Sensitivity Analysis)
- Sensitivity and Uncertainty - (CalSim-II)

Modeled future assumptions changes in operations expected to affect the CVP and SWP are:

- Limited Environmental Water Account Program
- Lower Yuba River Accord
- Freeport Regional Water Project
- Level of development (full contract/Table A demand in future)
- Sacramento River Water Reliability Project
- American River Flow Management
- New Melones Draft Transitional Operation Plan
- The California Aqueduct (CA) and Delta-Mendota Canal (DMC) Intertie
- South Delta Improvement Project Stage 1 (permanent gates)
- Red Bluff Diversion Dam

The modeling is comprised of studies that represent the following range of conditions:

- Present
- Near Future
- Future
- Future with climate change and sea level rise

The Operations Criteria and Plan (OCAP) Biological Assessment (BA) modeling is defined as the quantitative simulation of the CVP and SWP (within the extent possible, using the best available tools) to identify if a current action or proposed action may affect listed or proposed species, or designated or proposed critical habitat which is protected by the Endangered Species Act (ESA). The following general metrics were identified to prepare this biological assessment:

- River flows
- Reservoir storage
- Sacramento-San Joaquin Delta exports, hydrodynamics, and salinity
- River temperature
- Salmon life cycle and mortality

The objective was to provide the above identified metrics resulting from the CVP and SWP system operations under various hydrologic and assumed conditions (see Studies and Assumptions). Specific metrics used in the evaluation of the biological effects analysis are identified and discussed in Chapter 11: Upstream Effects and Chapter 13: Delta Effects.

# Modeling Methods

Model simulations describe water surface storage, conveyance, water quality, temperature, and salmon lifecycle and mortality for the Central Valley and Sacramento-San Joaquin Delta. The suite of simulation models developed and/or applied by Reclamation and DWR include:

- Statewide planning model of water supply, stream flow, and Delta export capability (CalSim-II and CalLite)
- Sacramento-San Joaquin Delta hydrodynamics and particle tracking (DSM2)
- River temperature (Reclamation Temperature, SRWQM, and Feather River Model)
- Salmon mortality (Reclamation Mortality, SALMOD, and IOS)

Specific model methodologies for CalSim-II, DSM2, temperature models, salmon models, climate change and sea level rise, and sensitivity and uncertainty are briefly described in the sections below.

The modeling process for this BA uses a tiered approach where models function independently and are not dynamically linked. After CalSim-II modeling results were complete, they were used as input to the DSM2 model to find hydrodynamic conditions in the Delta. CalSim-II results were also used in temperature models that provide estimates of mean monthly temperatures at a variety of locations and mean daily temperature at select locations along CVP- and SWP-influenced rivers. Modeled temperatures were then compared to thermal criteria for specific life stages in the months when they would be present in the given river as the primary means of assessing potential effects of proposed CVP and SWP operations. These results were used to assess potential effects for proposed CVP and SWP export operations. This process is used to maintain consistency amongst the model results. The models and data flow are graphically shown in Figure 9-1. A list of temporal model characteristics is presented in Table 9-1.

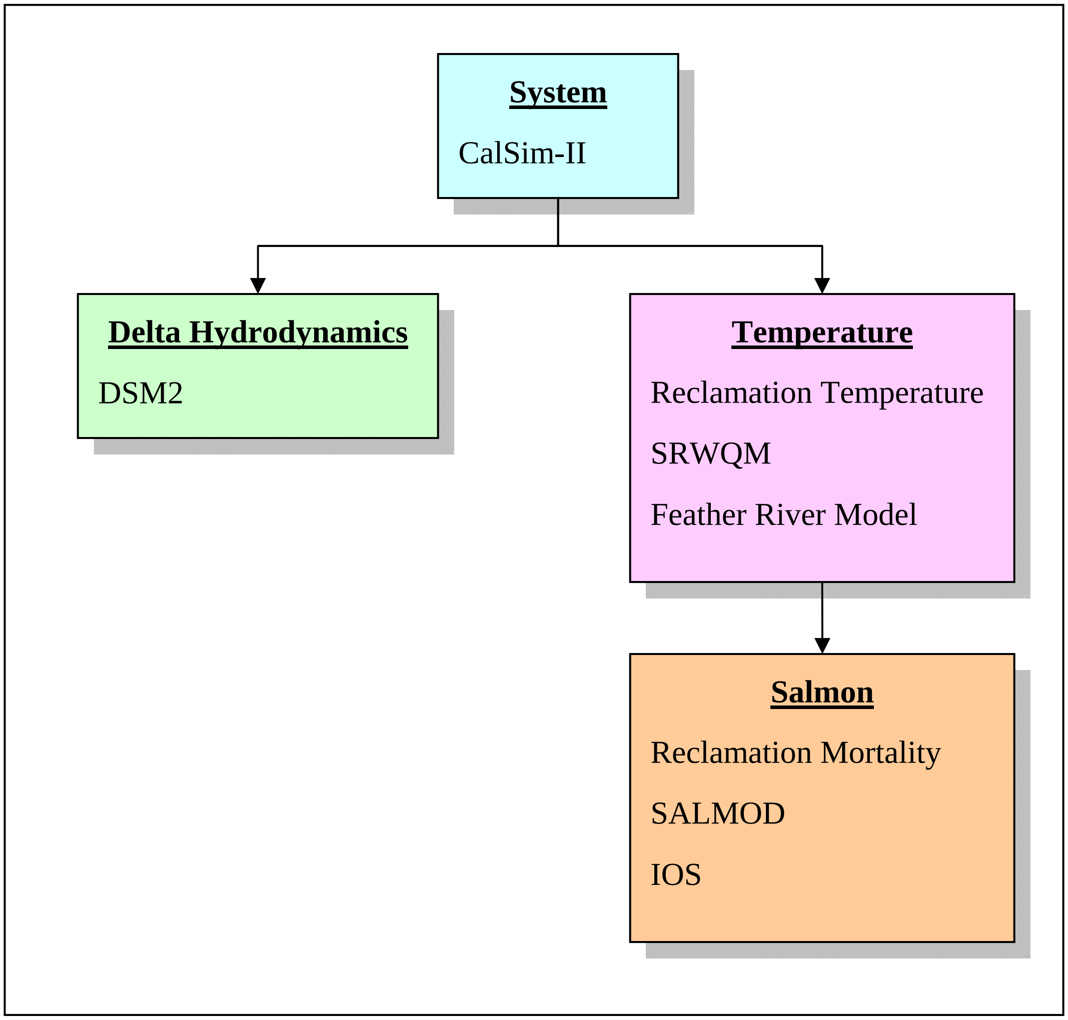



**Figure 9-1 OCAP BA Model Information Flow**

**Table 9-1 Temporal and Simulation Characteristics**

| Model | Model Time Step | Simulation Period (Water Year) |
|---|---|---|
| CalSim-II | Monthly | 1922-2003 |
| DSM2 | 15 minute | 1976-1991 |
| Reclamation Temperature | Monthly | 1922-2003 |
| SRWQM | 6 hour | 1922-2003 |
| Feather River Model | 1 hour | 1922-1994 |
| Reclamation Mortality | Daily | 1922-2003 |
| SALMOD | Weekly | 1922-2003 |
| IOS | Daily | 1923-2002 |

The simulation results of the OCAP BA are designed for a comparative evaluation because the CalSim-II model uses generalized rules to operate the CVP and SWP systems and the results are a gross estimate that may not reflect how actual operations would occur. Generalizations are also made for various programs based on adaptive management that are too dynamic in nature to codify or capture the wide spectrum of factors used in actual decision making. Results should only be used as a comparative evaluation to reflect how changes in facilities and operations may affect the CVP-SWP system. Biological effects assessing future conditions in the OCAP BA using simulated results were based on comparative evaluations. While models can provide useful insight to complex systems or overcome the deficiencies of incomplete observed data, they are a simplification of the true system or natural processes and yield results with limitations (see Modeling Limitations).

The model appendices (Appendices D, F, H, J, L, N, P, and R) document efforts to demonstrate tangible measures of OCAP BA modeling adequacy, credibility, data quality, model testing, sensitivity, and uncertainty. The results presented (Appendices E, G, I, K, M, O, Q, S, and T) are the product of the best science available at the time this document was prepared. For example, CalSim-II is the SWP-CVP simulation model developed and used by the DWR and the Reclamation. CalSim-II represents the best available planning model for the CVP-SWP system as quoted in the April 9, 2004, Draft Response Plan from the CALFED Science Program Peer Review of CalSim-II:

> *"As the official model of those projects, CalSim-II is the default system model for any inter-regional or statewide analysis of water in the Central*

*Valley…California needs a large-scale relatively versatile inter-regional operations planning model and CalSim-II serves that purpose reasonably well."*

## Hydrologic Modeling Methods

The objective of the hydrologic models is to simulate the CVP and SWP project operations with a set of historical hydrology (water-years 1922 to 2003) with existing and assumed future conditions. These results provided the inputs to hydrodynamic and temperature models that assist in the fisheries effects evaluations of alternative CVP/SWP operations. Both the CalSim-II and CalLite models produce monthly results. These results are used to examine the seasonal and water year type (Wet, Above Normal, Below Normal, Dry, and Critical) trends in a comparative manner (as described previously).

### CalSim-II

The CalSim model is a water resources simulation planning tool developed jointly by DWR and Reclamation. The CalSim-II model is applied to the SWP, the CVP, and the Sacramento and San Joaquin Delta (Figure 9-2). The model is designed to evaluate the performance of the CVP and SWP systems for: existing or future levels of land development, potential future facilities, current or alternative operational policies and regulatory environments. Key model output includes reservoir storage, instream river flow, water delivery, Delta exports and conditions, biological indicators, and operational and regulatory metrics.

CalSim-II simulates 82 years of hydrology for the region spanning from water year 1922 to water year 2003. The hydrology data is composed of assumed water demands, stream accretions and depletions, stream-groundwater interaction, rim basin inflows, irrigation efficiency, return flows, and non-recoverable losses. The model employs an optimization algorithm to find routing solutions on monthly time step. The movement of water in the system is governed by an internal weighting structure to ensure regulatory and operational priorities. The Sacramento and San Joaquin Delta (Delta) is also represented by DWR's Artificial Neural Network (ANN), which simulates flow and salinity relationships. Delta flow and electrical conductivity is also reported at key regulatory locations. Details of the level of land development (demands) and hydrology and ANN are discussed in Appendix D.

CalSim-II water deliveries are simulated for water contractors based on a method that estimates the actual forecast allocation process. The North of Delta (NOD) and South of Delta (SOD) deliveries for both the CVP and SWP contractors are determined using a set of rules for governing the allocation of water. CalSim-II uses a water supply and water demand relationship to find delivery quantities given available water, operational constraints and desired reservoir carryover storage volumes. Additional details of the delivery allocation process are available in Appendix D.

CalSim-II simulates a suite of environments to represent the CVP and SWP systems. The regulatory environments consist of the SWRCD D-1485, and the D-1641 (also referred to as the 1995 Water Quality Control Plan "WQCP"). These two environments are necessary for the determination of the CVPIA (b)(2) regulatory environment which implements fish protection actions and is next in the sequence. Following the (b)(2) environment is the conveyance step (formerly known as the Joint Point of Diversion (JPOD)) where water is exported or "wheeled" at the Delta pumping facilities. Next is the Transfers environment. This environment is deactivated and no transfers are dynamically simulated for these studies. However, a post-processed transfer analysis is evaluated. The final regulatory environment is the Environmental Water Account (EWA) or the Limited EWA (the Lower Yuba River Accord transfers are dynamically simulated in the EWA regulatory environment). The following discussion details the CVPIA (b)(2) and the EWA specific for the OCAP BA.


**Figure 9-2 General spatial representation of the CalSim-II network**

### CVPIA 3406 (b)(2) and Environmental Water Account Modeling

CalSim-II dynamically models Central Valley Project Improvement Act (CVPIA) 3406(b)(2) and the Environmental Water Account (EWA). CVPIA 3406(b)(2) accounting procedures in CalSim-II are based on system conditions under operations associated with SWRCB D-1485 and D-1641 regulatory requirements (DWR 2002). Similarly, the operating guidelines for selecting actions and allocating assets under the EWA are based on system conditions under operations associated with a Regulatory Baseline as defined by the CALFED Record of Decision which includes SWRCB D-1641 and CVPIA 3406 (b)(2), among other elements. Given the task of simulating dynamic EWA operations, and the reality of interdependent operational baselines embedded in EWA's Regulatory Baseline, a modeling analysis was developed to dynamically integrate five operational baselines for each water year of the hydrologic sequence.

#### *CVPIA (b)(2)*

Consistent with CVPIA, Reclamation manages the CVP to "dedicate and manage annually 800,000 acre-feet of Central Valley Project yield for the primary purpose of implementing the fish, wildlife, and habitat restoration purposes and measures authorized by this title; to assist the State of California in its efforts to protect the waters of the San Francisco Bay/Sacramento-San Joaquin Delta Estuary; and to help to meet such obligations as may be legally imposed upon the Central Valley Project under State or Federal law following the date of enactment of this title, including but not limited to additional obligations under the Federal Endangered Species Act."

The water allotted under the authorization of CVPIA (b)(2) is dedicated and managed in a manner consistent with processes outlined in Chapter 2 and are generally managed to augment river flows and to limit pumping in the Delta to supplement the requirements of D-1641 and to protect fish species.

To simulate the 3406 (b)(2) accounting, the model uses metrics calculated in the (b)(2) simulation. The metrics measure the flow increases and export decreases from D-1485 to D-1641 WQCP Costs, and from D-1485 to (b)(2), total (b)(2) costs. The following assumptions were used to model the May 2003 3406 (b)(2) Department of the Interior decision.

1. **Allocation of (b)(2) water** is 800,000 acre-feet per year (af/yr), 700,000 af/yr in 40-30-30 Dry Years, and 600,000 af/yr in 40-30-30 Critical years
2. **Upstream flow metrics** are calculated at Clear Creek, Keswick, Nimbus, and Goodwin Reservoirs where (b)(2) water can be used to increase flow for fishery purposes. The assumptions used in CalSim-II for taking an upstream action at one of the previously mentioned reservoirs are:
   - **October-January**
     - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
     - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af.
     - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af.

  - For all releases, if the 200,000-af target is projected to be violated the model will try to reduce the magnitude of the actions in December and/or January.
- **February-September**
  - Clear Creek Releases: Action is on if Trinity Beginning of Month Storage >600,000 af.
  - Keswick Releases: Action is on if Shasta Beginning-of-Month Storage > 1,900,000 af and if remaining (b)(2) account > projected coming WQCP costs.
  - Nimbus Releases: Action is on if Folsom Beginning-of-Month Storage > 300,000 af and if remaining (b)(2) account > projected coming WQCP costs.

3. **The export metric** is the change in total CVP pumping (Jones + CVP Banks) from the base case (D1485). Assumptions used in CalSim-II for taking a delta action are:
   - **Winter Actions** (December through February) and Pre-Vernalis Adaptive Management Plan (VAMP) (April Shoulder) actions are off.
   - **VAMP Actions**: Always taken and done at a 2:1 ratio (Vernalis flow to CVP pumping ratio) if non-VAMP Vernalis flows are greater than 8,600 cubic feet per second (cfs).
   - **May Shoulder**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (25,000 af). DISCOUNT = If the annual WQCP cost > 500,000 af, the difference is subtracted from the remaining WQCP cost.
   - **June Ramping**: Action turned on if the remaining (b)(2) is greater than or equal to the discounted remaining WQCP cost + anticipated Clear Creek cost (20,000 af).
   - **Both May Shoulder and June Ramping** are further restricted to stay within the remaining (b)(2)account – remaining WQCP costs.

### *Environmental Water Account*

The three management agencies (FWS, NMFS, and DFG) and the two project agencies (Reclamation and DWR) share responsibility for implementing and managing the Environmental Water Account (EWA) as described in Chapter 2. The objective of simulating EWA for OCAP BA modeling is to represent the functionality of the program in two ways: as it has been implemented by EWAT during WY2001-2007, referred to as Full EWA and as it is foreseen to be implemented in a limited capacity in coming years, referred to as Limited EWA. The EWA representation that CalSim-II simulates is not a prescription for operations; it is only a representation of the following EWA operating functions:

- Implementing actions at SWP and CVP Delta export facilities
- Assessing debt caused by these actions
- Year-to-year carryover debt was represented for Full EWA, but not for Limited EWA
- Acquiring assets for managing debt

- Storing assets in San Luis, and transferring (or losing) stored assets to the projects as a result of projects' operations to fill San Luis during winter months
- Spending assets to compensate for debt south of the Delta (SOD)
- Tracking and mitigating the effects of debt north of the Delta (NOD) and NOD backed-up water
- Spilling carryover debt to the SWP at San Luis Reservoir was represented for Full EWA, but not for Limited EWA
- Conveyance of assets from NOD to SOD
- Accounting system re-operation effects resulting from EWA operations

For the OCAP BA modeling, action definitions reflect monthly to seasonal aggregate actions implemented by EWAT from WY2001-2007 and in the immediately foreseeable future.

The following actions are simulated in the OCAP BA modeling for Full EWA fishery purposes:

- **Winter-period Export Reduction (December–February):**

  Definition: "Asset spending goal" where a constraint is imposed on total Delta exports that equal 50,000 af less per month relative to the amount of export under the Regulatory Baseline. This is modeled as a monthly action and conceptually represents EWAT implementation of multiple several-day actions during the month.

  Trigger: All years for December and January; also in February if the hydrologic year-type is assessed to be Above Normal and Wet according to the Sacramento 40-30-30 Index.

- **VAMP-period Export Reduction (April 15–May 15):**

  Definition: Reduce exports to a target-restriction level during the VAMP period, regardless of the export level under the Regulatory Baseline; target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Pre-VAMP "Shoulder-period" Export Reduction (April –April 15):**

  Definition: Extend the target-restriction level applied for VAMP period into the April 1-April 15 period.

  Trigger: It was not simulated to occur based on actions implemented by EWAT from WY2001–2007 and in the foreseeable future.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

  Definition: Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.

Trigger: In any May if collateral exceeds debt at the start of May.

- **June Export Reduction:**

Definition: Steadily relieve the constraint on exports from the target-restriction level of the Post-VAMP period to the June Export-to-Inflow constraint level. Complete this steady relief on constraint during a 7-day period.

Trigger: If the Post-VAMP "Shoulder-period" Export Reduction was implemented and if collateral exceeds debt at the start of June.

The following assets are included in the OCAP BA modeling:

- Allowance for Carryover Debt (Replacing "One-Time Acquisition of Stored-Water Equivalent" defined in the CALFED ROD)
- Water Purchases, North and South of Delta
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD)
- July-September Dedicated Export Capacity at Banks (additional 500 cfs capacity)
- Source shifting and dry/wet exchange operations are represented (for the Full EWA simulation, but not the Limited EWA)

The role of these fixed and operational assets in mitigating the effects of EWA actions depends on operational conditions and is ascertained dynamically during the simulation. On the issue of the one-time acquisition of stored-water equivalent, the CALFED ROD specified the acquisition of initial and annual assets dedicated to the EWA, and EWA was to be guaranteed 200 thousand acre-feet (taf) of stored water SOD. This SOD groundwater bank was excluded in the CalSim-II studies for OCAP BA given its absence in actual EWAT operations from WY2001–2007. Since development of this asset has been delayed, EWAT developed a replacement asset (i.e., allowance for carryover debt and subsequent debt spilling) and operational procedures for managing this asset. OCAP BA modeling reflects EWAT guidelines for carrying over and spilling debt in the case of debt situated at SWP San Luis.

The impacts of actions on system operations are assessed in the OCAP BA modeling as EWA debt. Debt is defined as a reduction in project deliveries and/or storage relative to the EWA baseline (i.e., results from Step 5). CalSim-II tracks three general types of EWA debt:

- Deliveries to contractors SOD
- Storage levels SOD
- Storage levels NOD

Occurrence of SOD deliveries, debt, and subsequent failure to immediately pay back this debt, is an indicator that the simulated EWA program's assets are not in balance with the assumed actions. Occurrence of storage debt does not require immediate debt management.

Carried-over SOD storage debt is simulated to be managed through either: (1) direct dedication of assets, or (2) debt spilling. Dedication of assets involves transferring the accumulated purchases and variable assets from EWA San Luis into the projects' shares of San Luis to repay impacts caused by this year's actions and/or carried-over impacts from last year. The second tool, debt spilling, involves elimination of carried-over SOD debt at SWP San Luis assuming that several conditions were met at the end of the previous month (as described by EWAT):

- There was remaining capacity at Banks
- There was surplus water in the Delta that could have been exported
- The sum of end-of-month debt and stored water at SWP San Luis exceeded the sum of storage capacity and the "Article 21 deficit" (Figure 9-3) an Article 21 deficit represents demand minus what was delivered
- There was carried-over debt left to be spilled at SWP San Luis
- There was carried-over debt left to be spilled at SWP San Luis

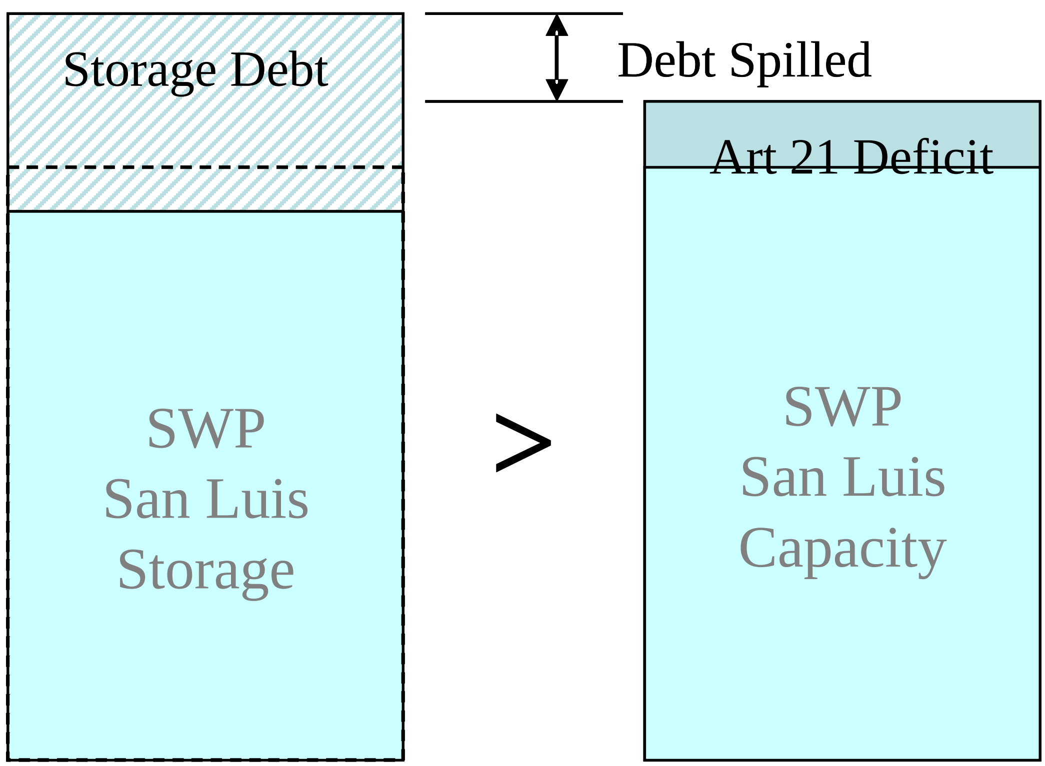



**Figure 9-3 Conditions for Spilling Carried-over Debt at SWP San Luis in CalSim-II**
*Because the Regulatory Baseline cannot exceed SWP San Luis Capacity (i.e., the dashed line in Stack A), then the debt above this capacity line must be carried-over debt. Therefore, this spill tool will only be applicable to erasing carried-over debt and will not affect "new" debt conditions from this year's actions.*

*Spill amount is limited by the availability of excess capacity at Banks and surplus water in the Delta.*

The following actions are simulated in the OCAP BA modeling for Limited EWA fishery purposes:

- **VAMP-period Export Reduction (April 15–May 15):**

  Definition: Reduce exports to a target-restriction level during the VAMP period, only up to the amount covered by available assets in storage and available assets through Yuba Accord. Otherwise target depends on San Joaquin River flow conditions.

  Trigger: All years. Taking action during the VAMP period has been an EWAT high priority in 2001–2007 and is, therefore, modeled as a high priority.

- **Post-VAMP "Shoulder-period" Export Reduction (May 16–May 31):**

  Definition: Extend the target-restriction level applied for VAMP period into the May 16-May 31 period.

  Trigger: In any May, if assets are remaining after VAMP actions.

The following assets are included in the Limited EWA OCAP BA modeling:

- Water Purchases, Yuba Accord
- 50 percent Gain of SWP Pumping of (b)(2)/ERP Upstream Releases
- 50 percent Dedication of SWP Excess Pumping Capacity (i.e., JPOD) for conveyance of EWA purchase or delta surplus outflow
- July-September Dedicated Export Capacity at Banks for conveyance of EWA purchase or delta surplus outflow

## CalLite

The CalLite tool is a rapid and interactive screening tool that simulates California's water management system for planning purposes. The CalLite tool is based on CalSim-II's 82 years of hydrologic inputs and logic using a simplified CalSim-II network which simulates, on a monthly time-step, CVP and SWP system conditions. "CalLite simulates the hydrology of the Central Valley, reservoir operations, project operations and delivery allocation decisions, Delta salinity responses to river flow and export changes, and habitat-ecosystem indices." (Munévar et al., 2008). The CalLite tool features:

- Rapid simulation evaluation (approximately 5 minutes depending on the scenario)
- User friendly Graphical User Interface (GUI)
- Flexible selection of policy alternatives or mode of simulation
- Pre-packaged post processing tools for output evaluation and alternative comparisons
- Cross-over of resources with CalSim-II data and logic

The following aspects of the CalLite model highlight areas where the model is coarser than the CalSim-II model to achieve the features listed above. The extent of the CalLite model reaches from northern California's Central Valley south to the Sacramento and San Joaquin Delta where the model terminates at the CVP and SWP Dos Amigos facility. All major CVP and SWP storage and conveyance facilities are included in the CalLite model. For the interim, the San Joaquin River Basin is simulated as a fixed time-series from CalSim-II results, while development is in progress. Differences between the CalSim-II and CalLite model are found in the aggregation of demands and hydrology inputs (accretions and depletions). The model represents “base” regulatory protection measures of SWRCB D-1641, allowing for screening additional policy proposals to augment above the “base” condition.

CalLite focuses on two specific areas which are not simplified “1) aspects governing operation and control of Delta facilities, water quality, channel flows, and ecosystem indicators; and (2) delivery allocation procedures for the CVP and SWP” (Munévar et al., 2008). The Delta is represented in an equivalent level of detail as the CalSim-II model. The CVP and SWP allocation procedures are also enhanced with an embedded module that more closely mimics the allocation forecasting process. In addition, this application has focused on the influence of uncertain hydrologic conditions in the allocation decision-making process.

The purpose of the CalLite tool for the OCAP BA is to screen and evaluate proposed Sacramento-San Joaquin Delta management actions for delta smelt and anadromous fish protection. This tool is well suited to quickly examine the tradeoffs of conflicting objectives for multiple alternatives. “CalLite is not a replacement for existing models, but rather is informed by the data and results of existing models and allows users to explore the future water management actions, improve understanding, and support more stakeholder-involved decision-making.” (Munévar et al., 2008). Hence, interactive screening workshops define criteria that are then implemented in the more detailed planning model (CalSim-II) for final simulation. The screening process and selected results of alternative management scenarios requested by USFWS, NMFS and DFG are presented in Appendix V

## Delta Hydrodynamic Modeling Methods

The objective of the hydrodynamic model, DSM2, is to simulate the Sacramento-San Joaquin River Delta (Delta) given monthly CVP and SWP project operations from the CalSim-II model results. These results provide flow, velocity, salinity, and particle movement (described below) in the Delta. DSM2 Old and Middle River flow results, an index for Delta fisheries, are used in the determination of the biological effects analysis. These results are also examined in a comparative evaluation because monthly output from the CalSim-II model is used as input to the DSM2 model.

### DSM2

The DWR Delta Simulation Model Version 2 (DSM2) was used to simulate the flow, velocity, and particle movement in the Delta (Figure 9-4). DSM2 consists of three one-dimensional modules that simulate the dynamic tidal hydraulics, water quality, and particle movement in a network of riverine channels. The DSM2 modules used for the OCAP-BA were the hydrodynamics module Hydro, and particle tracking module PTM. DSM2 was developed by DWR in the early 1990’s. Since its introduction DSM2 has been used for many projects. It has also been continually improved upon. Some of the most recent enhancements have been:

- Incorporation of a database to control and archive study input parameters,

- Operable gates that allow the model to operate gates in based on a hydrodynamic condition.

DSM2-Hydro is a one dimensional hydrodynamics module that simulates unsteady, open channel flow, along with open water areas, gates and barriers. The Hydro module simulates flow, velocity and water elevations every 15 minutes for a little over 500 channels that represent the Delta channels. The simulated flow, velocity and water elevations are then used to drive the water quality and particle tracking simulations. These hydrodynamic parameters can also be pulled out for individual locations and analyzed. DSM2-PTM is a particle-tracking module that simulates the transport and fate of neutrally buoyant particles in the Delta channels. The module uses velocity and water elevation information from DSM2-Hydro to simulate the movement of virtual particles in the Delta. The movement of particles is tracked on a 15-minute time-step throughout the simulation. If a particle leaves the Delta system by way of an export, diversion, or through any other model boundary, this information is logged for latter analysis and termed the “fate” of the particle. The model grid can also be broken up into groups and the percentage of particles in each group can also be logged and analyzed.

DSM2 models all of the major rivers and waterways in the Sacramento – San Joaquin Delta. The model simulates these rivers and waterways in the Delta starting from the Sacramento River at I Street in the north, and the San Joaquin River at Vernalis in the south, to Benicia Bridge in the west. Major inflows to the model include the Sacramento River, San Joaquin River, Mokelumne River, Cosumnes River, Calaveras River, and Yolo Bypass. Major exports and diversions include Banks Pumping Plant, Jones Pumping Plant, North Bay Pumping Plant, and Contra Costa intake at Old River and Rock Slough. In addition to these inflows and diversions there is also a representation of Delta Island Consumptive Use (DICU), which are the agriculture diversions and return flows throughout the Delta. At the Benicia Bridge is the Martinez stage boundary where a historically based stage is defined every 15 minutes throughout the simulation.

For this effort DSM2-Hydro was used to evaluate the changes in flow and velocity in specific channels and regions of the Delta. DSM2-PTM was used to evaluate the affect of these changes on particle movement in the Delta. Both of the modules were used to evaluate conditions for water-years 1976 through 1991. This period has been traditionally selected because it offers a good mix of water year classifications as well as including an extreme critical year (1977), and extreme wet year (1983).

DSM2-Hydro used monthly operations from the individual CalSim-II simulations as input. The inflow to DSM2-Hydro included the Sacramento River, Yolo Bypass, Mokelumne River, Cosumnes River, Calaveras River and San Joaquin River flows. The exports and diversions included Banks Pumping Plant, Jones Pumping Plant, Contra Costa Water District diversions at Rock Slough and Old River at Highway 4, and North Bay Pumping Plant. Additionally Delta Island Consumptive Use (DICU) was also modeled (Mahadevan 1995). A 15 minute adjusted astronomical tide (Ateljevich 2001a) was used to drive the Martinez tidal boundary.

As described in Appendix F, some pre-processing of monthly CalSim-II flows was needed before DSM2-Hydro could appropriately characterize the system. Since CalSim-II provides monthly flows, and DSM2-Hydro is a 15 minute model some disaggregation and smoothing of data is required to transition from month to month stepwise flows. The Vernalis Adaptive Management Program (VAMP) period was also pre-processed from a monthly average to a daily average in order to include the pulse flows and export cut backs associated with VAMP which typically starts on April 15 and ends May 15.

DSM2 model assumptions can also be modified for Delta Temporary Barriers Project (TBP) and the South Delta Improvements Program (SDIP) Stage 1, permanent gates.

DSM2-PTM used the hydrodynamic information from DSM2-Hydro in order to simulate the movement of particles in the Delta. PTM simulates the movement of neutrally buoyant particles, and so if one can assume that a fish larvae behaves similar to a neutrally buoyant particle then the affects can be evaluated. For this reason, particles were injected every month and then tracked to determine the fate for each month. The particles were counted when they enter the exports, diversions and when they pass Chipps Island in the western Delta. The particles remaining in the Delta are then reported as being in the northern or southern Delta.

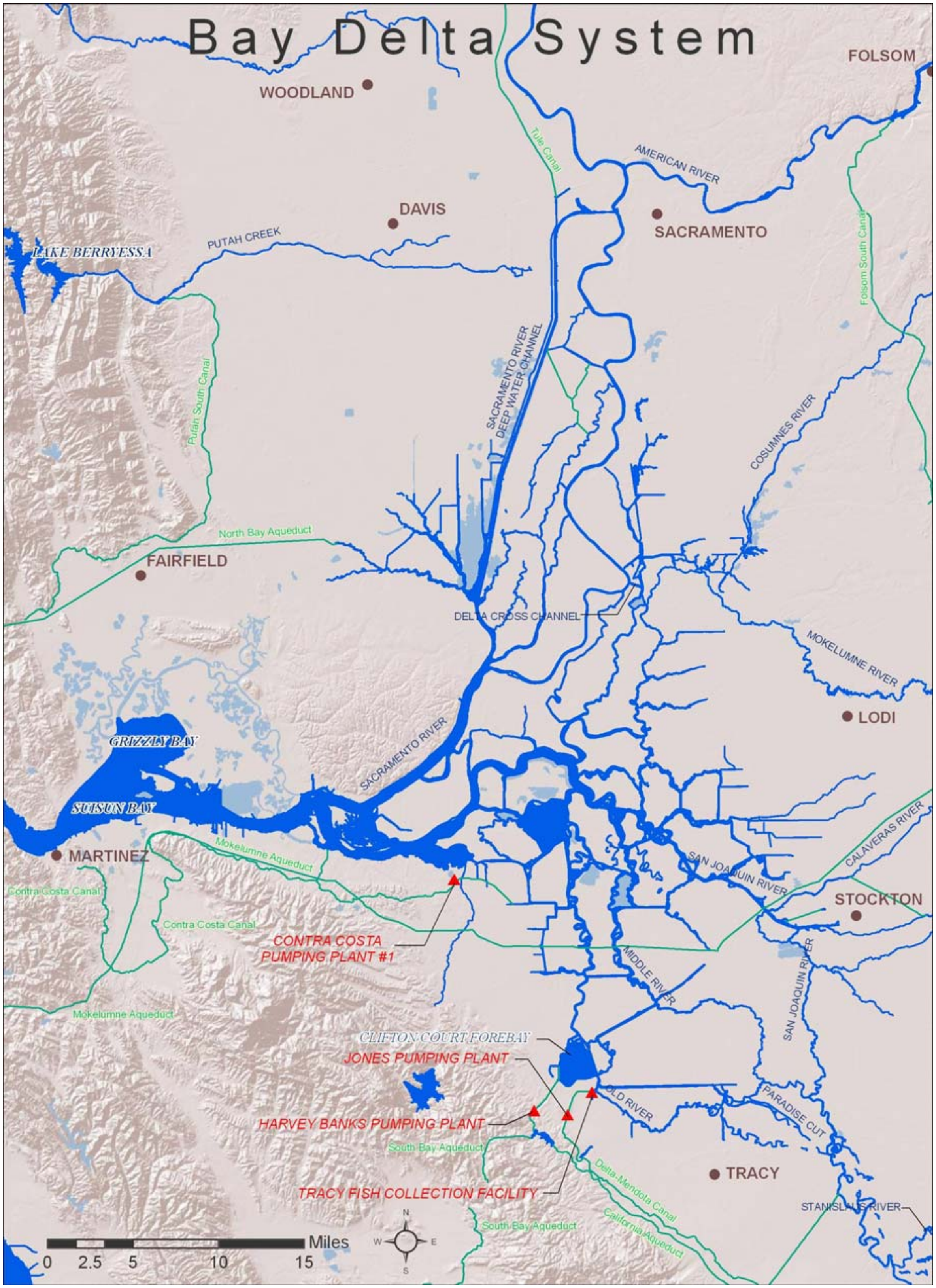



**Figure 9-4 General spatial representation of the DSM2 network.**

## Temperature Modeling Methods

The objective of the temperature models is to assist in the fisheries impact evaluations of the various CVP/SWP operations studies. The Reclamation temperature model was used to estimate temperatures in the Trinity, Sacramento, American, and Stanislaus River systems. In addition, daily temperature simulation was performed on Clear Creek and the upper Sacramento River system using the SRWQM model. Refer to the FERC BO for a temperature evaluation on the Feather River. The joint DWR/Reclamation simulation model CalSim-II provided monthly CVP/SWP project operations input to the temperature model for an 82-year hydrologic period (WY1922-2003). All three temperature model reaches are spatially represented in Figure 9-5 Because of the CalSim-II Model's complex structure, CalSim-II, flow arcs were combined at appropriate nodes to ensure compatibility with the temperature models.

### Reclamation Temperature Model

The reservoir temperature models simulate monthly mean vertical temperature profiles and release temperatures for Trinity, Whiskeytown, Shasta, Folsom, New Melones, and Tulloch Reservoirs based on hydrologic and climatic input data. The temperature control devices (TCD) at Shasta, and Folsom Dams can selectively withdraw water from different reservoir levels to provide downstream temperature control. The TCDs are generally operated to conserve cold water for the summer and fall months when river temperatures become critical for fisheries. The models simulate the TCD operations by making upper-level releases in the winter and spring, mid-level releases in the late spring and summer, and low-level releases in the late summer and fall.

Temperature changes in the downstream regulating reservoirs – Lewiston, Keswick, Natomas, and Goodwin – are computed from equilibrium temperature decay equations in the reservoir models, which are similar to the river model equations. The river temperature models output temperatures are listed in Table 9-2.

**Table 9-2 Reclamation Temperature Model Key Output locations**

| RIVER OR CREEK SYSTEM | LOCATION |
|---|---|
| TRINITY RIVER | Trinity Dam |
| | Lewiston Dam |
| | Douglas City |
| | North Fork |
| CLEAR CREEK | Whiskeytown Dam |
| | Above Igo |
| | Below Igo |
| | Mouth |

| RIVER OR CREEK SYSTEM | LOCATION |
|---|---|
| AMERICAN RIVER | Folsom Dam |
| | Nimbus Dam |
| | Sunrise Bridge |
| | Cordova Park |
| | Arden Rapids |
| | Watt Avenue Bridge |
| | American River Filtration Plant |
| | H Street |
| | 16th Street |
| | Mouth |
| SACRAMENTO RIVER | Shasta Dam |
| | Keswick Lake above Spring Creek Tunnel |
| | Spring Creek Tunnel |
| | Keswick Dam |
| | Balls Ferry |
| | Jellys Ferry |
| | Bend Bridge |
| | Red Bluff |
| | Vina |
| | Butte City |
| | Wilkins Slough |
| | Colusa Basin Drain |
| | Feather River |
| | American River |
| | Freeport |
| STANISLAUS RIVER | New Melones Dam |
| | Tulloch Dam |

| RIVER OR CREEK SYSTEM | LOCATION |
|---|---|
| | Goodwin Dam |
| | Knights Ferry |
| | Orange Blossom |
| | Oakdale |
| | Riverbank |
| | McHenry Bridge |
| | Ripon |
| | Mouth |

The river temperature calculations are based on regulating reservoir release temperatures, river flows, and climatic data. Monthly mean historical air temperatures for the 82-year period and other long-term average climatic data for Trinity, Shasta, Whiskeytown, Redding, Red Bluff, Colusa, Folsom, Sacramento, New Melones, and Stockton were obtained from National Weather Service records and are used to represent climatic conditions for the four river systems. Additional details of the Reclamation Temperature Model are located in Appendix H.

### Sacramento River Water Quality Model (SRWQM) Temperature Model

A HEC-5Q model was developed and calibrated for the upper Sacramento River system, including Trinity Dam, Trinity River to Lewiston, Lewiston Dam, Clear Creek Tunnel, Whiskeytown Dam, Spring Creek Tunnel, Shasta Dam, Keswick Dam, Sacramento River from Keswick to Knights Landing, Clear Creek below Whiskeytown, Red Bluff Diversion Dam, Black Butte Dam, and downstream Stony Creek.

The water quality simulation module (HEC-5Q) was developed so that temperature could be readily included as considerations in system planning and management. Using system flows computed by HEC-5, HEC-5Q computes the distribution of temperature in the reservoirs and in stream reaches. HEC-5Q is designed for long-term simulations of flow and temperature using daily average hydrology and 6-hour meteorology. Vertically stratified reservoirs are represented conceptually by a series of one-dimensional horizontal slices or layered volume elements, each characterized by an area, thickness, and volume. The HEC-5Q model simulation approximates diurnal variations in temperature for a 6-hour time step. The model was calibrated for the period of January 1998 through November 2002, using temperature time series field observations at numerous locations in the Trinity River, Clear Creek, and upper Sacramento River.

HEC-5Q is used to evaluate options for coordinating reservoir releases among projects to examine the effects on flow and water temperature at specified locations in the system. The model is used to evaluate instream temperatures at critical locations in a system, and examination of the potential effects of changing reservoir operations or water use patterns on temperature. Reservoirs, such as Shasta Lake, equipped with selective withdrawal structures can be simulated using HEC-5Q to determine operations necessary to meet water quality objectives downstream. For this analysis, the Temperature Control Device (TCD) algorithm was modified to operate the Shasta Dam spillway, flood control outlets, and TCD gates to meet tailwater temperature targets. Key reporting locations are listed in Table 9-3.

**Table 9-3. SRWQM Model Key Output locations**

| RIVER OR CREEK SYSTEM | LOCATION |
|---|---|
| Shasta Dam | Tailwater |
| Lewiston | Fish Hatchery |
| Spring Creek | Powerhouse |
| Sacramento River | Below Keswick Dam |
| | Clear Creek Confluence |
| | Balls Ferry |
| | Jellys Ferry |
| | Bend Bridge |
| | Red Bluff Diversion Dam |
| | Tehama |
| | Woodson Bridge |
| | Hamilton City |
| | Butte City |
| | Colusa |
| | Above Colusa Basin Drain |
| Black Butte Dam | Black Butte Dam |
| Stony Creek | Tehama Colusa Canal |

Additional information is available in the Appendix H.

## Oroville Facilities Water Temperature Modeling

The operations on the Feather River for the Oroville Facilities are currently being covered under a separate Section 7 ESA consultation process for the Federal Energy Regulatory Commission (FERC) relicensing process. The draft NMFS BO is scheduled for release in late May 2008. Oroville Facilities water temperature modeling information is being provided for information purposes only.

Water temperature modeling supporting the Oroville Facilities FERC Relicensing utilized a suite of five models linked through a central database. The five models included reservoir simulations of Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay, and a river model of the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. All models were 1-dimensional models operating on an hourly timestep; the reservoirs were simulated as a series of vertically segregated, one-meter thick layers, the Feather River was simulated as a series of depth-averaged river segments with cross-section data from a calibrated flow-stage model, based on hydrologic and climactic input data. The modeling suite included iteration to meet water temperature objectives at the two Feather River water temperature compliance locations, the Feather River Fish Hatchery (FRFH) and Robinson Riffle. Operations for the water temperature objectives incorporated a range of temperature control actions including: curtailment of pumpback operations, elimination of hydropower peaking operations, removal of shutters on the Hyatt Pumping-Generating Plant intake, increasing the flow in the Low Flow Channel, and making releases through the Oroville Dam river valve. The water temperature modeling suite provided the following data output:

-Water temperatures in 100 river segments on the Feather River between the Thermalito Diversion Dam and the Sacramento River confluence. Several key river segments were used in evaluation, two of which, the FRFH and Robinson Riffle, were used to determine water temperature compliance (see Appendix J for key output locations).
-Reservoir profiles and release temperatures for Oroville Reservoir, the Thermalito Diversion Pool, the Thermalito Forebay, and the Thermalito Afterbay
-Agricultural diversion temperatures at four locations in the Thermalito Afterbay
-Water temperature in the Feather River Fish Hatchery

Hydrologic and climactic input data were based on historical records from the Durham and Nicolaus stations of the California Irrigation Management Information System (CIMIS) and extrapolated out for a 73 year (1922-1994) period of record based on available historical Sacramento Valley data. DWR collected field data for the model calibration and verification from March 28, 2002 through December 30, 2003. Calibration of the model was performed with data from August 11, 2002 to December 30, 2003, including two occurrences of the most critical period for water temperature management, September through October. The model was verified against conditions from the remaining time period of the available data, March 28 through July 15, 2002. It is anticipated that additional model calibration and verification will be included in future modeling efforts for the implementation phase of the Oroville Facilities Relicensing. Additional information about the water temperature model can be found in Appendix J and Appendix K.

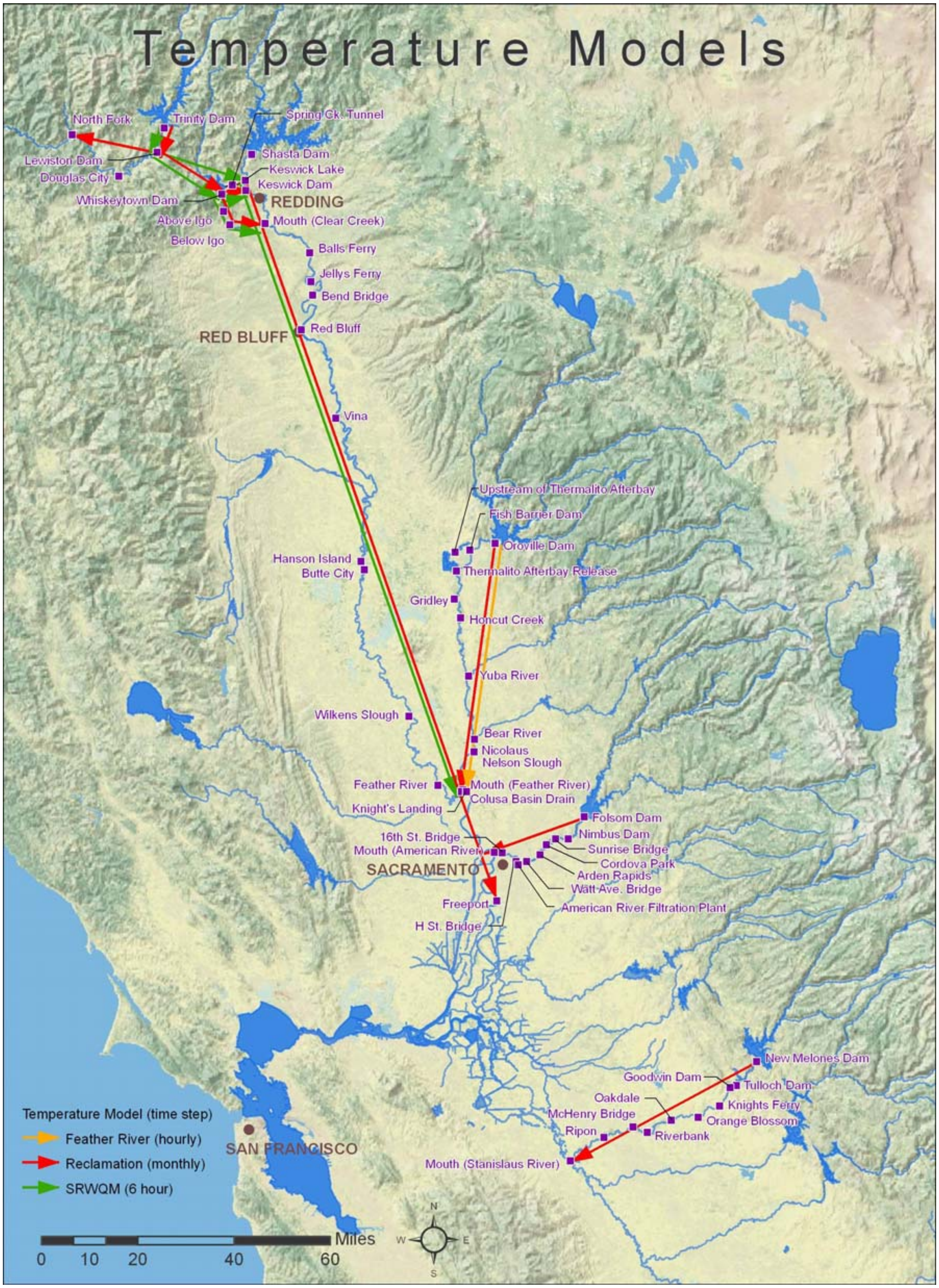



**Figure 9-5 General spatial representation of the temperature model networks.**

## Salmon Mortality and Life Cycle Modeling Methods

The objective of the salmon mortality and life cycle models is to simulate salmon losses and population dynamics. These results quantify the change of salmon loss and population dynamics as compared amongst the model scenarios. The salmon models use simulated temperature results and CVP/SWP operation results from CalSim-II, described above. The three models applied to the OCAP BA are the Reclamation salmon mortality model, SALMOD, and the Interactive Object-Oriented Salmon Simulation (IOS) life cycle model for winter-run salmon. Each of the three salmon models is spatially represented in Figure 9-6.

### Reclamation Salmon Mortality Model

The Reclamation salmon mortality model computes salmon spawning losses in the four rivers, Trinity, Sacramento, American, and Stanislaus, based on the Reclamation Temperature Model estimates. The model uses DFG and FWS data on Chinook salmon spawning distribution and timing in the five rivers (Reclamation 1991, Loudermilk 1994, and Reclamation 1994) Temperature-exposure mortality criteria for three life stages (pre-spawned eggs, fertilized eggs, and pre-emergent fry) are used along with the spawning distribution data and output from the river temperature models to compute percents of salmon spawning losses. Temperature units (TU), defined as the difference between river temperatures and 32°F, are calculated daily by the mortality model and used to track life-stage development. Eggs are assumed to hatch upon exposure to 750 TUs following fertilization. Fry are assumed to emerge from the gravel after exposure to 750 TUs following egg hatching into the pre-emergent fry stage. The temperature mortality rates for fertilized eggs, the most sensitive life stage, range from 8 percent in 24 days at 57°F to 100 percent in 7 days at 64°F or above (Reclamation, 1994). Most salmon spawning generally occurs above the North Fork on the Trinity River, above Red Bluff on the Sacramento River main stem for all four Chinook salmon runs, above Watt Avenue on the American River, and above Riverbank on the Stanislaus River. Fall-run salmon spawning usually occurs from mid-October through December, peaking about mid-November. Winter-run salmon usually spawn in the Sacramento River during May-July, and spring-run salmon during August-October. Additional information on the Reclamation mortality model is located in Appendix L.

### SALMOD

SALMOD is a computer model that simulates the dynamics of freshwater salmonid populations. SALMOD was applied to this project because the model had been previously used on the upper Sacramento River (from Keswick Dam down to Battle Creek), and because a thorough review and update of model parameters and techniques on the Klamath River enabled a smooth transfer of relevant model parameters to the Sacramento River (Bartholow, 2003). The study area for this analysis covers a 53-mile (85-kilometer) stretch of the Sacramento River from Keswick Dam to just above the RBDD. Keswick Dam forms the current upstream boundary of anadromous fish migration in the Sacramento River, and the RBDD marks the current downstream limit of habitat that has been consistently classified by mesohabitat type and evaluated using the Physical Habitat Simulation System (PHABSIM) and River 2D. The study area terminates at this point because RBDD is operated with gates that can be raised or lowered that alter the inundation pool’s hydraulics. This pool has not been modeled for habitat value. SALMOD functions to integrate microhabitat and macrohabitat limitations to a population through time and space. The term “habitat limitations” does not imply that freshwater habitat is the ultimate factor limiting the populations, but that habitat constraints may reduce populations while other factors, such as ocean conditions or fishing pressure, may be the ultimate limiting factor.

SALMOD simulates population dynamics for all four runs of Chinook salmon in the Sacramento River between Keswick Dam and RBDD. SALMOD presupposes egg and fish mortality are directly related to spatially and temporally variable microhabitat and macrohabitat limitations, which themselves are related to the timing and volume of streamflow and other meteorological variables. SALMOD is a spatially explicit model in which habitat quality and carrying capacity are characterized by the hydraulic and thermal properties of individual mesohabitats, which serve as spatial computation units in the model. The model tracks a population of spatially distinct cohorts that originate as eggs and grow from one life stage to another as a function of water temperature in a computational unit. Individual cohorts either remain in the computational unit in which they emerged or move, in whole or in part, to nearby units.

Model processes include spawning (with redd superimposition), incubation losses (from either redd scouring or dewatering), growth (including egg maturation), mortality due to water temperature and other causes, and movement (habitat and seasonally induced). SALMOD is organized around physical and environmental events on a weekly basis occurring during a fish’s biological year (also termed a brood year), beginning with adult holding and typically concluding with fish that are physiologically “ready” to begin migration towards the ocean. Input variables, represented as weekly average values, include streamflow, water temperature, and number and distribution of adult spawners. The study area is divided into individual mesohabitats (i.e., pool, riffle, and run) categorized primarily by channel structure and hydraulic geometry, but modified by the distribution of features such as fish cover. Thus, habitat quality in all computational units of a given mesohabitat type changes similarly in response to discharge variation. Habitat type and streamflow determine the available habitat area for a particular life stage for each time step and computational unit. Habitat area (quantified as weighted usable area, or WUA) is computed from flow: microhabitat area functions developed empirically or by using PHABSIM (Milhous et al., 1989) or River 2D for the reach from Keswick Dam to Battle Creek and a two dimensional hydraulic model for Battle Creek to RBDD. Habitat capacity for each life stage is a fixed maximum number of salmon per unit of habitat area available estimated from literature or empirical data. Thus, the maximum number of individuals that can reside in each computational unit is calculated for each time step based on streamflow, habitat type, and available microhabitat. Fish in excess of the habitat’s capacity must move to seek unoccupied habitat elsewhere. Fish from outside the model domain (from tributary production) were also added to the modeled stream as fry and juveniles.

Flow and water temperature time series values were derived from the CalSim-II and HEC-5Q models. Data for each day corresponded to the weekly average conditions for that day forward. Data covered the period 1921 to 2003, a total of 82 water-years. Additional information on the SALMOD model is located in Appendix P.

### Interactive Object-Oriented Salmon Simulation (IOS) Winter-Run Life Cycle Model

The IOS Winter-Run Life Cycle model was used to evaluate the influence of different Central Valley water operations on the life cycle of Sacramento River winter-run Chinook salmon over an 80 year period using simulated historical flow and water temperature inputs. The IOS model was designed to serve as a quantitative framework for estimating the long-term response of Sacramento River Chinook populations to changing environmental conditions (e.g. river discharge, temperature, habitat quality at a reach scale). Life cycle models are well-suited for such evaluations because they integrate survival changes at various life stages, across multiple habitats, and through many years. The IOS model was seeded with 5,000 spawners for the first four years then allowed to cycle through multiple generations during years 1923-2002.

Reach specific, daily (disaggregated CalSim-II) discharge and daily HEC-5Q water temperature provided the basic inputs for model runs. In addition, monthly average Delta conditions (inflow, exports, DCC operations, temperature) were provided by CalSim-II. Other model settings were set specifically for this analysis and at constant values throughout the 80-year run of the IOS model. The use of constant values for parameters with little uncertainty or with lesser management significance is desirable because it simplifies the model and facilitates easier interpretation of results.

The effect of different water operation scenarios on the Sacramento River winter-run Chinook salmon population was evaluated by comparing abundance and survival trends at various life stages among the three runs of the IOS Model. The annual abundance of returning spawners and juveniles out-migrating past RBDD were reported for each model run. Trends in survival through time at various life stages were examined to explain patterns seen in yearly escapement under each water operation scenario. Average differences in winter-run survival between water operation scenarios were translated into average differences in annual escapement to better evaluate the potential impact each water operation scenario has on the winter-run abundance in the Sacramento River. Finally, typical monthly spatial distribution of juvenile salmon during model runs was reported. Additional details of the IOS model are also presented in Appendix N.


**Figure 9-6 General spatial representation of the salmon model networks.**

## Climate Change and Sea Level Rise Sensitivity Analysis Modeling Methods

The approach selected for the climate change analysis is being referred to as "Sensitivity Analysis", which includes a quantitative analysis of implications for future CVP and SWP operations under a range of potential climates in order to illustrate how the OCAP BA future operational baseline is sensitive to the future climate assumptions. With respect to the OCAP BA, the Sensitivity Analysis is focused on exploring how climate change might affect:

- Operational conditions of interest (e.g., storage, deliveries, flows, reservoir and river water temperature, Delta water levels and salinity),
- Described statistically during long-term, by year-type, or during drought-periods,
- Assessed at a 2030 look-ahead consistent with the consultation horizon.

The chosen approach for incorporating climate change information calls for re-evaluating the OCAP BA future operations baseline given assumptions consistent with different future climates, representing a range of potential future climates. These re-evaluated results are then compared against baseline results represented under "recent" climate. The comparison of results illustrates the sensitivity of the operations condition to the future climate assumption. The re-evaluations will focus on regional climate change defined in terms of monthly temperature and precipitation changes translated into surface water supply changes, and to global climate change defined in terms of sea level rise affecting Delta conditions. CVP and SWP operational policies are not modified to respond to the future climates and sea level rise.

To define a range of future climate possibilities, four projections were selected to encapsulate a reasonable range of projected climate conditions over the study region. The four projections will were selected based on how they collectively represent a range of:

- "lower" to "greater" temperature changes (which correspond to "*less warming*" to "*more warming*" over California),
- combined with a range of "lower" to "greater" precipitation magnitude changes (which correspond to "*drier*" to "*wetter*" conditions).

Projections selection depends on several factors that are study-specific:

- **Factor 1 –** Look-ahead horizon relevant to this study
- **Factor 2 –** Climate metric relevant to the study's operational questions
- **Factor 3 –** Location representative of the study region
- **Factor 4 –** Projected "Change Range" of Interest, a subjective choice on how much projections spread to represent.

Climate projection selection for the OCAP BA sensitivity analysis then proceeds with a four-step implementation process based on the four selection factor decisions.

- **Step 1**: Survey climate projections data from the Downscaled Climate Projections (DCP) archive spanning the periods of selection factor decision #1, reported at the location of selection factor decision #3.
- **Step 2:** For base and future periods (selection factor decision #1), compute mean annual Temperature (T) and Precipitation (P) conditions for each of the 112 projections surveyed in Step 1. "Mean annual" is the climate metric of selection factor decision #2. Next, compute change in mean annual T and P ($\Delta T$ and $\Delta P$, change respectively) from base to future period, by projection, and evaluate the rank-distribution of changes among the projections for each variable. Identify rank-percentile changes for each variable based on selection factor decision #4 (i.e. focusing on $10^{th}$ and $90^{th}$ percentile changes for both variables).
- **Step 3**: Switch focus to "projections spread", and evaluate the plot of $\Delta T$ versus $\Delta P$. Overlay rank-percentile changes identified for each variable in Step 2. The intersection of the $\Delta T_{10\%\text{-tile}}$ and $\Delta T_{90\%\text{-tile}}$ with $\Delta P_{10\%\text{-tile}}$ and $\Delta P_{90\%\text{-tile}}$ formulates a two-variable "change range of interest".
- **Step 4:** Choose 4 projections having paired projected changes (i.e. $\{\Delta T, \Delta P\}$) that most closely match the four vertices of the two-variable "change range of interest."

CalSim-II hydrology inputs are modified to reflect the 4 projected changes in temperature and precipitation. Sea level rise assumptions are also implemented and evaluated using the DSM2 hydrodynamic model. See Appendix R for additional details.

## Sensitivity and Uncertainty

Ongoing future work is exploring sensitivity and uncertainty analyses using the OCAP BA version of the CalSim-II model. Unfortunately, studies are not immediately available for this BA. The purposes of the analyses are two fold:

1. Sensitivity Analysis: Identify parameters and input data which have a major impact to the system, and
2. Uncertainty Analysis: Understand the confidence of simulated results.

The CalSim-II sensitivity results are useful in tandem with the uncertainty results to affirm model performance, identify sensitive variables, and understand a likely band of modeled CVP and SWP operational uncertainty. Ongoing sensitivity and uncertainty analyses are limited to the CalSim-II model. At the present time, data and testing routines established to perform sensitivity and uncertainty for other models used in the BA are unavailable.

The ongoing analyses examine a limited perspective of uncertainty but do not evaluate all aspects of uncertainty. Uncertainty of engineered water resources systems is generally categorized as hydrologic, hydraulic, structural, and economic (Mays and Tung, 1992). Ecosystems are an additional category of uncertainty to consider. Cumulative uncertainty or total uncertainty, defined here, is the collective simulated uncertainty due to the application of tiered modeling and to the categories mentioned above. Hydrologic uncertainty is addressed in the ongoing analysis for CalSim-II. However, a rigorous uncertainty evaluation including tiered modeling, hydraulic, structural, economic, and ecosystem drivers was not attempted due to the level of effort required for this type of analysis.

The results presented below and elsewhere (Chapters 10-13) are generated using models with uncertain information. The uncertainty of absolute results, as models build upon another with the tiered approach, is expected to increase. For example, the CalSim-II representation of the current operational conditions captures seasonal trends, frequencies and magnitudes well but imperfectly (see Appendix U). This qualitative uncertainty should be considered in the evaluation of simulated results.

## Other Tools

Qualitative or quantitative tools which are, or could be, applied to the CVP and SWP systems but were not used in OCAP BA are also acknowledged. Some tools are in development or contained a component of incompatibility that could not be applied. These tools or processes should be considered for future evaluation when available or made compatible.

In early 2008 the California Department of Fish and Game introduced new conceptual models to better manage species and ecosystem responses. These models were not available for use during the development of this BA, however, they seem promising and should be considered in the future. The following are excerpts from the Delta Restoration Plan Species Life History Models Report (DFG, 2007) summarizing the DRERIP model and process:

> "*Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) will implement adaptive management by incorporating scientific evaluation of restoration actions in light of the current state of knowledge and restoration projects implemented to date. The DRERIP science input process is divided into four phases; (1) process design; (2) the development of species life history models and ecosystem element conceptual models; (3) the development and evaluation of proposed ERP actions; and (4) an analysis of the feasibility and prioritization of the actions.*
>
> *The California Department of Fish and Game, working with the CALFED Science Program and other CALFED agencies, is engaged in the development of a series of conceptual models for the Delta that can inform decision making regarding future conservation and restoration actions. The following provides general guidelines for the preparation of these species models, including how the models will be used, definitions of terms, information that should be included in each model, and a basic outline that should be followed. These guidelines have been amended following beta-testing of the overall Delta Restoration Plan (DRERIP) suite of models in order to facilitate vetting of likely restoration actions.*
>
> *The purpose of these guidelines is to promote consistency between the structure, format, and level of information contained within each species model. The guidelines are also intended to improve the application of the models, including linkages between the species models and related ecosystem element conceptual models being developed separately that describe natural processes, habitats, and stressors acting upon the population dynamics of the component species within the community."*

> *"The purpose of the species models is to describe the basic biology (life cycle and life history) of several key species, and to articulate explicitly the current state of knowledge regarding factors influencing their reproductive success, growth, and survival—the underlying population dynamics as we understand them. This information will necessarily direct appropriate restoration actions most efficiently, and forms the foundation for adaptive management within the CALFED ERP process. It is critically important that these models address the most appropriate outputs (outcomes) to define particular restoration actions and objectives towards long-term population viability of your particular species. This information includes a comprehensive treatment of the threats facing different lifestages of these species under different seasonal scenarios and conditions."*

> *"The DRERIP conceptual models follow a deterministic paradigm, using the DLO approach: drivers (D), linkages (L), and outcomes (O).* ***Drivers*** *are physical, chemical, or biological forces that control the species or system of interest.* ***Linkages*** *are cause-and-effect relationships between drivers and outcomes.* ***Outcomes*** *are response variables (such as reproductive success, growth, and mortality) that the conceptual model is attempting to explain. In the context of the DRERIP species conceptual models, "ultimate" outcomes reflect population-level responses to drivers."*

Other temperature models were also examined but not used during the development of the OCAP BA. Various water temperature models are available and applied to CVP Rivers and tributaries. These models represent a variety of geographic locations and temporal resolution. The simulation of water temperature in the OCAP BA captures short term variability (e.g. daily time-step) in the Clear Creek, Sacramento, and the Feather Rivers and a coarser time step elsewhere.

Other temperature models applied in the Central Valley include simulation of the American River (Reclamation) and the Stanislaus River (AD and RMA, 2002) at a sub-monthly time-step. However, daily and sub-daily disaggregation assumptions, testing, and verification were not available for these locations using the full 82 year CalSim-II data sets for the American and Stanislaus rivers. Tools simulating real-time temperature operations, such as optimizing cold water pool storage using CalSim-II data, were also not available. Supplemental historical temperature observations were evaluated to overcome these modeling limitations.

The treatment of temperature simulation is unequal amongst the basins presented in the BA. This is due in part to present data availability, inconsistency in model approach between agencies, model complexity, and computation time. For the short term, supplemental historical temperature observations are presented to overcome these modeling limitations (Appendix U). A long-term temperature model development plan including consistent spatial and temporal application for the CVP and SWP systems will be considered for future applications.

# Modeling Studies and Assumptions

DWR and Reclamation developed a set of "Common Assumptions" (as part of CALFED Storage Project Investigations) for the purpose of developing an updated CalSim-II study to be used as a basis for comparing project alternatives. From the "Common Assumptions" base, six CalSim-II studies (and one study from the previous 2004 BA modeling) have been developed to evaluate the effects of changes in future operations for the OCAP BA. The programs evaluated include: Freeport Regional Water Project, California Aqueduct and Delta-Mendota Canal Intertie, level of development (future demands), Yuba River Accord, Full Environmental Water Account (EWA) and Limited EWA, Red Bluff Diversion Dam, American River Flow Management, Sacramento River Reliability, South Delta Improvements Program (SDIP) Stage 1, and climate change and sea level rise.

The study scenarios were formed to capture the past assumptions, present, near-future, future, and future with an alternative climate conditions:

1. **Study 3a –** This study is repeated from the previous OCAP BA 2004 for comparative purposes. It represents a then condition (a 2001 level of land use development) and simulates through the CVPIA (b)(2) and Joint Point of Diversion steps. Study 3a also includes the Trinity Record of Decision (ROD) implementation.

2. **Study 6.0 –** This study represents the previous OCAP BA 2004 assumptions within the new CalSim-II model framework. Conditions for water demands, facilities, and water project-operational policy are duplicated, to the extent possible, to Study 3a. This study corresponds to the today condition (with a 2005 level of land use development) simulates through the (b)(2) and Joint Point of Diversion steps. This study is designed to compare to Study 3a and highlights differences due to model structural refinement.

3. **Study 6.1 –** This study is designed to emulate pre-Trinity ROD conditions. This study is identical to Study 6.0 with the following exceptions:

    a. 2005 Trinity record of decision is removed, and

    b. Simulates only through (b)(2).

4. **Study 7.0 –** This study forms the base model to compare future proposed operations. Study 7.0 describes existing water demands, facilities, and water project operational policy. It represents the today condition (a 2005 level of land use development) through the EWA step.

5. **Study 7.1 –** This study represents water demands and policy for existing conditions, current and near-future facilities, and existing and near-future water project operational policy. It corresponds to the today condition (a 2005 level of land use development) through the Limited EWA step. Study 7.1 should be compared to Study 7.0 to determine the effect of near-future facilities and policies

6. **Study 8.0 –** This study represents assumed water demands and policy for the future. It represents the future condition (a 2030 level of land use development) through the Limited EWA. Study 8.0 should be compared to Study 7.0 to determine the effect of future facilities and policies.

7. **Study 9.0 suite –** These studies constitute the future with climate change and sea level rise. It represents the future condition (a 2030 level of land use development) for D-1641 WQCP. The Study 9.0 suite is identical to Study 8.0’s D-1641 except:

    a. Climate modified hydrology, and

b. Sea level rise.

The sub-suite studies represent the range of temperature and precipitation explored for climate change. The Study 9.0 suite represents future condition as a separate study for sensitivity evaluation.

Compatible comparisons can be made with the following studies:

1. **Study 3a and Study 6.0 –** This comparison identifies the difference between model development/refinement since the OCAP BA 2004 (see Table 9-3 for CalSim-II model revisions). Appendix E presents the comparison between OCAP BA 2004 Study 3a and Study 6.0 CalSim-II results.
2. **Study 6.0 and Study 6.1 –** This comparison highlights the affect of conditions prior to the POD and the Trinity ROD.[1]
3. **Study 6.1 and Studies 7.0, 7.1, and 8.0 –** The comparison between Study 6.1, the "Pre-POD" condition, and the "Today", "Near Future", and "Future", Studies 7.0, 7.1, and 8.0 respectively, is presented for Delta evaluation only. This comparison is made to highlight the change in present and future Delta entrainment and X2 conditions when compared to a condition prior to the POD. Note that Studies 7,0, 7.1, and 8.0 are simulated with EWA, however, Study 6.1, the "Pre-POD", is not simulated with the EWA, in order to capture this specific condition.
4. **Study 7.0 and Study 7.1 –** A comparison between Study 7.0 and Study 7.1 illustrates the change between the "Today" and "Near-Future" conditions. Where the "Near Future" contains the Limited EWA, South Delta Improvement Project Stage 1, Freeport Regional Water Project, and California Aqueduct/Delta Mendota Canal Intertie.
5. **Study 7.0 and Study 8 –** This comparison presents the change between the base model, "Today" and "Future" conditions. The "Future" contains the Limited EWA, the South Delta Improvement Project Stage 1, Freeport Regional Water Project, California Aqueduct/Delta Mendota Canal Intertie, and future water demands.
6. **Study 7.1 and Study 8.0 –** A comparison between Study 7.1, the "Near Future", and Study 8.0, the "Future" highlights the change in future water demands.

**Error! Reference source not found.Error! Reference source not found.** shows the seven studies developed for OCAP BA and generally how changes in operations are incorporated into them and Table 9-5 shows the detailed assumptions of Studies 3a through 9.0. The latter table also illustrates specific operational changes regarding regulatory and operational rules

[1] Note that Study 6.0 represents CVPIA (b)(2) and the Joint point of Diversion whereas Study 6.1 represents only CVPIA (b)(2).

**Table 9-4 Summary of Assumptions in the OCAP BA Runs**

| | Trinity Min Flows | CVPIA 3406 (b)(2) | Level of Development | EWA | SDIP Stage 1 | Freeport | Intertie |
|---|---|---|---|---|---|---|---|
| Study 3a Today JPOD | 368,600-815,000 af/yr | May 2003 | 2001 | | | | |
| Study 6.0 Today CONV | 368,600-815,000 af/yr | May 2003 | 2005 | | | | |
| Study 6.1 Today b(2) | 368,600-452,600 af/yr | May 2003 | 2005 | | | | |
| Study 7.0 Today EWA | 368,600-815,000 af/yr | May 2003 | 2005 | Full | | | |
| Study 7.1 Today Limited EWA | 368,600-815,000 af/yr | May 2003 | 2005 | Limited | X | X | X |
| Study 8.0 Future Limited EWA | 368,600-815,000 af/yr | May 2003 | 2030 | Limited | X | X | X |
| Study 9.0a-d Future D1641 SA Climate Change | 368,600-815,000 af/yr | May 2003 | 2030 | Limited | X | X | X |

## Table 9-5. Assumptions for the Base and Future Studies

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | **OCAP BA 2004 Today CVPIA 3406 (b)(2) and JPOD** | **Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model CVPIA 3406 (b)(2) and JPOD** | **Today-OCAP BA 2004 Assumptions in Revised CalSim-II Model CVPIA 3406 (b)(2)** | **Today-Existing Conditions, CVPIA 3406 (b)(2) and EWA** | **Today-Existing Conditions and OCAP BA 2004 Consulted Projects, CVPIA 3406 (b)(2) and Limited EWA** | **Future -CVPIA 3406 (b)(2) and Limited EWA** | **Future Climate Change-D1641** | |
| OCAP BA Base model: Common Assumptions: Common Model Package (Version 8D) | | | | | | | | | |
| *"Same" indicates an assumption from a column to the left* | | | | | | | | | |
| Planning horizon | | 2001 | 2005[a] | 2005[a] | Same | Same | 2030[a] | Same | |
| Period of Simulation | | 73 years (1922-1994) | 82 years (1922-2003) | 82 years (1922-2003) | Same | Same | Same | Same | Extended hydrology timeseries |
| **HYDROLOGY** | | | | | | | | Inflows are modified based on alternative climate inputs [b] | Revised level of detail in the Yuba and Colusa Basin including rice decomposition operations |
| **Level of development (Land Use)** | | 2001 Level | 2005 level | 2005 level | Same | Same | 2030 level[c] | Same | |
| **Sacramento Valley** (excluding American R.) | | | | | | | | | |
| | CVP | Land-use based, limited by contract amounts[d] | Same | Same | Same | Same | CVP Land-use based, Full build out of CVP contract amounts[d] | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | SWP (FRSA) | Land-use based, limited by contract amounts[e] | Same | Same | Same | Same | Same | Same | |
| | Non-project | Land-use based | Same | Same | Same | Same | Same | Same | |
| | Federal refuges | Firm Level 2 | Same | Same | Recent Historical Firm Level 2 water needs[f] | Same | Firm Level 2 water needs[f] | Same | |
| **American River** | | | | | | | | | |
| | Water rights | 2001[g] | Same | Same | 2005[g] | Same | 2025 | Same | |
| | CVP (PCWA American River Pump Station) | No project | Same | Same | CVP (PCWA modified)[g] | Same | Same | Same | |
| **San Joaquin River[h]** | | | | | | | | | |
| | Friant Unit | Regression of Historical Demands | Limited by contract amounts, based on current allocation policy | Limited by contract amounts, based on current allocation policy | Same | Same | Same | Same | Developed land-use based demands, water quality calculations, and revised accretions/depletions in the East-Side San Joaquin Valley |
| | Lower Basin | Fixed Annual Demands | Land-use based, based on district level operations and constraints | Land-use based, based on district level operations and constraints | Same | Same | Same | Same | |
| | Stanislaus River | New Melones Interim Operations Plan | Same | Same | Same | Draft Transitional Operations Plan[r] | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **South of Delta** | | | | | | | | | |
| | (CVP/SWP project facilities) | CVP Demand based on contracts amounts[d] | Same | Same | Same | Same | Same | Same | |
| | Contra Costa Water District | 124 TAF/yr | Same | Same | 135 TAF/yr CVP contract supply and water rights[i] | Same | 195 TAF CVP contract supply and water rights[i] | Same | |
| | SWP Demand - Table A | Variable 3.1-4.1 MAF/Yr | Same | Same | Variable 3.1-4.2 MAF/Yr [e,j] | Same | Full Table A | Same | Revised SWP delivery logic. Three patterns with Art 56 and more accurately defined Table A / Article 21 split modeled |
| | SWP Demand - North Bay Aqueduct (Table A) | 48 TAF/Yr | Same | Same | 71 TAF/Yr | Same | 77 TAF/Yr | Same | |
| | SWP Demand - Article 21 demand | Up to 134 TAF/month December to March, total of other demands up to 84 TAF/month in all months | Same | Same | Up to 314 TAF/month from December to March, total of demands up to 214 TAF/month in all other months[e,j] | Same | Same | Same | |
| | Federal refuges | Firm Level 2 | Same | Same | Recent Historical Firm Level 2 water needs[f] | Same | Firm Level 2 water needs[f] | Same | |
| **FACILITIES** | | | | | | | | | |
| **Systemwide** | | Existing facilities[a] | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **Sacramento Valley** | | | | | | | | | |
| | Red Bluff Diversion Dam | No diversion constraint | Same | Same | Diversion Dam operated May 15 - Sept 15 (diversion constraint) | Same | Diversion Dam operated July - August (diversion constraint) | Same | |
| | Colusa Basin | Existing conveyance and storage facilities | Same | Same | Same | Same | Same | Same | |
| | Upper American River | No project | Same | Same | PCWA American River pump station[k] | Same | Same | Same | |
| | Sacramento River Water Reliability | No project | Same | Same | Same | Same | American/Sacramento River Diversions[t] | Same | |
| | Lower Sacramento River | No project | Same | Same | Same | Freeport Regional Water Project (Full Demand)[l] | Same | Same | |
| **Delta Region** | | | | | | | | | |
| | SWP Banks Pumping Plant | South Delta Improvements Program Temporary Barriers, 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through Mar 15.(additional 500 cfs | Same | Same | Same | South Delta Improvements Program Permanent Barriers (Stage 1). 6,680 cfs capacity in all months and an additional 1/3 of Vernalis flow from Dec 15 through Mar 15 (additional 500 cfs Jul - Sep)[a] | Same | Same | |

| | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|
| | Jul - Sep post processed)[a] | | | | | | | |
| CVP C.W. Bill Jones (Tracy) Pumping Plant | 4,200 cfs + deliveries upstream of DMC constriction | Same | Same | Same | 4,600 cfs capacity in all months (allowed for by the Delta-Mendota Canal–California Aqueduct Intertie) | Same | Same | |
| City of Stockton Delta Water Supply Project (DWSP) | No project | Same | Same | DWSP WTP 0 mgd | Same | DWSP WTP 30 mgd | Same | |
| Contra Costa Water District | Existing pump locations | Same | Same | Same | Same | Same[m] | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **South of Delta (CVP/SWP project facilities)** | | | | | | | | | |
| | South Bay Aqueduct (SBA) | Existing capacity 300 cfs | Same | Same | SBA Rehabilitation: 430 cfs capacity from junction with California Aqueduct to Alameda County FC&WSD Zone 7 diversion point | Same | Same | Same | |
| **REGULATORY STANDARDS** | | | | | | | | | |
| **Trinity River** | | | | | | | | | |
| | Minimum flow below Lewiston Dam | Trinity EIS Preferred Alternative (369-815 TAF/year) | Same | Pre Trinity ROD (367-453 TAF/year) | Trinity EIS Preferred Alternative (369-815 TAF/year) | Same | Same | Same | |
| | Trinity Reservoir end-of-September minimum storage | Trinity EIS Preferred Alternative (600 TAF as able) | Same | Same | Same | Same | Same | Same | |
| **Clear Creek** | | | | | | | | | |
| | Minimum flow below Whiskeytown Dam | Downstream water rights, 1963 USBR Proposal to USFWS and NPS, and USFWS discretionary use of CVPIA | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | 3406(b)(2) | | | | | | | |
| **Upper Sacramento River** | | | | | | | | | |
| | Shasta Lake | NMFS 2004 BiOp: 1.9 MAF end of Sep. storage target in non-critical years | Same | Same | Same | Same | Same | Same | |
| | Minimum flow below Keswick Dam | Flows for SWRCB WR 90-5 temperature control, and USFWS discretionary use of CVPIA 3406(b)(2) | Same | Same | Same | Same | Same | Same | |
| **Feather River** | | | | | | | | | |
| | Minimum flow below Thermalito Diversion Dam | 1983 DWR, DFG Agreement (600 cfs) | Same | Same | Same | 2006 Settlement Agreement (700 / 800 cfs) | Same | Same | |
| | Minimum flow below Thermalito Afterbay outlet | 1983 DWR, DFG Agreement (750-1,700 cfs) | Same | Same | Same | Same | Same | Same | |
| **Yuba River** | | | | | | | | | |
| | Minimum flow below | Available Yuba River | D-1644 Interim | D-1644 Interim | Same | Yuba Accord Adjusted | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | Daguerre Point Dam | Data[p] | Operations[p] | Operations[p] | | Data[p] | | | |
| **American River** | | | | | | | | | |
| | Minimum flow below Nimbus Dam | SWRCB D-893 (see Operations Criteria), and USFWS discretionary use of CVPIA 3406(b)(2) | Same | Same | (b)(2) Minimum Instream Flow management[s] | Same | American River Flow Management [s] | Same | |
| | Minimum Flow at H Street Bridge | SWRCB D-893 | Same | Same | Same | Same | Same | Same | |
| **Lower Sacramento River** | | | | | | | | | |
| | Minimum flow near Rio Vista | SWRCB D-1641 | Same | Same | Same | Same | Same | Same | |
| **Mokelumne River** | | | | | | | | | |
| | Minimum flow below Camanche Dam | FERC 2916-029, 1996 (Joint Settlement Agreement) (100-325 cfs) | Same | Same | Same | Same | Same | Same | |
| | Minimum flow below Woodbridge Diversion Dam | FERC 2916-029, 1996 (Joint Settlement Agreement) (25-300 cfs) | Same | Same | Same | Same | Same | Same | |
| **Stanislaus River** | | | | | | | | | |
| | Minimum flow below Goodwin Dam | 1987 USBR, DFG agreement, | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | and USFWS discretionary use of CVPIA 3406(b)(2) | | | | | | | |
| | Minimum dissolved oxygen | SWRCB D-1422 | Same | Same | Same | Same | Same | Same | |
| **Merced River** | | | | | | | | | |
| | Minimum flow below Crocker-Huffman Diversion Dam | Davis-Grunsky (180-220 cfs, Nov-Mar), Cowell Agreement | Same | Same | Same | Same | Same | Same | |
| | Minimum flow at Shaffer Bridge | FERC 2179 (25-100 cfs) | Same | Same | Same | Same | Same | Same | |
| **Tuolumne River** | | | | | | | | | |
| | Minimum flow at Lagrange Bridge | FERC 2299-024, 1995 (Settlement Agreement) (94-301 TAF/year) | Same | Same | Same | Same | Same | Same | |
| **San Joaquin River** | | | | | | | | | |
| | Maximum salinity near Vernalis | SWRCB D-1641 | Same | Same | Same | Same | Same | Same | |
| | Minimum flow near Vernalis | SWRCB D-1641, and Vernalis Adaptive Management Plan per San Joaquin | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | River Agreement | | | | | | | |
| **Sacramento River–San Joaquin River Delta** | | | | | | | | | |
| | Delta Outflow Index (Flow and Salinity) | SWRCB D-1641 | Same | Same | Same | Same | Same | Same | Revised Delta ANN (salinity estimation) |
| | Delta Cross Channel gate operation | SWRCB D-1641 | Same | Same | Same | Same | Same | Same | |
| | Delta exports | SWRCB D-1641, USFWS discretionary use of CVPIA 3406(b)(2) | Same | Same | Same | Same | Same | Same | |
| **OPERATIONS CRITERIA: RIVER-SPECIFIC** | | | | | | | | | |
| **Upper Sacramento River** | | | | | | | | | |
| | Flow objective for navigation (Wilkins Slough) | 3,250 - 5,000 cfs based on CVP water supply condition | Same | Same | Same | Same | Same | Same | |
| **American River** | | | | | | | | | |
| | Folsom Dam flood control | Variable 400/670 flood control diagram (without outlet modification | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | s) | | | | | | | |
| | Flow below Nimbus Dam | Discretionary operations criteria corresponding to SWRCB D-893 required minimum flow | Same | Same | (b)(2) Minimum Instream Flow management[s] | Same | American River Flow Management [s] | Same | |
| | Sacramento Area Water Forum "Replacement" Water | "Replacement" water is not implemented | Same | Same | Same | Same | Same | Same | |
| **Stanislaus River** | | | | | | | | | |
| | Flow below Goodwin Dam | 1997 New Melones Interim Operations Plan | Same | Same | Same | Draft Transitional Operations Plan[r] | Same | Same | |
| **San Joaquin River** | | | | | | | | | |
| | Flow at Vernalis | D1641 | Same | Same | Same | Same | Same[q] | Same | |
| **OPERATIONS CRITERIA: SYSTEMWIDE** | | | | | | | | | |
| **CVP water allocation** | | | | | | | | | |
| | CVP Settlement and Exchange | 100% (75% in Shasta critical years) | Same | Same | Same | Same | Same | Same | |
| | CVP refuges | 100% (75% in Shasta critical years) | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | CVP agriculture | 100%-0% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions) | Same | Same | Same | Same | Same | Same | |
| | CVP municipal & industrial | 100%-50% based on supply (South-of-Delta allocations are reduced due to D-1641 and 3406(b)(2) allocation-related export restrictions) | Same | Same | Same | Same | Same | Same | |
| **SWP water allocation** | | | | | | | | | |
| | North of Delta (FRSA) | Contract specific | Same | Same | Same | Same | Same | Same | |
| | South of Delta (including North Bay Aqueduct) | Based on supply; equal prioritization between Ag and M&I based on Monterey Agreement | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| **CVP-SWP coordinated operations** | | | | | | | | | |
| | Sharing of responsibility for in-basin-use | 1986 Coordinated Operations Agreement (FRWP EBMUD and 2/3 of the North Bay Aqueduct diversions are considered as Delta Export, 1/3 of the North Bay Aqueduct diversion is considered as in-basin-use) | Same | Same | Same | Same | Same | Same | |
| | Sharing of surplus flows | 1986 Coordinated Operations Agreement | Same | Same | Same | Same | Same | Same | |
| | Sharing of Export/Inflow Ratio | Equal sharing of export capacity under SWRCB D-1641; use of CVPIA 3406(b)(2) restricts only CVP and/or SWP exports | Same | Same | Same | Same | Same | Same | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | Sharing of export capacity for lesser priority and wheeling related pumping | Cross Valley Canal wheeling (max of 128 TAF/year), CALFED ROD defined Joint Point of Diversion (JPOD) | Same | Same | Same | Same | Same | Same | |
| **Study assumptions from above apply** | | | **Study 6a** | **Study 6.1a** | **Study 7a** | **Study 7.1a** | **Study 8a** | **NA** | |
| **CVPIA 3406(b)(2): Per May 2003 Dept. of Interior Decision** | | | | | | | | | |
| | Allocation | 800 TAF, 700 TAF in 40-30-30 dry years, and 600 TAF in 40-30-30 critical years[n] | Same | Same | Same | Same | Same | NA | |
| **Study assumptions from above apply** | | | **Study 6b** | **Study 6.1b** | **Study 7b** | **Study 7.1b** | **Study 8b** | **NA** | |
| **CALFED Environmental Water Account / Limited Environmental Water Account** | | | | | | | | | |

| | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|
| Actions | NA | Same | Same | Dec/Jan 50 TAF/mon export reduction, Feb 50 TAF export reduction in Wet/AN years, Feb/Mar 100, 75, or 50 TAF reduction dependent on species habitat conditions; VAMP (Apr 15 - May 16) export restriction on SWP; Pre (Apr 1-14) VAMP export reduction in Dry/Crit years; Post (May 16-31) export restriction; June ramping restriction if PostVAMP action was done. Pre- and Post-VAMP and June actions done if foreseeable October debt at San Luis does not exceed 150 TAF. | VAMP (Apr 15 - May 16) export restriction on SWP; If Stored assets and Purchases from the Yuba are sufficient, Post (May 16-31) VAMP export restriction on SWP [pq] | Same | NA | The EWA actions, assets, and debt were revised and vetted as part of the Long Term Environmental Water Account EIS/R project |

| | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|
| Assets | NA | Same | Same | Fixed Water Purchases 250 TAF/yr, 230 TAF/yr in 40-30-30 dry years, 210 TAF/yr in 40-30-30 critical years. NOD share of annual purchase target ranges from 90% to 50% based on SWP Ag Allocation as an indicator of conveyance capacity. Variable/operational assets include use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep, source shifting, Semitropic Groundwater Bank, “spill” of San Luis carryover debt, and backed-up stored water from Spring | Purchase of Yuba River Stored Water under the Lower Yuba River Accord (average of 48 TAF/yr), use of 50% of any CVPIA 3406(b)(2) releases pumped by SWP, additional 500 CFS pumping capacity at Banks in Jul-Sep | Same | | |

| | | Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | EWA actions. | | | | |
| | Debt | NA | Same | Same | Same | No Carryover Debt | Same | | |
| | | | | | | | | | |
| **Post Processing Assumptions** | | | | | | | | | |
| **WATER MANAGEMENT ACTIONS (CALFED)** | | | | | | | | | |
| **Water Transfers** | | | | | | | | | |
| | Water transfers | Acquisitions by SWP contractors are wheeled at priority in Banks Pumping Plant over non-SWP users | Same | NA | Same | Same | Same | NA | |
| | Phase 8[o] | Evaluate available capacity | Same | | Same | Same | Same | | |
| | Refuge Level 4 water | Evaluate available capacity | Same | | Same | Same | Same | | |

**Notes:**

[a] The OCAP BA project description is described in Chapter 2.

[b]Climate change sensitivity analysis assumptions and documentation are presented in Appendix R.

| Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|

[c] The Sacramento Valley hydrology used in the CalSim-II model reflects 2020 land-use assumptions associated with Bulletin 160-98. The San Joaquin Valley hydrology reflects draft 2030 land-use assumptions developed by Reclamation. Development of 2030 land-use assumptions are being coordinated with the California Water Plan Update for future models.

[d] CVP contract amounts have been reviewed and updated according to existing and amended contracts as appropriate. Assumptions regarding CVP agricultural and M&I service contracts and Settlement Contract amounts are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D: Delivery Specifications section of the Technical Appendix.

[e] SWP contract amounts have been reviewed and updated as appropriate. Assumptions regarding SWP agricultural and M&I contract amounts are documented in Table 1A (North of Delta) and Table 2A (South of Delta) of Appendix D: Delivery Specifications section.

[f] Water needs for federal refuges have been reviewed and updated as appropriate. Assumptions regarding firm Level 2 refuge water needs are documented in Table 3A (North of Delta) and 5A (South of Delta) of Appendix D:Delivery Specifications. Incremental Level 4 refuge water needs have been documented as part of the assumptions of future water transfers.

[g] PCWA demand in the foreseeable existing condition is 8.5 TAF/yr of CVP contract supply diverted at the new American River PCWA Pump Station. In the future scenario, PCWA is allowed 35 TAF/yr. Assumptions regarding American River water rights and CVP contracts are documented in Appendix D: Delivery Specifications section.

[h] The new CalSim-II representation of the San Joaquin River has been included in this model package (CalSim-II San Joaquin River Model, Reclamation, 2005). Updates to the San Joaquin River have been included since the preliminary model release in August 2005. The model reflects the difficulties of on-going groundwater overdraft problems. The 2030 level of development representation of the San Joaquin River Basin does not make any attempt to offer solutions to on-going groundwater overdraft problems. In addition, a dynamic groundwater simulation is not yet developed for San Joaquin River Valley. Groundwater extraction/ recharge and stream-groundwater interaction are static assumptions and may not accurately reflect a response to simulated actions. These limitations should be considered in the analysis of results.

[i] Los Vaqueros Reservoir storage capacity is 100 TAF.

[j] Table A deliveries into the San Francisco Bay Area Region for existing cases are based on a variable demand and a full Table A for future cases. The variable demand is dependent on the availability of other water during wet years resulting in less demand for Table A. In the future cases it is assumed that the demand for full Table A will be independent of other water sources. Article 21 demand assumes MWD demand of 100 TAF (Dec-Mar), Kern demand of 180 TAF (Jan-Dec), and other contractor demand of 34 TAF (Jan-Dec).

| Study 3a | Study 6.0 COMPARISON | Study 6.1 EMULATES PRE TRINITY ROD | Study 7.0 BASE MODEL | Study 7.1 ANALYTICAL | Study 8.0 ANALYTICAL | Study 9.0 - 9.3 SENSITIVITY | CalSim-II Model Revisions since OCAP BA 2004 |
|---|---|---|---|---|---|---|---|

[k] PCWA American River pumping facility upstream of Folsom Lake is under construction.

[l] Mokelumne River flows reflect EBMUD supplies associated with the Freeport Regional Water Project.

[m] The CCWD Alternate Intake Project (AIP), an intake at Victoria Canal, which operates as an alternate Delta diversion for Los Vaqueros Reservoir is not included in Study 8.0. AIP is included a separate consultation. AIP will be further evaluated after regulatory and operational management assumptions have been determined.

[n] The allocation representation in CalSim-II replicates key processes, shortage changes are checked by post-processing.

[o] This Phase 8 requirement is assumed to be met through Sacramento Valley Water Management Agreement Implementation.

[p] OCAP BA 2004 modeling used available hydrology at the time which was data developed based on 1965 Yuba County Water Agency -Department of Fish of Game Agreement. Since the OCAP BA 2004 modeling, Yuba River hydrology was revised. Interim D-1644 is assumed to be fully implemented with or without the implementation of the Lower Yuba River Accord. This is consistent with the future no-action condition being assumed by the Lower Yuba River Accord EIS/EIR study team. For studies with the Lower Yuba River Accord, an adjusted hydrology is used.

[q] It is assumed that either VAMP, a functional equivalent, or D-1641 requirements would be in place in 2030.

[r] The Draft Transitional Operations Plan assumptions are discussed in Chapter 2.

[s] For Studies 7.0, 7.1, and 8.0 the flow components of the proposed American River Flow Management is included and applied using CVPIA 3406(b)(2). For Study 8.0 the American River Flow Management is assumed to be the new minimum instream flow.

[t] OCAP BA assumes the flexibility of diversion location but does not assume the Sacramento Area Water Forum Water Forum "replacement water" in drier water year types.

## Assumed Future Demands

The CalSim-II model results are very sensitive to assumed demands for the CVP and SWP systems. The modeled representation of future demands are assumed as full water right and contract demands for the CVP and full Table A for the SWP. Assumed delivery specifications for diversion locations in the CalSim-II model are listed in detail for both the existing and future levels of development in the Appendix D.

The following explains only the significant future delivery assumptions that deviate from the previous OCAP BA model representation (OCAP BA, 2004):

- The future total American River Basin water demand is greater than the demands assumed for 2004 BA analysis and, does not include the representation of the Water Forum program for demand reductions in certain dry and critical hydrologic conditions. The modeling assumes 311,800 af/yr in future water right demands for the city of Sacramento which is also greater than the previous models (the OCAP BA 2004 simulated a year 2020 level of development, the current OCAP BA simulates a year 2030 level of development). Finally, the modeling does not include the representation of the Water Forum program for additional releases from the Middle Fork Project. These changes represent a more realistic picture of the CVP's ability to meet water rights and water contract obligations. Another important change is the representation of the American River minimum flow requirements below Lake Natoma. These flows are augmented according to the proposed American River Flow Management schedule.
- The Sacramento River Reliability Project also affects the future representation which reduces the delivery burden on the American River by shifting demands to a Sacramento River diversion. Assumed delivery specifications for the American River are also listed in the CalSim-II modeling Appendix D.
- The City of Stockton Delta Water Supply Project is included in the future representation. This captures the expansion of future Delta demands with the development of the 30 mgd Delta Water Supply Project.
- The modeling of SWP deliveries has been significantly refined in the latest version of CalSim-II to better reflect current delivery classification practices. The three significant changes in the delivery modeling are 1) the incorporation of a three-pattern demand, 2) explicit modeling of the previous year's Table A supplies that are delivered in the current year ("Carryover" or Article 56 deliveries), and 3) increased assumption for Article 21 demands.
    - The three-pattern demand allows for demand adjustments associated with various levels of Table A allocation. Based on the amount of Table A allocation one of the three demand patterns is selected to more accurately model the monthly delivery pattern.
    - In the model used for the 2004 BA, a single demand pattern was used with the current year's Article 56 water inappropriately delivered at the beginning of the current year rather than being carried over for delivery in the following year. This artificially increased the Table A demand at the beginning of each year, and

potentially reduced Article 21 deliveries during the early part of the year. The new delivery methodology allows for the storage, delivery and "spilling" of the previous year's Article 56 carryover at the beginning of the current year. Delivery of the previous year's Article 56 is typically within the first three months of the current year. As the SWP share of San Luis Reservoir fills, there is a chance that Article 56 will "spill" i.e. it is converted to the current year's Table A supply.

- The new model also incorporates an Article 21 demand increase that more accurately represents actual Article 21 demand. However, with the incorporation of the three-pattern Table A demand, Article 56, and increased Article 21 demand, the overall total delivery remains largely the same. The previous version of the model tended to overestimate the delivery of Table A and underestimate the delivery of Article 21 by a like amount.
- The existing condition studies (Study 7.0, and Study 7.1) used a variable annual Table A demand which is consistent with the 2004 modeling. This assumes that the demand for Table A water would be less during very wet years, but would be greater in dry years.
- The future condition studies (Study 8.0, and Studies 9 suite) used full entitlement demand in all years. This condition assumes that, independent on the year type, the demand would remain the same. By contrast, the 2004 modeling assumed a variable demand for the future condition studies.

# Modeling Results

## Hydrologic Modeling Results

A summary of long-term averages (i.e., WY1922 to WY2003) and critical drought-period averages (i.e., WY1928 to WY1934) is shown in Table 9-6 for flows, storages, Delta output, and deliveries. These values represent long-term averages, for example CalSim-II results for CVP SOD Agricultural allocations range from 0 to 100 percent. The remaining section presents results for 3406 CVPIA (b)(2) accounting and EWA. Discussions of results are presented in Chapter 10: Streams Controlled by CVP and SWP Operations and Chapter 12: CVP and SWP Delta Operations. Additional results, including month-by-year tables, exceedance charts, monthly averages by water-year type, and monthly percentiles for selected CalSim-II outputs, are located in the appendix (Appendix E).

Selected results in this chapter are shown in exceedance charts for a particular month or set of months, average and percentile monthly data, and sorted by water-year type for a particular month. The probability-of-exceedance charts show values on the y-axis with the percent of time (probability of exceedance) that the value was exceeded. For example, the end-of-September exceedance charts show the probability that the reservoir was able to carry over storage into the next water year for each of the studies. The exceedance charts are also a good measure of trend between the studies, either higher or lower on average. Averages by water-year type are sorted in this chapter based on the 40-30-30 Sacramento Valley Index and show how the average changes from Wet to Critical years. The 60-20-20 San Joaquin Valley Index was used for sorting temperature and CalSim-II output from the Stanislaus and San Joaquin rivers. The percentile graphs show monthly values for the $50^{th}$, $5^{th}$, and $95^{th}$ percentiles for a given output variable and were used to indicate how flows are being affected by flood and minimum-flow requirements.

**Table 9-6. Long-term Averages and 28-34 Averages From Each of the Five Studies**

| | 2004 OCAP BA Study3a | | Study 6.0 | | Study 6.1 | | Study 7.0 | | Study 7.1 | | Study 8.0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **End of Sep Storages (TAF)** | 1922-94 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 |
| Trinity | 1305 | 607 | 1421 | 729 | 1501 | 721 | 1425 | 733 | 1418 | 667 | 1409 | 675 |
| Whiskeytown | 233 | 217 | 235 | 234 | 235 | 233 | 234 | 227 | 234 | 228 | 235 | 233 |
| Shasta | 2591 | 1253 | 2798 | 1530 | 2807 | 1577 | 2875 | 1608 | 2773 | 1332 | 2753 | 1338 |
| Folsom | 534 | 413 | 543 | 444 | 541 | 448 | 555 | 434 | 536 | 420 | 518 | 396 |
| New Melones | 1379 | 833 | 1471 | 866 | 1471 | 866 | 1486 | 883 | 1496 | 881 | 1557 | 1047 |
| CVP San Luis | 250 | 371 | 226 | 417 | 221 | 405 | 222 | 345 | 261 | 418 | 257 | 431 |
| SWP San Luis | 382 | 298 | 291 | 203 | 301 | 206 | 602 | 517 | 665 | 472 | 535 | 474 |
| Total San Luis | 562 | 669 | 517 | 620 | 522 | 611 | 836 | 889 | 962 | 908 | 822 | 930 |
| **River Flows (cfs)** | | | | | | | | | | | | |
| Trinity Release | 924 | 566 | 972 | 566 | 787 | 566 | 972 | 566 | 970 | 566 | 968 | 566 |
| Clear Creek Tunnel | 748 | 498 | 738 | 484 | 919 | 523 | 736 | 459 | 738 | 479 | 739 | 486 |
| Clear Creek Release | 165 | 96 | 171 | 119 | 172 | 119 | 169 | 117 | 168 | 100 | 169 | 99 |
| Keswick Release | 8356 | 5534 | 8572 | 5452 | 8751 | 5456 | 8559 | 5461 | 8573 | 5462 | 8574 | 5458 |
| Nimbus Release | 3457 | 1930 | 3492 | 1849 | 3492 | 1831 | 3472 | 1864 | 3474 | 1841 | 3335 | 1730 |
| Mouth of American | 3326 | 1793 | 3322 | 1684 | 3322 | 1667 | 3351 | 1745 | 3355 | 1722 | 2974 | 1365 |
| Sac River blw Red Bluff Diversion Dam | 10931 | 6958 | 11324 | 6922 | 11493 | 6926 | 11297 | 6893 | 11313 | 6909 | 11351 | 6953 |
| Wilkin's Slough | 8928 | 5489 | 9258 | 5598 | 9411 | 5601 | 9428 | 5794 | 9247 | 5588 | 9230 | 5582 |
| Sac at Freeport | 22100 | 11509 | 22452 | 11352 | 22619 | 11327 | 22674 | 12017 | 22467 | 11546 | 22474 | 11518 |
| Tulloch Release | 1382 | 1011 | 1445 | 1078 | 1445 | 1078 | 652 | 351 | 659 | 413 | 654 | 364 |
| Stanislaus Mouth | 886 | 487 | 779 | 406 | 779 | 406 | 788 | 407 | 795 | 469 | 790 | 421 |
| SJR Flow w/o Stanislaus | 2843 | 1236 | 3377 | 1454 | 3377 | 1454 | 3383 | 1456 | 3378 | 1448 | 3335 | 1416 |
| Flow at Vernalis | 3694 | 1685 | 4192 | 1882 | 4192 | 1882 | 4206 | 1886 | 4209 | 1939 | 4161 | 1859 |
| Yolo Bypass | 2028 | 132 | 2744 | 152 | 2745 | 166 | 2685 | 129 | 2638 | 148 | 2638 | 158 |
| Mokelumne | 869 | 278 | 924 | 281 | 924 | 281 | 924 | 281 | 924 | 281 | 918 | 286 |
| Spring Creek Tunnel | 927 | 511 | 935 | 461 | 1116 | 500 | 936 | 439 | 939 | 476 | 939 | 483 |
| **Delta Parameters** | | | | | | | | | | | | |
| SWP Banks (cfs) | 4448 | 2602 | 4480 | 2701 | 4483 | 2707 | 4510 | 2714 | 4722 | 2896 | 4766 | 2892 |

| | 2004 OCAP BA Study3a | | Study 6.0 | | Study 6.1 | | Study 7.0 | | Study 7.1 | | Study 8.0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CVP Banks (cfs) | 186 | 40 | 101 | 11 | 110 | 16 | 94 | 33 | 101 | 14 | 95 | 6 |
| Jones (cfs) | 3264 | 2096 | 3301 | 2074 | 3322 | 2069 | 3158 | 2007 | 3260 | 2039 | 3199 | 1928 |
| Total Banks (cfs) | 4633 | 2643 | 4580 | 2712 | 4593 | 2723 | 4867 | 3131 | 4926 | 2966 | 4960 | 2955 |
| Cross Valley Pumping (cfs) | 106 | 23 | 101 | 11 | 110 | 16 | 85 | 24 | 89 | 14 | 85 | 6 |
| Sac Flow at Freeport (cfs) | 22100 | 11509 | 22452 | 11352 | 22619 | 11327 | 22674 | 12017 | 22467 | 11546 | 22474 | 11518 |
| Flow at Rio Vista (cfs) | 18152 | 7192 | 19232 | 7114 | 19380 | 7104 | 19240 | 7525 | 19033 | 7202 | 19034 | 7202 |
| Excess Outflow (cfs) | 11750 | 1327 | 13416 | 1557 | 13518 | 1538 | 15043 | 1542 | 14573 | 1261 | 14578 | 1313 |
| Required Outflow (cfs) | 7735 | 5911 | 7717 | 5664 | 7750 | 5666 | 6016 | 5858 | 6076 | 5870 | 6068 | 5874 |
| X2 Position (km) | 76 | 82 | 76 | 82 | 75 | 82 | 76 | 85 | 76 | 85 | 76 | 85 |
| Yolo Bypass (cfs) | 2028 | 132 | 2744 | 152 | 2745 | 166 | 2685 | 129 | 2638 | 148 | 2638 | 158 |
| Mokelumne Flow (cfs) | 869 | 278 | 924 | 281 | 924 | 281 | 924 | 281 | 924 | 281 | 918 | 286 |
| SJR + Calaveras Flow (cfs) | 3887 | 1755 | 4351 | 1908 | 4351 | 1908 | 4348 | 1897 | 4351 | 1950 | 4307 | 1873 |
| Modeled Required DO (cfs) | 7532 | 5675 | 7717 | 5664 | 7750 | 5666 | 6021 | 5877 | 6077 | 5870 | 6068 | 5874 |
| Flow at Georgiana Slough (cfs) | 3768 | 2360 | 3815 | 2339 | 3837 | 2336 | 3845 | 2427 | 3817 | 2365 | 3818 | 2361 |
| DXC Flow (cfs) | 1729 | 1567 | 1685 | 1531 | 1684 | 1533 | 1763 | 1638 | 1746 | 1569 | 1745 | 1560 |
| Flow below DXC (cfs) | 16603 | 7582 | 16952 | 7482 | 17099 | 7459 | 17066 | 7952 | 16904 | 7612 | 16911 | 7597 |
| North Bay Aqueduct (cfs) | 54 | 28 | 52 | 29 | 52 | 29 | 36 | 26 | 34 | 25 | 40 | 28 |
| CCWD (cfs) | 171 | 159 | 171 | 159 | 171 | 159 | 213 | 223 | 213 | 223 | 213 | 223 |
| Total Outflow (cfs) | 19485 | 7238 | 21132 | 7221 | 21267 | 7204 | 21059 | 7400 | 20649 | 7132 | 20647 | 7187 |
| Total Inflow (cfs) | 28884 | 13675 | 30471 | 13693 | 30639 | 13682 | 30631 | 14325 | 30380 | 13925 | 30337 | 13834 |
| Old&Middle River (cfs) | -- | -- | -4764 | -3278 | -4795 | -3284 | -4888 | -3597 | -5033 | -3445 | -5037 | -3380 |
| QWEST (cfs) | -- | -- | 1877 | 117 | 1864 | 109 | 1748 | -152 | 1548 | -99 | 1528 | -47 |
| **Deliveries (TAF)** | | | | | | | | | | | | |
| CVP | | | | | | | | | | | | |
| North of Delta | | | | | | | | | | | | |
| Agriculture | 227 | 36 | 227 | 23 | 235 | 24 | 235 | 49 | 231 | 28 | 221 | 13 |
| Settlement Contracts | 1832 | 1750 | 1838 | 1727 | 1838 | 1727 | 1658 | 1547 | 1836 | 1725 | 1852 | 1735 |
| M&I | 26 | 27 | 42 | 34 | 43 | 34 | 89 | 66 | 87 | 60 | 216 | 140 |
| Refuge | 101 | 91 | 72 | 62 | 72 | 62 | 72 | 62 | 71 | 62 | 90 | 78 |
| **Total** | 2198 | 1903 | 2179 | 1847 | 2188 | 1847 | 2053 | 1724 | 2225 | 1875 | 2379 | 1967 |
| South of Delta | | | | | | | | | | | | |

| | 2004 OCAP BA Study3a | | Study 6.0 | | Study 6.1 | | Study 7.0 | | Study 7.1 | | Study 8.0 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Agriculture | 1064 | 182 | 1046 | 123 | 1060 | 125 | 1041 | 252 | 1044 | 143 | 1019 | 67 |
| Exchange | 841 | 737 | 852 | 741 | 852 | 741 | 852 | 741 | 852 | 741 | 852 | 741 |
| M&I | 118 | 86 | 123 | 83 | 124 | 83 | 123 | 94 | 125 | 85 | 124 | 79 |
| Refuge | 274 | 240 | 296 | 254 | 296 | 254 | 296 | 254 | 296 | 254 | 273 | 234 |
| **Total**** | 2492 | 1429 | 2501 | 1385 | 2516 | 1386 | 2496 | 1524 | 2500 | 1406 | 2452 | 1305 |
| SWP | | | | | | | | | | | | |
| Allocation | 2982 | 1612 | 3297 | 1784 | 3284 | 1778 | 3371 | 1477 | 3264 | 1460 | 3246 | 1442 |
| Table A | 2982 | 1612 | 2954 | 1709 | 2944 | 1703 | 2563 | 1370 | 2493 | 1352 | 2991 | 1375 |
| Article 56 | 0 | 0 | 0 | 0 | 0 | 0 | 341 | 70 | 345 | 99 | 118 | 37 |
| Article 21 | 168 | 127 | 218 | 108 | 230 | 117 | 499 | 535 | 558 | 574 | 363 | 581 |
| Table A + Art 56 | 2982 | 1612 | 2954 | 1709 | 2944 | 1703 | 2904 | 1440 | 2838 | 1451 | 3109 | 1412 |
| Table A + Art 56 + Art 21 | 3150 | 1739 | 3172 | 1817 | 3174 | 1820 | 3402 | 1975 | 3396 | 2025 | 3472 | 1993 |
| Anticipated Carryover | 0 | 0 | 0 | 0 | 0 | 0 | 484 | 34 | 463 | 35 | 186 | 1 |
| **Allocations (%)** | | | | | | | | | | | | |
| CVP Allocation | | | | | | | | | | | | |
| North of Delta | | | | | | | | | | | | |
| Agriculture | 69% | 19% | 66% | 17% | 69% | 17% | 69% | 21% | 68% | 16% | 63% | 13% |
| M&I | 87% | 65% | 87% | 62% | 88% | 63% | 88% | 67% | 88% | 62% | 86% | 58% |
| South of Delta | | | | | | | | | | | | |
| Agriculture | 59% | 19% | 56% | 17% | 57% | 17% | 58% | 21% | 58% | 16% | 57% | 13% |
| M&I | 86% | 65% | 84% | 62% | 85% | 63% | 85% | 67% | 85% | 62% | 85% | 58% |
| SWP | | | | | | | | | | | | |
| All SWC | 72% | 39% | 78% | 42% | 78% | 42% | 80% | 35% | 77% | 35% | 77% | 34% |

## CVPIA 3406 (b)(2)

This section analyzes water use for the CVPIA Section 3046 (b)(2), known as “(b)(2)” actions. Results from the CalSim-II accounting describe the long-term average (b)(2) costs for each study by water year type (see Table 9-7, Table 9-8, and Table 9-9). The long-term average annual cost of (b)(2) water use ranges from 671 taf annually to 689 taf annually.

Simulated (b)(2) costs for individual years (1922 – 2003) are presented in Figure 9-7, Figure 9-8, and Figure 9-9. These plots show the Water Quality Control Plan (WQCP) costs (non-discretionary) that are accounted up to 500 taf per year and discretionary or (b)(2) costs. The (b)(2) allocation, based on hydrologic conditions, are also noted for each year. CalSim-II does not use any forecasting algorithm for overall (b)(2) costs. This also results in over- and under-utilization of the allocated amount of (b)(2) water. The years when the (b)(2) costs are less than the allocated amount are generally Wet years, because flood releases are nearly identical between the D-1485 baseline and (b)(2) annual simulations, and VAMP export curtailments are up to the 2:1 ratio when non-VAMP flows are greater than 8,600 cfs.

An additional measure of (b)(2) performance is the probability of exceeding the 200 taf target during the October–January period. The probability of exceeding 200 taf October – January for Study 7.0, Study 7.1, and Study 8.0 is 17%, 15%, and 25% respectively (Figure 9-10, Figure 9-11, and Figure 9-12). Exceeding the 200-taf target is generally a result of the model taking high-cost upstream actions (at Nimbus and Keswick) before the accounting algorithms can reduce costs for this period. Another reason for high costs during this period is Delta salinity requirements during Dry and Critical years in the WQCP accounting. Similar percent exceedence graphics are presented for the total annual WQCP and (b)(2) costs in **Figure 9-13**, Figure 9-14, and Figure 9-15.

Table 9-10 shows the average required costs for a (b)(2) export action and what the simulated (b)(2) operation was able to support with the water available in the account and anticipated WQCP costs for Studies 7.0, 7.1, and 8.0. Study 8.0 shows a shift in actions where June Ramping and May Shoulders slightly increased and April-May VAMP slightly decreased. However, the frequency of (b)(2) releases and export reductions are similar between Studies 7.0, 7.1, and 8.0. This is presented in Table 9-11 which lists the percentage of times that the simulated actions were triggered under the assumptions for taking an action.

**Table 9-7 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.0 Today**

| Study 7.0 | Oct | Nov | Dec | Jan | Oct-Jan Subtotal | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WQCP Release Cost | 19 | 20 | 23 | 15 | 78 | 17 | 24 | 11 | 29 | 58 | 14 | 21 | 33 | 285 |
| WQCP Export Cost | 3 | 2 | 6 | 4 | 15 | 15 | 28 | 38 | 19 | 7 | 26 | 63 | 2 | 213 |
| WQCP Total Cost | 22 | 22 | 29 | 19 | 93 | 32 | 52 | 49 | 48 | 65 | 40 | 83 | 36 | 498 |

| Study 7.0 | Oct | Nov | Dec | Jan | Oct-Jan Subtotal | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (b)(2) Release Cost | 21 | 35 | 37 | 30 | 122 | 30 | 49 | 39 | 43 | 51 | 16 | 22 | 22 | 394 |
| (b)(2) Export Cost | 3 | 1 | 5 | 4 | 13 | 12 | 28 | 68 | 64 | 13 | 31 | 61 | 5 | 295 |
| (b)(2) Total Cost | 24 | 36 | 41 | 34 | 135 | 42 | 77 | 107 | 107 | 64 | 47 | 83 | 28 | 689 |

**Table 9-8 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 7.1 Near Future**

| Study 7.1 | Oct | Nov | Dec | Jan | Oct-Jan Subtotal | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WQCP Release Cost | 20 | 24 | 22 | 16 | 83 | 15 | 18 | 14 | 29 | 63 | 18 | 24 | 38 | 301 |
| WQCP Export Cost | 3 | 2 | 4 | 6 | 15 | 27 | 21 | 38 | 19 | 10 | 22 | 61 | 4 | 218 |
| WQCP Total Cost | 23 | 26 | 27 | 22 | 98 | 42 | 39 | 52 | 48 | 73 | 40 | 85 | 41 | 519 |
| (b)(2) Release Cost | 21 | 36 | 34 | 25 | 115 | 26 | 42 | 28 | 30 | 50 | 22 | 23 | 22 | 357 |
| (b)(2) Export Cost | 4 | 1 | 4 | 5 | 14 | 28 | 32 | 64 | 62 | 17 | 27 | 65 | 10 | 317 |
| (b)(2) Total Cost | 25 | 36 | 38 | 30 | 129 | 54 | 74 | 92 | 92 | 67 | 48 | 87 | 32 | 674 |

**Table 9-9 Average Monthly WQCP and Total (b)(2) Costs by Month, Total Oct – Jan Costs, and Total Annual Costs for Study 8.0 Future**

| Study 8.0 | Oct | Nov | Dec | Jan | Oct-Jan Subtotal | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WQCP Release Cost | 23 | 23 | 23 | 17 | 86 | 27 | 19 | 13 | 24 | 53 | 16 | 16 | 26 | 278 |
| WQCP Export Cost | 2 | 3 | 7 | 8 | 19 | 23 | 22 | 33 | 20 | 15 | 20 | 68 | 6 | 226 |
| WQCP Total Cost | 25 | 26 | 30 | 25 | 105 | 49 | 40 | 46 | 44 | 68 | 36 | 84 | 32 | 504 |
| (b)(2) Release Cost | 22 | 40 | 40 | 26 | 128 | 29 | 38 | 29 | 27 | 46 | 19 | 18 | 19 | 353 |
| (b)(2) Export Cost | 3 | 3 | 5 | 7 | 17 | 24 | 30 | 58 | 70 | 20 | 23 | 68 | 10 | 319 |
| (b)(2) Total Cost | 25 | 43 | 45 | 33 | 145 | 53 | 68 | 86 | 96 | 66 | 42 | 86 | 29 | 671 |

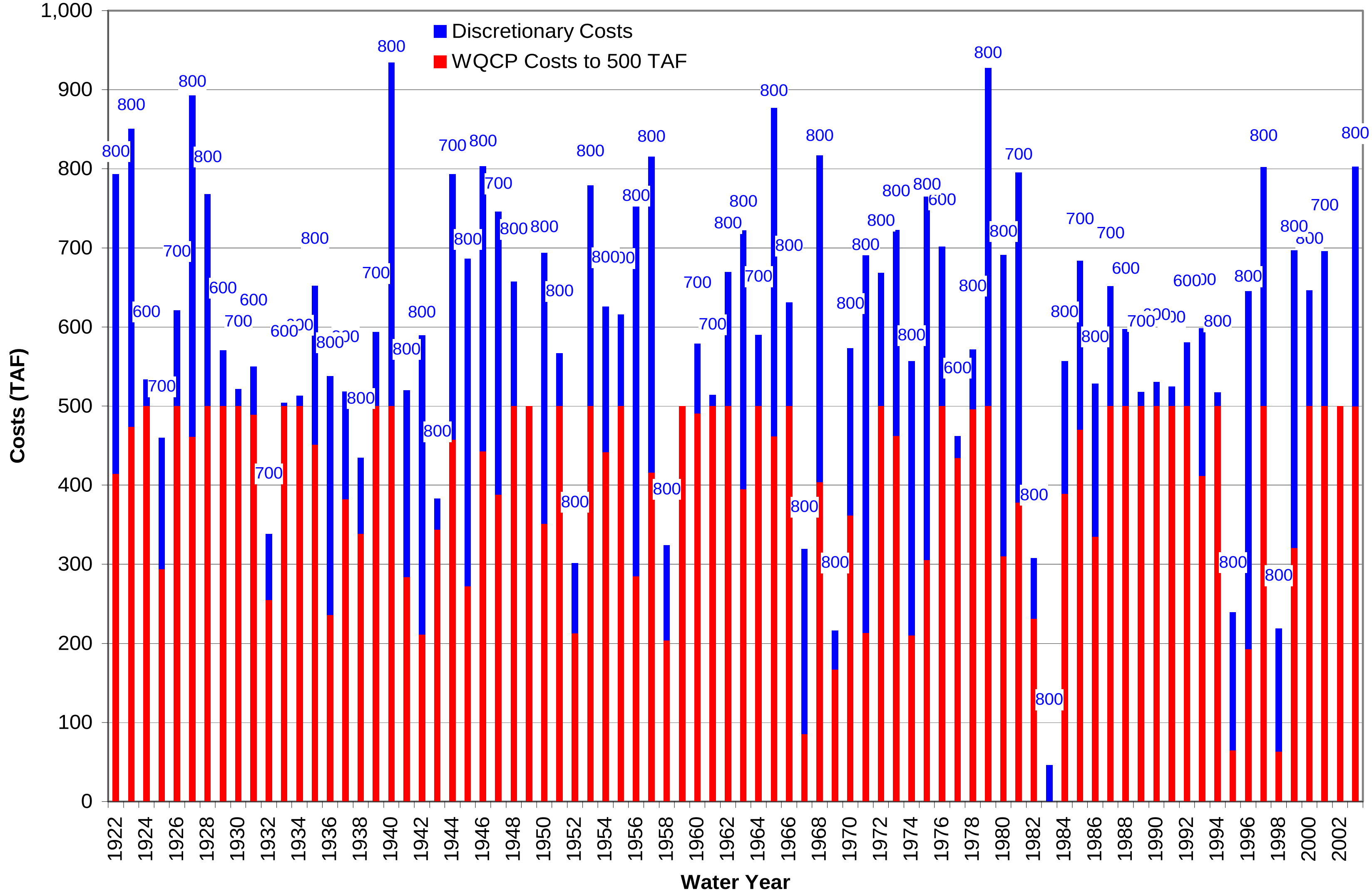



**Figure 9-7 Study 7.0 Total Annual WQCP and Total (b)(2) Costs**

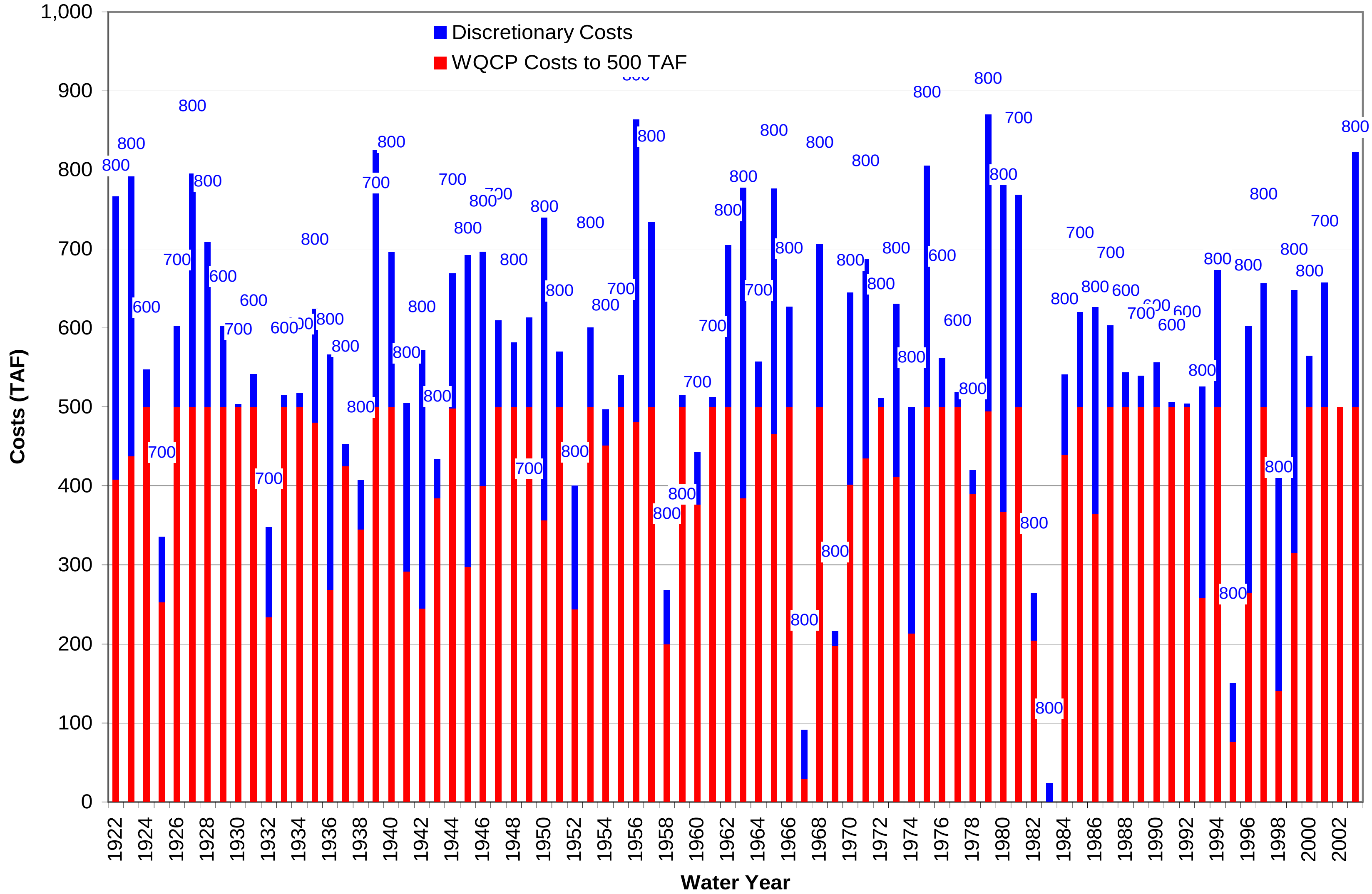



**Figure 9-8 Study 7.1 Total Annual WQCP and Total (b)(2) Costs**

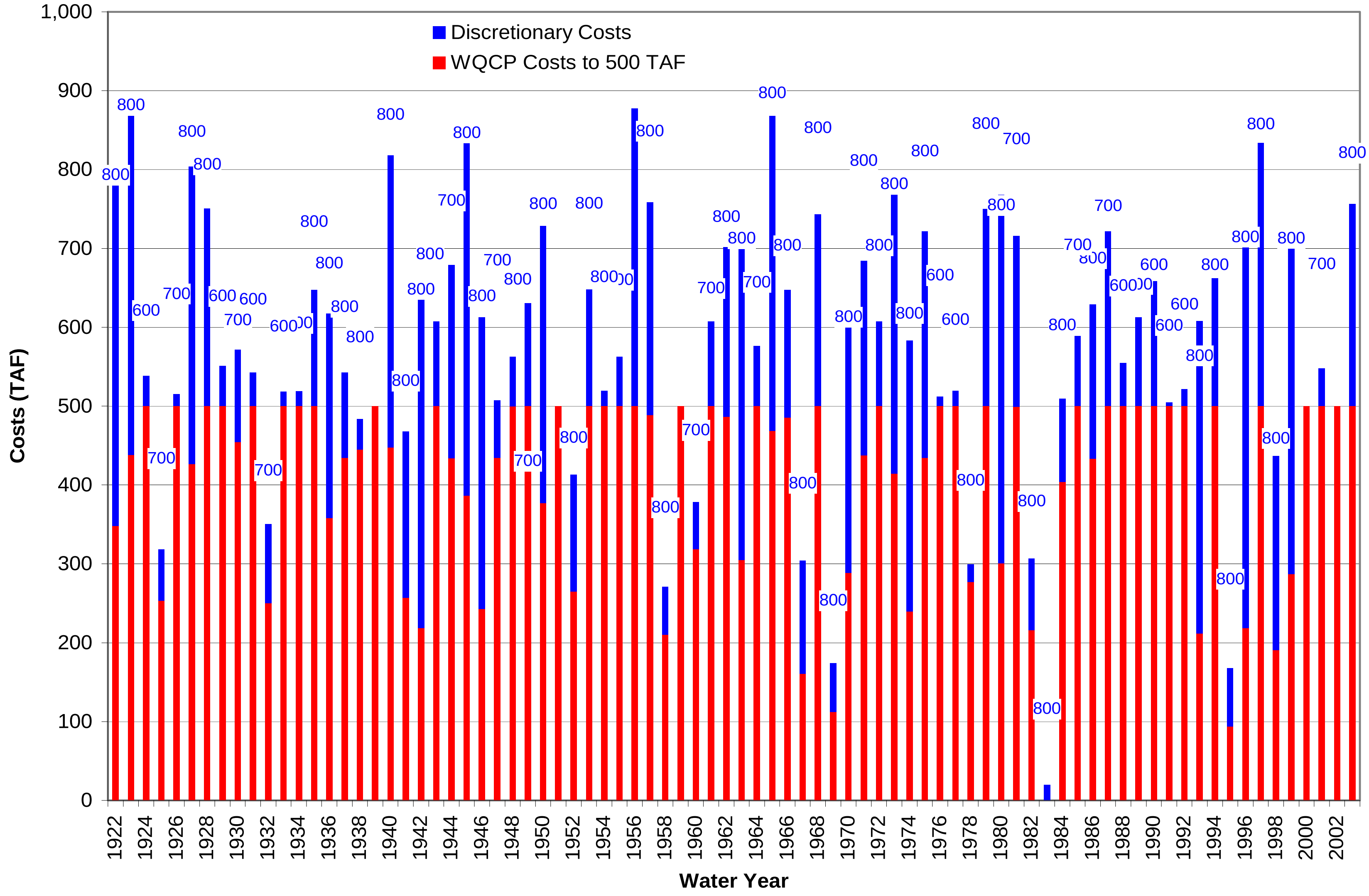



**Figure 9-9 Study 8.0 Total Annual WQCP and Total (b)(2) Costs**

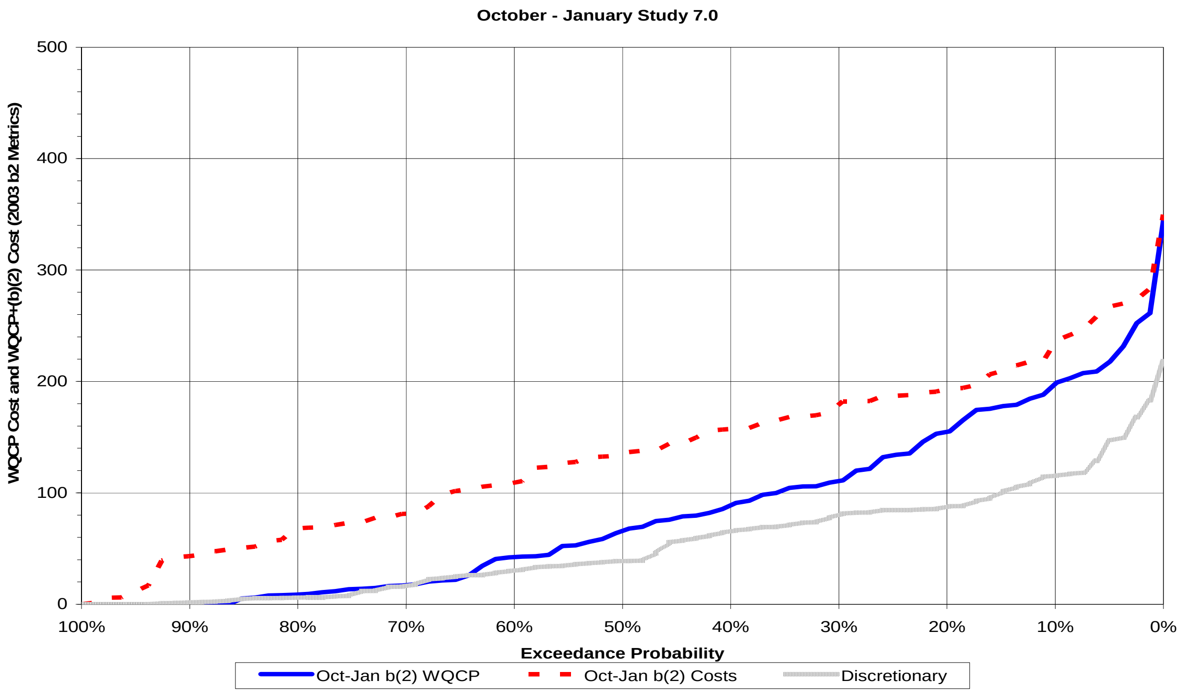



**Figure 9-10 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.0**

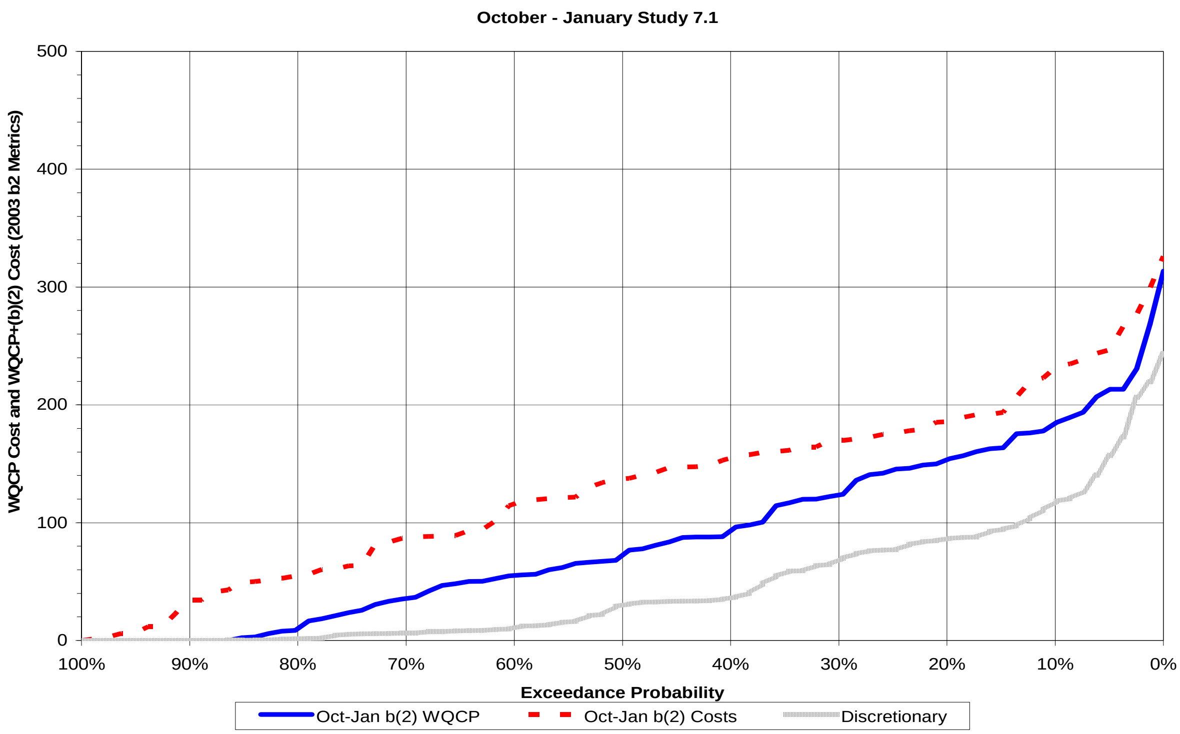



**Figure 9-11 Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 7.1**

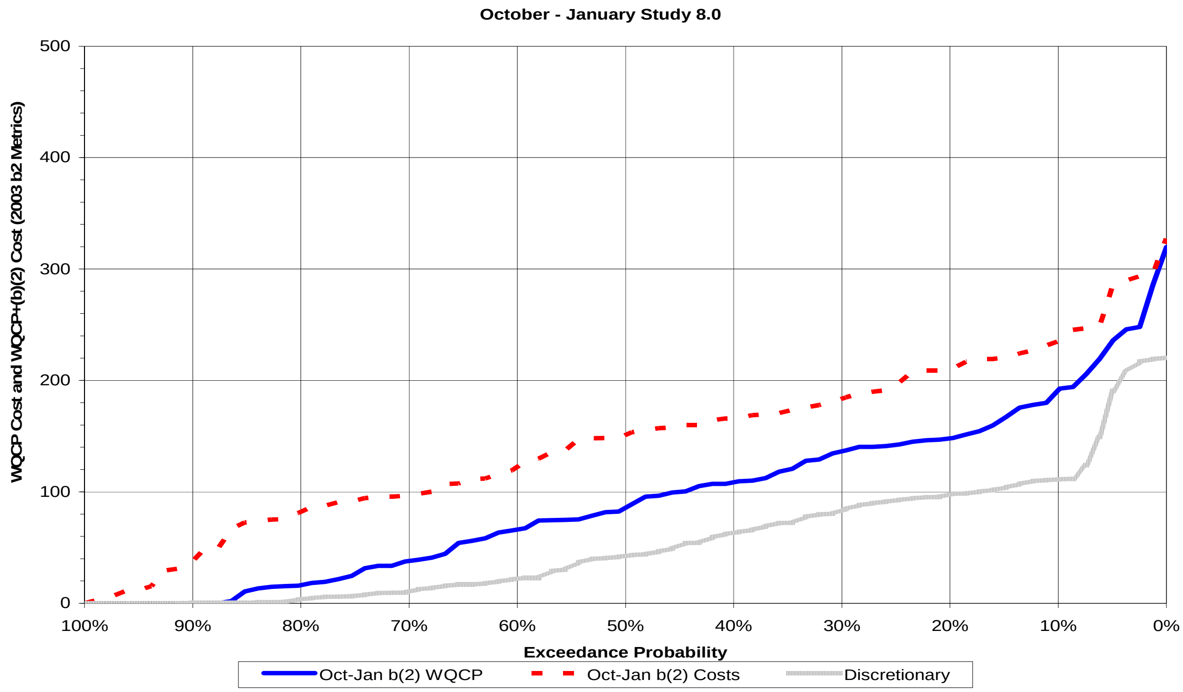



**Figure 9-12. Oct – Jan WQCP and Total (b)(2) Costs Probability of Exceedance Study 8.0**

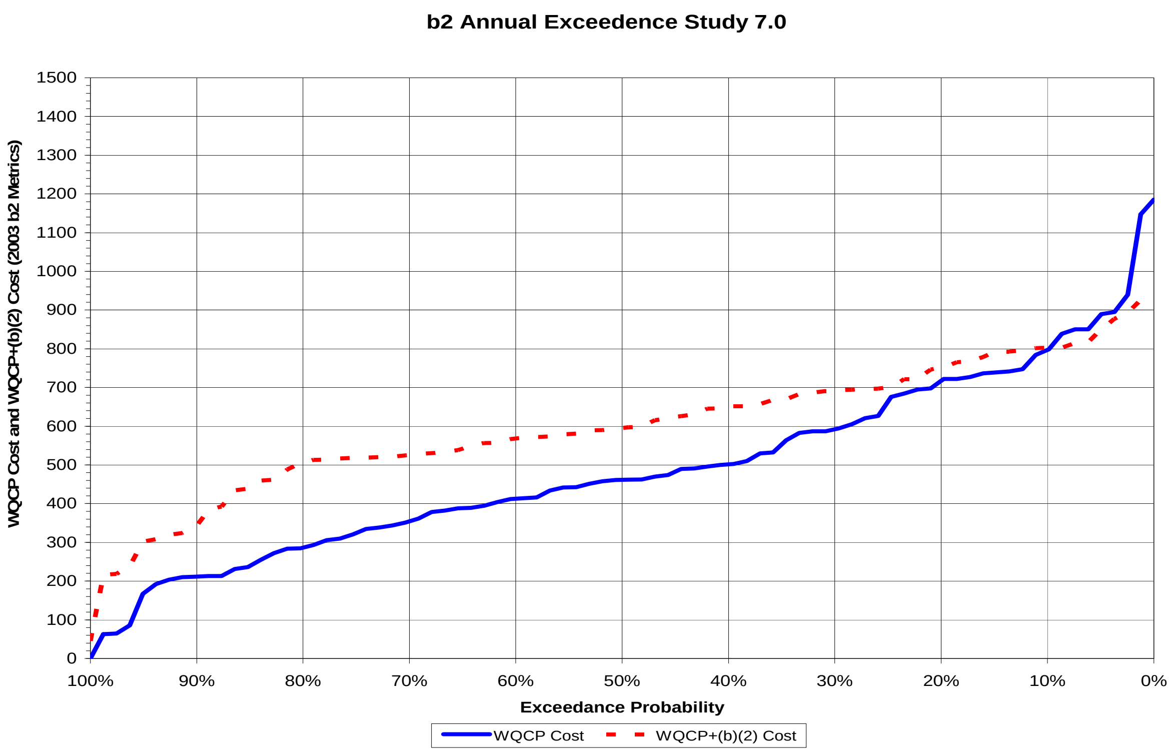



**Figure 9-13. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.0**

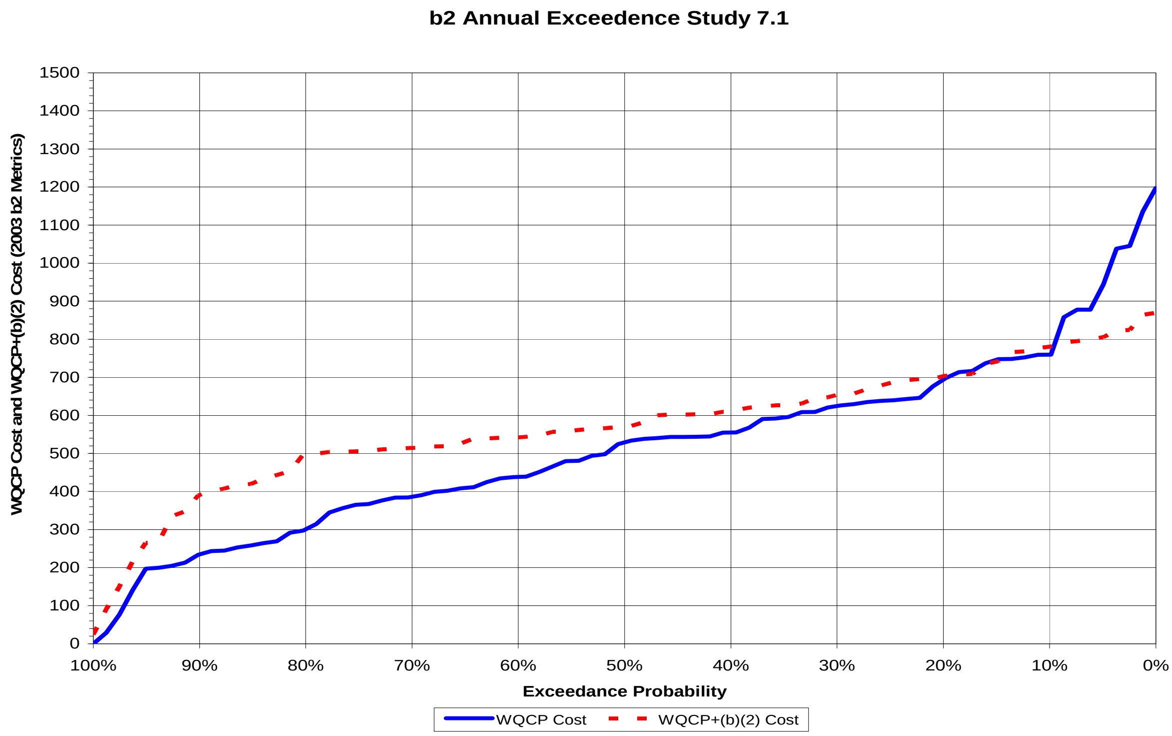



**Figure 9-14. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 7.1**

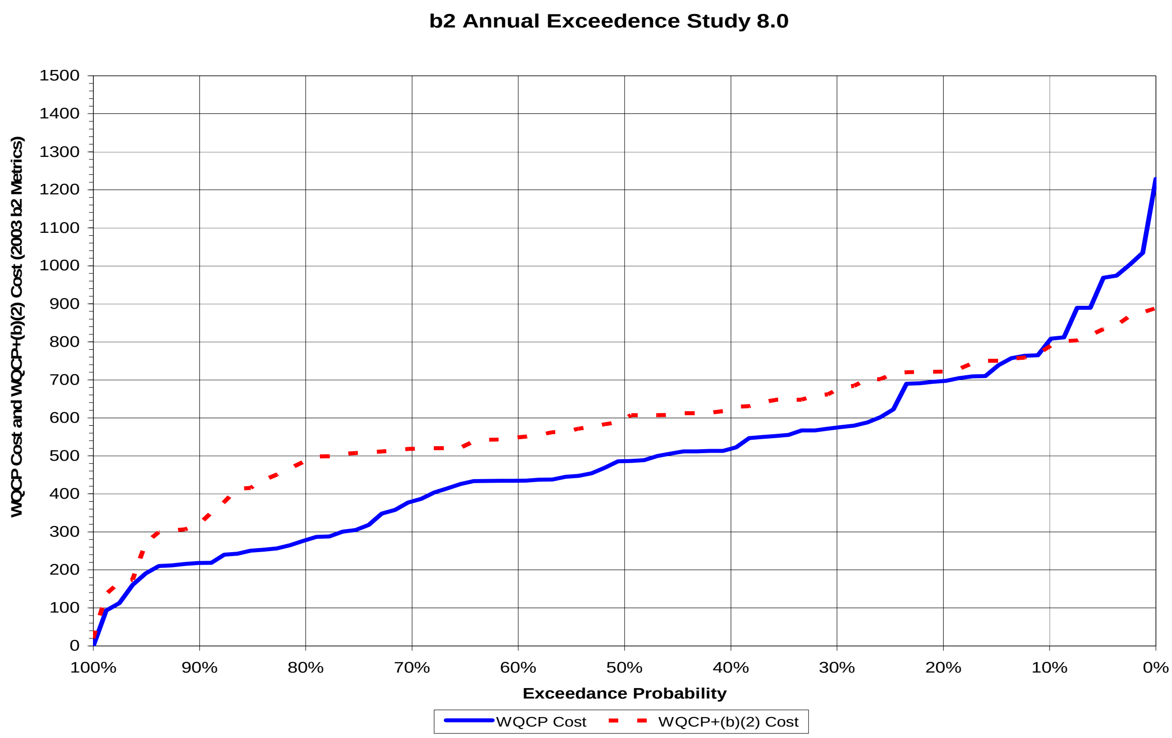



**Figure 9-15. Annual WQCP and Total (b)(2) Costs Probability of Exceedance for Study 8.0**

**Table 9-10. Total (b)(2) Water Requested for Export Actions Versus Amount of (b)(2) Water Used**

| | Total Water Requested | | | Simulated (b)(2) Water Used | | |
|---|---|---|---|---|---|---|
| **Study 7.0** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** |
| Average | 103 | 45 | 19 | 103 | 22 | 8 |
| W | 79 | 33 | 14 | 79 | 27 | 9 |
| AB | 127 | 52 | 22 | 127 | 31 | 9 |
| BN | 130 | 53 | 24 | 130 | 26 | 10 |
| D | 115 | 55 | 26 | 115 | 9 | 10 |
| C | 80 | 41 | 7 | 80 | 15 | 0 |
| **Study 7.1** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** |
| Average | 101 | 45 | 19 | 101 | 22 | 12 |
| W | 78 | 33 | 14 | 78 | 27 | 9 |
| AB | 135 | 52 | 22 | 135 | 28 | 11 |
| BN | 125 | 53 | 24 | 125 | 27 | 14 |
| D | 110 | 55 | 26 | 110 | 12 | 16 |
| C | 77 | 41 | 7 | 77 | 14 | 10 |
| **Study 8.0** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** | **Apr-May VAMP** | **May Shoulder** | **June Ramping** |
| Average | 96 | 45 | 19 | 96 | 29 | 17 |
| W | 77 | 33 | 14 | 77 | 30 | 9 |
| AB | 135 | 52 | 22 | 135 | 44 | 14 |
| BN | 122 | 53 | 24 | 122 | 34 | 18 |
| D | 98 | 55 | 26 | 98 | 19 | 34 |
| C | 66 | 41 | 7 | 66 | 19 | 9 |

**Table 9-11. Percent That Possible Occurrences Action Was Triggered**

| Actions | Study 7.0 | Study 7.1 | Study 8.0 |
|---|---|---|---|
| Keswick Releases | 70% | 70% | 72% |
| Whiskeytown Releases | 98% | 97% | 97% |
| Nimbus Releases | 100% | 100% | 100% |
| Dec-Jan Export Cuts | N/A | NA | NA |
| VAMP Export Cuts | 100% | 100% | 100% |
| Late May Export Cuts | 89% | 89% | 90% |
| Jun Export Cuts | 68% | 73% | 73% |
| Early Apr Export Cuts | N/A | NA | NA |
| Feb-Mar Export Cuts | N/A | NA | NA |

## Environmental Water Account

This section summarizes the EWA operations for Study 7.0 (i.e., Today EWA), Study 7.1 (i.e., Near Future Limited EWA), and Study 8.0 (i.e., Future Limited EWA). Operations are summarized for the following categories:

- Annual costs of EWA actions (i.e., expenditures) measured as export reductions
- Delivery debt status and payback (i.e., adherence to the No Harm Principle)
- Carryover debt conditions from year-to-year
- Annual accrual of EWA assets to mitigate impacts of EWA actions (i.e., water purchases, (b)(2) gains, use of JPOD capacity, wheeling of backed-up water)
- Spilling of carryover EWA debt situated at SWP San Luis
- Annual costs specific to each EWA action measured as export reductions

The annual EWA expenditures for the simulation are shown on Figure 9-16, first as the sum of expenditures associated with winter and spring EWA actions, and second as the expenditures only associated with the spring VAMP action (i.e., EWA Action 3). The Full EWA had annual expenditures ranging from 100,000 af to 600,000 af. whereas both of the Limited EWA studies had annual expenditures ranging from 0 af to 77,000 af. Looking at the VAMP costs it can be seen that for the Full EWA the range of expenditure is 0 af to 235,000 af, but for the Limited EWA nearly all of the costs are associated with EWA.

Another way of viewing annual EWA expenditures is to consider their year-type-dependent averages. The Sacramento River Basin 40-30-30 index was used to classify and sort years. Average annual expenditures by year type are listed in Table 9-12. Comparing Full EWA (Study 7.0) and Limited EWA (Study 7.1, and Study8.0) results, the year-type-dependent averages are quite different.

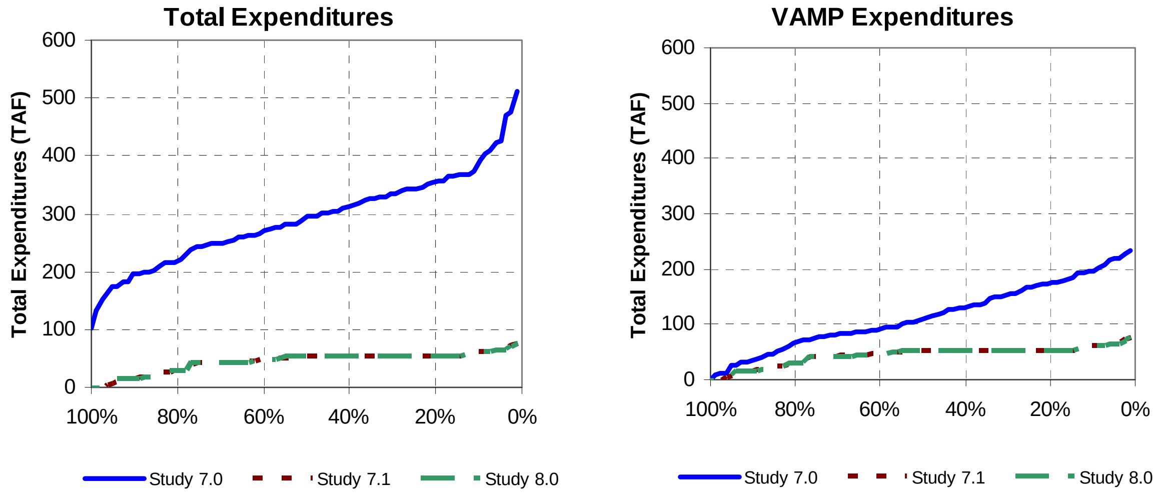



**Figure 9-16. Annual EWA expenditures simulated by CalSim-II, measured in terms of export reductions from exports under the EWA Regulatory Baseline relative to exports with EWA operations.**

**Table 9-12. Annual EWA Expenditures Simulated by CalSim-II, Averaged by Hydrologic Year Type, Defined According to the Sacramento River 40-30-30 Index.**

| Hydrologic Year Type | Study 7.0 (TAF) | Study 7.1 (TAF) | Study 8.0 (TAF) |
|---|---|---|---|
| Average | 291 | 46 | 46 |
| Wet | 320 | 53 | 54 |
| Above Normal | 322 | 43 | 43 |
| Below Normal | 296 | 53 | 52 |
| Dry | 289 | 48 | 47 |
| Critical | 192 | 22 | 23 |

The measure of “deliveries debt payback” is the key indicator of whether the simulated EWA operations adhere to the No Harm to Deliveries principle set forth in the CALFED ROD. In CalSim-II modeling, SOD delivery debt is assessed in the month after it occurs.

A debt is to be repaid in full upon assessment through dedication of an EWA asset available SOD (either as a SOD purchase planned for that month, a wheeled NOD asset planned for that month, or an EWA San Luis storage withdrawal that month). Instances when SOD delivery debt could not be repaid in full can be seen through post-simulation analysis of CalSim-II results. As shown in Table 9-13 there were no instances of not adhering to the “No Harm Principle” for Study 7.0, Study 7.1 and Study 8.0. Study 7.1 and Study 8.0 assumed a Limited EWA and no debt was not allowed to accumulate.

**Table 9-13. Instances of not Adhering to the EWA “No Harm Principle” (i.e., not repaying delivery debt in full upon assessment), Simulated by CalSim-II.**

| Delivery Debt Account | Study 7.0 (Full EWA) | Study 7.1 (Limited EWA) | Study 8.0 (Limited EWA) |
|---|---|---|---|
| CVP South of Delta | None | No debt allowed | No debt allowed |
| SWP South of Delta | None | No debt allowed | No debt allowed |

A key feature of simulated and real EWA operations that enables increased flexibility to mitigate the impacts of EWA actions is the allowance for carryover debt. In the CalSim-II modeling, because of the model structure, Figure 9-3, the annual interruption of the simulated EWA operational baseline necessitates special measures to account for carryover debt relative to debt caused by this year’s actions (i.e., “new debt” in CalSim-II semantics). The result of these measures is separate debt accounts for carryover and new debt. Unpaid new debt ultimately gets rolled over into the carryover debt account, which can represent one or more years of unpaid debt.

The rollover of new debt into the carryover debt account occurs in November. Results on carryover debt conditions at total CVP/SWP San Luis are shown on Figure 9-17 for the 82 Octobers and Novembers simulated. These carryover debt conditions are at a maximum in November, after which they are managed to a minimum in October through dedication of physical EWA assets available SOD or spilling of carryover debt at SWP San Luis.

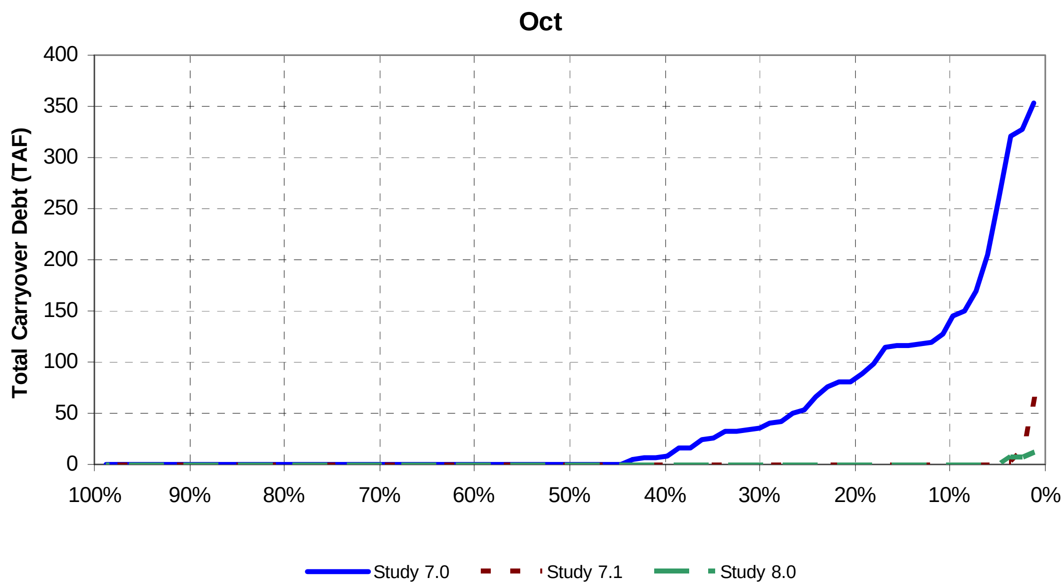



**Figure 9-17. Combined Carryover Debt at CVP and SWP San Luis, Simulated in CalSim- II, at the End (Oct) and Start (Nov) of the Carryover Debt Assessment Year**

The comparative ranges of acquired EWA assets under Full EWA (Study 7.0) and Limited EWA (Studies 7.1 and 8.0) are summarized on Figure 9-18. In Figure 9-18 the "Total Acquired Assets" includes water purchases and operational assets (i.e., EWA acquisition of 50 percent of SWP gains from B2 releases, EWA conveyance of Delta Surplus flows using 50 percent of JPOD capacity or summer dedicated capacity, EWA conveyance of backed-up water caused by Spring EWA actions on exports.

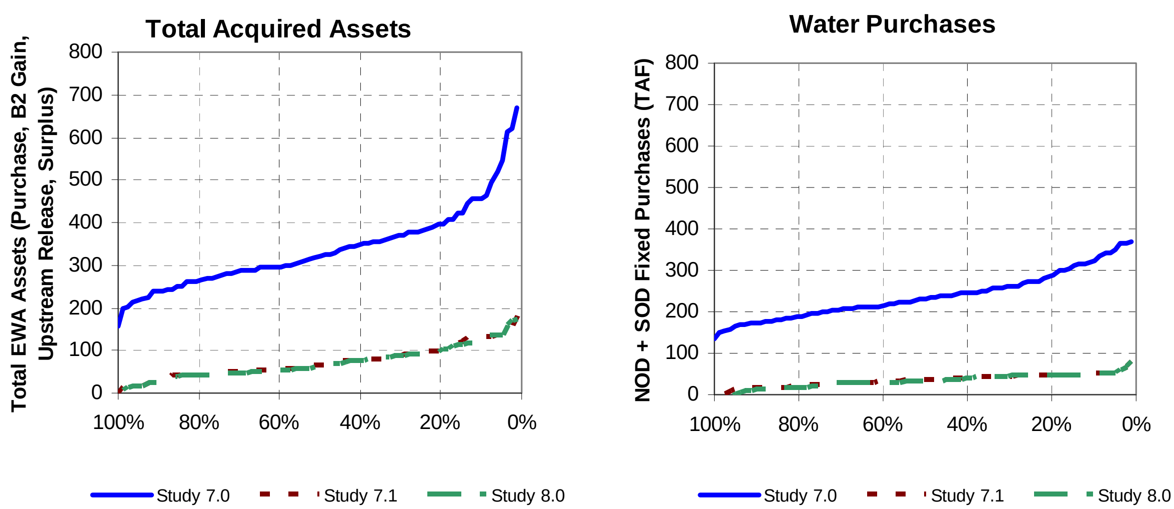



**Figure 9-18. Annual EWA assets simulated in CalSim-II.**

A unique tool for managing carryover debt at SWP San Luis is debt spilling, described earlier. In CalSim-II, carryover debt conditions need to be present and severe enough to trigger the use of this tool under the spill conditions that were outlined earlier. Also note that there is a semantics difference between what is called “spill” in CalSim-II and what is called “spill” by EWAT. CalSim-II only designates erasing of carryover debt at SWP San Luis, or reservoir filling in NOD reservoirs as “spilling” debt; it does not designate “pumping-to-erase” new debt at San Luis as “spill,” even though this is a term sometimes used by EWAT. That distinction noted, the occurrence of carryover debt spilling at SWP San Luis is depicted on Figure 9-19.

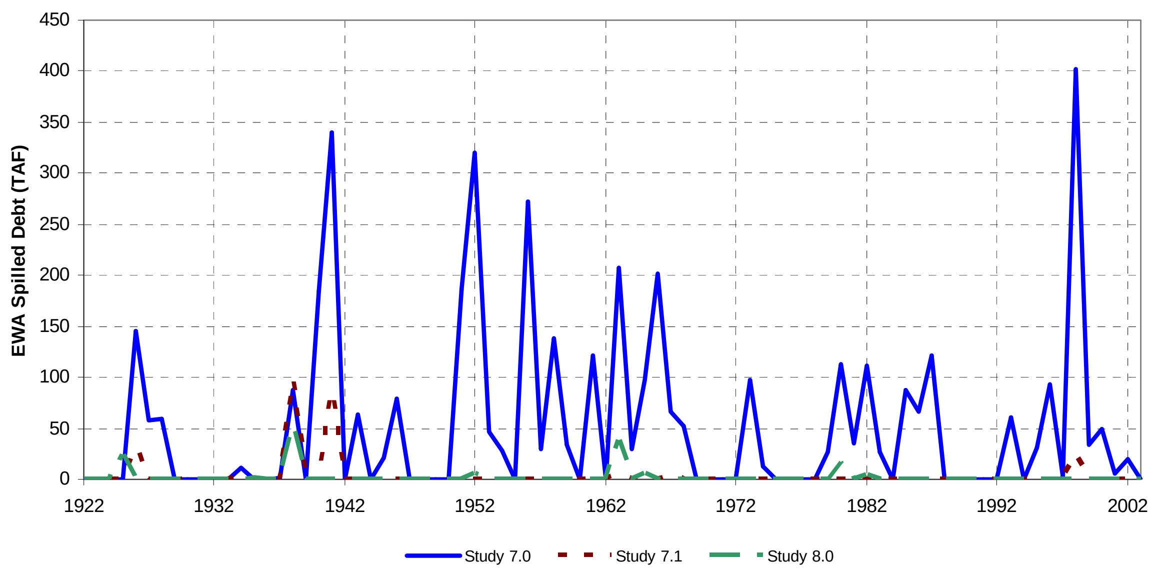



**Figure 9-19. Annual Carryover-debt Spilling at SWP San Luis, Simulated in CalSim-II.**

EWA action-specific expenditures for Winter Export Reductions are expected to be 50,000 af for each month in which they are implemented, according to modeling assumptions. Generally, this is the case, as indicated by simulated export reductions measured between Step 4 and Step 5 in Full EWA study (Figure 9-20). The action is always taken in December and January, and it is also taken in February if the Sacramento River 40-30-30 Index defines the year to be Above Normal or Wet. Simulation results show that export reductions are always as expected for January and February and nearly always as expected for December (approximately 95 percent of the years).

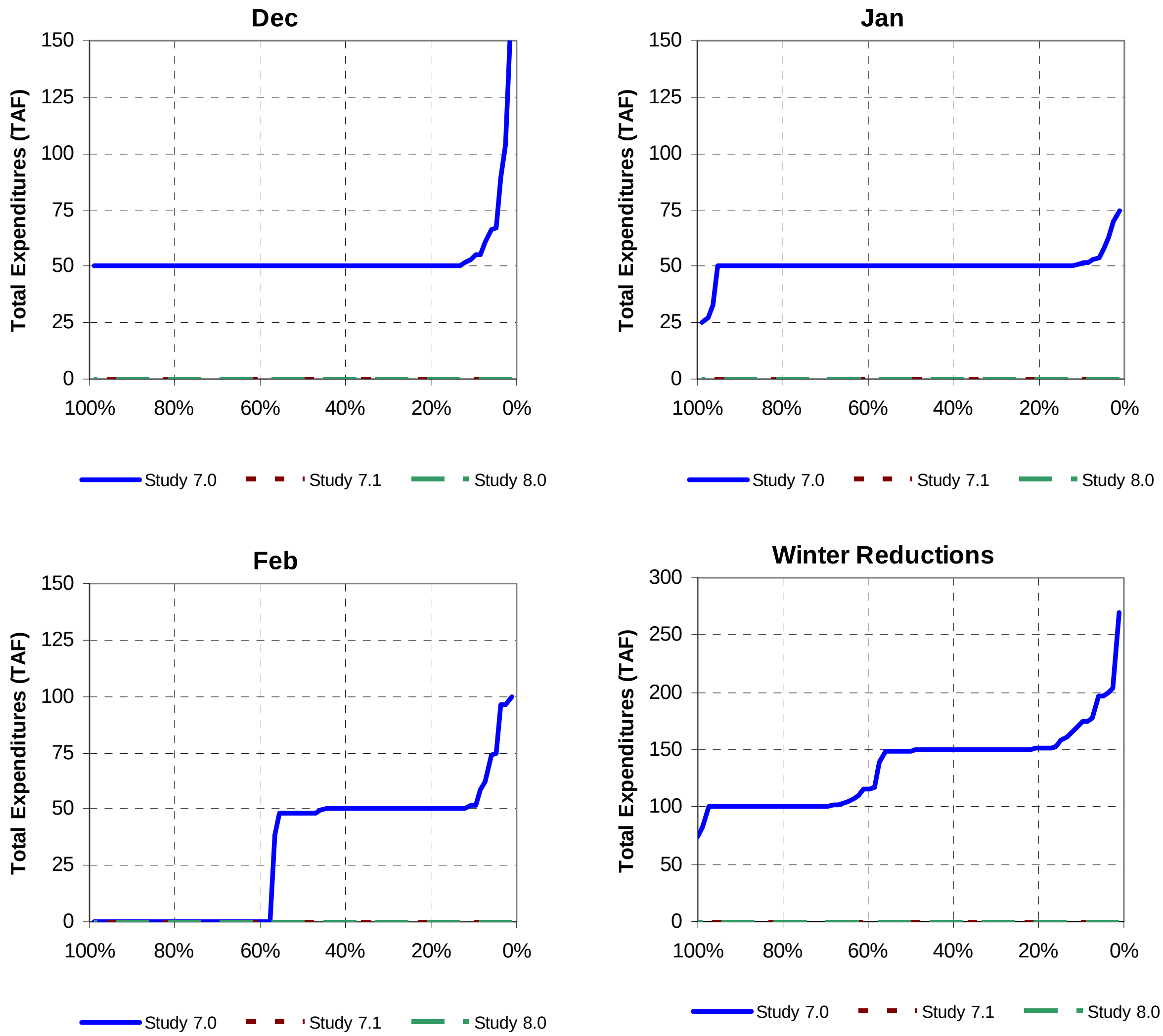
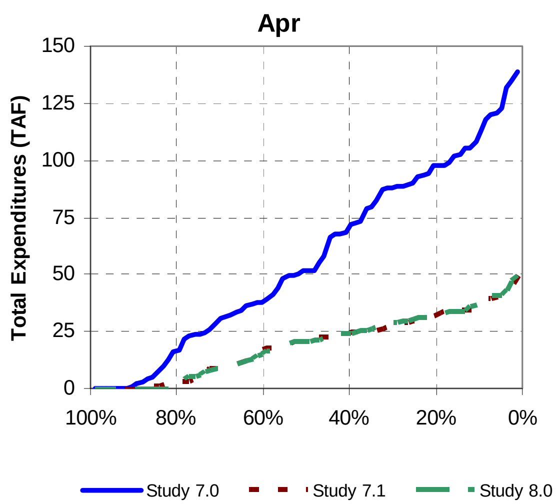



**Figure 9-20. Simulated Export Reductions Associated with Taking EWA Action 2 (i.e., Winter Export Reductions). Note that Export Reductions for Studies 7.1 and 8.0 are zero.**

Expectations for spring actions expenditures are more difficult to predict prior to simulation compared to expenditures for winter actions. This is because spring actions are not linked to spending goals, but are instead linked to target export restriction levels related to VAMP. Results show that action-specific export costs for spring actions are slightly higher in the Full EWA study compared to the Limited EWA studies (Figure 9-21 through Figure 9-23). Moreover, the frequency of implementing June export reductions only occurs in the Full EWA.



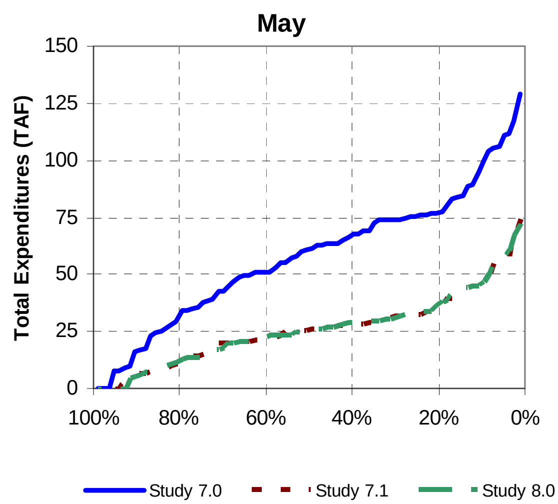




**Figure 9-21** – **Simulated Export Reductions Associated with Taking EWA Action 3 (i.e., VAMP-related restrictions).**

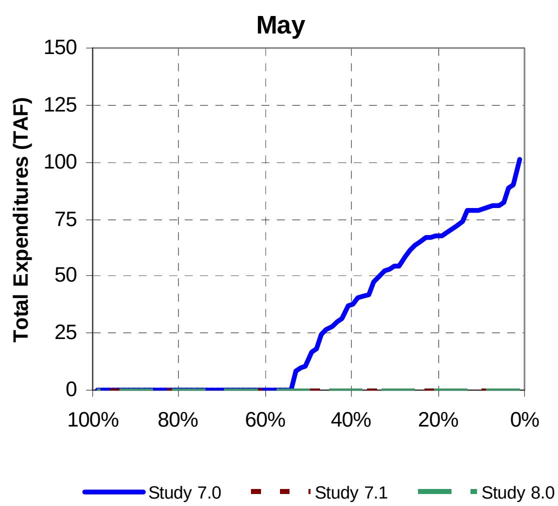



**Figure 9-22** – **Simulated Export Reductions Associated with Taking EWA Action 5 (i.e., extension of VAMP-related restrictions into May 16–May 31 (i.e., the May Shoulder)).**

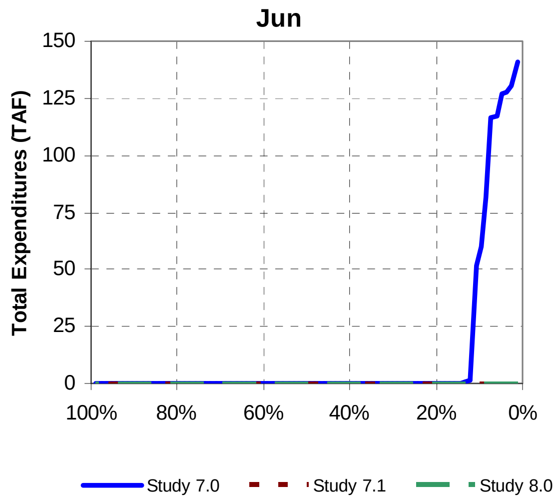



**Figure 9-23– Simulated Export Reductions Associated with Taking EWA Action 6 (i.e., representation of June "ramping" from May Shoulder restriction to June Export-to-Inflow restriction).**

## Delta Hydrodynamic Results

The DSM2-Hrodro was run from water years 1976 to 1991 and output was provided for a number of locations in the Delta. Figure 9-24 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-14 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this BA and Appendix G, only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- Cross Delta flow – a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-24).
- QWest flow – a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-24).
- Old and Middle River flow – a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-24).
- Old River at Head – described by a single output location ROLD074 as labeled in Figure 9-24.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

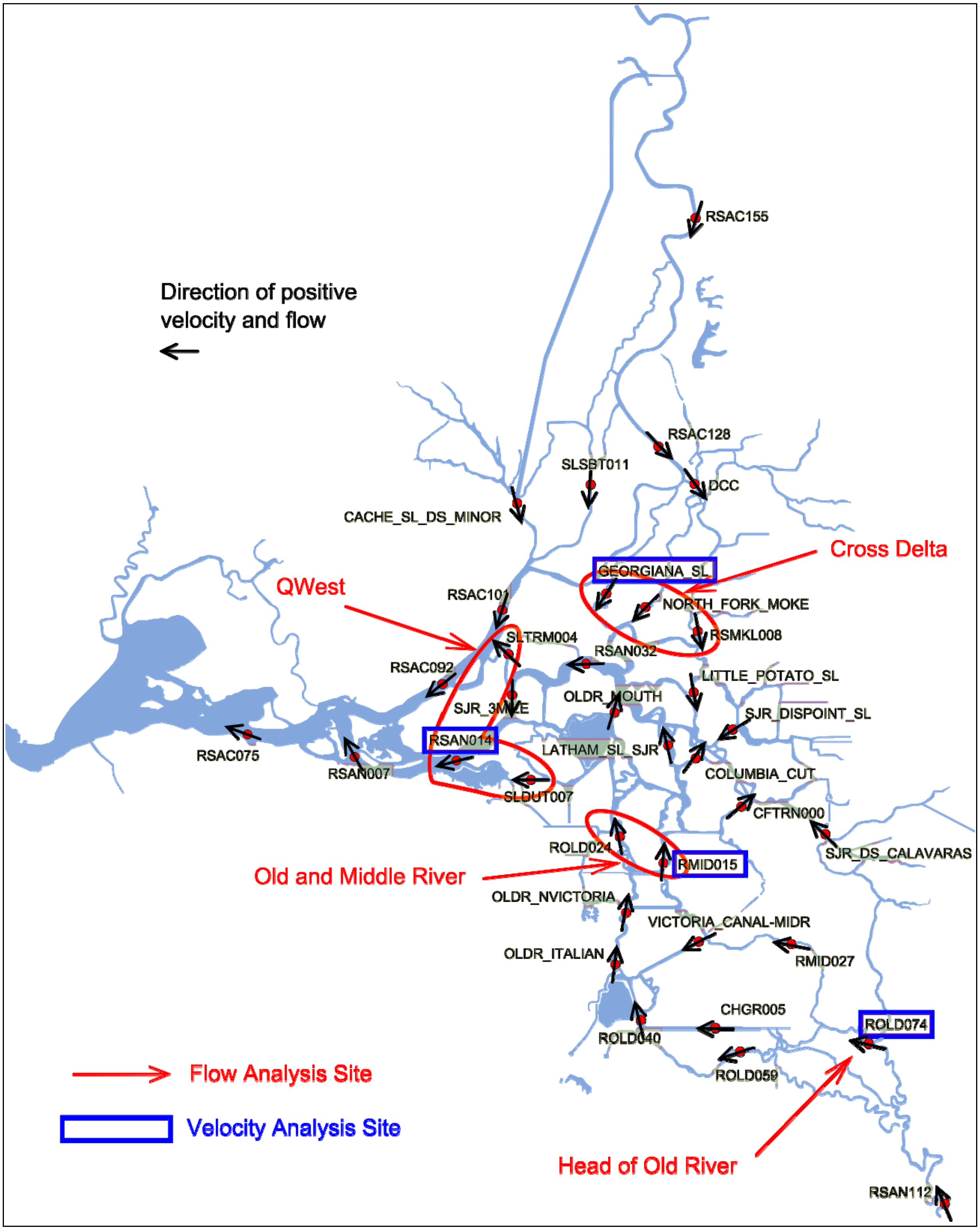



**Figure 9-24. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.**

**Table 9-14. Definitions for the DSM2 output**

| DSM2 Output Name | Channel | Distance | Common Name |
|---|---|---|---|
| CFTRN000 | 172 | 727 | Turner Cut |
| CHGRL005 | 211 | 1585 | Grant Line Canal (West Position) |
| RMID015 | 144 - 145 | 838 | Middle River at Middle River (west channel) |
| RMID027 | 133 | 3641 | Middle River at Tracy Blvd |
| ROLD014 | 117 | 0 | Old River at Holland Cut |
| ROLD024 | 106 | 2718 | Old River at Bacon Island |
| ROLD040 | 82 | 2609 | Old River at Clifton Court Ferry |
| ROLD059 | 71 | 3116 | Old River at Tracy Road |
| ROLD074 | 54 | 735 | Head of Old River |
| RSAC075 | 437 | 11108 | Sacramento River at Mallard Island |
| RSAC092 | 434 | 435 | Sacramento River at Emmaton |
| RSAC101 | 430 | 9684 | Sacramento River at Rio Vista |
| RSAC128 | 421 | 8585 | Sacramento River above Delta Cross Channel |
| RSAC155 | 414 | 11921 | Sacramento River at Freeport |
| RSAN007 | 52 | 366 | San Joaquin River at Antioch |
| RSAN014 | 49 | 9570 | San Joaquin River at Blind Point |
| RSAN024 | 47 | 8246 | San Joaquin River at Bradford Isl. |
| RSAN032 | 349 | 9672 | San Joaquin River at San Andreas Landing |
| RSAN058 | 20 | 2520 | San Joaquin River at Stockton Ship Channel |
| RSAN112 | 17 | 4744 | San Joaquin River at Vernalis |
| RSMKL008 | 344 | 7088 | South Fork Mokelumne at Staten Island |
| SLDUT007 | 274 | 7351 | Dutch Slough |
| SLSBT011 | 385 | 2273 | Steamboat Slough |
| SLTRM004 | 310 | 540 | Three Mile Slough |
| DCC | 365 | 0 | Delta Cross Channel |
| COLUMBIA_CUT | 160 | 50 | Columbia Cut |
| SJR_DS_CALAVARAS | 21 | 0 | San Joaquin River downstream Calaveras River |
| SJR_3MILE | 49 | 9570 | San Joaquin River at Three Mile Slough |

| DSM2 Output Name | Channel | Distance | Common Name |
|---|---|---|---|
| OLDR_ITALIAN | 88 | 0 | Old River at Italian Slough |
| OLDR_NVICTORIA | 91 | 4119 | Old River at North Victoria Canal |
| OLDR_MOUTH | 124 | 7062 | Mouth of Old River |
| LATHAM_SL_SJR | 161 | 10808 | Latham Slough at San Joaquin River |
| VICTORIA_CANAL_MIDR | 226 | 4153 | Victoria Canal at Middle River |
| SJR_DISPOINT_SL | 314 | 8130 | Disappointment Slough at San Joaquin River |
| LITTLE_POTATO_SL | 325 | 9962 | Little Potato Slough |
| NORTH_FORK_MOKE | 363 | 6133 | North Fork Mokelumne River |
| GEORGIANA_SL | 371 | 7766 | Georgiana Slough |
| CACHE_SL_DS_MINOR | 398 | 0 | Cache Slough downstream Minor Slough |
| OMR | 144 - 145 + 106 | -- | Old and Middle River |
| QWEST | 274 + 49 + 310 | -- | Western Flow (QWEST) |
| XDELTA | 371 + 363 + 344 | -- | Cross Delta Flow |

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the United States Geological Survey (USGS) uses to determine daily averages for locations under tidal influence. The flow results are presented in Table 9-15 and velocity results are presented in Table 9-16. Both tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

Appendix G presents DSM2-Hydro results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Along with the box plots results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded.

**Table 9-15. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.**

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head of Old River | W AN | Jan-Mar | 1433 | 3775 | 8318 | 9720 | 17680 | 1194 | 3703 | 8073 | 9554 | 16721 | 1180 | 3674 | 8050 | 9539 | 16691 |
| | | Apr-Jun | 1291 | 3703 | 5549 | 9032 | 11788 | 0 | 3611 | 5673 | 8727 | 11293 | 0 | 3609 | 5662 | 8683 | 11277 |
| | | Jul-Sep | 887 | 1362 | 1633 | 3735 | 10082 | 461 | 1763 | 1973 | 3969 | 9703 | 453 | 1780 | 1975 | 3928 | 9714 |
| | | Oct-Dec | 237 | 712 | 1441 | 3543 | 9985 | 160 | 299 | 856 | 1545 | 9603 | 151 | 297 | 851 | 1535 | 9593 |
| | C D BN | Jan-Mar | 778 | 1038 | 1434 | 1700 | 4783 | 620 | 1059 | 1309 | 1585 | 4561 | 515 | 951 | 1254 | 1550 | 4521 |
| | | Apr-Jun | 188 | 442 | 645 | 956 | 4498 | 0 | 0 | 699 | 1114 | 4105 | 0 | 0 | 578 | 1022 | 4093 |
| | | Jul-Sep | 206 | 356 | 628 | 800 | 1306 | 215 | 314 | 369 | 467 | 1303 | 193 | 301 | 361 | 458 | 1178 |
| | | Oct-Dec | 254 | 564 | 987 | 1238 | 1681 | 157 | 245 | 408 | 1105 | 1562 | 149 | 237 | 405 | 1065 | 1572 |
| Old and Middle River | W AN | Jan-Mar | -9917 | -5877 | -2761 | 2758 | 22691 | -11084 | -5666 | -2779 | 5073 | 22417 | -10995 | -5894 | -2827 | 5401 | 22034 |
| | | Apr-Jun | -5747 | -4178 | -664 | 1513 | 13725 | -6915 | -4423 | -3166 | 147 | 13555 | -7016 | -4357 | -3070 | 121 | 13360 |
| | | Jul-Sep | -11281 | -10281 | -9517 | -7832 | 3531 | -10671 | -9775 | -9344 | -7852 | 3329 | -11656 | -9911 | -9269 | -7923 | 3392 |
| | | Oct-Dec | -10767 | -8548 | -7521 | -5007 | 6638 | -11589 | -10071 | -8411 | -4714 | 7096 | -11581 | -10084 | -8668 | -4582 | 7044 |
| | C D BN | Jan-Mar | -10201 | -8040 | -6146 | -2521 | 112 | -11508 | -8447 | -5765 | -3075 | -242 | -11475 | -8560 | -5907 | -2656 | -265 |
| | | Apr-Jun | -8469 | -5114 | -2094 | -1496 | 2080 | -8519 | -5026 | -3206 | -2223 | -771 | -8709 | -4999 | -2884 | -2084 | -758 |
| | | Jul-Sep | -12271 | -9233 | -7263 | -5612 | -3121 | -12433 | -10202 | -6052 | -3831 | -1694 | -12252 | -10147 | -5601 | -3700 | -1720 |
| | | Oct-Dec | -10755 | -8409 | -6653 | -5620 | -1539 | -11975 | -9035 | -6991 | -5861 | -2733 | -11975 | -9209 | -6886 | -5125 | -2838 |
| QWEST | W AN | Jan-Mar | -5144 | 7888 | 18828 | 32323 | 71462 | -6431 | 6583 | 18760 | 33528 | 71795 | -6505 | 6746 | 17709 | 33617 | 71357 |
| | | Apr-Jun | -2061 | 5106 | 7946 | 17809 | 47658 | -3391 | 4387 | 6778 | 17093 | 47818 | -3432 | 4238 | 6718 | 16991 | 47622 |
| | | Jul-Sep | -6224 | -2506 | -1131 | 1525 | 26405 | -6020 | -2668 | -1312 | 1100 | 26217 | -6316 | -2749 | -1405 | 977 | 26124 |
| | | Oct-Dec | -10735 | -1605 | 302 | 5277 | 42561 | -12409 | -2217 | -22 | 4491 | 43264 | -13002 | -2314 | -57 | 4660 | 43205 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C D BN | Jan-Mar | -9596 | -2446 | 3 | 2178 | 10439 | -10900 | -2737 | -260 | 1959 | 12202 | -11036 | -2600 | -212 | 1802 | 11035 |
| | | Apr-Jun | -7335 | -858 | 848 | 2622 | 12154 | -7462 | -1050 | 488 | 2419 | 10002 | -7521 | -1046 | 682 | 2560 | 9717 |
| | | Jul-Sep | -7790 | -3080 | -1882 | -863 | 2459 | -8471 | -3192 | -1311 | 477 | 4454 | -8522 | -3210 | -1293 | 487 | 4103 |
| | | Oct-Dec | -12092 | -2548 | -1083 | 140 | 7181 | -13143 | -2782 | -1251 | 131 | 5689 | -13071 | -2603 | -1084 | 255 | 5600 |
| Cross Delta | W AN | Jan-Mar | 4770 | 8924 | 13917 | 16613 | 23908 | 4760 | 8861 | 13918 | 16607 | 23907 | 4697 | 8826 | 13829 | 16407 | 23686 |
| | | Apr-Jun | 3241 | 4405 | 6218 | 9146 | 18445 | 3239 | 4426 | 6408 | 9198 | 18441 | 3029 | 4330 | 6367 | 9128 | 18447 |
| | | Jul-Sep | 5556 | 7044 | 7398 | 7849 | 12110 | 5377 | 6870 | 7226 | 8776 | 11901 | 5455 | 6880 | 7303 | 8646 | 11703 |
| | | Oct-Dec | 2258 | 5291 | 6634 | 9047 | 17467 | 2148 | 5217 | 6798 | 9042 | 17464 | 2139 | 5302 | 6653 | 8893 | 17476 |
| | C D BN | Jan-Mar | 1966 | 3130 | 4123 | 5296 | 9532 | 1936 | 3114 | 3931 | 5220 | 9594 | 2006 | 3184 | 3931 | 5488 | 9949 |
| | | Apr-Jun | 1603 | 2573 | 3288 | 5120 | 7546 | 1519 | 2517 | 3215 | 4812 | 8395 | 1512 | 2553 | 3292 | 4923 | 8366 |
| | | Jul-Sep | 4245 | 5212 | 5826 | 7218 | 9105 | 3371 | 4394 | 5249 | 7154 | 9301 | 3450 | 4377 | 5331 | 7033 | 9107 |
| | | Oct-Dec | 1851 | 4081 | 5253 | 5748 | 9502 | 1856 | 3962 | 5082 | 5723 | 9507 | 1961 | 4028 | 4989 | 5613 | 9760 |

**Table 9-16. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.**

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head of Old River | W AN | Jan-Mar | 0.89 | 1.70 | 2.56 | 2.62 | 3.29 | 0.74 | 1.68 | 2.52 | 2.58 | 3.19 | 0.73 | 1.67 | 2.52 | 2.58 | 3.19 |
| | | Apr-Jun | 0.73 | 1.67 | 2.00 | 2.62 | 2.76 | 0.00 | 1.67 | 2.13 | 2.57 | 2.70 | 0.00 | 1.66 | 2.13 | 2.56 | 2.70 |
| | | Jul-Sep | 0.53 | 0.75 | 0.86 | 1.57 | 2.68 | 0.30 | 1.00 | 1.08 | 1.74 | 2.63 | 0.30 | 1.01 | 1.08 | 1.73 | 2.63 |
| | | Oct-Dec | 0.15 | 0.44 | 0.84 | 1.52 | 2.67 | 0.11 | 0.20 | 0.53 | 0.88 | 2.63 | 0.10 | 0.20 | 0.53 | 0.87 | 2.63 |
| | C D BN | Jan-Mar | 0.50 | 0.65 | 0.87 | 1.00 | 1.94 | 0.41 | 0.65 | 0.79 | 0.92 | 1.89 | 0.34 | 0.57 | 0.76 | 0.90 | 1.88 |
| | | Apr-Jun | 0.11 | 0.28 | 0.40 | 0.60 | 1.89 | 0.00 | 0.00 | 0.44 | 0.68 | 1.78 | 0.00 | 0.00 | 0.37 | 0.62 | 1.78 |
| | | Jul-Sep | 0.12 | 0.21 | 0.38 | 0.47 | 0.73 | 0.14 | 0.20 | 0.24 | 0.31 | 0.80 | 0.12 | 0.19 | 0.24 | 0.30 | 0.73 |
| | | Oct-Dec | 0.16 | 0.34 | 0.58 | 0.76 | 0.99 | 0.10 | 0.16 | 0.27 | 0.67 | 0.90 | 0.10 | 0.15 | 0.27 | 0.65 | 0.91 |
| Middle River at Middle River | W AN | Jan-Mar | -0.26 | -0.15 | -0.07 | 0.07 | 0.55 | -0.30 | -0.15 | -0.07 | 0.13 | 0.54 | -0.29 | -0.16 | -0.07 | 0.14 | 0.53 |
| | | Apr-Jun | -0.16 | -0.11 | -0.01 | 0.04 | 0.35 | -0.19 | -0.12 | -0.08 | 0.01 | 0.35 | -0.19 | -0.11 | -0.08 | 0.01 | 0.34 |
| | | Jul-Sep | -0.30 | -0.28 | -0.26 | -0.21 | 0.10 | -0.29 | -0.26 | -0.25 | -0.20 | 0.09 | -0.31 | -0.27 | -0.25 | -0.21 | 0.09 |
| | | Oct-Dec | -0.29 | -0.23 | -0.20 | -0.13 | 0.17 | -0.31 | -0.27 | -0.23 | -0.13 | 0.18 | -0.31 | -0.27 | -0.24 | -0.12 | 0.18 |
| | C D BN | Jan-Mar | -0.27 | -0.21 | -0.16 | -0.06 | 0.01 | -0.31 | -0.23 | -0.16 | -0.08 | 0.00 | -0.31 | -0.23 | -0.16 | -0.07 | -0.01 |
| | | Apr-Jun | -0.23 | -0.14 | -0.05 | -0.04 | 0.06 | -0.24 | -0.14 | -0.08 | -0.06 | -0.02 | -0.24 | -0.14 | -0.08 | -0.06 | -0.02 |
| | | Jul-Sep | -0.34 | -0.25 | -0.20 | -0.15 | -0.08 | -0.34 | -0.28 | -0.16 | -0.10 | -0.05 | -0.33 | -0.28 | -0.15 | -0.10 | -0.05 |
| | | Oct-Dec | -0.29 | -0.23 | -0.18 | -0.15 | -0.04 | -0.33 | -0.25 | -0.19 | -0.16 | -0.08 | -0.33 | -0.25 | -0.19 | -0.14 | -0.08 |
| San Joaquin River at Blind Point | W AN | Jan-Mar | 0.00 | 0.16 | 0.27 | 0.41 | 0.85 | -0.01 | 0.15 | 0.27 | 0.42 | 0.85 | -0.01 | 0.15 | 0.26 | 0.42 | 0.85 |
| | | Apr-Jun | 0.05 | 0.12 | 0.15 | 0.25 | 0.57 | 0.03 | 0.11 | 0.13 | 0.24 | 0.57 | 0.03 | 0.11 | 0.13 | 0.24 | 0.57 |
| | | Jul-Sep | -0.01 | 0.04 | 0.06 | 0.08 | 0.32 | -0.01 | 0.04 | 0.05 | 0.08 | 0.31 | -0.02 | 0.03 | 0.05 | 0.08 | 0.31 |
| | | Oct-Dec | -0.05 | 0.05 | 0.07 | 0.14 | 0.53 | -0.06 | 0.04 | 0.06 | 0.13 | 0.54 | -0.06 | 0.04 | 0.06 | 0.13 | 0.54 |

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C D BN | Jan-Mar | -0.04 | 0.05 | 0.07 | 0.09 | 0.19 | -0.05 | 0.04 | 0.07 | 0.09 | 0.21 | -0.06 | 0.04 | 0.07 | 0.09 | 0.20 |
| | | Apr-Jun | 0.00 | 0.06 | 0.07 | 0.09 | 0.20 | 0.00 | 0.05 | 0.07 | 0.09 | 0.18 | 0.00 | 0.06 | 0.07 | 0.09 | 0.18 |
| | | Jul-Sep | -0.02 | 0.03 | 0.04 | 0.06 | 0.10 | -0.03 | 0.03 | 0.05 | 0.07 | 0.11 | -0.03 | 0.03 | 0.05 | 0.07 | 0.12 |
| | | Oct-Dec | -0.07 | 0.04 | 0.05 | 0.07 | 0.14 | -0.08 | 0.04 | 0.05 | 0.06 | 0.12 | -0.08 | 0.04 | 0.05 | 0.07 | 0.11 |
| Georgiana Slough | W AN | Jan-Mar | 1.00 | 2.00 | 2.47 | 2.61 | 2.74 | 1.00 | 1.98 | 2.47 | 2.61 | 2.74 | 1.00 | 1.97 | 2.47 | 2.61 | 2.74 |
| | | Apr-Jun | 0.64 | 0.87 | 1.02 | 1.48 | 2.71 | 0.64 | 0.88 | 1.02 | 1.48 | 2.71 | 0.61 | 0.87 | 1.02 | 1.48 | 2.71 |
| | | Jul-Sep | 0.72 | 0.82 | 0.86 | 0.94 | 1.38 | 0.64 | 0.80 | 0.86 | 0.97 | 1.37 | 0.65 | 0.81 | 0.86 | 0.96 | 1.36 |
| | | Oct-Dec | 0.55 | 0.73 | 0.93 | 1.75 | 2.76 | 0.52 | 0.73 | 0.93 | 1.78 | 2.76 | 0.52 | 0.75 | 0.95 | 1.65 | 2.76 |
| | C D BN | Jan-Mar | 0.53 | 0.83 | 1.03 | 1.37 | 2.11 | 0.52 | 0.82 | 1.01 | 1.35 | 2.13 | 0.52 | 0.83 | 1.02 | 1.31 | 2.14 |
| | | Apr-Jun | 0.60 | 0.74 | 0.85 | 0.95 | 1.64 | 0.55 | 0.78 | 0.87 | 0.95 | 1.63 | 0.56 | 0.76 | 0.87 | 0.96 | 1.64 |
| | | Jul-Sep | 0.56 | 0.67 | 0.74 | 0.88 | 1.05 | 0.50 | 0.60 | 0.69 | 0.87 | 1.08 | 0.51 | 0.60 | 0.69 | 0.86 | 1.08 |
| | | Oct-Dec | 0.53 | 0.67 | 0.72 | 0.87 | 1.55 | 0.53 | 0.66 | 0.71 | 0.87 | 1.58 | 0.53 | 0.64 | 0.71 | 0.87 | 1.62 |

DSM2-PTM was run for each month in water-years 1976 to 1991. In each simulation 1000 particles were injected over a period of 24 hours at the nodes described in Table 9-17. Particles were injected starting at the beginning of the forth day of each month. The particles were then tracked until the end of the twenty-fifth day, so the particle locations were reported after approximately twenty-one days. The particles were counted at each of the output locations in Table 9-18. These output locations represent the major locations where particles could go. “Past Chipps” represents the percentage of particles that travel past Chipps Island and into the Suisun Bay. “Exports” represents the combined percentage of particles that end up in Banks Pumping Plant and Jones Pumping Plant. “Other Diversion” represents the combined percentage of particles that end up in the Contra Costa Water District diversions on Old River and Rock Slough, North Bay Aqueduct, and agricultural diversions. The particles that remain in the Delta are grouped into two groups “In North Delta” and “In South Delta”. The delineation line between North and South is shown in Figure 9-25.

For the purposes of this document only three injection locations are presented, however output for all of the injection locations are available in the spreadsheets provided in Appendix G. The injection locations selected for presentation were the San Joaquin River at Mossdale (node 7), Little Potato Slough (node 249), and Sacramento River at Rio Vista (node 350).

The PTM results are presented in Table 9-19 for the injection at node 7, Table 9-20 for the injection at node 249, and Table 9-21 for the injection at node 350. The three tables present the minimum, 25 percentile, median, 75 percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN).

Appendix G presents DSM2-PTM results in graphical form. Box plots show the minimum, 25 percentile, median, 75 percentile, and maximum value. Results are also displayed in exceedence plots that show the percent of time in which a certain value was exceeded. Additionally graphical comparisons are made between percent of particles at the exports to Old and Middle River flow, Qwest flow, and Cross Delta flow.

**Table 9-17. Injection Locations**

| Node | Common Name |
|---|---|
| 335 | Sacramento River at Freeport |
| 341 | Sacramento River above Cross Channel |
| 321 | Cache Slough |
| 350 | Sacramento River at Rio Vista |
| 353 | Sacramento River at Emmaton |
| 355 | Sacramento River at Collinsville |

| | |
|---|---|
| 45 | San Joaquin River at Blind Point |
| 272 | Mokelumne River near San Joaquin River |
| 249 | Little Potato Slough |
| 21 | San Joaquin River at Stockton |
| 7 | San Joaquin River at Mossdale |

**Table 9-18. PTM Output**

| Name | Description |
|---|---|
| Past Chipps | Particles that pass Chipps Island |
| In North Delta | Particles that remain in the Northern Delta (Figure 9-25) |
| In South Delta | Particles that remain in the Southern Delta (Figure 9-25) |
| Exports | Combined SWP and CVP exports |
| Other Diversion | Agricultural Diversions, CCWD Diversions, and North Bay Aqueduct |

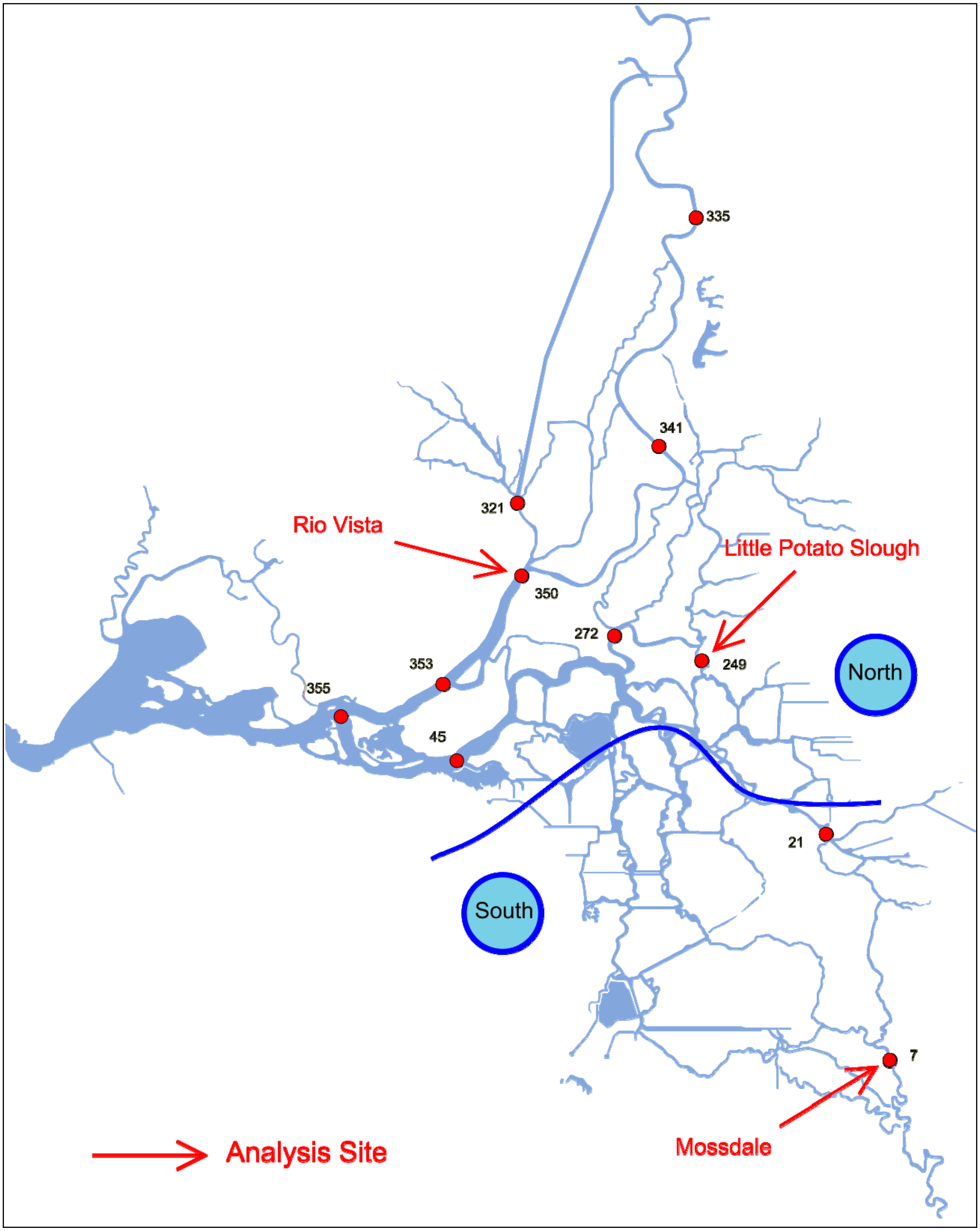



**Figure 9-25. DSM2-PTM locations for particle injection.**

**Table 9-19. Percent particle fate percentiles after 21 days for particle injection at node 7.**

| Name | Year Types | Month Range | Study 7.0 | | | | | Study 7.1 | | | | | Study 8.0 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max |
| Past Chipps | W AN | Jan-Mar | 0 | 0 | 0 | 32 | 89 | 0 | 0 | 0 | 34 | 90 | 0 | 0 | 0 | 34 | 89 |
| | | Apr-Jun | 0 | 0 | 0 | 8 | 73 | 0 | 0 | 0 | 5 | 76 | 0 | 0 | 0 | 4 | 76 |
| | | Jul-Sep | 0 | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 72 |
| | | Oct-Dec | 0 | 0 | 0 | 0 | 69 | 0 | 0 | 0 | 0 | 72 | 0 | 0 | 0 | 0 | 72 |
| | C D BN | Jan-Mar | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 3 |
| | | Apr-Jun | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 | 0 | 8 |
| | | Jul-Sep | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Oct-Dec | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| In North Delta | W AN | Jan-Mar | 0 | 2 | 3 | 4 | 47 | 0 | 1 | 3 | 4 | 27 | 0 | 2 | 3 | 4 | 30 |
| | | Apr-Jun | 1 | 2 | 4 | 12 | 47 | 1 | 3 | 4 | 10 | 39 | 1 | 2 | 4 | 10 | 39 |
| | | Jul-Sep | 1 | 2 | 3 | 4 | 47 | 1 | 2 | 3 | 4 | 27 | 1 | 2 | 3 | 4 | 30 |
| | | Oct-Dec | 1 | 3 | 4 | 6 | 47 | 1 | 3 | 4 | 5 | 27 | 1 | 3 | 4 | 5 | 30 |
| | C D BN | Jan-Mar | 0 | 3 | 9 | 16 | 45 | 0 | 4 | 9 | 16 | 29 | 0 | 4 | 9 | 17 | 44 |
| | | Apr-Jun | 0 | 3 | 11 | 19 | 45 | 0 | 4 | 11 | 18 | 40 | 0 | 4 | 11 | 17 | 44 |
| | | Jul-Sep | 0 | 1 | 5 | 12 | 45 | 0 | 3 | 6 | 14 | 27 | 0 | 3 | 6 | 14 | 44 |
| | | Oct-Dec | 1 | 3 | 8 | 12 | 38 | 1 | 4 | 6 | 13 | 24 | 2 | 4 | 8 | 13 | 25 |
| In South Delta | W AN | Jan-Mar | 0 | 4 | 7 | 9 | 30 | 0 | 5 | 6 | 8 | 44 | 0 | 4 | 6 | 7 | 46 |
| | | Apr-Jun | 1 | 6 | 8 | 13 | 34 | 1 | 5 | 8 | 12 | 44 | 0 | 5 | 7 | 12 | 46 |

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Jul-Sep | 2 | 5 | 7 | 9 | 30 | 2 | 5 | 6 | 8 | 44 | 1 | 5 | 6 | 7 | 46 |
| | | Oct-Dec | 2 | 6 | 8 | 15 | 30 | 2 | 5 | 7 | 14 | 44 | 1 | 5 | 6 | 16 | 46 |
| | C D BN | Jan-Mar | 2 | 8 | 13 | 20 | 50 | 3 | 10 | 16 | 25 | 46 | 2 | 8 | 16 | 25 | 43 |
| | | Apr-Jun | 1 | 11 | 16 | 25 | 50 | 2 | 12 | 19 | 32 | 55 | 1 | 11 | 19 | 34 | 54 |
| | | Jul-Sep | 1 | 8 | 15 | 22 | 50 | 0 | 7 | 16 | 30 | 46 | 0 | 6 | 15 | 30 | 43 |
| | | Oct-Dec | 4 | 8 | 14 | 23 | 50 | 3 | 8 | 14 | 29 | 46 | 3 | 7 | 16 | 34 | 43 |
| Exports | W AN | Jan-Mar | 10 | 56 | 77 | 86 | 92 | 9 | 53 | 78 | 88 | 93 | 9 | 55 | 78 | 88 | 94 |
| | | Apr-Jun | 15 | 48 | 70 | 85 | 90 | 21 | 54 | 72 | 85 | 93 | 16 | 55 | 73 | 86 | 94 |
| | | Jul-Sep | 16 | 68 | 80 | 86 | 90 | 23 | 72 | 81 | 87 | 93 | 16 | 71 | 82 | 88 | 94 |
| | | Oct-Dec | 16 | 59 | 75 | 86 | 90 | 23 | 58 | 76 | 89 | 93 | 16 | 58 | 74 | 89 | 94 |
| | C D BN | Jan-Mar | 14 | 52 | 67 | 81 | 92 | 13 | 49 | 69 | 82 | 96 | 11 | 48 | 66 | 82 | 95 |
| | | Apr-Jun | 0 | 27 | 48 | 73 | 91 | 0 | 36 | 54 | 70 | 92 | 0 | 30 | 50 | 67 | 92 |
| | | Jul-Sep | 0 | 30 | 57 | 76 | 91 | 13 | 44 | 63 | 77 | 92 | 11 | 44 | 61 | 80 | 92 |
| | | Oct-Dec | 19 | 59 | 75 | 80 | 91 | 27 | 58 | 72 | 82 | 92 | 21 | 49 | 70 | 87 | 92 |
| Other Diversions | W AN | Jan-Mar | 0 | 0 | 2 | 5 | 19 | 0 | 0 | 1 | 4 | 14 | 0 | 0 | 1 | 4 | 16 |
| | | Apr-Jun | 0 | 2 | 4 | 8 | 31 | 0 | 1 | 3 | 7 | 30 | 0 | 1 | 3 | 8 | 29 |
| | | Jul-Sep | 0 | 2 | 5 | 10 | 37 | 0 | 1 | 4 | 9 | 20 | 0 | 2 | 4 | 9 | 28 |
| | | Oct-Dec | 0 | 1 | 2 | 5 | 19 | 0 | 1 | 2 | 3 | 10 | 0 | 1 | 2 | 3 | 14 |
| | C | Jan-Mar | 0 | 2 | 5 | 12 | 61 | 0 | 2 | 3 | 9 | 30 | 0 | 2 | 3 | 9 | 40 |

| Name | Year Types | Month Range | Study 7.0 Min | 25% | 50% | 75% | Max | Study 7.1 Min | 25% | 50% | 75% | Max | Study 8.0 Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D BN | Apr-Jun | 2 | 5 | 12 | 27 | 80 | 1 | 4 | 9 | 18 | 56 | 1 | 4 | 9 | 19 | 60 |
| | | Jul-Sep | 2 | 4 | 10 | 40 | 99 | 1 | 3 | 8 | 22 | 69 | 1 | 3 | 8 | 22 | 75 |
| | | Oct-Dec | 2 | 3 | 4 | 7 | 22 | 1 | 2 | 3 | 6 | 11 | 1 | 2 | 3 | 5 | 11 |

**Table 9-20. Percent particle fate percentiles after 21 days for particle injection at node 249.**

| Name | Year Types | Month Range | Study 7.0 Min | 25% | 50% | 75% | Max | Study 7.1 Min | 25% | 50% | 75% | Max | Study 8.0 Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Past Chipps | W AN | Jan-Mar | 0 | 32 | 92 | 99 | 99 | 0 | 23 | 92 | 98 | 99 | 0 | 25 | 92 | 98 | 99 |
| | | Apr-Jun | 0 | 8 | 30 | 90 | 99 | 0 | 6 | 21 | 89 | 99 | 0 | 5 | 16 | 87 | 98 |
| | | Jul-Sep | 0 | 0 | 0 | 0 | 93 | 0 | 0 | 0 | 0 | 92 | 0 | 0 | 0 | 0 | 91 |
| | | Oct-Dec | 0 | 0 | 0 | 3 | 99 | 0 | 0 | 0 | 4 | 99 | 0 | 0 | 0 | 4 | 100 |
| | C D BN | Jan-Mar | 0 | 0 | 0 | 0 | 20 | 0 | 0 | 0 | 0 | 38 | 0 | 0 | 0 | 1 | 26 |
| | | Apr-Jun | 0 | 0 | 0 | 0 | 26 | 0 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 0 | 17 |
| | | Jul-Sep | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Oct-Dec | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| In North Delta | W AN | Jan-Mar | 0 | 0 | 2 | 7 | 24 | 0 | 0 | 2 | 4 | 24 | 0 | 0 | 2 | 4 | 25 |
| | | Apr-Jun | 0 | 5 | 32 | 53 | 72 | 0 | 4 | 39 | 48 | 62 | 0 | 5 | 34 | 49 | 65 |
| | | Jul-Sep | 1 | 2 | 5 | 7 | 19 | 2 | 2 | 3 | 10 | 17 | 1 | 2 | 4 | 9 | 20 |
| | | Oct-Dec | 0 | 3 | 6 | 8 | 21 | 0 | 2 | 4 | 9 | 26 | 0 | 2 | 4 | 9 | 30 |

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C D BN | Jan-Mar | 1 | 4 | 13 | 41 | 67 | 1 | 3 | 12 | 32 | 65 | 1 | 4 | 11 | 36 | 67 |
| | | Apr-Jun | 3 | 8 | 42 | 54 | 62 | 3 | 10 | 34 | 48 | 63 | 3 | 12 | 32 | 47 | 63 |
| | | Jul-Sep | 1 | 2 | 4 | 8 | 18 | 1 | 2 | 9 | 22 | 40 | 1 | 2 | 6 | 22 | 36 |
| | | Oct-Dec | 3 | 6 | 10 | 15 | 48 | 2 | 5 | 11 | 15 | 31 | 3 | 4 | 12 | 16 | 35 |
| In South Delta | W AN | Jan-Mar | 0 | 0 | 2 | 9 | 23 | 0 | 0 | 2 | 7 | 23 | 0 | 0 | 2 | 7 | 21 |
| | | Apr-Jun | 0 | 2 | 11 | 19 | 42 | 0 | 4 | 17 | 21 | 30 | 0 | 4 | 17 | 20 | 33 |
| | | Jul-Sep | 1 | 4 | 6 | 13 | 19 | 1 | 4 | 7 | 13 | 21 | 1 | 4 | 6 | 13 | 21 |
| | | Oct-Dec | 0 | 6 | 11 | 16 | 39 | 0 | 3 | 8 | 13 | 46 | 0 | 4 | 7 | 11 | 47 |
| | C D BN | Jan-Mar | 5 | 10 | 21 | 33 | 54 | 4 | 10 | 23 | 37 | 54 | 4 | 10 | 23 | 39 | 53 |
| | | Apr-Jun | 15 | 32 | 37 | 46 | 60 | 14 | 29 | 40 | 52 | 64 | 14 | 30 | 39 | 51 | 63 |
| | | Jul-Sep | 2 | 6 | 16 | 32 | 46 | 2 | 4 | 32 | 48 | 59 | 2 | 6 | 29 | 50 | 57 |
| | | Oct-Dec | 4 | 13 | 21 | 28 | 46 | 5 | 10 | 24 | 33 | 49 | 5 | 10 | 23 | 40 | 49 |
| Exports | W AN | Jan-Mar | 0 | 0 | 4 | 36 | 84 | 0 | 0 | 3 | 38 | 90 | 0 | 0 | 3 | 40 | 91 |
| | | Apr-Jun | 0 | 0 | 0 | 11 | 31 | 0 | 0 | 8 | 20 | 57 | 0 | 0 | 7 | 18 | 55 |
| | | Jul-Sep | 0 | 61 | 78 | 84 | 91 | 0 | 63 | 78 | 81 | 90 | 0 | 63 | 79 | 81 | 90 |
| | | Oct-Dec | 0 | 39 | 73 | 83 | 93 | 0 | 29 | 74 | 87 | 95 | 0 | 25 | 75 | 88 | 94 |
| | C D BN | Jan-Mar | 0 | 10 | 58 | 84 | 93 | 0 | 16 | 52 | 84 | 93 | 0 | 11 | 59 | 85 | 93 |
| | | Apr-Jun | 0 | 0 | 4 | 38 | 67 | 0 | 2 | 11 | 30 | 63 | 0 | 1 | 9 | 20 | 63 |
| | | Jul-Sep | 25 | 50 | 68 | 82 | 90 | 2 | 19 | 50 | 78 | 90 | 2 | 15 | 45 | 79 | 91 |

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Oct-Dec | 3 | 49 | 66 | 79 | 88 | 17 | 48 | 63 | 79 | 89 | 14 | 40 | 63 | 82 | 90 |
| Other Diversions | W AN | Jan-Mar | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 1 | 3 |
| | | Apr-Jun | 0 | 2 | 3 | 7 | 13 | 0 | 2 | 4 | 7 | 13 | 0 | 2 | 4 | 6 | 13 |
| | | Jul-Sep | 3 | 4 | 6 | 11 | 16 | 2 | 5 | 8 | 11 | 15 | 3 | 5 | 8 | 12 | 15 |
| | | Oct-Dec | 0 | 1 | 2 | 3 | 6 | 0 | 1 | 2 | 3 | 6 | 0 | 1 | 2 | 3 | 5 |
| | C D BN | Jan-Mar | 0 | 1 | 2 | 2 | 3 | 1 | 1 | 2 | 2 | 5 | 1 | 1 | 2 | 2 | 5 |
| | | Apr-Jun | 2 | 4 | 6 | 15 | 26 | 3 | 5 | 6 | 19 | 22 | 3 | 5 | 6 | 18 | 22 |
| | | Jul-Sep | 3 | 6 | 9 | 14 | 22 | 4 | 7 | 10 | 16 | 26 | 3 | 7 | 10 | 17 | 29 |
| | | Oct-Dec | 1 | 2 | 3 | 4 | 6 | 2 | 2 | 3 | 4 | 5 | 2 | 2 | 3 | 4 | 6 |

**Table 9-21. Percent particle fate percentiles after 21 days for particle injection at node 350.**

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Past Chipps | W AN | Jan-Mar | 76 | 98 | 98 | 99 | 99 | 70 | 98 | 98 | 98 | 99 | 69 | 98 | 98 | 99 | 99 |
| | | Apr-Jun | 32 | 93 | 98 | 99 | 99 | 52 | 86 | 97 | 99 | 99 | 53 | 83 | 97 | 99 | 99 |
| | | Jul-Sep | 18 | 32 | 46 | 60 | 99 | 17 | 26 | 37 | 67 | 98 | 20 | 26 | 39 | 68 | 98 |
| | | Oct-Dec | 13 | 25 | 55 | 96 | 99 | 10 | 23 | 43 | 96 | 99 | 13 | 24 | 47 | 96 | 99 |
| | C D | Jan-Mar | 25 | 54 | 70 | 78 | 99 | 21 | 54 | 64 | 77 | 99 | 23 | 52 | 64 | 78 | 99 |
| | | Apr-Jun | 7 | 25 | 49 | 72 | 96 | 7 | 32 | 49 | 67 | 95 | 6 | 34 | 51 | 69 | 95 |

| Name | Year Types | Month Range | Study 7.0 Min | Study 7.0 25% | Study 7.0 50% | Study 7.0 75% | Study 7.0 Max | Study 7.1 Min | Study 7.1 25% | Study 7.1 50% | Study 7.1 75% | Study 7.1 Max | Study 8.0 Min | Study 8.0 25% | Study 8.0 50% | Study 8.0 75% | Study 8.0 Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BN | Jul-Sep | 9 | 17 | 24 | 31 | 50 | 7 | 13 | 23 | 29 | 56 | 6 | 13 | 24 | 28 | 56 |
| | | Oct-Dec | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| In North Delta | W AN | Jan-Mar | 0 | 0 | 0 | 0 | 11 | 0 | 0 | 0 | 0 | 15 | 0 | 0 | 0 | 0 | 13 |
| | | Apr-Jun | 0 | 0 | 1 | 5 | 60 | 0 | 0 | 2 | 11 | 39 | 0 | 0 | 2 | 14 | 39 |
| | | Jul-Sep | 0 | 29 | 40 | 49 | 53 | 0 | 20 | 44 | 52 | 55 | 0 | 20 | 42 | 51 | 59 |
| | | Oct-Dec | 0 | 1 | 24 | 55 | 70 | 0 | 1 | 29 | 53 | 76 | 0 | 1 | 26 | 51 | 73 |
| | C D BN | Jan-Mar | 0 | 9 | 18 | 31 | 59 | 0 | 9 | 22 | 33 | 55 | 0 | 10 | 22 | 32 | 57 |
| | | Apr-Jun | 2 | 24 | 42 | 61 | 84 | 3 | 29 | 42 | 57 | 84 | 3 | 25 | 39 | 56 | 85 |
| | | Jul-Sep | 29 | 47 | 58 | 64 | 80 | 23 | 47 | 64 | 70 | 86 | 24 | 48 | 62 | 70 | 85 |
| | | Oct-Dec | 3 | 6 | 10 | 15 | 48 | 2 | 5 | 11 | 15 | 31 | 3 | 4 | 12 | 16 | 35 |
| In South Delta | W AN | Jan-Mar | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 4 |
| | | Apr-Jun | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 3 |
| | | Jul-Sep | 0 | 2 | 6 | 11 | 15 | 0 | 2 | 9 | 12 | 13 | 0 | 2 | 8 | 11 | 13 |
| | | Oct-Dec | 0 | 0 | 4 | 8 | 9 | 0 | 0 | 6 | 10 | 13 | 0 | 0 | 6 | 9 | 12 |
| | C D BN | Jan-Mar | 0 | 1 | 2 | 4 | 11 | 0 | 1 | 2 | 6 | 12 | 0 | 2 | 3 | 5 | 13 |
| | | Apr-Jun | 0 | 2 | 4 | 6 | 10 | 0 | 3 | 5 | 6 | 8 | 0 | 2 | 4 | 6 | 10 |
| | | Jul-Sep | 5 | 9 | 10 | 11 | 15 | 5 | 6 | 7 | 10 | 18 | 5 | 6 | 9 | 11 | 17 |
| | | Oct-Dec | 4 | 13 | 21 | 28 | 46 | 5 | 10 | 24 | 33 | 49 | 5 | 10 | 23 | 40 | 49 |
| Exports | W | Jan-Mar | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 6 | 0 | 0 | 0 | 0 | 5 |

| Name | Year Types | Month Range | Study 7.0 Min | 25% | 50% | 75% | Max | Study 7.1 Min | 25% | 50% | 75% | Max | Study 8.0 Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | AN | Apr-Jun | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 2 |
| | | Jul-Sep | 0 | 2 | 6 | 9 | 13 | 0 | 3 | 6 | 9 | 13 | 0 | 3 | 6 | 10 | 15 |
| | | Oct-Dec | 0 | 0 | 3 | 5 | 8 | 0 | 0 | 4 | 6 | 9 | 0 | 1 | 4 | 7 | 10 |
| | C D BN | Jan-Mar | 0 | 0 | 1 | 5 | 9 | 0 | 0 | 1 | 4 | 10 | 0 | 0 | 1 | 3 | 13 |
| | | Apr-Jun | 0 | 0 | 0 | 2 | 4 | 0 | 0 | 1 | 1 | 4 | 0 | 0 | 0 | 2 | 4 |
| | | Jul-Sep | 1 | 3 | 5 | 11 | 20 | 0 | 1 | 2 | 12 | 18 | 0 | 1 | 3 | 11 | 19 |
| | | Oct-Dec | 3 | 49 | 66 | 79 | 88 | 17 | 48 | 63 | 79 | 89 | 14 | 40 | 63 | 82 | 90 |
| Other Diversions | W AN | Jan-Mar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | | Apr-Jun | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 0 | 1 | 3 |
| | | Jul-Sep | 0 | 1 | 2 | 2 | 3 | 0 | 1 | 2 | 2 | 3 | 0 | 1 | 2 | 2 | 3 |
| | | Oct-Dec | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 |
| | C D BN | Jan-Mar | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | Apr-Jun | 0 | 1 | 1 | 3 | 3 | 0 | 1 | 1 | 2 | 3 | 0 | 1 | 1 | 2 | 3 |
| | | Jul-Sep | 0 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 4 | 1 | 1 | 2 | 3 | 5 |
| | | Oct-Dec | 1 | 2 | 3 | 4 | 6 | 2 | 2 | 3 | 4 | 5 | 2 | 2 | 3 | 4 | 6 |

## Temperature Results

Simulated temperature results for Study 7.0, Study 7.1, and Study 8.0 are located in Chapter 10, Upstream Effects and in Appendices I and K. The treatment of the Feather River Temperature modeling is different than the other reaches previously mentioned is presented in Appendix K and described below

The Oroville Facilities Relicensing Draft Environmental Impact Report (DEIR) and Biological Assessment (BA) included evaluation of modeling output for three alternatives: the Existing Conditions, the No Project, and the Proposed Project. Operations under OCAP Study 7.0 include the same flow and water temperature requirements as the Existing Conditions Alternative. The Proposed Project simulation utilized flow requirements and water temperature targets from the March 2006 Settlement Agreement for Licensing of the Oroville Facilities (Settlement Agreement), as evaluated in OCAP Study 7.1. While simulated storage conditions in Oroville Reservoir might be different under the 2008 OCAP BA, temperature management actions would follow the same procedures as the Proposed Project. Simulated operations for the 2008 OCAP BA would be able to utilize temperature management actions not exhausted in simulation of the Proposed Project.

The primary difference with regards to water temperature between OCAP Study 7.1 and 8.0 would be the construction of a facility modification to improve DWR's ability to manage Feather River water temperatures. However, the specific configuration of a facility modification will be examined in a separate environmental process, so no water temperature modeling of a facility modification has been completed. While none of the previously conducted water temperature modeling is directly applicable to OCAP Study 8.0, because the respective flow requirements and water temperature objectives are the same, conditions at the Feather River Fish Hatchery and Robinson Riffle would also be expected to be similar.

## Salmon Mortality, Population, and Life Cycle Results

Simulated salmon fishery results are discussed in Chapter 10, Upstream Effects and in Appendices M, O, and Q.

## Climate Change Results

CalSim-II long-term average (1922-2003) and dry period average (1929-1934) climate change results are reported in Table 9-22. Appendix R discusses the results of the climate change and sea level rise sensitivity evaluation. The Base Model is the future condition, Study 8.0, simulating the D1641 step. The studies examined include:

1. **Study 9.0 Base Without 1 ft Sea Level Change**: Base Model without the 1 foot sea level rise and 4 inch increase in tidal amplitude
2. **Study 9.1 Base With 1 ft Sea Level Change:** Base Model with 1 foot sea level rise and 4 inch increase in tidal amplitude
3. **Study 9.2 Wetter, Less Warming**: Same assumptions as Study 9.1 hydrology inputs modified for a wetter, less warming climate

4. **Study 9.3 Wetter, More Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a wetter , more warming climate
5. **Study 9.4 Drier, Less Warming**: Same assumptions as Study 9.1 with hydrology inputs modified for a drier, less warming climate
6. **Study 9.5 Drier, More Warming**: Same assumptions as Study 9.1with hydrology inputs modified for a drier, more warming climate

**Table 9-22. Climate Change and Sea Level Rise Long-term Averages and 28-34 Averages**

| | Study 9.0 Base Without 1' Sea Level Change | | Study 9.1 Base With 1' Sea Level Change | | Study 9.4 Drier, Less Warming | | Study 9.2 Wetter, Less Warming | | Study9.5 Drier, More Warming | | Study 9.3 Wetter, More Warming | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **End of Sep Storages (TAF)** | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 | 1922-2003 | 1929-34 |
| Trinity | 1393 | 698 | 1322 | 564 | 1299 | 454 | 1514 | 923 | 1118 | 402 | 1389 | 780 |
| Whiskeytown | 235 | 231 | 232 | 210 | 230 | 200 | 235 | 235 | 229 | 195 | 235 | 235 |
| Shasta | 2721 | 1416 | 2618 | 1084 | 2559 | 955 | 2896 | 2137 | 2292 | 816 | 2703 | 1718 |
| Oroville | 1729 | 643 | 1682 | 592 | 1267 | 246 | 2084 | 1180 | 1106 | 213 | 1722 | 1034 |
| Folsom | 500 | 411 | 467 | 317 | 408 | 228 | 510 | 433 | 382 | 233 | 461 | 393 |
| New Melones | 1534 | 1047 | 1534 | 1048 | 1023 | 293 | 1696 | 1305 | 1255 | 538 | 1594 | 1191 |
| CVP San Luis | 292 | 448 | 267 | 377 | 204 | 131 | 268 | 387 | 229 | 124 | 229 | 346 |
| SWP San Luis | 519 | 365 | 476 | 322 | 412 | 202 | 539 | 524 | 405 | 264 | 506 | 477 |
| Total San Luis | 811 | 814 | 743 | 699 | 616 | 333 | 808 | 912 | 634 | 387 | 735 | 823 |
| **River Flows (cfs)** | | | | | | | | | | | | |
| Trinity Release | 973 | 566 | 960 | 566 | 979 | 555 | 1147 | 585 | 868 | 499 | 1129 | 585 |
| Clear Creek Tunnel | 734 | 481 | 752 | 549 | 780 | 590 | 832 | 573 | 706 | 497 | 815 | 538 |
| Clear Creek Release | 63 | 46 | 63 | 46 | 63 | 49 | 70 | 55 | 59 | 40 | 74 | 55 |
| Keswick Release | 8674 | 5517 | 8695 | 5626 | 8906 | 5767 | 10047 | 6140 | 8022 | 5172 | 9972 | 6092 |
| Nimbus Release | 3334 | 1722 | 3342 | 1771 | 2533 | 1321 | 4235 | 2208 | 2597 | 1365 | 4154 | 2155 |
| Mouth of American | 2986 | 1379 | 2985 | 1411 | 2282 | 1503 | 3879 | 1842 | 2396 | 1656 | 3795 | 1788 |

| | Study 9.0 Base Without 1' Sea Level Change | | Study 9.1 Base With 1' Sea Level Change | | Study 9.4 Drier, Less Warming | | Study 9.2 Wetter, Less Warming | | Study9.5 Drier, More Warming | | Study 9.3 Wetter, More Warming | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sac River blw Red Bluff Diversion Dam | 11338 | 6951 | 11385 | 7075 | 11614 | 7249 | 12684 | 7557 | 10764 | 6681 | 12653 | 7550 |
| Wilkin's Slough | 9190 | 5578 | 9303 | 5702 | 9492 | 5874 | 9983 | 5968 | 8977 | 5546 | 9662 | 5958 |
| Feather Low Flow Channel | 756 | 756 | 756 | 756 | 756 | 750 | 756 | 756 | 756 | 756 | 756 | 756 |
| Flow Below Thermalito | 4384 | 2379 | 4391 | 2373 | 3442 | 1859 | 5733 | 2898 | 3423 | 1853 | 5731 | 2814 |
| Feather Flow Below Yuba Mouth | 6318 | 3126 | 6392 | 3177 | 5038 | 2467 | 8220 | 3952 | 5033 | 2466 | 8215 | 3864 |
| Feather Mouth | 7701 | 3216 | 7772 | 3267 | 6310 | 2521 | 9727 | 4098 | 6309 | 2534 | 9715 | 4008 |
| Sac at Freeport | 22414 | 11455 | 22588 | 11666 | 21007 | 11189 | 25599 | 13184 | 20352 | 11028 | 24818 | 13030 |
| Tulloch Release | 1453 | 1099 | 1453 | 1098 | 1080 | 865 | 1813 | 1182 | 1185 | 976 | 1642 | 1141 |
| Stanislaus Mouth | 790 | 421 | 790 | 420 | 524 | 385 | 1112 | 445 | 586 | 409 | 962 | 427 |
| SJR Flow w/o Stanislaus | 3335 | 1417 | 3335 | 1416 | 2529 | 1384 | 4189 | 1520 | 2817 | 1382 | 3627 | 1463 |
| Flow at Vernalis | 4161 | 1859 | 4161 | 1858 | 3085 | 1789 | 5338 | 1990 | 3437 | 1812 | 4625 | 1912 |
| Yolo Bypass | 2632 | 164 | 2588 | 160 | 2186 | 159 | 3699 | 161 | 2145 | 159 | 4350 | 160 |
| Mokelumne | 918 | 286 | 918 | 286 | 700 | 218 | 1142 | 355 | 739 | 229 | 1083 | 338 |
| Spring Creek Tunnel | 1040 | 532 | 1058 | 613 | 1097 | 653 | 1194 | 634 | 982 | 558 | 1164 | 596 |
| **Delta Parameters** | | | | | | | | | | | | |
| SWP Banks (cfs) | 4784 | 2833 | 4522 | 2442 | 4007 | 2017 | 5096 | 3175 | 4017 | 2183 | 4827 | 3061 |
| CVP Banks (cfs) | 103 | 9 | 90 | 3 | 92 | 5 | 82 | 22 | 78 | 0 | 97 | 7 |
| Jones (cfs) | 3421 | 1997 | 3259 | 1868 | 3204 | 1898 | 3548 | 2309 | 2960 | 1628 | 3399 | 2060 |
| Total Banks (cfs) | 4887 | 2842 | 4612 | 2445 | 4099 | 2022 | 5178 | 3197 | 4095 | 2183 | 4924 | 3068 |

| | **Study 9.0 Base Without 1' Sea Level Change** | | **Study 9.1 Base With 1' Sea Level Change** | | **Study 9.4 Drier, Less Warming** | | **Study 9.2 Wetter, Less Warming** | | **Study9.5 Drier, More Warming** | | **Study 9.3 Wetter, More Warming** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cross Valley Pumping (cfs) | 103 | 9 | 90 | 3 | 92 | 5 | 82 | 22 | 78 | 0 | 97 | 7 |
| Sac Flow at Freeport (cfs) | 22414 | 11455 | 22588 | 11666 | 21007 | 11189 | 25599 | 13184 | 20352 | 11028 | 24818 | 13030 |
| Flow at Rio Vista (cfs) | 18977 | 7165 | 19063 | 7307 | 17330 | 6946 | 22766 | 8457 | 16761 | 6822 | 22714 | 8378 |
| Excess Outflow (cfs) | 14148 | 1293 | 15081 | 2044 | 11931 | 1943 | 20114 | 2407 | 12062 | 1928 | 19514 | 2528 |
| Required Outflow (cfs) | 6158 | 5874 | 5792 | 5852 | 6244 | 5743 | 5419 | 6008 | 6057 | 5735 | 5524 | 6016 |
| X2 Position (km) | 77 | 85 | 78 | 86 | 80 | 86 | 76 | 85 | 80 | 86 | 77 | 85 |
| Yolo Bypass (cfs) | 2632 | 164 | 2588 | 160 | 2186 | 159 | 3699 | 161 | 2145 | 159 | 4350 | 160 |
| Mokelumne Flow (cfs) | 918 | 286 | 918 | 286 | 700 | 218 | 1142 | 355 | 739 | 229 | 1083 | 338 |
| SJR + Calaveras Flow (cfs) | 4168 | 1865 | 4167 | 1864 | 3091 | 1795 | 5345 | 1996 | 3443 | 1818 | 4632 | 1918 |
| Modeled Required DO (cfs) | 6158 | 5874 | 5792 | 5852 | 6244 | 5743 | 5419 | 6008 | 6057 | 5735 | 5524 | 6016 |
| Flow at Georgiana Slough (cfs) | 3810 | 2353 | 3833 | 2381 | 3623 | 2317 | 4234 | 2582 | 3536 | 2296 | 4130 | 2562 |
| DXC Flow (cfs) | 1745 | 1551 | 1767 | 1586 | 1739 | 1545 | 1776 | 1744 | 1700 | 1524 | 1807 | 1691 |
| Flow below DXC (cfs) | 16859 | 7551 | 16988 | 7699 | 15645 | 7328 | 19589 | 8857 | 15116 | 7209 | 18881 | 8776 |
| North Bay Aqueduct (cfs) | 40 | 26 | 40 | 28 | 37 | 24 | 42 | 31 | 37 | 26 | 42 | 30 |
| CCWD (cfs) | 202 | 225 | 202 | 225 | 202 | 225 | 202 | 225 | 202 | 225 | 202 | 225 |
| Total Outflow (cfs) | 20306 | 7167 | 20873 | 7896 | 18175 | 7686 | 25532 | 8415 | 18118 | 7663 | 25038 | 8544 |
| Total Inflow (cfs) | 30132 | 13770 | 30261 | 13975 | 26984 | 13361 | 35785 | 15696 | 26679 | 13234 | 34884 | 15445 |
| Old&Middle River (cfs) | -- | -- | -6010 | -3680 | -5911 | -3338 | -6336 | -4748 | -5536 | -3226 | -6247 | -4424 |
| QWEST (cfs) | -- | -- | 1728 | 557 | 776 | 720 | 2675 | -83 | 1288 | 816 | 2238 | 128 |

| | Study 9.0 Base Without 1' Sea Level Change | | Study 9.1 Base With 1' Sea Level Change | | Study 9.4 Drier, Less Warming | | Study 9.2 Wetter, Less Warming | | Study9.5 Drier, More Warming | | Study 9.3 Wetter, More Warming | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Deliveries (TAF)** | | | | | | | | | | | | |
| CVP | | | | | | | | | | | | |
| North of Delta | | | | | | | | | | | | |
| Agriculture | 1146 | 94 | 206 | 6 | 193 | 10 | 255 | 46 | 165 | 0 | 224 | 14 |
| Settlement Contracts | 852 | 741 | 1855 | 1728 | 1857 | 1709 | 1879 | 1899 | 1810 | 1512 | 1879 | 1899 |
| M&I | 126 | 81 | 193 | 127 | 188 | 123 | 207 | 148 | 179 | 118 | 199 | 132 |
| Refuge | 273 | 234 | 90 | 76 | 90 | 73 | 92 | 89 | 88 | 65 | 92 | 89 |
| **Total** | 2581 | 1334 | 2344 | 1937 | 2328 | 1914 | 2432 | 2181 | 2242 | 1695 | 2393 | 2134 |
| South of Delta | | | | | | | | | | | | |
| Agriculture | 0 | 0 | 1032 | 31 | 959 | 49 | 1256 | 232 | 832 | 0 | 1122 | 69 |
| Exchange | 0 | 0 | 852 | 741 | 857 | 774 | 867 | 841 | 835 | 707 | 867 | 841 |
| M&I | 0 | 0 | 121 | 76 | 119 | 78 | 130 | 90 | 112 | 71 | 125 | 79 |
| Refuge | 9192 | 8263 | 273 | 234 | 274 | 245 | 278 | 269 | 266 | 218 | 278 | 269 |
| **Total**** | 165 | 258 | 2461 | 1266 | 2392 | 1330 | 2715 | 1617 | 2226 | 1171 | 2576 | 1443 |
| SWP | | | | | | | | | | | | |
| Allocation | 3245 | 1511 | 3100 | 1359 | 2703 | 1179 | 3489 | 1930 | 2682 | 1256 | 3341 | 1859 |
| Table A | 2996 | 1441 | 2864 | 1288 | 2508 | 1112 | 3206 | 1825 | 2494 | 1190 | 3075 | 1761 |
| Article 56 | 114 | 39 | 114 | 37 | 98 | 5 | 120 | 73 | 89 | 10 | 124 | 62 |
| Article 21 | 327 | 465 | 267 | 331 | 251 | 226 | 343 | 327 | 282 | 245 | 266 | 332 |

| | **Study 9.0 Base Without 1' Sea Level Change** | | **Study 9.1 Base With 1' Sea Level Change** | | **Study 9.4 Drier, Less Warming** | | **Study 9.2 Wetter, Less Warming** | | **Study9.5 Drier, More Warming** | | **Study 9.3 Wetter, More Warming** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Table A + Art 56 | 3109 | 1480 | 2978 | 1326 | 2606 | 1118 | 3326 | 1898 | 2583 | 1200 | 3199 | 1822 |
| Table A + Art 56 + Art 21 | 3437 | 1945 | 3246 | 1656 | 2857 | 1344 | 3669 | 2224 | 2865 | 1444 | 3465 | 2154 |
| Anticipated Carryover | 181 | 3 | 167 | 3 | 124 | 0 | 211 | 39 | 119 | 0 | 194 | 32 |
| **Allocations (%)** | | | | | | | | | | | | |
| CVP Allocation | | | | | | | | | | | | |
| North of Delta | | | | | | | | | | | | |
| Agriculture | 65% | 13% | 59% | 10% | 55% | 11% | 72% | 21% | 47% | 5% | 64% | 12% |
| M&I | 86% | 59% | 83% | 56% | 81% | 57% | 90% | 65% | 77% | 54% | 86% | 58% |
| South of Delta | | | | | | | | | | | | |
| Agriculture | 63% | 13% | 57% | 10% | 53% | 11% | 70% | 21% | 46% | 5% | 62% | 12% |
| M&I | 86% | 59% | 83% | 56% | 81% | 57% | 89% | 65% | 77% | 54% | 85% | 58% |
| SWP | | | | | | | | | | | | |
| All SWC | 79% | 37% | 73% | 32% | 64% | 28% | 82% | 46% | 63% | 30% | 79% | 44% |

The DSM2-Hydro climate change analysis was run from Water Year 1976 to 1991 and output was provided for a number of locations in the Delta. The boundary tide incorporated a one-foot and four-inch (10% increase) amplitude adjustment for sea-level rise which was consistent with the ANN used in CalSim-II. Figure 9-24 shows a map of the Delta and all of the available output locations as well as the direction of positive flow and velocity for each location. Table 9-14 lists these output locations along with the common name, representative DSM2 channel number and distance in channel. All of the results from DSM2-Hydro are provided in spreadsheets, but for purposes of this document and Appendix G only four sites were selected for discussion. These four sites were generally a combination of flows that represent an imaginary boundary internal to the Delta. These four sites were:

- **Cross Delta flow –** a combination of Georgiana Slough, North Fork of Mokelumne, and South Fork of the Mokelumne (GEORGIANA_SL, NORTH_FORK_MOKE, and RSMKL008 as respectively labeled in Figure 9-24).
- **QWest flow –** a combination of San Joaquin River at Blind Point, Three Mile Slough, and Dutch Slough (RSAN014,SLTRM004, and SLDUT007 as respectively labeled in Figure 9-24).
- **Old and Middle River flow –** a combination of Old River at Bacon Island and Middle River at Middle River (ROLD024, and RMID015 as respectively labeled in Figure 9-24).
- **Old River at Head –** described by a single output location ROLD074 as labeled in Figure 9-24.

One location from each of the groups was used to give an indication of the average velocity. From the Cross Delta group GEORGIANA_SL is presented for velocity. From the Qwest group RANS014 is presented for velocity, and from Old and Middle River RMID015 is presented.

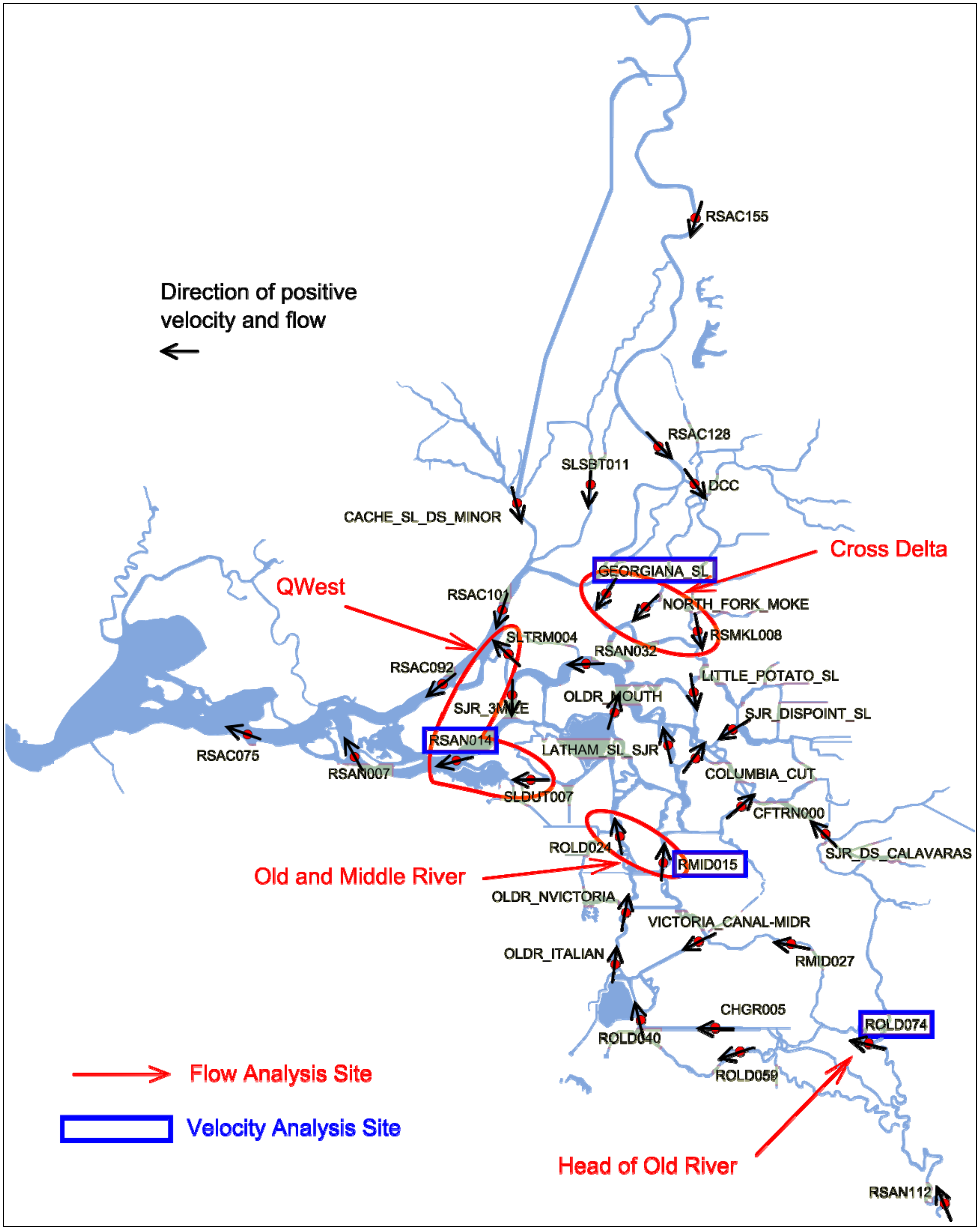



**Figure 9-26. DSM2-Hydro locations of output for flow (cfs) and velocity (ft/s). Arrows represent the direction of positive flow and velocity.**

**Table 9-23. Definitions for the DSM2 output**

| DSM2 Output Name | Channel | Distance | Common Name |
|---|---|---|---|
| CFTRN000 | 172 | 727 | Turner Cut |
| CHGRL005 | 211 | 1585 | Grant Line Canal (West Position) |
| RMID015 | 144 - 145 | 838 | Middle River at Middle River (west channel) |
| RMID027 | 133 | 3641 | Middle River at Tracy Blvd |
| ROLD014 | 117 | 0 | Old River at Holland Cut |
| ROLD024 | 106 | 2718 | Old River at Bacon Island |
| ROLD040 | 82 | 2609 | Old River at Clifton Court Ferry |
| ROLD059 | 71 | 3116 | Old River at Tracy Road |
| ROLD074 | 54 | 735 | Head of Old River |
| RSAC075 | 437 | 11108 | Sacramento River at Mallard Island |
| RSAC092 | 434 | 435 | Sacramento River at Emmaton |
| RSAC101 | 430 | 9684 | Sacramento River at Rio Vista |
| RSAC128 | 421 | 8585 | Sacramento River above Delta Cross Channel |
| RSAC155 | 414 | 11921 | Sacramento River at Freeport |
| RSAN007 | 52 | 366 | San Joaquin River at Antioch |
| RSAN014 | 49 | 9570 | San Joaquin River at Blind Point |
| RSAN024 | 47 | 8246 | San Joaquin River at Bradford Isl. |
| RSAN032 | 349 | 9672 | San Joaquin River at San Andreas Landing |
| RSAN058 | 20 | 2520 | San Joaquin River at Stockton Ship Channel |
| RSAN112 | 17 | 4744 | San Joaquin River at Vernalis |
| RSMKL008 | 344 | 7088 | South Fork Mokelumne at Staten Island |
| SLDUT007 | 274 | 7351 | Dutch Slough |
| SLSBT011 | 385 | 2273 | Steamboat Slough |
| SLTRM004 | 310 | 540 | Three Mile Slough |
| DCC | 365 | 0 | Delta Cross Channel |
| COLUMBIA_CUT | 160 | 50 | Columbia Cut |
| SJR_DS_CALAVARAS | 21 | 0 | San Joaquin River downstream Calaveras River |
| SJR_3MILE | 49 | 9570 | San Joaquin River at Three Mile Slough |

| | | | |
|---|---|---|---|
| OLDR_ITALIAN | 88 | 0 | Old River at Italian Slough |
| OLDR_NVICTORIA | 91 | 4119 | Old River at North Victoria Canal |
| OLDR_MOUTH | 124 | 7062 | Mouth of Old River |
| LATHAM_SL_SJR | 161 | 10808 | Latham Slough at San Joaquin River |
| VICTORIA_CANAL_MIDR | 226 | 4153 | Victoria Canal at Middle River |
| SJR_DISPOINT_SL | 314 | 8130 | Disappointment Slough at San Joaquin River |
| LITTLE_POTATO_SL | 325 | 9962 | Little Potato Slough |
| NORTH_FORK_MOKE | 363 | 6133 | North Fork Mokelumne River |
| GEORGIANA_SL | 371 | 7766 | Georgiana Slough |
| CACHE_SL_DS_MINOR | 398 | 0 | Cache Slough downstream Minor Slough |
| OMR | 144 - 145 + 106 | -- | Old and Middle River |
| QWEST | 274 + 49 + 310 | -- | Western Flow (QWEST) |
| XDELTA | 371 + 363 + 344 | -- | Cross Delta Flow |

The DSM2-Hydro results were aggregated from a fifteen-minute time-step to a daily average. A Godin filter was first applied to the data to remove the tidal variations, and then a daily average of the filtered data was applied. This is the same process that the USGS uses to determine daily averages for locations under tidal influence.

The flow results for the more warming case are presented in Table 9-24 and the less warming case results are presented in Table 9-25. The velocity results for the more warming case are presented in Table 9-26 and the less warming case results are presented in Table 9-27 The tables present the minimum, twenty five percentile, median, seventy five percentile, and maximum value for water-years 1976 to 1991, broken down into groups representing annual quarters, and year type groups. The monthly output was grouped into the annual quarters: January through March (Jan-Mar), April through June (Apr-Jun), July through September (Jul-Sep), and October through December (Oct-Dec). The year types were grouped into two representative groups: Wet and Above Normal (W-AN), and Below Normal, Dry and Critical (C-D-BN). For regional flows that cross more than one individual location, for example Old and Middle River includes two output locations, a simple time period summation was conducted.

**Table 9-24. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.**

| Name | Year Types | Month Range | Base | | | | | Study 9.4 Drier, Less Warming | | | | | Study 9.2 Wetter, Less Warming | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max |
| Head of Old River | W AN | Jan-Mar | 1349 | 3722 | 8034 | 9478 | 16704 | 1348 | 2917 | 4496 | 7080 | 14335 | 1408 | 5568 | 8698 | 10565 | 17970 |
| | | Apr-Jun | 0 | 3685 | 5707 | 8645 | 11251 | 0 | 1625 | 2430 | 6105 | 10492 | 0 | 5068 | 7441 | 9164 | 12909 |
| | | Jul-Sep | 468 | 1922 | 2114 | 3979 | 9682 | 372 | 489 | 1842 | 2288 | 5631 | 467 | 2257 | 3064 | 4963 | 12213 |
| | | Oct-Dec | 105 | 315 | 822 | 1607 | 9549 | 148 | 282 | 523 | 1554 | 8693 | 128 | 321 | 1105 | 5461 | 13198 |
| | C D BN | Jan-Mar | 643 | 1025 | 1350 | 1650 | 4568 | 670 | 1024 | 1310 | 1530 | 3143 | 645 | 1059 | 1362 | 1782 | 6363 |
| | | Apr-Jun | 0 | 0 | 624 | 1145 | 4163 | 0 | 0 | 614 | 1083 | 2243 | 0 | 0 | 836 | 1241 | 5473 |
| | | Jul-Sep | 174 | 311 | 380 | 471 | 1279 | 178 | 300 | 358 | 436 | 1182 | 177 | 308 | 394 | 518 | 1894 |
| | | Oct-Dec | 112 | 255 | 408 | 967 | 1612 | 114 | 251 | 370 | 890 | 1532 | 115 | 267 | 433 | 1074 | 2228 |
| Old and Middle River | W AN | Jan-Mar | -10905 | -6299 | -2407 | 4437 | 22137 | -11026 | -8054 | -6380 | -1285 | 18085 | -10315 | -5603 | -135 | 7934 | 24229 |
| | | Apr-Jun | -9196 | -5894 | -4283 | -684 | 12565 | -9271 | -6525 | -4895 | -3907 | 10161 | -9391 | -5253 | -3278 | 1183 | 14282 |
| | | Jul-Sep | -10519 | -9239 | -8256 | -7281 | 3238 | -11552 | -9831 | -8898 | -7895 | -5422 | -10431 | -8599 | -7824 | -6465 | 9561 |
| | | Oct-Dec | -11582 | -9401 | -7559 | -4051 | 6751 | -11582 | -9527 | -6104 | -4424 | 2694 | -11582 | -9509 | -7260 | -3875 | 15512 |
| | C D BN | Jan-Mar | -11347 | -8018 | -5552 | -2995 | -13 | -11347 | -8192 | -5901 | -2778 | -12 | -11345 | -7760 | -6040 | -3072 | -282 |
| | | Apr-Jun | -9637 | -5391 | -3122 | -2199 | -570 | -9393 | -4286 | -2912 | -2075 | -214 | -9205 | -6191 | -4112 | -2841 | -230 |
| | | Jul-Sep | -12039 | -8653 | -6096 | -3659 | -1123 | -11654 | -7432 | -4616 | -2881 | -1076 | -11893 | -8555 | -6396 | -3851 | -1273 |
| | | Oct-Dec | -11213 | -7277 | -5583 | -4229 | 179 | -11265 | -7092 | -4605 | -2616 | 367 | -11204 | -9935 | -8216 | -5248 | -703 |
| QWEST | W AN | Jan-Mar | -6726 | 6087 | 17955 | 31334 | 68870 | -7110 | 4555 | 10594 | 18536 | 59946 | -6823 | 8629 | 21153 | 36483 | 73759 |
| | | Apr-Jun | -5182 | 3313 | 6144 | 15919 | 45875 | -5789 | 1067 | 4086 | 8674 | 40150 | -5029 | 5089 | 9424 | 20059 | 49665 |
| | | Jul-Sep | -6148 | -2035 | -648 | 2092 | 25791 | -6722 | -2503 | -1273 | 78 | 10331 | -5897 | -1030 | 778 | 3347 | 33393 |
| | | Oct-Dec | -11186 | -1079 | 1202 | 4942 | 41666 | -11503 | -1240 | 976 | 3411 | 33556 | -11226 | -1262 | 1757 | 7613 | 61070 |

| Name | Year Types | Month Range | Base | | | | | Study 9.4 Drier, Less Warming | | | | | Study 9.2 Wetter, Less Warming | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max |
| | C D BN | Jan-Mar | -11189 | -2584 | -193 | 1843 | 10641 | -11853 | -2672 | -553 | 1357 | 6399 | -10881 | -2163 | 23 | 2175 | 16540 |
| | | Apr-Jun | -8720 | -889 | 821 | 2554 | 8710 | -8768 | -524 | 941 | 2584 | 8328 | -8288 | -1117 | 684 | 2663 | 8287 |
| | | Jul-Sep | -7551 | -2128 | -693 | 742 | 5690 | -7354 | -1553 | -226 | 1409 | 5417 | -8228 | -1955 | -689 | 934 | 5597 |
| | | Oct-Dec | -11930 | -1649 | 340 | 1987 | 7585 | -9584 | -1274 | 927 | 2675 | 8144 | -12021 | -2584 | -642 | 1320 | 7708 |
| Cross Delta | W AN | Jan-Mar | 4742 | 8666 | 13715 | 16299 | 23607 | 4364 | 7962 | 12565 | 14957 | 21348 | 5383 | 9487 | 14647 | 16990 | 25979 |
| | | Apr-Jun | 3439 | 4401 | 6542 | 9692 | 18352 | 3329 | 4055 | 5987 | 9119 | 16567 | 3394 | 4842 | 6078 | 9864 | 19132 |
| | | Jul-Sep | 5031 | 6672 | 7461 | 8899 | 11620 | 5137 | 6319 | 8016 | 8738 | 10151 | 5180 | 6345 | 6902 | 7533 | 10494 |
| | | Oct-Dec | 2177 | 5450 | 7038 | 8914 | 17435 | 2137 | 5089 | 6313 | 8827 | 15200 | 2186 | 5476 | 7169 | 9696 | 22815 |
| | C D BN | Jan-Mar | 2029 | 3242 | 3997 | 5651 | 10336 | 1878 | 3034 | 3824 | 5065 | 9855 | 2084 | 3354 | 4355 | 6122 | 12845 |
| | | Apr-Jun | 1477 | 2655 | 3585 | 4862 | 9543 | 1550 | 2453 | 3306 | 4919 | 9346 | 1609 | 3037 | 3699 | 5795 | 9520 |
| | | Jul-Sep | 3879 | 4712 | 5556 | 7487 | 9741 | 3781 | 4511 | 5102 | 6167 | 9437 | 3800 | 4569 | 5887 | 7479 | 9590 |
| | | Oct-Dec | 2110 | 3944 | 5043 | 5857 | 9821 | 2012 | 3855 | 4720 | 5596 | 9579 | 2252 | 4530 | 6054 | 6946 | 10220 |

**Table 9-25. DSM2-Hydro tidally filtered daily average flow for water-years 1976 to 1991. Shading indicates negative (landward) flows. Positive flows are towards the ocean.**

| Name | Year Types | Month Range | Base Min | Base 25% | Base 50% | Base 75% | Base Max | Study 9.5 Drier, More Warming Min | 25% | 50% | 75% | Max | Study 9.3 Wetter, More Warming Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head of Old River | W AN | Jan-Mar | 1349 | 3722 | 8034 | 9478 | 16704 | 1347 | 3205 | 5323 | 8800 | 18179 | 1350 | 4929 | 8628 | 11289 | 18545 |
| | | Apr-Jun | 0 | 3685 | 5707 | 8645 | 11251 | 0 | 2143 | 2769 | 6709 | 11621 | 0 | 2325 | 4167 | 8548 | 11885 |
| | | Jul-Sep | 468 | 1922 | 2114 | 3979 | 9682 | 422 | 490 | 1964 | 2528 | 5968 | 420 | 1782 | 2054 | 3010 | 8613 |
| | | Oct-Dec | 105 | 315 | 822 | 1607 | 9549 | 141 | 260 | 701 | 1604 | 9008 | 136 | 315 | 752 | 1668 | 11305 |
| | C D BN | Jan-Mar | 643 | 1025 | 1350 | 1650 | 4568 | 637 | 1025 | 1308 | 1544 | 3469 | 667 | 1091 | 1347 | 1737 | 7757 |
| | | Apr-Jun | 0 | 0 | 624 | 1145 | 4163 | 0 | 0 | 542 | 1044 | 2915 | 0 | 0 | 724 | 1193 | 4024 |
| | | Jul-Sep | 174 | 311 | 380 | 471 | 1279 | 200 | 278 | 337 | 436 | 1161 | 177 | 305 | 377 | 483 | 1486 |
| | | Oct-Dec | 112 | 255 | 408 | 967 | 1612 | 126 | 249 | 375 | 836 | 1531 | 133 | 260 | 397 | 1084 | 1861 |
| Old and Middle River | W AN | Jan-Mar | -10905 | -6299 | -2407 | 4437 | 22137 | -11026 | -7987 | -4333 | 2994 | 24579 | -10333 | -5631 | 423 | 8740 | 25161 |
| | | Apr-Jun | -9196 | -5894 | -4283 | -684 | 12565 | -8344 | -5751 | -4494 | -2181 | 13721 | -8898 | -5991 | -4266 | -1382 | 14545 |
| | | Jul-Sep | -10519 | -9239 | -8256 | -7281 | 3238 | -10821 | -8945 | -8240 | -7196 | -5038 | -10767 | -9188 | -7835 | -7126 | -1814 |
| | | Oct-Dec | -11582 | -9401 | -7559 | -4051 | 6751 | -11583 | -9494 | -5356 | -2711 | 3919 | -11582 | -9729 | -7336 | -4058 | 11929 |
| | C D BN | Jan-Mar | -11347 | -8018 | -5552 | -2995 | -13 | -11346 | -8340 | -5980 | -1987 | 7 | -11345 | -8484 | -6070 | -3836 | -362 |
| | | Apr-Jun | -9637 | -5391 | -3122 | -2199 | -570 | -7854 | -4060 | -2808 | -1908 | -71 | -9547 | -6134 | -4309 | -2703 | -397 |
| | | Jul-Sep | -12039 | -8653 | -6096 | -3659 | -1123 | -10321 | -4984 | -4131 | -3030 | -1443 | -11757 | -8327 | -6421 | -4006 | -1273 |
| | | Oct-Dec | -11213 | -7277 | -5583 | -4229 | 179 | -11125 | -6798 | -4557 | -2514 | 498 | -11223 | -7890 | -6244 | -4498 | 81 |
| QWEST | W AN | Jan-Mar | -6726 | 6087 | 17955 | 31334 | 68870 | -7375 | 5269 | 12254 | 25320 | 73655 | -7116 | 11602 | 20747 | 39692 | 75915 |
| | | Apr-Jun | -5182 | 3313 | 6144 | 15919 | 45875 | -5258 | 1780 | 4948 | 8556 | 47516 | -5541 | 2682 | 5820 | 14400 | 50549 |
| | | Jul-Sep | -6148 | -2035 | -648 | 2092 | 25791 | -6985 | -2032 | -691 | 820 | 8361 | -5387 | -2066 | -585 | 1605 | 17212 |
| | | Oct-Dec | -11186 | -1079 | 1202 | 4942 | 41666 | -11981 | -779 | 1650 | 5088 | 35036 | -11923 | -1219 | 945 | 4945 | 52562 |

| Name | Year Types | Month Range | Base | | | | | Study 9.5 Drier, More Warming | | | | | Study 9.3 Wetter, More Warming | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max | Min | 25% | 50% | 75% | Max |
| | C D BN | Jan-Mar | -11189 | -2584 | -193 | 1843 | 10641 | -11517 | -2804 | -421 | 1638 | 6415 | -10923 | -2487 | -128 | 2033 | 16607 |
| | | Apr-Jun | -8720 | -889 | 821 | 2554 | 8710 | -7582 | -375 | 1079 | 2796 | 8710 | -8646 | -1398 | 470 | 2220 | 8343 |
| | | Jul-Sep | -7551 | -2128 | -693 | 742 | 5690 | -6044 | -1009 | 309 | 1636 | 5367 | -7430 | -2129 | -874 | 813 | 5645 |
| | | Oct-Dec | -11930 | -1649 | 340 | 1987 | 7585 | -9881 | -855 | 1086 | 2735 | 8922 | -11718 | -1944 | 108 | 1700 | 6790 |
| Cross Delta | W AN | Jan-Mar | 4742 | 8666 | 13715 | 16299 | 23607 | 4101 | 8057 | 11046 | 15632 | 21347 | 5100 | 10890 | 15266 | 17433 | 29178 |
| | | Apr-Jun | 3439 | 4401 | 6542 | 9692 | 18352 | 3085 | 3981 | 6073 | 7943 | 17530 | 3394 | 4151 | 7532 | 9286 | 18831 |
| | | Jul-Sep | 5031 | 6672 | 7461 | 8899 | 11620 | 5087 | 6202 | 7302 | 8598 | 11273 | 4848 | 6278 | 7319 | 8855 | 10449 |
| | | Oct-Dec | 2177 | 5450 | 7038 | 8914 | 17435 | 2171 | 5010 | 6525 | 8228 | 15059 | 2176 | 5906 | 6827 | 8945 | 20283 |
| | C D BN | Jan-Mar | 2029 | 3242 | 3997 | 5651 | 10336 | 1777 | 2982 | 3785 | 4965 | 9509 | 2191 | 3487 | 4548 | 6282 | 12701 |
| | | Apr-Jun | 1477 | 2655 | 3585 | 4862 | 9543 | 1580 | 2463 | 3175 | 5076 | 8646 | 1528 | 2975 | 3616 | 5876 | 9460 |
| | | Jul-Sep | 3879 | 4712 | 5556 | 7487 | 9741 | 3867 | 4444 | 4920 | 5394 | 8515 | 3858 | 4593 | 5399 | 7304 | 9737 |
| | | Oct-Dec | 2110 | 3944 | 5043 | 5857 | 9821 | 2118 | 3876 | 4650 | 5574 | 9789 | 2123 | 4297 | 5475 | 5952 | 9364 |

**Table 9-26. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.**

| Name | Year Types | Month Range | Base Min | Base 25% | Base 50% | Base 75% | Base Max | Study 9.4 Drier, Less Warming Min | 25% | 50% | 75% | Max | Study 9.2 Wetter, Less Warming Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head of Old River | W AN | Jan-Mar | 0.76 | 1.62 | 2.48 | 2.54 | 3.17 | 0.76 | 1.33 | 1.80 | 2.31 | 2.96 | 0.79 | 2.04 | 2.52 | 2.59 | 3.28 |
| | | Apr-Jun | 0.00 | 1.63 | 2.10 | 2.53 | 2.67 | 0.00 | 0.88 | 1.20 | 2.16 | 2.62 | 0.00 | 1.96 | 2.42 | 2.57 | 2.86 |
| | | Jul-Sep | 0.27 | 0.99 | 1.08 | 1.67 | 2.60 | 0.22 | 0.29 | 0.97 | 1.16 | 2.04 | 0.27 | 1.10 | 1.43 | 1.92 | 2.78 |
| | | Oct-Dec | 0.06 | 0.19 | 0.46 | 0.85 | 2.60 | 0.09 | 0.16 | 0.29 | 0.83 | 2.57 | 0.08 | 0.20 | 0.59 | 2.04 | 2.87 |
| | C D BN | Jan-Mar | 0.38 | 0.56 | 0.74 | 0.88 | 1.83 | 0.39 | 0.56 | 0.72 | 0.82 | 1.45 | 0.38 | 0.59 | 0.74 | 0.95 | 2.23 |
| | | Apr-Jun | 0.00 | 0.00 | 0.36 | 0.65 | 1.75 | 0.00 | 0.00 | 0.35 | 0.60 | 1.13 | 0.00 | 0.00 | 0.48 | 0.68 | 2.07 |
| | | Jul-Sep | 0.10 | 0.18 | 0.22 | 0.28 | 0.74 | 0.10 | 0.17 | 0.21 | 0.26 | 0.69 | 0.10 | 0.18 | 0.23 | 0.30 | 1.02 |
| | | Oct-Dec | 0.07 | 0.15 | 0.24 | 0.53 | 0.87 | 0.07 | 0.15 | 0.22 | 0.49 | 0.84 | 0.07 | 0.16 | 0.26 | 0.58 | 1.14 |
| Middle River at Middle River | W AN | Jan-Mar | -0.28 | -0.15 | -0.06 | 0.11 | 0.51 | -0.28 | -0.20 | -0.16 | -0.03 | 0.42 | -0.27 | -0.14 | 0.00 | 0.20 | 0.56 |
| | | Apr-Jun | -0.23 | -0.15 | -0.10 | -0.01 | 0.31 | -0.23 | -0.16 | -0.12 | -0.10 | 0.25 | -0.24 | -0.13 | -0.08 | 0.04 | 0.35 |
| | | Jul-Sep | -0.27 | -0.23 | -0.21 | -0.18 | 0.09 | -0.30 | -0.25 | -0.22 | -0.20 | -0.13 | -0.26 | -0.22 | -0.20 | -0.16 | 0.25 |
| | | Oct-Dec | -0.29 | -0.24 | -0.19 | -0.10 | 0.17 | -0.29 | -0.24 | -0.15 | -0.11 | 0.07 | -0.29 | -0.24 | -0.19 | -0.10 | 0.38 |
| | C D BN | Jan-Mar | -0.29 | -0.21 | -0.14 | -0.07 | 0.00 | -0.29 | -0.21 | -0.15 | -0.07 | 0.00 | -0.29 | -0.20 | -0.15 | -0.08 | 0.00 |
| | | Apr-Jun | -0.25 | -0.14 | -0.08 | -0.05 | -0.01 | -0.24 | -0.11 | -0.07 | -0.05 | 0.00 | -0.24 | -0.16 | -0.10 | -0.07 | 0.00 |
| | | Jul-Sep | -0.31 | -0.22 | -0.15 | -0.09 | -0.03 | -0.30 | -0.19 | -0.12 | -0.07 | -0.02 | -0.31 | -0.22 | -0.16 | -0.10 | -0.03 |
| | | Oct-Dec | -0.29 | -0.19 | -0.14 | -0.11 | 0.01 | -0.30 | -0.18 | -0.12 | -0.06 | 0.01 | -0.29 | -0.26 | -0.21 | -0.13 | -0.01 |
| San Joaquin River at Blind Point | W AN | Jan-Mar | -0.01 | 0.14 | 0.25 | 0.40 | 0.77 | -0.01 | 0.13 | 0.19 | 0.28 | 0.69 | 0.00 | 0.17 | 0.28 | 0.44 | 0.83 |
| | | Apr-Jun | 0.02 | 0.10 | 0.13 | 0.22 | 0.52 | 0.02 | 0.08 | 0.11 | 0.15 | 0.47 | 0.02 | 0.12 | 0.16 | 0.26 | 0.56 |
| | | Jul-Sep | 0.00 | 0.05 | 0.06 | 0.09 | 0.30 | 0.00 | 0.04 | 0.06 | 0.07 | 0.15 | 0.00 | 0.06 | 0.08 | 0.10 | 0.37 |
| | | Oct-Dec | -0.04 | 0.06 | 0.08 | 0.12 | 0.50 | -0.03 | 0.05 | 0.08 | 0.10 | 0.42 | -0.04 | 0.06 | 0.08 | 0.18 | 0.72 |

| Name | Year Types | Month Range | Base Min | Base 25% | Base 50% | Base 75% | Base Max | Study 9.4 Drier, Less Warming Min | Study 9.4 Drier, Less Warming 25% | Study 9.4 Drier, Less Warming 50% | Study 9.4 Drier, Less Warming 75% | Study 9.4 Drier, Less Warming Max | Study 9.2 Wetter, Less Warming Min | Study 9.2 Wetter, Less Warming 25% | Study 9.2 Wetter, Less Warming 50% | Study 9.2 Wetter, Less Warming 75% | Study 9.2 Wetter, Less Warming Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C D BN | Jan-Mar | -0.04 | 0.05 | 0.07 | 0.09 | 0.19 | -0.06 | 0.04 | 0.07 | 0.09 | 0.14 | -0.03 | 0.05 | 0.07 | 0.10 | 0.23 |
| | | Apr-Jun | 0.00 | 0.06 | 0.08 | 0.09 | 0.17 | 0.00 | 0.06 | 0.08 | 0.09 | 0.16 | 0.00 | 0.06 | 0.08 | 0.10 | 0.16 |
| | | Jul-Sep | -0.01 | 0.05 | 0.06 | 0.08 | 0.13 | -0.01 | 0.05 | 0.06 | 0.08 | 0.13 | -0.02 | 0.05 | 0.06 | 0.08 | 0.13 |
| | | Oct-Dec | -0.06 | 0.05 | 0.07 | 0.09 | 0.14 | -0.03 | 0.06 | 0.07 | 0.09 | 0.15 | -0.06 | 0.05 | 0.06 | 0.08 | 0.15 |
| Georgiana Slough | W AN | Jan-Mar | 0.96 | 1.83 | 2.36 | 2.51 | 2.64 | 0.90 | 1.80 | 2.25 | 2.51 | 2.64 | 1.26 | 1.91 | 2.44 | 2.52 | 2.62 |
| | | Apr-Jun | 0.65 | 0.90 | 1.00 | 1.42 | 2.60 | 0.78 | 0.92 | 1.06 | 1.37 | 2.60 | 0.64 | 0.92 | 1.07 | 1.66 | 2.59 |
| | | Jul-Sep | 0.58 | 0.76 | 0.82 | 0.93 | 1.32 | 0.63 | 0.75 | 0.86 | 0.97 | 1.30 | 0.59 | 0.75 | 0.80 | 0.94 | 1.72 |
| | | Oct-Dec | 0.50 | 0.75 | 0.91 | 1.55 | 2.64 | 0.50 | 0.72 | 0.85 | 1.32 | 2.62 | 0.50 | 0.78 | 1.07 | 1.82 | 2.68 |
| | C D BN | Jan-Mar | 0.49 | 0.80 | 0.98 | 1.27 | 2.01 | 0.46 | 0.80 | 0.95 | 1.22 | 1.81 | 0.50 | 0.82 | 1.03 | 1.43 | 2.66 |
| | | Apr-Jun | 0.52 | 0.71 | 0.87 | 1.00 | 1.62 | 0.54 | 0.72 | 0.84 | 0.91 | 1.56 | 0.56 | 0.81 | 0.92 | 1.03 | 1.90 |
| | | Jul-Sep | 0.50 | 0.60 | 0.68 | 0.87 | 1.08 | 0.50 | 0.58 | 0.64 | 0.75 | 1.05 | 0.50 | 0.59 | 0.70 | 0.86 | 1.09 |
| | | Oct-Dec | 0.50 | 0.63 | 0.70 | 0.83 | 1.39 | 0.48 | 0.60 | 0.68 | 0.82 | 1.25 | 0.54 | 0.71 | 0.79 | 0.98 | 1.71 |

**Table 9-27. DSM2-Hydro tidally filtered daily average velocity for water-years 1976 to 1991. Shading indicates negative (landward) velocities. Positive velocities are towards the ocean.**

| Name | Year Types | Month Range | Base Min | Base 25% | Base 50% | Base 75% | Base Max | Study 9.5 Drier, More Warming Min | 25% | 50% | 75% | Max | Study 9.5 Wetter, More Warming Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Head of Old River | W AN | Jan-Mar | 0.76 | 1.62 | 2.48 | 2.54 | 3.17 | 0.76 | 1.44 | 1.99 | 2.53 | 3.30 | 0.76 | 1.90 | 2.54 | 2.67 | 3.33 |
| | | Apr-Jun | 0.00 | 1.63 | 2.10 | 2.53 | 2.67 | 0.00 | 1.08 | 1.34 | 2.28 | 2.70 | 0.00 | 1.19 | 1.77 | 2.54 | 2.71 |
| | | Jul-Sep | 0.27 | 0.99 | 1.08 | 1.67 | 2.60 | 0.24 | 0.28 | 1.02 | 1.25 | 2.12 | 0.24 | 0.93 | 1.04 | 1.42 | 2.56 |
| | | Oct-Dec | 0.06 | 0.19 | 0.46 | 0.85 | 2.60 | 0.08 | 0.15 | 0.40 | 0.85 | 2.59 | 0.08 | 0.19 | 0.43 | 0.89 | 2.69 |
| | C D BN | Jan-Mar | 0.38 | 0.56 | 0.74 | 0.88 | 1.83 | 0.36 | 0.55 | 0.73 | 0.83 | 1.52 | 0.39 | 0.61 | 0.73 | 0.92 | 2.48 |
| | | Apr-Jun | 0.00 | 0.00 | 0.36 | 0.65 | 1.75 | 0.00 | 0.00 | 0.33 | 0.59 | 1.36 | 0.00 | 0.00 | 0.42 | 0.67 | 1.69 |
| | | Jul-Sep | 0.10 | 0.18 | 0.22 | 0.28 | 0.74 | 0.12 | 0.16 | 0.20 | 0.25 | 0.68 | 0.10 | 0.18 | 0.22 | 0.29 | 0.87 |
| | | Oct-Dec | 0.07 | 0.15 | 0.24 | 0.53 | 0.87 | 0.07 | 0.15 | 0.23 | 0.45 | 0.84 | 0.08 | 0.15 | 0.24 | 0.59 | 0.99 |
| Middle River at Middle River | W AN | Jan-Mar | -0.28 | -0.15 | -0.06 | 0.11 | 0.51 | -0.28 | -0.20 | -0.11 | 0.08 | 0.57 | -0.27 | -0.14 | 0.01 | 0.22 | 0.58 |
| | | Apr-Jun | -0.23 | -0.15 | -0.10 | -0.01 | 0.31 | -0.21 | -0.14 | -0.11 | -0.05 | 0.33 | -0.22 | -0.15 | -0.10 | -0.03 | 0.35 |
| | | Jul-Sep | -0.27 | -0.23 | -0.21 | -0.18 | 0.09 | -0.27 | -0.22 | -0.21 | -0.18 | -0.12 | -0.27 | -0.23 | -0.20 | -0.18 | -0.04 |
| | | Oct-Dec | -0.29 | -0.24 | -0.19 | -0.10 | 0.17 | -0.29 | -0.24 | -0.13 | -0.07 | 0.10 | -0.29 | -0.25 | -0.19 | -0.10 | 0.29 |
| | C D BN | Jan-Mar | -0.29 | -0.21 | -0.14 | -0.07 | 0.00 | -0.29 | -0.22 | -0.15 | -0.05 | 0.00 | -0.29 | -0.22 | -0.15 | -0.10 | -0.01 |
| | | Apr-Jun | -0.25 | -0.14 | -0.08 | -0.05 | -0.01 | -0.20 | -0.10 | -0.07 | -0.05 | 0.00 | -0.25 | -0.15 | -0.11 | -0.07 | -0.01 |
| | | Jul-Sep | -0.31 | -0.22 | -0.15 | -0.09 | -0.03 | -0.26 | -0.12 | -0.10 | -0.07 | -0.03 | -0.30 | -0.21 | -0.16 | -0.10 | -0.03 |
| | | Oct-Dec | -0.29 | -0.19 | -0.14 | -0.11 | 0.01 | -0.28 | -0.17 | -0.11 | -0.06 | 0.02 | -0.29 | -0.20 | -0.16 | -0.11 | 0.00 |
| San Joaquin River at Blind Point | W AN | Jan-Mar | -0.01 | 0.14 | 0.25 | 0.40 | 0.77 | -0.02 | 0.13 | 0.21 | 0.32 | 0.82 | 0.00 | 0.20 | 0.29 | 0.48 | 0.87 |
| | | Apr-Jun | 0.02 | 0.10 | 0.13 | 0.22 | 0.52 | 0.02 | 0.09 | 0.12 | 0.15 | 0.54 | 0.01 | 0.10 | 0.12 | 0.21 | 0.57 |
| | | Jul-Sep | 0.00 | 0.05 | 0.06 | 0.09 | 0.30 | 0.00 | 0.04 | 0.06 | 0.08 | 0.16 | 0.01 | 0.05 | 0.07 | 0.08 | 0.22 |
| | | Oct-Dec | -0.04 | 0.06 | 0.08 | 0.12 | 0.50 | -0.03 | 0.06 | 0.08 | 0.12 | 0.43 | -0.04 | 0.05 | 0.08 | 0.15 | 0.64 |

| Name | Year Types | Month Range | Base Min | Base 25% | Base 50% | Base 75% | Base Max | Study 9.5 Drier, More Warming Min | 25% | 50% | 75% | Max | Study 9.5 Wetter, More Warming Min | 25% | 50% | 75% | Max |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | C D BN | Jan-Mar | -0.04 | 0.05 | 0.07 | 0.09 | 0.19 | -0.05 | 0.04 | 0.07 | 0.09 | 0.15 | -0.04 | 0.05 | 0.07 | 0.10 | 0.24 |
| | | Apr-Jun | 0.00 | 0.06 | 0.08 | 0.09 | 0.17 | 0.01 | 0.07 | 0.08 | 0.10 | 0.17 | 0.00 | 0.06 | 0.08 | 0.09 | 0.16 |
| | | Jul-Sep | -0.01 | 0.05 | 0.06 | 0.08 | 0.13 | 0.00 | 0.05 | 0.07 | 0.08 | 0.12 | -0.01 | 0.04 | 0.06 | 0.08 | 0.13 |
| | | Oct-Dec | -0.06 | 0.05 | 0.07 | 0.09 | 0.14 | -0.02 | 0.06 | 0.08 | 0.09 | 0.15 | -0.05 | 0.05 | 0.07 | 0.08 | 0.14 |
| Georgiana Slough | W AN | Jan-Mar | 0.96 | 1.83 | 2.36 | 2.51 | 2.64 | 0.90 | 1.70 | 2.22 | 2.48 | 2.64 | 1.19 | 2.08 | 2.48 | 2.55 | 2.67 |
| | | Apr-Jun | 0.65 | 0.90 | 1.00 | 1.42 | 2.60 | 0.79 | 0.90 | 0.96 | 1.26 | 2.59 | 0.74 | 0.88 | 1.00 | 1.59 | 2.60 |
| | | Jul-Sep | 0.58 | 0.76 | 0.82 | 0.93 | 1.32 | 0.57 | 0.71 | 0.80 | 0.93 | 1.05 | 0.57 | 0.74 | 0.82 | 0.96 | 1.33 |
| | | Oct-Dec | 0.50 | 0.75 | 0.91 | 1.55 | 2.64 | 0.50 | 0.69 | 0.86 | 1.51 | 2.60 | 0.50 | 0.74 | 0.87 | 1.59 | 2.67 |
| | C D BN | Jan-Mar | 0.49 | 0.80 | 0.98 | 1.27 | 2.01 | 0.44 | 0.80 | 0.95 | 1.19 | 1.96 | 0.54 | 0.84 | 1.06 | 1.38 | 2.65 |
| | | Apr-Jun | 0.52 | 0.71 | 0.87 | 1.00 | 1.62 | 0.55 | 0.72 | 0.82 | 0.91 | 1.63 | 0.54 | 0.80 | 0.91 | 1.01 | 1.92 |
| | | Jul-Sep | 0.50 | 0.60 | 0.68 | 0.87 | 1.08 | 0.50 | 0.58 | 0.62 | 0.67 | 0.99 | 0.50 | 0.59 | 0.67 | 0.85 | 1.09 |
| | | Oct-Dec | 0.50 | 0.63 | 0.70 | 0.83 | 1.39 | 0.50 | 0.59 | 0.68 | 0.79 | 1.24 | 0.51 | 0.66 | 0.72 | 0.86 | 1.45 |

# Model Limitations

## General Modeling Limitations

- The models are good representations of the laws of conservation, but nonetheless include simplifications or estimations of certain processes. For example, temporal and spatial resolution (i.e. monthly time step) is aggregated to simulate a longer period of time (82 years) rather than a short period of time at a shorter time step for similar levels of effort and computation. Therefore, model uncertainty is inherent in the results.
- Input model data are imperfect. Model parameter error can accumulate such as in this example: river flow data may be plus or minus 5-10%; temperature data are subject to instrument resolution and deployment technique and location; geometry data can have considerable effects on temperature due to approximations in surface area depth/cross sectional area; meteorological data is often not local and model domains are sufficiently large that meteorological data can vary notably from one location to another. All input parameters introduce some level of uncertainty.
- The numerical solution to the governing equations included in the models can also introduce error.
- The OCAP BA models are designed to compare and contrast the effect of current and assumed future operational conditions. The models are not predictive; they are not intended to forecast the future (i.e. no forecast data or information are used).

## CalSim-II

- The main limitation of CalSim-II model is the time step. Mean monthly flows do not define daily variations that could occur in the rivers from dynamic conditions. However, monthly results are still useful for general comparison of scenarios.
- CalSim-II cannot completely capture the policy-oriented operation and coordination the 800,000 af of dedicated CVPIA 3406 (b)(2) water and the CALFED EWA (regular WOMT, B2IT, and EWAT agencies meetings). The CalSim-II model is set up to run each step of the 3406(b)(2) on an annual basis and because the WQCP and Endangered Species Act (ESA) actions are set on a priority basis that can trigger actions using 3406(b)(2) water or EWA assets, the model will exceed at times the dedicated amount of 3406(b)(2) water that is available. Moreover, the 3406(b)(2) and EWA operations in CalSim-II are just one set of plausible actions aggregated to a monthly representation and modulated by year type. However, they do not fully account for the potential weighing of assets versus cost or the dynamic influence of biological factors on the timing of actions. The monthly time-step of CalSim-II also requires day-weighted monthly averaging to simulate minimum in-stream flow levels, VAMP actions, export reductions, and X2-based operations that occur within a month. This averaging can either under- or over-estimate the amount of water needed for these actions.
- CalSim-II uses simplified rules and guidelines to simulate SWP and CVP delivery allocation. Therefore the results may not reflect how the SWP and CVP would actually

operate under extreme hydrologic conditions (very wet or very dry). The allocation process in the modeling is weighted heavily on storage conditions and inflow to the reservoirs that are fed into the curves mentioned previously in the Hydrologic Modeling Methods section and does not project inflow from contributing streams when making an allocation. This curve-based approach does cause some variation in results between studies that would be closer with a more robust approach to the allocation process.

- There are a number of rule-curves embedded in CalSim-II and it is these rule-curves that drive the water balance between the reservoirs, determine how much water to carryover until the following year, and allocate the amount of water for delivery. It is difficult to produce a rule-curve in CalSim-II that produces good realistic results in the full spectrum of year types. CalSim-II rule-curves often produce sub-optimal results with respect to Project operations in the driest years. Some results imply that the projects would operate the reservoirs to unrealistically low levels in these dry year outliers. In reality the Projects could and would operate to higher reservoir elevations in these extremely dry years. An examination of modeling output suggests that this would be possible by reducing project releases and exports to minimums rather than the unrealistic rates often assumed by the models in these years. .
- Transfer capacity is calculated by looking at the amount of flow available under the EI ratio and the amount of available capacity at the exports. This gives a very general view of the amount of water that could be transferred. However, to be more complete in the analysis transfers should also take the current salinity profile into account as well. Generally during a transfer, a unit of water will be released somewhere in the system and increase the inflow to the Delta. As that unit of water enters the Delta the exports will increase and a portion of that unit gets exported and the remaining portion goes to support the Delta standards. The portion of the unit that goes to support Delta standards is called "carriage water". Transfers for OCAP were post-processed and incorporating constraints based on the salinity profile to determine carriage water was not done. So the estimated transfers will be on the high side.

## DSM2

- DSM2 is a one-dimensional model. As such, it is only capable of simulating the flow in the longitudinal direction. Any detailed description such as vertical/lateral mixing, changing of the flow patterns due to bends or unusual expansion or contraction of the rivers are not simulated.
- DSM2 simulates reservoirs as constantly mixed reactors and each is essentially only a container that holds water. Any mixing of water in there occurs instantly. Reservoirs are used for five locations in the model: Clifton Court Forebay, Franks Tract, Little Franks Tract, Mildred Island, and Discovery Bay.
- DSM2 uses CalSim-II results for Delta inflows. These inflows are monthly average flows so the model at times may see very steep transitions in flow from month to month. Because of these transitions the hydrodynamic conditions may take a few simulation days to adjust to the new inflows. Given this transition period the results from DSM2-Hydro should not be used during the transitions between months. Therefore all of the PTM

simulations were begun 4 days after these transitions, and particle fate collected 3 to 6 days before these transitions. However the hydrodynamic results do include periods up to the transition.

- The Delta Island Consumptive Use (DICU) simulates the agriculture diversions and return flows. The DICU for the model is consistent with the total monthly volume in CalSim-II. Though the DICU for DSM2 is more spatially represented it still assumes a constant monthly flow rate.
- The DSM2-PTM has the ability to use in channel dispersion but in order to run the simulations as quickly as possible only advection was used. This means that rather than using the pseudo three-dimensional velocity profiles to determine the velocity imposed on a particle, a one-dimensional velocity straight from DSM2-Hydro was used. This means that the particles only disperse when moving from channel to channel.

## Temperature Models

- The monthly temperature models are unable to accurately simulate certain aspects of the actual operations strategies used when attempting to meet temperature objectives. This is especially true on the upper Sacramento River, and the American River where adjustments can be made for temperature control. The SRWQM and the Feather River models (with shorter time-steps) were applied to compensate for the deficiencies of the monthly model. Elsewhere, the monthly temperature model results may not capture the full range of daily temperature variability. In addition, imperfections in simulated monthly results from CalSim-II reservoir operations can influence cold water pool storage and downstream temperature results. Historical temperature observations are also presented in Appendix U where sub-monthly temperature model results are unavailable.
- There is also uncertainty regarding performance characteristics of the Shasta TCD. Because of the hydraulic characteristics of the TCD, including leakage, overflow, and performance of the side intakes, the typical model releases are cooler than can be achieved in real-time operations; therefore, a more conservative approach is taken in real-time operations that is not fully represented by the models.

## Salmon Mortality and Life Cycle Models

- The salmon mortality models (Reclamation salmon mortality model and SALMOD) are limited to temperature effects on early life stages of Chinook salmon. They do not evaluate potential direct or indirect temperature impacts on later life stages, such as emergent fry, smolts, juvenile out-migrants, or adults. Also, they do not consider other factors that may affect salmon mortality, such as in-stream flows, gravel sedimentation, diversion structures, predation, ocean harvest, etc.
- Because the salmon mortality model operates on a daily time step, a disaggregation procedure is required to use the monthly temperature model output. The salmon model computes daily temperatures by using linear interpolation between the monthly temperatures, which are assumed to occur on the 15$^{th}$ day of the month.

- The application of the IOS model is used to address salmon life cycle stages which are ecological, not evolutionary.
- Salmon models do not address mortality, life cycle, or temperature effects on green sturgeon, or delta smelt.