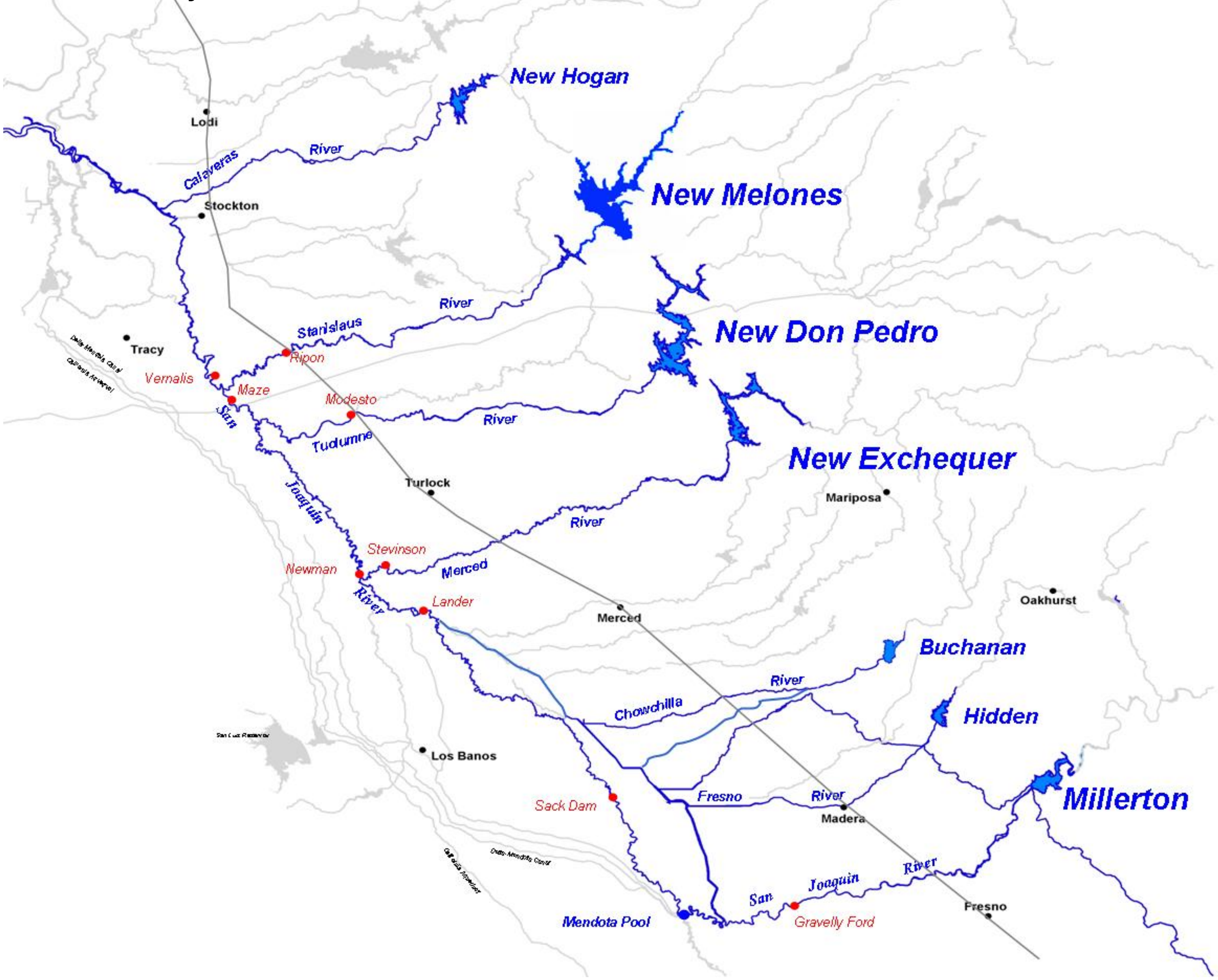
CalSim-II San Joaquin River Peer Review Response

In Reply to the Peer Review of the CalSim-II San Joaquin River Model, January 2006



U.S. Department of the Interior
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1.0 Executive Summary

The CalSim-II San Joaquin River Peer Review Response Report captures Reclamation and the Department of Water Resources' (DWR) reply to specific comments and criticisms, short-term and long-term recommendations, sensitivity uncertainty testing, and details of documentation plans and water quality evaluation.

In 2001 Reclamation began a four-year development effort to improve the CalSim-II San Joaquin River Eastside model representation. The objectives were: (1) to improve surface water hydrology and operations representation in the area east of the San Joaquin River (Eastside), (2) improve Eastside demands representation, (3) improve the San Joaquin River (SJR) main-stem formulation for water quality simulation, and (4) expand model documentation. This effort reached a milestone when preliminary modeling and documentation objectives were completed in early 2005. These work products were submitted for external peer review initiated in August 2005 (SJR Review).

The SJR Review, sponsored by the CALFED Science Program and the California Water and Environmental Modeling Forum (CWEMF), was tasked to evaluate the accuracy and improvements of the model's hydrology, operations, demands, and water quality. The Review Panel's short-term recommendations included: improving model documentation, conducting testing and error analysis studies, and examining and re-calibrating the water quality simulation. Long-term recommendations included: implementing a CalSim development plan, addressing model utility (absolute and comparative model use), establishing protocols for testing and documentation, improving the ground water representation, implementing land-use-based demands on the area west (Westside) of the San Joaquin River, and acquiring data to further refine model inputs as data becomes available.

Upon receiving the SJR Review report in early 2006, Reclamation acted on a number of the Review Panel suggestions. Reclamation initiated documentation improvements (as recommended by the panel) and expects completion of a revised Draft CalSim-II San Joaquin River Basin model documentation package in February 2007. Reclamation also initiated ground water and land-use-based demand development in the San Joaquin River Basin. In response to the panel's request for error analysis information, Reclamation conducted parameter sensitivity and uncertainty analyses that are presented in this report. Results from those analyses are also used in a review of the water quality module.

A CalSim-II San Joaquin sensitivity analysis demonstrated the level of output response to input variations and provided a preliminary guideline for objective prioritization of areas for model refinement. Some areas identified for potential improvement include:

- refined demand projections allowing for better carryover storage simulation
- refined accretion estimations allowing for better in-stream flow simulation
- refined flow-EC regressions controlling water quality module calibration at Maze and Newman allowing for better SJR salinity simulation

Additional details and discussions of sensitivity analyses can be found in Appendix B.

Uncertainty analyses focused on how both joint and random input changes influence output uncertainty for a variety of variable types (storage, deliveries, river flows, river salinities) represented by various performance metrics (e.g., 1922-2003 monthly means, SJR 60-20-20 Water Year Types monthly means, etc). The uncertainty analyses targets a long-term bias by using a scaling factor for variable inputs. Fundamental to this analysis is the assumption that all input variables are independent. The range of the scaling factor is further assumed to be uniformly distributed within the input variable limits of variation, resulting in a broader, more conservative estimate of the output's uncertainty distributions.

Results show that storage and salinity simulation have greater uncertainty during dry periods, and river flow simulation have more uncertainty during wet periods. However, results only show the uncertainty relative to the base model simulation. Describing uncertainties associated with potential planning alternatives would require further study. Additional uncertainty information is located in Appendix B. Further uncertainty analyses are also being investigated by the DWR and UC Davis for future applications.

The water quality model evaluation (Appendix C) led to findings that support Reclamation's confidence in the current method and calibration of the flow-salinity relationships. Significant findings of the examination include:

- Water quality releases from New Melones Reservoir are most sensitive to the Maze water quality regressions and delivery demands in the basin.
- Low flows within the water quality calibration set are characteristic of the lowest flows over the simulation period (1922 to 2003).
- Based on the assumptions inherent in the uncertainty analysis, results can be used to define a range of total water quality release from New Melones.

Further information and discussion of the water quality evaluation is located in Appendix C. Water quality model parameters will be revisited and updated frequently as additional water quality and flow data become available.

2.0 Introduction

The San Joaquin River CalSim-II model is a portion of a more comprehensive model jointly developed and maintained by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) that includes the Sacramento Valley, Sacramento-San Joaquin Delta, and the Delta-Mendota Canal and California Aqueduct service areas south of the Delta. The computer model simulates the management of the water resources of the State Water Project (SWP) and the Central Valley Project (CVP) for planning studies. The CalSim-II model, which includes the revised version of the San Joaquin River, is part of an ongoing model development and documentation effort by both DWR and Reclamation. The revised San Joaquin River representation in the CalSim-II model was an effort led by Reclamation, with some support and a thorough review by DWR.

Many agencies, interest groups, and individuals in the water modeling community have expressed interest in the revised San Joaquin River CalSim-II model. This interest spurred the second review of the CalSim-II model focused specifically on the San Joaquin River. The San Joaquin River CalSim-II model review was commissioned by the CALFED Science Program and the CWEMF. On August 4, 2005, Reclamation initiated this review with a one-day public workshop, followed by Review Panel presentations in November 2005 and January 2006.

The two primary objectives of the Review Panel were to judge model improvements over the previous representation and to comment on the accuracy of the model. The Panel was directed to scrutinize the areas east of the San Joaquin River (Eastside), Eastside hydrology and operations, Eastside water demands and San Joaquin River flow and salinity. The Review Panel's findings are documented in the final report, "*Review Panel Report: San Joaquin River Valley CalSim II Model Review*" (Ford et al., 2006) herein referred to as the SJR Review.

This report is in response to the San Joaquin River CalSim-II SJR Review Report. It addresses both short-term and long-term recommendations by the Review Panel and includes responses to selected comments, model sensitivity and uncertainty analyses, and an evaluation of the water quality representation. Reclamation is also developing a revised model documentation package available in February 2007. In addition, this report outlines a development plan for future refinements. The CalSim-II San Joaquin River model and results provide the most up-to-date information available, but are also considered draft and subject to change with anticipated revisions described later in this report.

3.0 Goals of CalSim-II Development

DWR and Reclamation strive to maintain CalSim-II as the simulation model of the SWP and CVP that best represents the two projects for planning and management studies.

A joint development philosophy has been reaffirmed by DWR and Reclamation as a result of the first CalSim-II peer review in November of 2003. Both agencies identified the following six CalSim modeling goals (DWR and Reclamation, 2004):

1. Establish credibility and trust by performing sensitivity and uncertainty testing, documentation and training.

2. Enhance the simulation of the Sacramento and San Joaquin hydrology by re-defining the water budget areas and refining or implementing ground water representations.

3. Develop software version control, data control, error checking, provide optimization improvements and graphical system representation.

4. Enhance CalSim with module packages, such as allocation logic or water quality.

5. Develop software modularity, improve runtime and the capability to link to more complex models.

6. Apply CalSim for demand management and supply augmentation, such as conjunctive use.

Several of these goals directly relate to the development efforts made by the CalSim-II San Joaquin River Team. Reclamation is appreciative of the cooperation afforded by irrigation, water districts and local entities in the San Joaquin River Basin who shared data and information. These efforts support the credibility of the model. Other significant advances are the completion of the first round of the San Joaquin uncertainty and sensitivity analyses and improved documentation. Additional CalSim-II model improvements and support enhancements are scheduled for the future.

Reclamation and DWR plan to continue the priority and philosophy listed above to steer CalSim-II development. This report not only addresses the concerns and comments of the Review Panel to support the utility of the current version of the CalSim-II San Joaquin River Basin model, but also identifies planned model improvements. This will be accomplished through model sensitivity and uncertainty testing, and revised documentation and model evaluation described in the remainder of this report. Appendix D summarizes comments made by the Review Panel.

4.0 Recent Modifications to the CalSim-II San Joaquin River Model

Since the first public distribution of the CalSim-II San Joaquin River model in August of 2004, several modifications have been made. Hydrology and water quality above the Newman node in the CalSim-II model was disaggregated to enhance the detail and flexibility of the water quality model. These modifications directly address criticisms made by the Review Panel and have improved the salinity comparisons between the historical and simulated results (see Appendix C). In addition, an accretion on the lower Stanislaus River was reviewed and modified, decreasing the contribution by approximately 23 thousand-acre-feet (TAF) per year on average from 1921-1940. A CalSim-II module isolating the San Joaquin River was developed to expedite model testing. Modifications and model details are described in Appendix B.

5.0 Response to Specific Issues

The following responses from Reclamation and DWR address specific comments or criticisms from the SJR Review Report. Responses are categorized by subtopics found in the SJR Review Report under the following main headings: *Eastside Hydrology and Operations*, *Eastside Water Demands* and *San Joaquin River Salinity*. A guide of significant comment categories and responses is listed in Appendix D. Part of the sensitivity analysis is provided (where applicable) in the responses below; this information is preliminary and may change when additional model enhancements are incorporated.

Both sensitivity and uncertainty test evaluation assumptions and CalSim-II model assumptions should be taken into consideration when analyzing the results of either test. Additional sensitivity information and details of the uncertainty test are left for discussion in Appendix B. Unless otherwise noted, the data, simulation range and annual average evaluations are from water year 1922 through 2003.

5.1 Data

Quality data are essential for a meaningful simulation of the CalSim-II San Joaquin River model. Present CalSim-II models use historical hydrology, diversions, return flows, ground water pumping, water quality, and other data. Plans for future models include the use of more recent data sets.

5.1.1 Response to Review Panel Concerns

- The Review Panel expressed a concern shared by Reclamation and DWR for securing and maintaining comprehensive data sets for CalSim modeling. Expanding or enhancing existing data would assist efforts described in the SJR Peer Review such as model calibration, operations, ground water representation, and water quality modeling. Reclamation's response to the long-term recommendations plan calls for an assessment of CalSim data needs. The results from the sensitivity analysis will help guide this effort. Section 7.1 discusses additional plans for data assessment and Appendix B describes specific directions for data improvement.

5.2 Land Use Data

The application of land-use based demands is one of several significant improvements to the San Joaquin River CalSim-II representation. The land use data are created by DWR's Division of Planning and Local Assistance (DPLA) and represents the San Joaquin River year 2005 level of development. The CalSim-II San Joaquin River model originally used historical land use data from 1994 to 1998, but was later modified to the 2005 level of development to be consistent with other CalSim-II models.

5.2.1 Response to Review Panel Concerns

- The following responds to a series of questions regarding the Consumptive Use (CU) model (p.32 and p.33) from the SJR Review. DWR's CU model currently processes only a limited number of crop types (improvement of this model is discussed in the Consumptive Use Model section below). DPLA data are re-classified to coincide with one of the thirteen DWR CU model land use categories. Aggregated categories will affect only the percent distribution of the class to which they were assigned, not the area of total land use in the water management area. Also, some land use categories such as "idle" and "not-surveyed" are classified as "non-consumptive." These areas are relatively small in comparison to the remaining unrelated categories of land use and can be rectified with a more detailed model.

- The presumption (p. 35 of the SJR Review) that an existing land use data set can be used for a future application is incorrect. The existing land use data set is designed to be used for representing the year 2005 or current level of development in the San Joaquin. DWR and Reclamation are creating a future (e.g. year 2030) level of development CalSim-II San Joaquin model with different assumptions, input data sets, and additional documentation.

5.2.2 Sensitivity Analysis

Sensitivity testing was performed to evaluate potential land use bias. The sensitivity analysis for land use was evaluated as an aggregate demand parameter. The aggregate demand parameter is a combination of demands based on consumptive use of applied water determined by both land area and evapotranspiration, deep percolation of applied water, and losses. Additional details of the aggregate demand parameter can be found in Appendix B. The sensitivity analysis and ranges (for all sensitivity discussions) are listed in order of response from the minimum to maximum limits of variation. The percentages that follow the range of sensitivity are percent change relative to the base.

The land use (aggregate demand) parameter variation revealed responses in river flows and reservoir storage. Flow responses were the most pronounced in the Tuolumne and Merced River confluences and tributaries. Storage conditions in New Don Pedro, New Melones and Exchequer reservoirs were most sensitive to parameter changes.

Results show an annual average range of +113 to -110 TAF (+8.5% to -8.3%), +60 to -21 TAF (+4.1% to -1.5%), and +38 to -39 TAF (+7.6% to -8.0%) compared to the base, in each of the storage reservoirs respectively. A change in the demand parameter also had a commensurate effect on main-stem San Joaquin River flows. Flows at Vernalis show an annual average range of +76 to -72 TAF (+2.5% to -2.4%) change from the base model. Additional sensitivity and uncertainty information and analyses are located in Appendix B.

5.3 Consumptive Use Model

The CU model uses climatic data, antecedent precipitation, location and crop type to calculate water demand for each of the water management areas.

5.3.1 Response to Review Panel Concerns

- DWR and Reclamation are pursuing alternative tools to develop water demands that incorporate additional data and improved methodology as part of a long-term implementation plan. Section 7.2 discusses enhancements to the CU model in more detail.

5.3.2 Sensitivity Analysis

The CU model calculates agricultural water demands for areas in the San Joaquin River system. Agricultural water demand is considered one part of the aggregated demand parameter in the sensitivity analysis. Results for deep percolation, distribution loss, irrigation efficiency and non-recoverable loss are also included in the consumptive use/aggregated demand sensitivity results.

Sensitivity results show a mean annual average change of -30 to +27 µS/cm (-2.9% to +2.6%), as compared to the base, on the main-stem of the San Joaquin River by varying the Merced River agricultural demands. Additional details of the sensitivity and uncertainty tests are located in Appendix B.

5.4 Operations

Calsim-II is implemented with a monthly time step because this is considered an acceptable level of detail for long-term planning purposes when weighed against other costs such as increased data requirements and longer runtimes. Following the same reasoning, the CalSim-II network is simplified, where necessary, to a level that represents the most essential features of the system.

5.4.1 Response to Review Panel Concerns

- The SJR Review revealed some concerns between actual and simulated operations (p. 28). CalSim-II logic does not necessarily simulate a conservative water demand or instream requirement allocation. The allocation logic is generally designed to approximate the monthly effects of real-time operations. Similar logic is applied to the CalSim-II simulation of the Sacramento Valley reservoirs. Quantitative analyses to evaluate conservative operations were not performed due to time limitations; however, operational investigations may better address this issue in the future.

- In addition, several assumptions of the CalSim-II San Joaquin River model were made to simplify the physical representation. Approximately 25 upstream reservoirs ranging in size from .001 to .36 million-acre-feet (MAF) were not explicitly represented as a storage node in the model. However, the operations of these comparatively smaller upstream reservoirs are represented within the inflow data to the larger rim basin reservoirs. Explicit CalSim-II simulations of the upstream reservoir systems are not necessary to capture CVP and SWP system-wide operations. However, the model can accommodate additional reservoir systems if desired. The revised documentation will also include more detailed information on the rim inflows to the San Joaquin River Basin system.

- Return flows from urban waste water treatment facilities are not explicitly modeled in the CalSim-II San Joaquin River model. In reality, most of the effluent from the San Joaquin River Basin water treatment facilities (with the exception of the City of Stockton) use percolation, evaporation and land disposal rather than discharging into the San Joaquin River. According to their web-site, the City of Stockton treats and discharges approximately 3.2 TAF of waste water per month (City of Stockton, 2006) and is assumed negligible to model in the current version of CalSim-II. Any discharge that reaches the main-stem influences water quality downstream of Stockton, but has negligible effect on the water quality of the San Joaquin River at Vernalis.

5.5 Deep Percolation

Deep percolation parameters, found for each water management area, are based on water balance calculations. These parameters are calibrated (without a numerical optimization algorithm) using field data for the most recent 12 to 19 years.

5.5.1 Response to Review Panel Concerns

- The revised Draft CalSim-II San Joaquin River documentation will include enhanced details of the deep percolation in the individual water management areas explaining the estimation procedure.

- Future efforts to improve the model representation in the San Joaquin River Basin will also address deep percolation parameter assumptions (see section 7.2 on CalSim data assessment for more details).

5.5.2 Sensitivity Analysis

The sensitivity analysis for deep percolation was again evaluated as an aggregate demand parameter. A definition of the demand parameter can be found in Appendix B. Land use and consumptive use parameter results are applicable to the sensitivity of deep percolation. Demand parameter variation revealed responses in river flows and reservoir storage, but relatively small changes to salinity on the main-stem of the San Joaquin River. Additional sensitivity and uncertainty information and analyses are located in Appendix B.

5.6 Distribution System Losses and Efficiency

Estimates for distribution system losses were developed for each water budget area through cooperation with irrigation district managers. These parameters represent leakage, seepage or evaporation in canals and ditches.

5.6.1 Response to Review Panel Concerns

- Distribution loss estimates are dependent on information directly from water/irrigation districts or they are assumed. In our experience this parameter is sometimes unavailable, as evidenced by other regional reports which made similar assumptions for other San Joaquin River analyses, such as the DWR Bulletin-160 California Water Plan Update, (McGinnis, personal communication 2005). Losses were evaluated in the water budget computation as part of the parameter estimation process for both irrigation districts with or without record of distribution losses. Because some assumption is made for the distribution loss parameter, it was also analyzed in both the sensitivity and uncertainty tests. In addition, enhanced documentation will discuss in greater detail the distribution loss parameter. Improving future distribution system losses are currently being investigated with the most recent hydrology development and are noted in the CalSim Data Development Plan in section 7.2.

- Because irrigation efficiency is impractical to determine everywhere at the field scale, CalSim-II typically uses one regional estimate of efficiency. Localized research has found that some individual southern San Joaquin micro-irrigators reach up to 97 percent efficiency or greater (Sanden et al., 2004). However, in the absence of intensive data collection, the CalSim-II model represents broad characteristics of areas with greatly varied crop types and irrigation practices. The CalSim-II San Joaquin River model generally uses an irrigation efficiency of 75 percent. The irrigation efficiency assumption or "agricultural water use efficiency (AgWUE) is generally perceived as being somewhere between 65 to 85 percent depending on the crop, irrigation system and cost of water; with regional averages often placed around 75 percent." (Sanden et al., 2004).

- The non-recoverable loss estimate of 10 percent is derived from assumptions made in previous CalSim models and is retained in the San Joaquin River Basin to maintain consistency with other model components. This parameter however, is currently being revised as part of the latest CalSim hydrology development.

- Additional distribution loss, non-recoverable loss and efficiency parameter investigations are forthcoming as described in the CalSim Data Development Plan (see section 7.2).

5.6.2 Sensitivity Analysis

Like other estimated parameters, sensitivity and uncertainty analyses were performed for irrigation efficiency and non-recoverable loss. Similar to deep percolation, distribution losses, irrigation efficiency and non-recoverable loss are components of the demand parameter. Additional information on the definition of the aggregation demand parameter is found in Appendix B. Sensitivity analysis reveals effects on storage and San Joaquin River main-stem flows as noted in section 5.2. Additional information on the sensitivity and uncertainty analysis is located in Appendix B.

5.7 Ground water

The San Joaquin River CalSim-II model represents water/irrigation district, non-district and municipal ground water extraction without explicit consideration of sub-surface ground water depths, but does account for ground water interaction with accretions and depletions at the stream-ground water interface.

5.7.1 Response to Review Panel Concerns

- As noted by the Review Panel (p. 31 SJR Review), there is little concern for ground water using the existing level of development model because the model has been adjusted to current conditions. Greater concern is for future applications where ground water interaction exceeds existing level use. Reclamation is currently supporting work to develop a ground water representation (see section 7.2 on CalSim Development Plan) which should alleviate some concerns for future condition applications.

- The Panel also suggested evaluating the ground water closure term to quantify potential error. A preliminary evaluation of the Merced water management area was performed by comparing historical and simulated groundwater pumping. Historical and simulated irrigation district and urban ground water pumping deviations were 0 TAF and 4 TAF respectively for year 1999 (historical data from Merced Irrigation District, 2001). A comparison of private pumping (in CalSim-II it is a combined ground water and closure term) was not possible because of inconsistent boundaries between the historical records and the CalSim-II water budget area. Further investigation, when time and budget permit, is necessary to evaluate the private ground water closure term.

5.7.2 Sensitivity Analysis

Recommendations from the Review Panel include an evaluation of ground water pumping sensitivity. In the San Joaquin River region, water districts typically use a minimum amount of ground water prior to using surface water, and then return to ground water supply (if necessary) to meet demands. The sensitivity of minimum ground water pumping, which could impact surface water supply, was examined. Minimum ground water pumping revealed a maximum annual average range of -47 TAF to 53 TAF (-3.6% to 4.0%) change, compared to the base, in upstream reservoir storage at New Don Pedro (see Appendix B for more details). All other sensitivity response indicators remained generally unchanged with changes in minimum ground water pumping.

5.8 Accretions and Depletions

Stream accretions and depletions represent the stream-ground water interaction in the tributaries and main-stem of the San Joaquin River Basin. Nearly all accretions and depletions were revised using mass balance techniques to update and extend the hydrology in the San Joaquin River Basin through water year 2003.

5.8.1 Response to Review Panel Concerns

- The San Joaquin River reach between Newman and Vernalis (an exception to using mass balance calculations) used a statistical relationship based on historical main-stem flow to calculate accretions and depletions. This accretion is derived from the United States Geological Survey (USGS) Vernalis stream gage and DWR planning data relationships in lieu of suspect historical data. The revised Draft CalSim-II San Joaquin River Basin documentation, available February 2007, will discuss additional detail and rationale.

- The San Joaquin model accretion and depletion parameters were calculated using data from available historical information. Future levels of development accretions and depletions may have different stream-ground water interactions than those represented in the 2005 level of development. To address this issue, an improved representation of ground water in the San Joaquin Basin, currently under development, is expected to alleviate concerns for future level of development applications.

5.8.2 Sensitivity Analysis

Testing was performed to find the sensitivity of accretions and depletions on model results. The sensitivity of Vernalis San Joaquin River main-stem flows at Maze show a range of -74 to +73 TAF (-3.0% to +3.0%) annual average change, compared to the base, with changes to accretions from Newman to Maze. Accretion and depletion sensitivity response was also evident in tributary flow and September carryover storage when compared to the base model. The greatest changes from the base model are: Maze EC, with a range of +37 to -33 μS/cm (+5.3% to -4.8%) and end of September New Melones carryover with a range of -15 to +10 TAF (+/-0.0%) due to perturbations in Newman to Maze accretions. Additional data on accretion and depletion sensitivity and uncertainty analyses is found in Appendix B.

5.9 San Joaquin River Salinity

The CalSim-II San Joaquin River water quality module is designed to simulate electrical conductivity (EC) from upstream of Lander Avenue to Vernalis on the main-stem of the San Joaquin River.

5.9.1 Response to Review Panel Concerns

- The Peer Review Panel's primary concern with the CalSim-II water quality representation was the effect downstream of Maze because EC values affect the magnitude of water released from New Melones reservoir. In particular, the assertion was made that an additional 50 TAF of water from New Melones may be needed annually during the 1996-2003 calibration period for occurrences where Maze water quality exceeded the Vernalis standard (seasonally 700 or 1000 µs/cm).

- The uncertainty analysis provided some information to aid understanding the effects of water quality and other model parameters as an output response of combined Goodwin releases (dissolved oxygen, Vernalis Adaptive Management Plan (VAMP), and water quality) from New Melones reservoir. During the simulation period, the average base release from New Melones for combined Goodwin release was 36 TAF. Under the uncertainty analysis of randomly varying input realizations, the mean annual release was 37 TAF. The 80 percent confidence interval results ranged from 30- 45 TAF or approximately +/- 7TAF.

- The uncertainty of combined releases from New Melones Goodwin during a critical water year type is of interest to both the users and the Peer Review Panel of the model. The base average annual release under a critical year type is on the order of 100 TAF with the 80 percent confidence interval ranging from 85 - 113 TAF. In summary, the range of response of total water quality releases to the ensemble of scenarios resulted in no more than a +/-15 TAF range of uncertainty.

5.9.2 Sensitivity Analysis

Sensitivity tests on water quality parameters found the greatest range of variation, from the base model, on Stanislaus River EC at Ripon. The ranges are -7 to +7 µs/cm (-5.4% to +5.4%) and -5 to +6 µs/cm (-4.0% to 4.5%) due to changes in upper Stanislaus River EC and Goodwin release EC, respectively. Other parameters measured remained relatively unchanged. Additional water quality parameter related sensitivity analysis is presented in Appendix B.

5.10 Closure Terms for Water and Salinity Balances

The residual loads or closure terms provide a method to adjust results to simulate observed historical water quality conditions within the San Joaquin River. Concern was raised that the magnitude of the closure terms were large compared to the known loadings within the system and that the intermediate solutions were also large in magnitude. The intermediate load closure values for the VAMP operations are not relevant to the estimate of error and uncertainty of the model. After distribution to returns and accretions, the residual salinity loads that are not attributed to a specific return are redistributed by splitting the closure term and introducing one half of the value upstream and one half of the value downstream of the model node (i.e. above and below Newman and above and below Maze).

5.10.1 Response to Review Panel Concerns

Fundamentally, the use of the load closure terms is a method of addressing three potential sources of error within the water quality (WQ) representation of the SJR:

- Missing load: that associated with accretion sub-components representing precipitation-runoff and local-creek inflow

- First error source: under- or over-estimation of explicit loads in the module

- Second error source: under- or over-estimation of calibration flow-EC relationships at Maze and Newman (i.e. the regression equations representing downstream control on load budget calculations).

One final comment on the load closure time series, it is important to understand they are meant to represent missing load, with error sources noted, relative to explicit load representation and recent historical salinity management. This sets up the need to use recent historical data to estimate the current associated load residuals (see WQ module Appendix B CalSim-II Peer review Session Support Documentation August 4, 2005).

5.11 Historical Comparisons

The graphics presented in the Draft CalSim-II San Joaquin River Basin documentation of historical and simulated records (from the early 1983 to 2003) show the frequency of peaks and troughs coinciding from visual inspection. This information affirms water entering and leaving the system is occurring with approximately the same timing and strengthens confidence of the timing of the operational logic.

5.11.1 Response to Review Panel Concerns

- While it is noted the storage projects in the San Joaquin River function with relatively similar operational objectives over several years or more, comparisons of simulated and historical data should be examined with an understanding of the historical conditions. The magnitude of the past historical information is not necessarily coincident with the simulated data. Land use changes, regulatory changes, reservoir construction, operational practices, operations and maintenance improvements and other static model assumptions prevent making a meaningful direct comparison between simulated and historical data. Comparisons of the magnitude between historical and simulated results of recent years have greater similarity and can realistically be compared. A more detailed discussion of recent historical observations and simulated results will be prepared in the revised Draft San Joaquin River Basin CalSim-II model documentation.

5.12 Testing, Quality Control, and Quality Assurance

The Review Panel highlighted three areas of model testing in the SJR Peer Review Report (p. 10):

1. Relevant historical comparisons
2. Uncertainty and Sensitivity analyses
3. Local expert involvement

5.12.1 Response to Review Panel Concerns

- Reclamation continues to develop procedures and has prepared documentation supporting the suggested model tests for quality control and quality assurance. The revised Draft CalSim-II San Joaquin River Documentation (available February 2007) will contain a section specifically dedicated to the comparisons of the new model, old model and historical records.

- Testing of the CalSim-II San Joaquin River model for sensitivity and uncertainty is complete and can be found in Appendix B.

- Both Reclamation and DWR encourage continued collaboration with local experts to evaluate model assumptions.

5.13 Documentation

Reclamation and DWR have worked to improve documentation and are pleased that model documentation is noted as "superb, relative to previous efforts" (Ford et al., 2006).

5.13.1 Response to Review Panel Concerns

- In the short term, a revised documentation package which responds to specific comments or criticism of the SJR Review is anticipated in February 2007. A list of modifications in the revised Draft CalSim-II San Joaquin River documentation package is presented in Appendix A. The revised Draft CalSim-II San Joaquin River documentation will enhance items that the Review Panel noted and incorporate additional features to improve the document. However, Reclamation and DWR realize that maintaining documentation is an on-going project.

- Long-term CalSim development plans also include developing a documentation system which is one of the highest priority projects of the CalSim development effort. This documentation system would specify format, content and media requirements and set maintenance standards. The documentation system proposed by Reclamation has the following expectations:

    - Develop documentation protocols and adopt a documentation management system
    - Apply protocols to update documentation on input data
    - Apply protocols to update documentation on model logic
    - Document applicability and limitations

5.14 Future Levels of Development

Reclamation and DWR have generated the existing level of development CalSim-II San Joaquin River model representation. Models representing the future are currently under construction by the agencies.

5.14.1 Response to Review Panel Concerns

- The future models will have additional assumptions, input data sets and documentation. Numerous perceived shortcomings of a future model are noted by the Review Panel.

However, the Panel's comments for a future level of development model will be documented in greater detail when this model is released including:

- Future land use data
- Water management areas and calibration of parameters
- Ground water interaction, and
- Water quality assumptions.

6.0 Response to Short term Recommendations

6.1 Model Documentation

Reclamation continues to support the improvement and maintenance of the Draft CalSim-II San Joaquin River documentation package (as mentioned previously in the Documentation section). To satisfy this short-term recommendation, a second version of the document addressing concerns raised by the SJR Review Panel is currently under development. The revised documentation will include enhanced discussion on parameter estimation, comparisons between historical observations and simulated results, and will feature an electronic reference archive. Additional information is listed in Appendix A. The revised Draft CalSim-II San Joaquin River documentation is scheduled for release in February 2007. Future documentation and maintenance is also built into the CalSim development plan (see Section 7.2 for more details).

6.2 Sensitivity and Uncertainty Analysis

The second short-term recommendation, an investigation into the sensitivity and uncertainty of the CalSim-II San Joaquin model, is also complete. Sensitivity tests provide insight into model performance and identify parameters that may require additional refinement. Targeted parameters for the sensitivity analysis include variables estimated in water budget analysis such as deep percolation, non-recoverable loss, irrigation efficiency, minimum ground water pumping and distribution losses. Other important parameters examined include water quality loads, land use estimates, consumptive use parameters, inflows and accretions. An automated CalSim-II San Joaquin River model was used to perform these sensitivity simulations. Significant sensitivity testing results show that more refined estimates for model parameters will likely lead to a more precise result for the following variables:

- Reservoir carryover storages (through improved demand estimation)
- In-stream flow (through improved accretion and depletion estimation)
- Regression equations and salinity
- New Melones inflow and basin demands and Stanislaus deliveries

Less significant relationships were found in the following pairs:

- Basin characteristics (minimum ground water pumping, demands, inflows)/salinity
- Source loads/main-stem salinity (relative to Maze regressions)
- Minimum ground water pumping/main-stem salinity or New Melones releases

Details of the results and discussion are documented in Appendix B.

Uncertainty testing and analysis can reveal the degree of model confidence compared to a base model. The uncertainty testing includes 10,000 Monte Carlo realizations simultaneously varying parameters, similar to those used in the sensitivity analysis, over a probable range of values. Key uncertainty results reveal:

- Uncertainty accumulates for reservoir storage results especially during multi-year dry periods
- Uncertainty is generally greater for Goodwin release during dry periods
- Uncertainty is generally greater for river flow variables during the wet periods
- Uncertainty is generally greater for river salinity variables during the dryer years

Discussions and details of the uncertainty analysis results are found in Appendix B.

6.3 Examination of the Water Quality Model

The specific concerns of the Review Panel regarding the water quality module and the potential for bias in representing the salt loads within the San Joaquin River at Maze, resulting in associated dilution flows from New Melones, were investigated and are addressed as follows:

- Low-flow maze EC is probably biased somewhat in the model, as the Review Panel pointed out, but year-type representation in the calibration period has little to do with observed bias and the Panel's estimates for influence on below-Maze operations were likely overstatements based on our sensitivity analysis (which is a certain overestimate by itself). The sensitivity analysis of the base scenario pinned the greatest responses of water quality releases on the Maze regressions and delivery demands within the basin.

- The uncertainty analysis of the base scenario provided an estimate of the potential range of releases from New Melones over the complete simulation period. Uncertainty analysis for specific year types reveals that collective input uncertainties may not translate into additional output bias. The observed range results in an estimated uncertainty of no more than +/- 15TAF during dry and critical year types.

- Although the calibration period does contain wet periods, the population of low flows in the calibration period represents the lowest 10 percent of flows (93% exceedence) over the simulation period.

For further information see Appendix C, Water Quality Analysis Response.

7.0 Response to Long-Term Recommendations

7.1 Data Assessment

Future model improvement strategies may benefit from a better understanding of data such as hydrology, water quality, socioeconomic, and water operation. A database of this information would be useful to all modelers. A data survey project proposed by Reclamation and DWR includes the following tasks:

1. Identify data categories
2. Survey available data
3. Update data documentation
4. Assess available data types
5. Identify additional data-monitoring needs

The following data inputs are currently used by the CalSim-II San Joaquin River model and would be scrutinized under the data survey project:

- Hydrology
- Climate
- Water Quality
- Ground water
- Land Use
- Demand
- Irrigation Efficiency
- Distribution System
- Deep Percolation
- Water System Operation
- Regulatory Requirements

Specific Tasks include the following:

1. Develop protocols for data development
2. Survey available hydrologic data (space, time-step, period)
3. Survey available water quality data (space, time-step, period)
4. Survey available management data (operations, water use, projected change)
5. Scope the development of a geospatial database serving historical hydrologic, water quality, hydrogeologic, and agroeconomic data

After the completion of the proposed data survey, actions suggested by the Review Panel would be addressed, including:

- Expansion of data monitoring and data collection
- Secure long-term data collection
- Establish partnerships with other agencies for data sharing
- Explore alternative data sources

7.2 CalSim Development Plan

Reclamation and DWR have established a development plan for CalSim-II San Joaquin River model improvements. The next phase of system-wide hydrology improvements currently underway is called CalSim-III. Development efforts target the following tasks:

- Improve accuracy of water supply estimates

- Update agricultural demands, distribution losses, and water use efficiencies
- Associate agricultural demand with the correct water supply source
- Reconcile differences between ground water model and planning model
- Reduce development time for new hydrology inputs associated with new land use scenarios
- Represent ground water with sufficient accuracy for impact analysis and preliminary conjunctive use studies
- Develop documentation

The proposed CalSim-III hydrology development for the future San Joaquin River system includes the following longer-term projects:

1. **Strategy:**
    a. Implement data development plan
    b. Implement model development plan
    c. Implement model testing and documentation protocols
2. **Ground water:**
    a. Link a new ground water representation to the planning model. See section 7.4 on ground water development for more details.
3. **Operations:**
    a. Enhance procedures for allocating priorities to meet water demands from the different sources of surface water and ground water
    b. Develop rules for meeting projected level demands during dry/critical periods by modifying land use
4. **Demands:**
    a. Develop land-use based demands for the San Joaquin Westside
    b. Defining and refining new area boundaries for water budget purposes (Water Budget Areas [WBAs]); relate WBAs to CALSIM III network
    c. Enhance procedures for dividing land-use based demands into SWP/CVP Project and non-Project demands
5. **Hydrology:**
    a. Enhance methods for estimating local water supplies (on-farm irrigation efficiencies, agricultural re-use, and wildlife refuges)
    b. Disaggregate some main-stem San Joaquin River reaches upstream of Newman
6. **Closure Terms**:
    a. Continue to collect data both for flow and water quality and use the results from testing analysis to reduce sources of uncertainty (see Appendix A).
    b. For future models, test rainfall runoff models and maintain consistent system-wide methods

7. **Data Collection:**
    a. Develop and apply protocols for data documentation and model development
8. **Testing:**
    a. Historical and simulated comparisons
    b. Sensitivity and uncertainty testing
    c. CALSIM III Testing - individual components

    d. CALSIM III Testing - completed model simulations for the current (2005) and projected (2030) levels of land-use development

Current CalSim San Joaquin River development is linked with the CalSim-III hydrology development effort. The data assessment (7.1), enhanced Westside demand simulation, and improved ground water simulation are currently underway in the San Joaquin region.

7.3 Protocols for Documentation and Testing

As previously stated in section 7.2, Reclamation and DWR have established a long-term development plan for SWP and CVP reservoir system modeling. This plan calls for the development of protocols for both documentation and testing (1c and 8 listed in the previous section).

7.4 Ground water, Westside San Joaquin Demands and Consumptive Use

DWR has recently enhanced CalSim's ground water capability with the development of C2VSIM. The model C2VSIM is an application to California's Central Valley and DWR's Integrated Water Flow Model (IWFM). IWFM is an integrated hydrologic model for simulating ground water flow, stream flow, and the surface water – ground water interaction.

DWR has recently completed an initial calibration of C2VSIM for the period 1975-2003 and an extended simulation from 1922-2003. This model can be used either as a standalone model or implemented in the CalSim model for developing hydrology or emulating surface water – ground water flow and interaction. A dynamic ground water representation for the San Joaquin River Basin in CalSim would include the following:

1. Additional calibration of the C2VSIM model for the Central Valley regions in California
2. Develop a CalSim standalone model to estimate land-use-based water demands, surface runoff, return flow, and deep percolation of precipitation and applied water
3. Develop ground water response functions to emulate C2VSIM within CalSim, and
4. Adjust C2VSIM grids to conform to water budget areas (called water management areas in this report)

A reconfigured San Joaquin River CalSim-II model including ground water representation, revised surface runoff, return flow and deep percolation is part of a future CalSim development effort. Future CalSim San Joaquin River models may further improve ground water representation by enhancing the resolution of the physical system, additional calibration of C2VSIM and enhancing/modifying the replacing response functions.

Substantial improvements are also planned for the San Joaquin River Westside as part of the future CalSim development effort. Westside demands are the only demands currently in CalSim estimated by contract quantities and not by land use. Land-use-based demands in the Westside may improve the return flows and San Joaquin River salinity, as well as San Luis Reservoir operations. Westside demand development methods will also use similar methods used to develop the Eastside. This approach of calculating land-use based demands is being applied to maintain consistency throughout the Sacramento and San Joaquin River basins.

In the longer-term, improved demand estimate calculations are also planned using a tool capable of capturing variable evapotranspiration. DWR's DPLA and U.C. Davis plan to develop this new crop water demand estimation model. This new model is expected to be similar to the existing water demand models such as the SIMETAW model used by DPLA and the recently completed DETAW model for the Delta.

7.5 Absolute and Comparative Modeling

The performance expectations of the CalSim-II San Joaquin model have been raised in past CalSim-II reviews. A frequent comment in past model reviews has been whether CalSim is an appropriate tool for analysis in the absolute mode. DWR and Reclamation reiterate the following information from the first peer review response (DWR and Reclamation, 2004):

"CalSim-II and its predecessor models can be used in two ways. The first is in the comparative mode and the other is in the absolute mode. The comparative mode consists of comparing two model runs: one that contains a proposed action and one that does not. Differences in certain factors, such as deliveries or reservoir storage levels, are analyzed to determine the effect of the proposed action. In the absolute mode, the results of one model run, such as the amount of delivery or reservoir levels, are analyzed directly."

"CalSim-II and its predecessors DWRSIM, PROSIM, and SANJASM were originally conceived for comparative analysis. However, for endangered species consultation, biological assessments, facility re-licensing efforts under [Federal Energy Regulatory Commission] FERC, or local planning efforts by project contractors and local agencies, absolute values of delivery reliability or other performance measures are required. DWR and Reclamation recognize the requirement of CalSim-II to provide absolute predictions and consequently, the need for further work in refining model inputs and quantifying the likely range of model error. Relying on analysis of long periods (anywhere from a few years to the period of record) through calculation of statistical parameters and development of exceedence data may be useful for absolute predictions. Reliance on individual monthly values or yearly averages is not recommended."

As noted in the previous and current San Joaquin River Peer Reviews, model testing was recommended to provide model users relative accuracy of simulation results. Since the last two CalSim-II model reviews, DWR and Reclamation have performed sensitivity and uncertainty testing. DWR completed the "*CalSim-II Model Sensitivity Analysis Study: Technical Memorandum Report*" in October 2005 covering the Sacramento-San Joaquin River Delta and northern portions of the model. DWR also plans to initiate an uncertainty assessment study, uncertainty testing, and the development of an ongoing program to reduce model uncertainty. Reclamation completed the CalSim-II San Joaquin River region sensitivity and uncertainty analyses and the results are presented in Appendix B of this report.

Results from these two studies yield some useful information:

1. Sensitivity results show a response in an output variable to a change in a single input parameter, and therefore, can guide efforts to identify and improve sensitive input data.

2. Uncertainty study results show a cumulative response of all parameter variations in comparison to the base model.

However, base model sensitivity and uncertainty testing of the CalSim-II San Joaquin River alone do not provide complete performance evaluation for long-term proposed actions. More useful information may be found by testing of specific applications or alternatives. Further discussions of the sensitivity and uncertainty results and next steps are found in Appendix B.

8.0 Conclusion

The San Joaquin Peer Review Response report provides an opportunity to reaffirm one of the goals of CalSim development, credibility and trust. Reclamation has responded to the Review Panel concerns in two ways:

1. Addressing the concern through one of the three short term recommendations, and

2. Presenting a plan to address the concern within long-term model development.

This response has primarily focused on the efforts made to address all short-term recommendations: sensitivity analysis, uncertainty analysis, water quality evaluation and revised documentation. Specific parameters for data improvement and uncertainty trends were revealed by performing the sensitivity and uncertainty analyses. The water quality evaluation also provided clarification toward concerns regarding bias and overestimation. The revised Draft CalSim-II San Joaquin River documentation, available in February 2007, will contain enhanced discussions detailing parameter estimation, comparisons between historical observations and simulated results, and feature an electronic reference archive. Priority long-term CalSim development plans include establishing documentation and testing protocols, surveying model data needs, and better representing ground water interactions.

Reclamation and DWR are confident the new version of the model is improved over the old in the areas revised. The Review Panel’s overall assessment describes the new representation as “significantly updated, improved methodologically and better documented.” (Ford et al., 2006). However, both agencies acknowledge improvements of items not scheduled in the 2001 effort will further enhance the model’s accuracy, such as ground water representation and San Joaquin River Westside land-use-based demands. Although the current version of the CalSim model is the best available analytical tool for planning and management of the CVP and SWP systems, both agencies reaffirm their commitment to continue the model enhancement efforts according to the long-term development plan, partially laid out in this document.

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Appendix A: Revisions to the Draft CalSim-II San Joaquin River Basin Model Documentation

Reclamation is supporting a second revision to the Draft CalSim-II San Joaquin River Basin model documentation package to enhance the text and graphical contents. The revised document will address the documentation weaknesses identified by the Review Panel. The document is scheduled for release in February 2007. The following list identifies the areas of revision, enhanced documentation, and supplemental components:

1. Demand areas:
    a. Land Use
    b. Assembly of Land Use Data
    c. Rectification of Overlapping Water Districts
    d. Consumptive Use of Applied Water Model
    e. Deep Percolation of Applied Water
    f. Distribution System Losses
    g. Non-Recoverable Losses
    h. Irrigation Districts
    i. Water Management Area Graphics
    j. Water Management Area Summary
    k. Municipal Demands and Return Flow
    l. Westside Demands
2. Accretions and Depletions:
    a. San Joaquin River Mainstem accretions
    b. Groundwater
    c. Losses
3. Rim Basin Inflows:
    a. Graphics
    b. References
4. Eastside Tributary Operations:
    a. References
    b. Return flows
    c. Schematics
5. Westside Operations:
    a. Refuge
    b. Contractors and Riparian Diversion Return flows
6. Simulated Results and Historical Comparison:
    a. Discussion
7. Simulated Results Comparison between model versions:
    a. Discussion
8. Recommendations for Future Work:
    a. Data Assessment
9. References:
10. Appendices:
    a. Sensitivity and Uncertainty Analyses
    b. Water Quality Evaluation

11. Reference Archive:
    a. Electronic San Joaquin River Basin Regulations and Agreements

Appendix B:

Error Analysis For CalSim II “San Joaquin River” Standalone Model

October 31, 2006
U.S. Bureau of Reclamation (prepared by 86-68520, MP-700, MP-CVOO)

EXECUTIVE SUMMARY

An error analysis was conducted on the updated CalSim II San Joaquin River (SJR) representation. The analyzed representation is an “existing condition” for the region and includes model logic and input data as they were reviewed during 2005 peer review, plus two modifications: extension of the water quality module from Lander Avenue to the head of Chowchilla Bypass, and modification of the Stanislaus River accretion between Goodwin and Ripon. The analysis included two stages: sensitivity analysis and uncertainty analysis.

The sensitivity analysis involved measuring output response relative to a *single input* changes. The purpose was to produce information that could steer strategy for model improvements and related data collection. Key steps included: (a) establishing assumptions for positive and negative limits for scaling the input value during the entire simulation period, (b) simulating model response with the input scaled either positively or negatively, and (c) comparing output performance metrics associated with both of these scenarios to base model metrics in order to define a performance response *interval* associated with a given input’s assumed limits of variation.

The uncertainty analysis involved measuring output distributions relative to the collective uncertainties of inputs included in the sensitivity analysis. The purpose was to produce information on base model error as requested by the peer review panel, which could assist decision-makers’ interpretation of model results. Key steps included: (a) establishing assumptions on input scaling distributions constrained by limits of scaling used in the sensitivity analysis, (b) Monte Carlo generation of input-set scenarios where, for each scenario, all scoped inputs were allowed take on random values from their respective distributions, (c) simulating the model for each scenario, and (d) pooling scenario model outputs to assess range and variation for various performance metrics describing output uncertainty.

Results from the sensitivity analysis suggest that the uncertainty of various outputs could be most readily reduced by reducing the input uncertainties of modeled demands, accretions, and salt load residuals in the main-stem San Joaquin River (SJR). Although uncertainty reductions might be achieved through either improved model representation or calibration datasets, it is recommended that immediate attention be given toward data collection strategies that would increase knowledge related to accretions and salt-load residuals calibration.

Results from the uncertainty analysis do little to inform decision-making *by themselves*. However, the analysis serves as a first-step towards potentially introducing risk-based decision-making concepts into long-term planning efforts served by CalSim II. Two potentially beneficial products came from the analysis. First, the results illustrate one approach for describing CalSim II output uncertainty. Also, the methodology and set of automation tools developed for this analysis could be readily extended to explore uncertainty in future versions of CalSim II SJR or the full-system CalSim II model, should such information be of interest in future planning studies.

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B.1 INTRODUCTION

An error analysis was conducted on the updated CalSim II San Joaquin River (SJR) Valley representation. Two general questions were addressed in the analysis:

- How do changes to specific model inputs affect model outputs?
- How do collective uncertainties about model inputs translate into uncertainties of model outputs?

These two questions were addressed through sensitivity and uncertainty analyses, respectively. Motivations for exploring these questions and related objectives for each analysis are discussed in the following sections.

B.1.1 Background

CalSim II (Draper et al. 2004) is the joint-agency planning model used primarily by the California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) to study long-term proposed actions for the Central Valley Project (CVP) and State Water Project (SWP) systems. The model represents federal, state, and local operations within the Sacramento and San Joaquin River (SJR) basins.

In 2005, Reclamation released an updated SJR Valley representation in CalSim II, both in terms of model structure and input data sets. The updates (Reclamation 2004, 2005) include improved representation of Eastside SJR water demands, Eastside SJR hydrology, Eastside local district operations, and salinity-routing in the SJR from Lander Avenue to Vernalis (**Figure 1**). The updates expand model use to future SJR scenarios driven by projected Eastside land use scenarios and salinity-management proposals above Maze. A schematic view of the new SJR model structure is shown on **Figure 2**.

Reclamation submitted these model updates to peer review by an external panel in late 2005. The panel published several key findings (Ford et al. 2006), one of which was that CalSim II with the SJR updates was an improvement relative to the old SJR representation. However, the panel noted the absence of guidance on how to interpret the precision and utility of model results for planning applications without knowing the inherent level of error in the outputs.

One recommendation was to document the sensitivities of model outputs in response to changes in key inputs. It was suggested that these sensitivities should be evaluated where inputs are adjusted to their estimated limits of potential variation. The proposed purpose of such an analysis would be to reveal relative influence among inputs on affecting output uncertainty, and potentially guide planning of future improvements or data collection efforts.

Similar comments were made during an external review of the full-system CalSim II model (Close et al. 2003). The earlier panel also emphasized the need for analyzing how collective inputs' uncertainties translate into uncertainties of model outputs, using techniques like Monte Carlo (Roberts et al. 2004). It was suggested that uncertainty analysis would aid users in understanding the risks of various decisions based on model output. CalSim II practitioners have also expressed interest in understanding CalSim II model error (Ferreira et al. 2005), suggesting that it is unclear which parameters most influence model output.

B.1.2 Analysis Objectives

In response to Peer Review Panel recommendations and practitioner interest, Reclamation completed an error analysis on CalSim II model outputs in the SJR region, emphasizing output relations to inputs that were updated for the new representation. The analysis scope includes both sensitivity and uncertainty analysis. The objectives were:

- Produce model sensitivity information for Reclamation's CalSim II model development planners, particularly on which inputs seem most influential on model outputs; and, among these influential inputs, which seem most feasible to target for improved precision through improved model representation or data collection.

- Produce model uncertainty information that might be referenced by decision-makers responsible for interpreting CalSim II model outputs.

- Produce model error information that could support development of Reclamation's response report to peer review findings.

- Document model error information, consistent with peer review recommendation.

In terms of quantifying sensitivity and uncertainty, the project generally follows methodologies that have been previously developed. One example of a sensitivity analysis was demonstrated by DWR for the full-system CalSim II model (DWR 2005), where a matrix of systematically changed inputs followed simulation and output response measurement. One difference between that analysis and the one here is that input changes in this sensitivity analysis are coordinated with assumptions about input-specific limits of potential bias (Section B.2.3). Uncertainty analysis using Monte Carlo techniques was described in the first panel's report (Close et al. 2003); additional documentation is widely available (e.g., Robert and Casella 2004). Project-specific assumptions associated with implementing this technique are discussed in Section B.2.4.

The main challenges of this project are primarily computational as opposed to analytical (e.g., managing a large amount of data, handling data efficiently across multiple applications, translating data across multiple formats, and acquiring sufficient computational resources). Ultimately, automation tools were developed to meet these challenges. Those tools, along with other methodological elements, are described in Section B.2.5 and Attachment B1.

B.2 METHODOLOGY

This section describes the base model subjected to error analysis, including two features that were implemented after the model was submitted for peer review in August 2005. The section then continues with descriptions of inputs and outputs considered in the analysis, sensitivity analysis methods, uncertainty analysis methods, and automation tools that were used to expedite analysis and data-handling.

B.2.1 Base Model

A stand-alone version of CalSim II's San Joaquin River Valley representation was used in the error analysis. It includes the region's hydrologic and operational features included in the full-system model called the "SJR Stand-alone" model (base model). Full-system model features not dynamically simulated in the stand-alone model include Sacramento Valley and Delta operations, and Delta-export service area operations. Solutions for Delta conditions that affect New Melones operations to meet the Vernalis flow-objective, and solutions to Delta-Mendota Canal deliveries that affect return flows to the San Joaquin River were provided from a preprocessed full-system simulation. An advantage of using the SJR stand-alone model is that execution run time is reduced from approximately 40 minutes to 3 minutes for one full-period simulation.

Like the full-system CalSim II model, the stand-alone model simulates reservoir operations on a monthly time step (and features operations of CVP and local facilities in the San Joaquin River Valley). Solutions for monthly operational decisions are determined using mixed-integer/linear programming techniques. Information on the mathematical formulations employed by CalSim II and its underlying software environment can be obtained at http://modeling.water.ca.gov/hydro/model/index.html.

Base model simulation solves for operations during a sequence of 82 water years (WYs) representing the region's climate variability experienced during WY1922-2003. Base model representation of basin hydrology and operational strategies is an approximation of recent historical conditions in the region.

The model version used for this error analysis is consistent with that submitted to peer review (Ford et al. 2006) except for two changes. First, the water quality module's salt mass-balancing methodology was geographically extended above Lander Avenue, up to the head of Chowchilla Bypass above Mendota Pool (**Figure 2**). This extension also featured accretions refinements between Newman and the head of Chowchilla Bypass to improve the detail of flow and salinity entering the main-stem of the San Joaquin (MWH 2005). Second, an adjustment was made to the assumed accretion in the Stanislaus Basin downstream of Goodwin Dam and upstream of Ripon (i.e. CalSim II state variable I528, **Figure 2**). Details on this change are discussed below.

The I528 accretion time series is shown on **Figure 3** before and after adjustment. Review of I528 variability before adjustment showed a significant shift in variability after WY1940. It was judged that the August 2005 model's I528 variance from WY1922-1940 was probably insufficient and an artifact of the methodology used to extend the accretion back in time before WY1941. Additionally, it was assumed there should be consistent variation between the simulated accretions at Goodwin-to-Ripon (I528) and Tulloch-to-Goodwin (I520, **Figure 2**). Given this latter assumption, a procedure was implemented to force variance consistency between I520 and I528 during WY1922-1940:

- pooling WY1941-2003 data on a month-specific basis, identify month-specific rank-distributions for I520 data, and sorting the month-specific data and assigning rank-percentiles for each data value.

- pooling WY1941-2003 data on a month-specific basis, identify month-specific rank-distributions for I528 data, and sorting the month-specific data and assigning rank-percentiles for each data value.

- assigning percentile ranks to I520 data during WY1922-1940 on a month-specific basis, treating WY1922-1940 data as look-up values relative to the WY1941-2003 rank-percentile distributions, and then matching WY1922-1940 values with either identical WY1941-2003 values or next-largest values from the later period.

- assuming equal monthly percentile ranks for I520 and I528 values during WY1922-1940.

- following the previous assumption, assigning percentile ranks to I528 data during WY1922-1940, and then using these ranks as inverse-look-up values relative to the I528 rank-percentile distributions defined during WY1941-2003 to estimate I528 values for WY1922-1940.

This procedure produces the "after" curve shown on **Figure 3**. The effect of making this adjustment was a 23 thousand-acre-feet (TAF) average annual reduction in cumulative Goodwin-to-Ripon accretion during WY1922-1940.

B.2.2 Scope of Inputs and Outputs

Attempts were made to adequately represent the base model's range of inputs and outputs, at least in a categorical sense. There are hundreds of inputs and outputs that might have been analyzed and doing so would have expanded the scope beyond feasibility. Instead, thought was given towards which general categories of inputs should be analyzed for conceptual influence, and on what general categories of outputs. In the end, it might be summarized that scoped inputs represented: salt sources above Maze, salt sources below Maze, and Eastside hydrology components. Outputs represented deliveries, storage and flow results grouped by tributary area, and flow and salinity solutions along the San Joaquin River above and below Newman. Specific lists of scoped inputs and outputs are presented in the following sections.

B.2.2.1 Inputs: The analysis considered 22 input "types" where each type features one or more input parameters to be adjusted in error analysis (**Table 1**). The inputs are subdivided according to the three categories mentioned above.

The first category features salt load inputs that produce the majority of salt load reaching Maze (**Table 2**): load residuals at Maze and Newman, and two source loads entering the module above Newman. These loads were selected for sensitivity analysis because they represent the bulk of cumulative salt load entering the water quality module between Lander Avenue and Maze (i.e. entering at nodes "Mud/Salt Slough," "Merced Confluence (Newman)," "Tuolumne

Confluence," and "Maze"). The cumulative salt load entering the module along this reach is approximately 2.17 x 10^6 (cfs*µS/cm) per year during the WY1922-2003 averaging period. These inputs represent 79 percent of that amount.

The second category features salt loads entering the module below Maze that might affect water quality mixing at the Stanislaus and SJR confluence and the upstream operation of New Melones Reservoir. It was reasoned that variations among Stanislaus loads might affect the amount of New Melones release necessary for meeting water quality objectives at Vernalis.

The final category features Eastside hydrology inputs that affect upstream reservoir operations, downstream SJR flows, and downstream SJR salt loads. Hydrologic inputs were considered on a tributary-specific basis and include variables describing local accretions, minimum groundwater pumping, reservoir inflows, and water demands. Section B.2.3 provides more discussion on why these inputs were considered, limits of variation assumptions, and what the scenario adjustments are intended to represent.

Information is provided in **Table 1** on what CalSim II input data items are associated with the 22 input types (column 5). The location of these inputs varies (column 6): model look-up tables (i.e. text files), pre-processing spreadsheets, time-series database, and model logic files. Assumed scaling limits (column 7) are introduced in Section B.2.3. Discussions on input interdependencies (column 8) relate to the uncertainty analysis and are discussed in Section B.2.4.

B.2.2.2 Outputs: The analysis considered several types of outputs (i.e. CalSim II decision variables, **Table 3**) grouped by tributary area (Stanislaus, Tuolumne, Merced) and sub-areas along the SJR (above the Merced confluence to Millerton Lake, and below the Merced confluence to Vernalis). Scenario results were stored for each output variable listed in **Table 3**. However, *error analysis was only conducted on a subset of variables* (indicated by "yes" in column 3).

Error analysis involved computing scenario-specific performance metrics. These metrics were computed on a variable-specific basis. For flow-related variables (i.e. river flows, deliveries, depletions, reservoir releases), the metric was a period-average annual or monthly flow volume. For storage variables, the metrics were a period-average end-of-month volumes. For salinity variables, the metric was a period-average annual or monthly concentration. Several averaging periods were considered for all metrics: WY1922-2003 (simulation period), WY1928-1934 (early drought), WY1987-1992 (late drought), and simulation year groups consistent with San Joaquin Basin 60-20-20 year-type classifications (Wet, Above Normal, Below Normal, Dry and Critical).

B.2.3 Sensitivity Analysis

Sensitivity analysis procedures are consistent with methods proposed by the Peer Review Panel (Close et al. 2003; Ford et al. 2006) and similar to what was implemented by DWR (DWR 2005) in response to the earlier review (Close et al. 2003). The analysis focused on how output responds to an assumed adjustment to an input, applied uniformly to the entire simulation period.

Forcing a full-period uniform adjustment implies that the analysis is focused on "simulation-period" or long-term potential bias in the input value relative to its true (unknown) value. It does not represent shorter period bias in the input value that might manifest in a specific year or year-group. The rationale for not doing the latter is that while inputs may be over- or under-estimated for various years during simulation, the errors from these biases will be somewhat offsetting when considering the performance metrics described in Section B.2.2.2. In contrast, presence of long-term bias in the inputs would be more likely to influence performance metric values.

Given this focus, the analysis involved two main assumptions:

- long-term input bias could be represented as the base input value multiplied by a scaling factor (i.e. base value = base value * (1.0 + scaling factor), where the scaling factor is associated with Input types in **Table 1**, column 7, expressed as percentage changes from base).
- scaling factors should be chosen so that when inputs are adjusted by their respective assumed scaling factors, then the resultant modified inputs will represent the assumed limit of variation in the input's full-period average value.

Adopting these assumptions, analysis involved comparing results from three modeling scenarios for each input listed in **Table 1**:

- simulation using unadjusted input,
- simulation with the input set at its inflated limit using the positive scaling factor,
- simulation with the input set at its deflated limit using the negative scaling factor.

For most of the input rows in **Table 1**, the row-specific variables listed in the fifth column were scaled as a group, positively or negatively according to the scaling factor limits in the seventh column. Thus, there were generally two sensitivity scenarios for each of these rows. The exception to this rule was for the rows addressing salt load residual calibration curves (Inputs 3 and 4). In these rows, the calibration-curves were scaled on a season-specific basis. Thus, these two rows had 6 and 12 scenarios associated with them, respectively, increasing the number of input-specific sensitivity scenarios from 22 (number of rows in **Table 1**) to 29. Considering positive and negative scaling, the analysis included 58 sensitivity scenarios and one base model simulation.

Output performance metrics were computed for each of the variables identified for analysis in **Table 3** (column 3). Metrics were computed for each of the averaging periods mentioned in Section B.2.2 (e.g., WY1922-2003, WY1928-1934, WY1987-1992, and SJR60-20-20 year-type groups). Changes in performance metrics were then identified, representing performance sensitivity to the given input adjustment.

The critical assumptions of the sensitivity analysis are associated with setting scaling factor limits. Those assumptions are discussed on an input-specific basis in the following sections.

B.2.3.1 Assumptions – Source Salt Loads above Newman: (**Table 1**, inputs 1 and 2) These inputs were considered with the goal of understanding whether the most significant source loads above Newman significantly affect simulated operations below Maze. Focus was arbitrarily given to the two largest source loads in the module above Newman (**Table 2**). These source loads vary by both flow and concentration. Information on these source loads is limited to the information used to develop the base model. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 20 percent, arbitrarily focusing the adjustment on either the load's flow component (e.g., Input 1) or quality component (e.g., Input 2).

B.2.3.2 Assumptions – Salt Load Residuals computed at Newman and Maze: (**Table 1**, Inputs 3 and 4) These inputs were considered with the goal of understanding whether calibration flow-salinity relations at Newman and Maze significantly affect simulated salinity management below Maze. These calibration relations affected development of the base model's water quality module, shown schematically on **Figure 4** (shown only for the portion between Lander Avenue and Vernalis). Base model calibration relations are shown on **Figures 5 and 6a-b** (solid lines on each figure). The relations affect water quality module development by helping to determine the load residual time series at Newman and Maze. The purpose of the residual time series is to ensure that the water quality module simulates flow-salinity relationships that are consistent with recent observations at Newman and Maze.

The calibration relations were developed on a seasonal basis. Mathematically, they are formulated as: EC = Intercept – Slope*ln(Flow). The selection of seasons was documented in base model development (Reclamation 2004).

Uncertainty of these calibration relations arrives from both observations support curve-fitting and the choice of mathematical formulation to describe the EC-flow relationship. A decision was made to describe the potential range of EC-flow relationships by developing parallel curves associated with EC data scaling (at observed flows). Scaling the data higher or lower leads to regression curves (i.e. calibration EC values at given flow rates) being higher or lower, respectively. Alternatively, curve scaling could have also been accomplished using parameter uncertainties associated with the base-curve fits, which is information provided from the regression analysis (Haan 1977). This approach was explored, using slope and intercept parameters adjusted to the limits of their 90 percent and 80 percent confidence intervals. However, this approach led to unrealistic curve adjustments relative to observations. This is understandable since the size of calibration data sets were relatively small, leading to larger confidence intervals being associated with the regression parameters. Since the size of the calibration data set couldn't be augmented to address this parameter uncertainty issue, EC data scaling was instead used to drive curve scaling.

Given the choice of EC data scaling, the chosen amount of scaling was ultimately arbitrary. This is because there was no information to suggest the uncertainty of EC measurement at a given flow rate (at either Newman or Maze). Given an absence of such information, it was assumed that while the regression parameters and curve placements are highly uncertain, there's no rationale to defend curve-adjustments that significantly deviate from the base curves. Subjectively, scaling factors were chosen independently for each season-specific calibration curve. The first rule was that the scaling factor had to be at least 10 percent in magnitude (+ or -), meaning that the actual EC value observed at a given flow rate could be consistently over- or under-estimated 10 percent of the time during the period of observation. The second rule was that the scaling magnitude had to be inflated in order to produce an adjusted curve that is either above or below ~75 percent of the EC observations at the given observed flows for positive and negative scaling, respectively (**Figures 5, 6a-b**; long- and short-dashed curves, respectively).

B.2.3.3 Assumptions – Salinity of Goodwin Release, Stanislaus Returns & Stanislaus Accretions: (**Table 1**, Inputs 5 and 6)
These inputs were considered with the goal of understanding whether the quality of "clean" load (high quality water) sources above Ripon significantly affect the operation of New Melones for water quality management at Vernalis. There was no source-specific information on how the base model's assumed salinity for these flows might be biased. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 10 percent.

For an indirect check on the base model's cumulative assumptions about Stanislaus flow-arc qualities, the aggregate simulated Stanislaus load above Ripon was checked against recent historical EC monitoring at Ripon (http://iep.water.ca.gov/cgi-bin/dss/dss1.pl?station=RSTAN009).

The 1996-2005 maximum-hour measurement was 169 μS/cm, while the period average was 94 μS/cm. By comparison, the base model simulates a 1922-2003 maximum-month Ripon EC of 283 μS/cm, and a full-period average of 131 μS/cm. Based on this comparison, it might have been reasonable to consider scaling factors that primarily *deflate* salinity values associated with these sources, since it appears the base model over-estimates the cumulative concentration from these sources (given that the observed 1996-2005 flows are represented in the range of simulated Ripon flows). In spite of this finding, salinity inflating was still considered.

B.2.3.4 Assumptions – Salinity of Non-Project Returns near Stanislaus confluence with SJR: (**Table 1**, Input 7) These inputs were considered with the goal of understanding whether the quality of "clean" load sources below Maze and Ripon significantly affect the operation of New Melones for water quality management at Vernalis. There was no source-specific information on how the base model's assumed salinity for these flows might be biased. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 20 percent.

B.2.3.5 Assumptions – Accretions in Eastside Tributaries and along the SJR: (**Table 1**, Inputs 8 through 12) These inputs were considered with the goal of understanding whether accretion/depletion variables from hydrology development (i.e. flow residuals) affect simulated operations below Maze. Accretion computations involve a historical water budget analysis where input information includes upstream and downstream USGS gage data, and assumed historical diversions/returns in between the gages that explain gage differences. Confidence in USGS gage data is relatively highest among these inputs. Historical diversions and returns data were typically generalized during hydrology development due to lack of data (Reclamation 2005). Ultimately there was no information on how the base model's assumed accretion time series might be biased over the long-term. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 10 percent.

B.2.3.6 Assumptions –Minimum Groundwater Pumping in Eastside Tributaries: (**Table 1**, Inputs 13 through 15) These inputs were considered with the goal of understanding whether assumed minimum amounts of monthly groundwater pumping within Eastside tributary basins affect simulated operations below Maze and in upstream reservoirs. Base model hydrology development (Reclamation 2005) involved developing monthly assumptions about supply management to satisfy diversion requirements. For most districts, the model features a three-tiered scheme where diversions are first satisfied by a minimum amount of groundwater pumping, then by available surface water (based on upstream operations and allocations), and finally by additional groundwater pumping. Assumptions were developed separately for district and non-district pumping. Assumptions were further split between minimum amount pumped before use of surface water, and amount pumped after surface water availability was exhausted. Confidence is generally higher for district assumptions than for non-district assumptions. Confidence is also higher for total district pumping amounts than the minimum component pumped before surface water use.

For this analysis, district and non-district minimum groundwater pumping amounts were considered and scaled at a tributary level (i.e. in the Stanislaus, Tuolumne, and Merced basins). There was no information on how the base model's assumed minimum pumping amounts might be biased over the long-term. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 20 percent.

B.2.3.7 Assumptions – Reservoir Inflows to Major Eastside Reservoirs: (**Table 1**, Inputs 16 through 18) These inputs were considered with the goal of understanding how potential long-term bias in the assumed inflows to major Eastside reservoirs (i.e. New Melones, New Don Pedro, Exchequer) would affect simulated downstream operations. To gain a sense for this potential bias, CALSIM II monthly impaired inflow data for 1922-2003 were compared against monthly full-natural flows reported by the California Data Exchange Center (CDEC, http://cdec.water.ca.gov/cgi-progs/staSearch). Comparisons were made at: New Melones (CDEC Data ID: SNS), Lake McClure (CDEC Data ID: MRC), and Millerton Lake (CDEC Data ID: SJF). Also at New Melones, CALSIM II seasonal Mar-Sep volumes from 1990-2002 were compared against CVO records for seasonal impaired inflow volumes during that period.

The first comparison revealed bias in average annual CALSIM II inflow relative to annual full natural flow (CDEC): +1 percent at New Melones, -1 percent at Exchequer, and +2 percent at Millerton Lake. Consideration was given towards assessing this bias at New Don Pedro Reservoir. However, such an analysis was limited by lack of available information on upstream depletion/accretions associated with Hetch Hetchy Reservoir operations.

The second comparison showed that the average annual 1990-2002 Mar-Sep inflow volume at New Melones is 1 percent higher in CALSIM II relative to CVO records. The decision to focus on Mar-Sep was related to how the model simulates annual allocation of New Melones water supplies based on a Mar-Sep inflow forecast that's perfectly foreseen as the Mar-Sep inflow volume.

Results from the second comparison seemed to suggest that potential bias in seasonal inflow volumes may not be any more significant than potential bias in annual-average inflow. Subjectively, focus was placed on potential bias in the annual volume. It was reasoned that exploring the influence of bias in annual flow volumes would be adequate for addressing the issue of how reservoir inflow uncertainty might affect operations. Subjectively, scaling factors were set at +/-3 percent, which represents a conservative bias interval relative to results from the first comparison.

B.2.3.8 Assumptions – Water Demands in Eastside Tributary Regions: (**Table 1**, Inputs 19 through 21) These inputs were considered with the goal of understanding how aggregate basin demand components from hydrology development affect simulated operations (i.e. consumptive use of applied water (CUAW) determined by both land area and evapotranspiration, deep percolation of applied water [DPAW], and losses). Ultimately, aggregate scaling factors were rationalized and applied to only CUAW inputs. Component-specific assumptions leading up to these aggregate scaling factors are discussed below:

- *CUAW - Land Area*: The base model's land use area assumptions are based on land use information obtained from DWR. It is understood that when DWR conducts land use surveys, gross reported land areas are overestimates of actual planted areas due to the presence of canals, ditches, farm roads, other roads, farmsteads, utilities, et cetera. (DWR, 2000). It is reasonable to assume that the gross reported area is a 5 percent overestimate (*Tom Hawkins, DWR Division of Planning and Local Assistance, personal communication, September 2005*). It was assumed that this same area inflation may have been present in the base model's land area classes analyzed for consumptive use. Therefore, a base assumption setting CUAW scaling factors was that the limits should not represent potential inflation based on land area uncertainty (i.e. 0 % positive scaling) but should consider the land area overestimation potential described above (i.e. 5% negative scaling).

- *CUAW – Evapotranspiration (ET)*: The ET estimates assumed for base model development are those featured in the DWR Consumptive Use models for the Eastside SJR region. Those estimates are disaggregated among 13 crop categories and are based on field measurements from 1967. Development of base model CUAW estimates could have been affected by biased assumptions for crop-specific ET. However, there is inadequate information to suggest whether that was the case. Analysis of bias would require comparison of these estimates with historical data collected within the Eastside San Joaquin region. Such data were not available for this analysis.

- *DPAW*: Development of base model diversion requirements typically featured an assumption that DPAW for Eastside districts equaled 25-30 percent of CUAW. This assumption could have been biased. However, as with ET, there is inadequate evidence to suggest whether that was the case. DPAW variation is linked to irrigation methods and local geology. DWR typically uses estimated DPAW values when computing area water budgets, which for the Eastside San Joaquin have varied depending on boundary area and accounting assumptions (*Mike McGinnis, DWR Watershed Management Section, personal communication, August 2005 and August 2006*).

- *Losses*: Development of base model diversion requirements typically featured an assumption that losses totaled a volume equal to 10 percent of CUAW. Demands development could have been affected by assumed losses prior to irrigation (conveyance) or after (non-recoverable losses). DAU county DWR SJR District's 1999 report indicates an assumption for conveyance and miscellaneous losses of 6 percent (*McGinnis, personal communication, August 2006*). Bulletin 160 reports typical losses for the San Joaquin Region in 1998, 2000 and 2001 that range from 11-13 percent (see California Water Plan Update Bulletin 160-05 San Joaquin River Regional Reports).

Given these four components, one sensitivity analysis approach would have been to scope scenarios where each individual component would be scaled on its own. However, the model structure offers the opportunity to just scale CUAW and implicitly represent scaling of each demand component. This is because model simulates Eastside diversion requirements as a function of CUAW, where the requirement equals CUAW* [1+DPAW factor + loss factor], or [1 + 0.25 to 0.3 for DPAW) + 0.1 for Losses)], or CUAW * 1.35 to 1.4. Given this model structure, the sensitivity of model outputs to scaled CUAW inputs can be used to infer sensitivity to scaled DPAW or losses, even though the latter are not targeted explicitly. For example, scaling CUAW +/- 10 percent is equivalent to alternatively scaling DPAW +/- 40 percent relative to a base DPAW value of 0.25 and Losses +/- 100 percent relative to a base value of 0.1.

Development of scaling factors for CUAW is based on the following set of assumptions:

- CUAW bias: -10 percent to +5 percent, reflecting an assumed ET bias of +/-5 percent and a land area bias of -5 percent to 0 percent

- DPAW: assumed uncertainty of 20-35%*CUAW, representing an expanded range relative to the base model's range of 25-30%*CUAW

- Loss bias: assumed uncertainty of 9-13%*CUAW, representing an assumed range about the base model's nominal value of 10%*CUAW (note: the lower limit on this assumed uncertainty reflects a pre-analysis error assuming the lower limit to be 9 percent rather than 6 percent as mentioned above)

Next, the sum of coefficients was computed, where the sum is used to translate CUAW into diversion requirement (i.e. 1 + DPAW coefficient + loss coefficient):

- Base sum: 1.35 (assuming a DPAW coefficient of 0.25)

- Negatively biased sum: 0.9+0.2+0.09 = 1.19

- Positively biased sum: 1.05+0.35+0.13 = 1.53

Finally, the coefficient sums were used to compute scaling factors. The positive scaling factor equals the ratio of the positively biased sum to the base sum; and, the negative scaling factor equals the ratio of the negatively biased sum to the base sum (i.e. +13% or -12% respectively).

In summary, the sensitivity analysis involved scaling the CUAW time series inputs by these factors, producing results that could infer output sensitivities to each of the demand components mentioned above. Following this scaling approach, it was not necessary to do prior consumptive use modeling and water budget analysis.

B.2.3.9 Assumptions – Merced Basin loss term: (**Table 1**, Input 22) Losses on the Merced River system are modeled differently than those in the Stanislaus and Tuolumne Basins, and therefore warrant different consideration than what was discussed in the previous section. This input was considered with the goal of understanding how a relatively large annual loss assumption in the Merced Basin might affect simulated operations below Newman. There was no information on how the base model's assumed loss amount might be biased over the long-term. Given lack of uncertainty information, scaling factor limits were subjectively set to +/- 20 percent.

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B.2.4 Uncertainty Analysis

The uncertainty analysis focused on translating inputs' uncertainty (**Table 1**) into uncertainties of the various outputs scoped for analysis (**Table 3**, column 3). Several assumptions framed the analysis:

- representation of input uncertainties was constrained to potential long-term input bias could be defined as base input value times a scaling factor (i.e. 1.0 + "Table 1, column 7" percentages expressed as fractions)
- each input's scaling factor is a uniformly distributed random value bounded by the input's assumed limits of variation (**Table 1**, column 7)
- each input's scaling factor can take on any value within its distribution, independent of the other inputs' scaling factor values (more discussion on this assumption of input independence is provided later in this section)

Given these assumptions, the uncertainty analysis proceeded with a Monte Carlo methodology (Robert et al. 2004), where:

- 10,000 scenarios were generated, each representing a unique set of scaling factors for each of the inputs listed in Table 1. (Note: It was uncertain whether 10,000 would be enough, so the decision was to do as many scenarios as allowed by project budget, deadlines, and access to computing resources. The adequacy of this choice was evaluated post-analysis [discussed in Section B.3.2].)
- inputs data sets (i.e. subset state variable tables, model look-up tables) were generated for each set of scaling factors.
- each input data set (i.e. scenario) was simulated in CalSim SJR; recalibration of the water quality module was performed for each scenario (the need for recalibration is discussed in Section B.2.5).
- output performance metrics were computed for each scenario
- output results were pooled by variable and performance metric to reveal output uncertainty distributions as a function of collective inputs' uncertainty.

Generating "scaling factor sets" involved developing a matrix of random probabilities, each sampled from a uniform distribution between 0 and 1. These probabilities were treated as lookup cumulative probabilities in respective inputs' scaling factor distributions in order to get an associated scaling factor value.

<u>B.2.4.1 Distributional Assumptions</u>: There was not adequate information to suggest how input scaling factors should vary within limits of variation for any of the parameters investigated. Uniform distributions were assumed, which appears to be a conservative assumption for the

purpose of characterizing output uncertainty intervals. Choosing a uniform distribution rather than a centrally biased distribution (e.g., triangular, Normal) leads to greater output uncertainty estimated by the Monte Carlo analysis because equal probability is assigned to any scaling factor value within its limits of variation.

B.2.4.2 Assumptions on Inputs Independence: Input scaling factor distributions were treated as mutually exclusive. Rationale for this approach is discussed on an input-specific basis below. In summary, this assumption is mostly acceptable resulting in a conservative estimate of uncertainty, although there may be some rationale for dependence of inputs, this was not investigated and was left for future examination:

- Source Salt Loads (**Table 1**, Inputs 1-2 and 5-7): These are meant to represent source-specific characteristics and are not dependent on other inputs.

- Salt Load Residual Time Series (**Table 1**, Inputs 3-4): The scaling of the calibration curves that determine these residuals can be treated independently of other input changes. However, the salt-load residuals themselves are dependent on changes to these curves and to other inputs describing basin hydrology and salinity. This dependency on input changes is addressed through recalculation of the salt-load residuals for each scenario. This is appropriate because each scenario represents a recast “existing condition.” Section 2.4.1 provides discussion on the procedure for determining load residuals.

- Accretions (**Table 1**, Inputs 8-12): The scaling of accretions would be interdependent if the scaling factors were thought to represent long-term gage bias (which would affect both upstream and downstream accretion calculations). However, this was not the assumption behind the scaling factors. Long-term gage bias is assumed to be a relatively minor factor in the accretion calculation relative to potential bias introduced by assumptions on historical diversions and returns. Given this perspective, accretions were scaled independently and meant to represent reach-specific bias in assumed historical diversions.

- Minimum Groundwater Pumping (**Table 1**, Inputs 13-15): These are meant to represent district supply management practices and are not dependent on other assumptions.

- Reservoir Inflow (**Table 1**, Inputs 16-18): These inputs are not dependent on downstream assumptions.

- Basin Demand Inputs (**Table 1**, Inputs 19-21): These tributary-specific inputs are independent on a tributary-specific basis (except potentially for assumed bias in land areas assumed for Eastside CUAW analyses). There are no obvious relations between demand inputs and the other inputs of **Table 1**.

- Merced Loss Term (**Table 1**, Input 22): This term may be related to the assumed Merced Basin demands through simulated diversion requirement. However, dependencies between these two inputs were not considered in the analysis.

B.2.5 Computational Issues and Automation Tools

Analytically, the methods are straight forward. Computationally, there were several challenges associated with generating the large number of scenario input sets, simulating each scenario, and analyzing results. Challenges included: scenario-specific simulation handling (managing run-time errors), scenario-specific data handling (creating input files, extracting output subsets), and scenario-driven load-closure recalculation. This latter issue motivated development of a scenario-specific automation module, which is the first of two automation tools that were essential in completing the analysis.

B.2.5.1 Salt-Load Residual Computation: A change to any of the **Table 1** inputs affects the model's water quality module calibration. The module is intended to simulate flow-salinity relations that are consistent with recent historical observations at Newman and Maze (Reclamation 2004). This is accomplished by identifying load residuals in an "existing condition" simulation where upstream simulated loads are compared to instream expected loads defined by simulated flow and observed flow-salinity relationships. Changing any of the inputs in **Table 1** will either affect the loads entering the water quality module domain above each control point (Newman or Maze), or the observed flow-salinity relationships that help define instream expected load. Thus, the load residual calculations must be revisited for each input scenario.

Table 4 outlines the procedure for computing load closure time series (Reclamation 2004). Steps and information flow are illustrated on **Figure 7**.

- Step 1 involves selection of inputs representing an existing condition and setting the load residuals to zero.

- Step 2 follows with simulation of the base model given these inputs and no load residuals.

- Step 3 involves identifying the difference between the simulated perimeter load above Newman and instream expected load at Newman based on (i) simulated SJR flow at Newman and (ii) post-1999 observations describing seasonal flow-salinity relationships (Reclamation 2004). The latter is defined by three seasonal flow-salinity regression curves (i.e. Input 3, **Table 1**) illustrated on **Figure 5** (e.g., solid lines). The difference between instream expected load and simulated perimeter load above Newman is treated as an "Above Newman" load residual and introduced into the model as a residual time series with distributed entry at the Newman and Mud/Salt Slough nodes. Introduction of these load residuals is analogous to introducing stream accretion time series at various locations in the model, each representing "flow closure" terms.

- Step 4 involves a second simulation, this time with the "Above Newman" load residual introduced.

- Step 5 is similar to Step 3, and involves identifying the difference between the simulated perimeter load from Newman to Maze and the instream expected load at Maze. Step 5 relies on use of six seasonal flow-salinity regression curves based on post-1997 observations at Maze (Reclamation 2004) illustrated on **Figures 6a-b** (e.g., solid lines). The difference between expected load and simulated load is treated as a "Between Newman and Maze" load residual and introduced into the model at the Tuolumne and Maze nodes.

- At the end of Step 5, Maze load residuals from prior to Step 2 and after Step 5 are compared. The maximum single-month change in Maze load is identified. If this maximum change exceeds 10,000 (representing a load of 1000 cfs * 10 µS/cm) then the procedure iterates back to Step 2 and continues. If this change is less than 10,000 in magnitude, then the procedure proceeds below.

- Step 6 involves a final simulation, introducing the last update to the "Between Newman and Maze" load residual.

Given the need to consider many scenarios of input adjustment, manual execution of the load closure procedure was not feasible. As a result, an automation module (**Figure 8**) was developed to manipulate the various software applications and files illustrated in **Figure 7**. Development of the module is described in Attachment B1. Control of data handling and software control occurs at each of the steps is shown on **Figure 8**. Use of the module resulted in faster completion time, removal of need to supervise the process, and more reliable data-handling.

B.2.5.2 Scenario Development, Management, and Analysis: Scenario-development involved producing scenario-specific input sets that included a subset of CALSIM II state variables, listed in **Table 1** column 5, and a collection of look-up tables identified in **Table 1**, column 6. Confining the input changes to only modified look-up tables and state variable data allowed for the base model's executable file to *not* have to be recompiled for each input scenario. If input changes had involved change to WRESL logic, then recompilation would have been necessary, adding complexity to the analysis.

Scenario-development was completed using Matlab (http://www.mathworks.com). Scripts were written to first generate scenario-specific sampling probabilities, scenario-specific scaling factors, and ultimately use of scaling factors to generate formatted look-up tables with adjusted inputs and state variable data blocks. The latter were read into the model's state variable file using an interface developed for this analysis (Attachment B1).

Scenario execution and management was performed using a second automation tool (**Figure 9**). This tool involved customized client-server applications and the use of distributed computing. Development of these applications is highlighted below; more information is provided in Attachment B1.

- The client application wraps around the automation module (**Figure 8**) and controls the running of scenarios (sensitivity and uncertainty analysis). The client also communicates with the server through a server-side daemon program to client-driven file-transfer protocol (FTP) activity involving transmission of input and output data. The client application also included the capability of allocating scenario "jobs" to individual machine processors, taking advantage of parallel computing capabilities on PCs with multiple processors. So although the client application was installed on a network of 12 PCs, the presence of multiple processors on each machine transformed the network of 12 PCs into 42 clients.

- The server application includes an FTP server and continuously running study daemon that enables client communication with the server through FTP activity. Server-side application also included output organization to generated output-specific "all-scenarios" data files for ensemble analysis (e.g., New Melones Storage results for all scenarios, simulation periods by rows, scenarios by columns). These latter files were read into Matlab for performance metric analysis and generation of output graphics.

B.3 RESULTS

B.3.1 Sensitivities

B.3.1.1 Results Presentation: One standard graphic (**Figure 10**) was produced to show period-specific performance changes from base. Each graphic summarized performance sensitivities for up to three output variables relative to all scoped inputs. The 29 analyzed inputs are labeled along the vertical axis (consistent with labels listed in **Table 1**, column 2). The left panel shows output response to positive input scaling (inflated input). The right panel shows output response to negative input scaling (deflated input). The **Figure 10** example shows three SJR flow responses (at Vernalis, Maze and Newman).

Following each variable's line vertically among the inputs reveals which inputs are relatively more influential on that output's performance (indicated by greater departure from zero). In **Figure 10**, it would be reasoned that the most influential inputs on Maze flows (green lines) were inputs describing Tuolumne Basin demand and mainstem SJR accretion between Newman and Maze.

A table of performance sensitivity intervals was produced for each output variable in **Table 3**, column 3, but for only a single metric of each variable (mean annual sum for flow variables, and mean end-of-September for storage and salinity variables). An example is shown for Vernalis Flow on **Figure 11**. The tables include a header describing measured output (e.g., variable, description, metric, units, averaging period, and metric's base value by averaging period). Below that is a section on performance sensitivity intervals related to changes in all inputs for all averaging periods.

B.3.1.2 Library of Results: A total of 240 standard graphics and 30 intervals tables were produced and catalogued for review in an HTML Viewer, released in association with this report (**Figure 12**). The viewer features a collapsible menu of graphics and tables in the left panel, and viewing area to the right.

B.3.1.3 Key Messages: In an attempt to distill the collection of analysis results into key messages, this section discusses results in a categorical sense. The idea is that these messages might be used to guide future data and model development efforts. Analyzed outputs were categorized into four categories:

(1) an Eastside Storage category representing simulated storage at New Melones, New Don Pedro, and Exchequer,

(2) a Goodwin Release category representing simulated releases for water quality objective at Vernalis, dissolved oxygen at Ripon, VAMP, and the Bay-Delta flow objective at Vernalis,

(3) a SJR/Stanislaus River category (SJR/Stan) representing simulated flow and salinity results at Vernalis, Maze, Newman, Tuolumne confluence, Stanislaus confluence, and Ripon, and

(4) a Stanislaus Basin (Stan) Deliveries category representing simulated surface water deliveries to Oakdale Irrigation District, South San Joaquin Irrigation District and CVP Contractors (Stockton East Water District and Central San Joaquin Water Conservation District).

For each output, the "most influential input" was identified based on the output having the greatest performance response interval relative to changes in the given input. Then, by output category, the frequency of each input being the "most influential" was tallied. This exercise was repeated for three of the averaging periods: WY1922-2003 (All Years), SJR Wet years, and SJR Critical years. Results are shown graphically (**Figures 13-15**, respectively). The following impressions are based on review of these figures:

- Eastside storage results seem most influenced by their respective tributary's basin demands. More certain demand estimates will likely lead to more certain storage simulation on a tributary basis.

- River flow results seem most influenced by assumed accretions during drier years. However, during periods that include wetter years, river flow results seem most influenced by a combination of assumed accretions and upstream demands. It seems that a more certain flow simulation might be accomplished for all years by focusing on reducing uncertainty in the accretion estimates, perhaps through expanded data collection that supports SJR accretion analysis.

- River salinity results along the mainstem SJR were influenced differently than the Stanislaus River salinity results at Ripon. Although not revealed by the figure, review of associated variable-specific results (Section 3.1.2, using the HTML Viewer) shows that the SJR solutions were all most influenced by calibration curves affecting salt-load residual computation. The Stanislaus solution at Ripon was most influenced by the qualities of Goodwin Release and basin accretions/returns. Focusing on SJR salinity results, it appears that more certain solutions could be accomplished by reducing the uncertainties of the calibration-curves. However, such uncertainty reductions can only develop slowly, as years pass and more flow-salinity monitoring is completed in the river and at upstream salt sources. Another potential avenue of improvement would involve sustained expansion of SJR flow-salinity monitoring above Maze at locations other than Maze and Newman. Doing so would offer the opportunity to introduce additional "control" relationships and calibration points for the water quality module.

- Stanislaus deliveries results seem most influenced by the assumed New Melones inflow and Stanislaus Basin demands. However, such results are also sensitive to the assumed operational strategy at New Melones, which was not scoped for adjustment in this sensitivity analysis.

- Goodwin Release results were affected by a variety of "most influential" input types, contrasting from the other output categories that seemed most influenced by one or two input types. For Goodwin Release, the mix of influential inputs includes: New Melones inflow, Stanislaus Basin demand, various above-Maze accretions, and salt load calibration curves at Maze. The latter two inputs have already been mentioned as input areas where uncertainty reductions might lead to more precise solutions in other output areas. Reducing uncertainties of Goodwin Releases would seem to be an additional benefit from such activities. Beyond these inputs, it is also understood that the assumed operational strategy at New Melones is very influential on Goodwin Release results.

B.3.1.4 Miscellaneous Findings: The following judgments are based on review of graphics contained in the Viewer discussed in Section B.3.1.2.

- Eastside hydrologic inputs, minimum groundwater pumping, demand, and reservoir inflow exert relatively small influence on mainstem EC solutions (e.g., graphics for SJR Critical years ("Figs_YTavg5") named "Salinity*"). This seems to be an artifact of the water quality module calibration. The module is calibrated so that the model's simulated flow-salinity relations at Newman and Maze is consistent with calibration-curves (**Figures 5, 6a-b**). At the simulated flow rates, the curves tend to show higher river salinity than what can be accounted for by upstream simulated loadings (including those arriving from Eastside tributaries). Thus, changes in Eastside flow results associated with pumping, demands, and inflows tend to cause changes in salt-load residuals at Maze and Newman, but not in EC solutions from Maze downstream. (Note: this statement only holds true for recasting a *base case* that reflects input adjustments and involves load residual recalibration. Application of this recast model to study eastside operational scenarios would not involve load-residual recalibration, and eastside flow changes would certainly affect below Maze EC).

- Source loads had a relatively small influence on mainstem EC solutions compared to the influence of Maze flow-salinity calibration curves (e.g., graphics for SJR Critical years ("Figs_YTavg5") named "Salinity*").

- Minimum groundwater pumping has some influence on upstream storage, but little influence on mainstem EC or Goodwin release (e.g., graphics named "CarryoverStorage_NM*", "ReleaseGoodwin*" and "Salinity*").

- Newman calibration curves for flow-salinity relations influence the EC solution at Newman, but have little influence on the solutions below Newman. This is because balance of expected Maze load (determined by Maze flow-salinity calibration curves) minus perimeter loads entering the module between Newman and Maze happens to consistently be an unexplained load at Maze (i.e. identified as the salt load residual), regardless of the amount of scaling considered for the Newman calibration-curves.

- Input uncertainties below Newman do not affect output results upstream of Newman (e.g., graphics named "CarryoverStorage_East*"). In other words, storage outputs above Newman are insensitive to any of the input changes considered in this sensitivity analysis and therefore, were not considered further in the uncertainty analysis.

- Annual Goodwin release volumes for Ripon dissolved oxygen (DO) and Vernalis water quality (WQ) sometimes responded *in-phase* to a change in input. At first review, this seemed counter-intuitive. For example, consider the positive-scaling scenario "calibEC_Maze_FebMar" for "Figs_1922_2003avg." This scenario forces more saline conditions at Maze at given flow rates, leading to greater likelihood for necessary Goodwin WQ release. Annually, results show that this occurs: average October-September WQ release was +16.4 TAF relative to base. Coincidentally, annual Goodwin DO release was +5.81 TAF relative to base. In the model structure, monthly DO releases during June-September are forced not to exceed monthly amounts, less any WQ release already scheduled. This means that if WQ release increases during June-September, then associated DO releases will decrease. Considering the annual responses of WQ and DO releases, the result can be understood if the sensitivities are evaluated on a monthly basis (results not shown). All of the DO response for this scenario occurred during the Jun-Sep season, as determined by model structure. The WQ release response happened to be -4.0 TAF for the Jun-Sep season (increase in other months plus this decrease during Jun-Sep led to the *net* annual change of +16.4 TAF). Also, the response associated with other Goodwin releases independent of WQ, DO, and MIN happened to be -2.7 TAF for the Jun-Sep season. Thus, the total flow change prior to DO release during the Jun-Sep season averaged -6.7 TAF, which approximately accounts for the DO response mentioned above (+5.8 TAF).

B.3.2 Uncertainty Analyses

B.3.2.1 Results Presentation: A set of graphics were produced for each of the outputs marked for analysis in Table 3 (plus some additional outputs from Table 3). Each graphic type illustrates uncertainty in a unique way:

- *Type (1) Time-Evolving Uncertainty, Absolute Results*: The purpose of this graphic was to show the base model's time series results, and an overlay of uncertainty showing how it evolves during the simulation (e.g., **Figure 16**). The overlay of uncertainty results includes 10,000 scenario-specific time series, as analyzed in the Monte Carlo procedure. For flow-related variables, the graphic shows an annual sum time series. For storage and salinity-related variables, the graphic shows a monthly time series.

- *Type (2) Time Evolving Uncertainty Intervals, Changes from Base*: The purpose of this graphic was to show time-changing intervals information embedded in the uncertainty band illustrated in graphic Type (1). First, a WY1922-2003 "difference" time series (scenario minus base) was computed for each of the 10,000 scenarios. Then at each stage in the time series, the ensemble of 10,000 difference values was sorted and sampled at threshold exceedence probabilities (**Figure 17**). Threshold exceedence probabilities are selected to show a median scenario minus base, 50 percent uncertainty interval (75% to 25% exceedence), 80 percent uncertainty interval (90% to 10% exceedence), and full range of uncertainty (minimum to maximum differences). As with Type (1), for flow-related variables the graphic shows an annual sum time series. For storage and salinity-related variables, the graphic shows a monthly time series.

- *Type (3) Performance Metric Uncertainty – Monthly Absolute Results*: The purpose of this graphic (and the next three) is to show uncertainties of output performance metrics that are frequently used to describe CalSim II output for long-term planning efforts. This graphic type (and the next three) was repeated for each of the eight averaging periods discussed in the Sensitivity Analysis. One example graphic Type (3) is shown on **Figure 18,** for averaging period WY1922-2003. The uncertainty of monthly mean values is displayed using a collection of monthly box plots. For each month, the blue box indicates the 50 percent confidence interval on the monthly mean (i.e. interquartile range, or 75% to 25% exceedence range). The red line through the blue box plot shows the median value for monthly mean among the 10,000 scenarios analyzed. Red symbols above and below the blue box indicate scenarios that produced monthly mean values outside the interquartile range. Green markers (upward and downward triangles, respectively) indicate 10 percent and 90 percent exceedence values for monthly mean among the 10,000 scenarios analyzed.

- *Type (4) Performance Metric Uncertainty – Annual Absolute Results*: Similar to (3), but for annual mean rather than monthly mean (e.g., **Figure 19**).

- *Type (5) Performance Metric Uncertainty – Monthly Change from Base*: Similar to (3), but for "difference" results on monthly mean (i.e. scenario monthly mean minus base monthly mean) (e.g., **Figure 20**).

- *Type (6) Performance Metric Uncertainty – Annual Change from Base*: Similar to (5), but for annual rather than monthly "difference" (e.g., **Figure 21**).

- *Type (7) Verification of Uncertainty Convergence*: The purpose of this final graphic type was to inform whether the Monte Carlo analysis achieved "convergence" in characterizing the performance metric uncertainty distributions. Data for this graphic were developed by considering the uncertainty distribution of a "critical metric" as it evolves with completion of more scenarios during the Monte Carlo analysis (e.g., **Figure 22**). For flow- and salinity-related variables, the "critical metric" was the monthly mean "difference" for July (e.g., July result from graphic Type (5)), where monthly mean was computed for only the SJR 60-20-20 Critical years averaging period. For storage-related variables, the "critical metric" was the mean end-of-September "difference," also averaged during the SJR 60-20-20 Critical years.

<u>B.3.2.2 Library of Results</u>: Given the eight averaging periods considered, a total of 35 graphics were generated for 53 model output variables (1 each for graphic types 1, 2, and 7; and 8 each for graphic types 3-6). These graphics were catalogued in an HTML Viewer (**Figure 23**) similar to that produced for the Sensitivity Analysis. Graphics are organized by figure type, but with types 3-6 expanded to indicate averaging period represented by the metrics. This resulted in 35 Viewer Graphics per output variable:

- Fig01 = Type (1)
- Fig02 = Type (2)
- Fig03-Fig06 = Types (3)-(6) for the WY1922-2003 averaging period
- Fig07-Fig10 = Types (3)-(6) for the WY1928-1934 averaging period
- Fig11-Fig14 = Types (3)-(6) for the WY1987-1992 averaging period
- Fig15-Fig18 = Types (3)-(6) for the SJR 60-20-20 Wet Years group
- Fig19-Fig22 = Types (3)-(6) for the SJR 60-20-20 Above Normal Years group
- Fig23-Fig26 = Types (3)-(6) for the SJR 60-20-20 Below Normal Years group
- Fig27-Fig30 = Types (3)-(6) for the SJR 60-20-20 Dry Years group
- Fig31-Fig34 = Types (3)-(6) for the SJR 60-20-20 Critical Years group
- Fig35 = Type (7)

<u>B.3.2.3 Messages</u>: The purpose of the Viewer is to provide a catalog of uncertainty information on the base model, consistent with the requests from peer review (Section B.1). These results might be used by decision-makers to better understand the uncertainties of base model error, and potential provide context for CalSim II usage in planning scenarios. The reader is invited to evaluate Viewer results on specific output metrics and draw impressions on the significance of base model uncertainty. To supplement that evaluation, the following observations are offered:

- Uncertainty accumulation during simulation is most apparent among the storage variables. Storage uncertainty tends to accumulate during drier periods, especially during the early and late droughts (WY1928-1934 and WY1987-1992). Accumulated uncertainty gets erased from the system during wetter years when reservoirs fill.

- Uncertainty is generally greatest during drier periods for Goodwin releases in support of water quality at Vernalis (WQ), dissolved oxygen at Ripon (DO) and VAMP. The uncertainties of these release components are dependent. Comparison of Type (1) graphics for each individual component with the Type (1) graphic on the sum of these release components shows that the uncertainties of each component are somewhat offsetting.

- For river flow variables, uncertainty is generally greatest during wetter periods.

- For river salinity variables, uncertainty is generally greater during drier periods (particularly for monthly performance metrics).

- On the matter of uncertainty convergence, it appears that 10,000 scenarios was more than enough to characterize CalSim II SJR output uncertainty relative to the scoped set of inputs. Considering Type (7) graphics in the Viewer (i.e. directory Fig35_Uncertainty_RelationToNumberOfScenarios), it appears that 1000 to 2000 scenarios would have been sufficient to characterize uncertainty in this analysis.

B.4 DISCUSSION

B.4.1 Limitations

Results from these analyses provide reasonable descriptions of model error as long as several key assumptions are true:

1. The set of model inputs considered in this analysis (**Table 1**) represent most of the collective influence on model output.

2. Output uncertainty is dominantly affected by long-term potential bias in inputs rather than year- or period-specific bias.

3. Assumed limits of potential input bias are valid (Table 1, column 7).

4. Assumed uniform distributions describing potential input bias within assumed limits are valid.

5. Assumption that inputs’ potential biases can independently take on random values within distributions is valid.

The adequacy of assumption (1) is difficult to evaluate because a comprehensive uncertainty analysis involving adjustment to all inputs was not conducted. However, the inputs in this analysis were thoughtfully selected to represent a range of input types within the CalSim II SJR model. Thought was also given toward selecting inputs that seem to introduce dominant amounts of flow or salt load to the model domain.

Assumption (2) represents a philosophy on how to relate aspects of input uncertainty to output uncertainty. Focus was placed on long-term (i.e. "simulation period") bias in input values rather than a combination of this bias and interannual "noise" about the bias. In other words, uncertainty scenarios considered x% changes in input values where x is fixed, rather than (x+y(t))% changes in input where y varies during the simulation.

The latter method might be an appropriate approach for uncertainty analysis if the goal is to precisely quantify uncertainty at a specific stage during simulation. However, the goal of this analysis was to place emphasis on estimating the uncertainty of output performance averaged during a period of simulation years or for the entire simulation period. It is understood that the time-varying component of input bias will produce offsetting model output errors that are somewhat offsetting when evaluating average output performance.

Assumption (3) is arguably the most significant and uncertain assumption in the analysis. Ideally, there would be data available on potential input bias to guide setting of scaling factor limits. Such data were used where possible. However, many of the inputs listed in Table 1 were scaled at subjectively chosen limits due to lack of uncertainty information.

Assumption (4) is arguably a conservative assumption in the analysis that serves to maximize characterization of output uncertainty relative to Assumptions (1)-(3). This is because inputs are allowed to take on any value within their assumed scaling factor limits with equal probability. If the true distributions within scaling factor limits are more centrally oriented (e.g., triangular or Normal in shape), then the Monte Carlo scenarios would feature input values that more frequently take on central values within their distributions. This would result in scenario output that's frequently more similar to base results and the distributions shown on uncertainty graphics (Types (2)-(7)) would feature reduced 50 percent and 80 percent intervals.

Assumption (5) seems to be mostly reasonable, particularly because salt load residuals were recomputed for each recast input scenario. One potential exception involves the Merced Special Loss input (Section B.2.3.9), which may be dependent on Merced Basin demand inputs. However, sensitivity analyses revealed that downstream outputs were largely insensitive to changes in the Merced Special Loss term. This suggests if Assumption (5) were not valid for the Merced Special Loss term, its lack of influence relative to the other inputs probably prevented it from significantly affecting uncertainty analysis results.

B.4.2 Utility of Sensitivity Results in Model and Data Development Planning

Results from the analyses generally confirm intuitive data collection priorities prior to conducting the sensitivity analysis. It appears that a majority of the model outputs considered in this analysis could be made more certain if it were possible to reduce uncertainty in three input areas:

- calibration curves for salt-load residual calculation

- accretions above Maze (in the tributaries and along the mainstem)

- Eastside tributary demands

Reduced uncertainty in each of these areas could be achieved either through improved model representation or improved observations that support calibration of these representations. It is speculated that the adequacy of model representations are less of a factor than the availability of data to support calibration. It would be beneficial to CalSim II model improvement planning if future data collection efforts could target variables that might improve knowledge in each of these areas. Among these three areas, it is suggested that co-located flow-salinity data collection at multiple locations along the mainstem SJR should be promoted (as mentioned in Section B.3.1).

Results are most beneficial for understanding model performance for the purpose of strategizing improved precision in specific output areas. From the perspective of providing decision-makers with information on model uncertainty, the sensitivity analysis exercise was useful in terms of exploring and documenting input uncertainty. However, the results are not useful in the discussion of output uncertainty. For those discussions, uncertainty analysis results should be referenced.

B.4.3 Utility of Uncertainty Results for Decision-Making

The uncertainty analysis represents a first step towards potentially introducing risk-based decision-making concepts into long-term planning efforts supported by CalSim II. That said, this analysis was only a base model "existing condition" uncertainty assessment and does not enable risk-based decision-making on its own. Several questions have to first be addressed:

- What are the parallel output uncertainties of a "future base" model at some projected level of development, or of "future alternative" versions of the model (e.g., as what might be developed for a NEPA/CEQA process)?

- For a "future alternative" version of the model, what are the uncertainties of new inputs and how do these uncertainties interact with those of the "future base" model to affect "future alternative" output uncertainty?

- For known uncertainties of "existing condition," "future base," and "future alternative" models, how should we measure differences between model results? (e.g., for effects analysis for NEPA/CEQA actions, or for baseline comparisons in Endangered Species Act (ESA) consultations) Should we focus on change in median metric conditions (e.g., from graphic Types (5) or (6) in Section B.3.2.1), or change in metric conditions sample at some probability threshold in its uncertainty distribution?

- What role do decision-maker risk values play in answering the previous question?

By itself, the analysis led to two potential beneficial outcomes. First, the results products serve as examples of how to potentially regard CalSim II uncertainty in long-term planning efforts (e.g., uncertain "blurred" baselines rather than certain "single-trace" baselines). Second, the automation tools used to complete these analyses can be readily applied to explore other versions of CalSim II SJR or the full-system CalSim II model, should planning groups request such information.

It is speculative to say whether uncertainty information will eventually be (or should be) considered in long-term planning analyses involving CalSim II. This is ultimately a values question where the answer will vary among planning groups and stakeholders. As this question is vetted, two thoughts are proposed for consideration:

- It is not certain that information on collective uncertainty (i.e. the uncertainty introduced by the complete set of model inputs translated into model output uncertainty) would affect decision-making in a given environmental document. Decisions would only be affected if the distribution of output uncertainties change between planning alternatives or baselines relative to where the distributions are being sampled for measuring alternatives' differences (e.g., we're sampling 90% exceedence values in metric distributions, and the alternatives' distributions tend to differ in terms of shape, bandwidth, skew, et cetera). If distributions do not differ in shape between alternatives, then knowing the uncertainty does not affect measurement of differences, regardless of the risk-based threshold considered.

- Rather than focus on collective uncertainty, it may be of interest to address action-specific uncertainty in a planning study, where the uncertainties associated with introduced inputs (related to a specific action) are estimated and translated into model output uncertainty using the Monte Carlo methods presented above. However, the uncertainty of model inputs common to all alternatives or baselines would not be represented in this approach. Framing the exercise in this manner would focus discussion on the uncertainties of proposed actions and alternatives' differences.

B. 5 REFERENCES

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ATTACHMENT B1:
Software Implementation for San Joaquin River Sensitivity/Uncertainty Study

Introduction

As introduced in Appendix B (Section B.2.5), two software tools were developed for this analysis:

- an automation module that controls recomputation of the model's salt load residuals (labeled here as "SJR simulation code"), and
- a scenario management tool that controls distributed execution of the sensitivity and uncertainty analysis simulations by a network of client PCs (labeled here as "client/server code").

Development of each code is discussed in subsequent sections. The SJR simulation code can operate in stand-alone fashion. However, for this analysis, it was embedded into the client application that controls running of scenarios and communication with the server to download study data and upload results. The server application controls input scenario queuing and output result management.

SJR Simulation Code

The SJR simulation code automates the steps salt load residual calculations, as described in Appendix B (Section B.2.5.1). The Python programming language (http://www.python.org) was used to develop the code and manipulate sub-components. Notable sub-components include interfaces to interact with Excel spreadsheets and HEC-DSS databases (**Figure B1-1**).

Excel spreadsheets: The updating of salt-load closure terms was calculated in spreadsheets (steps 3 and 5). Python can access Excel using the COM interface and requires the installation of the 'Python for Windows extensions' on the development platform (http://sourceforge.net/projects/pywin32/). COM extension usage is described at http://www.oreilly.com/catalog/pythonwin32/chapter/ch12.html#49339.

HEC-DSS interface: A Python interface was developed to read and write HEC-DSS databases (steps 1, 3, and 5) as needed to update the salt-load closure terms. This was possible using the ctypes module (http://starship.python.net/crew/theller/ctypes/) to access FORTRAN routines in the HEC-DSS library (hlib42.dll).

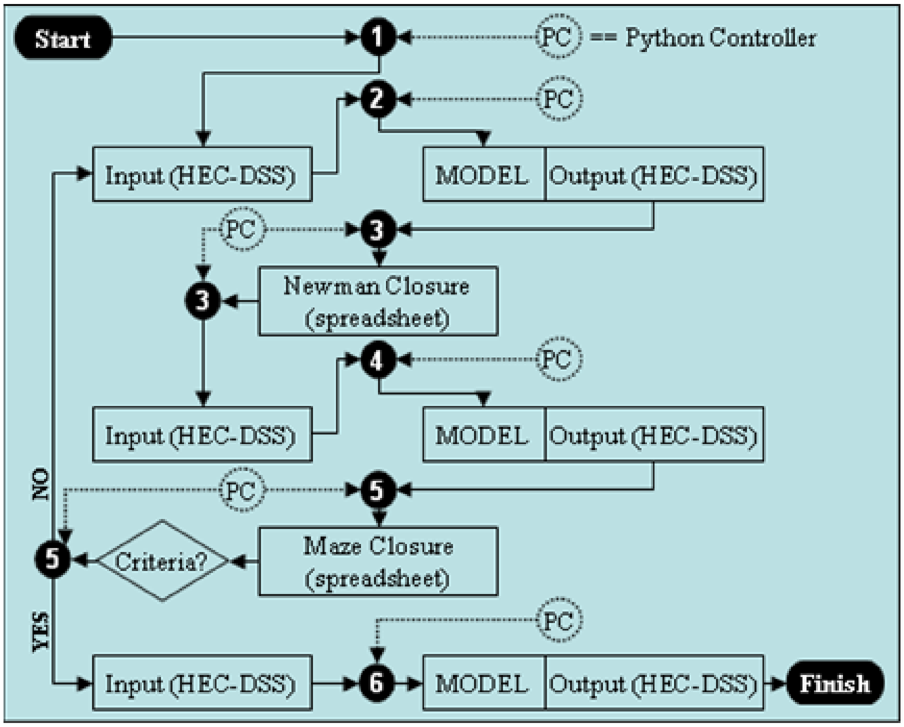


Figure B1-1. Scenario-specific automation elements
(Appendix B, Table 4 steps are numerated with black circles and white text).

Client/Server Implementation

The Python programming language (http://www.python.org) was used to develop the server-side study daemon and client software. The Python client code was converted to executable programs using the py2exe utility (http://www.py2exe.org/) and distributed to the client machines. This alleviated the need to install the Python interpreter and other Python-related software on client machines.

The client application assigns the SJR Simulation Code to run on a separate thread (**Figure B1-1**, steps 2, 4, and 6) to allow detection and recovery from runtime problems. Normally when a problem occurs, the compiled executable (i.e. CalSim II WRESL files compiled as a MS-DOS executable) displays a pop-up window containing a button that must be pressed to end execution. Detection of this condition was achieved by periodically accessing a system process counter and comparing successive values.

Access to the system counter was made possible by using a Windows Management Instrumentation interface (http://timgolden.me.uk/python/wmi.html). This feature became invaluable as some of the client PCs using XA license dongles would occasionally be unable to "find" the USB dongle, which led to this error condition. By monitoring the system processes, the client applications were able to manage this problem without human intervention.

The study server in **Figure B1-2** consists of two parts: a Solaris FTP server and a Python daemon program (study daemon). Since a standard FTP server can only be used to transfer files, the client communicates with the study daemon via file names (see subsequent section on Server File System). The use of the FTP server was chosen to avoid security issues involved in the operation of a server specifically designed to interact directly with clients.

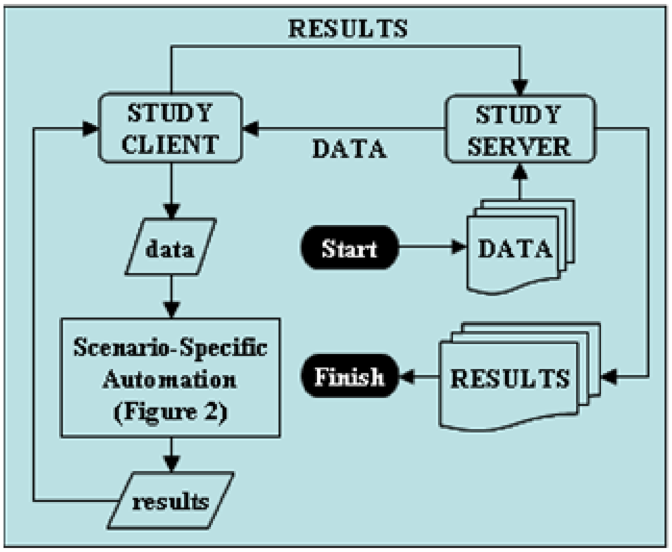


Figure B1-2. Client-Server Concept

<u>Server File System:</u> A directory structure and simple file naming system was devised to allow communication between the client and study daemon. In this scheme, the reading of files is not necessary; the information exchanged between the study daemon and clients is contained in the file name. The exception is that clients read study data once it is downloaded from the server. There are four types of files: archive, handle, job, and label.

```
ftp/
   assign/<user@ip_cnum--study>          (job)
   completed/<user@ip_cnum--study>       (job)
   data/<study>.zip                      (archive)
   delegated/<user@ip_cnum--study>       (job)
   failed/<user@ip_cnum--study>          (job)
   queue/<study>                         (label)
   request/<user@ip_cnum>                (handle)
   results/<study>.zip                   (archive)
   stopped/<user@ip_cnum--study>         (job)
```

Each client has a *handle*, which is in the form user@ip_cnum. Since a machine may run up to four clients, a client number (cnum) is part of the client's *handle*. The user and internet address of the host machine is identified by the client.

Each study has a label *study*, which in this case is a study number (values varied from 0000 to 9999 in the uncertainty analysis and from 000 to 057 in the sensitivity analysis). Files with the name *study* reside under queue/ and represent the studies to be simulated. A job is a study affiliated with a client. It is represented by appending the label *study* to a client *handle*, for example, *handle--study* or user@ip_cnum--study. An *archive* is study data originating on the server or results placed on the server by clients. These file names are always *study*.zip and reside under the data/ and results/ directories.

<u>*Study Daemon:*</u> The study daemon watches for new files that have been placed by clients (**Table B1-1**, steps 1 and 6). Actions taken by the daemon include assigning *jobs* to clients and re-queue of stopped or failed *jobs* (**Table B1-1**, steps 2, 3, and 6). The daemon also records its activity in a log. Additional information can be obtaining by simply viewing/processing the current state of the file system.

<u>*Client:*</u> All communication with the server is via FTP using Python's ftp module. A client initiates a study request by placing a file with the name of its *handle* in the request/ directory. The client watches for a *job* in the assign/ directory. Then retrieves/processes the *study* data and runs the study (**Table B1-1**, steps 3-6). The status of the run is reported to the server and, if the run is successful, results are uploaded (**Table B1-1**, steps 7 and 8).

Table B1-1. Server/Client procedure and roles

Step	**File**	**Study Daemon**	**Client**
1. Request	request/*handle*	Detect request; delete request/*handle*	Initiate request; watch for *job* assignment
2. Queue	queue/*study*	Get the next *study*; remove queue/*study*	
3. Assign	assign/*job*	Place *job* assignment with next *study*	Detect *job* assignment; parse *study* from name
4. Data	data/*study*.zip		Retrieve *study*.zip; remove assign/*job*
5. Delegate	delegated/*job*		Place *job* as delegated
6. Run			Run simulation using data in *study*.zip
7. Status	completed/*job* stopped/*job* failed/*job*	Detect failed/stopped *jobs* and place queue/*study*	Place status of *job*; if not complete, make new request
8. Results	results/*study*.zip		If completed, send results to server; make new request.

Table 1: Inputs adjusted during Sensitivity Analysis

Input Description	Abbreviation	Num.	Error from:	Model Variable to Adjust	Location in Model Files	Assumed Scaling Factor Limits	Dependent on which other inputs?
Salt Loads above Maze							
Salt Load Source: San Luis Drain (Grasslands Bypass)	SrcEC, San Luis Drain	1	flow	SLDR_614	SLDR.table	+/-20%	None
Salt Load Source: Westside Returns through Mud/Salt Slough from Refuge and Exchange Contractor Operations	SrcFlow, Mud/Salt West Returns	2	quality	EC_SWR642, EC_SWR648	SV.DSS database	+/-20%	None
Salt Load Residual Time Series: Above Newman	calib_EC_Nwmn_AugNov, calib_EC_Nwmn_DecMar, calib_EC_Nwmn_AprJul	3	quality as f(flow)	Regression Line-Fit	Excel Workbook	+10%, -15% (1) +15%, -15% +10%, -10%	Primarly 1 and 2; all others to a lesser degree through VAMP relation to load-closure
Salt Load Residual Time Series: Newman to Maze	calib_EC_Maze_OctDec, calib_EC_Maze_DecJan, calib_EC_Maze_FebMar, calib_EC_Maze_AprMay, calib_EC_Maze_JunJul, calib_EC_Maze_AugSep	4	quality as f(flow)	Regression Line-Fit	Excel Workbook	+10%, -10% (1) +10%, -10% +10%, -10% +15%, -15% +10%, -10% +10%, -10%	Primarily Nums. 1-3, 8-12, 14-15, 17-18, and 20-22; all others to a lesser degree through VAMP relation to load-closure
Salt Loads below Maze							
Salinity of Goodwin Release	SrcEC, Goodwin Release	5	quality	EC_Goodwin	EC_Table_Stan.table	+/-10%	None
Salinity of Stanislaus Basin Drainage Returns and Accretions	SrcEC, Stan Rtn and Accr.	6	quality	EC_Stan_Accr, EC_Stan_Return, EC_Stan_Rip_Rtn	EC_Table_Stan.table	+/-10%	None
Salinity of Non-Project Drainage Returns near Stanislaus/San Joaquin confluence	SrcEC, NPRtn Qual	7	quality	EC_NPR602, EC_NPR603, EC_NPR604, EC_NPR605	SV.DSS database	+/-20%	None
Eastside Hydrology							
Accretion: Merced County Stream Group	Accretion, MercStrmGrp	8	flow	I589	SV.DSS database	+/-20%	None given unbiased long-term gage data
Accretion: LaGrange to Modesto	Accretion, LaGr2Mod	9	flow	I545	SV.DSS database	+/-20%	None given unbiased long-term gage data
Accretion: Crocker-Huffman to Cressey	Accretion, Croc2Cres	10	flow	I562	SV.DSS database	+/-20%	None given unbiased long-term gage data
Accretion: Goodwin to Ripon	Accretion, Gdwn2Rip	11	flow	I528	SV.DSS database	+/-20%	None given unbiased long-term gage data
Accretion: Newman to Maze	Accretion, Nwmn2Maze	12	flow	I636	SV.DSS database	+/-20%	None given unbiased long-term gage data
Groundwater Pumping: Minimum monthly pumping amounts (district and non-district), Stanislaus Basin	min GW pumping, Stan	13	flow	GP530_min_prv_limit, GP530_min_pag_limit, GP522_min_prv_limit, GP522_min_pag_limit	SV.DSS database	+/-20%	None
Groundwater Pumping: Minimum monthly pumping amounts (district and non-district), Tuolumne Basin	min GW pumping, Tuol	14	flow	GP532_min_prv_limit, GP532_min_pag_limit, GP548_min_pag_limit, GP548_min_prv_limit	TuolGWPUMP.table	+/-20%	None
Groundwater Pumping: Minimum monthly pumping amounts (district and non-district), Merced Basin	min GW pumping, Merc	15	flow	Merced_surface_demand, annual_GP570_min_pag, annual_GP570_min_prv	Merced_dems.wresl lines 126 & 268 --> new lookup table "MercedTerms.wresl"	+/-20%	None
Reservoir Inflows: Stanislaus River to New Melones	Res. Inflow, Stan	16	flow	I10	SV.DSS database	+/- 3%	None
Reservoir Inflows: Tuolumne River to New Don Pedro	Res. Inflow, Tuol	17	flow	I81	SV.DSS database	+/- 3%	None
Reservoir Inflows: Merced River to Lake McClure	Res. Inflow, Merc	18	flow	I20	SV.DSS database	+/- 3%	None
Water Demand: Stanislaus Basin (consumptive use, losses, deep percolation)	Basin Demand, Stan	19	flow	cuaw_531_pag, cuaw_523OID_pag, cuaw_523SSJ_pag, cuaw_512_pag, cuaw_531_ND	SV.DSS database	+13%, -12%	None
Water Demand: Tuolumne Basin (consumptive use, losses, deep percolation)	Basin Demand, Tuol	20	flow	cuaw_545A_pag, cuaw_549_ND, cuaw_549_pag, cuaw_551_pag, cuaw_533_pag, cuaw_535_pag	SV.DSS database	+13%, -12%	None
Water Demand: Merced Basin (consumptive use, losses, deep percolation)	Basin Demand, Merc	21	flow	cuaw_562A_pag, cuaw_571_pag	SV.DSS database	+13%, -12%	None
Special Loss Assumption: Merced Basin	Loss SpecialMerc	22	flow	Merced_surface_demand, dloss_571_pag	Merced_dems.wresl lines 126 & 268 --> new lookup table "MercedTerms.wresl"	+/-20%	Potentially 21.

Note:
(1) scaling factors were applied to observed EC values at measured flows; scaling magnitudes (positive or negative) were are at least 10%, and possibly larger so that curve-fit is approximately above or below 75% of the plotted observations for positive or negative scaling, respectively

Table 2: Salt Loads (cfs * µS/cm) entering the base WQ Module, below Lander Avenue [1]

Module Nodes [2]	LT Avg	Monthly Average (1922-2003)												
	1922-2003	oct	nov	dec	jan	feb	mar	apr	may	jun	jul	aug	sep	Description
Mud/Salt Slough	4404	2946	3533	4189	4836	4859	5042	4955	4888	5780	5056	3698	3062	Mud/Salt Slough Base Flow
	330394	236676	245040	253323	288249	427592	451641	378769	351149	405984	373740	331688	220879	San Luis Drain (Grasslands Bypass)
	363667	208782	449347	348078	269592	684963	665099	229633	241595	238157	224959	203092	600711	Westside (WS) Returns: Lander Ave
	2510	0	0	0	0	0	0	13064	17051	0	0	0	0	Mendota Pool Exch donation to VAMP
	238926	33014	108210	304155	462916	562315	424107	322507	304957	196383	91712	4788	52051	Residual Load: Abv Newman, half
Merced Confluence (Newman)	73296	52661	53272	64647	87385	107034	83385	86091	92830	93017	73565	51697	33964	Merced River at Mouth
	8639	5146	1186	2217	2736	7754	7274	9656	11264	13783	16762	15794	10096	WS Returns: Newman
	4130	3284	799	0	0	1120	1435	5217	7155	8756	8913	7979	4905	Eastside (ES) Returns: Newman
	238926	33014	108210	304155	462916	562315	424107	322507	304957	196383	91712	4788	52051	Residual Load: Abv Newman, half
	126603	78133	76385	96168	130740	162440	196704	195061	190031	141594	115850	67709	68415	Tuolumne River at Mouth
Tuolumne Confluence	8785	2866	718	920	807	1463	2941	14841	14504	15482	22423	19413	9047	WS Returns: Tuolumne
	514	443	122	157	170	173	183	656	870	907	975	920	592	ES Returns: Tuolumne
	958	1034	77	26	26	100	622	1401	1665	1679	1679	1695	1493	ES Returns: Tuolumne
	13177	37666	4668	0	0	2801	4716	16638	18345	19209	18589	17582	17915	ES Returns: Tuolumne
	31256	11215	632	61	61	1179	23122	46714	50643	70987	75803	56437	38222	Non-Project Returns: Tuolumne
	76284	43933	40304	39466	39139	54045	86847	99680	104725	145107	123882	83443	54837	Salt Load from Tile Drains & GW Base Flow: Tuolumne
	267957	305787	141491	311514	313308	257097	312272	208885	221752	354262	394940	260578	133599	Residual Load: Btw Nwmn and Maze, half
Maze	2926	7582	1121	0	0	459	1470	3715	4462	4034	3904	4273	4096	ES Returns: Maze
	1113	7143	1780	0	0	721	1318	1095	212	0	0	0	1093	ES Returns: Maze
	1	0	12	0	0	0	0	0	0	0	0	0	0	ES Returns: Maze
	9531	5962	4590	4814	5098	8742	11118	12493	12258	16408	14479	10656	7755	Salt Load from Tile Drains & GW Base Flow: Maze Node
	267957	305787	141491	311514	313308	257097	312272	208885	221752	354262	394940	260578	133599	Residual Load: Btw Nwmn and Maze, half
	54727	45649	34061	42688	47678	65447	58703	91804	90456	65496	38962	37680	38095	Goodwin Release
	748	1602	457	0	0	143	599	840	1079	981	949	1216	1115	ES Returns: Stanislaus
	2586	5494	1523	0	0	662	2171	2874	3708	3353	3245	4172	3832	ES Returns: Stanislaus
	1902	4928	729	0	0	298	955	2415	2900	2622	2538	2778	2663	ES Returns: Stanislaus
	39471	56828	48455	42809	49264	61165	29372	27912	26153	40865	32918	27259	30656	Accretions: Goodwin to Ripon
Stanislaus Confluence	6897	7191	7152	8415	10928	10034	7510	5621	7789	4951	5190	4112	3876	Accretions: Maze/Ripon to Vernalis
	4390	11373	1682	0	0	689	2204	5572	6693	6051	5856	6410	6145	ES Returns: Stanislaus/SJR Confluence
	1344	2412	468	0	0	164	676	1415	1913	2774	2791	2069	1450	ES Returns: Stanislaus/SJR Confluence
	1081	690	122	132	148	135	177	1143	2183	2375	2516	2131	1226	ES Returns: Stanislaus/SJR Confluence
	11830	3320	249	26	22	343	7536	17783	19860	27871	29205	21865	13883	Non-Project Returns: Stan/SJR Confluence
Vernalis	0	0	0	0	0	0	0	0	0	0	0	0	0	Non-Project Returns: Vernalis
	1894	425	109	227	140	192	560	3602	3581	3482	4440	4114	1856	WS Returns: Vernalis

Notes

(1) Average annual river load increases by a factor of 10 below Mud/Salt slough. Hence, source-adjustement above Lander Avenue was not considered for Sensitivity Analysis.

(2) See Figure 4.

(3) Loads considered in the Sensitivity Analysis are indicated by shaded rows.

Table 3: Output retained from each Scenario's Simulation

CalSim II Variable	Description	Analyzed?
STANISLAUS BASIN		
C10DO	Release - New Melones - Ripon dissolved oxygen requirement	
C10F	Release - New Melones - flood flow	
C10INSTREAM	Release - New Melones - purchased water from Oakdale Irrigation District	
C10M	Release - New Melones - non-flood flow prior to DO/WQ/VAMP/MIN/INSTREAM	
C10MIN	Release - New Melones - Vernalis flow objective (D1641)	
C10VAMP_M	Release - New Melones - Vernalis Adapt. Mngt. Plan (VAMP), Stanislaus flow	
C10VAMP_T	Release - New Melones - VAMP transfer to Modesto Irrigation District	
C10WQ	Release - New Melones - Vernalis water quality standard	
C520_exc_a	Release - Goodwin - excess flow (non-flood)	
C520DO	Release - Goodwin - Ripon dissolved oxygen requirement	yes
C520F	Release - Goodwin - excess flow (flood)	
C520INSTREAM	Release - Goodwin - purchased water from Oakdale Irrigation District	
C520MIN	Release - Goodwin - Vernalis flow objective (D1641)	yes
C520VAMP	Release - Goodwin - VAMP	yes
C520WQ	Release - Goodwin - Vernalis water quality standard	yes
C528	Flow - Stanislaus River at Mouth	yes
D520A	Deliveries - Stockton East Water District (SEWD), Central San Joaquin WCD	yes
D520A1	Deliveries - Oakdale/South San Jaoquin Irrig. Districts' (OSSJID) sale to SEWD	yes
D520B	Deliveries - Oakdale Irrigation District (North), South San Joaquin Irrigation District	yes
D520C	Deliveries - Oakdale Irrigation District (South)	yes
D523	Depletion - Oakdale Irrigation District (North), South San Joaquin Irrigation District	
D528	Deliveries - Stanislaus River Diversion	
D528A	Depletion - Stanislaus River	
D530_VAMP	Deliveries - VAMP Exchange with NDP Release	
D531	Depletion - Oakdale Irrigation District (South)	
EC_528_final	Salinity - Stanislaus River at Ripon	yes
EC_528_NP_DV	Salinity - Stanislaus River at Ripon - Non-Pulse portion of April-May	
EC_528_P_DV	Salinity - Stanislaus River at Ripon - Pulse portion of April-May	
S10	Storage - New Melones - Stanislaus Basin	yes
TUOLUMNE BASIN		
C545	Flow - Tuolumne River at Mouth	
EC_545_final	Salinity - Tuolumne River at Mouth	
EC_545_NP_DV	Salinity - Tuolumne River at Mouth - Non-Pulse portion of April-May	
EC_545_P_DV	Salinity - Tuolumne River at Mouth - Pulse portion of April-May	
S81	Storage - New Don Pedro - Tuolumne Basin	yes
MERCED BASIN		
C566	Flow - Merced River at Mouth	
EC_566_final	Salinity - Merced River at Mouth	
EC_566_NP_DV	Salinity - Merced River at Mouth - Non-Pulse portion of April-May	
EC_566_P_DV	Salinity - Merced River at Mouth - Pulse portion of April-May	
S20	Storage - Lake McClure - Merced Basin	yes
SAN JOAQUIN RIVER (above the Merced confluence to Millerton Lake)		
C587	Flow - San Joaquin River below Chowchilla River	
C589	Flow - Chowchilla Bypass below Chowchilla River & accretion	
C595	Flow - Chowchilla Bypass blow Fresno River	
C605	Flow - San Joaquin River below Chowchilla Bifurcation, head of bypass	
C607	Flow - San Joaquin River below Mendota Pool	
C608	Flow - San Joaquin River below Sack Dam	
C609	Flow - San Joaquin River below Sand Slough	
C610	Flow - San Joaquin River confluence with Mariposa Bypass	
C611	Flow - San Joaquin River confluence with Eastside Bypass	
C614	Flow - San Joaquin River at Lander Avenue	
EC_587_final	Salinity - San Joaquin River below Chowchilla River	
EC_589_final	Salinity - Chowchilla Bypass below Chowchilla River & accretion	
EC_595_final	Salinity - Chowchilla Bypass blow Fresno River	
EC_605_final	Salinity - San Joaquin River below Chowchilla Bifurcation, head of bypass	
EC_607_final	Salinity - San Joaquin River below Mendota Pool	
EC_608_final	Salinity - San Joaquin River below Sack Dam	
EC_609_final	Salinity - San Joaquin River below Sand Slough	
EC_610_final	Salinity - San Joaquin River confluence with Mariposa Bypass	
EC_611_final	Salinity - San Joaquin River confluence with Eastside Bypass	
EC_614_final	Salinity - San Joaquin River at Lander Avenue	
EC_614_NP_DV	Salinity - San Joaquin River at Lander Avenue - Non-Pulse portion of April-May	
EC_614_P_DV	Salinity - San Joaquin River at Lander Avenue - Pulse portion of April-May	
S18	Storage - Millerton Lake - Upper San Joaquin Basin	yes
S52	Storage - Hensley Lake - Fresno Basin	yes
S53	Storage - Eastman Lake - Chowchilla Basin	yes
SAN JOAQUIN RIVER (below the Merced confluence to Vernalis)		
C620	Flow - San Joaquin River below Merced	yes
C630	Flow - San Joaquin River below Tuolumne	yes
C636	Flow - San Joaquin River at Maze	yes
C637	Flow - San Joaquin River below Stanislaus	yes
C639	Flow - San Joaquin River at Vernalis	yes
EC_620_final	Salinity - San Joaquin River below Merced	yes
EC_620_NP_DV	Salinity - San Joaquin River below Merced - Non-Pulse portion of April-May	
EC_620_P_DV	Salinity - San Joaquin River below Merced - Pulse portion of April-May	
EC_630_final	Salinity - San Joaquin River below Tuolumne	yes
EC_630_NP_DV	Salinity - San Joaquin River below Tuolumne - Non-Pulse portion of April-May	
EC_630_P_DV	Salinity - San Joaquin River below Tuolumne - Pulse portion of April-May	
EC_636_final	Salinity - San Joaquin River at Maze	yes
EC_636_NP_DV	Salinity - San Joaquin River at Maze - Non-Pulse portion of April-May	
EC_636_P_DV	Salinity - San Joaquin River at Maze - Pulse portion of April-May	
EC_637_final	Salinity - San Joaquin River below Stanislaus	yes
EC_637_NP_DV	Salinity - San Joaquin River below Stanislaus - Non-Pulse portion of April-May	
EC_637_P_DV	Salinity - San Joaquin River below Stanislaus - Pulse portion of April-May	
VernWQfinal	Salinity - San Joaquin River at Vernalis	yes
VERNWQNONPULSEDV	Salinity - San Joaquin River at Vernalis - Non-Pulse portion of April-May	
VERNWQPULSEDV	Salinity - San Joaquin River at Vernalis - Pulse portion of April-May	

Table 4. Procedure to identify salt-load closure in SJR WQ Module v1.0

Step	Description
1	Reset Newman and Maze load-closure time series to zero values.
2	Simulate full-period SJR Standalone Module.
3	Compare time series of total source load *upstream of Newman* and expected instream load *at Newman;* latter based on simulated flow and historical monitoring of *Newman* flow-salinity relations; residual difference is updated load closure at *Newman* .
4	Simulate full-period SJR Standalone Module.
5	Same as 3, but comparing time series of total source load *between Newman and Maze* and expected instream load *at Maze;* leads to updated load closure at *Maze* ; iterate from step 2 as necessary
6	Do final simulation of SJR Standalone Module.

Figure 1. San Joaquin River Region, California (Adapted from Ford et al. 2006)

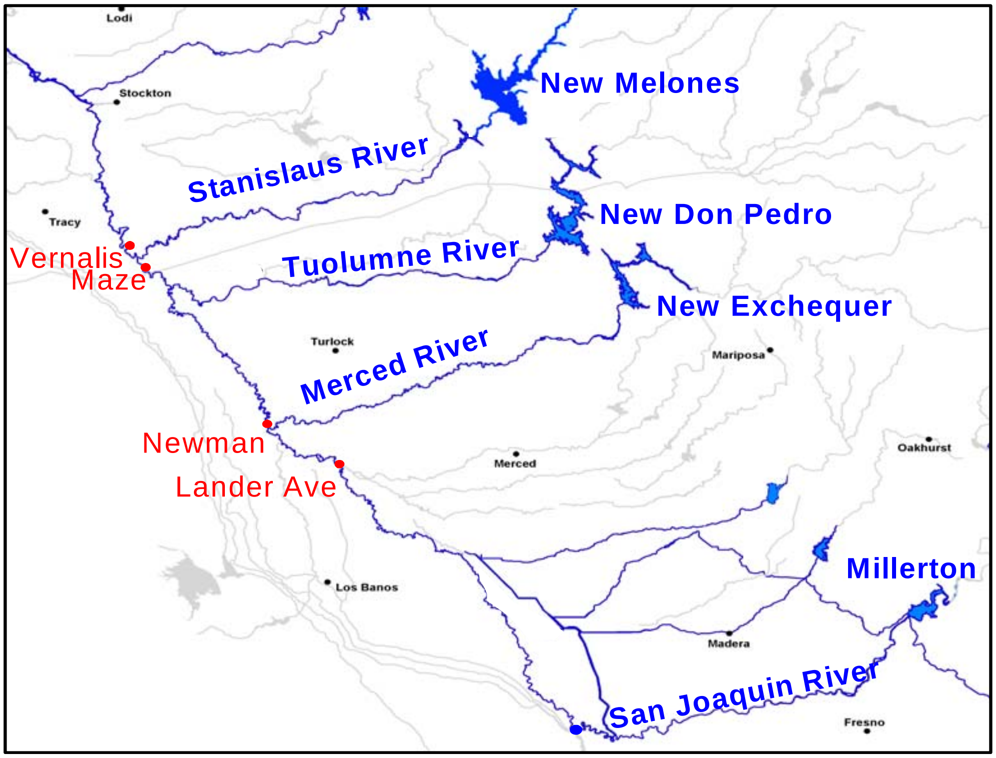


Figure 2. CALSIM II San Joaquin River region schematic

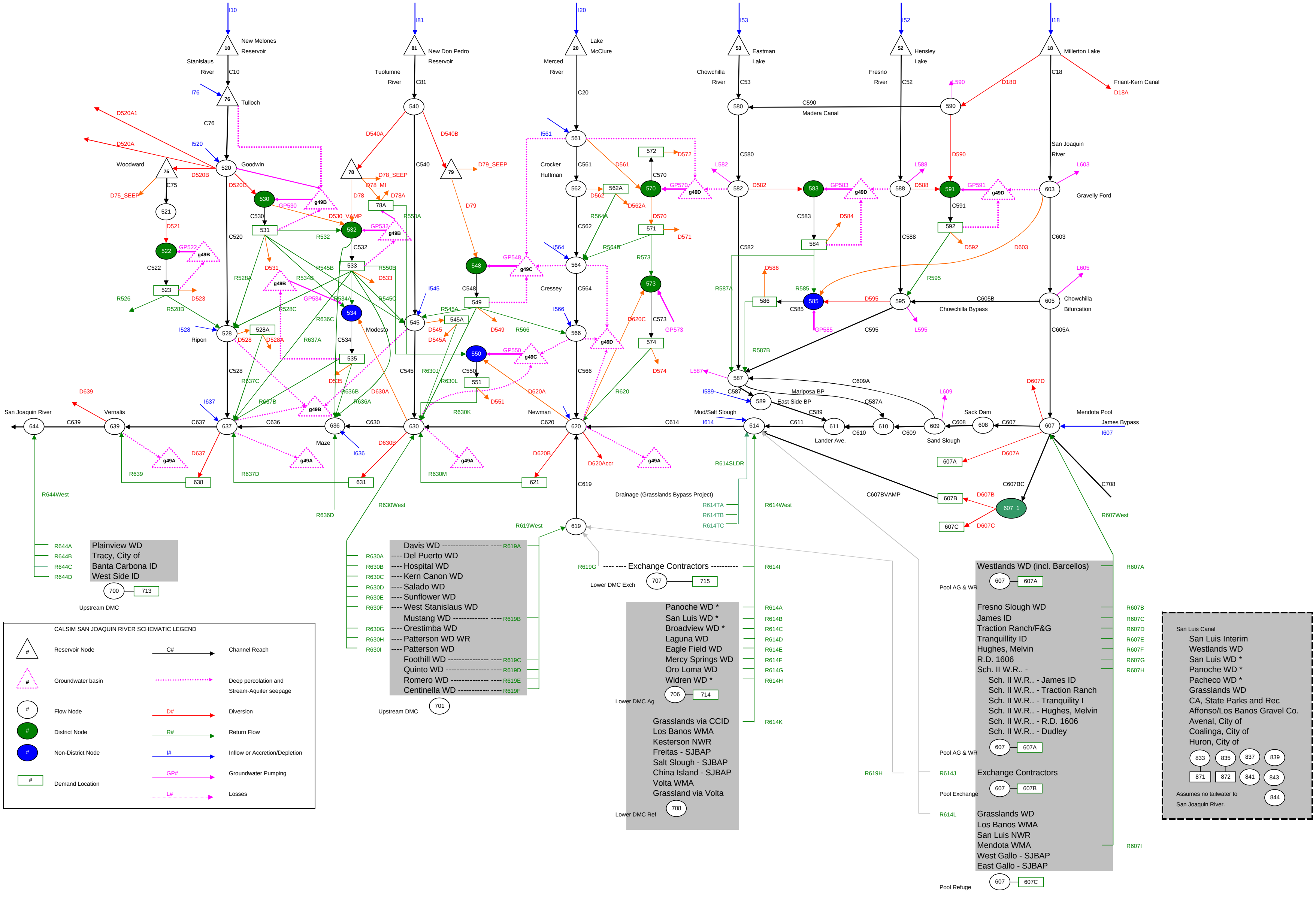


Figure 3. Stanislaus Accretion Adjustment (May 2006)

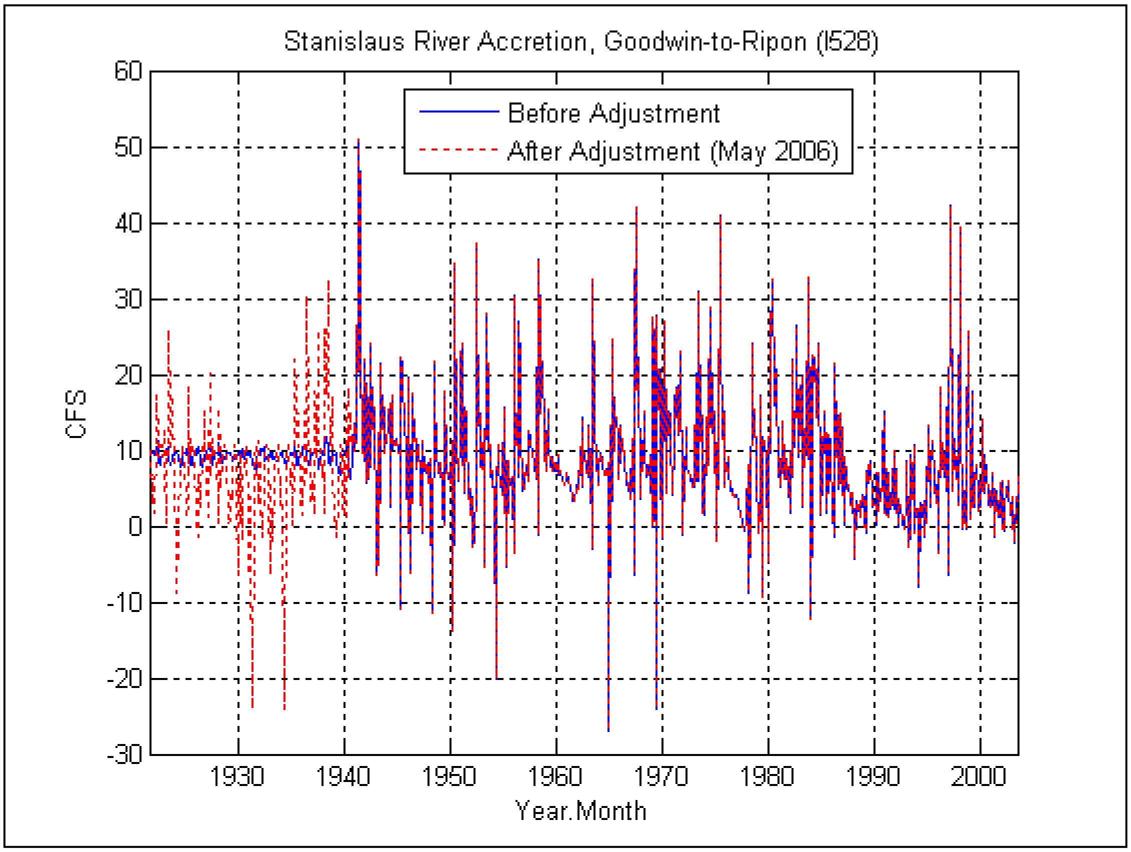


Figure 4. Schematic of San Joaquin River Water Quality Module below Lander Avenue

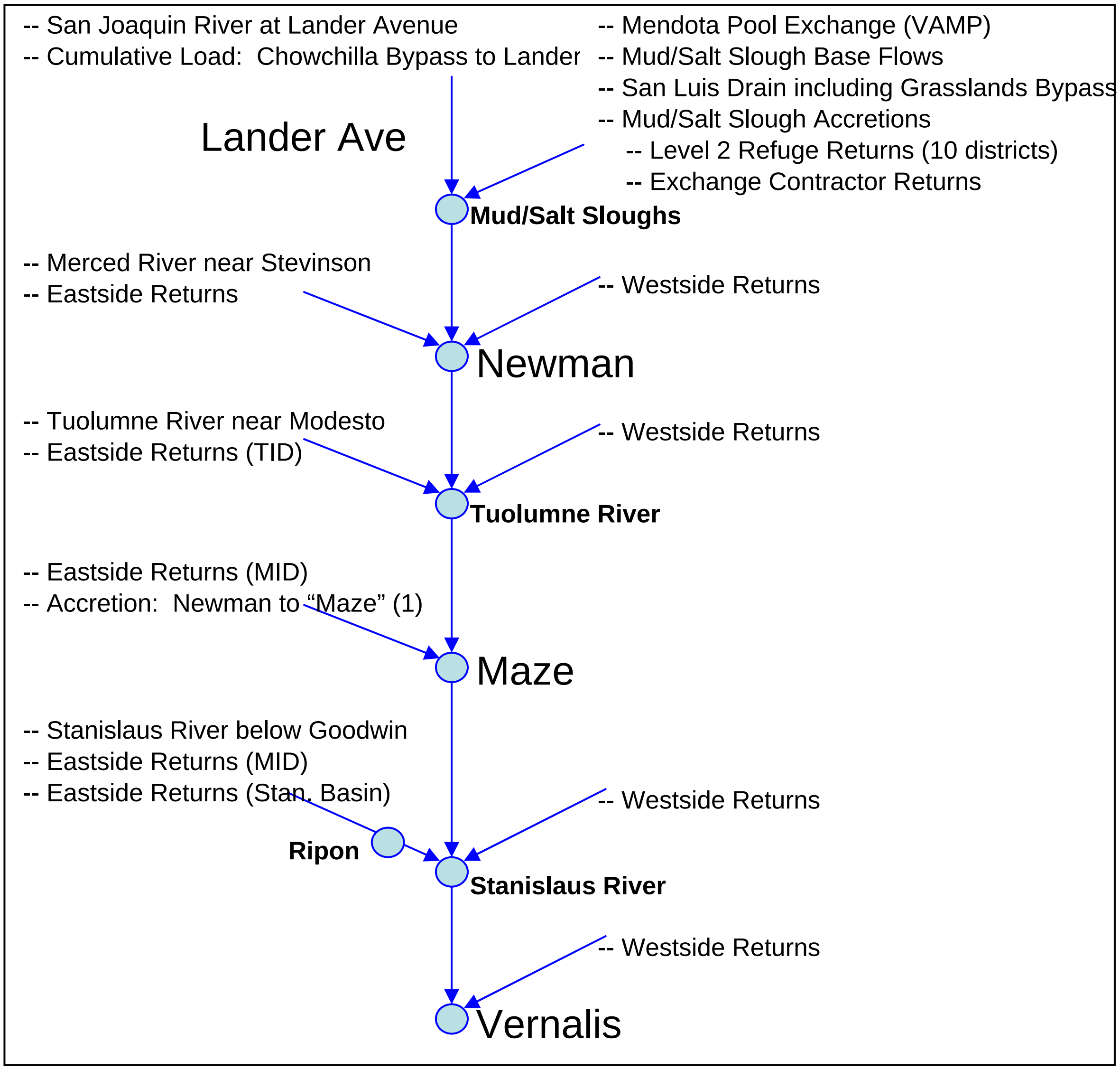
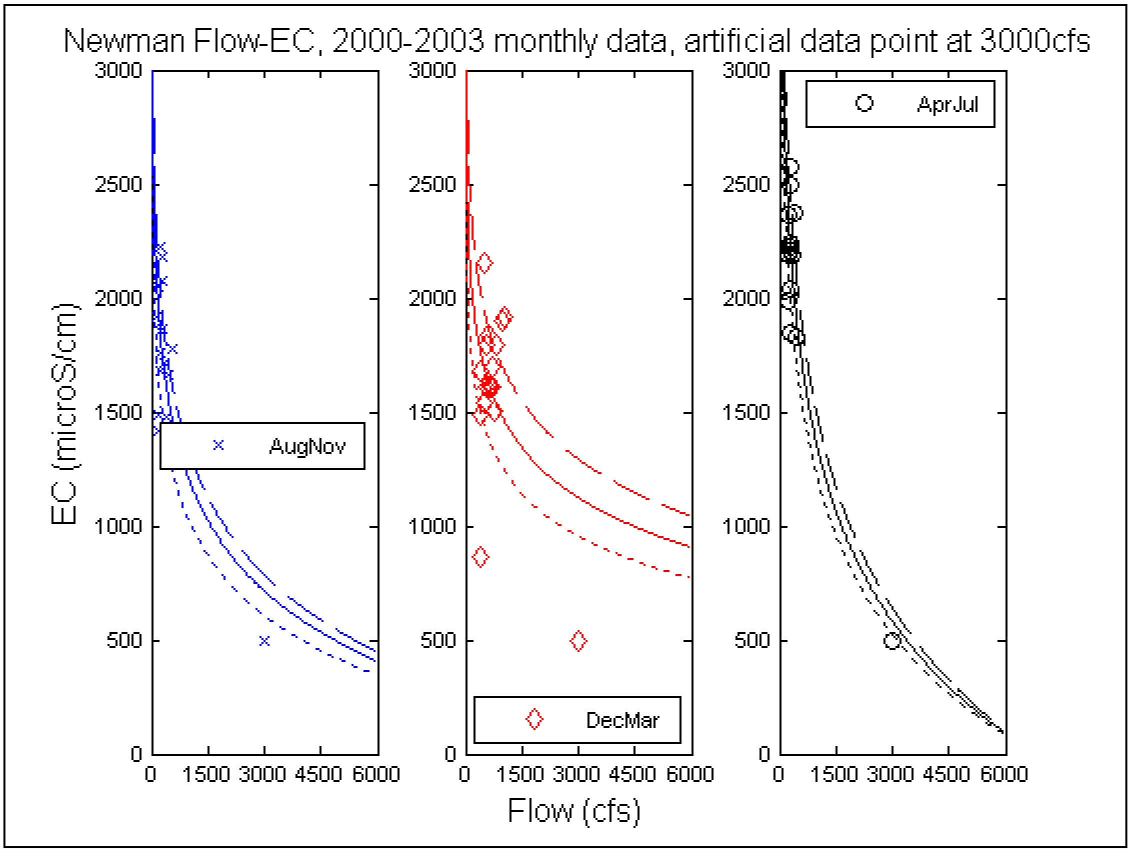
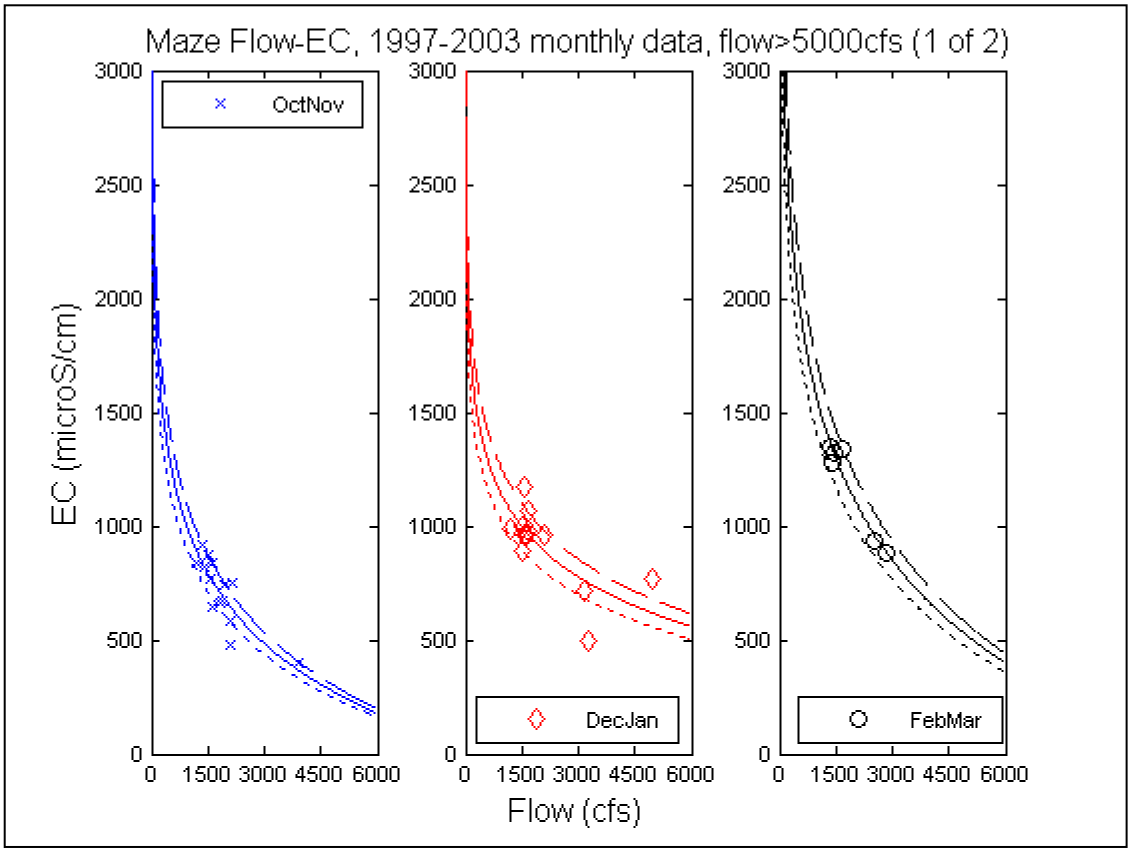


Figure 5. Calibration Flow-Salinity Relations for Above Newman



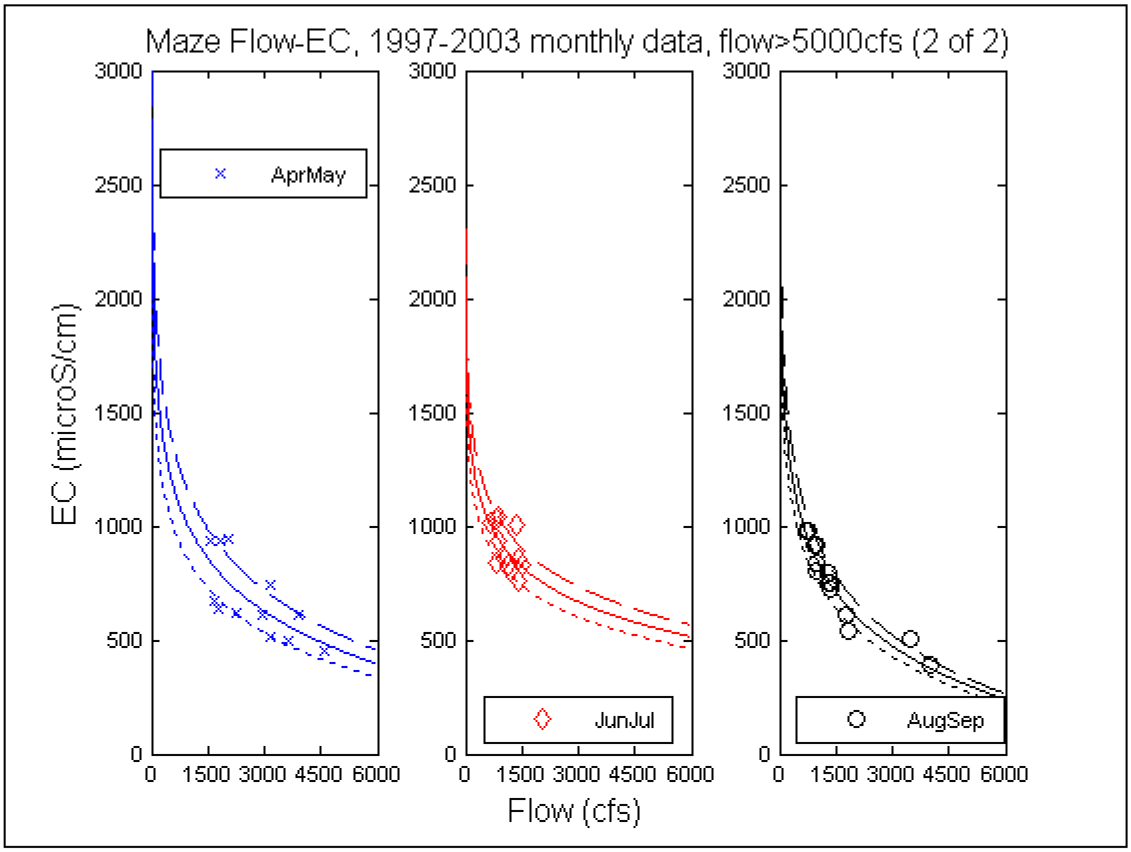
Base curve (solid), negatively scaled curve (short dash), positively scaled curve (long dash)

Figure 6a. Calibration Flow-Salinity Relations for Newman to Maze, Seasons 1-3



Base curve (solid), negatively scaled curve (short dash), positively scaled curve (long dash)

Figure 6b. Calibration Flow-Salinity Relations for Newman to Maze, Seasons 4-6



Base curve (solid), negatively scaled curve (short dash), positively scaled curve (long dash)

Figure 7. Load Closure Calculation - Flow of Information (steps from Table 4 are numerated on the schematic)

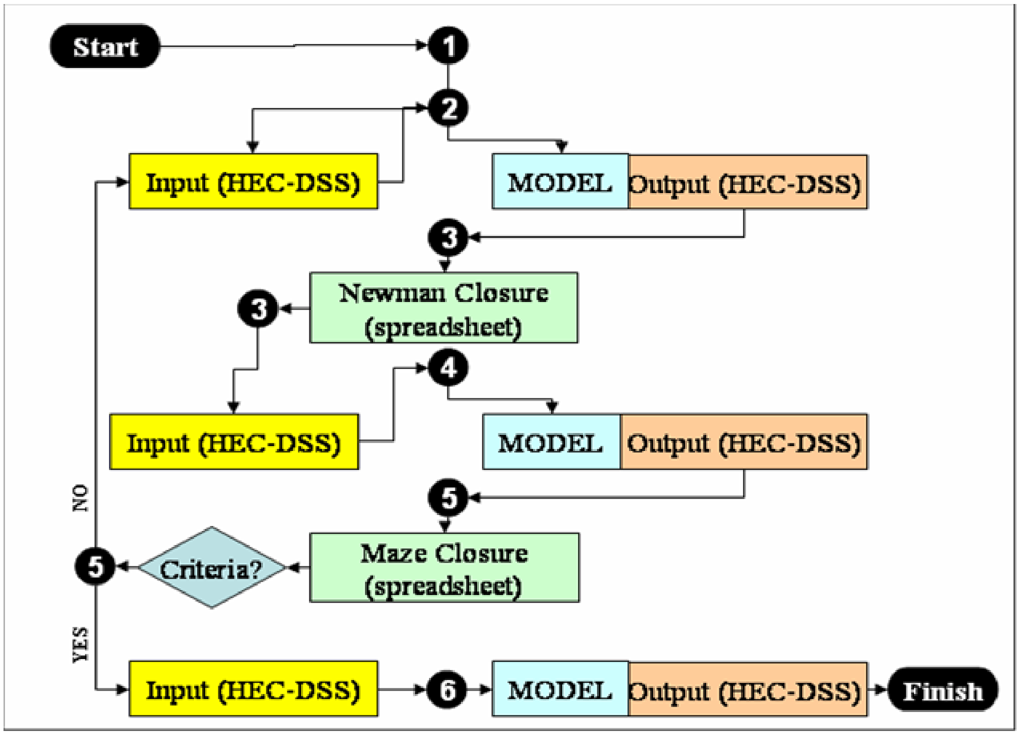


Figure 8. Automation Module for Load Closure Calculation

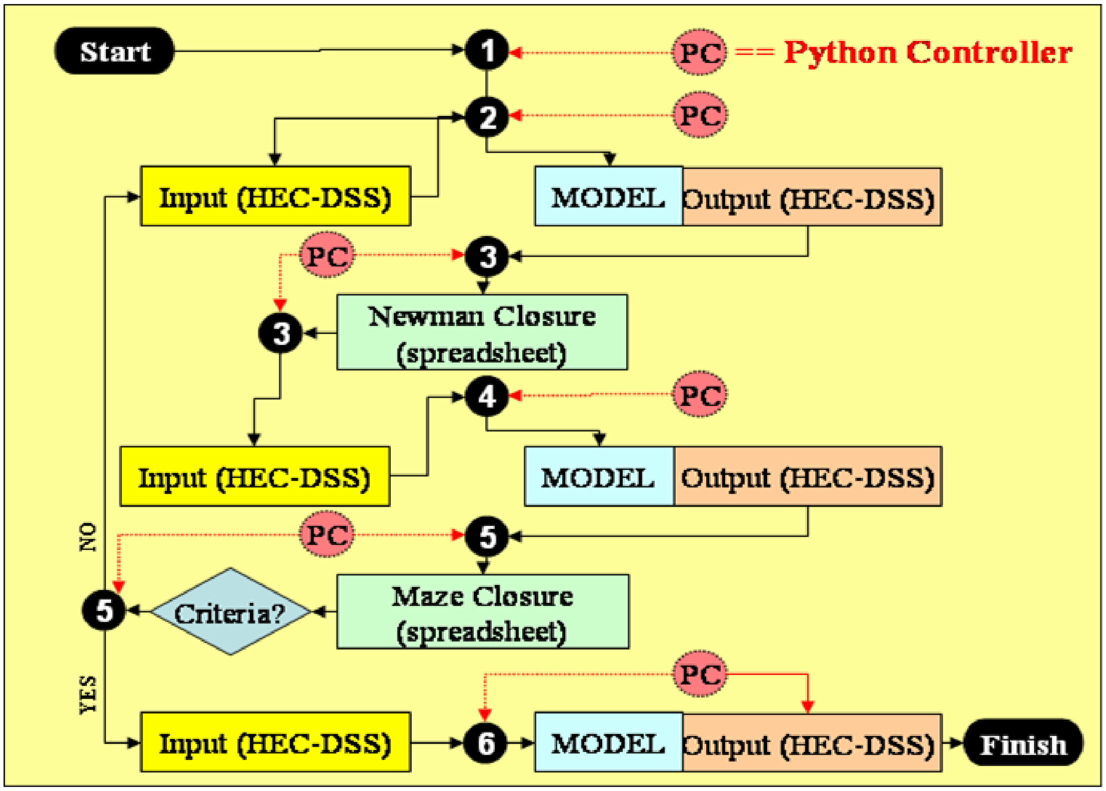


Figure 9. Client-Server Wrapper for Distributed Computing

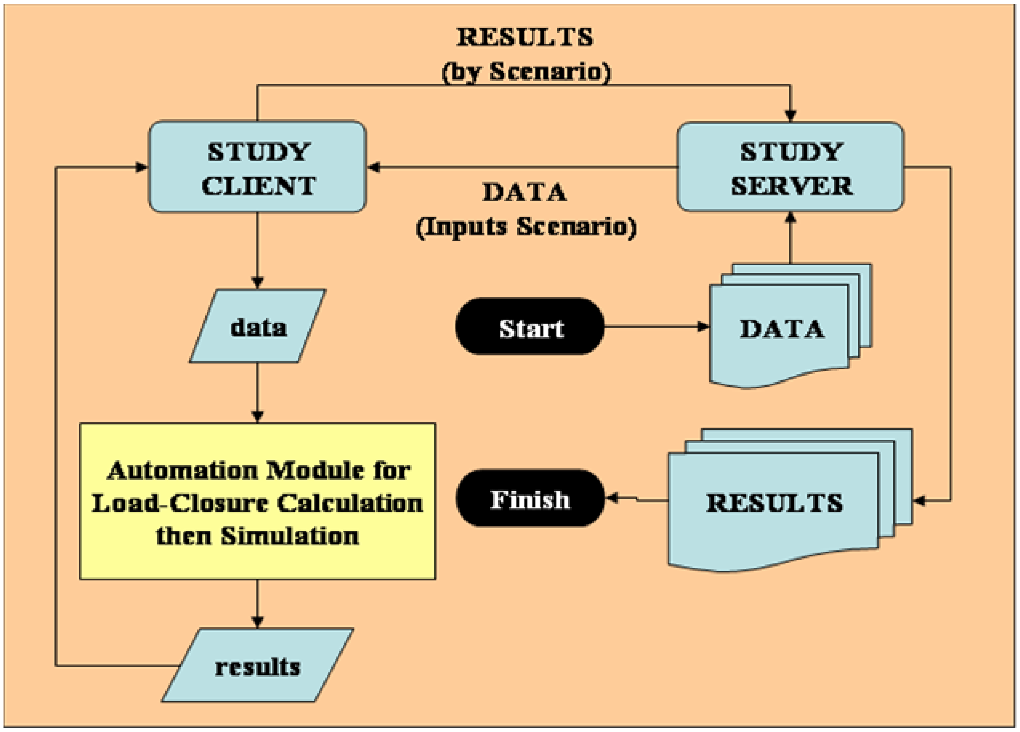


Figure 10. Sensitivity Analysis Standard Graphic showing multiple variable response for a single metric and averaging period

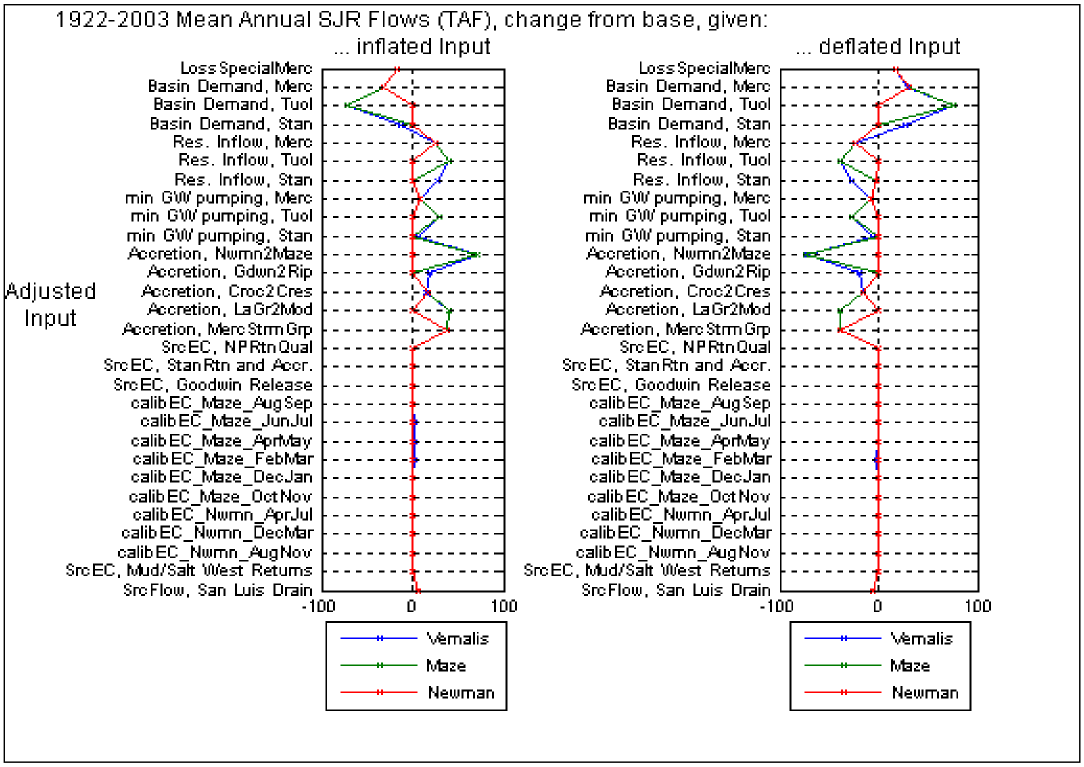
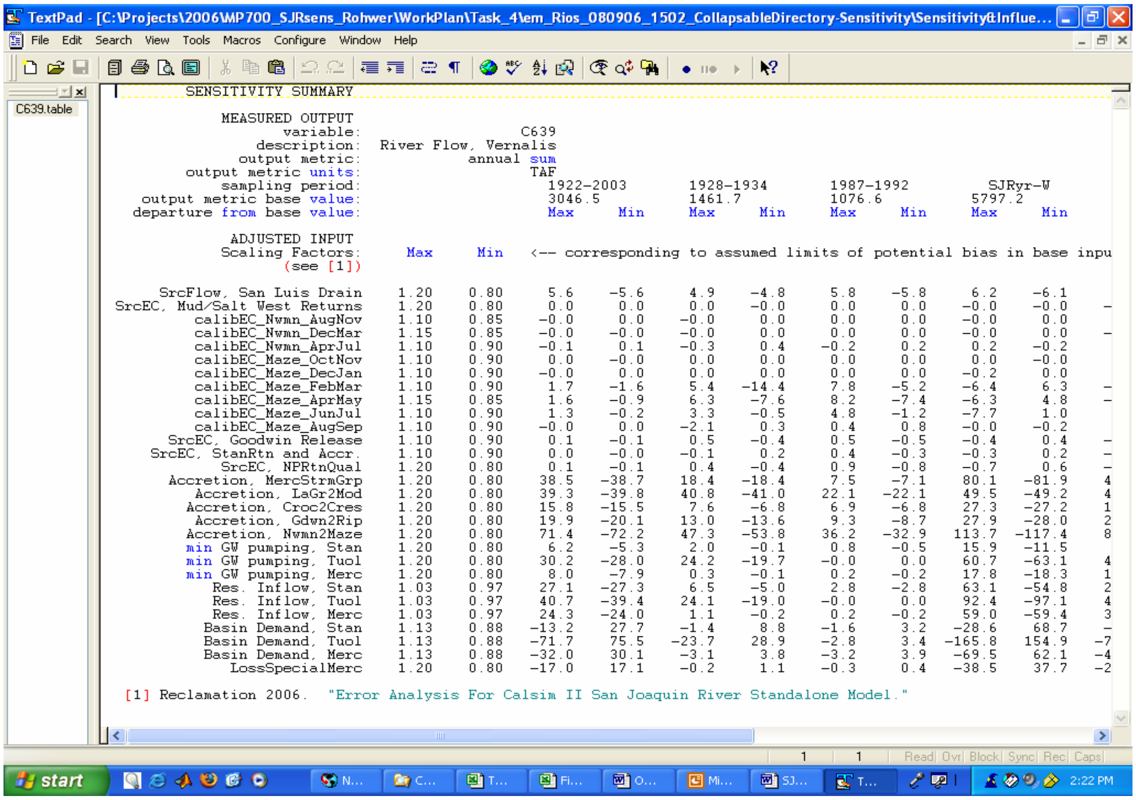


Figure 11. Sensitivity Analysis Standard Intervals Table for a single output metric



```
        SENSITIVITY SUMMARY

            MEASURED OUTPUT
                   variable:                  C639
                description:  River Flow, Vernalis
              output metric:            annual sum
        output metric units:                   TAF
            sampling period:                     1922-2003       1928-1934       1987-1992         SJRyr-W
   output metric base value:                     3046.5          1461.7          1076.6          5797.2
 departure from base value:                      Max     Min     Max     Min     Max     Min     Max     Min

             ADJUSTED INPUT
            Scaling Factors:     Max     Min   <-- corresponding to assumed limits of potential bias in base inpu
                   (see [1])

     SrcFlow, San Luis Drain    1.20    0.80     5.6    -5.6     4.9    -4.8     5.8    -5.8     6.2    -6.1
SrcEC, Mud/Salt West Returns    1.20    0.80     0.0     0.0     0.0    -0.0     0.0     0.0    -0.0    -0.0    -
         calibEC_Nwmn_AugNov    1.10    0.85    -0.0     0.0    -0.0     0.0     0.0     0.0    -0.0     0.0
         calibEC_Nwmn_DecMar    1.15    0.85    -0.0    -0.0    -0.0     0.0     0.0     0.0    -0.0     0.0    -
         calibEC_Nwmn_AprJul    1.10    0.90    -0.1     0.1    -0.3     0.4    -0.2     0.2     0.2    -0.2
         calibEC_Maze_OctNov    1.10    0.90     0.0    -0.0     0.0     0.0     0.0     0.0     0.0    -0.0
         calibEC_Maze_DecJan    1.10    0.90    -0.0     0.0     0.0     0.0     0.0     0.0    -0.2     0.0
         calibEC_Maze_FebMar    1.10    0.90     1.7    -1.6     5.4   -14.4     7.8    -5.2    -6.4     6.3    -
         calibEC_Maze_AprMay    1.15    0.85     1.6    -0.9     6.3    -7.6     8.2    -7.4    -6.3     4.8    -
         calibEC_Maze_JunJul    1.10    0.90     1.3    -0.2     3.3    -0.5     4.8    -1.2    -7.7     1.0
         calibEC_Maze_AugSep    1.10    0.90    -0.0     0.0    -2.1     0.3     0.4     0.8    -0.0    -0.2
      SrcEC, Goodwin Release    1.10    0.90     0.1    -0.1     0.5    -0.4     0.5    -0.5    -0.4     0.4    -
    SrcEC, StanRtn and Accr.    1.10    0.90     0.0    -0.0    -0.1     0.2     0.4    -0.3    -0.3     0.2    -
            SrcEC, NPRtnQual    1.20    0.80     0.1    -0.1     0.4    -0.4     0.9    -0.8    -0.7     0.6    -
      Accretion, MercStrmGrp    1.20    0.80    38.5   -38.7    18.4   -18.4     7.5    -7.1    80.1   -81.9    4
         Accretion, LaGr2Mod    1.20    0.80    39.3   -39.8    40.8   -41.0    22.1   -22.1    49.5   -49.2    4
        Accretion, Croc2Cres    1.20    0.80    15.8   -15.5     7.6    -6.8     6.9    -6.8    27.3   -27.2    1
         Accretion, Gdwn2Rip    1.20    0.80    19.9   -20.1    13.0   -13.6     9.3    -8.7    27.9   -28.0    2
        Accretion, Nwmn2Maze    1.20    0.80    71.4   -72.2    47.3   -53.8    36.2   -32.9   113.7  -117.4    8
        min GW pumping, Stan    1.20    0.80     6.2    -5.3     2.0    -0.1     0.8    -0.5    15.9   -11.5
        min GW pumping, Tuol    1.20    0.80    30.2   -28.0    24.2   -19.7    -0.0     0.0    60.7   -63.1    4
        min GW pumping, Merc    1.20    0.80     8.0    -7.9     0.3    -0.1     0.2    -0.2    17.8   -18.3    1
           Res. Inflow, Stan    1.03    0.97    27.1   -27.3     6.5    -5.0     2.8    -2.8    63.1   -54.8    2
           Res. Inflow, Tuol    1.03    0.97    40.7   -39.4    24.1   -19.0    -0.0     0.0    92.4   -97.1    4
           Res. Inflow, Merc    1.03    0.97    24.3   -24.0     1.1    -0.2     0.2    -0.2    59.0   -59.4    3
          Basin Demand, Stan    1.13    0.88   -13.2    27.7    -1.4     8.8    -1.6     3.2   -28.6    68.7    -
          Basin Demand, Tuol    1.13    0.88   -71.7    75.5   -23.7    28.9    -2.8     3.4  -165.8   154.9   -7
          Basin Demand, Merc    1.13    0.88   -32.0    30.1    -3.1     3.8    -3.2     3.9   -69.5    62.1   -4
             LossSpecialMerc    1.20    0.80   -17.0    17.1    -0.2     1.1    -0.3     0.4   -38.5    37.7   -2

 [1] Reclamation 2006.  "Error Analysis For Calsim II San Joaquin River Standalone Model."
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Figure 12. HTML Viewer for Sensitivity Analysis Standard Graphics and Intervals Tables

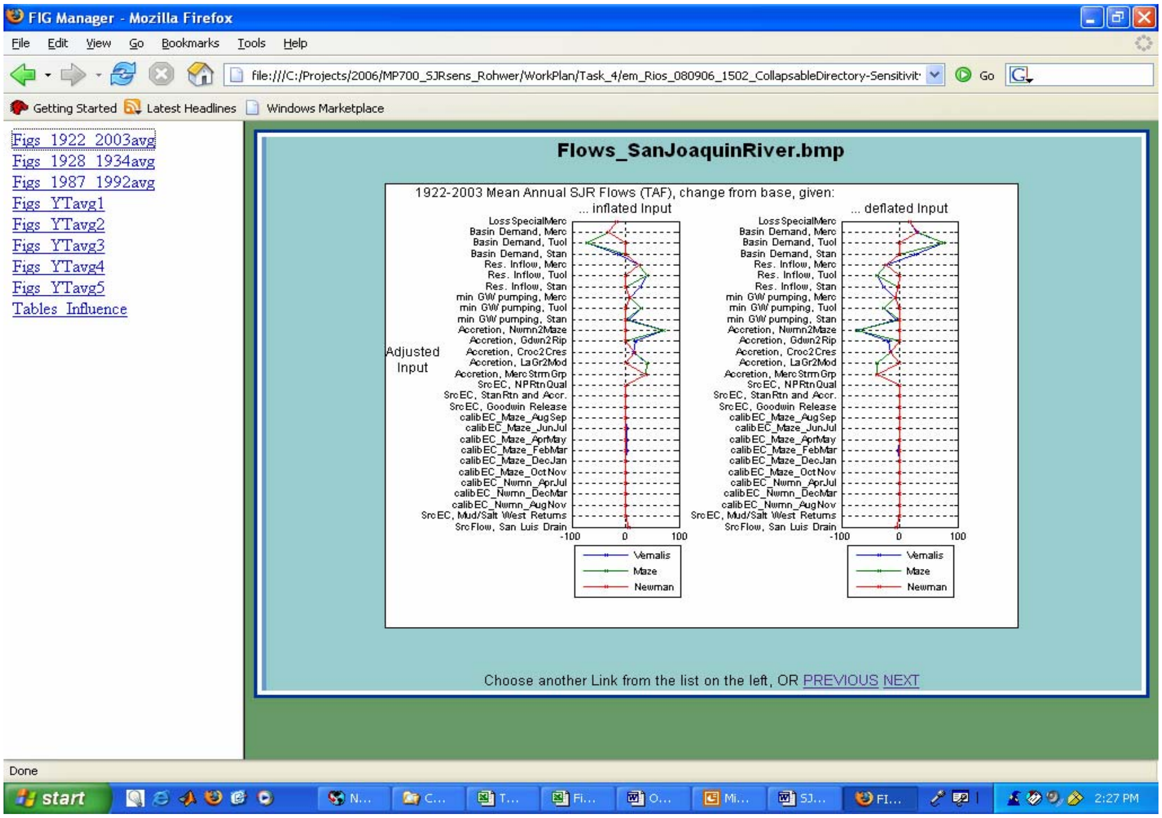

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Figure 13. Inputs' Frequent as "Most Influential" on all analyzed Outputs, focusing on metrics representing <u>All</u> Years

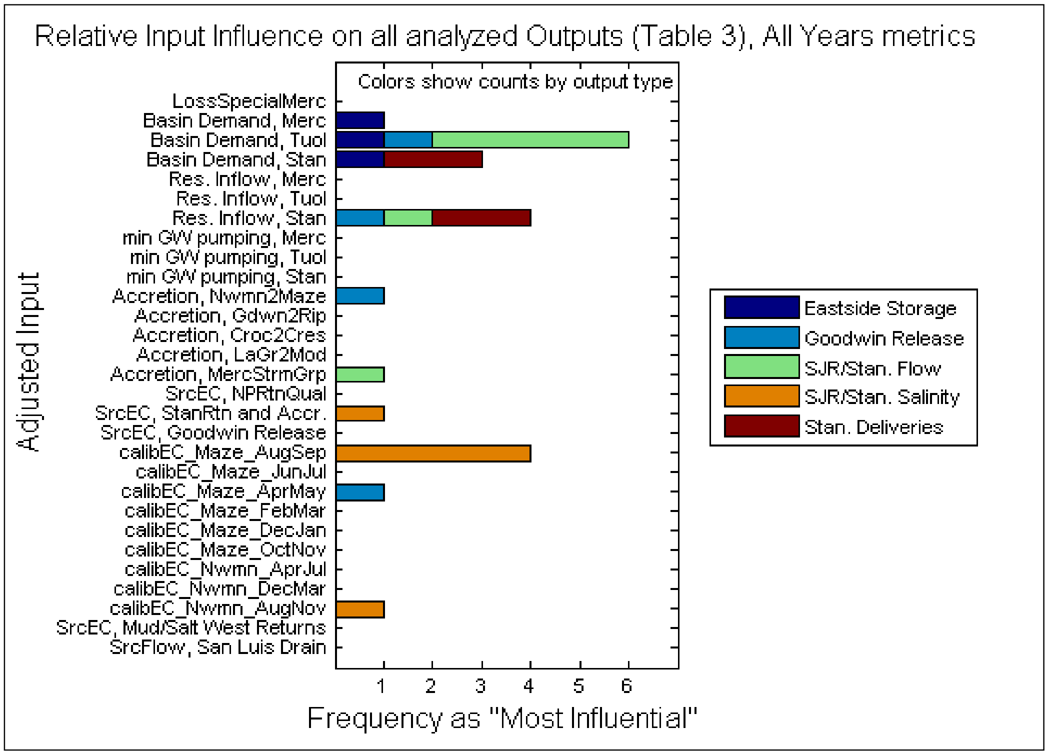

Figure 14. Inputs' Frequent as "Most Influential" on all analyzed Outputs, focusing on metrics representing <u>Wet</u> Years

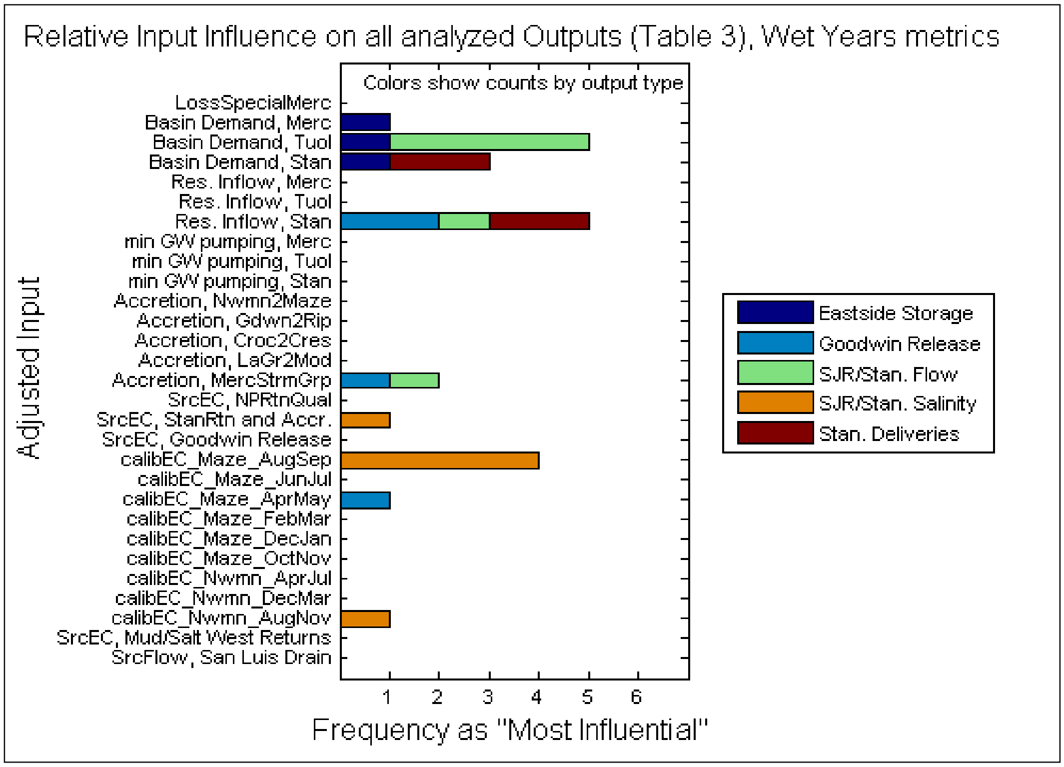

Figure 15. Inputs' Frequent as "Most Influential" on all analyzed Outputs, focusing on metrics representing Critical Years

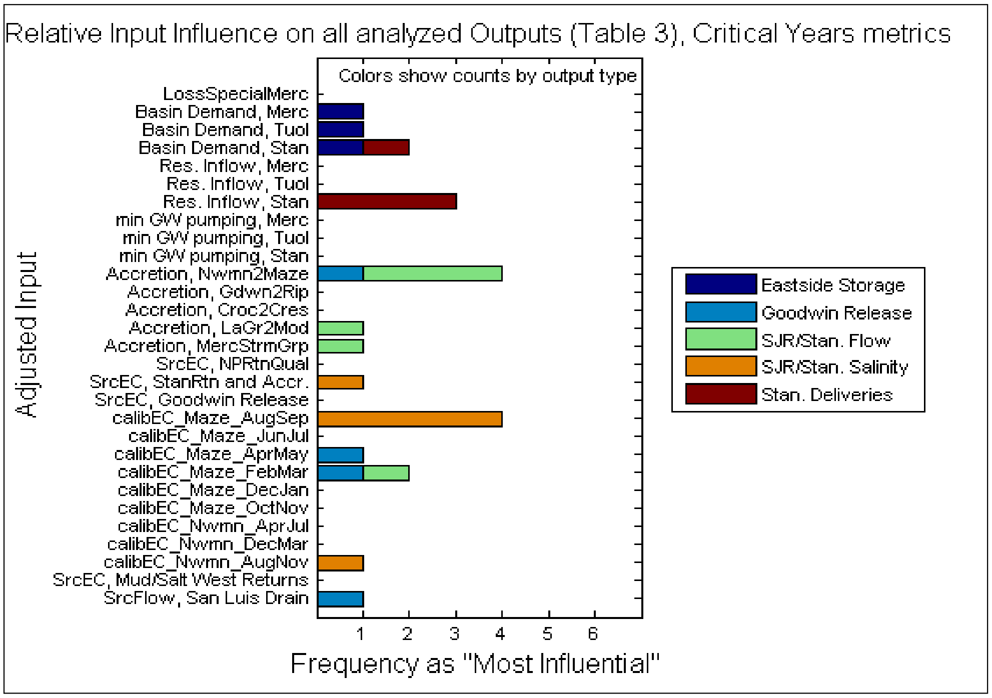

Figure 16. Standard Uncertainty Graphic: Time-Evolving Uncertainty, Absolute Results

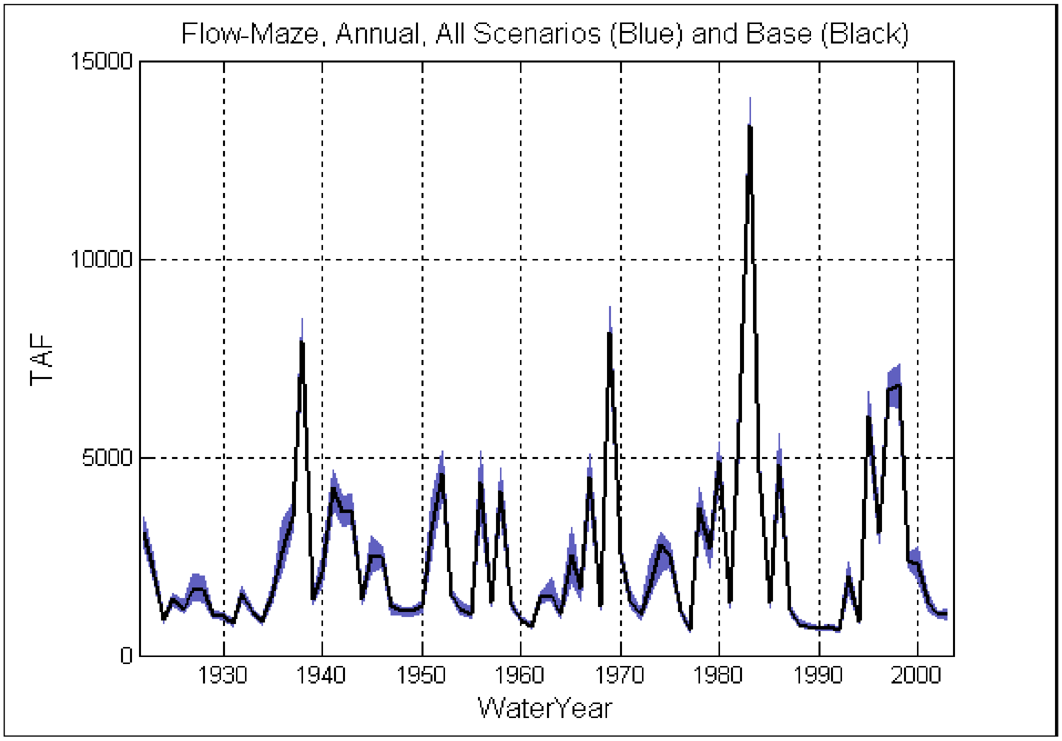

Figure 17. Standard Uncertainty Graphic: Time-Evolving Uncertainty Intervals, Changes from Base

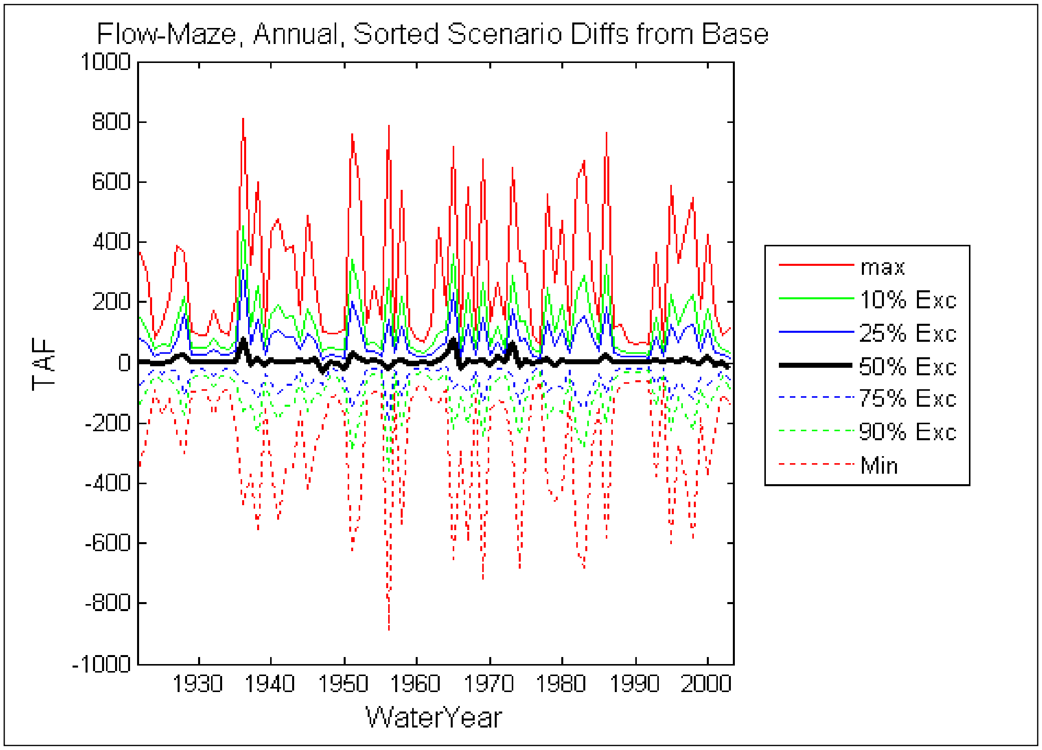

Figure 18. Standard Uncertainty Graphic: Performance Metric Uncertainty, Monthly Absolute Result

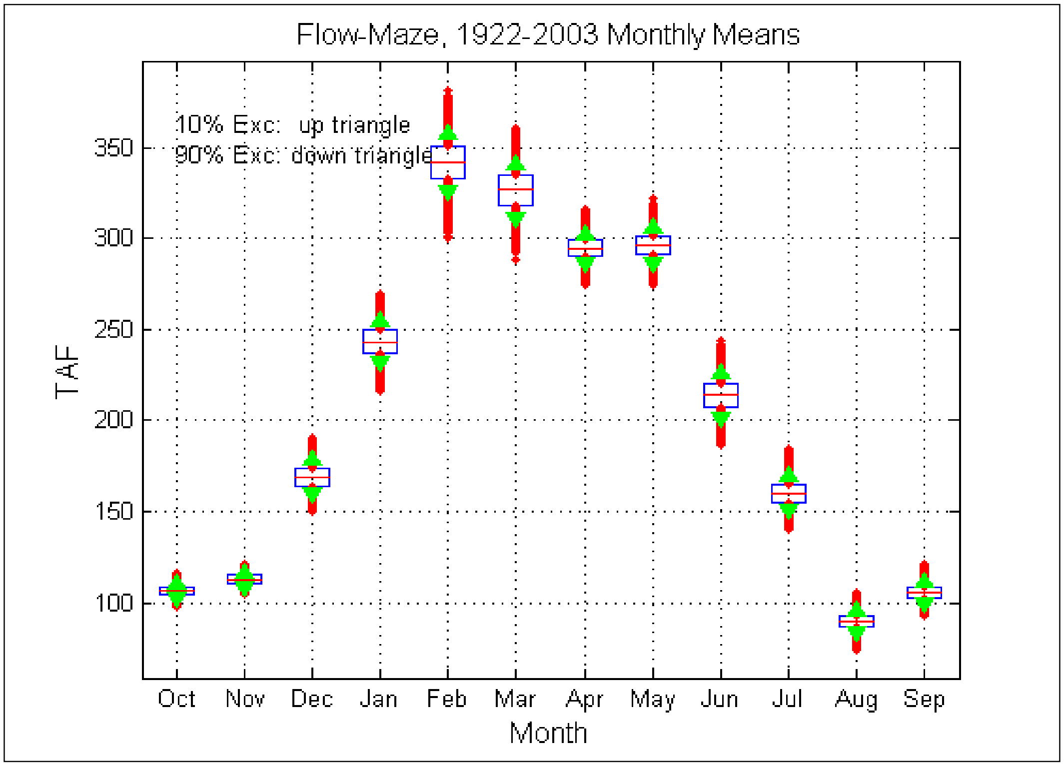

Figure 19. Standard Uncertainty Graphic: Performance Metric Uncertainty, Annual Absolute Result

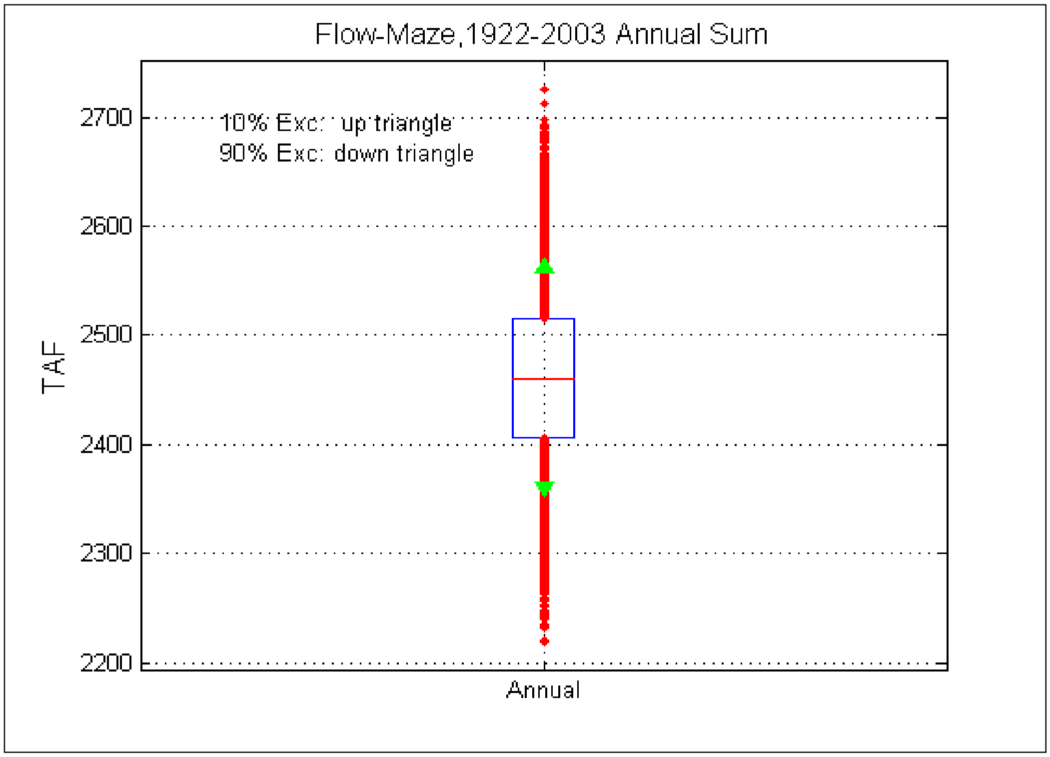

Figure 20. Standard Uncertainty Graphic: Performance Metric Uncertainty, Monthly Change from Base

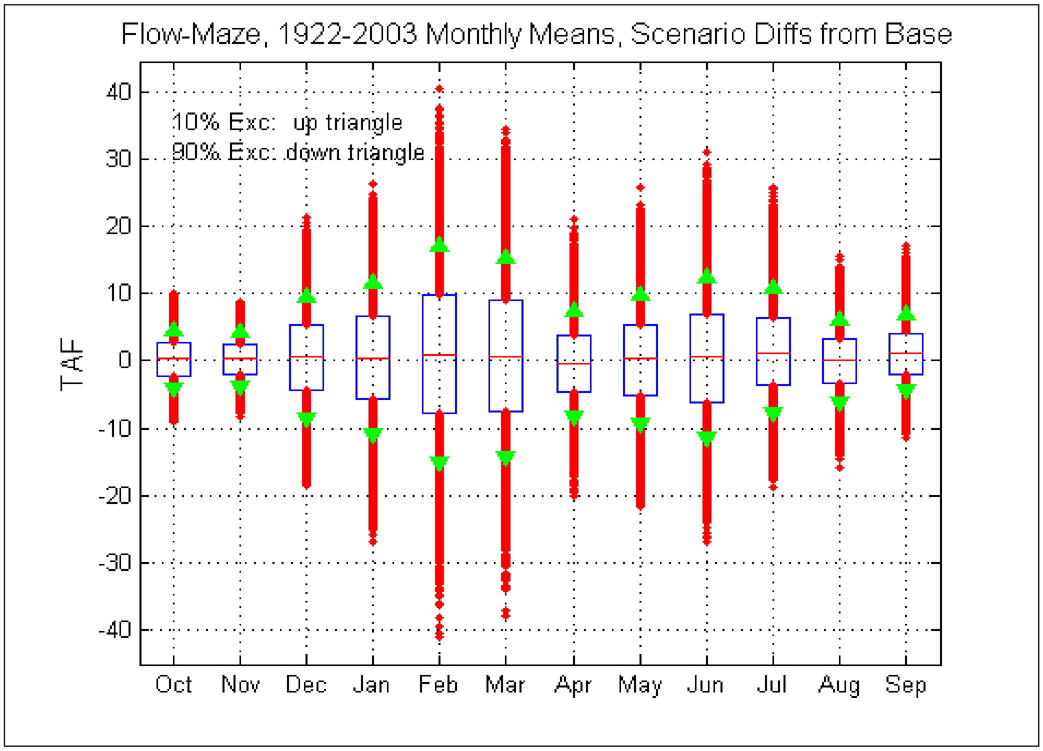

Figure 21. Standard Uncertainty Graphic: Performance Metric Uncertainty, Annual Change from Base

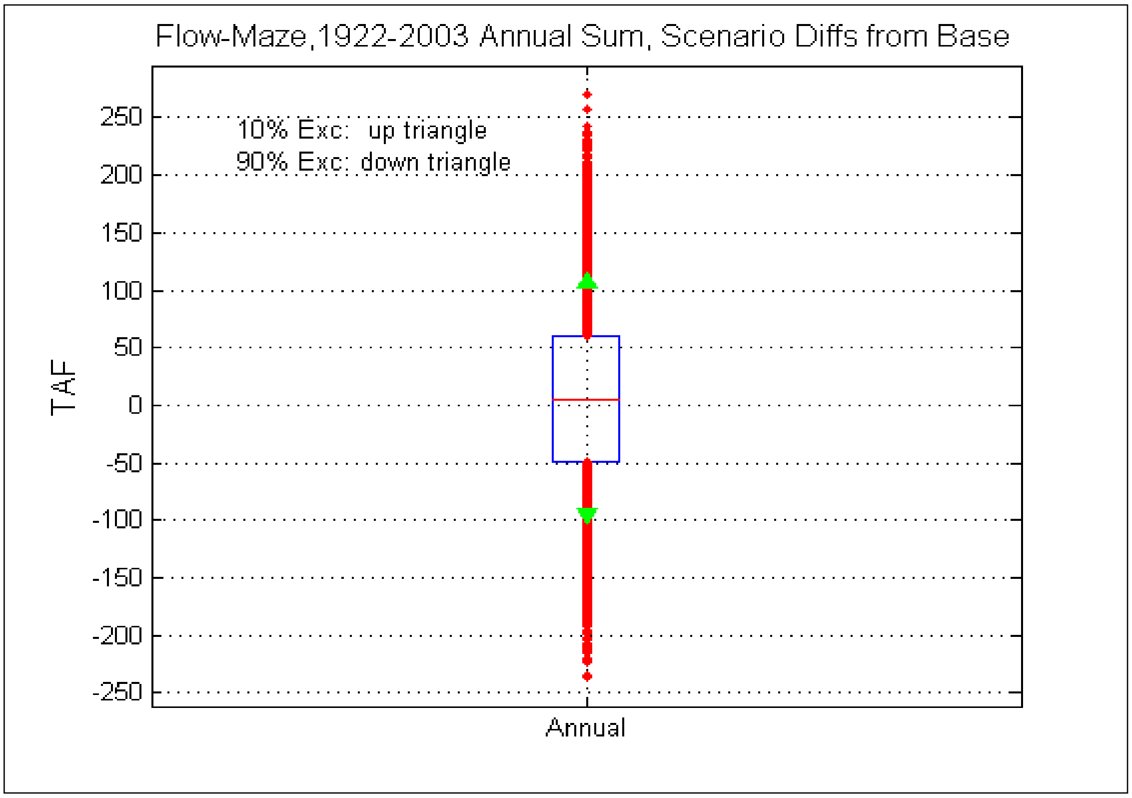

Figure 22. Standard Uncertainty Graphic: Verification of Uncertainty Convergence

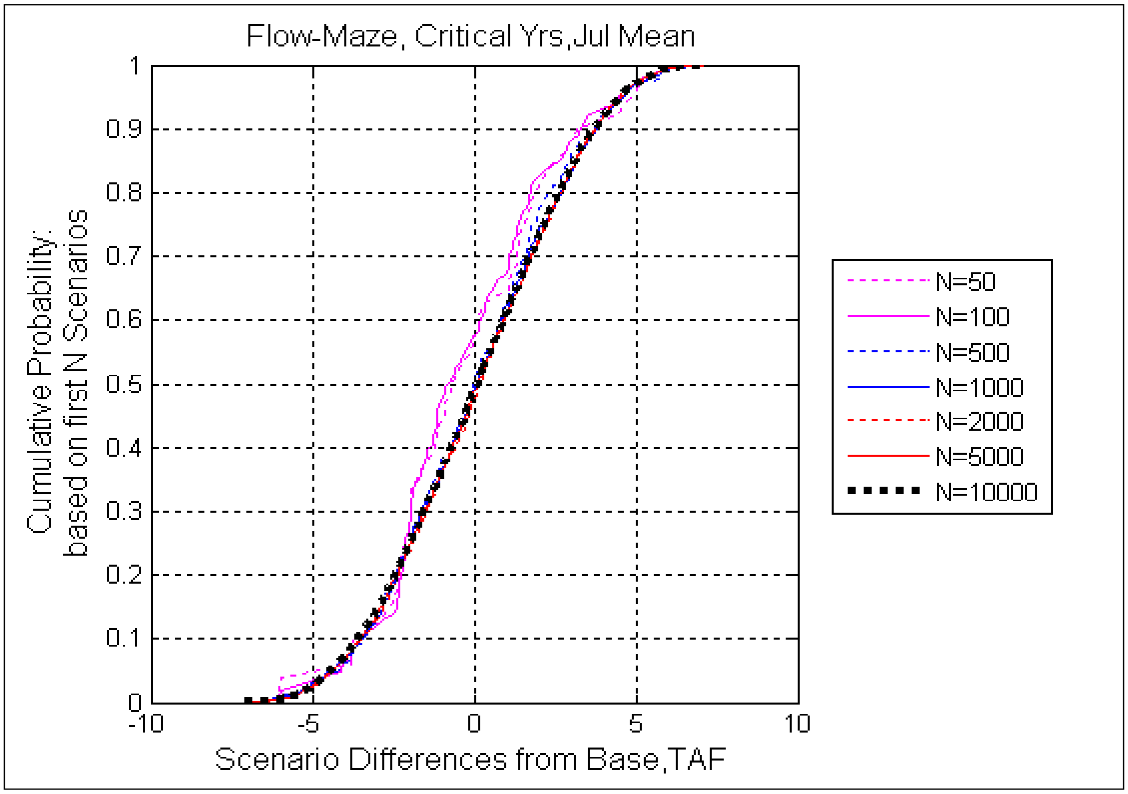

Figure 23. HTML Viewer for Uncertainty Analysis Standard Graphics

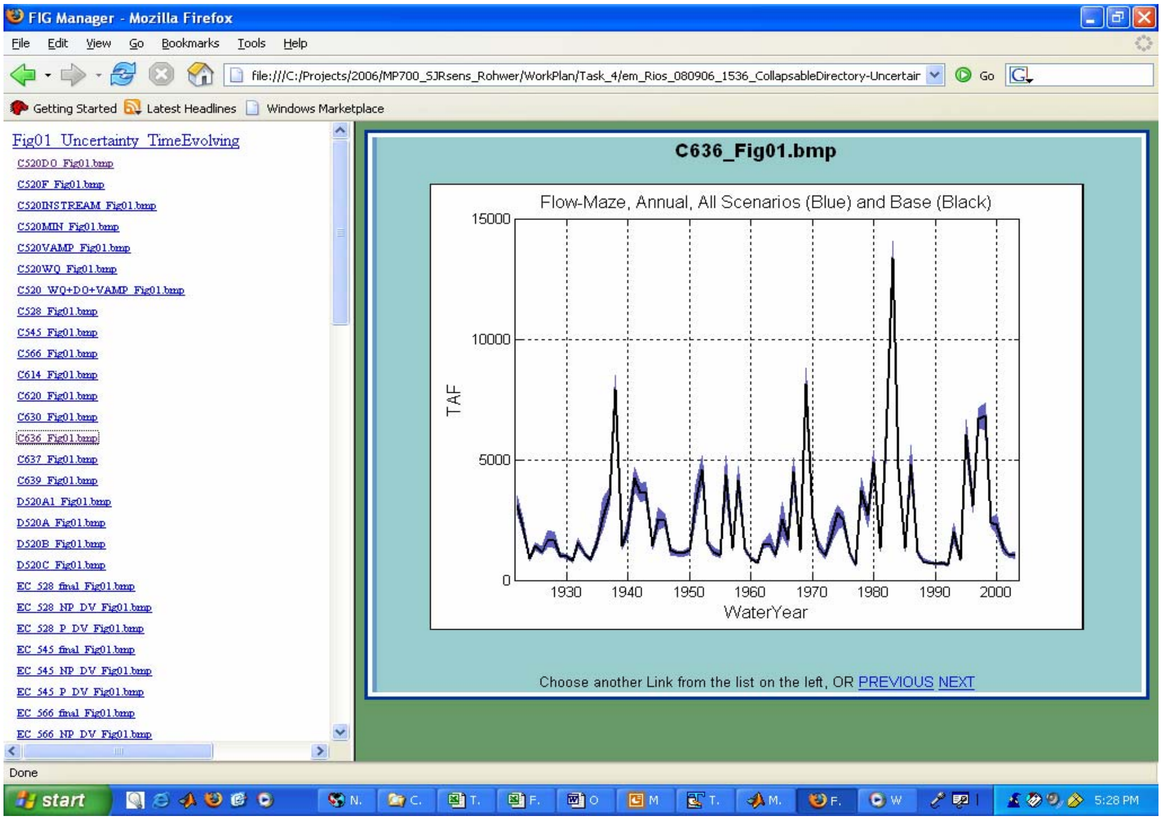

Fig01 Uncertainty TimeEvolving

C520DO Fig01.bmp
C520F Fig01.bmp
C520INSTREAM Fig01.bmp
C520MIN Fig01.bmp
C520VAMP Fig01.bmp
C520WQ Fig01.bmp
C520 WQ+DO+VAMP Fig01.bmp
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Appendix C:

Water Quality Analysis Response to San Joaquin Valley CalSim II External Review

14 November 2006

U.S. Bureau of Reclamation (86-68520, MP-700, MP-CVOO)

C.1 Purpose

This document is in response to the water quality analysis presented in the Peer Review Response to the San Joaquin Valley CalSim II External review of January 12, 2006 (Ford et al. 2006), "Appendix B: Supporting Calculations and Illustrative Examples Regarding Systematic Bias in Calsim II Water Quality Results." The intent is to discuss several points introduced in the Peer Review analysis and to provide complimentary or clarifying analyses when applicable.

Appendix B of Ford et al. (2006) expressed several concerns/issues with the simulated water quality module within the San Joaquin Valley representation of CalSim II. These included:

- Use of the October 1996 through September 2003 calibration period

- Underestimation of Maze EC for the October 1996 through September 2003 calibration period

- Large residual flow and salt loads

- Lack of variability in the model elements

C.2 Use of the October 1996 Through September 2003 Calibration period

In order to model the relationship of San Joaquin River (SJR) flow and resultant electrical conductivity (EC) of the river, a time series of recent historical data were selected from October 1996 to September 2003 as a calibration period. Since EC is a surrogate for salinity, the use of a flow to EC relationship allows the Calsim II model to simulate the water quality of the SJR at locations where flow is modeled. It was questioned whether the chosen calibration period introduced bias in the model. In particular, the point was raised that the seven-year period had wetter conditions relative to longer-term historical observations (e.g., 1922-2003, the model's full simulation period). For example, none of the calibration period years were classified as Critically Dry based on the San Joaquin 60-20-20 Index.

A review of the time series and the filtered data may provide answers to the following questions regarding the calibration data set:

- Does the period of calibration capture the variability of flows that would be experienced over the simulation period?
- What seasonal periods or windows were used for the Maze and Newman flow and EC relationships?

Computed mean daily flows from January 1, 1993, to the present are available at the California Department of Water Resources (DWR) California Data Exchange Center CDEC website (cdec.ca.gov). Graphical presentation of the time series of flow regimes within the calibration period for both Maze and Newman are presented in Figures 1 and 2 below.

During the calibration period, low flows may represent conditions when the EC is in the higher ranges for SJR and primarily occur in the late summer and fall months. The seasonal low flows are marked with symbols for the August through November window. The calibration period (within the black outline) contains a majority of flows in the 1000-2000 cfs range. Looking outside of the calibration period at the other August-November periods, the flows are variable and range from 864-7200 cfs and are not consistently in the < 2000 cfs range as observed within the calibration window. The calibration period flows appear to represent the observed range of lower flows and do not seem to bias the calibration period toward wetter conditions at Maze. Analyzing the plot of the time series of Newman flows in Figure 2, the period primarily consisted of low August through November flows during the 2000-2004 calibration.

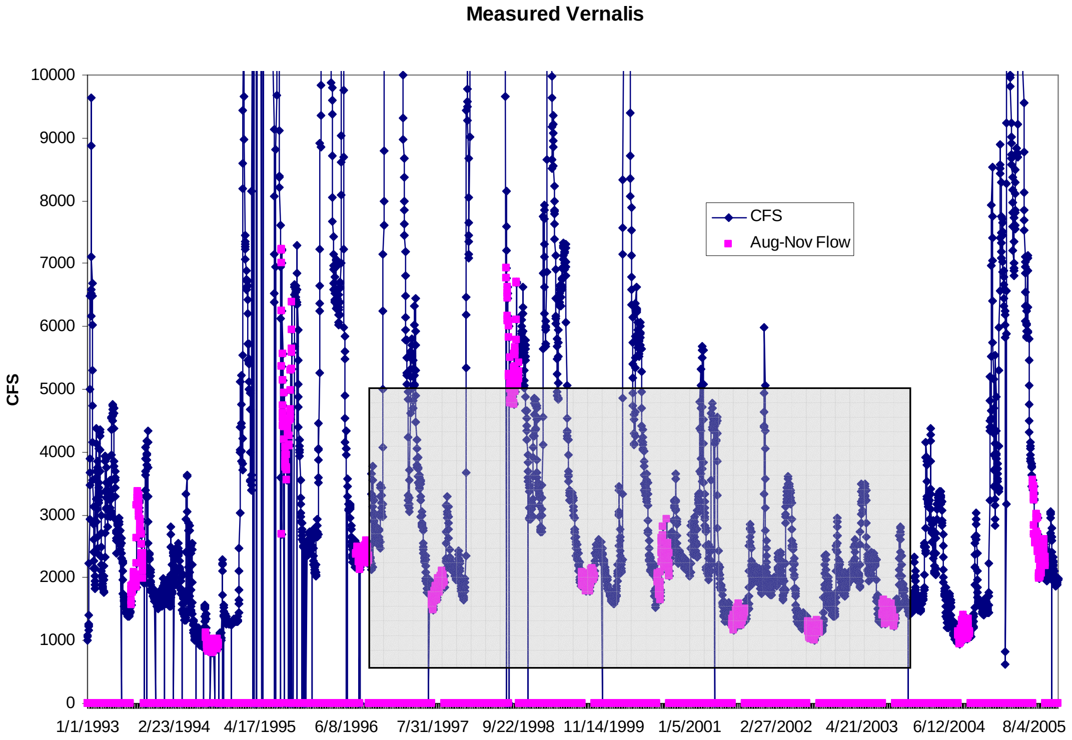

Figure 1: Vernalis flows and calibration period (with Aug-November flows highlighted)

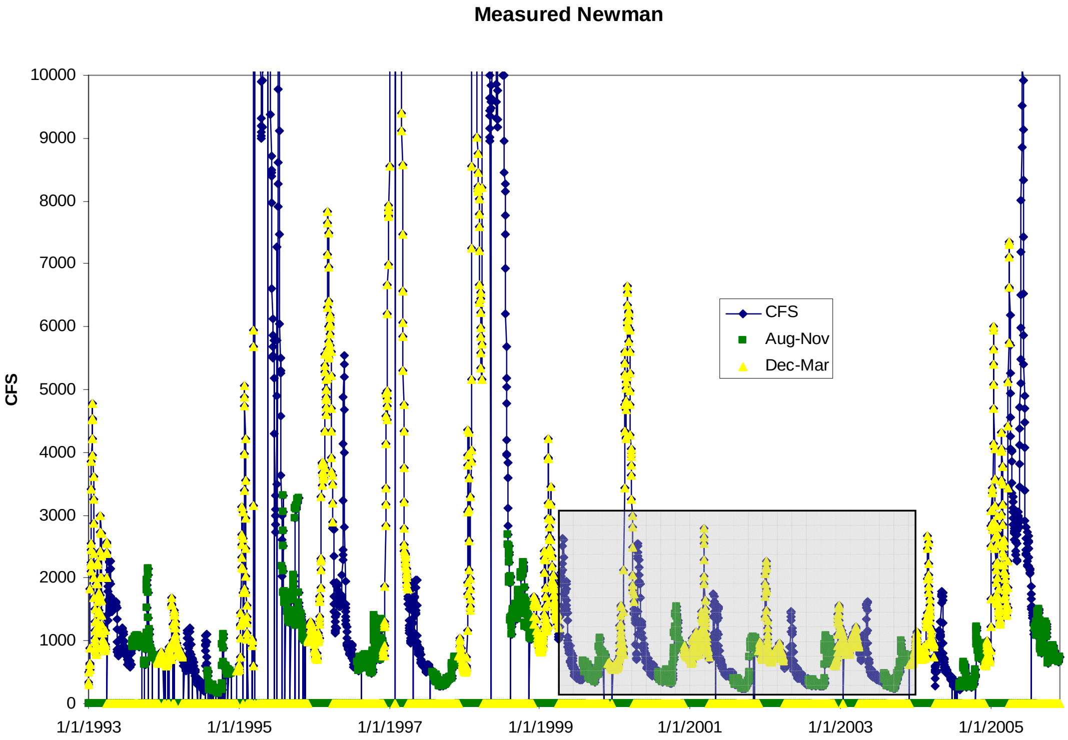

Figure 2: Newman Flows and calibration period (with seasonal flows highlighted)

With the seasonal low flows marked by symbols in the August through November and the December through March seasons, the calibration period contains a majority of flows in the 200-3000 cfs range. Looking outside of the calibration period at the other August-November periods, the flows are variable and range from 100-10,000 cfs and are not consistently in the < 2000 cfs range as observed within the calibration window. The calibration period flows appear to represent the observed range of lower flows and do not seem to bias the calibration period toward wetter conditions at Newman.

Inspection of the time series graphs, and in particular the filtered monthly flow periods, does not reveal apparent bias toward wetter conditions within the calibration period, even though the more recent calibration time series do not contain critical year types. Except for the 1994 low flows, the calibration period contained the lowest summer and fall flows since 1993.

Beyond the graphical inspections using Figures 1 and 2, it is also possible to explore whether the chosen calibration period is biased towards wetter conditions (on a monthly basis rather than year-type basis) relative to longer-term flow distributions (e.g., 1922-1995). Presented in the table below are the percentile rank ranges of monthly flows at Maze during the calibration period. As shown in the table, the population minimum flows for the August through December months are below 96.3 percent exceedence when compared to the entire 1992-2003 simulation period. When observing the median percentile rank, the calibration period does contain wetter years than the entire record;

however, the population of data still exhibits some of the lowest flows of the entire simulation.

Table 1 Rank Percentile of Monthly Flows (1996-2003) Compared to 1922-2003 periods

	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Median	68.7%	58.7%	37.5%	66.2%	60.0%	67.5%	46.2%	57.5%	62.5%	61.2%	63.7%	75.0%
MIN	0.1%	0.1%	1.2%	10.0%	7.5%	3.7%	11.2%	13.7%	6.2%	5.0%	3.7%	3.7%
MAX	97.5%	96.2%	97.5%	100.0%	96.2%	95.0%	93.7%	97.5%	97.5%	98.7%	98.7%	95.0%

C.3 Underestimation of Maze EC for the October 1996 Through September 2003 Calibration Period

An assertion was made that simulated Maze EC is consistently lower than historical values during the calibration period and therefore introduces simulated bias in New Melones operations for water quality. To further explore this issue, the following components/concepts of the model are examined:

- Regression equations
- Data variability of the model
- Systematic bias in the model
- Sensitivity analysis of the model
- Uncertainty analysis of the model

C.3.1 Regression Equations:

The Review Panel presented the concern that if the flow-EC relationship was biased toward overestimating flow, then the resultant EC would be underrepresented. The potential for monthly EC values to be consistently lower than potential values could lead to an underestimation of water needed from New Melones for dilution of the salt load at Vernalis. The regression equations developed at Maze were instituted to capture the mean flow EC condition in order to reduce the effects of bias in simulating water quality.

It was questioned whether it is valid to calibrate the water quality module’s flow-EC performance against a regression-defined relationship that only describes a mean flow-EC relationship at Maze and Newman rather than the true variable relationship (i.e. noisy relationship about the mean curve). As it stands, the calibration adhered to a regression-defined relationship that had a 50 percent chance of being either low or high in its assignment of Maze EC at the simulated flow.

It is important to note that development of the water quality module was focused on having the module represent statistically consistent flow-EC relations over a longer-term period. For this reason, calibrating to a regression-defined flow-EC relation is appropriate. Error terms could have been introduced in the regression equations; however, application of regression equations with error terms would still have involved computing Maze or Newman EC as a function of flow for the simulated 1922-2003 period, and then identifying a load residual (Reclamation 2004).

The presence of a random error term centered about the explanatory portion of the regression curve would have certainly adjusted the load residual time series positive or negative at various monthly stages (following the random nature of the error term). However, the net affect of these positive and negative adjustments to the load residuals would likely balance out in terms of causing cumulative effect on below-Maze operations.

C.3.2 Data Variability of the Model:

Current application of the model does not involve tracking the translation of input uncertainty to output uncertainty. The Peer Review Panel considered this to be an important piece of information that should be offered in the documentation of these model improvements. Therefore, sensitivity and uncertainty analyses were conducted where inputs were systematically varied within assumed limits of variation on a single- or joint- basis (i.e. for measuring output sensitivity or output uncertainty, respectively). For more details on that analysis, see Appendix B of this report.

C.3.3 Output Bias Relative to Observations:

Independent of the issues discussed related to calibrating to a regression, and not simulating input data variability during calibration, it is still possible to examine the calibrated model's output against observations to determine the presence of bias. Within the recent operations of the SJR, the period of 1985-2003 approximately represents a point of first fill of New Melones to the end of the simulation. The period of 1996-2003, as described earlier, is the calibration period for EC to Flow relationships.

During these windows of historical record for 1985-2003 and 1996-2003, computed EC and load at Maze can be compared to the historical EC and load by an expression of the percent bias of the two numbers for each month [100%*(1-(simulated/historical))]. The long term average of these ratios may be interpreted as an estimate for long-term bias in the model output for the given historical period. Presented in Table 2 are the results of the initial bias analysis.

Table 2: Bias of Simulated to Observed Maze EC (%) and Maze Load (1996-2003)

	Bias in Computed EC (us/cm)			Bias in Computed Loads (cfs *EC)		
	All EC	EC >800	EC<500	All Flows (cfs)	Flows > 2000 (cfs)	Flows < 2000 (cfs)
Time period						
1985-2003	-5.14%	-6.8%	4.1%	1.36%	-5.35%	4.36%
1996-2003	-4.44%	-2.10%	-1.55%	-3.98%	-13.03%	2.72%

The potential bias in computed EC and Loads can be further categorized by separating the ranges of interest into numerical bins. With this method, the potential for value-specific or skewed bias can be explored. Binning of ratios in Table 2 is based on either observed EC or flows at Maze. For example, in the period of 1985-2003, for the category "EC > 800," all months with EC in this category were noted. Corresponding simulated EC conditions during these months were noted and ratios were computed. The average of these ratios is shown in Table 2 (-6.8%).

Estimated bias for Maze loads during October 1996 to September 2003 ranges from -13 percent to +3 percent, depending on the flow range of interest. This bias indicates that a small percentage of Maze loadings are overrepresented during low flows within the calibration period, while during higher flows the loading at Maze may be under-represented.

Estimated bias for Maze EC during October 1996 through September 2003 ranges from -4 percent to -2 percent. Thus, the Peer Review Panel's assertion that Maze EC may be underestimated seems to hold true when the statistics are based on the 1996-2003 period. However, for the EC>800 category (i.e. high salinity months), the bias is approximately -2 percent, or -16 to -32 EC if the biased level ranges from 800 to 1600 EC. A bias magnitude of -16 to -32 EC is well within the range of Maze EC scenario adjustments explored in the sensitivity and uncertainty analyses (Appendix B). Results from those Maze EC scenario adjustments are presented in the next section.

C.3.4 Sensitivity of Simulated Output to Change in Calibration Maze EC:

As mentioned, a sensitivity analysis was conducted to explore simulated output response to individual changes in model inputs (Appendix B). One set of scenarios involved scaling the Maze flow-EC regression curves, positive or negative, on a season-by-season basis and then re-simulating to assess below-Maze operational response. Other sensitivity analysis scenarios were also considered involving other flow and salinity inputs (Appendix B).

By comparison, the response of simulated water quality release from New Melones (Goodwin) during the entire simulation period (1922-2003) was most sensitive to Maze EC calibration. The maximum increase in the long-term average annual release was +6.7 TAF, or approximately 31 percent of the base, in response to inflating the June-July Maze flow-EC calibration curve (see Appendix B for inflation assumptions).

In comparison to the bias amounts discussed in Section C.3.3, the inflation of this curve represents a Maze EC increase (at specified flows) of approximately +80 to -80 over base-level Ekes of 800 to 1600 (i.e. comparing base and inflated curves in Appendix B, Figure: 1922-2003 Mean Jun and Jul EC). Focusing on release response during only San Joaquin Index 60-20-20 Critical years, the maximum increase of total New Melones releases to Maze EC calibration was on the order of 12 TAF (approximately 13% of the base). Other inputs showed various relative levels of influence on below-Maze operations (see Appendix B for further discussion).

From the preceding section, it was shown that bias-relative-to-observations is approximately +2 percent for EC>800 conditions. If sensitivity scenarios involving Maze EC inflation of +80 to -80 over base-level Ekes results in a Goodwin water quality response of 6.7 TAF (13 TAF for Critical YT), then an inflation of +2 percent would approximately translate to a Goodwin water quality response of approximately 1.5 TAF during the long-term average and approximately +3 TAF during the dry and critical year types.

It is important to note that the preceding numbers should *not* be interpreted outside the context of model input bias and potential collective uncertainty. Other factors affect below-Maze operations in the model beside Maze EC. To explore the collective influence of multiple input uncertainties, an uncertainty analysis was conducted (Appendix B). The next section summarizes results relevant to this section.

C.3.5 Uncertainty of Simulated Output Relative to Multiple Input Uncertainties: The results of the uncertainty analysis are summarized below for simulated annual release volumes at Goodwin, for both water quality only, and for the combined sum of water quality, dissolved oxygen, and VAMP. The output is further filtered into the average annual variation over the entire simulation period and the output for a critical year type. For further investigation, the results of all year types and alternative time periods are presented in Appendix B "Sensitivity and Uncertainty Analysis."

Table 3: Mean Annual Variations of Uncertainty for Representative Parameters

Output	**Total Period 1922-2003**			**San Joaquin Index 60-20-20 Critical Years from 1922-2003**		
	Median - Base	Limits - Base	80% C.I. about Base	Median – Base	Limits - Base	80% C.I. about Base
Goodwin water quality release (TAF/yr)	+2	-14 to +20	-6 to +8	+1	-37 to +12	-13 to +5
Goodwin total release for water quality, dissolved oxygen, and VAMP (TAF/yr)	+2	-15 to +23	-7 to +9	+2	-32 to +28	-15 to +15

Monthly variations of salinity differences from base for representative locations are presented in Table 4. In addition to the maximum variation and 80% confidence interval, the specific month when the maximum is observed is included in the table.

Table 4: Uncertainty of Monthly Mean relative to Base Monthly Mean

	1922-2003		**Critical Years Only**	
	Limits minus Base	80% C.I. about Base	Limits minus Base	80% C.I. about Base
Newman EC (μs/cm)	-175 to +175 (March)	-75 to +75 (March)	-210 to +220 (March)	-125 to +110 (March)
Below Tuolumne EC (μs/cm)	-125 to +150 (March)	-50 to +50 (March)	-175 to +200 (July)	-100 to +110 (July)
Maze EC (μs/cm)	-150 to +150 (March)	-75 to +75 (March)	-200 to + 250 (July)	-125 to +135 (July)
Stanislaus EC (μs/cm)	-100 to + 100 (December)	-60 to +60 (December)	-120 to +120 (Jan , Feb)	-75 to +75 (Jan, Feb)

C.4 Large Residual Flows and Salt Loads

The residual loads or closure terms are identified through iterative model simulations in order to produce simulated flow-EC relations at Maze and Newman that are in balance with VAMP operations spanning the basin from New Melones to Mendota Pool. Concern was raised that the magnitudes of the closure terms were large compared to the explicitly estimated loadings within the system.

It is acknowledged that the load closures time series are relatively large, as the Peer Review Panel has noted. Further information on the magnitudes of load closure terms relative to other modeled loads between Vernalis and Lander Avenue is provided in Appendix B, Table 2. Fundamentally, the load closure terms represent one missing load-type and two sources of error within the water quality module:

- Missing load: that associated with accretion sub-components representing precipitation-runoff and local-creek inflow

- Error source one: under- or over-estimation of explicit loads in the module

- Error source two: under- or over-estimation of calibration flow-EC relationships at Maze and Newman (i.e. the regression equations representing downstream control on load budget calculations).

One final comment on the load closure time series, it is important to understand they are meant to represent missing load, with error sources noted, relative to explicit load representation and recent historical salinity management. This requires the need to use recent historical data to estimate the current associated load residuals (see water quality module Appendix B, Calsim II Peer Review Session Support Documentation August 4, 2005).

C.5 Summary of Potential Maze EC Underestimation Response

Relative to observed conditions, it appears there may be a tendency for the model to underestimate Maze EC during months of higher EC (~2%). The magnitude of the bias is still within the magnitude of potential error sources in the input data to the model. The application of the sensitivity analysis may provide a range to this potential bias.

Borrowing response information from the sensitivity analysis, this bias would translate to a Goodwin release response probably no greater than 3.4 TAF over the dry year average base condition of 30 TAF. This estimated response is probably an overestimate because it is based only on underestimation of Maze EC conditions and not potential error in other upstream inputs.

In order to understand the potential cloud of variability that could be observed due to model bias and input errors the uncertainty analysis results were presented. Relative to collective upstream inputs' uncertainty and assumptions for uncertainty analysis, there appears to be little introduced bias in simulated Maze EC (see Table 4).

C.6 Implication and Synthesis of Responses

C.6.1 Simulated and Historical Data Comparisons

The simulated/historical data comparison relies on the analysis of simulated vs. historical EC and loading in the system at Maze. The comparison may provide an initial estimate of potential long term bias. Previously reported graphical analysis of the time series does not capture or describe any bias, but only offers a comparative or qualitative "exactness" of fit. The utility of generating summary statistical data for comparison of the simulated and historical data sets is not recommended since the model is not intended as a tool for generating long-term deterministic output. The CalSim II representation is, fundamentally, a planning tool to provide a reasonable analysis of alternative development through comparative study outcomes.

To show the recent water quality module enhancements, simulated loading and EC at Maze are presented in two separate figures. Figure 3 depicts the comparison of simulated load (EC* flow) and measured load for the calibration period. Figure 4 depicts the comparison of simulated EC and measured EC for the calibration period.

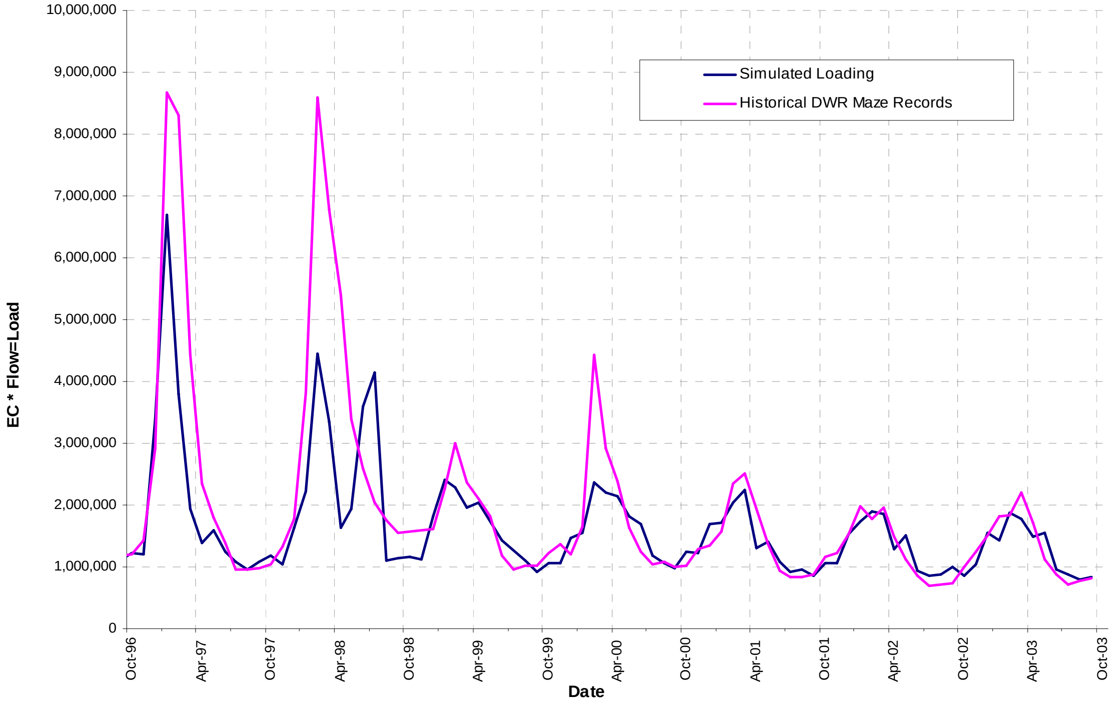

Figure 3: Comparison of Simulated and Historical Load 1996-2003

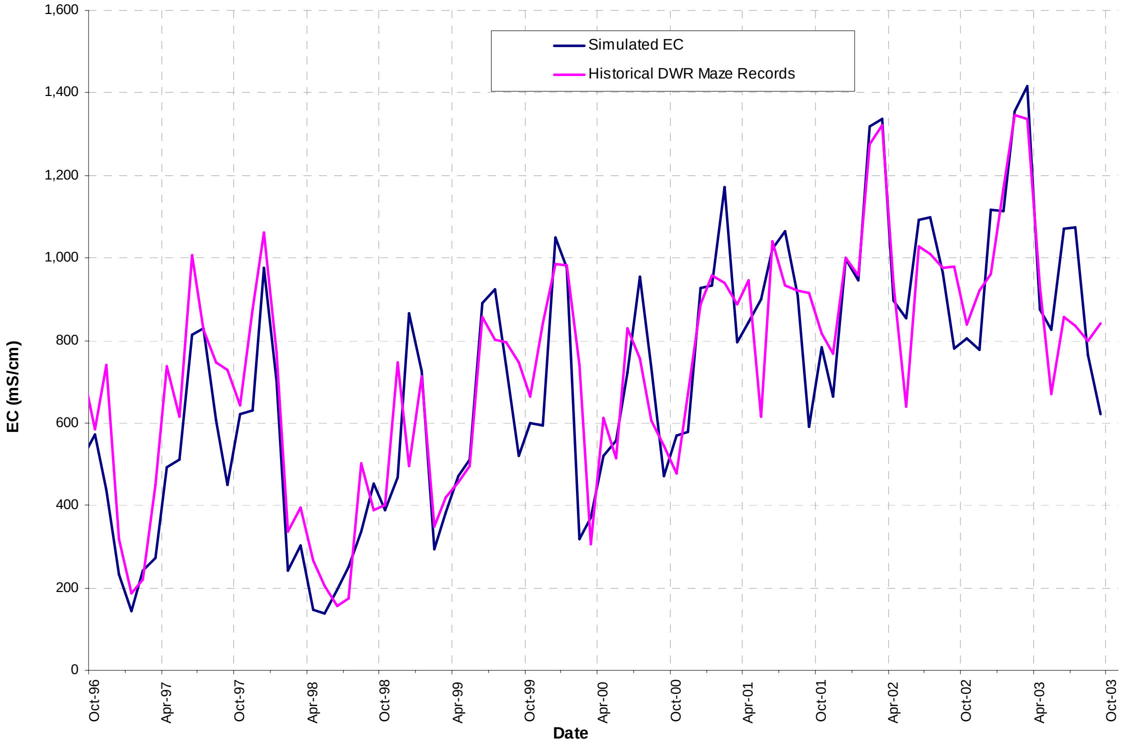

Figure 4: Comparison of Simulated and Historical EC 1996-2003

C.6.2 Effect of Water Quality on New Melones Storage Releases

The Peer Review Panel's primary concern with the Calsim II water quality representation was the effect of downstream Maze EC values on the magnitude of water releases from New Melones reservoir. The Peer Review Panel stated the potential for an additional 50 TAF of water from New Melones may be needed annually when Maze water quality exceeded the Vernalis standard (seasonally 700 or 1000 µs/cm).

In order to investigate these concerns, the uncertainty analysis provides a potential tool in understanding the effects of water quality and other model parameters as an output response of water quality releases from New Melones reservoir. The uncertainty analysis investigated a distribution of input scenarios including the Maze EC regression (see Appendix B) and the response of the model parameters were captured in parameter output ranges.

Of particular interest is the parameter of New Melones total water quality releases (water quality release, dissolved oxygen (DO) release, and VAMP releases). Annual average releases for varying time periods and San Joaquin Year Types were presented in both the sensitivity and uncertainty analysis (see Appendix B). During the 1922-2003 simulation period, the average base release from New Melones for water quality, DO and VAMP releases was about 36.2 TAF. Under the uncertainty analysis of randomly varying input realizations the simulated mean annual release was 37 TAF. The 80 percent confidence interval of results about the mean ranged from 29 to 46 TAF or approximately +/- 10 TAF.

The uncertainty of New Melones water quality releases during a critical year type under the base scenario is of particular interest to the users and Peer Review Panel of the model. The simulated base average annual release under a critical year type is on the order of 100 TAF with the 80 percent confidence interval ranging from 83 to 113 TAF (roughly a +/-17 TAF range).

C.7 Summary

The specific concerns of the Peer Review Panel regarding the water quality module and the potential for bias in representing the salt loads within the SJR at Maze (resulting in associated dilution flows from New Melones) were investigated within this document. A summary of the results are presented below:

- Low-flow Maze EC is probably biased somewhat in the model, as the Review Panel pointed out. However, year-type representation in the calibration period has little to do with observed bias and the Panel's estimates for influence on below-Maze operations were likely overstatements based on the sensitivity analysis results. As a guide for further enhancements of the model, the sensitivity analysis of the base scenario pinned the greatest responses of water quality releases on the Maze regressions and delivery demands within the basin.

- The Uncertainty analysis of the base scenario provided an estimate of the potential range of releases from New Melones under the complete simulation period and specific year type. The uncertainty analysis reveals that collective input uncertainties don't seem to translate into additional output bias.

- The calibration period does contain wet periods; however, the population of low flows represents the lowest 10 percent flows (93% exceedence) over the simulation period of 1922-2003.

In this analysis, precipitated by the Peer Review Response, it has been demonstrated that the CalSim II water quality representation of the SJR Valley is an update to previous models and the results are not invalid, nor lacking in utility for the simulation of the San Joaquin Valley River system.

References

Ford, D.F., L. Grober, T. Harmon, J.R. Lund, and D.C. McKinney. (2006). *Review Panel Report – San Joaquin River Valley CalSim II Model Review.* Report to the CALFED Science Program and the California Water and Environmental Modeling Forum, Sacramento, CA.

Reclamation, 2004. "San Joaquin Water Quality Module version 1.00 for CALSIM II". Draft Report for External Review.

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Appendix D. Summary of Peer Review Comments

Category	**Specific Response Section**	**Appendix A**	**Appendix B**	**Appendix C**
Groundwater	6.7, 8.2		X	
Accretions	6.8		X	
System Losses	6.6, 8.1		X	
Historical Comparisons	6.11, 6.13			
Operations	6.4			
Water Demands	6.2, 6.5, 6.6		X	
Salinity	6.9		X	X
Testing	6.12, 7.2, 8.3		X	
Documentation	6.13, 7.1, 8.2, 8.3	X		