DWR-1087

SAN JOAQUIN RIVER BASIN-WIDE WATER TEMPERATURE AND EC MODEL

A Report for
Department of Fish and Wildlife

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San Joaquin River Temperature and EC Model

1. Introduction

The U.S. Army Corps of Engineers (COE), Hydrologic Engineering Center HEC-5Q temperature model simulates long term flow and temperature relations along the San Joaquin River using daily average hydrology and six-hour meteorology (RMA, 2007; AD *et al*., 2007; AD *et al*., 2009). While the model has proved to be a useful management tool in the lower San Joaquin River (SJR) basin, several model enhancements to further improve model capabilities have been identified. First, the model's geographical coverage is limited. In order to model Friant restoration flows and various hydropower re-operation alternatives, reaches represented in the model had to be expanded. In addition, with salinity being a principal water quality concern in the river, incorporating electrical conductivity (EC) will increase modeling capabilities of the existing flow and temperature model. This added EC representation would subsequently provide a mechanism to assess possible salinity management objectives in the San Joaquin River basin above Vernalis. Other enhancements were also added to the model, including a CALSIM II interface, optimization routines, and hydropower post-processing capabilities.

1.1. Report Organization

This report includes a presentation of background information, descriptions of modifications to the model, and discussion of model application. Several appendices that contain supporting technical information and user's manuals are included. Each section is outlined below.

Section 1 provides a general overview of the project, its scope and objectives, and organization.

Section 2 presents previous modeling work as a context for the current project. This presentation includes an overview of the modeling framework of the HEC-5Q model and its development history in the San Joaquin Basin.

Section 3 highlights the modifications performed on the previous HEC-5Q model. The modifications include expanding the model's geographical coverage, updating temperature calibration, adding EC representation, enabling CALSIM II integration, adding the capability for hydropower computation, and statistical support software for analyzing model results. In this section, the discussion of EC representation added to the HEC-5Q model is more extensive than the other model modifications presented. This is because previous phases of the San Joaquin River HEC-5Q model development (AD *et al*., 2007; RMA, 2007; AD *et al*., 2009; RMA & WCI, 2010) already contain extensive discussions of temperature model development, including calibration and data collection. As for the other modifications not directly related to temperature and EC, an overview of these changes is included in the main report; additional technical information has been included in the appendices.

Section 4 presents the applications of the updated San Joaquin River HEC-5Q model under several operational studies. The section also presents the modeling philosophy, model capabilities and simulated results.

Section 5 presents conclusions and recommendations for future model application and potential extensions of modeling capabilities.

Several appendices are attached at the end of this report. They include an EC user's manual, a description of the optimization routine used in the model, a presentation of EC calibration and validation results, a description of the CALSIM II pre-processor for HEC-5Q input, a description of how dam power production is computed, and a presentation of the model post-processor.

2. Previous Work

This section summarizes previous work performed on the SJR HEC-5Q model. The HEC-5Q modeling framework that identifies the basic approach to reservoir and river temperature modeling will be presented initially followed by a history of model development.

2.1. HEC-5Q Modeling Framework

HEC-5Q computes the vertical or longitudinal distribution of temperature in the reservoirs and longitudinal temperature distributions in stream reaches based on daily average flows. Reservoirs represented in the model include San Luis Reservoir; O'Neill Forebay of the SWP and CVP system; Millerton and Mendota Pool on the San Joaquin River; McClure, McSwain, Merced Falls, and Crocker Huffman on the Merced River; Don Pedro and La Grange on the Tuolumne River; and New Melones, Tulloch, and Goodwin on the Stanislaus River.

Although a comprehensive water quality model, the HEC-5Q model for the San Joaquin River basin initially only included temperature representation. Refer to the HEC-5Q user's manual (HEC, 1999; 2000) for a more complete description of the water quality relationships included in that version of the model.

The external heat sources and sinks that were considered in HEC-5Q were assumed to occur at the air-water interface and at the sediment-water interface. Equilibrium temperature and coefficient of surface heat exchange concepts were used to evaluate the net rate of heat transfer. Equilibrium temperature is defined as the water temperature at which the net rate of heat exchange between the water surface and the overlying atmosphere is zero. The coefficient of surface heat exchange is the rate at which the heat transfer process progresses. All heat transfer mechanisms, except short-wave solar radiation, were applied at the water surface. Short-wave radiation penetrates the water surface and may affect water temperatures below the air-water interface. The depth of penetration is a function of adsorption and scattering properties of the water as affected by particulate material (i.e., phytoplankton and suspended solids). The heat exchange with the bed is a function of conductance and the heat capacity of the bed sediment.

2.2. History of the SJR HEC-5Q Model

The development of the San Joaquin River Basin-wide Water Temperature Model (Model) started as a grass-roots project in December 1999 when a group of Stanislaus River stakeholders decided to analyze the relationship between operational alternatives, water temperature regimes, and fish mortality in the Stanislaus River. These stakeholders included the U.S. Bureau of Reclamation (USBR), U.S. Fish and Wildlife Service (USFWS), California Department of Fish and Game (now known as the California Department of Fish and Wildlife [CDFW]), Oakdale Irrigation District (OID), South San Joaquin Irrigation District (SSJID), and Stockton East Water District (SEWD). The group decided to join resources and fund the development of a high resolution reservoir operation-water temperature computer model built on the Army Corps of Engineers' HEC-5Q platform. The Model covered the Stanislaus River from New Melones Reservoir to its confluence with the San Joaquin River.

The Model enabled the stakeholders to evaluate water temperature objectives at critical points in the river system that would enhance habitat conditions for fall-run Chinook salmon and Steelhead rainbow trout under various river operation scenarios. The Model also allowed for examinations of thermal benefits that might be obtained from physical changes to existing facilities (e.g., removal or breaching the original Melones Dam which is still in place in New Melones Reservoir) or from new facilities (e.g., selective withdrawal structure at New Melones Reservoir or retrofitting Goodwin Dam).

The success of the Stanislaus work and the interest in this Model expressed by stakeholders from adjacent tributaries to the San Joaquin River (e.g., Tuolumne and Merced rivers), prompted CALFED to fund the expansion of the model. This was completed in two phases: 1) extending the Model to include the Lower San Joaquin River in the reach between the Stanislaus River and Mossdale, and 2) extending the Model to include the main stem SJR between the Stanislaus River and Stevinson (upstream of the Merced River confluence).

A working version of the Model was released to the SJR stakeholders in November 2008 and the final version of the model was submitted to CALFED and released to the public in December 2009. The model has been peer reviewed by a group of scientists selected by CALFED.

The Model in its current setting is designed to simulate reservoir operations and resulting flow regimes in the river system using daily time steps and then compute the water temperature response at any given location downstream of the reservoirs on a sub-daily basis (6-hour intervals). Reservoirs represented in the Model include McClure, McSwain, Merced Falls, and Crocker Huffman on the Merced River; Don Pedro and La Grange on the Tuolumne River; and New Melones, Tulloch, and Goodwin on the Stanislaus River.

The Model can perform two modes of simulations: The first mode uses the "top-down" approach. In this mode, the Model computes the temperature response downstream of the reservoirs given a prescribed release schedule. The second mode uses the "bottom-up" approach. In this mode, target temperatures at compliance points are identified (could be at multiple locations and times in the year) and the Model computes how much water should be released from the reservoirs and when (taking into account travel time), in an attempt to meet the target temperatures. Special constraints are imposed to ensure that the Model's proposed release is compatible with the physical system as well as with the operator's ability to manage this release (e.g., ramping rates, channel capacity, maximum volume of water available to managers to mitigate temperature violations, etc.).

Concurrent with the efforts of Model development described above, the USBR, as part of the 2006 Friant Litigation Settlement Agreement, funded Model extensions, to include: 1) the San Joaquin River flood and bypass systems from Millerton Lake/Friant Dam downstream to Stevinson, to evaluate thermal impacts of Friant restoration alternatives, and 2) the SWP and CVP system components (canals and storage facilities between the Bay-Delta and Mendota Pool). More recently, the USBR also funded a study to assess the viability (proof of concept) of expanding the Model to simulate salinity (Electrical Conductivity or EC) conditions at key locations within the San Joaquin River system.

3. Modifications to the HEC5Q Modeling Framework

The model was extended in this project to include several enhancements and modifications. The newly expanded/enhanced Model includes a complete geographical coverage of the SJR basin stretching from the SJR Basin rim reservoirs (New Melones, New Don Pedro, McClure, and Millerton) to the Bay-Delta, including representation of the SWP and CVP components. EC representation in the model has been refined and calibrated and the hydrological period with EC representation was extended through December 2010. One of the important features in the expanded/enhanced Model is the interface with CALSIM II. This feature is coupled with a new optimization routine whereby the Model disaggregates the monthly release from reservoirs to daily flow and reallocates the water in a way that maximizes the thermal downstream benefits, while maintaining the same volume of water released on an annual basis. The impact of reservoir release reallocation on EC is a byproduct of the simulation. The Model also includes representation of the hydropower generation facilities at the main dams in the SJR basin and new post-processing capabilities.

3.1. Expanded Geographical Coverage

The newly expanded/enhanced Model provides a complete geographical coverage of the SJR basin stretching from the SJR Basin rim reservoirs (New Melones, New Don Pedro, McClure, and Millerton) to the Bay-Delta, including representation of the SWP and CVP components. The San Joaquin River above Stevinson (south) includes the historical San Joaquin River channel; the various bypass channels and the Mendota Pool. SWP and CVP facilities include the California Aqueduct, Delta Mendota Canal (DMC), San Luis Reservoir and O'Neill Forebay.

The Mendota Pool forms the junction between the San Joaquin River and the DMC. Inclusion of the CVP and SWP facilities allows the updated model to account for Delta pumping and San Luis Reservoir operational impacts on DMC temperature and EC at Mendota. The DMC is the main driver of water quality conditions below Mendota Dam during periods of low releases from Friant Dam.

The expanded model utilized components of the San-Joaquin Basin Water Temperature Model (RMA, 2007) and the San Joaquin Electrical Conductivity Balance Model (RMA& WCI, 2010). Both of these models were initially calibrated against limited ambient temperature data. The expanded model representation is shown in Figure 1.

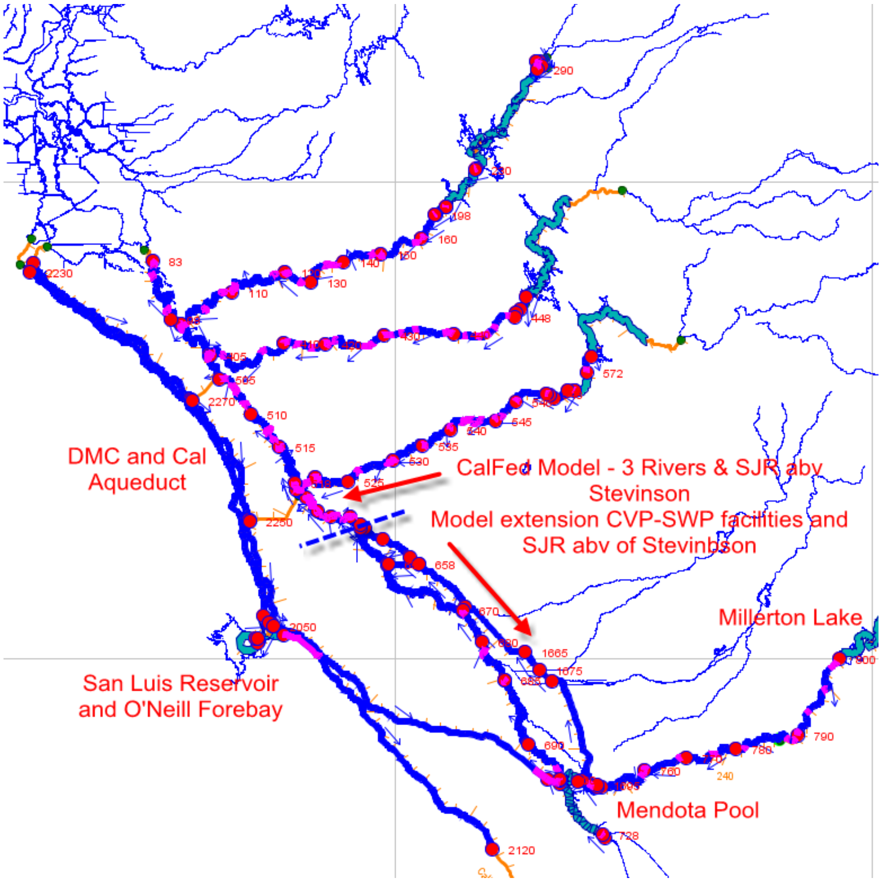

Figure 1. Schematic representation of the expanded San Joaquin Basin Model.

3.2. Temperature Calibration

The San Joaquin River model (CalFed Model) below Stevinson was calibrated to a comprehensive observed data set that included numerous monitoring locations. The calibration data set extended through 2007. Model calibration upstream of Stevinson utilized a considerably less robust data set. Data for the San Joaquin River below Friant included various CDEC stations with up to 4 years of data and several short term stations that were installed during Friant litigation preparation. Consequently, the current upstream of Stevinson calibration effort can be viewed as a true calibration. However, even though the initial calibration is considered preliminary, only minor changes in model parameters were required to better represent the expanded data set.

The calibration approach has been well documentation previously (RMA & WCI, 2010). Typical calibration plots and statistical comparisons are shown in Appendix G. The statistics compare the monthly and quarterly averages (computed and observed), bias and root mean square (RMS) and mean absolute difference for all monitoring stations considered during calibration. The statistics have been computed and compared for two time periods (before and after 2007). This comparison shows the variability of model results for different time periods and is somewhat analogous to the traditional calibration and validation approach to model development.

3.3. Electrical Conductivity

High levels of salt concentration in the San Joaquin River have been a water quality concern in the region (USGS, 2011). Federal, state, and local agencies have initiated various efforts to mitigate the trend of increasing salinity in the river. To evaluate the effectiveness of mitigation efforts, a basin-wide salinity model that can be used in tandem with temperature representation is necessary. This section will present the work involved in updating the existing San Joaquin River HEC-5Q temperature model (RMA, 2007; AD *et al*., 2007; AD *et al*., 2009) to include salinity representation. This work is an extension of a previous proof-of-concept study that was completed in 2009 (RMA & WCI, 2010). A fully functioning basin-wide temperature/salinity model would be an objective management tool that can guide decision-makers in selecting effective strategies for mitigation, and thus reduce risks of investing in measures that may not yield satisfactory results in the real world.

3.3.1. Background

The salinity of an aquatic system is usually represented by its electrical conductivity (EC), which acts as a surrogate for the amount of total dissolved solids (TDS) in the water. The Vernalis Water Quality Objective has separate EC standards for the irrigation season and the non-irrigation season (Table 1) (SWRCB, 1978; SWRCB, 1991).

Table 1. Vernalis Water Quality Objective for Salinity.

	EC Standard (µS/cm)
Irrigation Season (April to September)	700
Non-Irrigation Season (October to March)	1000

The San Joaquin River Basin is made up of the San Joaquin River and many other tributaries, diversions, and irrigation canals. These are the main waterways that distribute water throughout the California Central Valley. There are 7 million acres of irrigated agriculture in the Central Valley and over 340 water agencies that discharge into the river system. Each of these inflows into the main stem San Joaquin River and have varying degrees of contribution to the overall EC conditions along the San Joaquin River, and more importantly, the ability of the system to meet the EC standards at Vernalis.

EC is considered a conservative parameter and is unaffected by decay, settling, uptake, or other processes. It is passively transported by advection and diffusion. In the HEC-5Q modeling framework, EC would be simulated alongside flow and temperature. When the model is applied for resource management purposes, EC simulation would be a by-product of flow and temperature simulations that were altered based on dam re-operation and hydropower alternatives.

3.3.2. Previous EC Modeling Work in the SJR Basin

Various water quality assessments in the basin had been performed and are ongoing since the 1950s. One of the early attempts to model EC in the basin began in 1985 with the first formulation of the San Joaquin River Input-Output (SJRIO) model. This was a data-driven flow and water quality model of the main stem San Joaquin River (between Lander Avenue and Vernalis). The SJRIO model used hydrologic routing techniques and conservative mass transport to calculate water quality at various intervals along the river (Kratzer *et al*., 1987). Further modifications were made in subsequent years. A more updated version of the model is called SJRIO-2 (Grober, 1989).

SJRIODAY is the daily version of the SJRIO, and it was developed by the San Joaquin River Management Program’s Water Quality Subcommittee as a forecasting tool to predict assimilative capacity at various points on the San Joaquin River. This daily salt balance model is used to forecast EC conditions for a 14-day period after the model run date. The SJRIODAY is part of the real-time salinity management scheme in the San Joaquin River, which includes an extensive network of water quality monitoring sites that are used as model input. SJIRIODAY’s web-based model interface provides users with figures, tables and data on the flow, EC and assimilative capacity in the river at Crow’s Landing, Maze Road Bridge, and Vernalis (Quinn *et al*., 1997; Quinn and Karkoski, 1998; Quinn, 1999; Quinn *et al*., 2005). The SJRIODAY model was also used to estimate diversion flows along the San Joaquin River (Quinn & Tulloch, 2002).

In 2007, as part of creating a “data atlas” for San Joaquin River flow and water quality, Jones & Stokes (2007) performed a salt balance for 2005. Annual and monthly salt loads from Sierra Nevada runoffs, rainfall, and imported water supply (Delta Mendota Canal and intermediate agricultural discharges) were balanced with salt loads observed at Vernalis. Observations made in this study were generally consistent with findings from the proof-of-concept EC balance conducted in 2009. Mainly, the total salt load at Vernalis is greater than the combined salt load from the Sierra Nevada runoff and known inflows throughout the basin. In other words, while a general salt budget can be estimated for any portion of the watershed, the lack of data requires assigning accretion/depletion (A/D) flow and EC to close the balance. In addition, salt loads were observed to be higher during wet conditions because accumulated salts from soils and shallow groundwater have a tendency to get flushed into the main stem San Joaquin River.

More recently, EPA’s public domain model code (WARMF) was used to represent the San Joaquin watershed as part of the TMDL process (Quinn *et al*., 2010). The version of WARMF that has been implemented in the San Joaquin River basin is called WARMF-SJR. The model integrates smaller models, databases, and graphical software into a map-based stand alone tool. In addition, the WARMF-SJR contains an engineering module, which is a GIS-based watershed model that calculates surface runoff, groundwater flow, and water quality in the river. A daily time step is used to perform mass balance and heat budget calculations to capture dynamic responses of flow and various water quality parameters in the system.

In 2011, as part of the study to evaluate San Joaquin River flow objective alternatives, a spreadsheet model was created to estimate how EC at Vernalis could be affected by flow changes in the Stanislaus, Tuolumne, and Merced Rivers. This model used flow and EC inputs from the CALSIM II model. In this model, EC from each tributary is calculated as a simple mass balance.

In 2009, a USBR-sponsored effort was made to expand the existing HEC-5Q San Joaquin River temperature model to include EC representation. Previously, the HEC-5Q model had been used to assess water temperature impacts of Friant restoration alternatives (RMA, 2007) and impacts of Stanislaus, Tuolumne and Merced reservoir operation (AD *et al*., 2007; AD *et al*., 2009). In 2009, the model was expanded to include the SWP and CVP system. This 2009 study began with a preliminary appraisal to determine the potential for incorporating EC into the existing HEC-5Q modeling framework for flow and temperature. To achieve this, a conceptual EC balance (from 2000 to 2008) was performed on the San Joaquin River from below Friant Dam to Vernalis, and including major tributary contributions from the Merced, Tuolumne and Stanislaus Rivers. The San Joaquin River system was divided into eight reaches based on data availability. Data gaps were filled using linear interpolation, historical EC data, data from other stations, or wet/dry year data from other years. EC balances were done for each reach using a 7-day, 15-day, and 30-day running average of daily flow and EC data. The completed preliminary EC balance analysis and expanded HEC-5Q model were positive first steps in explicitly quantifying EC conditions in the river, and provided insight into the next steps needed to develop a HEC-5Q-based forecasting tool in the San Joaquin River basin.

3.3.3. Methodology

The extension of the San Joaquin River HEC-5Q temperature model to include EC representation began with putting together a comprehensive EC data set. Subsequently, measured or calculated data were used as EC boundary conditions for the model. Finally, model calibration and validation were performed. These steps are described in detail in this section.

3.3.3.1. Model Calibration

Model calibration is the stage wherein model parameters are modified to fit the model to field observations. In this section, the approach to EC calibration will be presented. Subsequent sections will present the calibration results and model validation.

EC calibration was performed through the adjustments of unknown EC loads: (1) accretion flows, and (2) tributary inflows with unknown EC (Figure 2).

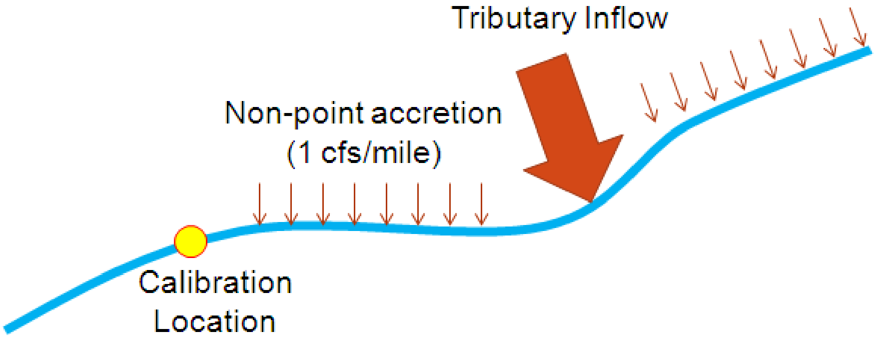

Figure 2. Schematic showing the terms representing unknown EC loads entering a river reach.

The first part of EC calibration involves the modification of accretion/depletion (A/D) terms. Given that the EC conditions of these A/D flows are largely unknown, they can be adjusted in order to allow the simulated data to match the measured data at several key locations that have been selected as calibration points for the model. The A/D term represents the net of all ungaged flows going in and out of the reach. Some examples of these ungaged flows throughout the basin are: irrigation returns, agricultural diversions, groundwater flows, and surface runoff. For any reach of a river, if measured upstream conditions are dissimilar to its measured downstream conditions; these ungaged flows between the upstream and downstream points are likely to have had some impact on that reach.

As part of the EC calibration process, a small, but constant, accretion flow (1 cfs/mile), which represents the net accretion-depletion, is applied to a stretch of the reach. This small accretion flow is given an arbitrary EC that is adjusted over several iterations of model runs. The accretion flow is small so as to not affect the flow calibration that has been completed on HEC-5. Using this method of calibration, the accretion EC concentrations that correspond with the small flows are often high (up to 7,000 µS/cm). These high EC concentrations are necessary in order to calibrate the model such that simulated EC values would be close to measured EC values at the calibration points. Nevertheless, the EC load (flow times concentration) would be equivalent to actual accretion EC loads entering the system. This net accretion flow and EC applied to each reach would be constant from year to year. In other words, the accretion flow and EC inputs are treated as parameters that make up the model rather than model input data. These constant flow and EC values represent the groundwater and ungaged surface flows throughout the various reaches that affect the model’s ability to predict EC. Once the calibration has been finalized, the model can then be used as a forecasting tool that does not require new calibration each time the dataset is expanded.

This procedure of adding a constant 1 cfs/mile of accretion enables the model to accurately represent EC conditions because the San Joaquin River basin consists of several large main stem reservoirs with dams near the valley floor. This ensures that nearly all runoffs with low EC are captured above the dams. As such, the accretion that enters into the San Joaquin River and its tributaries below these reservoirs are small and tend to have high EC. The baseflow in the streams below the lowest main stem reservoirs reflects influences of groundwater and ungaged surface water inflows, and the 1 cfs/mile of accretion added is representative of these flows. For periods above the lowest baseflow, reservoir releases are usually several magnitudes higher than the added 1 cfs/mile accretion that is used for calibration. Therefore, the effects of adding a constant 1 cfs/mile of accretion with a constant EC for calibration are limited during such events.

In some instances, there are flow data available for surface inflows, but there is no corresponding EC data. In such cases, in addition to the constant 1 cfs/mile accretion, several portions of the river were also calibrated through the adjustment of EC associated with tributary inflows. Adjustments were made within a range of EC values consistent with observed EC values in the basin. This calibration procedure only applies to the reaches with known tributary inflows, i.e. Dry Creek flowing into the Merced River and Dry Creek flowing into the Tuolumne River. The flows of these tributaries have been defined in HEC-5, and a constant EC assigned to the tributary – and iteratively adjusted – as part of the model calibration process.

Table 2. Summary of EC concentrations that were used for model EC calibration

Reach	EC Calibration Point Location(s)	Accretion EC (µS/cm)	Tributary Inflow EC (µS/cm)
San Joaquin River			
Friant to Gravelly Ford	Donny Bridge, Gravelly Ford	50	n/a
Mendota Pool	below Mendota Dam	n/a	n/a
Mendota Dam to Stevinson	Stevinson	2,000	n/a
Stevinson to Crows Landing	Crows Landing	n/a	n/a
Crows Landing to Vernalis	Vernalis	7,000	1,200 (at 5 discrete points)
Delta-Mendota Canal			
Delta to Check 21	Check 21	n/a	n/a
Merced River			
Crocker-Huffman Dam to Cressey	Cressey	150	200
Cressey to confluence	Merced River near Stevinson	600	n/a
Tuolumne River			
LaGrange Dam to Modesto	Modesto	700	160
Modesto to confluence	n/a	700	n/a
Stanislaus River			
Goodwin Dam to Ripon	Orange Blossom Bridge, Ripon	200	n/a
Ripon to confluence	n/a	200	n/a

3.3.3.2. Calibration Results

In this section, model calibration results from two locations are presented: San Joaquin River at Crow’s Landing (SCL) (Figure 3), and Vernalis (VNS) (Figure 4). The flow profiles (simulated) at the respective locations are also presented on the secondary axis. Calibration results at other locations are presented in Appendix C.

Figure 3. Comparison of simulated and measured EC in San Joaquin River at Crow's Landing after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

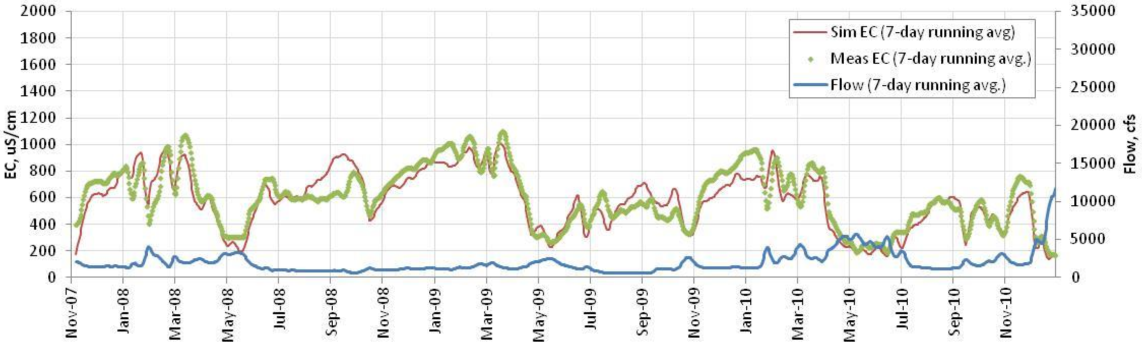

Figure 4. Comparison of simulated and measured EC in San Joaquin River at Vernalis after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

3.3.3.3. Model Validation

Model validation is the step after calibration where the model is tested on an independent set of data to show that the model can replicate field conditions with accretion and tributary EC concentrations that had been determined in calibration. For validation of the San Joaquin River temperature and EC model, the model was run from 2004 to 2007 without any additional adjustments to accretion or tributary EC (Figure 5 and Figure 6). If the model has been successfully calibrated for years 2008 through 2010, the model validation step would show good model performance for these other years outside the calibration period.

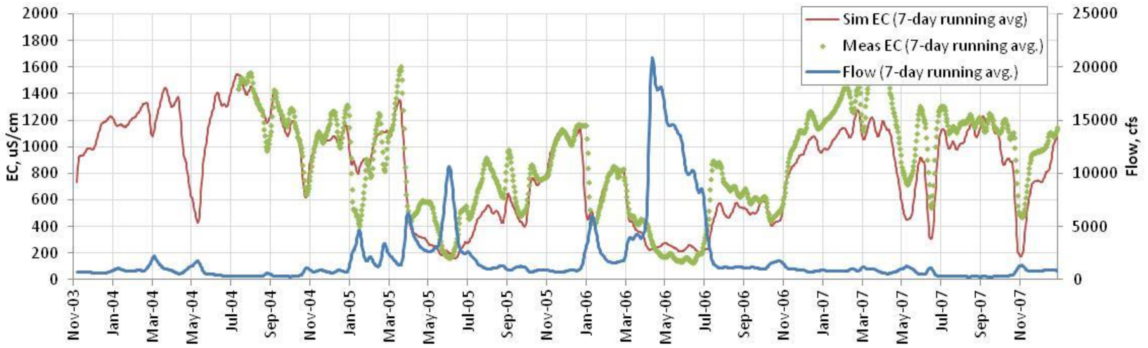

Figure 5. Comparison of simulated and measured EC in San Joaquin River at Crow's Landing as part of model validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

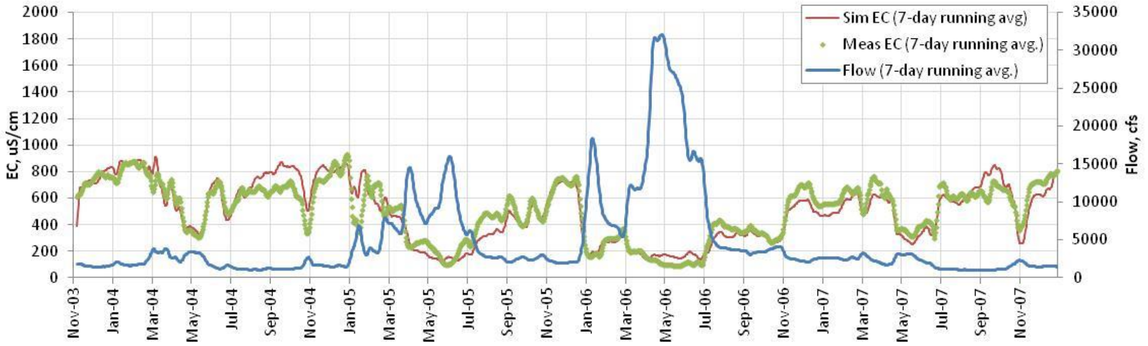

Figure 6. Comparison of simulated and measured EC in San Joaquin River at Vernalis as part of model validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

3.3.3.4. Discussion of EC Calibration Results

The temporal metric chosen for calibration is a 7-day running average. The flow and EC data are available in daily, hourly, or 15-minute data, while the San Joaquin River temperature model uses a 6-hour time step in order to approximate daily maximum and minimum. For calibration, the temporal metric of measured and simulated data were standardized for comparison purposes. In addition, the appropriate time step for EC representation depends on the travel time through the modeled reach. In the case of the San Joaquin River, the travel time from Friant to Vernalis varies with flow, but with the exception of the high flow rates, the travel time is greater than seven days. With that consideration, a weekly metric would be more representative of the system than a daily or sub-daily metric. A weekly metric is also consistent with the previous report, and allows the model to be used in conjunction with regulatory criteria (30-day running average).

After calibration, as shown in the calibration and validation results, the model is able to simulate EC concentrations quite closely (Figure 5 and Figure 6). However, the model does not perform as well when there are sudden rises in EC concentration. Often, these rises in EC concentration are related to increases in flow rate, i.e., EC concentration increased either during or slightly after the flow profile had peaked. These higher flow rates are usually a result of high rainfall events that led to increased surface and groundwater inflows. These inflows often come from or had passed through agricultural lands that would contribute to the EC levels, thus increasing the EC concentration in the river. As such, the model often performs better during drier periods. This observation is consistent with findings from a similar study in the San Joaquin River basin (Jones & Stokes, 2007). Sudden increases in flow and EC levels would require a higher resolution model with a more extensive dataset. Given the model resolution and data limitations, replicating the consequences of sudden flow and EC changes was not the goal of this HEC-5Q model enhancement. In addition, decline of EC model performance during certain periods could also be a result of other factors, such as the influence of ungaged flows and undocumented releases into the river, both of which are examples of possible EC contributions that are not represented in the model.

3.4. CALSIM II Integration

One of the important features in the expanded/enhanced Model is the interface with CALSIM II. A pre-processing routine converts CALSIM II output to Model compatible HEC-DSS[1] input. This routine serves two purposes: 1) to allow the Model to perform a long-term simulation compatible with the period used in CALSIM II; and 2) to disaggregate monthly output from CALSIM II to daily values in the Model. The latter feature is coupled with a revised optimization routine whereby the Model disaggregates the monthly release from reservoirs to daily flow and reallocates the water in a way that maximizes the thermal downstream benefits, while maintaining the same volume of water released on an annual basis. The impact of reservoir release reallocation on EC is a by-product of the simulation.

Information regarding the steps needed to incorporate CALSIM II data into the temperature modeling framework has been included in Appendix D.

3.5. Hydropower Computation

The expanded/enhanced model also includes the capability for computing power production at all power producing dams. The model computes the power production as a function of reservoir elevation and flow. Major power facilities in the San Joaquin River basin include:

1. New Melones (Stanislaus)
2. Tulloch (Stanislaus)
3. Don Pedro Dam (Tuolumne)
4. Exchequer Dam (Merced/Lake McClure)
5. McSwain Dam (Merced)
6. Friant-Kern Canal outlet (San Joaquin/Friant Dam)

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[1] HEC-DSS is a database system designed to efficiently store and retrieve scientific data. A special Java-based visual utilities program developed by the US Army Corps of Engineers called HEC-DSSVue allows users to plot, tabulate, edit, and manipulate data in a HEC-DSS database file. HEC-DSSVue can be downloaded from the following link: http://www.hec.usace.army.mil/software/hec-dss/hecdssvue-dssvue.htm

7. Madera Canal outlet (San Joaquin/Friant Dam)

8. Friant Dam (San Joaquin River outlet)

Power plant capacities in terms of rating and maximum output (power and flow), and operations mode are shown in Figure 7, below.

San Joaquin River Basin Hydropower Facilities					
River/Reach	**Power Plant**	**Rated Capacity (MW)**	**Maximum Capacity (MW)**	**Maximum Flow (CFS)**	**Operations Mode**
Stanislaus	New Melones	300.0	383.3	10,003	Peaking
Stanislaus	Tulloch	17.1	18.3	1,800	Run-of-River
Tuolumne	New Don Pedro	203.0	197.5	5,400	Run-of-River
Merced	New Exchequer	94.5	105.2	3,100	Peaking
Merced	McSwain	9.0	9.6	2,500	Run-of-River
Friant	Friant-Kern Canal	19.9	20.0	2,205	Run-of-River
Friant	Madera Canal	9.9	10.6	1,054	Run-of-River
Friant	River Outlet	2.3	2.5	130	Run-of-River

Figure 7. Major hydropower facilities in the San Joaquin River basin.

Directions for utilizing the power production computation capability in the Model can be found in Appendix E.

3.6. Statistical support software

The HEC-5Q model and graphical user interface (GUI) has several model options that provide results in various user specified formats. A binary file is also generated that interfaces with the GUI. Binary output contains user specified parameters (i.e., flow, temperature, and EC) at each time step and an every computational stream element. A complete set of computed values is necessary for animation of simulation results. The statistically support software accesses these results as directed by the user. The three options include:

1. Compare simulation results with observed data.

2. Compare one set of simulation results with another.

3. Provide a side by side comparison to two sets of simulation versus observed statistics (e.g., runs with different model coefficient sets).

The output includes monthly and user specified time period averages, measurement bias and RMS, and mean absolute differences between data and model results. For model run results comparison, the average and daily maximums as well as the difference is provided. This software utility is described in Appendix F

4. Application – Operational Studies

There were no operational studies proposed to deal with ongoing issues and proposals other than evaluation and ramifications of percent of "full natural flow" operation. This analysis was performed by CDFW staff with assistance and advice from project consultants. This CDFW study is a good example of model usage as initially envisioned. The ongoing model development effort has provided a modeling system for analysis of temperature and EC intended for use by stakeholders

To further expand the modeling system capability, the CALSIM II integration was added to facilitate operational studies. CALSIM II output reflects system demands and operational constraints including EC compliance at Vernalis. The added HEC-5Q model capability allows direct evaluation of temperature and an independent EC impact for CALSIM II generated monthly flows.

Experience has shown the daily variations in temperature can be pronounced in a constant flow environment. During the previous HEC-5Q development project, the capability to operate reservoir for downstream temperature control was developed. The concepts and utility of this HEC-5Q option is described in detail in Section 4.4 of the previous project report (AD *et al*., 2009). To facilitate and expand upon operational studies utilizing CALSIM II results, a demonstration of how the HEC5Q reservoir operation for temperature control option would be implemented. Associated with any operation for temperature objectives would be the EC impacts of revised flows. The reservoir operation is described in Appendix B along with detailed instructions for implementing and interpreting this option.

4.1. Philosophy

The temperature operation capability relies upon a flexible input data set that defines temperature objectives on a daily basis and end of year volume constraints. It considers the factors that an operator might use to manage reservoir releases for temperature control, namely, current system status (e.g., reservoir volumes, current flows and river temperatures, etc.), ramping rate constraints and weather forecasts. The model simulates forward in time to estimate a minimum flow requirement and operates the system accordingly. Defining the operational minimum flow allows the reservoir to operate for other constraints such as obeying the rule curve. Since operators cannot go back in time to adjust reservoir releases, the model does not iterate to achieve an exact match of the temperature target.

Temperature operation results in a change in end-of-period reservoir volume. The reoperation option allows the user to define the end-of-period volume. This volume can be historical, CALSIM II end of month, or user imposed. This allows the user to manipulate carryover storage.

In addition to the computed temperatures at user specified location, the incremental water costs expressed as cfs/°F is computed. This cost is the rate of change at the augmented flow rate and is not an indication of the quantity of water needed to reach the target temperature. It does, however, provide an indication of the effectiveness of further changes in the temperature target. This allows the modeler to assess the effectiveness of an alternative relative to the best use of the available water resource. The accompanying EC result addresses the water quality effects of water redistribution ramifications.

To aid in the evaluation of operation scenarios, the statistics utility program (see Appendix F) allows side by side comparison of simulation results.

The model capabilities and supporting programs allow the user to efficiently test a wide range of operational alternatives and constraints to achieve a better understanding of how the systems perform and what are reasonable expectations for temperature control.

4.2. Capabilities

In summary, the modeling system capabilities related to system operation for temperature control include:

- Volume Reset 1 – Reservoir volume is reset to a specific storage level (same volume each year) on each anniversary date.
- Volume Reset 2 – Reservoir volume is reset only when a specific storage level is exceeded on the anniversary date (no benefit from previous year's water savings).
- Volume Reset 3 – Reset reservoir volume on first year only.
- Volume Reset 4 –Reservoir volume is reset to a user specified storage level on each anniversary date, so the reservoir volume could vary from year to year. (This option is used for the hypothetical demonstration in Section 4.3.)
- Volume Reset 5 – Reservoir volume is reset to a user specified storage level for each year unless the end of period storage falls below the stated reset initial storage, then model does not reset the storage volume and there are penalties for shortfalls. This alternative is similar to Volume Reset 4, but shortfalls are accumulated.
- Reservoir operation limitations include maximum outflow temperature and minimum storage requirement for temperature operation.
- Daily specification of temperature objectives (temperature and location), maximum and minimum flow constraints, and raising and falling ramping rates.
- Re-operate reservoir to maintain end of period storage as specified by the user.

4.3. Results

The results presented below serve as a demonstration of the reservoir operation capability. The CALSIM II defined hydrology for the 1999 to 2002 period was selected because this period begins with full reservoirs and subsequent drawdown. The starting volume constraint was enforced on February 1st. A mid-winter start time is appropriate because the temperature profile is redefined on each anniversary date (February 1st). Results of temperature operation using historical operation data can be found in the 2009 project report (AD *et al.*, 2009).

This demonstration uses hypothetical temperature targets for all three major tributary rivers. The San Joaquin River below Friant Dam was not operated for temperature due to uncertainty associated with Friant restoration. The full model (including the CVP-SWP) was used for this demonstration; however the sub-model below the San Joaquin at Stevinson would yield the same result since the model representations of the Stanislaus, Tuolumne and Merced Rivers are identical in both the full and sub-model.

Due to the hypothetical nature of this demonstration, no conclusions related to temperature control potential can be drawn. All of these results should be viewed from the model capability perspective without regard to the temperature target, location, timing, flow constraints, and ramping rates. The Stanislaus River operation is used in this demonstration. The other two rivers yield comparable results.

The CALSIM II New Melones storage and flows and simulated temperature in the Stanislaus River at Oakdale are shown in Figure 8. The flows are monthly averages. The storage is computed daily from curve fit inflow rates and monthly average outflow. The temperatures are computed at 6-hour intervals (the model time step). The effects on river temperature of meteorology and abrupt changes in flow are clearly seen in these results.

The impact of New Melones Dam being operated to control temperature at Oakdale is shown in Figure 9. For this simulation, the maximum and minimum flow constraint was twice and half of the CALSIM II flows, respectively. The ramping rates were approximately a third of the CALSIM II flow. The hypothetical daily maximum temperature objectives were:

1. January 1 to April 15: High temperature objective to allow flow reduction to conserve water.

2. April 16 to May 20: 58°F at the confluence.

3. May 21 to September 15: 62°F at Oakdale Highway 120 Bridge.

4. September 16 to October 15: 66°F at the confluence.

5. October 16 to December 31: no temperature target, instead flow constraints were set to force flows near 250 cfs.

The New Melones storage was reset on February 1st of each year (i.e., Volume Reset 4). In 1999, the temperature targets were met with a decrease in New Melones Dam release (higher end-of-period storage). For all other years, a larger total release was required to satisfy the temperature targets.

The Oakdale flow plot shows how the model responds to the targets (Figure 8 through Figure 11). Flows during the first few months of 1999 are dictated by the rule curve (for flood control) that supersedes the minimum flow requirements set by temperature control. In all years, the flow prior to April 16th is reduced to the minimum flow as specified by input (half of the CALSIM II flow). The impact of lower flows during this period is small (average confluence temperatures of 54.25°F and 55.38°F for the CALSIM II flows and reduced flows, respectively).

Beginning on April 16th, the flow ramps up in response to the temperature objective at the confluence. The augmented flows are often twice the CALSIM II flows during the April 16th to May 20th period indicating that the objective cannot be attained with the upper flow constraint. During this period, the augmented flows result in an average decrease in confluence temperatures of only 1.55°F (59.88°F minus 58.32°F). The average incremental water cost of 1,120 cfs/°F during this period quantifies the insensitivity to flow. The spike in flow at the end of April is due to the higher upper flow constraint.

During the May 21st to September 15th period, flows are generally increased and often constrained by the maximum limit. The impacts on temperatures are pronounced and near the temperature target. The average incremental water cost is 205 cfs/°F during this period. The average incremental water cost is approximately 5.5 times less than that for the confluence.

The September 15th to October 15th period confluence target is attained at a relatively low flow that is below the CALSIM II flow. Keep in mind that the flow constraints were arbitrarily set relative to the CALSIM II flows. In an actual study, the flow constraints would likely be based on biological flow criteria.

For the remainder of the year, the flows were restricted to a narrow range and temperature objectives have little impact. This type of constraint may be appropriate for a salmonid spawning period.

The impact of the volume reset option (end-of-period storage constraint) on New Melones storage and the flow and temperature at Oakdale is shown in Figure 10. A shorter time period is plotted to provide more detail. During these two years, New Melones releases were reduced such that the flow below Goodwin Dam was reduced by a uniform factor. In 2000, the storage deficit corresponding flow reduction was small and resulted in a very slight increase in temperature. In 2001, the storage adjustment was approximately 68,000 acre-feet (af). With the larger adjustments, temperature impacts were greater; however the maximum temperature did not exceed 66.3°F. Without the volume reset option, the computed temperature (from CalSim II) was around 70°F. This result shows the impact of daily variations in releases in response to temperature objectives without increased total release to the river.

Figure 11 is similar to Figure 9 except that flow augmentation assumes that the temperature targets are daily average objectives rather than daily maximum. As expected, the additional water requirement to meet a higher temperature target is less. A decrease in storage occurs in 2001 and 2002 only.

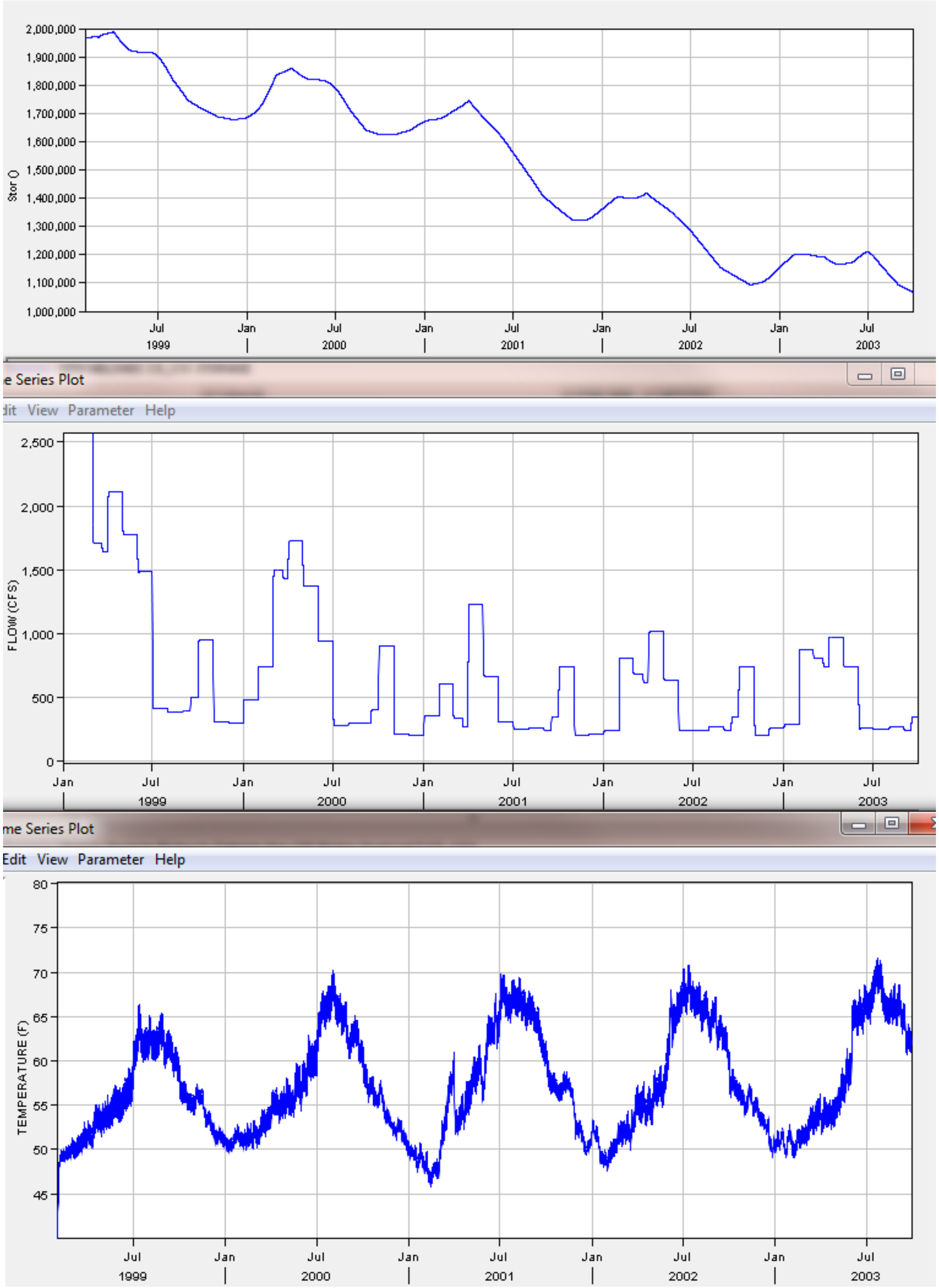

Figure 8. CALSIM II New Melones storage (top, af) and flows (middle, cfs) and computed temperature (bottom, °F) in the Stanislaus River at Oakdale.

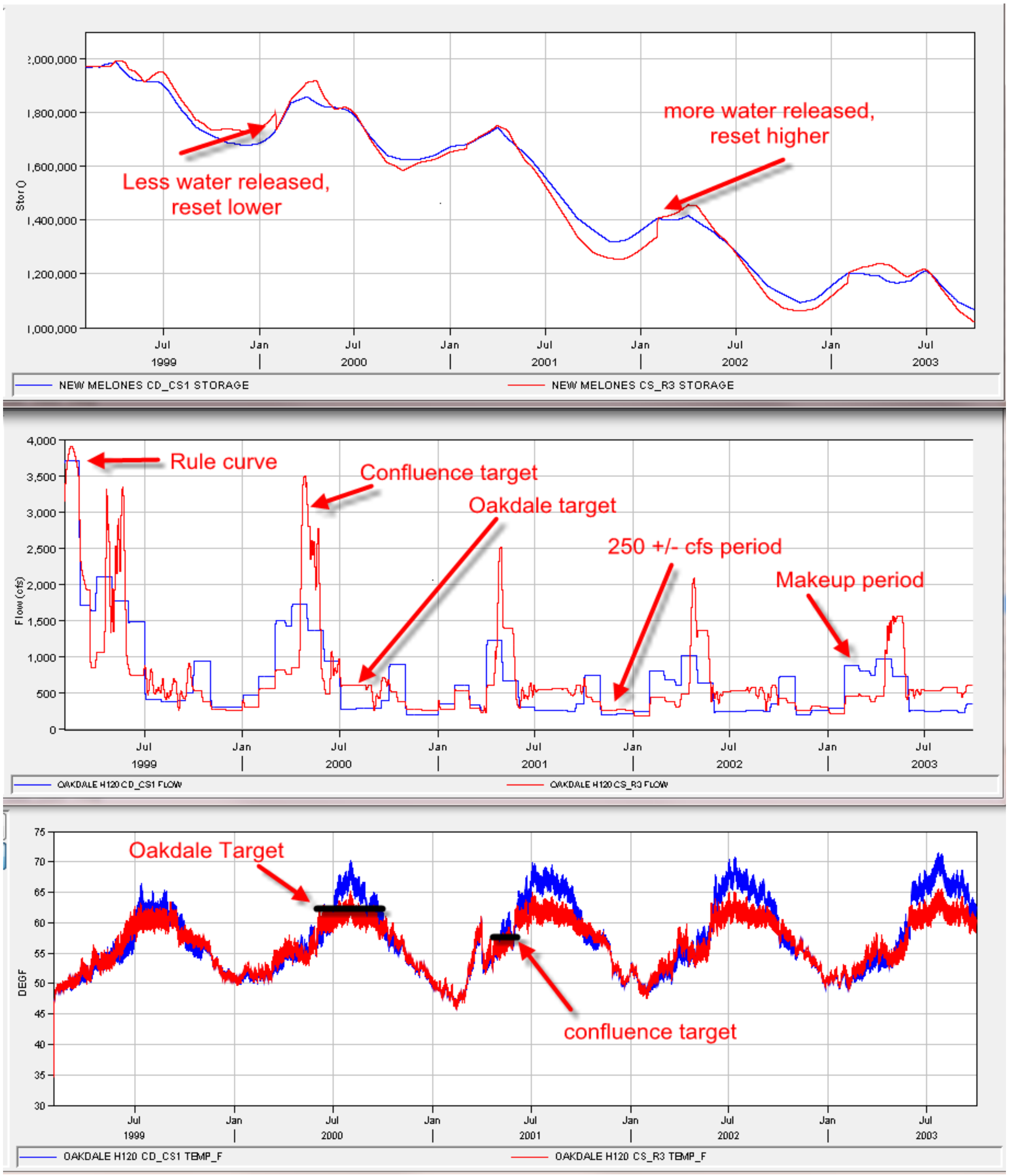

Figure 9. CALSIM II New Melones storage (top, af) and flows (middle, cfs) and computed temperature (bottom, °F) in the Stanislaus River at Oakdale with (red) and without (blue) temperature operation.

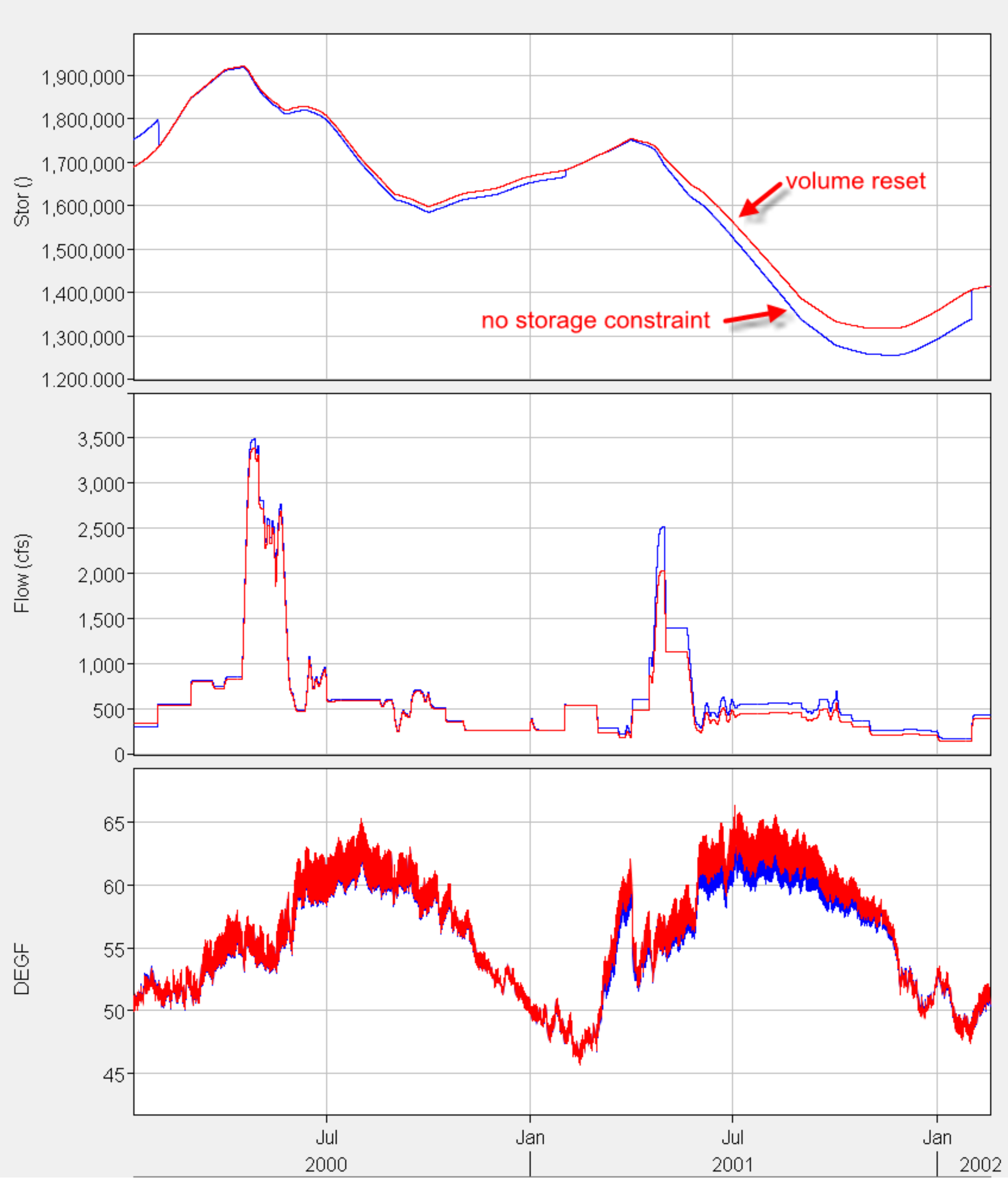

Figure 10. CALSIM II New Melones storage (top, af) and flows (middle, cfs) and computed temperature (bottom, °F) in the Stanislaus River at Oakdale with temperature targets and with (red) and without (blue) storage constraint.

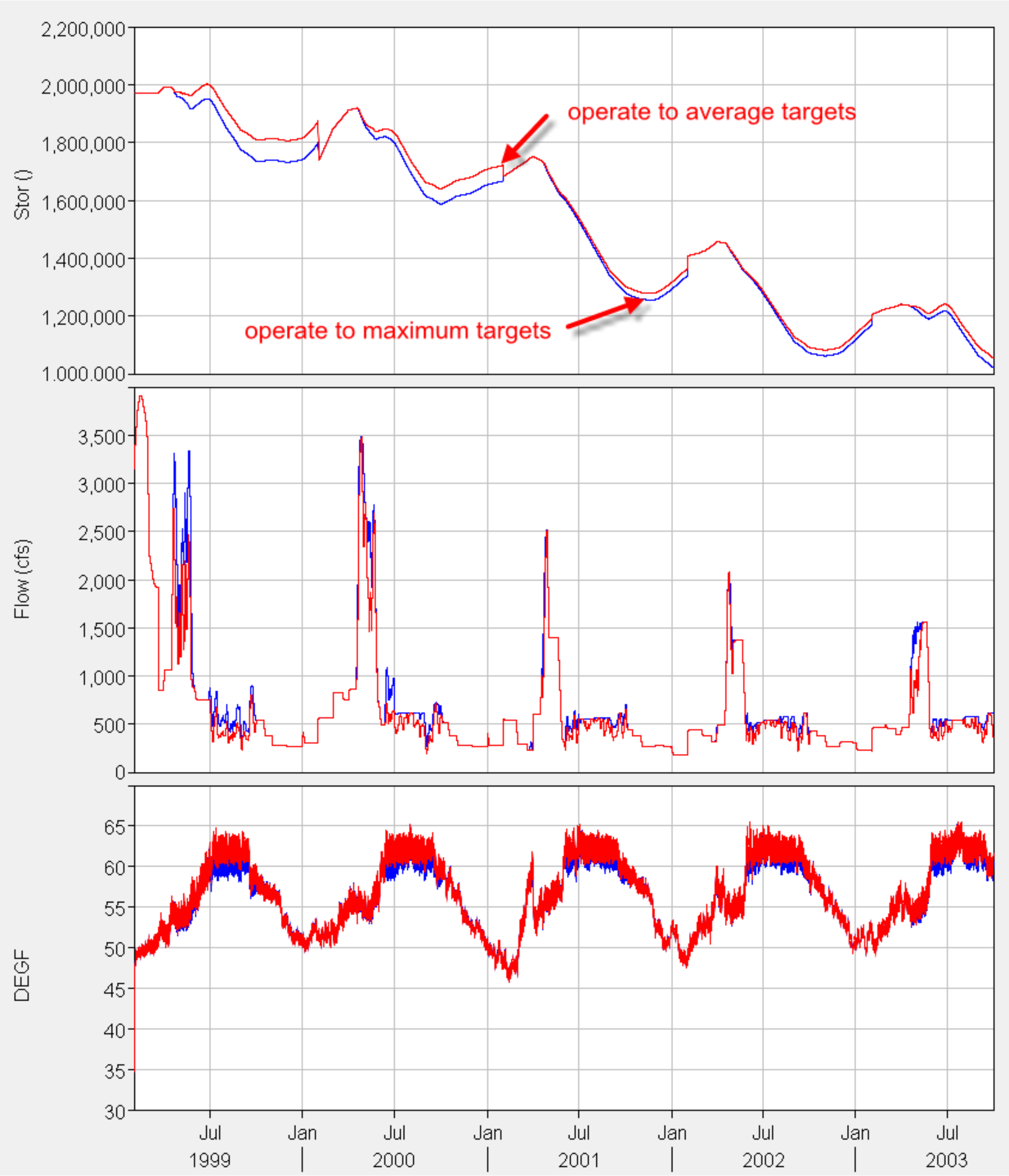

Figure 11. CALSIM II New Melones storage (top, af) and flows (middle, cfs) and computed temperature (bottom, °F) in the Stanislaus River at Oakdale with maximum (blue) and average (red) temperature targets.

5. Conclusion and Recommendation

The SJR Basin-wide Temperature and EC Model forms a powerful basin-scale tool to assess a wide range of hydrological, meteorological, and operational conditions in support of balancing multiple beneficial uses in the basin. This Model includes extended time series data, which makes possible assessments of assumed or proposed conditions through a variety of year-types (e.g., wet, dry, extended drought), while yielding results on a sub-daily time step (daily flow and 6-hour time interval temperature response). The EC representation (currently a weekly time step) provides a new insight about salinity conditions at key locations, with emphasis on the confluences of the tributaries with the main-stem SJR and at Vernalis, resulting from various water management scenarios tested with the model. The hydropower representation (treated in the Model as by-product of system operation), provides useful information about the ramifications of water management scenarios on power generation.

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Appendix

Appendix A. EC User's Manual

A.1. Introduction

This manual will provide guidelines for users interested in simulating electrical conductivity (EC) in the San Joaquin River. This latest EC representation has been developed to be used with the pre-existing flow (HEC-5) and temperature (HEC-5Q) model. Instructions for using the flow and temperature models can be found in separate manuals (HEC, 1998; RMA, 1998) and are not included herein. This manual is primarily concerned with providing users with instructions for manipulating EC inputs and viewing the EC simulation output through the Hydrologic Water-quality Modeling System interface (HWMS).

This manual begins with a presentation of previous work simulating San Joaquin River flow and temperature using HEC-5 and HEC-5Q, respectively, followed by an overview of the file organization. The manual will then be divided into three sections. In the first section, instructions will be given for adding or manipulating model EC boundary conditions, which are not done through the HWMS model interface. In the next section, the user will then learn about the HWMS model interface and how runs can be computed through the interface. In the third section, the user will learn how to view results within the HWMS interface, as well as to print simulated EC output into HEC Data Storage System (DSS) (HEC, 1995).

A.2. Background

The flow simulation module, HEC-5, was originally developed to assist in planning studies to evaluate the effects of proposed reservoirs in a system and to assist in sizing the flood control and conservation storage requirements for each proposed project. The model has also been used extensively to determine appropriate reservoir operations for hydropower, water supply and flood control.

The water quality simulation module, HEC-5Q, was developed so that temperature and selected conservative and non-conservative constituents could be readily included as a consideration in system planning and management. Using estimates of system flows generated by the flow simulation module (HEC-5), the water quality simulation module (HEC-5Q) computes the distribution of temperature and other constituents in the reservoirs and in the associated downstream reaches. The water quality module can be used in conjunction with the flow simulation module to determine concentrations resulting from operation of the reservoir system for flow and storage considerations, or alternately, flow rates necessary to meet water quality objectives.

Since development of the water quality simulation module, HEC-5 has been applied to systems to determine flows and reservoir releases necessary to meet water quality requirements. Documentation for the HEC-5 and HEC-5Q models, including descriptions of input and output files, can be found in the respective User's Manuals (see Reference section for a list of user's manuals available).

Flow and temperature representation using HEC-5 and HEC-5Q, respectively, has been developed for the San Joaquin River. In addition, simulation results may be analyzed using the HWMS model interface (RMA, 2006), which provides run management and model result visualization for a HEC-5Q river-reservoir water quality model. The HWMS map and stream alignments have been created for the San Joaquin River basin.

In this project, EC representation was added to the existing San Joaquin River flow and temperature model, and this manual will show the user how EC boundary conditions can be added, how the EC model can be run through the HWMS interface, and how to view the EC simulation results.

A.3. File Organization

Files pertinent to EC simulation are contained in the main folder, which is named "SJR_temp_EC". This folder has to be on the computer C drive in order for the model to run. Additionally, if the user desires to change the folder name, note that the folder name must not contain any space. Within the main folder, there are various sub-folders, as summarized in the diagram below (Figure A-1).

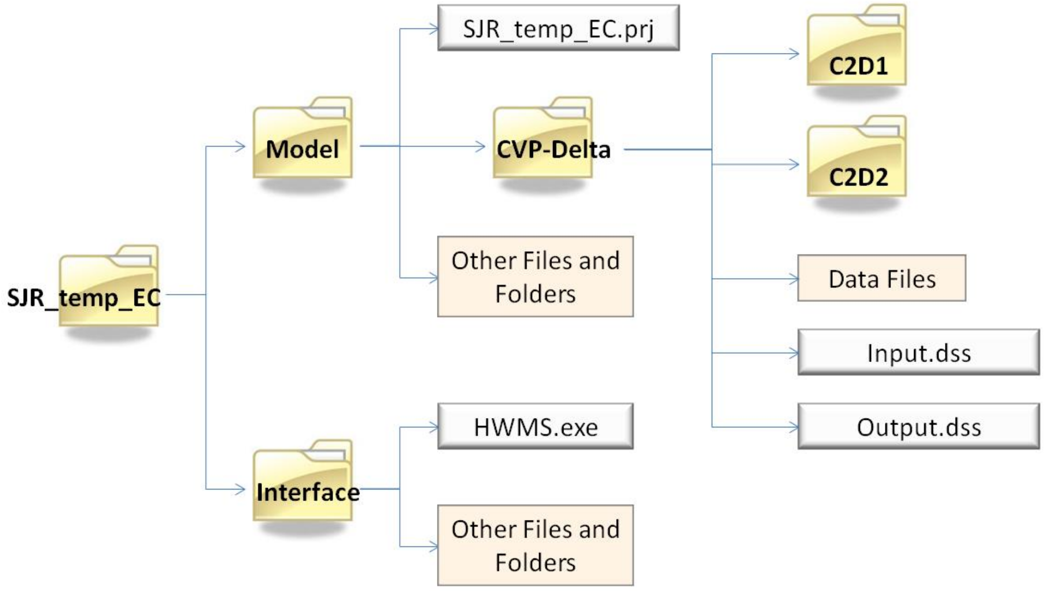


Figure A-1. Diagram summarizing the file and folder organization of model files.

There are two folders within the main folder: "Interface" and "Model".

The "Interface" folder contains the HWMS executable and other supporting files and folders. Note that the HEC-5Q executable is also contained in this folder, but the HWMS interface allows users to run the HEC-5Q model without directly accessing the HEC-5Q executable. The HWMS User's Manual is also included in this folder for reference.

The “Model” folder contains the model scenario folder (“CVP-Delta”), which includes all of the files needed to run the model. In addition, the project file that is to be opened within the HWMS interface is included in this folder (“SJR_temp_EC.prj”), along with the base map, layout, and stream alignments. These files serve as inputs for the HWMS interface. However, because they reference files that are in the “CVP-Delta” model scenario, they need to be located within the “Model” folder. Reference documents for the HEC-5 and HEC-5Q models are also included in this folder.

The “CVP-Delta” model scenario folder contains two sub-folders for two different model runs. “C2D1” is the model run for 2008 to 2010 (calendar years) that was used for calibration. “C2D2” is the model run for 2004 to 2007 that was used for validation. New model runs for a different time period can also be created. Instructions for creating new model runs can be found in the HWMS User’s Manual (RMA, 2006). Other files in the “CVP-Delta” folder are data files and input files that are needed for running the “CVP-Delta” model scenario. Also included in this folder is the output DSS file (Table A-1).

Table A-1. Summary of files in the “CVP-Delta” folder.

File Name	Description
CVP-Delta_5.dat	HEC-5 control file
CVP-Delta_5Q.dat	HEC-5Q control file
Friant_Madera_2010.dat	Historic Friant Dam operation definition file
All_tribs.dat	Tributary file
All_S3.dat	Cross-section file
input.dss	DSS file containing all model input data
output.dss	DSS file containing all model output data

A.4. EC Inputs

Prior to running the model, EC concentrations at the boundary conditions have to be set. The EC boundary conditions are specified in the “All_tribs.dat” file, located in the “CVP-Delta” model folder. In the “All_tribs.dat” file, each tributary is given a tributary number. The table below summarizes the tributary number for each tributary/boundary condition where EC concentration can be specified (Table A-2). Note that flow and temperature boundary conditions are also specified in the “All_tribs.dat” file.

Table A-2. Summary of tributary numbers associated with tributary inflows that represent EC boundary conditions for the model.

Tributary Number	Tributary/Boundary Condition
1	Above Millerton Lake (upstream of Friant Dam)
2	James Bypass/Fresno Slough
4	Salt Slough
5	Mud Slough
11	Banks Pumping Plant Outflow
12	Delta Pumping Plant Outflow
21	Above Lake McClure (Merced River boundary condition)
22	Above Don Pedro Reservoir (Tuolumne River boundary condition)
23,24,25	Above New Melones Reservoir (Stanislaus River boundary condition)

There are three ways that EC boundary condition concentration can be specified:

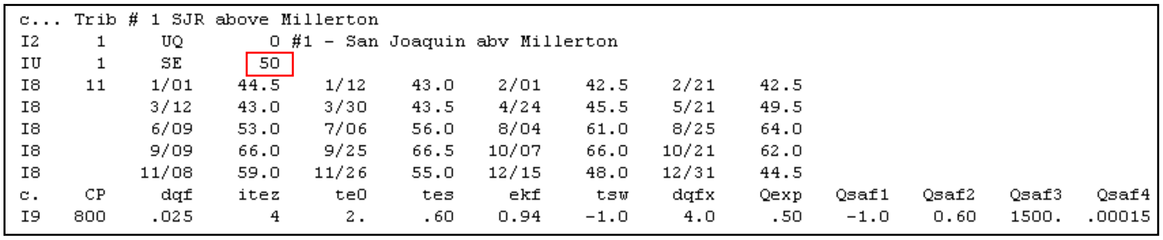
1. Constant EC,
2. Seasonal EC, or
3. Time series input data.

For each tributary, the option of how EC concentration is specified can be made on the third field of the “IU”. The “IU” line contains uniform inflow data for flow, temperature, and EC. The first and second fields are for flow and temperature.

In addition, EC concentrations of accretion flow and small tributaries (Dry Creek into Tuolumne River and Dry Creek into Merced River) can also be adjusted. However, these EC values had been set during the calibration process. Any adjustments to the calibrated model would require model re-calibration and re-validation. Instructions for model calibration are beyond the scope of this guide.

A.4.1. Constant EC

If boundary condition EC concentrations are to be specified as a constant, then the constant EC value is written on the third field on the “IU” line. No other changes to the code need to be made. An example of constant EC being specified for San Joaquin River above Millerton has been included in the figure below (Figure A-2).



```
c... Trib # 1 SJR above Millerton
I2     1      UQ       0 #1 - San Joaquin abv Millerton
IU     1      SE      50
I8    11    1/01    44.5    1/12    43.0    2/01    42.5    2/21    42.5
I8          3/12    43.0    3/30    43.5    4/24    45.5    5/21    49.5
I8          6/09    53.0    7/06    56.0    8/04    61.0    8/25    64.0
I8          9/09    66.0    9/25    66.5   10/07    66.0   10/21    62.0
I8         11/08    59.0   11/26    55.0   12/15    48.0   12/31    44.5
c.    CP     dqf    itez     te0     tes     ekf     tsw    dqfx    Qexp   Qsaf1   Qsaf2   Qsaf3   Qsaf4
I9   800    .025       4      2.     .60    0.94    -1.0     4.0     .50    -1.0    0.60   1500.  .00015
```

Figure A-2. Screen capture showing an example of constant EC boundary condition (50 µS/cm) being specified for San Joaquin River above Millerton.

A.4.2. Seasonal EC

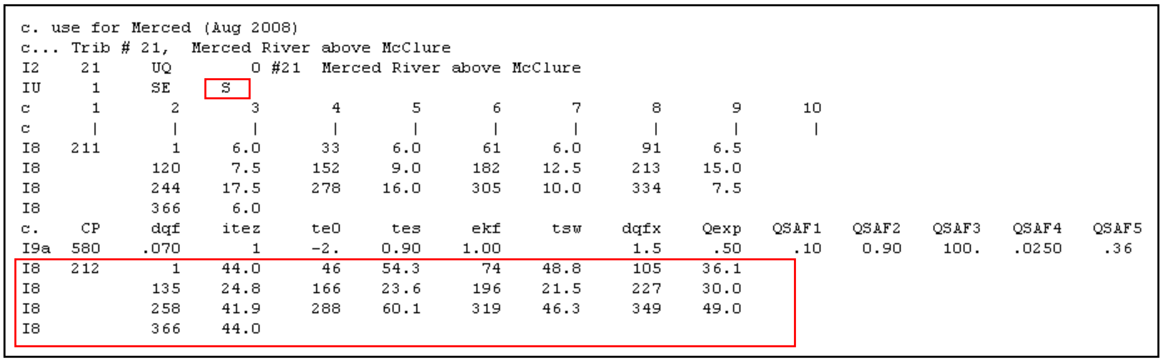
If a seasonal EC concentration is desired for the boundary condition, then an “S” is written on the third field on the “IU” line. This means that the EC concentration will be defined using the seasonal curve fit option. The curve fit parameters are entered on the “I8” record below (see Figure A-3 for the location of the “I8” line).

The curve fit parameters on each field is summarized below (Table A-3). The seasonal curve fit identification number on field 1 does not need to be changed.

Table A-3. Summary of curve fit parameters on the “I8” record.

Field	Variable	Description
1	JSEA	Seasonal curve fit identification number.
2,4,6,8	SEADY	Julian date of temperature or water quality value. Up to 13 records may be used to input a maximum of 52 time and concentration pairs defining the seasonal variations. The final entry must be “366”.
3,5,7,9	SEAC	Temperature or water quality corresponding to SEADY.

An example of seasonal EC being specified for Merced River above McClure has been included in the figure below (Figure A-3). The red boxes indicate the changes that need to be made on the “IU” line and the “I8” line.



```
c. use for Merced (Aug 2008)
c... Trib # 21,  Merced River above McClure
I2     21      UQ       0 #21  Merced River above McClure
IU      1      SE       S
c       1       2       3       4       5       6       7       8       9      10
c       |       |       |       |       |       |       |       |       |       |
I8    211       1     6.0      33     6.0      61     6.0      91     6.5
I8            120     7.5     152     9.0     182    12.5     213    15.0
I8            244    17.5     278    16.0     305    10.0     334     7.5
I8            366     6.0
c.     CP     dqf    itez     te0     tes     ekf     tsw    dqfx    Qexp   QSAF1   QSAF2   QSAF3   QSAF4   QSAF5
I9a   580    .070       1     -2.    0.90    1.00             1.5     .50     .10    0.90    100.   .0250     .36
I8    212       1    44.0      46    54.3      74    48.8     105    36.1
I8            135    24.8     166    23.6     196    21.5     227    30.0
I8            258    41.9     288    60.1     319    46.3     349    49.0
I8            366    44.0
```

Figure A-3. Screen capture showing an example of seasonal EC boundary condition being specified for Merced River above Lake McClure.

A.4.3. Time Series EC Data

If a time series EC concentration is desired as the boundary condition, then an “I3” is written on the third field on the “IU” line (Table A-4). “I3” records allow for specification of the inflow EC data at an hourly or daily time increment. Time series data used in HEC-5Q simulations are specified in the HEC Data Storage System (DSS), which stores data for inventory, retrieval, archiving, and model use. “ZR” records are used to identify types of records to be read in from the DSS file. Within the DSS file, data are stored in blocks, each block containing data at one location and throughout a specific time interval. The blocks are accessed by specifying path names in the “ZR” record which include the basin name, the name of the reservoir and the variable for which the time series data are being specified.

Table A-4. Summary of fields in an "I3" record.

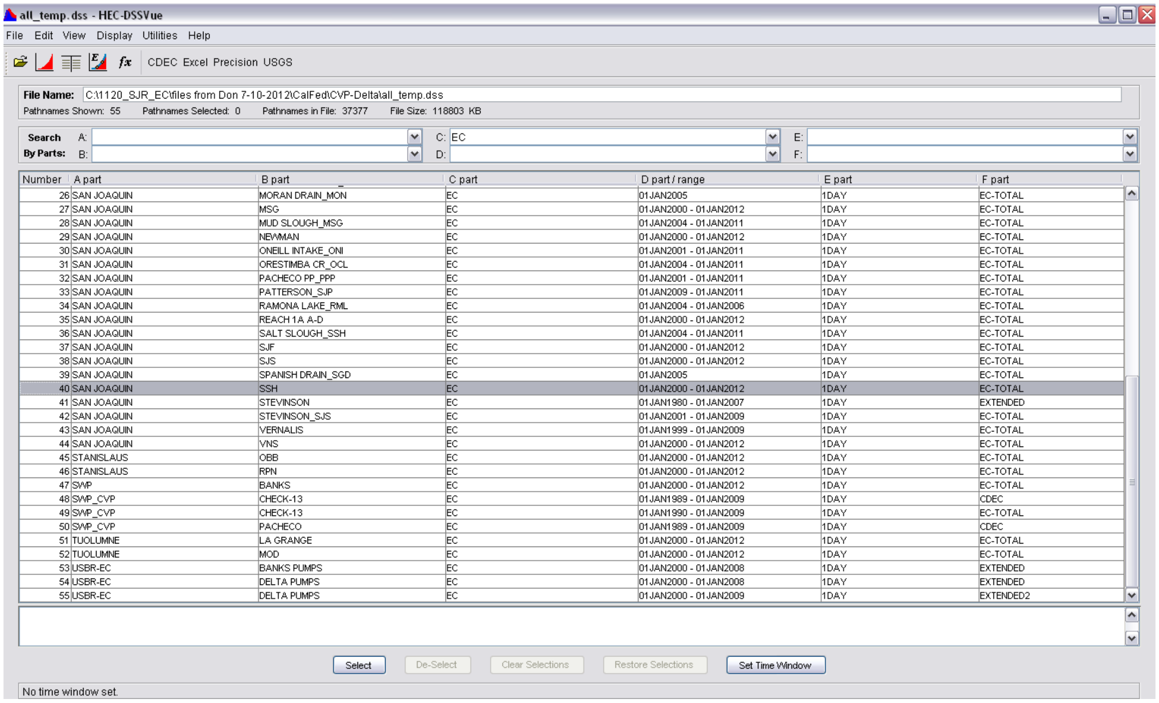
Field	Value	Description
1	"ZR"	Indicates the water quality parameter will be read from DSS.
2-10		DSS path name. (e.g., A=_______ , B=________, etc.)

The pathname consists of up to 80 characters and is, by convention, separated into six parts. The parts are referenced by the characters A, B, C, D, E, and F. Brief descriptions of each part of the time series pathname is provide in Table A-5.

Table A-5. Summary of parts in a DSS pathname.

Part	Description
A	River basin or project name
B	Location of inflow
C	Data variable
D	Starting date or range
E	Time interval
F	Additional user-defined description to further define the data

An example of time series EC concentration input at Salt Slough is highlighted in the screen capture below (Figure A-5).



File Name: C:\1120_SJR_EC\files from Don 7-10-2012\CalFed\CVP-Delta\all_temp.dss

Pathnames Shown: 55 Pathnames Selected: 0 Pathnames in File: 37377 File Size: 118803 KB

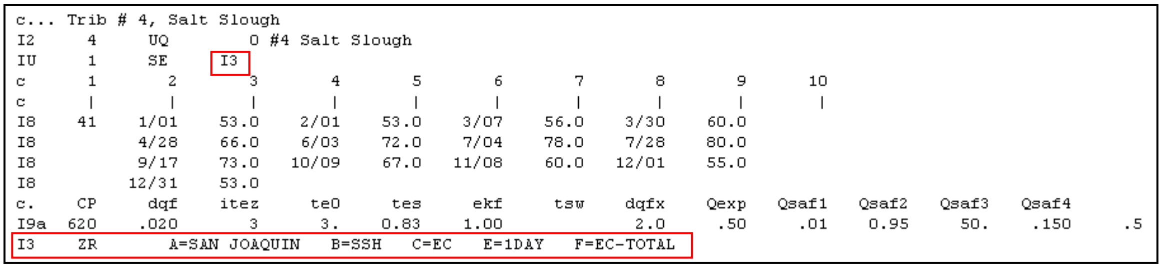
Search By Parts: A: B: C: EC D: E: F:

Number	A part	B part	C part	D part / range	E part	F part
26	SAN JOAQUIN	MORAN DRAIN_MON	EC	01JAN2005	1DAY	EC-TOTAL
27	SAN JOAQUIN	MSG	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
28	SAN JOAQUIN	MUD SLOUGH_MSG	EC	01JAN2004 - 01JAN2011	1DAY	EC-TOTAL
29	SAN JOAQUIN	NEWMAN	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
30	SAN JOAQUIN	ONEILL INTAKE_ONI	EC	01JAN2001 - 01JAN2011	1DAY	EC-TOTAL
31	SAN JOAQUIN	ORESTIMBA CR_OCL	EC	01JAN2004 - 01JAN2011	1DAY	EC-TOTAL
32	SAN JOAQUIN	PACHECO PP_PPP	EC	01JAN2001 - 01JAN2011	1DAY	EC-TOTAL
33	SAN JOAQUIN	PATTERSON_SJP	EC	01JAN2009 - 01JAN2011	1DAY	EC-TOTAL
34	SAN JOAQUIN	RAMONA LAKE_RML	EC	01JAN2004 - 01JAN2006	1DAY	EC-TOTAL
35	SAN JOAQUIN	REACH 1A A-D	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
36	SAN JOAQUIN	SALT SLOUGH_SSH	EC	01JAN2004 - 01JAN2011	1DAY	EC-TOTAL
37	SAN JOAQUIN	SJF	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
38	SAN JOAQUIN	SJS	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
39	SAN JOAQUIN	SPANISH DRAIN_SGD	EC	01JAN2005	1DAY	EC-TOTAL
40	SAN JOAQUIN	SSH	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
41	SAN JOAQUIN	STEVINSON	EC	01JAN1980 - 01JAN2007	1DAY	EXTENDED
42	SAN JOAQUIN	STEVINSON_SJS	EC	01JAN2001 - 01JAN2009	1DAY	EC-TOTAL
43	SAN JOAQUIN	VERNALIS	EC	01JAN1999 - 01JAN2009	1DAY	EC-TOTAL
44	SAN JOAQUIN	VNS	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
45	STANISLAUS	OBB	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
46	STANISLAUS	RPN	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
47	SWP	BANKS	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
48	SWP_CVP	CHECK-13	EC	01JAN1989 - 01JAN2009	1DAY	CDEC
49	SWP_CVP	CHECK-13	EC	01JAN1990 - 01JAN2009	1DAY	EC-TOTAL
50	SWP_CVP	PACHECO	EC	01JAN1989 - 01JAN2009	1DAY	CDEC
51	TUOLUMNE	LA GRANGE	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
52	TUOLUMNE	MOD	EC	01JAN2000 - 01JAN2012	1DAY	EC-TOTAL
53	USBR-EC	BANKS PUMPS	EC	01JAN2000 - 01JAN2008	1DAY	EXTENDED
54	USBR-EC	DELTA PUMPS	EC	01JAN2000 - 01JAN2008	1DAY	EXTENDED
55	USBR-EC	DELTA PUMPS	EC	01JAN2000 - 01JAN2009	1DAY	EXTENDED2

No time window set.

Figure A-4. Screen capture showing the example of time series EC input at various locations in DSS. EC input at Salt Slough highlighted for emphasis.

The DSS pathname written as part of the “ZR” record in the “all_tribs.dat” file must correspond to the pathnames in the DSS record. The D-part of the pathname may be omitted. An example of time series EC input specification at Salt Slough is shown below (Figure A-5).



```
c... Trib # 4, Salt Slough
I2      4      UQ        0 #4 Salt Slough
IU      1      SE    I3
c       1       2       3       4       5       6       7       8       9      10
c       |       |       |       |       |       |       |       |       |       |
I8     41    1/01    53.0    2/01    53.0    3/07    56.0    3/30    60.0
I8           4/28    66.0    6/03    72.0    7/04    78.0    7/28    80.0
I8           9/17    73.0   10/09    67.0   11/08    60.0   12/01    55.0
I8          12/31    53.0
c.     CP     dqf    itez     te0     tes     ekf     tsw    dqfx    Qexp   Qsaf1   Qsaf2   Qsaf3   Qsaf4
I9a   620    .020       3      3.    0.83    1.00             2.0     .50     .01    0.95     50.    .150      .5
I3     ZR        A=SAN JOAQUIN   B=SSH   C=EC   E=1DAY   F=EC-TOTAL
```

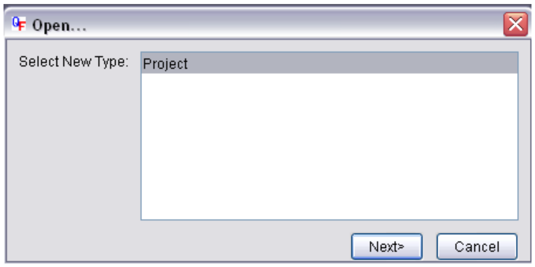
Figure A-5. Screen capture showing an example of time series EC boundary condition being specified at Salt Slough.

A.5. Computing Model Run through HWMS

The HWMS-HEC5Q User Interface provides run management and model result visualization for the HEC-5Q river-reservoir water quality model. For the San Joaquin River model, base maps and stream alignments have been created as part of the development of pre-existing flow and temperature representations. The map and stream alignments have thus been pre-loaded into the model.

To start the HWMS interface, double-click on the “HWMS.exe” executable file in the “Interface” folder. Note that if the main project folder (“SJR_temp_EC”) is not on the computer C Drive, the HWMS interface will not start.

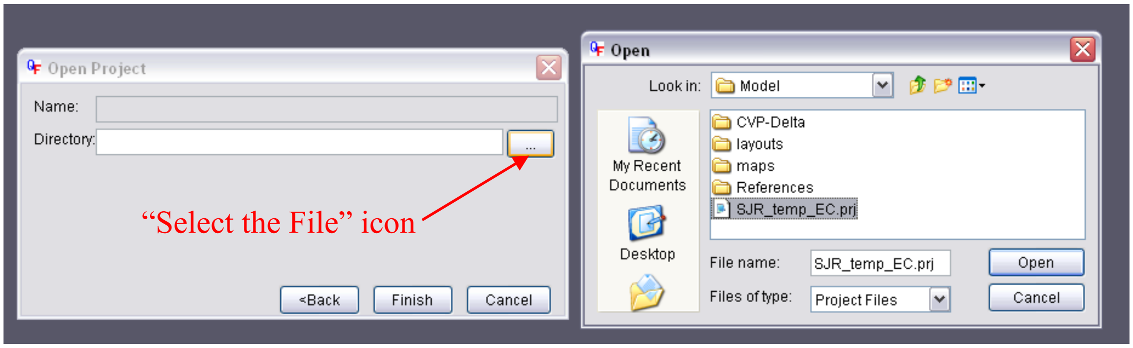
After the HWMS interface has been opened, click on the “Open a File” (📂) icon. The “Open…” window will appear (Figure A-6). The only available selection is “Project” and this will already be highlighted. Click “Next>” to proceed.



Select New Type: Project

Figure A-6. Screen capture of “Open…” window.

Subsequently, the “Open Project” window will appear. Clicking on the the “Select the File” icon will open up another window showing the computer directory (Figure A-7). From the directory window, locate and open the “SJR_temp_EC.prj” project file that is in the “Model” folder.



“Select the File” icon

Look in: Model

File name: SJR_temp_EC.prj

Files of type: Project Files

Figure A-7. Screen capture of “Open Project” window and the window showing the computer directory. The “SJR_temp_EC.prj” file is highlighted.

When the “SJR_temp_EC.prj” file is selected, the following map and model reaches should appear on the HWMS interface main screen (Figure A-8). Further details on how to navigate the HWMS interface can be found the HWMS User’s Manual (RMA, 2006).

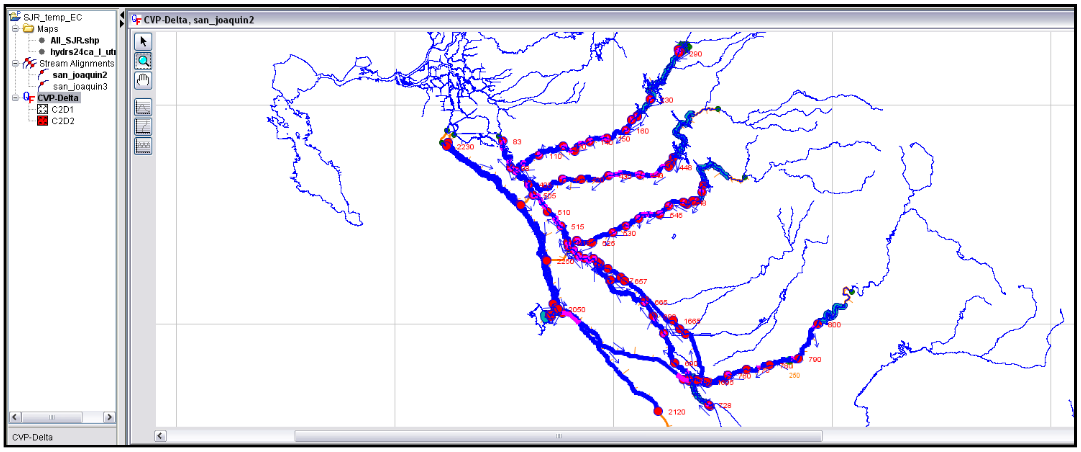


Figure A-8. Screen capture of HWMS model interface with San Joaquin River basin base map, stream alignments, and model reaches.

Multiple runs can be created for each model ("CVP-Delta"). Runs allow users to manipulate the original model data assigned in the HWMS model. This allows for manipulation of the model input without actually touching the original model data. "C2D1" is the model run for 2008 to 2010 that was used for calibration. "C2D2" is the model run for 2004 to 2007 that was used for validation. New model runs for a different time period can also be created. Instructions for creating new model runs can be found in the HWMS User's Manual (RMA, 2006).

After changes to the EC boundary conditions have been made (on the "all_tribs.dat" file), to compute a particular model run, right-click on "Run" in the project tree and select "Compute" in its context menu (Figure A-9). A progress dialog will appear while the run is computing.

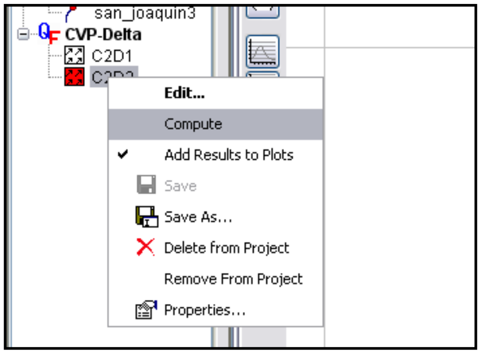


Figure A-9. Screen capture showing the drop-down context menu to start a model run.

This manual only pertains to EC representation in the model. For more information regarding the HWMS interface and simulation of flow and temperature, please refer to the HWMS User's Manual (RMA, 2006).

A.6. EC Outputs

After running the model, simulation results at all locations can be viewed through the HWMS interface. In addition, simulation results can also be printed into a DSS output file. Instructions on how to view the simulation results and to print the results into DSS will be given in this section.

A.6.1. Viewing Results in HWMS

To access the output for a particular run, the run's model must be displayed in the Map Schematic and the run must add its results to the plots. To add a run's results to the outcome plots, add a check mark next to the "Add Results to Plots" option in the run's context menu (Figure A-10). The run's icon background color will be red if the run is set to display its results.

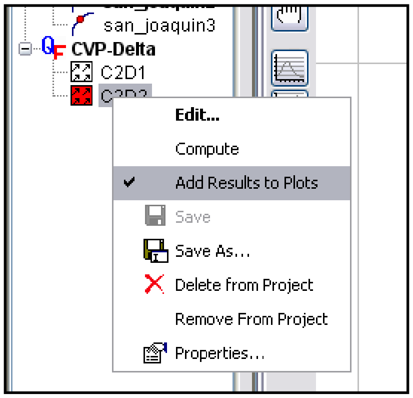


Figure A-10. Screen capture showing the drop-down context menu to display results.

The output data is displayed on plots which are accessed via context menus in the map schematic window (Figure A-11). First a plot icon must be selected. These icons represent the different output data that could be viewed. They include the Longitudinal Profile Plot (used for rivers or longitudinally segmented reservoirs), the Depth Profile Plot (used for vertically segmented reservoirs), and the Time Series Plot.

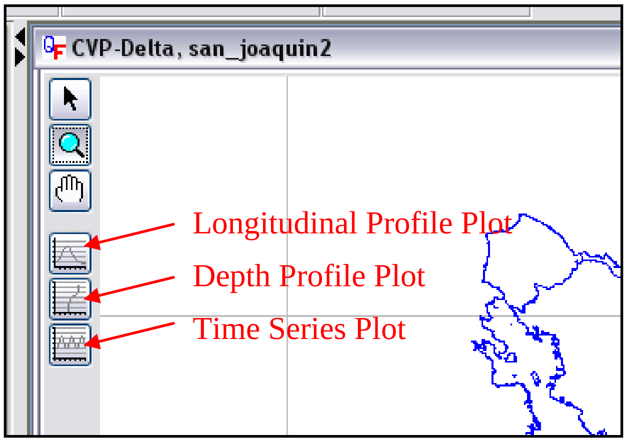


Figure A-11. Screen capture showing the icons that represent the different output data that can be viewed through the HWMS interface.

To view time series simulated results, click on the "Time Series Plot" icon and then right-click on a reach or reservoir segment displayed within the map schematic. A "plot time series" box will pop up next to the reach segment of interest (Figure A-12).

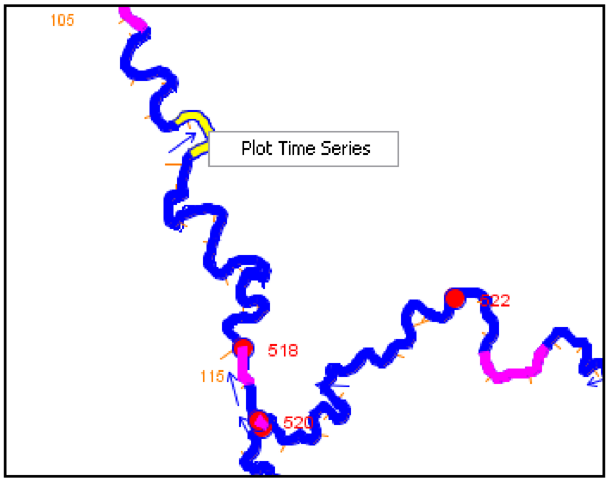


Figure A-12. Screen capture of "Plot Time Series" pop-up in the HWMS map schematic.

Click on the "Plot Time Series" box and a graphical plot of the simulated results will be displayed. The default parameter displayed is temperature. In order to view EC results, click on the "Parameter" tab on the header, and a drop-down context menu will appear (Figure A-13). Select "EC-TOTAL" to view EC results.

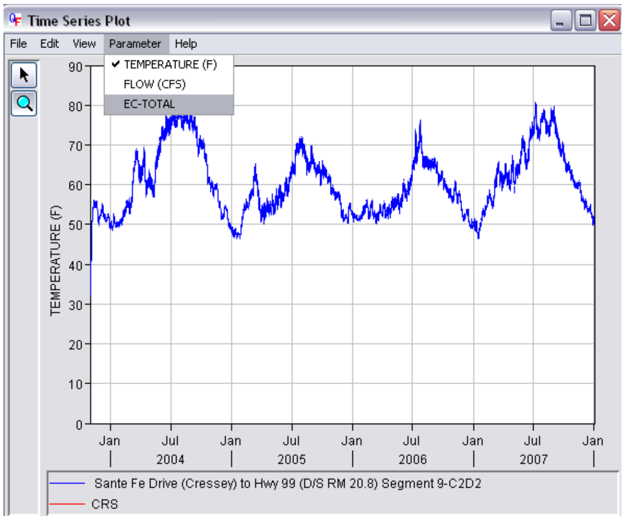


Figure A-13. Screen capture of the HWMS "time series plot" display showing the drop-down that allows users to select the parameter to be displayed.

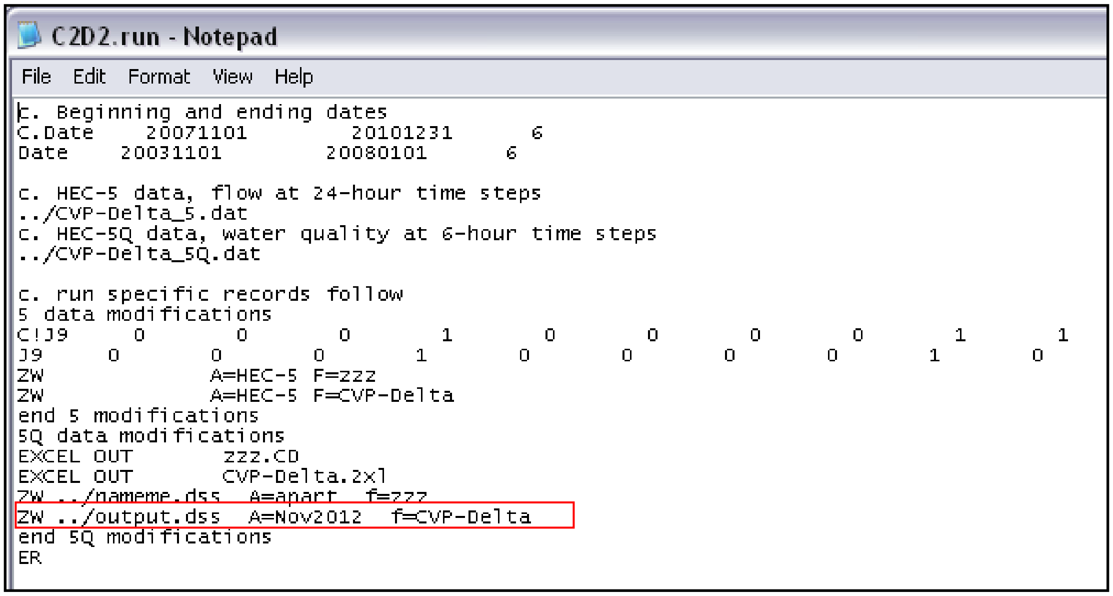
A.6.2. Printing Results into DSS

In addition to viewing the simulated results through the HWMS interface, users can print results into DSS, which allows for greater flexibility in data processing and analyses. To do so, the following steps are to be followed.

1) Specify DSS output file name.
2) List locations where EC data is to be printed into DSS.
3) Re-run model.

A.6.2.1. Step 1: Specify DSS Output File Name

In the run-specific ".run" file (for example, "C2D2.run"), specify the name of the DSS output file that will contain the printed model results. In the example below, the output for C2D2 model run is to be printed in a DSS file called "output.dss" (Figure A-14). The file name must end with ".dss". DSS pathnames can also be specified within the ".run" file. In the example below, only parts part A and F were specified. The user can also specify other parts of the pathname.



```
c. Beginning and ending dates
C.Date    20071101        20101231      6
Date    20031101        20080101      6

c. HEC-5 data, flow at 24-hour time steps
../CVP-Delta_5.dat
c. HEC-5Q data, water quality at 6-hour time steps
../CVP-Delta_5Q.dat

c. run specific records follow
5 data modifications
C!J9     0       0       0       1       0       0       0       0       1       1
J9     0       0       0       1       0       0       0       0       1       0
ZW             A=HEC-5 F=zzz
ZW             A=HEC-5 F=CVP-Delta
end 5 modifications
5Q data modifications
EXCEL OUT       zzz.CD
EXCEL OUT       CVP-Delta.2xl
ZW ../nameme.dss  A=apart  f=zzz
ZW ../output.dss  A=Nov2012  f=CVP-Delta
end 5Q modifications
ER
```

Figure A-14. Screen capture of the "C2D2.run" file showing the specification of the DSS file name.

A.6.2.2. Step 2: List Locations Where EC Data is to be Printed into DSS File

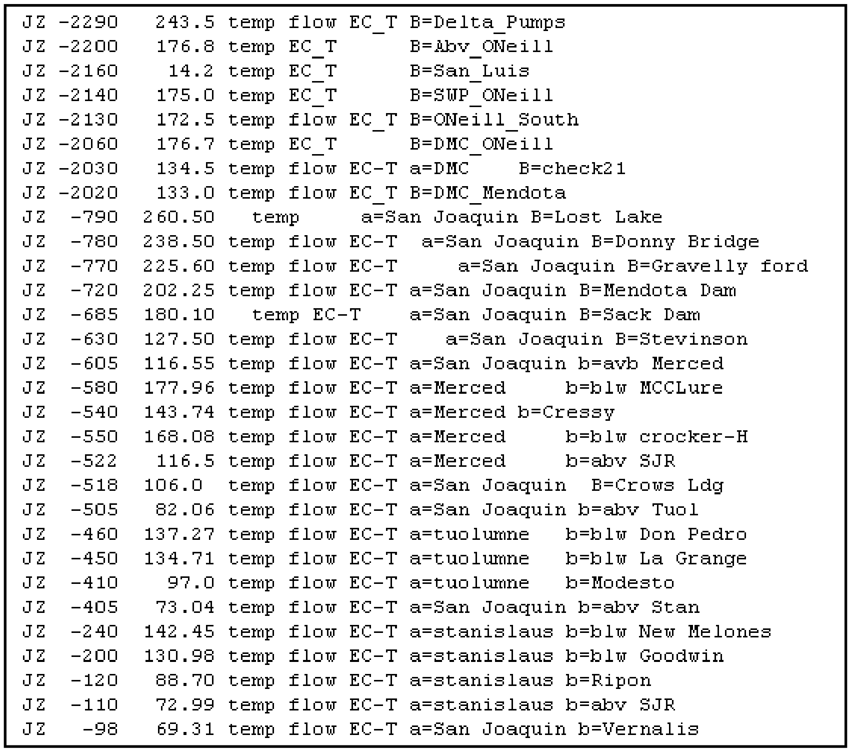
In the model-specific "…5Q.dat" file (for example, "CVP-Delta_5Q.dat"), add lines to the "JZ" records to specify locations on the river where EC data is to be printed into DSS. The JZ Record lists the locations and parameters to be saved to DSS. The following table summarizes the fields in the "JZ" record that require user input (Table A-6).

Table A-6. Summary of fields required for the "JZ" record.

Field	Variable	Description
1	IQCP	Reservoir/Stream control point number. Note that a positive number indicates a reservoir control point and a negative number indicates a stream control point.
2	QRM	River mile location within a stream reach or longitudinally segmented reservoir, or depth for vertically segmented reservoirs. If QRM is a river mile, the water quality of the element closest to the specified river mile will be reported. Note that a control point establishes the boundary between one or more stream reaches. Water quality is available above or below the control point but not at the control point.
3-10	IP	Water quality parameters codes ("temp", "flow", and/or "EC-T") indicating which data will be saved to DSS file.

3-10	Pathnames	Pathnames on the DSS record (optional). It must follow the last “IP” code.

A screen capture of the “JZ” records for “CVP-Delta” model is presented below as an example (Figure A-15).



```
JZ -2290   243.5 temp flow EC_T B=Delta_Pumps
JZ -2200   176.8 temp EC_T      B=Abv_ONeill
JZ -2160    14.2 temp EC_T      B=San_Luis
JZ -2140   175.0 temp EC_T      B=SWP_ONeill
JZ -2130   172.5 temp flow EC_T B=ONeill_South
JZ -2060   176.7 temp EC_T      B=DMC_ONeill
JZ -2030   134.5 temp flow EC-T a=DMC    B=check21
JZ -2020   133.0 temp flow EC_T B=DMC_Mendota
JZ  -790  260.50   temp     a=San Joaquin B=Lost Lake
JZ  -780  238.50 temp flow EC-T  a=San Joaquin B=Donny Bridge
JZ  -770  225.60 temp flow EC-T     a=San Joaquin B=Gravelly ford
JZ  -720  202.25 temp flow EC-T a=San Joaquin B=Mendota Dam
JZ  -685  180.10   temp EC-T    a=San Joaquin B=Sack Dam
JZ  -630  127.50 temp flow EC-T    a=San Joaquin B=Stevinson
JZ  -605  116.55 temp flow EC-T a=San Joaquin b=avb Merced
JZ  -580  177.96 temp flow EC-T a=Merced     b=blw MCCLure
JZ  -540  143.74 temp flow EC-T a=Merced b=Cressy
JZ  -550  168.08 temp flow EC-T a=Merced     b=blw crocker-H
JZ  -522   116.5 temp flow EC-T a=Merced     b=abv SJR
JZ  -518  106.0  temp flow EC-T a=San Joaquin  B=Crows Ldg
JZ  -505   82.06 temp flow EC-T a=San Joaquin b=abv Tuol
JZ  -460  137.27 temp flow EC-T a=tuolumne   b=blw Don Pedro
JZ  -450  134.71 temp flow EC-T a=tuolumne   b=blw La Grange
JZ  -410    97.0 temp flow EC-T a=tuolumne   b=Modesto
JZ  -405   73.04 temp flow EC-T a=San Joaquin b=abv Stan
JZ  -240  142.45 temp flow EC-T a=stanislaus b=blw New Melones
JZ  -200  130.98 temp flow EC-T a=stanislaus b=blw Goodwin
JZ  -120   88.70 temp flow EC-T a=stanislaus b=Ripon
JZ  -110   72.99 temp flow EC-T a=stanislaus b=abv SJR
JZ   -98   69.31 temp flow EC-T a=San Joaquin b=Vernalis
```

Figure A-15. Screen capture of “JZ” records in the “CVP-Delta” model.

A.6.2.3. Step 3: Re-run the Model

After the above-mentioned files have been updated, rerun the model. The results will be printed into the specified output DSS in the “CVP-Delta” folder.

A.7. References

Hydrologic Engineering Center (HEC). 1995. “HEC-DSS User’s Guide and Utility Manuals,” User’s Manual.

Hydrologic Engineering Center (HEC). 1998. “HEC-5 Simulation of Flood Control and Conservation Systems,” User’s Manual Version 8.0.

Resource Management Associates (RMA), 1998. “HEC-5Q Simulation of Flood Control and Conservation Systems, Appendix on Water Quality Analysis,” Computer Program Manual, prepared for the Department of the Army, Corps of Engineers, Kansas City District, Kansas City, Missouri.

Resource Management Associates (RMA), 2006. “Hydrologic Water-quality Modeling System (HWMS-HEC5Q) User Interface” User’s Manual.

Appendix B. System Operation for Temperature Control

The optimization capability allows the user to specify operational constraints and temperature objectives and have the model change flows to better achieve the temperature objectives. The optimization is designed to consider the factors that an operator might use to manage reservoir releases for temperature control, namely, current system status (e.g., reservoir volumes, current flows and river temperatures, travel time etc.), ramping rate constraints and, weather forecasts. The model simulates forward in time to estimate a minimum flow requirement and operates the system accordingly. Defining the operational minimum flow allows the reservoir to operate for other constraints such as obeying the rule curve. Since operators cannot go back in time to adjust reservoir releases, the model does not iterate to achieve an exact match of the temperature target. This program option is described in more detail in the previous project report (AD *et al*., 2009).

The temperature control option and associated input data required by this option resides in supplemental files that are triggered by charactering strings preceding the file names. There are two required data sets. The first defines the reservoir related constraints while the second defines the temperature objectives and controls.

One reservoir related file is used regardless of the number of reservoirs being operated. The character string “initial volume reset” (line 16) identifies the temperature control option followed by the file name. The controls for each reservoir are input sequentially in the order (upstream to downstream) of the model reservoir sequence (e.g., Lake McClure, Don Pedro then New Melones). If there are no objectives for the related river, data for the corresponding reservoir must not appear in this file.

Because the stream temperature targets are defined daily and therefore much more extensive, the data for each river is contained in separate files. The character string “temp opp” (lines 39-41) identifies the reservoir that will be operated and the temperature objectives. Only one reservoir may be operated to meet the temperature objectives. Consequently, a location such as Vernalis can only be referenced in one set of temperature objectives.

Figure B-2 provides an example run file naming both types of files. A general description of the run file is provided in the HEC5Q Input Description (\CDFW_07Jun2013\HWMS\documentation\5Q_Inputs.docx.)

In addition to the naming of temperature control files, the “ZR MR” records (lines 25-27) are inserted. These three records fulfill an HEC-5 requirement that the minimum flow be defined initially as a place holder. The initial minimum flow is replaced as the simulation progresses with the minimum flows computed by the temperature model. Note that when the reservoir is being operated for any flow or temperature criteria, the “ZR QA”, which define releases explicitly, must be deleted since “ZR QA” supersedes operational considerations.

B.1. Initial Volume Reset file

Five different reservoir volume reset options are available. These options are designed to allow the user to evaluate past or future operation scenarios and their impacts on temperature in an efficient manner using the calibrated model. The first three options do not work in tandem with the temperature control option. Volume reset options 4 and 5 are used with the temperature control option and are appropriate for use with historical flows and the CALSIM II interface model. Each option specifies reservoir volumes and temperature profiles on the simulation anniversary date of the beginning of simulation.

- Volume Reset 1 – Reset reservoir volume and temperature to a specific storage level at each anniversary date. This alternative can be used to examine the system state and temperature response given today's conditions for the range of historical conditions (hydrology and meteorology) over any simulation period within the 1980 to 2010 calibration period.

- Volume Reset 2 – Reset volume only when specific storage level is exceeded on the anniversary date. If storage is below the stated reset volume, then model does not reset and there is a carryover penalty for shortfalls.

- Volume Reset 3 – Reset volume on first year only (i.e., non-varying initial condition). This alternative examines multi-year operation given initial condition (e.g., current conditions).

- Volume Reset 4 – Reset volume is user specified (e.g., historical volumes or user specified alternative volume objectives) for each year. This alternative examines how the system could have operated year-by-year given temperature objectives. This option is the standard when utilizing CALSIM II data.

- Volume Reset 5 – Reset volume is user specified for each year unless the end of period storage falls below the stated reset initial storage, then model does not reset and there are penalties for shortfalls. This alternative is similar to Vol_set4, but shortfalls are accumulated. This option may also utilize CALSIM II data.

B.2. Input Data formats

B.2.1. Initial Volume Reset

The "Initial Volume Reset" data file for the Stanislaus River reservoirs is shown in Figure B-3. These inputs are from the "Merced-Tuol-Stan_vol_set4.prn" referenced in line 16 of Figure B-2. Note that there is no standard file naming convention. This "*.prn" file was generated from the Excel spreadsheet containing the necessary data although the use of Excel is not required. These inputs were used for the demonstration presented in Section 4.3. The Stanislaus data are preceded by inputs (lines 1-281) for the Merced and Tuolumne rivers that are also operated for temperature objectives. The "Initial Volume Reset" data file contains numerous comments. Comments can take any form because the model only recognizes a small set of character strings beginning in column 1. The following character strings (not case sensitive) are recognized as inputs to the model:

Table B-1. Summary of fields, lines, and descriptions.

Code/Field	Lines	Description
Vol_Set4	308-389	Defines the anniversary date volumes. The anniversary date is defined by the simulation starting date. Mid-winter starting dates are recommended since the initial thermal conditions are redefined on each anniversary date. Starting at times when reservoirs are well stratified may yield misleading results. Note that the character strings in lines 297 – 302 are interpreted as comments since they do not begin in column 1.
ZR QA and ZR MR	392 and 396	These two records are required when the reoperation option is specified. They define the adjusted reservoir outflow (Reservoir releases to meet temperature objectives and scaled to meet volume constraints) and the computed minimum flow (computed to meet temperature objectives without volume constraint scaling). The "ZR QA" defines the adjusted reservoir outflow for the second pass when the reservoir outflow is specified explicitly.
Temp_prof_CP	399	Identifies the reservoir by the control point number (e,g, CP 240 = New Melones)
Depth_temp	400-404	Defines the temperature profile (depth and temperature pairs) initially and on each anniversary date. For stratified conditions, the depths are normalized to the anniversary date elevation. A single value results in isothermal conditions

The data record formats adhere to the HEC standard of fields of 8. Table B-2 lists the field requirements for the various data records.

Table B-2. Field requirements for each record.

Records	Field(s)	Description
Vol_Set4	1	Record identification
	2	Year – February 1 based on the simulation time
	3	Reservoir control point number
	4	Anniversary volume (af)
ZR QA	1-10	Control point and path name
ZR MR	1-10	Control point and path name (including the E and F parts that will be appended as defined by the ZW Record in the HEC5 data set (e.g., E=1DAY F=CVP-SWP-Stan-RO3)
Temp_prof_CP	1-2	Record identification
	3	Reservoir control point number
Depth_temp	1-2	Record identification
	3	Water depth, any units
	4	Water temperature, °F

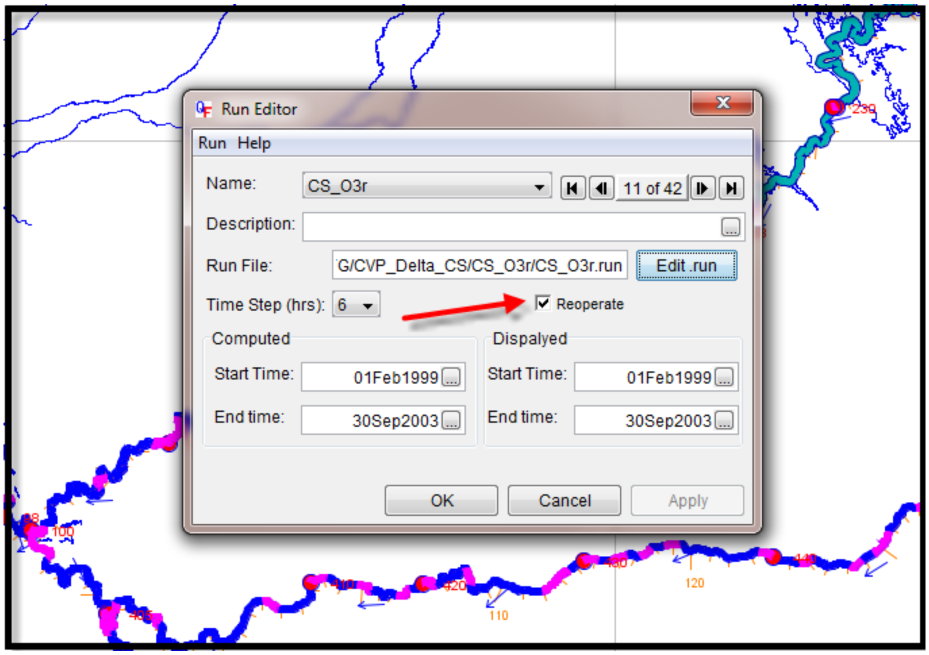
B.2.2. Temp_Opp file (Temperature Objectives and Operational Constraints)

The naming of the temperature objectives and operational constraints file via the ”Temp opp” record is shown in Figure B-2. Following the data file name (between columns 81 and 120) for the respective river systems are a series of text triggers that specify various program options. They include:

- dTdQ – Specifies output that quantifies the additional flow rate required to reduce temperature at the compliance point 1°F at the operated flow rate. This file provides insight into the effectiveness of temperature control on a daily basis. The name of the output file will be “dTdQ##.txt” where the ## will be the reservoir operation sequence number (e.g., “dTdQ03.txt” would be for the Stanislaus since New Melones is the third reservoir operated). This file will reside in the Run directory.

- Volume set – Required if reservoir reoperation is specified in the run editor. See Figure B-1 for an example.

- Average – Temperature targets will be interpreted as the daily averages if the word “Average” is included on the “Temp opp” line following “volume set”. If omitted (the B-2 example), the default is daily maximum.



Name: CS_O3r
11 of 42
Description:
Run File: G/CVP_Delta_CS/CS_O3r/CS_O3r.run
Time Step (hrs): 6
☑ Reoperate
Computed
Start Time: 01Feb1999
End time: 30Sep2003
Dispalyed
Start Time: 01Feb1999
End time: 30Sep2003

Figure B-1. Example of the volume reset specification.

A portion of the temperature objectives and operational constraints file for the Stanislaus River is shown in Figure B-4. The example data are for demonstrating the model capabilities and do not attempt to represent a viable or realistic operational condition. No conclusions should be drawn from these results. This is the file referenced in the run file shown in Figure B-2. The records that have been condensed are for the same location and temperature target. Only the flow constraints and ramping rates change monthly as the CALSIM II flows change. Keep in mind that all of the daily data can be changed at the discretion of the user.

The first 5 lines define the global variables. Line 6 signals the end of the global input and is required. Lines 8 through the end of the file define the daily operation targets and flow constraints. The file can have data that precede the start of the simulation period, however data for all days within the simulation period must be defined.

In general, the data record formats adhere to the HEC standard of fields of 8 (e.g., Field 6 has column limits of 41-48). The following table lists the fields required for the various data records.

Table B-3. Summary of fields, lines, and descriptions.

Line	Field(s)	Description
1	1-5	Line code – "operate reservoir"
	6	Reservoir control point number (e.g., 240 = New Melones)
2	1-5	Line code – "minimum operating storage"
	6	Minimum storage requirement for temperature operation
3	1-5	Line code – "temperature curtailment limits"
	6	Augmentation curtailment threshold(1)
	7	No augmentation threshold(1)
4	1-5	Line code – "U/S mile of control reach"
	6	River mile – Goodwin (2)
5	1-5	Line code – "CP and mile location of control"
	6	Control point number (Goodwin Dam)
	7	Control location river mile (Goodwin Dam)
6	1-5	Line code – "end global input"
8-on (one line required for each day of simulation – data outside of the simulation limits are ignored))	1	Calendar date – requirement format – columns 1- 10
	2	Control point of target location – column 11-16
	3	River mile of target location
	4	Temperature target, °F (maximum or average)
	5	Minimum allowable flow, cfs
	6	Maximum allowable flow, cfs
	7	Maximum rate of decrease in flow, cfs (down ramping)
	8	Maximum rate of increase in flow, cfs (up ramping)
	9	Not used
	10	Not used
	11	Not used – in this example, the CALSIM II flows were appended for reference. The flow limits and ramping

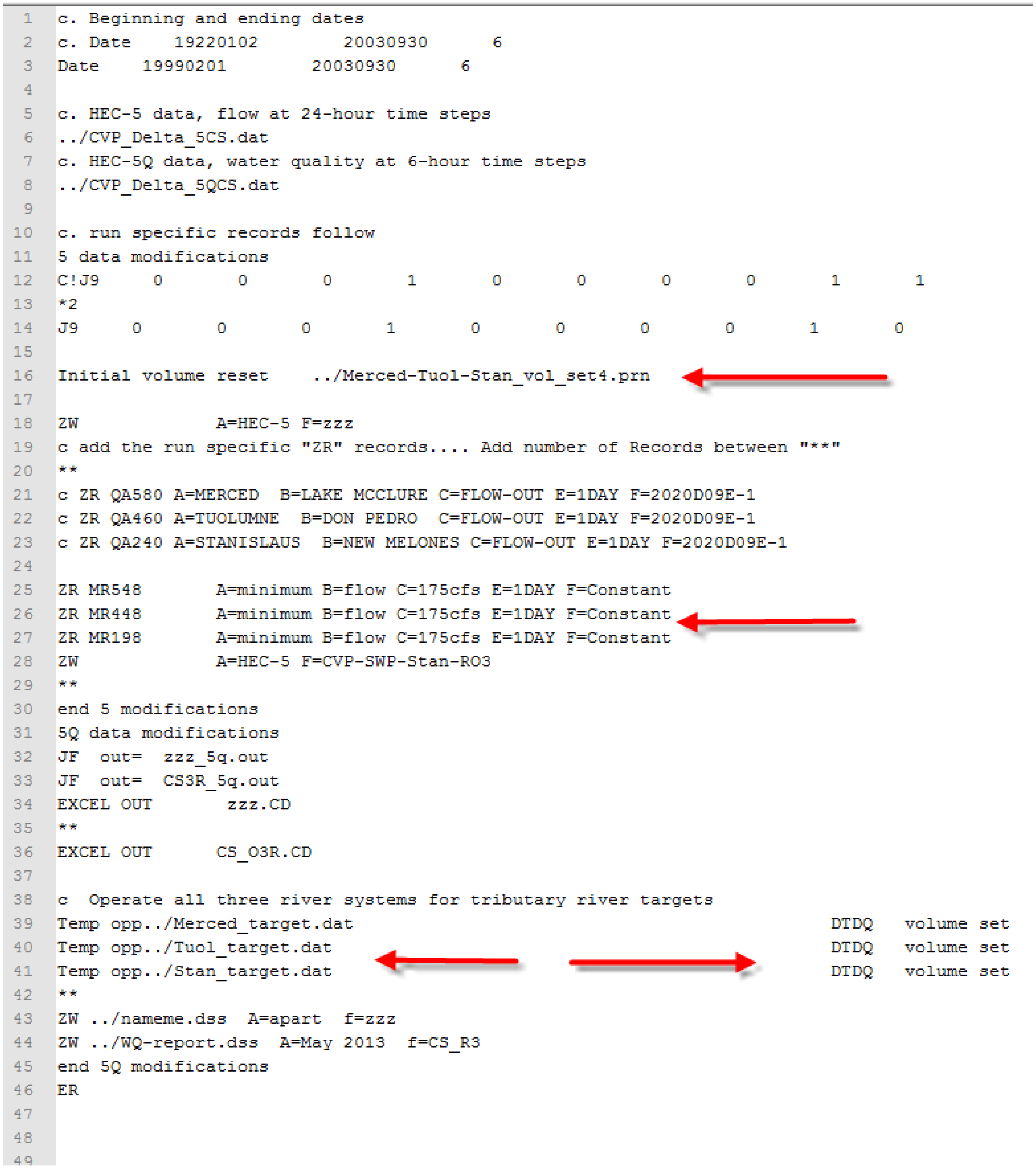
	rates were defined as fractions of the CALSIM II flows.

Flow augmentation may be suspended when the difference between the temperatures at the upstream control approaches the reservoir target. To avoid an abrupt flow augmentation cutoff, a beginning and ending temperature differential is specified. In Figure B-4, line 3 example the augmentation flow is decreased linearly between 3 and 1°F. There would be no augmentation if the target is within 1 °F of the upstream control reach. Not that the limits can be negative if the goal is to augment with very little potential benefit.

In the Stanislaus example both the control reach upstream river mile and the control location are below Goodwin Dam. If a location further downstream is the control, flow routing to the control location is not allowed.

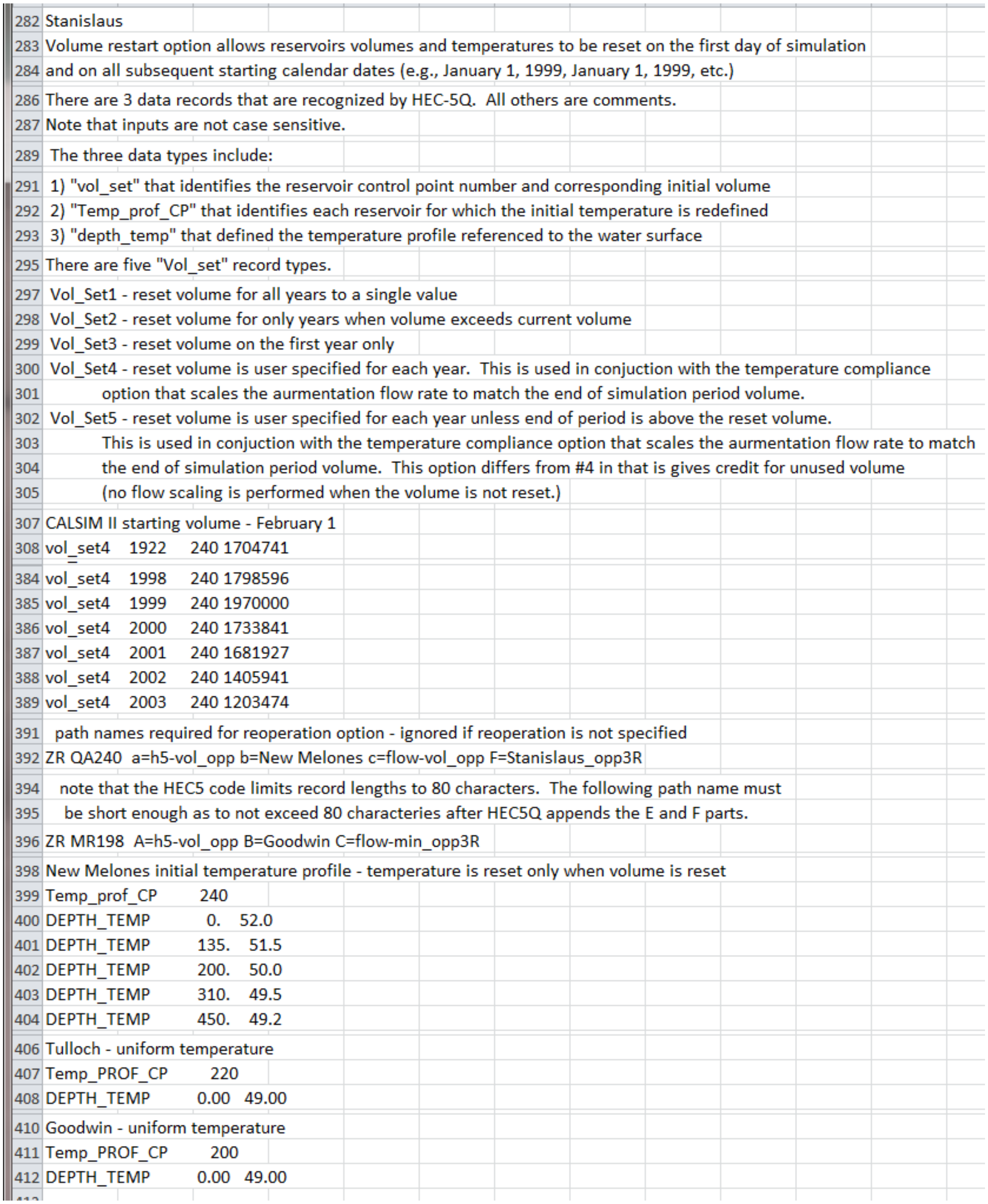
One record is required for each day of simulation. Records prior to the first day of simulation will be skipped.

The results of the system operation and temperature control utilize DSS output and GUI display capabilities. The two diagnostic output files (“Temp_Opp_#.log” and “Reoperation.log”) can be ignored.



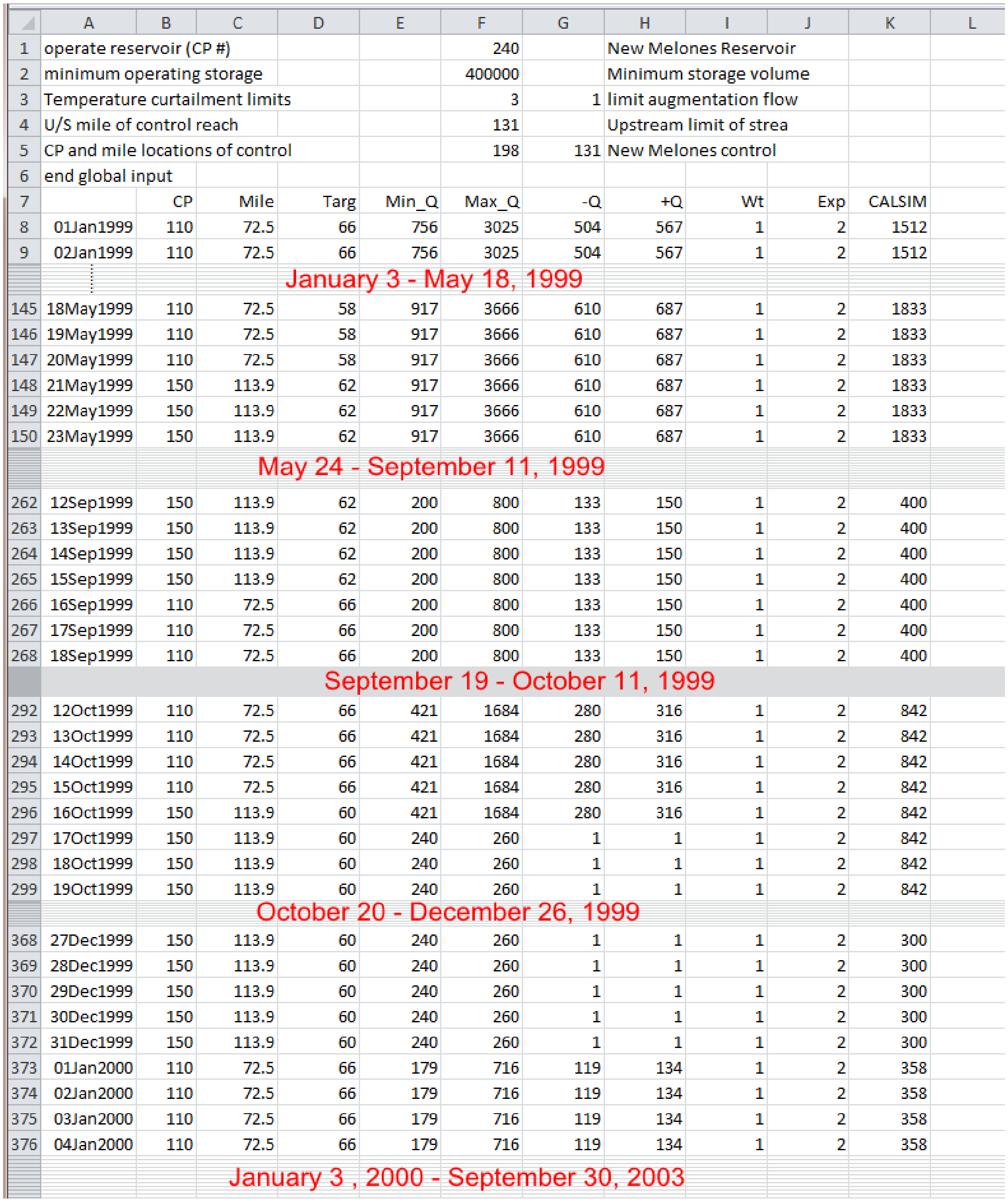
```
c. Beginning and ending dates
c. Date    19220102        20030930      6
Date    19990201        20030930      6

c. HEC-5 data, flow at 24-hour time steps
../CVP_Delta_5CS.dat
c. HEC-5Q data, water quality at 6-hour time steps
../CVP_Delta_5QCS.dat

c. run specific records follow
5 data modifications
C!J9      0       0       0       1       0       0       0       0       1       1
*2
J9      0       0       0       1       0       0       0       0       1       0

Initial volume reset    ../Merced-Tuol-Stan_vol_set4.prn

ZW             A=HEC-5 F=zzz
c add the run specific "ZR" records.... Add number of Records between "**"
**
c ZR QA580 A=MERCED  B=LAKE MCCLURE C=FLOW-OUT E=1DAY F=2020D09E-1
c ZR QA460 A=TUOLUMNE  B=DON PEDRO  C=FLOW-OUT E=1DAY F=2020D09E-1
c ZR QA240 A=STANISLAUS  B=NEW MELONES C=FLOW-OUT E=1DAY F=2020D09E-1

ZR MR548       A=minimum B=flow C=175cfs E=1DAY F=Constant
ZR MR448       A=minimum B=flow C=175cfs E=1DAY F=Constant
ZR MR198       A=minimum B=flow C=175cfs E=1DAY F=Constant
ZW             A=HEC-5 F=CVP-SWP-Stan-RO3
**
end 5 modifications
5Q data modifications
JF  out=  zzz_5q.out
JF  out=  CS3R_5q.out
EXCEL OUT       zzz.CD
**
EXCEL OUT      CS_O3R.CD

c  Operate all three river systems for tributary river targets
Temp opp../Merced_target.dat                                             DTDQ   volume set
Temp opp../Tuol_target.dat                                               DTDQ   volume set
Temp opp../Stan_target.dat                                               DTDQ   volume set
**
ZW ../nameme.dss  A=apart  f=zzz
ZW ../WQ-report.dss  A=May 2013  f=CS_R3
end 5Q modifications
ER
```

Figure B-2. Typical run file with Temperature Control Option inserts



```
Stanislaus
Volume restart option allows reservoirs volumes and temperatures to be reset on the first day of simulation
and on all subsequent starting calendar dates (e.g., January 1, 1999, January 1, 1999, etc.)
There are 3 data records that are recognized by HEC-5Q.  All others are comments.
Note that inputs are not case sensitive.
 The three data types include:
 1) "vol_set" that identifies the reservoir control point number and corresponding initial volume
 2) "Temp_prof_CP" that identifies each reservoir for which the initial temperature is redefined
 3) "depth_temp" that defined the temperature profile referenced to the water surface
There are five "Vol_set" record types.
 Vol_Set1 - reset volume for all years to a single value
 Vol_Set2 - reset volume for only years when volume exceeds current volume
 Vol_Set3 - reset volume on the first year only
 Vol_Set4 - reset volume is user specified for each year.  This is used in conjuction with the temperature compliance
          option that scales the aurmentation flow rate to match the end of simulation period volume.
 Vol_Set5 - reset volume is user specified for each year unless end of period is above the reset volume.
          This is used in conjuction with the temperature compliance option that scales the aurmentation flow rate to match
          the end of simulation period volume.  This option differs from #4 in that is gives credit for unused volume
          (no flow scaling is performed when the volume is not reset.)
CALSIM II starting volume - February 1
vol_set4   1922    240 1704741
vol_set4   1998    240 1798596
vol_set4   1999    240 1970000
vol_set4   2000    240 1733841
vol_set4   2001    240 1681927
vol_set4   2002    240 1405941
vol_set4   2003    240 1203474
  path names required for reoperation option - ignored if reoperation is not specified
ZR QA240  a=h5-vol_opp b=New Melones c=flow-vol_opp F=Stanislaus_opp3R
   note that the HEC5 code limits record lengths to 80 characters.  The following path name must
    be short enough as to not exceed 80 characteries after HEC5Q appends the E and F parts.
ZR MR198  A=h5-vol_opp B=Goodwin C=flow-min_opp3R
New Melones initial temperature profile - temperature is reset only when volume is reset
Temp_prof_CP       240
DEPTH_TEMP          0.   52.0
DEPTH_TEMP        135.   51.5
DEPTH_TEMP        200.   50.0
DEPTH_TEMP        310.   49.5
DEPTH_TEMP        450.   49.2
Tulloch - uniform temperature
Temp_PROF_CP       220
DEPTH_TEMP        0.00   49.00
Goodwin - uniform temperature
Temp_PROF_CP       200
DEPTH_TEMP        0.00   49.00
```

Figure B-3. Portion of the Initial Volume Reset file showing the data related to the Stanislaus River reservoir.



	A	B	C	D	E	F	G	H	I	J	K	L
1	operate reservoir (CP #)					240		New Melones Reservoir				
2	minimum operating storage					400000		Minimum storage volume				
3	Temperature curtailment limits					3	1	limit augmentation flow				
4	U/S mile of control reach					131		Upstream limit of strea				
5	CP and mile locations of control					198	131	New Melones control				
6	end global input											
7		CP	Mile	Targ	Min_Q	Max_Q	-Q	+Q	Wt	Exp	CALSIM	
8	01Jan1999	110	72.5	66	756	3025	504	567	1	2	1512	
9	02Jan1999	110	72.5	66	756	3025	504	567	1	2	1512	
	January 3 - May 18, 1999											
145	18May1999	110	72.5	58	917	3666	610	687	1	2	1833	
146	19May1999	110	72.5	58	917	3666	610	687	1	2	1833	
147	20May1999	110	72.5	58	917	3666	610	687	1	2	1833	
148	21May1999	150	113.9	62	917	3666	610	687	1	2	1833	
149	22May1999	150	113.9	62	917	3666	610	687	1	2	1833	
150	23May1999	150	113.9	62	917	3666	610	687	1	2	1833	
	May 24 - September 11, 1999											
262	12Sep1999	150	113.9	62	200	800	133	150	1	2	400	
263	13Sep1999	150	113.9	62	200	800	133	150	1	2	400	
264	14Sep1999	150	113.9	62	200	800	133	150	1	2	400	
265	15Sep1999	150	113.9	62	200	800	133	150	1	2	400	
266	16Sep1999	110	72.5	66	200	800	133	150	1	2	400	
267	17Sep1999	110	72.5	66	200	800	133	150	1	2	400	
268	18Sep1999	110	72.5	66	200	800	133	150	1	2	400	
	September 19 - October 11, 1999											
292	12Oct1999	110	72.5	66	421	1684	280	316	1	2	842	
293	13Oct1999	110	72.5	66	421	1684	280	316	1	2	842	
294	14Oct1999	110	72.5	66	421	1684	280	316	1	2	842	
295	15Oct1999	110	72.5	66	421	1684	280	316	1	2	842	
296	16Oct1999	150	113.9	60	421	1684	280	316	1	2	842	
297	17Oct1999	150	113.9	60	240	260	1	1	1	2	842	
298	18Oct1999	150	113.9	60	240	260	1	1	1	2	842	
299	19Oct1999	150	113.9	60	240	260	1	1	1	2	842	
	October 20 - December 26, 1999											
368	27Dec1999	150	113.9	60	240	260	1	1	1	2	300	
369	28Dec1999	150	113.9	60	240	260	1	1	1	2	300	
370	29Dec1999	150	113.9	60	240	260	1	1	1	2	300	
371	30Dec1999	150	113.9	60	240	260	1	1	1	2	300	
372	31Dec1999	150	113.9	60	240	260	1	1	1	2	300	
373	01Jan2000	110	72.5	66	179	716	119	134	1	2	358	
374	02Jan2000	110	72.5	66	179	716	119	134	1	2	358	
375	03Jan2000	110	72.5	66	179	716	119	134	1	2	358	
376	04Jan2000	110	72.5	66	179	716	119	134	1	2	358	
	January 3 , 2000 - September 30, 2003											

Figure B-4. Portion of the Initial Volume Reset file showing the data related to the Stanislaus River reservoir.

Appendix C. EC Calibration and Validation Results

C.1. EC Calibration Figures

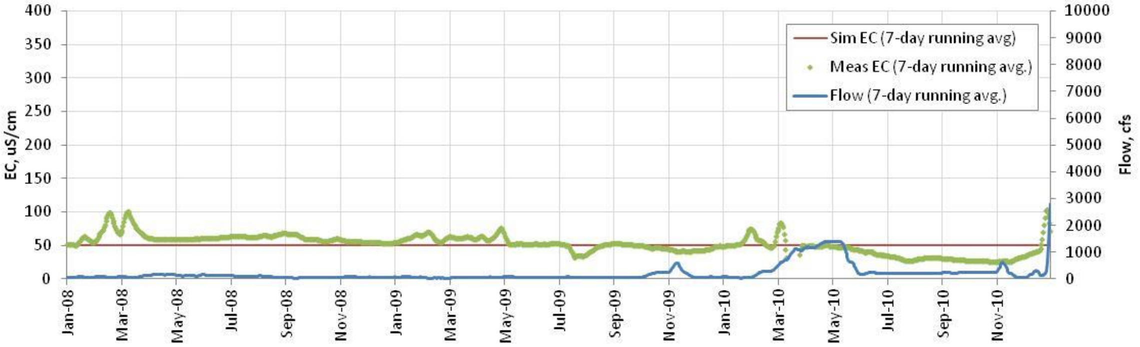


Figure C-1. Comparison of simulated and measured EC in San Joaquin River at Donny Bridge after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

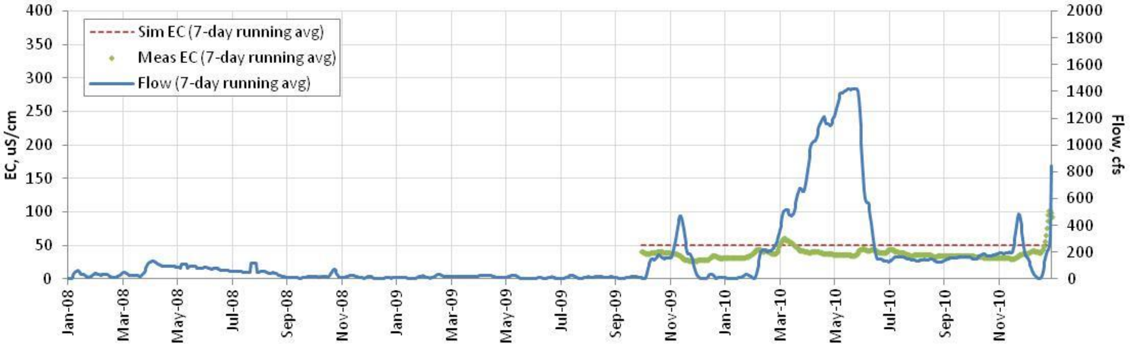


Figure C-2. Comparison of simulated and measured EC in San Joaquin River at Gravelly Ford after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

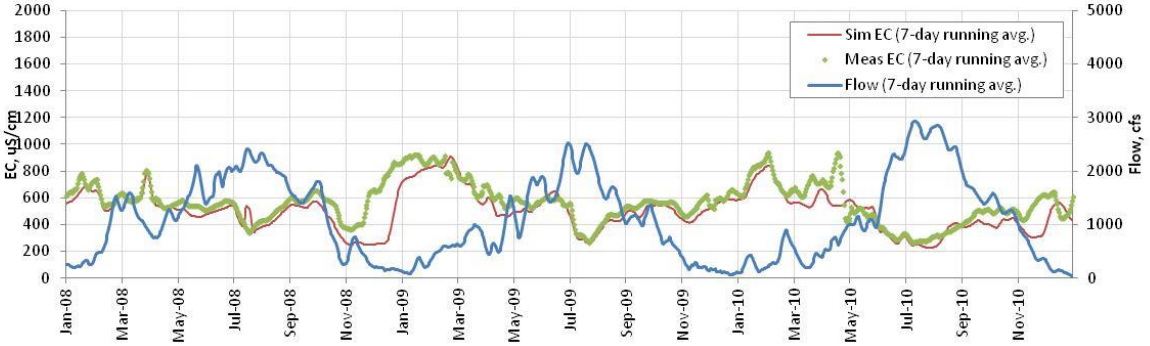


Figure C-3. Comparison of simulated and measured EC at Delta-Mendota Canal check 21 after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

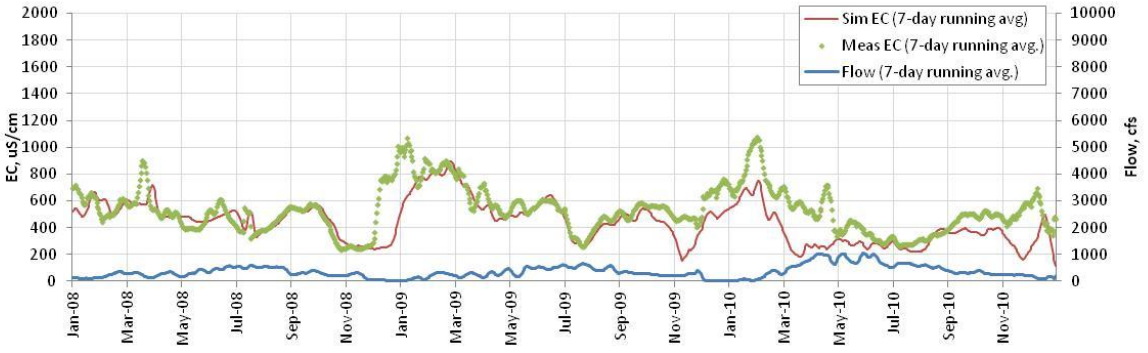


Figure C-4. Comparison of simulated and measured EC in San Joaquin River below Mendota Dam after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

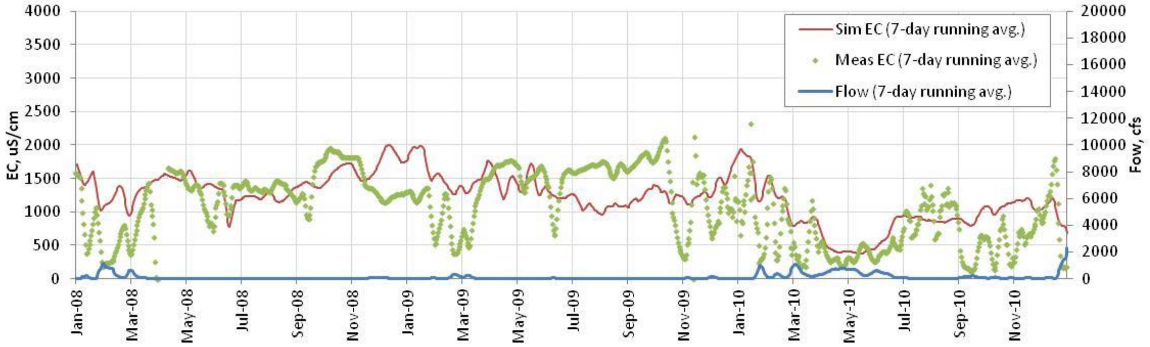


Figure C-5. Comparison of simulated and measured EC in San Joaquin River at Stevinson after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

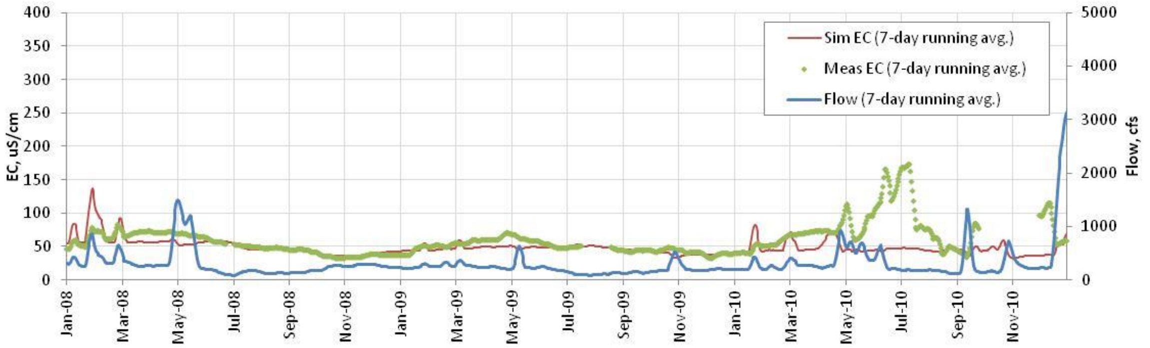


Figure C-6. Comparison of simulated and measured EC in Merced River at Cressey after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

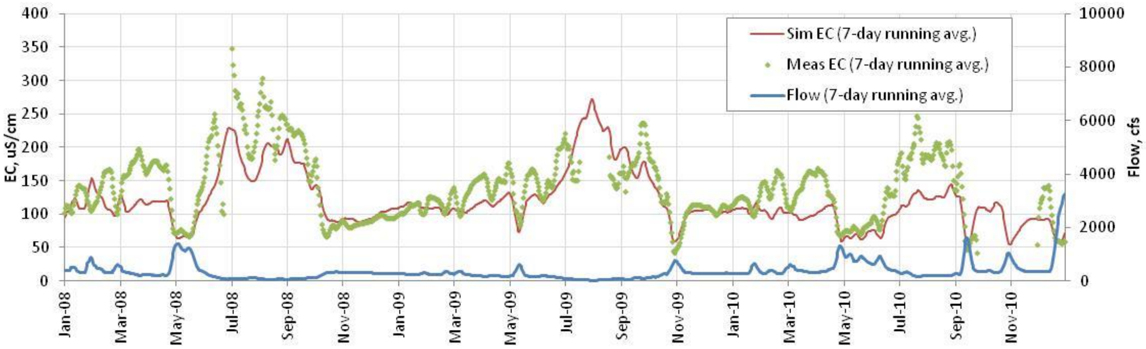


Figure C-7. Comparison of simulated and measured EC in Merced River near Stevinson after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

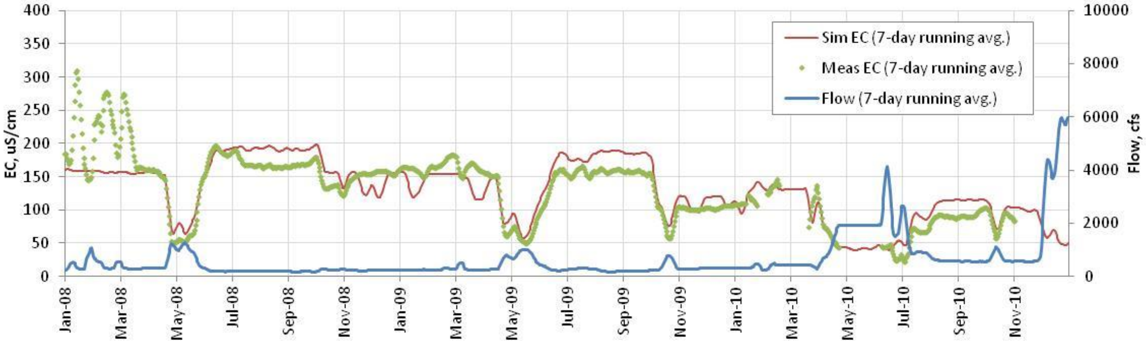


Figure C-8. Comparison of simulated and measured EC in Tuolumne River at Modesto after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

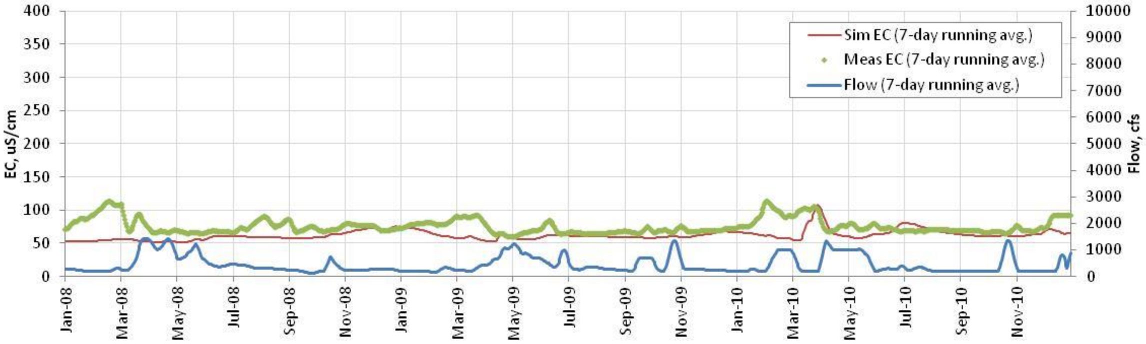


Figure C-9. Comparison of simulated and measured EC in Stanislaus River at Orange Blossom Bridge after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

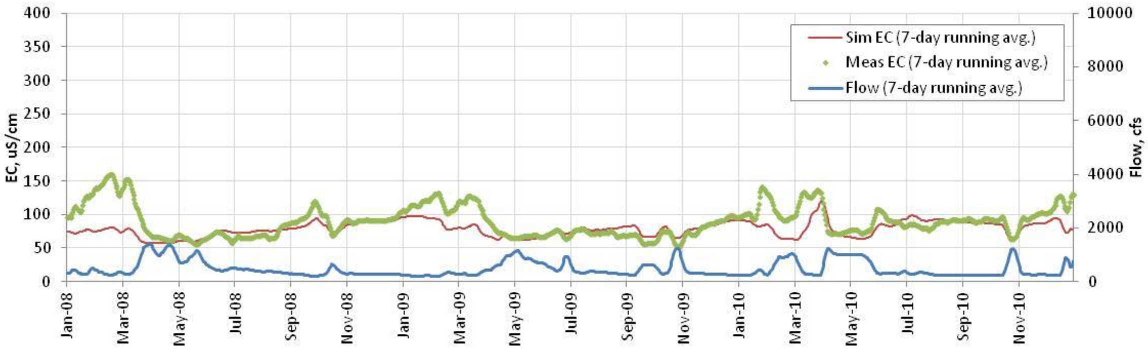


Figure C-10. Comparison of simulated and measured EC in Stanislaus River at Ripon after calibration (2008-2010). Simulated flow profile at that location is presented on the secondary axis.

C.2. EC Validation Figures

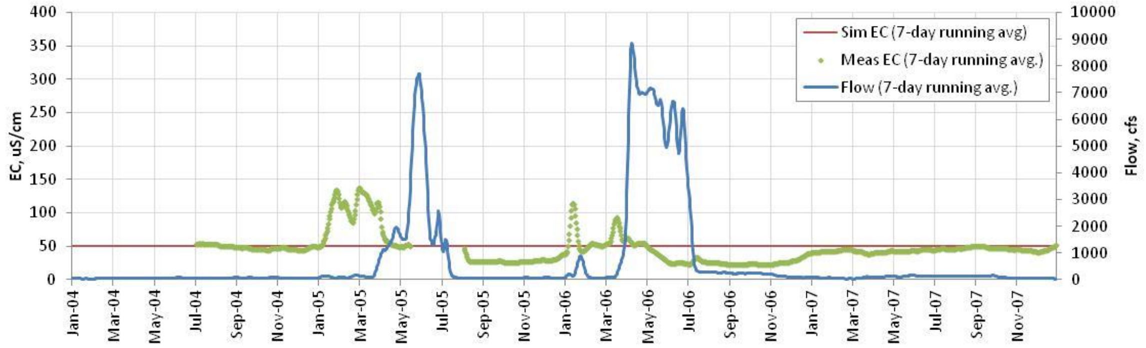


Figure C-11. Comparison of simulated and measured EC in San Joaquin River at Donny Bridge after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

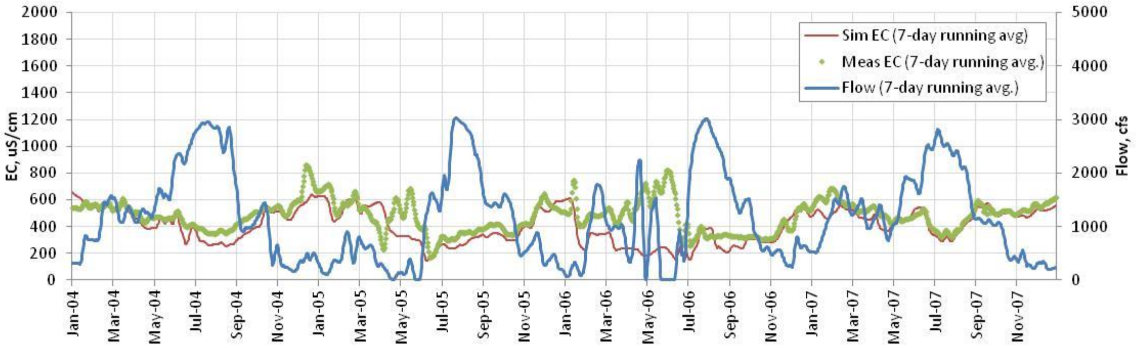


Figure C-12. Comparison of simulated and measured EC in Delta Mendota Canal Check 21 after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

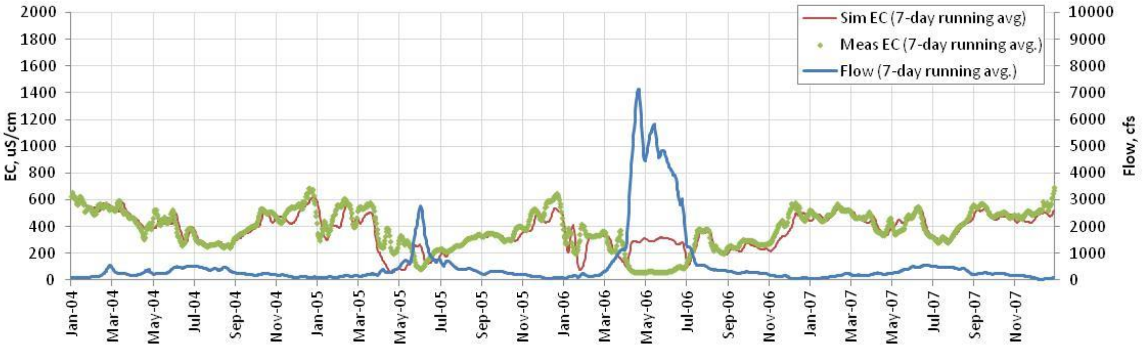


Figure C-13. Comparison of simulated and measured EC in San Joaquin River below Mendota Dam after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

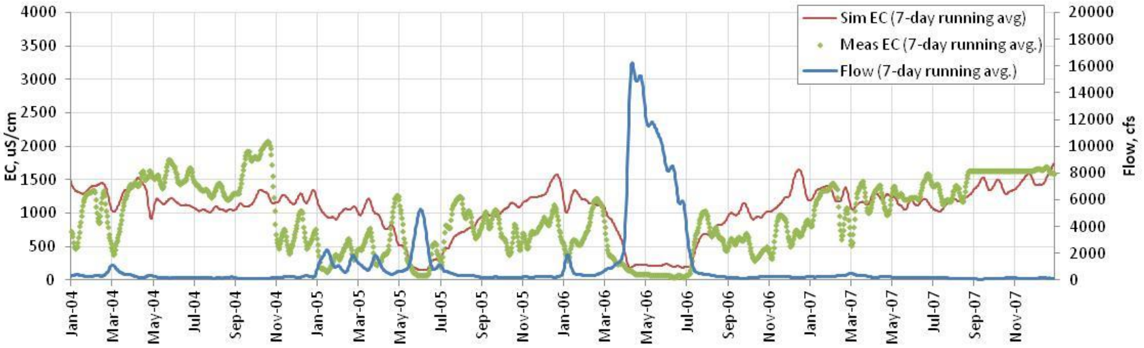


Figure C-14. Comparison of simulated and measured EC in San Joaquin River at Stevinson after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

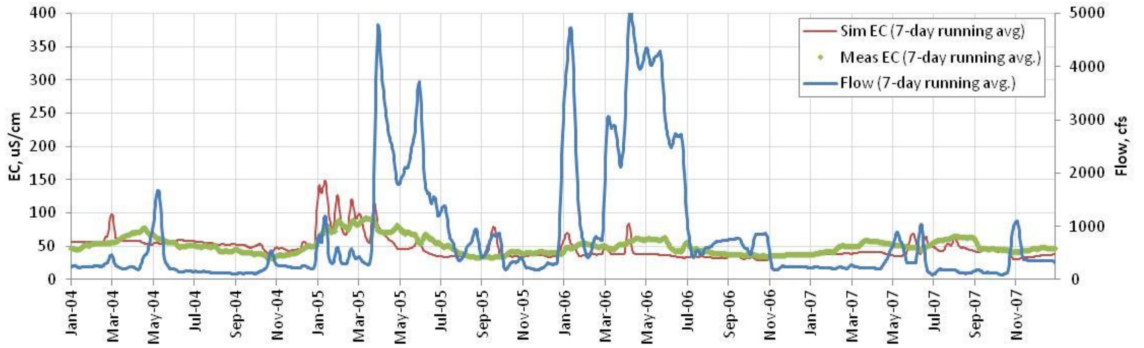


Figure C-15. Comparison of simulated and measured EC in Merced River at Cressy after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

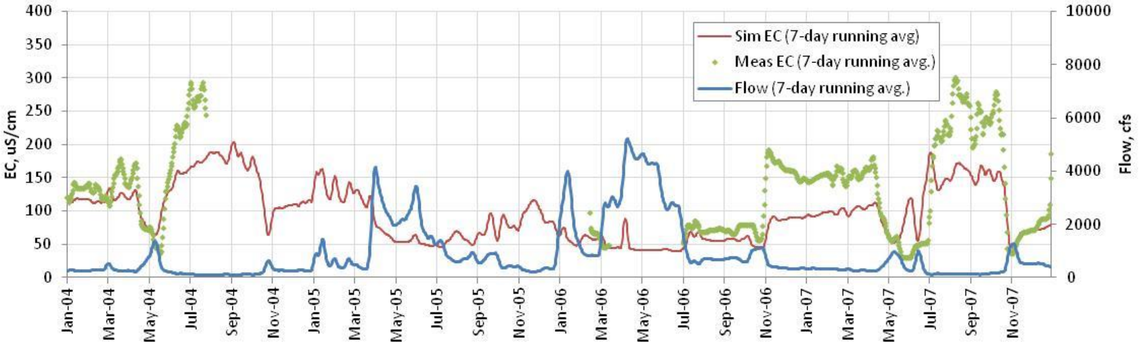


Figure C-16. Comparison of simulated and measured EC in Merced River at Stevinson after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

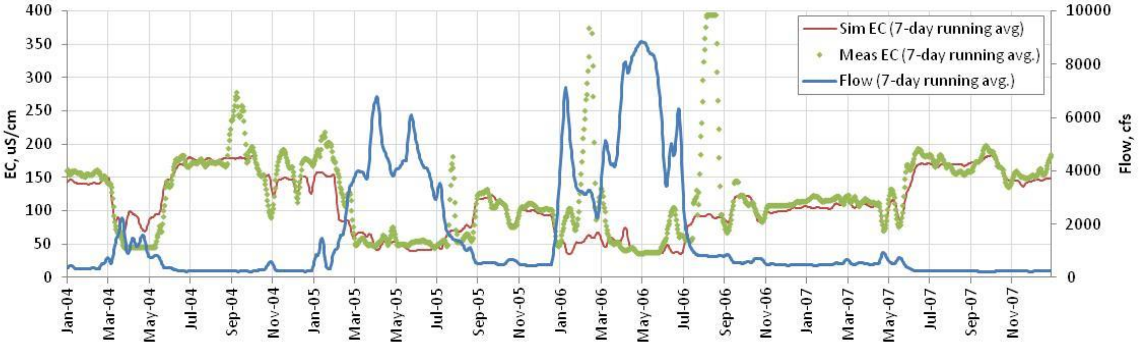


Figure C-17. Comparison of simulated and measured EC in Tuolumne River at Modesto after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

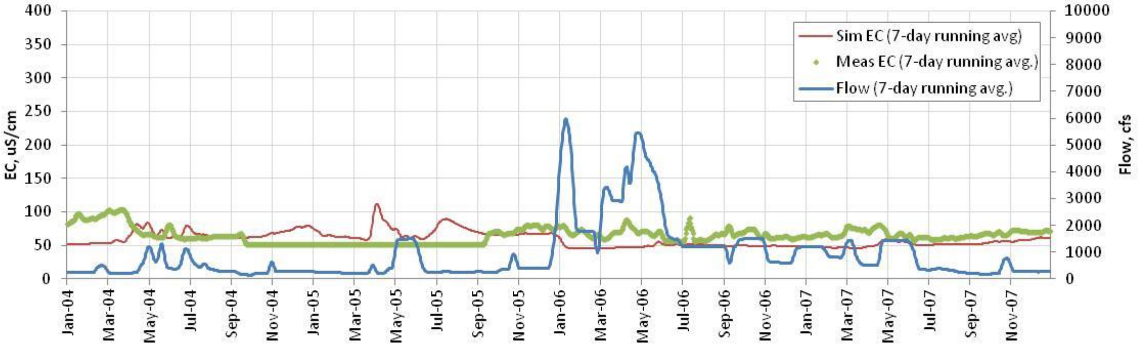


Figure C-18. Comparison of simulated and measured EC in Stanislaus River at Orange Blossom Bridge after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

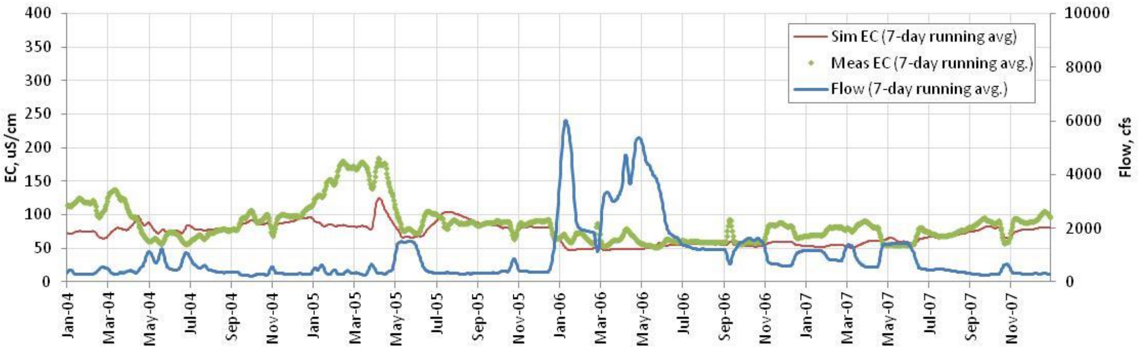


Figure C-19. Comparison of simulated and measured EC in Stanislaus River at Ripon after validation (2004-2007). Simulated flow profile at that location is presented on the secondary axis.

Appendix D. CALSIM II Preprocessor for HEC-5Q Input

CALSIM II preprocessor for HEC-5Q input is summarized in this appendix.

D.1. Background

The temperature and EC ramifications of San Joaquin River system operations are important in the planning and analysis environment. CALSIM II is the standard for simulating system operations within the Central Valley. Output from the CALSIM II model includes a wide range of hydrologic variable as monthly averages and end of month volumes. The HEC-5Q model relies upon daily hydrologic inputs. Therefore it is necessary to downscale the CALSIM II monthly values to daily and combine or subdivide the appropriate CALSIM II outputs to provide compatible inputs to HEC-5Q.

D.2. CALSIM II

The preprocessor ("CALSIM_H5Q") reads the CALSIM II DSS input/output file directly and relies upon a single input file ("SJR_CS_5.dat") to define and coordinate the DSS inputs and outputs. The various inputs to the CALSIM_H5Q program are described below. Note that the input data file contains numerous comments to aid in the interpretation of the input. A comment may begin with a blank or "c" in column one.

The first section of the data file (Figure D-1) defines the CALSIM II files and controls. Up to four CALSIM II DSS files may be accommodated although three files are typical (lines 6, 7, and 8). If fewer than four files are specified, the "no more" place holder is required (line 12) The DSS output file is named along with the F Part designation to identify the CALSIM II condition (lines 15 and 18, respectively). The first program step is to parse a complete list of all path names from the CALSIM II DSS output files. These files are processed sequentially and the record (path) hierarchy is defined by the DSS files input sequence. The source (DSS file) of the CALSIM II data records are recorded in the informational output file "file-path names_CS.txt".

The "get" records identify which path names are to be retrieved by identifying the C Part that is always unique. Figure D-2 shows a portion of the CALSIM II schematic of the Millerton Lake area that puts the C Parts of the "get" record seen in Figure D-1 in context (line 33). The end of the "get" data is signaled by "end".

The name of an informational file (Figure D-3, line 57) is required for output of all "get" data in semicolon delimited format that is compatible with Excel.

The remaining data define the HEC5Q DSS input path names.

Line 83 of Figure D-3 defines the DSS pathname for San Luis Reservoir storage as the sum of "S11" and "S12" DSS B part. Two paths are required since San Luis is represented by two reservoir volume components (See Figure D-4). (Note that the actual input data must maintain input column constraints with the "+S11" following column 72.)

The input sequence should begin with the storage volumes for all reservoirs because the HEC-5Q input requires that all starting storages be defined first. The list of DSS records is provided in the “ZR.rec.use” file which can be inserted into the HEC-5Q data file corresponding to the CALSIM II run. Details of this file are described later.

Figure D-5 illustrates additional ZR record data options. Line 141 defines the Tuolumne River inflow to Lake Don Pedro. The “fit” preceding the “+I81” results in a curve fit of the monthly CALSIM II inflow. The curve fit which is illustrated in Figure D-7, utilized the following steps:

1. Fit the monthly data with a cubic spline fit;
2. Move the curve up or down to match the total monthly inflow volume;
3. Impose a uniform slope over a 5-day period between months to eliminate abrupt changes while maintaining monthly inflow volume continuity.

Inflow and diversion can be defined explicitly or as a difference between in-river locations.

Line 144 (Figure D-5) defines the Dry Creek inflow to the Merced River as C562 minus C561. The “>0” results in only positive inflows and zero flow when the difference is negative. Lines 145, 146 and 147 define the depletion above Cressey as C561 minus C562 with the “>0” constraint. The three ZR records appear redundant; however, this depletion is distributed to three control points (545, 540, and 535) in HEC-5Q. The “QD” of the “ZR” record defines the flow increment as a diversion (outflows are positive). The depletion assigned to these three control points is scaled to equal 1.0 using the DR Records in the HEC5Q input data file. If the “>0” is omitted, the Cressey inflow would be considered as a line accretion and the “IN535” (line 144) flow would not be defined. When C562 > C561, the difference is a true depletion. However, when C562 < C561, the diversion flow is a negative. Negative diversions (accretions) enter the stream at the ambient temperature thus the inflow temperature does not need to be defined.

Redundant inflows (lines 138 and 139) are scaled using the C1 Record in HEC-5 to provide point inflow from Salt and Mud Sloughs (70 percent & 30 percent), respectively.

The “stop” on line 178 signals the end of the input. However, lines 189 through 192 serve as a reminder to define the Friant Dam outlet flow components. These records must be inserted into the HEC5Q input data following the “LD file=ZR” record for Control Point 800.

The list of DSS records is provided in the “ZR.rec.use” file which can be inserted into the HEC-5Q data file corresponding to the CALSIM II run. These JZ Records are consistent with the calibrated HEC-5Q model. However, CALSIM II does not provide all of the flow data required by HEC-5Q. Referring to Figure D-8, lines 46 through 49 list the four inflows to New Melones Reservoir represented by the HEC-5Q model. These inflows are a disaggregation of the New Melones total inflow (C10) considering Collierville and Stanislaus power plant capacities and the relative flow volume of the Middle and South

Forks of the Stanislaus River. The New Melones total inflow record in the DSS file but does not appear in the “ZR.rec.use” because it is not a model input.

In addition to the “ZR.rec.use” file, an informational file named “file-path names.txt” is generated. This file should be checked to ensure accurate (and proper interpretation) of input data. The three checks that should be investigated to ensure proper inputs are shown in Figure D-9.

1. Line 46 – a specified B part could not be found (this B part appears in the schematic but is missing from the CALSIM II DSS output).
2. Line 85 – the B part has been requested a second time. This does not create a problem but it should be checked to ensure that a different B part was intended (e.g., D708 was intended rather than C708)
3. Lines 352 & 353 – A missing B part was requested (example). Either a B part needs to be added to the “get” records or the ZR record needs to be corrected.

D.3. HEC-5Q Model Adaptations for CALSIM II Flows

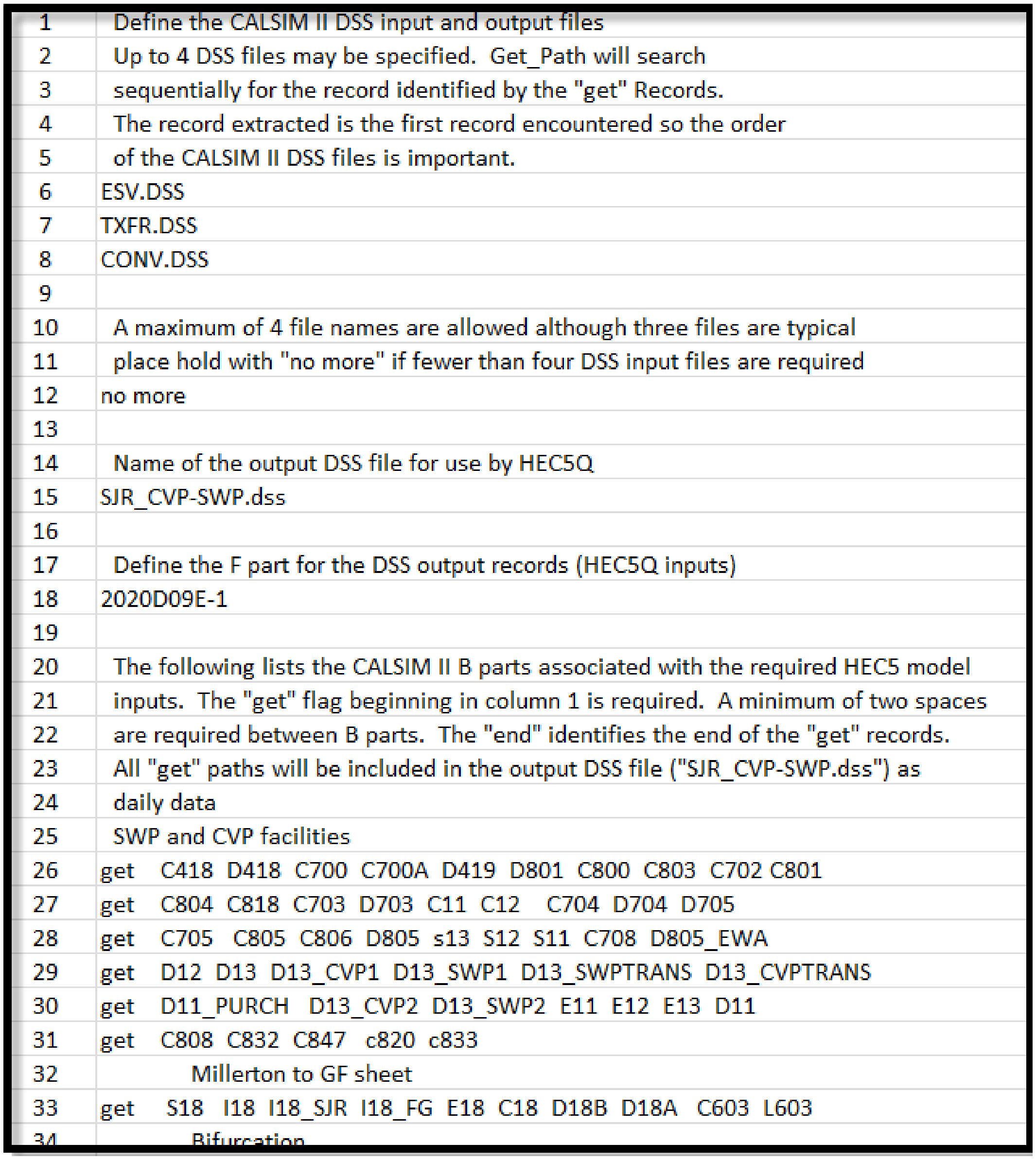
Minor modifications were required to accommodate the hydrologic data available from CALSIM II. The model schematic is indistinguishable from the calibrated San Joaquin basin (see Figure D-10) model schematic. These modifications include:

1. Reservoir evaporation defined in cfs rather than inches/month to maintain volume continuity.
2. Diversion to the Northside and Main Canals (Merced River) defined as a percentage (4 percent and 96 percent respectively) rather than explicit flow rates.
3. Mud and Salt Slough inflow defined as a percentage of “I614” (30 percent and 70 percent, respectively) rather than explicit flow rates.
4. New Melones inflows (Collierville and Stanislaus power plant and South and Middle Fork Stanislaus River) distributed based on typical power operation and River source percentages rather than explicit flow rates.
5. Tulloch Dam operation defined by rule curve with adjustments to New Melones outflow to account for incremental Tulloch Reservoir volume change
6. EC for Mud and Salt Sloughs defined as seasonal inputs developed from the time series data used during calibration
7. EC for Banks (CVP) and Delta (SWP) pumps defined daily based on DSM2 simulation results.

No changes were made to reservoir area-capacity tables, stream alignment and geometry or tributary inflow relationships.

D.4. DSS Output

The DSS output file named in the CALSIM_5Q will contain all of the flow and storage data required by HEC-5Q as well as the source data (CALSIM monthly flows as 1DAY data). The appropriate meteorological data must be added to the DSS file prior to simulating water temperature with HEC-5Q.



```
  Define the CALSIM II DSS input and output files
  Up to 4 DSS files may be specified.  Get_Path will search
  sequentially for the record identified by the "get" Records.
  The record extracted is the first record encountered so the order
  of the CALSIM II DSS files is important.
ESV.DSS
TXFR.DSS
CONV.DSS

  A maximum of 4 file names are allowed although three files are typical
  place hold with "no more" if fewer than four DSS input files are required
no more

  Name of the output DSS file for use by HEC5Q
SJR_CVP-SWP.dss

  Define the F part for the DSS output records (HEC5Q inputs)
2020D09E-1

  The following lists the CALSIM II B parts associated with the required HEC5 model
  inputs.  The "get" flag beginning in column 1 is required.  A minimum of two spaces
  are required between B parts.  The "end" identifies the end of the "get" records.
  All "get" paths will be included in the output DSS file ("SJR_CVP-SWP.dss") as
  daily data
  SWP and CVP facilities
get   C418  D418  C700  C700A  D419  D801  C800  C803  C702 C801
get   C804  C818  C703  D703  C11  C12   C704  D704  D705
get   C705   C805  C806  D805  s13  S12  S11  C708  D805_EWA
get   D12  D13  D13_CVP1  D13_SWP1  D13_SWPTRANS  D13_CVPTRANS
get   D11_PURCH   D13_CVP2  D13_SWP2  E11  E12  E13  D11
get   C808  C832  C847   c820  c833
            Millerton to GF sheet
get    S18   I18  I18_SJR  I18_FG  E18  C18  D18B  D18A   C603  L603
            Bifurcation
```

Figure D-1. Example CALSIM_H5Q input – DSS file specification, controls and “get” record.

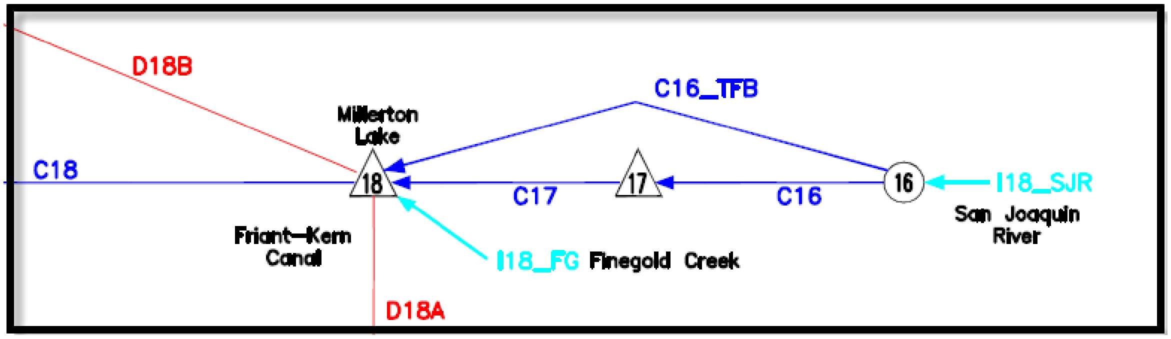
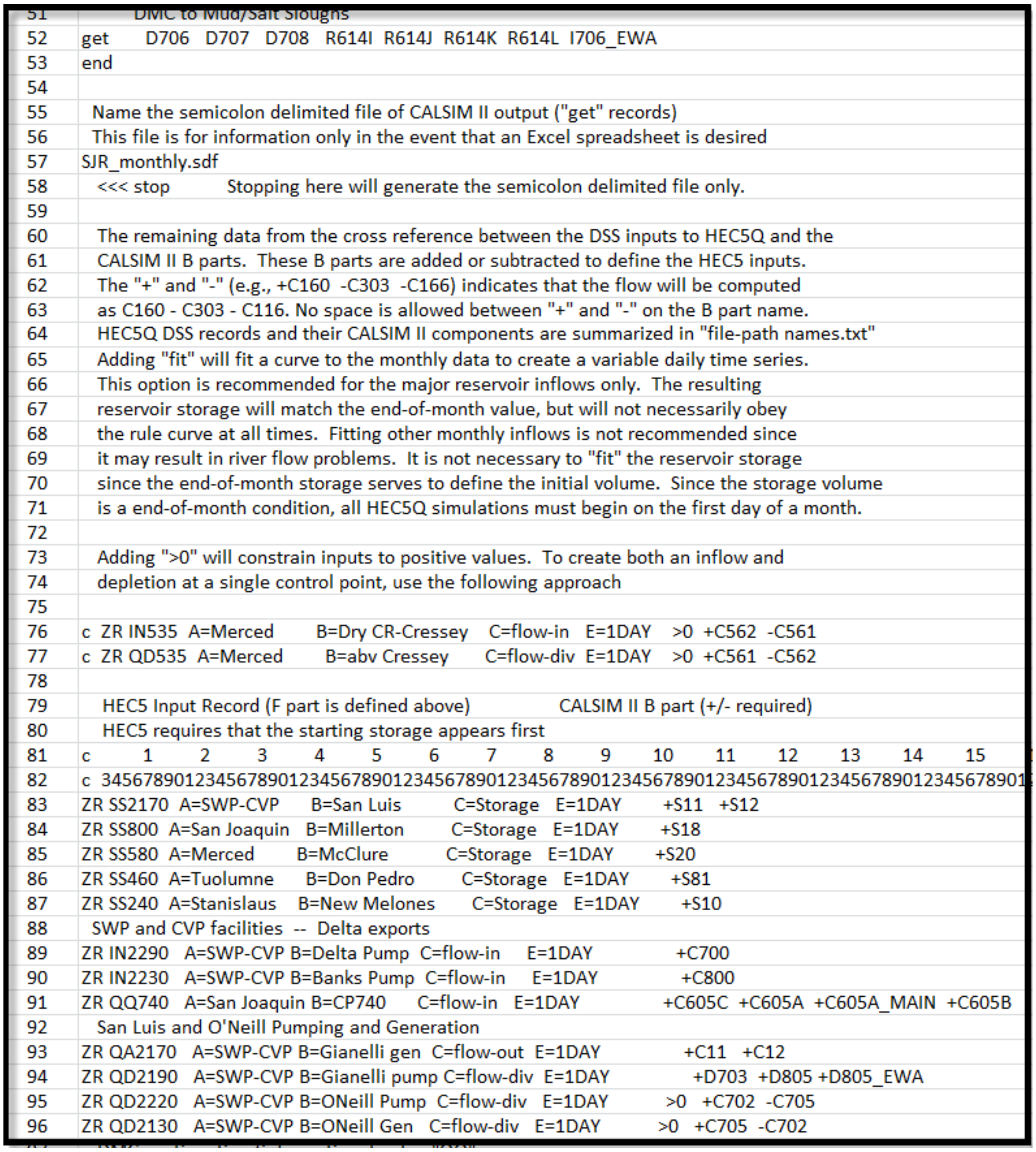


Figure D-2. Upper San Joaquin / Millerton Lake area CALSIM II Schematic.



```
        DMC to Mud/Salt Sloughs
get     D706   D707   D708   R614I  R614J  R614K  R614L  I706_EWA
end

  Name the semicolon delimited file of CALSIM II output ("get" records)
  This file is for information only in the event that an Excel spreadsheet is desired
SJR_monthly.sdf
   <<< stop          Stopping here will generate the semicolon delimited file only.

   The remaining data from the cross reference between the DSS inputs to HEC5Q and the
   CALSIM II B parts.  These B parts are added or subtracted to define the HEC5 inputs.
   The "+" and "-" (e.g., +C160  -C303  -C166) indicates that the flow will be computed
   as C160 - C303 - C116. No space is allowed between "+" and "-" on the B part name.
   HEC5Q DSS records and their CALSIM II components are summarized in "file-path names.txt"
   Adding "fit" will fit a curve to the monthly data to create a variable daily time series.
   This option is recommended for the major reservoir inflows only.  The resulting
   reservoir storage will match the end-of-month value, but will not necessarily obey
   the rule curve at all times.  Fitting other monthly inflows is not recommended since
   it may result in river flow problems.  It is not necessary to "fit" the reservoir storage
   since the end-of-month storage serves to define the initial volume.  Since the storage volume
   is a end-of-month condition, all HEC5Q simulations must begin on the first day of a month.

   Adding ">0" will constrain inputs to positive values.  To create both an inflow and
   depletion at a single control point, use the following approach

c  ZR IN535  A=Merced      B=Dry CR-Cressey   C=flow-in   E=1DAY    >0  +C562  -C561
c  ZR QD535  A=Merced       B=abv Cressey     C=flow-div  E=1DAY    >0  +C561  -C562

    HEC5 Input Record (F part is defined above)             CALSIM II B part (+/- required)
    HEC5 requires that the starting storage appears first
c       1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
c  34567890123456789012345678901234567890123456789012345678901234567890123456789012345678901
ZR SS2170  A=SWP-CVP     B=San Luis        C=Storage   E=1DAY      +S11   +S12
ZR SS800  A=San Joaquin   B=Millerton       C=Storage   E=1DAY      +S18
ZR SS580  A=Merced       B=McClure         C=Storage   E=1DAY      +S20
ZR SS460  A=Tuolumne     B=Don Pedro        C=Storage   E=1DAY      +S81
ZR SS240  A=Stanislaus    B=New Melones      C=Storage   E=1DAY      +S10
  SWP and CVP facilities  --  Delta exports
ZR IN2290   A=SWP-CVP B=Delta Pump  C=flow-in    E=1DAY              +C700
ZR IN2230   A=SWP-CVP B=Banks Pump  C=flow-in    E=1DAY              +C800
ZR QQ740   A=San Joaquin B=CP740     C=flow-in   E=1DAY             +C605C  +C605A  +C605A_MAIN  +C605B
   San Luis and O'Neill Pumping and Generation
ZR QA2170   A=SWP-CVP B=Gianelli gen  C=flow-out  E=1DAY              +C11   +C12
ZR QD2190   A=SWP-CVP B=Gianelli pump C=flow-div  E=1DAY               +D703  +D805 +D805_EWA
ZR QD2220   A=SWP-CVP B=ONeill Pump  C=flow-div   E=1DAY         >0   +C702  -C705
ZR QD2130   A=SWP-CVP B=ONeill Gen   C=flow-div   E=1DAY         >0   +C705  -C702
```

Figure D-3. Example CALSIM_H5Q input – Additional controls and ZR specifications.

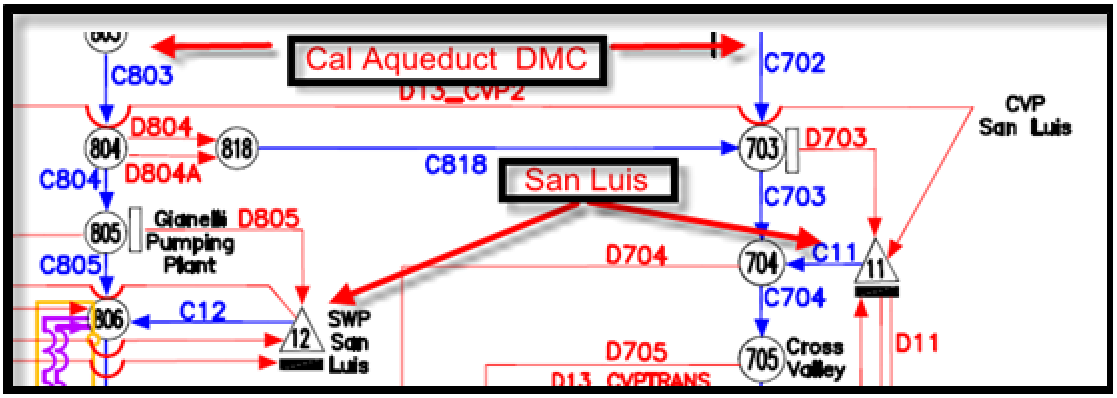
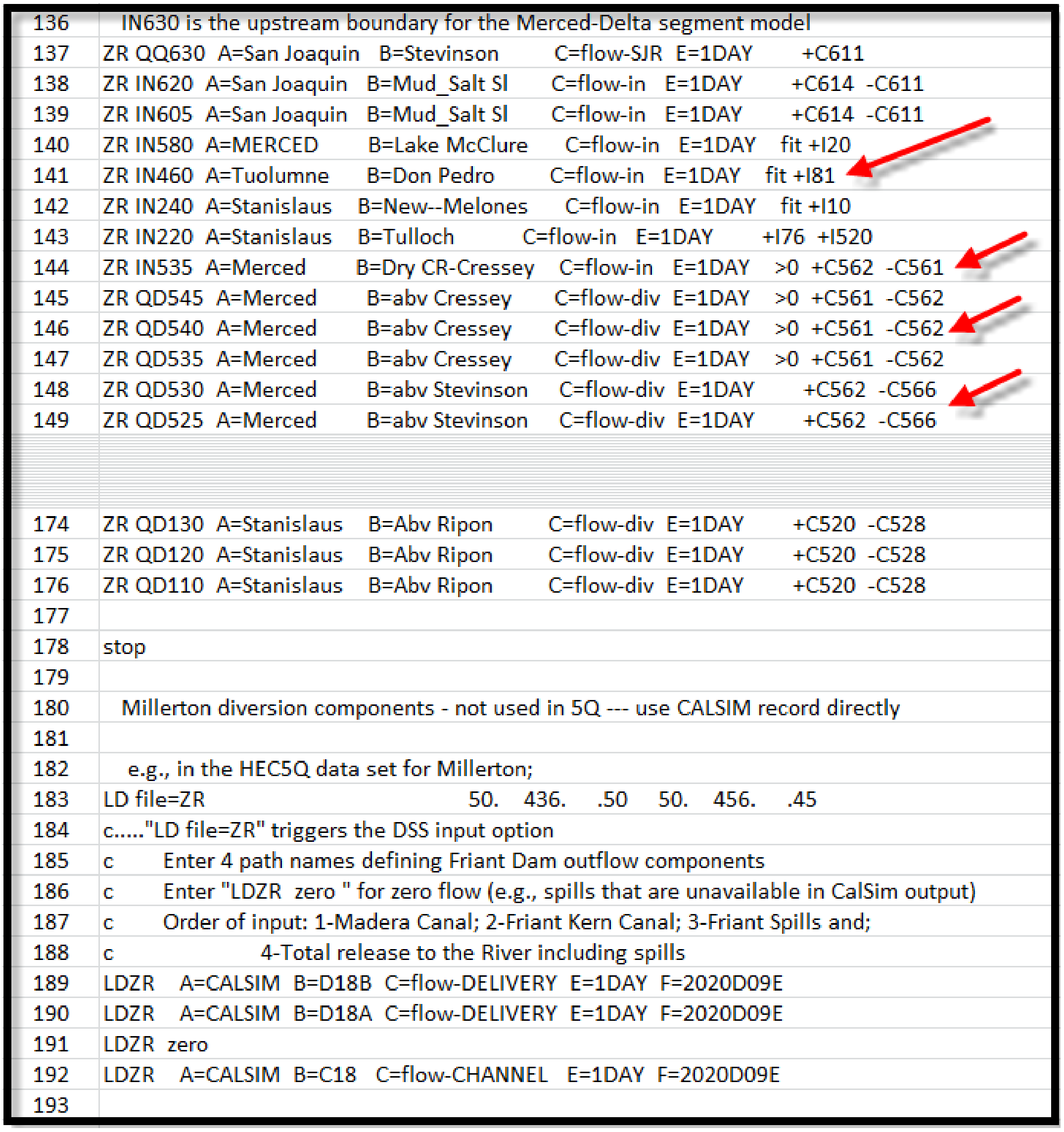


Figure D-4. San Luis Reservoir area CALSIM II Schematic.



```
  IN630 is the upstream boundary for the Merced-Delta segment model
ZR QQ630  A=San Joaquin   B=Stevinson       C=flow-SJR  E=1DAY      +C611
ZR IN620  A=San Joaquin   B=Mud_Salt Sl     C=flow-in   E=1DAY      +C614  -C611
ZR IN605  A=San Joaquin   B=Mud_Salt Sl     C=flow-in   E=1DAY      +C614  -C611
ZR IN580  A=MERCED        B=Lake McClure    C=flow-in   E=1DAY   fit +I20
ZR IN460  A=Tuolumne      B=Don Pedro       C=flow-in   E=1DAY   fit +I81
ZR IN240  A=Stanislaus    B=New--Melones    C=flow-in   E=1DAY   fit +I10
ZR IN220  A=Stanislaus    B=Tulloch       C=flow-in   E=1DAY     +I76  +I520
ZR IN535  A=Merced        B=Dry CR-Cressey  C=flow-in   E=1DAY   >0  +C562  -C561
ZR QD545  A=Merced        B=abv Cressey     C=flow-div  E=1DAY   >0  +C561  -C562
ZR QD540  A=Merced        B=abv Cressey     C=flow-div  E=1DAY   >0  +C561  -C562
ZR QD535  A=Merced        B=abv Cressey     C=flow-div  E=1DAY   >0  +C561  -C562
ZR QD530  A=Merced        B=abv Stevinson   C=flow-div  E=1DAY      +C562  -C566
ZR QD525  A=Merced        B=abv Stevinson   C=flow-div  E=1DAY      +C562  -C566

ZR QD130  A=Stanislaus    B=Abv Ripon      C=flow-div  E=1DAY      +C520  -C528
ZR QD120  A=Stanislaus    B=Abv Ripon      C=flow-div  E=1DAY      +C520  -C528
ZR QD110  A=Stanislaus    B=Abv Ripon      C=flow-div  E=1DAY      +C520  -C528

stop

  Millerton diversion components - not used in 5Q --- use CALSIM record directly

   e.g., in the HEC5Q data set for Millerton;
LD file=ZR                              50.   436.   .50    50.   456.    .45
c....."LD file=ZR" triggers the DSS input option
c       Enter 4 path names defining Friant Dam outflow components
c       Enter "LDZR  zero " for zero flow (e.g., spills that are unavailable in CalSim output)
c       Order of input: 1-Madera Canal; 2-Friant Kern Canal; 3-Friant Spills and;
c                      4-Total release to the River including spills
LDZR    A=CALSIM  B=D18B  C=flow-DELIVERY  E=1DAY  F=2020D09E
LDZR    A=CALSIM  B=D18A  C=flow-DELIVERY  E=1DAY  F=2020D09E
LDZR  zero
LDZR    A=CALSIM  B=C18   C=flow-CHANNEL   E=1DAY  F=2020D09E

```

Figure D-5. Example CALSIM_H5Q input – "fit" and ">0" ZR record options.

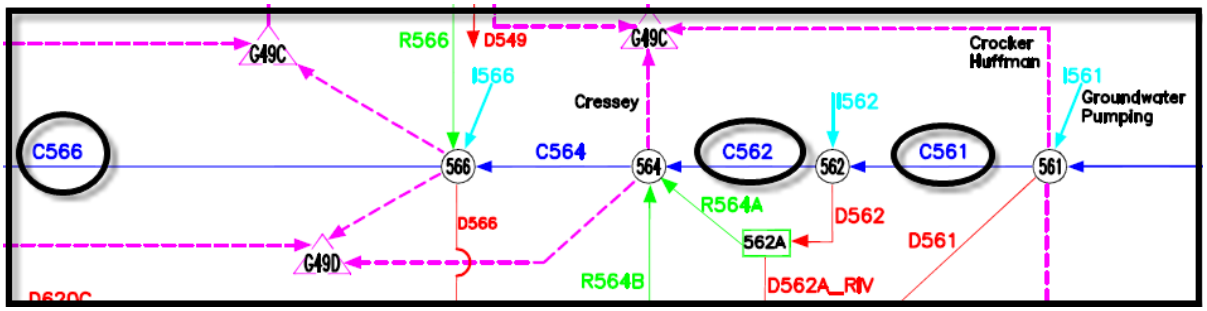


Figure D-6. Merced River Schematic.

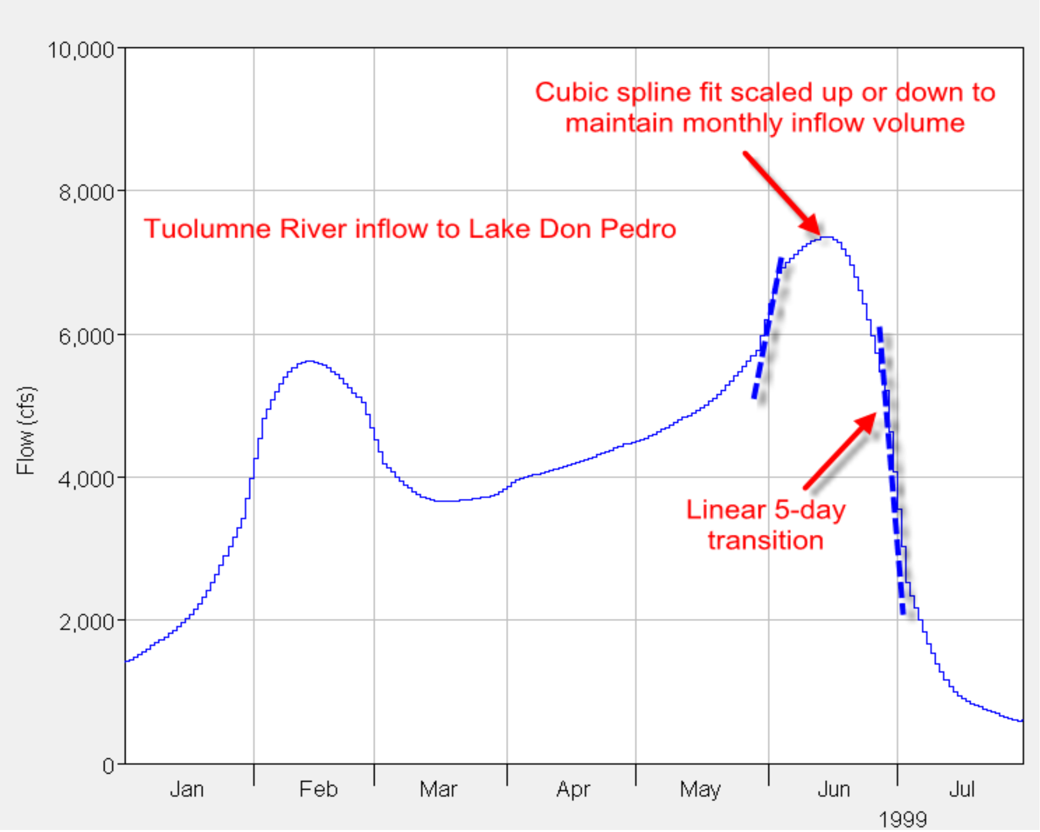
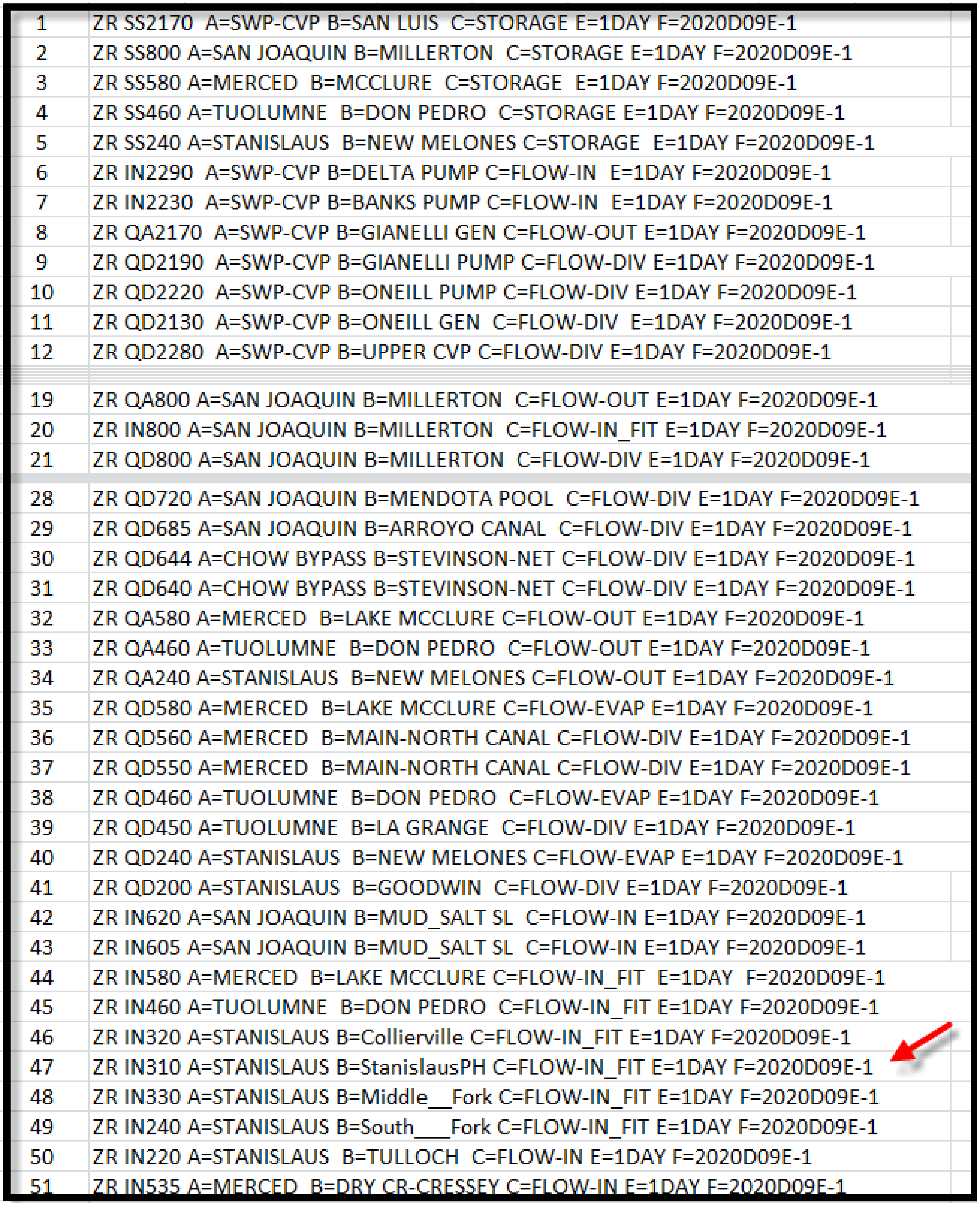
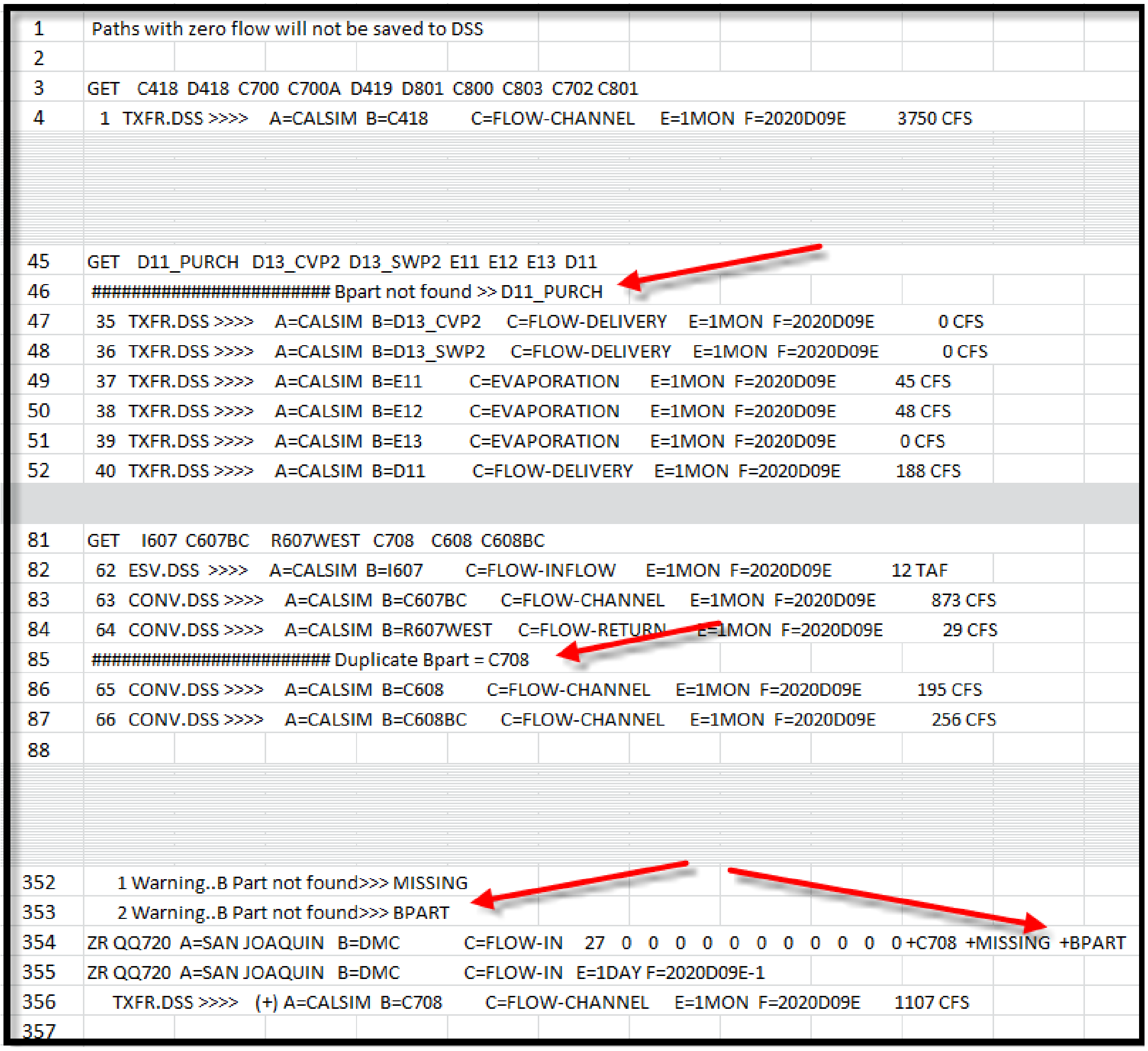


Figure D-7. Example of the inflow curve fit procedure.



```
ZR SS2170  A=SWP-CVP B=SAN LUIS  C=STORAGE E=1DAY F=2020D09E-1
ZR SS800 A=SAN JOAQUIN B=MILLERTON  C=STORAGE E=1DAY F=2020D09E-1
ZR SS580 A=MERCED  B=MCCLURE  C=STORAGE  E=1DAY F=2020D09E-1
ZR SS460 A=TUOLUMNE  B=DON PEDRO  C=STORAGE E=1DAY F=2020D09E-1
ZR SS240 A=STANISLAUS  B=NEW MELONES C=STORAGE  E=1DAY F=2020D09E-1
ZR IN2290  A=SWP-CVP B=DELTA PUMP C=FLOW-IN  E=1DAY F=2020D09E-1
ZR IN2230  A=SWP-CVP B=BANKS PUMP C=FLOW-IN  E=1DAY F=2020D09E-1
ZR QA2170  A=SWP-CVP B=GIANELLI GEN C=FLOW-OUT E=1DAY F=2020D09E-1
ZR QD2190  A=SWP-CVP B=GIANELLI PUMP C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD2220  A=SWP-CVP B=ONEILL PUMP C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD2130  A=SWP-CVP B=ONEILL GEN  C=FLOW-DIV  E=1DAY F=2020D09E-1
ZR QD2280  A=SWP-CVP B=UPPER CVP C=FLOW-DIV E=1DAY F=2020D09E-1

ZR QA800 A=SAN JOAQUIN B=MILLERTON  C=FLOW-OUT E=1DAY F=2020D09E-1
ZR IN800 A=SAN JOAQUIN B=MILLERTON  C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR QD800 A=SAN JOAQUIN B=MILLERTON  C=FLOW-DIV E=1DAY F=2020D09E-1

ZR QD720 A=SAN JOAQUIN B=MENDOTA POOL  C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD685 A=SAN JOAQUIN B=ARROYO CANAL  C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD644 A=CHOW BYPASS B=STEVINSON-NET C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD640 A=CHOW BYPASS B=STEVINSON-NET C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QA580 A=MERCED  B=LAKE MCCLURE C=FLOW-OUT E=1DAY F=2020D09E-1
ZR QA460 A=TUOLUMNE  B=DON PEDRO  C=FLOW-OUT E=1DAY F=2020D09E-1
ZR QA240 A=STANISLAUS  B=NEW MELONES C=FLOW-OUT E=1DAY F=2020D09E-1
ZR QD580 A=MERCED  B=LAKE MCCLURE C=FLOW-EVAP E=1DAY F=2020D09E-1
ZR QD560 A=MERCED  B=MAIN-NORTH CANAL C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD550 A=MERCED  B=MAIN-NORTH CANAL C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD460 A=TUOLUMNE  B=DON PEDRO  C=FLOW-EVAP E=1DAY F=2020D09E-1
ZR QD450 A=TUOLUMNE  B=LA GRANGE  C=FLOW-DIV E=1DAY F=2020D09E-1
ZR QD240 A=STANISLAUS  B=NEW MELONES C=FLOW-EVAP E=1DAY F=2020D09E-1
ZR QD200 A=STANISLAUS  B=GOODWIN  C=FLOW-DIV E=1DAY F=2020D09E-1
ZR IN620 A=SAN JOAQUIN B=MUD_SALT SL  C=FLOW-IN E=1DAY F=2020D09E-1
ZR IN605 A=SAN JOAQUIN B=MUD_SALT SL  C=FLOW-IN E=1DAY F=2020D09E-1
ZR IN580 A=MERCED  B=LAKE MCCLURE C=FLOW-IN_FIT  E=1DAY  F=2020D09E-1
ZR IN460 A=TUOLUMNE  B=DON PEDRO  C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR IN320 A=STANISLAUS B=Collierville C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR IN310 A=STANISLAUS B=StanislausPH C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR IN330 A=STANISLAUS B=Middle__Fork C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR IN240 A=STANISLAUS B=South___Fork C=FLOW-IN_FIT E=1DAY F=2020D09E-1
ZR IN220 A=STANISLAUS  B=TULLOCH  C=FLOW-IN E=1DAY F=2020D09E-1
ZR IN535 A=MERCED  B=DRY CR-CRESSEY C=FLOW-IN E=1DAY F=2020D09E-1
```

Figure D-8. Example "ZR.rec.use" file excerpt.



```
1    Paths with zero flow will not be saved to DSS
2
3    GET   C418  D418  C700  C700A  D419  D801  C800  C803  C702 C801
4     1  TXFR.DSS >>>>    A=CALSIM  B=C418       C=FLOW-CHANNEL    E=1MON  F=2020D09E       3750 CFS
45   GET   D11_PURCH  D13_CVP2  D13_SWP2  E11  E12  E13  D11
46   ########################## Bpart not found >> D11_PURCH
47    35  TXFR.DSS >>>>    A=CALSIM  B=D13_CVP2    C=FLOW-DELIVERY    E=1MON  F=2020D09E        0 CFS
48    36  TXFR.DSS >>>>    A=CALSIM  B=D13_SWP2    C=FLOW-DELIVERY    E=1MON  F=2020D09E        0 CFS
49    37  TXFR.DSS >>>>    A=CALSIM  B=E11         C=EVAPORATION      E=1MON  F=2020D09E       45 CFS
50    38  TXFR.DSS >>>>    A=CALSIM  B=E12         C=EVAPORATION      E=1MON  F=2020D09E       48 CFS
51    39  TXFR.DSS >>>>    A=CALSIM  B=E13         C=EVAPORATION      E=1MON  F=2020D09E        0 CFS
52    40  TXFR.DSS >>>>    A=CALSIM  B=D11         C=FLOW-DELIVERY    E=1MON  F=2020D09E      188 CFS
81   GET    I607  C607BC    R607WEST  C708   C608  C608BC
82    62  ESV.DSS  >>>>    A=CALSIM  B=I607       C=FLOW-INFLOW     E=1MON  F=2020D09E       12 TAF
83    63  CONV.DSS >>>>    A=CALSIM  B=C607BC     C=FLOW-CHANNEL    E=1MON  F=2020D09E       873 CFS
84    64  CONV.DSS >>>>    A=CALSIM  B=R607WEST   C=FLOW-RETURN     E=1MON  F=2020D09E        29 CFS
85   ########################## Duplicate Bpart = C708
86    65  CONV.DSS >>>>    A=CALSIM  B=C608       C=FLOW-CHANNEL    E=1MON  F=2020D09E       195 CFS
87    66  CONV.DSS >>>>    A=CALSIM  B=C608BC     C=FLOW-CHANNEL    E=1MON  F=2020D09E       256 CFS
88
352      1 Warning..B Part not found>>> MISSING
353      2 Warning..B Part not found>>> BPART
354  ZR QQ720  A=SAN JOAQUIN   B=DMC        C=FLOW-IN   27   0   0   0   0   0   0   0   0   0   0  0 +C708  +MISSING  +BPART
355  ZR QQ720  A=SAN JOAQUIN   B=DMC        C=FLOW-IN   E=1DAY F=2020D09E-1
356     TXFR.DSS >>>>   (+) A=CALSIM  B=C708       C=FLOW-CHANNEL    E=1MON  F=2020D09E      1107 CFS
357
```

Figure D-9. Partial “file-path names.txt”: report.

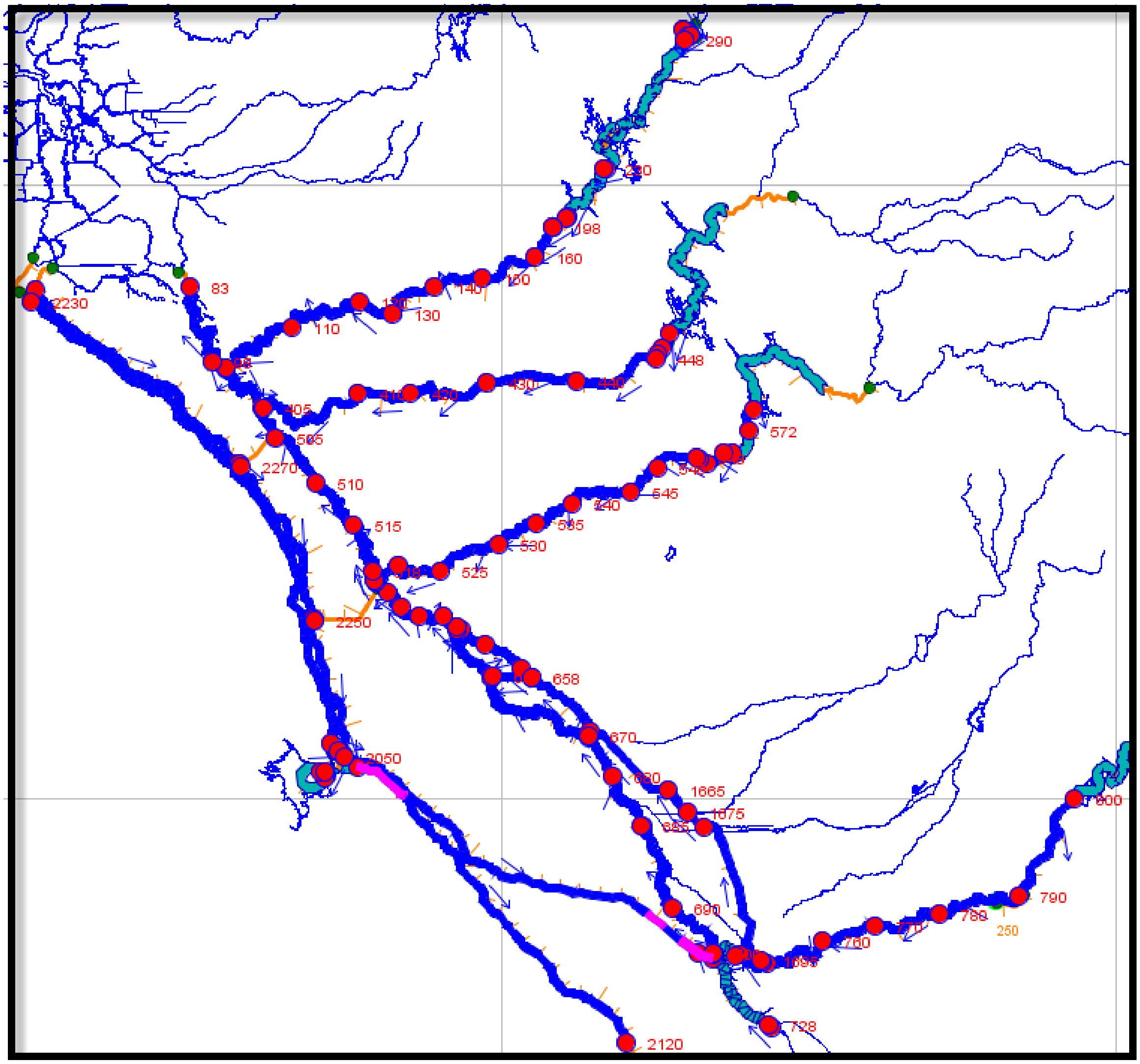


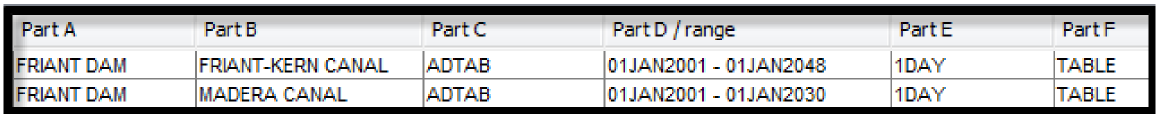
Figure D-10. San Joaquin Basin CALSIM II HEC-5Q model Schematic.

Appendix E. Computation of Dam Power Production

The San Joaquin River model includes the capability for computing the power production at the following power producing facilities:

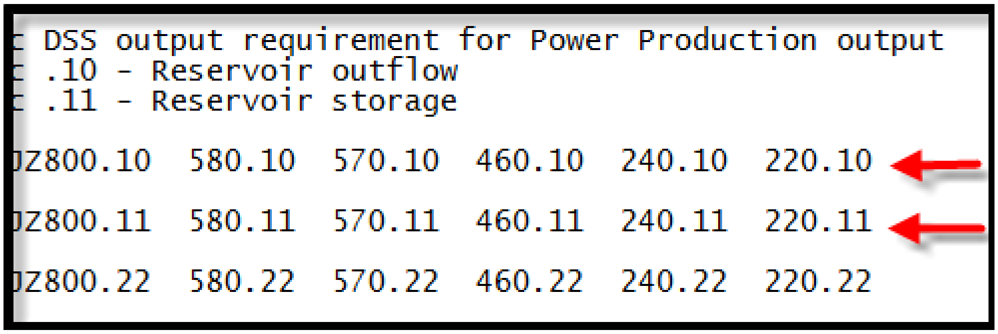
1. Friant-Kern Canal outlet (San Joaquin/Friant Dam),
2. Madera Canal outlet (San Joaquin/Friant Dam),
3. Friant Dam (San Joaquin River outlet),
4. Exchequer Dam (Merced/Lake McClure),
5. McSwain Dam (Merced),
6. Don Pedro Dam (Tuolumne),
7. New Melones (Stanislaus), and
8. Tulloch (Stanislaus).

The model computes the power production as a function of reservoir elevation and flow. The Friant-Kern and Madera Canal algorithms rely upon tabular data. These data seen below must reside in the HEC-5/5Q input DSS file. Note that the D part range is an indication of values and has nothing to do with dates.



Part A	Part B	Part C	Part D / range	Part E	Part F
FRIANT DAM	FRIANT-KERN CANAL	ADTAB	01JAN2001 - 01JAN2048	1DAY	TABLE
FRIANT DAM	MADERA CANAL	ADTAB	01JAN2001 - 01JAN2030	1DAY	TABLE

Reservoir elevations and flow components are stored in DSS and the power is computed at the end of the simulation. Therefore, the appropriate DSS outputs must be specified in the HEC5 data sets using the “JZ” record. The following HEC5 data segment shows a typical input. The “JZ” data are composite numbers that include the control point before the decimal and an output code following the decimal. As example, “460.10” and “460.11” specify Don Pedro (CP 460) reservoir outflow and storage, respectively.

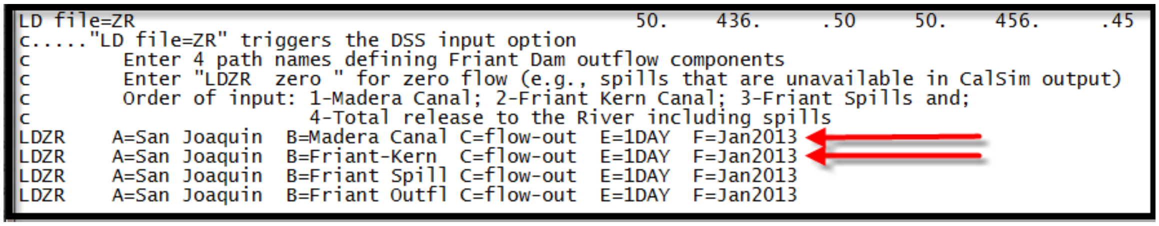


```
C DSS output requirement for Power Production output
C .10 - Reservoir outflow
C .11 - Reservoir storage

JZ800.10  580.10  570.10  460.10  240.10  220.10

JZ800.11  580.11  570.11  460.11  240.11  220.11

JZ800.22  580.22  570.22  460.22  240.22  220.22
```

The model code assumes an A and B part for the DSS pathname. The A part must be "HEC-5" which is defined in the input data by the "ZW" record (e.g., ZW, A=HEC-5, F=Friant-Delta). This A part naming convention cannot be changed if power output is desired. The F part is redefined by input (e.g., F=Friant-Delta) and the B part is the control point ID (e.g., IDT460-Don Pedro). The C part is an HEC-5 standard. As an example, the complete path name for Don Pedro Dam storage and outflow would be:

```
A=HEC-5 B=T460-DON PEDRO C=STOR-RES EOP E=1DAY F=FRIANT-DELTA
A=HEC-5 B=T460-DON PEDRO C=FLOW-RES OUT E=1DAY F=FRIANT-DELTA
```

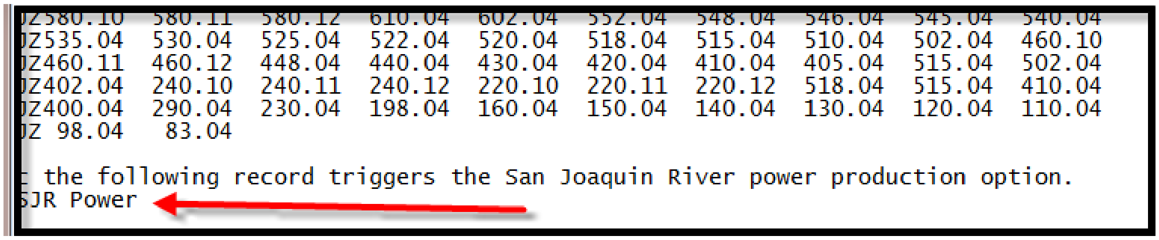
In addition to the HEC-5 output, the Friant Dam outflow components must be defined. The path names are provided in the HEC-5Q data by the LDZR Records that are required input for the Friant Dam model. The following is a typical example of this input.



```
LD file=ZR                                               50.    436.     .50     50.    456.     .45
c....."LD file=ZR" triggers the DSS input option
c        Enter 4 path names defining Friant Dam outflow components
c        Enter "LDZR  zero " for zero flow (e.g., spills that are unavailable in CalSim output)
c        Order of input: 1-Madera Canal; 2-Friant Kern Canal; 3-Friant Spills and;
c                        4-Total release to the River including spills
LDZR     A=San Joaquin  B=Madera Canal C=flow-out  E=1DAY  F=Jan2013
LDZR     A=San Joaquin  B=Friant-Kern  C=flow-out  E=1DAY  F=Jan2013
LDZR     A=San Joaquin  B=Friant Spill C=flow-out  E=1DAY  F=Jan2013
LDZR     A=San Joaquin  B=Friant Outfl C=flow-out  E=1DAY  F=Jan2013
```

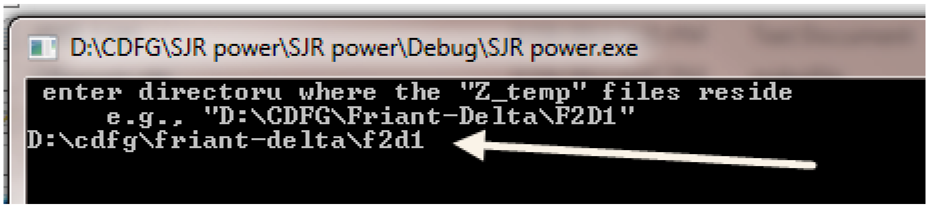
The appropriate DSS file and path names are extracted from the HEC-5 and HEC-5Q input files. Since these data may be modified by the *.run file, the modified data files are used. These files reside in the run directory and take the name of "Z_temp.5" and "Z_temp.5q" respectively.

The San Joaquin River power production option is triggered by placing "SJR Power" in the HEC-5 data set following the "JZ" Records, see below.



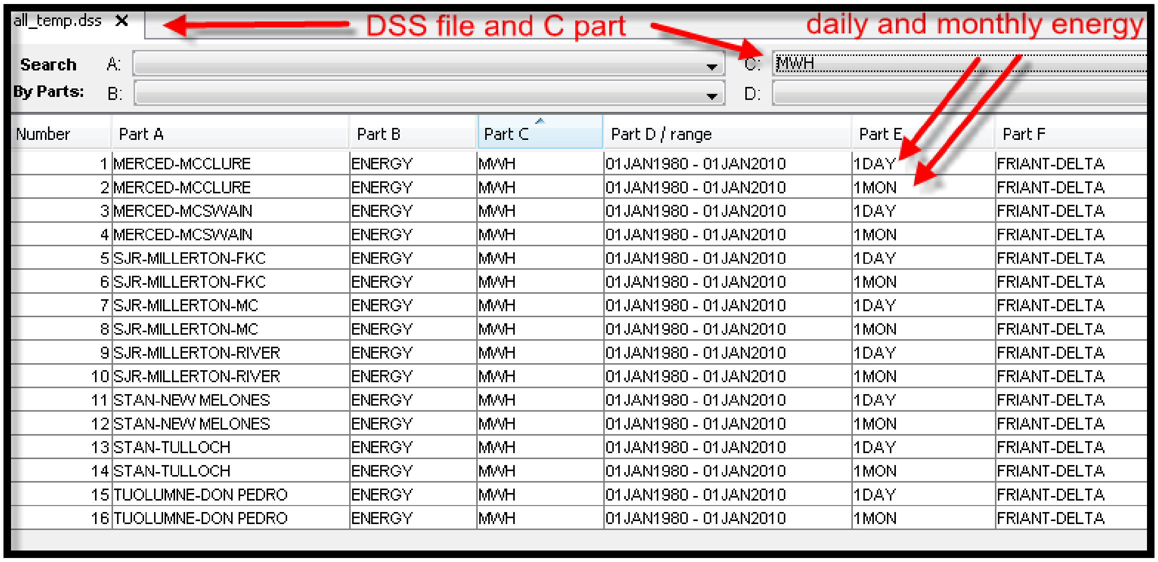
```
JZ580.10  580.11  580.12  610.04  602.04  552.04  548.04  546.04  545.04  540.04
JZ535.04  530.04  525.04  522.04  520.04  518.04  515.04  510.04  502.04  460.10
JZ460.11  460.12  448.04  440.04  430.04  420.04  410.04  405.04  515.04  502.04
JZ402.04  240.10  240.11  240.12  220.10  220.11  220.12  518.04  515.04  410.04
JZ400.04  290.04  230.04  198.04  160.04  150.04  140.04  130.04  120.04  110.04
JZ 98.04   83.04

c the following record triggers the San Joaquin River power production option.
SJR Power
```

Since the power production is computed at the end of the simulation, it is possible to make these computations externally. The stand-alone program named "SJR_power.exe" will access the HEC-5/5Q input and output files references above and compute the power production following successful completion of a simulation. The only input to this program is the directory name.



```
 enter directoru where the "Z_temp" files reside
     e.g., "D:\CDFG\Friant-Delta\F2D1"
D:\cdfg\friant-delta\f2d1
```

The program can reside anywhere and the output will reside in the DSS file identified in the “Z_temp.5” file. The DSS path names are shown below.



C: MWH

Number	Part A	Part B	Part C	Part D / range	Part E	Part F
1	MERCED-MCCLURE	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
2	MERCED-MCCLURE	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
3	MERCED-MCSWAIN	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
4	MERCED-MCSWAIN	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
5	SJR-MILLERTON-FKC	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
6	SJR-MILLERTON-FKC	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
7	SJR-MILLERTON-MC	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
8	SJR-MILLERTON-MC	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
9	SJR-MILLERTON-RIVER	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
10	SJR-MILLERTON-RIVER	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
11	STAN-NEW MELONES	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
12	STAN-NEW MELONES	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
13	STAN-TULLOCH	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
14	STAN-TULLOCH	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA
15	TUOLUMNE-DON PEDRO	ENERGY	MWH	01JAN1980 - 01JAN2010	1DAY	FRIANT-DELTA
16	TUOLUMNE-DON PEDRO	ENERGY	MWH	01JAN1980 - 01JAN2010	1MON	FRIANT-DELTA

Appendix F. Statistical Analysis Utility Program

F.1. Background

The statistical analysis utility provides a mechanism to assess HEC-5Q model accuracy as well as comparing results for two model conditions or time periods. This software utilizes various files that reside in the run directory that is created when utilizing the GUI. The Run directory will always contain a binary file (*.swm) that transfers simulation results to the GUI (contains all simulated values), a text file "SWMSbug.txt" that augments the *.swm file and "Z_temp.5" and "Z_temp.5A" files that contains the HEC5/5Q input data. The utility program access these file in the following manner.

1. The first line of the "SWMSbug.txt" file names the *.swm file. The program reads the file name and opens the binary file to access the computed values.
2. The "Z_temp.5" contains the name of the input DSS file where the observed data reside. The DSS file is opened to access these data
3. The "Z_temp.5Q" contains the observed data path names that are available for viewing with the GUI. The utility program processes only those observed data that are defined by the "CR" records.

Figure F-1shows the file structure and pertinent lines of the three files. The utility program has three modes of operation that are controlled by user prepared control files. The control file must reside in the same directory as the "Statistics.exe" file.

F.2. Option 1 - Computed versus observed statistics

Option 1 compares computed and observed temperatures, EC and flow for those locations and path names in the "Z_temp.5Q" file. A typical control file is shown in Figure F-2. All lines beginning with a "c." are comments. File line 7 identifies the option (all active inputs are in **Bold** type. Line 10 defines an existing directory where the output table will reside and line 13 defines the run directory where the model results reside. Line 18 defines the date limits for analysis. Lines 22-26 define date brackets for user specified date ranges and "END" (line 27) signals the end of the input file. If date limits are omitted, quarterly statistics will be computed as a default. If neither quarterly nor user specified statistics are desired, enter "NONE" in place of the date limits (the "END" is still required).

Two output files are generated. Each computed and corresponding observed value is listed in the file with the "CvsO" file extension. The complete file name is program generated as the source directory with the"\" replaced with "_". The second output file has the statistics (file extension of "table"). Note that the analysis limits (line 19) do not appear in the file name so the user must modify the name if various time periods are used. The statistical output table will include the following (referenced to Excel column):

A. Month / time period / year

B. Number of observations
C. Average computed value
D. Average observed value
E. Bias (computed value – observed value)
F. Root mean squared difference between the computed and observed
G. Mean absolute value of the computed versus observed value

The statistical output will always include monthly and yearly statistics. If time brackets are not specified, by default, quarterly statistics will be provided. In either case, the "END" is required. A typical text output is shown in Figure F-3. Data fields are semicolon delimited to facilitate import to Excel. The Excel equivalent is also included in Figure F-3.

F.3. Option 2 - Computed Versus Computed Statistics

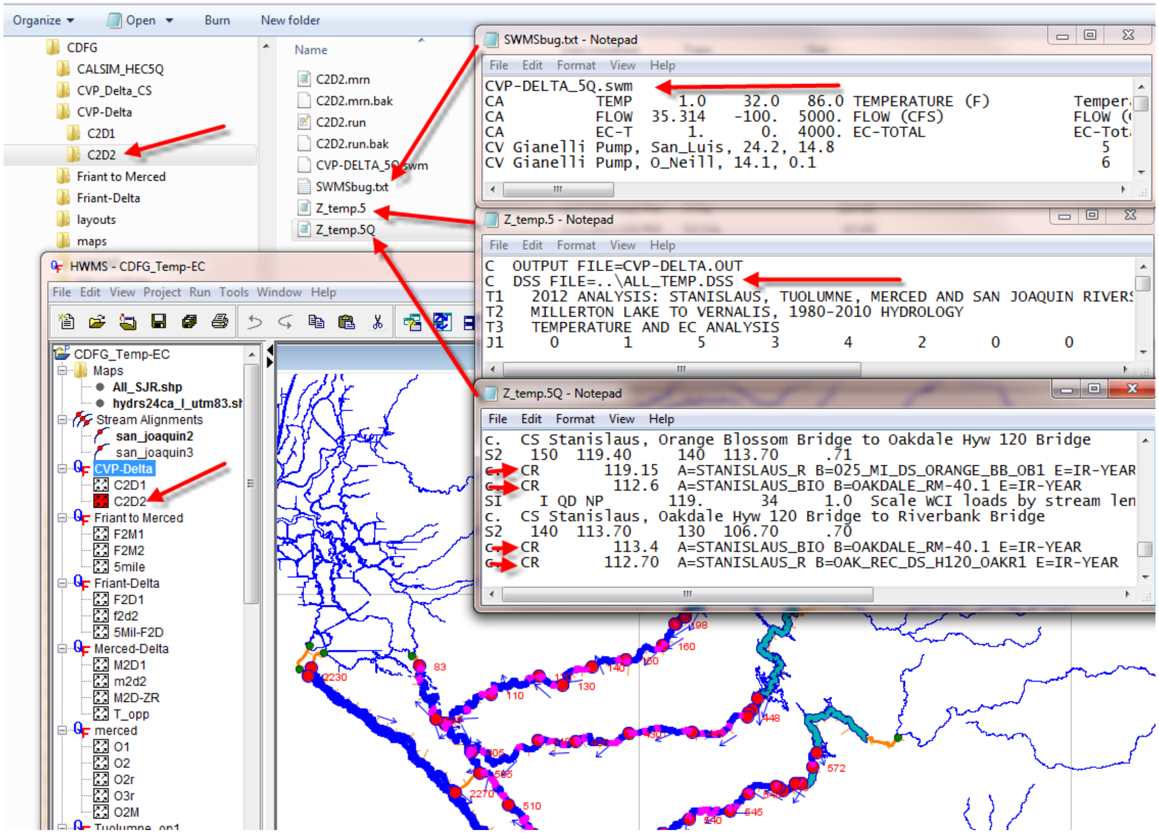
The second option compares two sets of results and lists the difference in the average and daily maximums. A typical control file for this option is shown in Figure F-4. File line 7 identifies the option and line 9 defines an existing directory where the output table will reside. Lines 11 and 12 define the two run directories where the two sets of model results reside. Line 15 defines the date limits for the comparison. Lines 18 -22 define the comparison locations. The location data include the upstream control point number and river mile and the table heading. Since the comparison does not rely upon observed data, the table will include all GUI output parameters that are specified by the "CA" records in the HEC-5Q input data set. Lines 25 - 29 define date brackets for user specified date ranges (optional) and line 31 signals the end of the input file.

The output file (Figure F-5) compares the daily average and average daily maximums for both sets of simulations results for each location, parameter and period. The name of the program generated output file is a composite name that includes the two source run directories. An example file name is "CD_CS1.vs.CS_O3r.table.txt" where "CD_CS1" and "CS_O3r" are the two run directories. The analysis limits (line 15) do not appear in the file name so the user must modify the name if various time periods are used.

F.4. Option 3 – Compare Computed Versus Observed Statistics (Option 1 Output)

The third option compares two sets of computed versus observed statistics and lists the difference between each metric. Figure F-6 shows a typical control file for this option. File line 6 identifies the option and line 8 defines the directory where the output tables generated under Option 1 reside. Lines 14 and 16 define the names of the two statistics tables.

The output file contains a side by side comparison of the statistics generated under Option 1. The name of the program generated output file is the two tables (including the directory path) joined by ".versus." An example of this comparison is seen in Figure F-7. This option is designed to facilitate evaluation of impacts due to time frame or model difference.

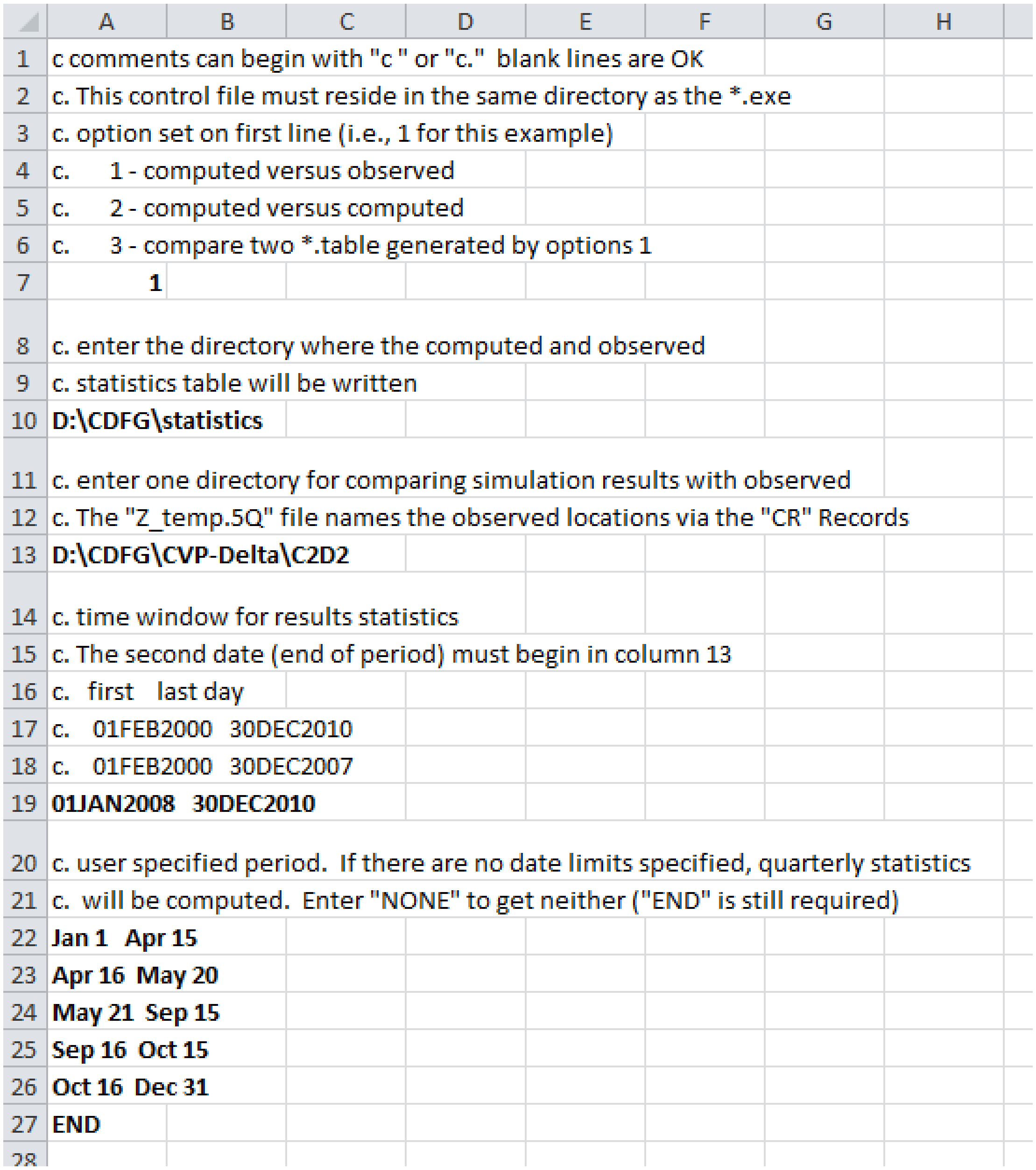


```
CVP-DELTA_5Q.swm
CA           TEMP     1.0     32.0    86.0 TEMPERATURE (F)         Temper
CA           FLOW  35.314    -100.   5000. FLOW (CFS)              FLOW (
CA           EC-T      1.       0.   4000. EC-TOTAL                EC-Tot
CV Gianelli Pump, San_Luis, 24.2, 14.8                                5
CV Gianelli Pump, O_Neill, 14.1, 0.1                                  6
```

```
C   OUTPUT FILE=CVP-DELTA.OUT
C   DSS FILE=..\ALL_TEMP.DSS
T1    2012 ANALYSIS: STANISLAUS, TUOLUMNE, MERCED AND SAN JOAQUIN RIVERS
T2    MILLERTON LAKE TO VERNALIS, 1980-2010 HYDROLOGY
T3    TEMPERATURE AND EC ANALYSIS
J1      0       1       5       3       4       2       0       0
```

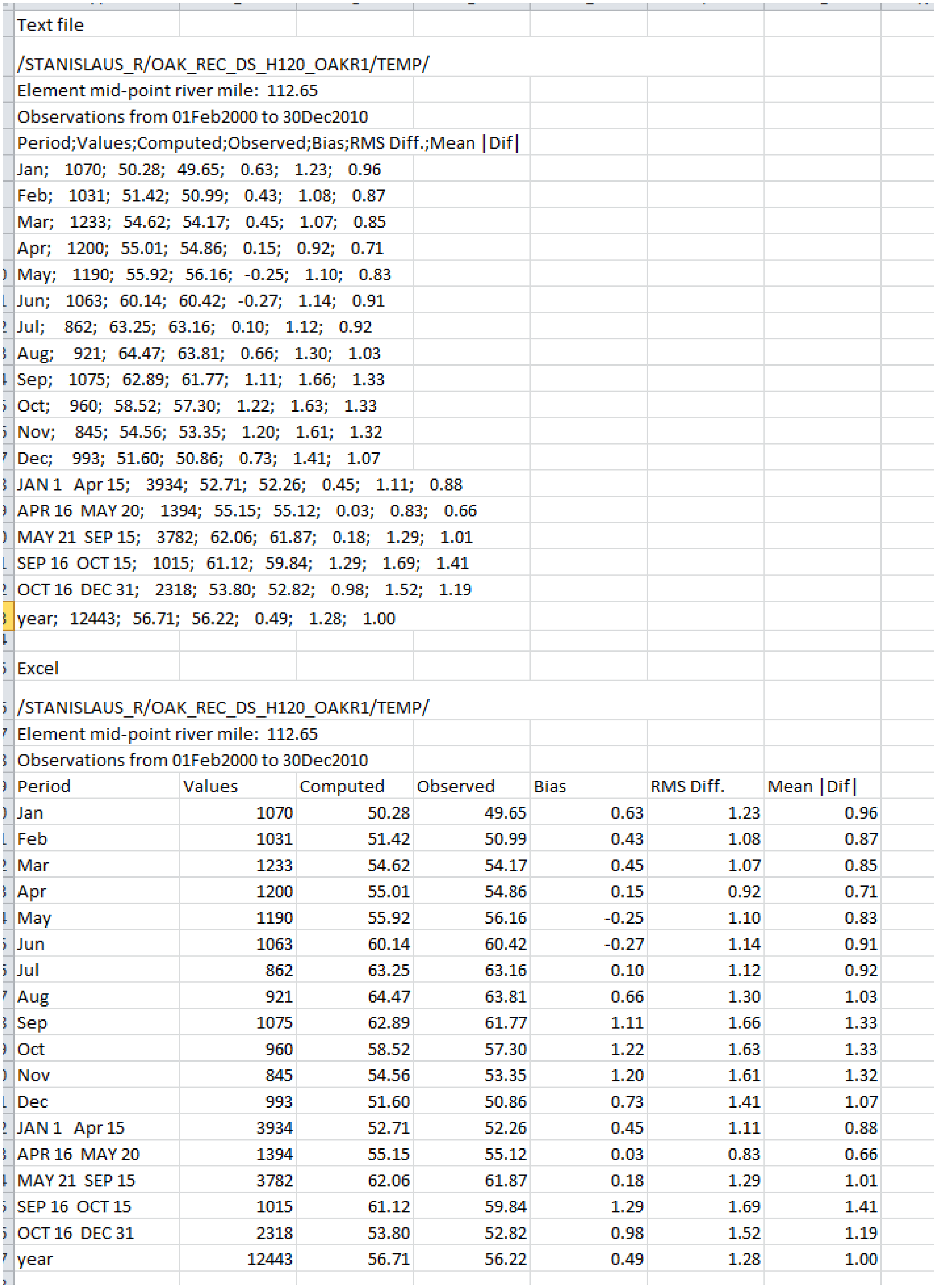
```
c.   CS Stanislaus, Orange Blossom Bridge to Oakdale Hyw 120 Bridge
S2    150  119.40     140  113.70      .71
c    CR        119.15   A=STANISLAUS_R B=025_MI_DS_ORANGE_BB_OB1 E=IR-YEAR
c    CR         112.6   A=STANISLAUS_BIO B=OAKDALE_RM-40.1 E=IR-YEAR
SI    I QD NP       119.      34      1.0  Scale WCI loads by stream len
c.   CS Stanislaus, Oakdale Hyw 120 Bridge to Riverbank Bridge
S2    140  113.70     130  106.70      .70
c    CR         113.4   A=STANISLAUS_BIO B=OAKDALE_RM-40.1 E=IR-YEAR
c    CR        112.70   A=STANISLAUS_R B=OAK_REC_DS_H120_OAKR1 E=IR-YEAR
```

Figure F-1. File structure and pertinent lines of the files accessed by the Statistical analysis utility program.



```
c comments can begin with "c " or "c."  blank lines are OK
c. This control file must reside in the same directory as the *.exe
c. option set on first line (i.e., 1 for this example)
c.      1 - computed versus observed
c.      2 - computed versus computed
c.      3 - compare two *.table generated by options 1
          1
c. enter the directory where the computed and observed
c. statistics table will be written
D:\CDFG\statistics
c. enter one directory for comparing simulation results with observed
c. The "Z_temp.5Q" file names the observed locations via the "CR" Records
D:\CDFG\CVP-Delta\C2D2
c. time window for results statistics
c. The second date (end of period) must begin in column 13
c.   first    last day
c.   01FEB2000   30DEC2010
c.   01FEB2000   30DEC2007
01JAN2008   30DEC2010
c. user specified period.  If there are no date limits specified, quarterly statistics
c.  will be computed.  Enter "NONE" to get neither ("END" is still required)
Jan 1   Apr 15
Apr 16  May 20
May 21  Sep 15
Sep 16  Oct 15
Oct 16  Dec 31
END
```

Figure F-2. Example control file for option 1 of the statistical analysis utility.



Text file

```
/STANISLAUS_R/OAK_REC_DS_H120_OAKR1/TEMP/
Element mid-point river mile:  112.65
Observations from 01Feb2000 to 30Dec2010
Period;Values;Computed;Observed;Bias;RMS Diff.;Mean |Dif|
Jan;   1070;  50.28;  49.65;   0.63;   1.23;   0.96
Feb;   1031;  51.42;  50.99;   0.43;   1.08;   0.87
Mar;   1233;  54.62;  54.17;   0.45;   1.07;   0.85
Apr;   1200;  55.01;  54.86;   0.15;   0.92;   0.71
May;   1190;  55.92;  56.16;  -0.25;   1.10;   0.83
Jun;   1063;  60.14;  60.42;  -0.27;   1.14;   0.91
Jul;    862;  63.25;  63.16;   0.10;   1.12;   0.92
Aug;    921;  64.47;  63.81;   0.66;   1.30;   1.03
Sep;   1075;  62.89;  61.77;   1.11;   1.66;   1.33
Oct;    960;  58.52;  57.30;   1.22;   1.63;   1.33
Nov;    845;  54.56;  53.35;   1.20;   1.61;   1.32
Dec;    993;  51.60;  50.86;   0.73;   1.41;   1.07
JAN 1  Apr 15;   3934;  52.71;  52.26;   0.45;   1.11;   0.88
APR 16  MAY 20;   1394;  55.15;  55.12;   0.03;   0.83;   0.66
MAY 21  SEP 15;   3782;  62.06;  61.87;   0.18;   1.29;   1.01
SEP 16  OCT 15;   1015;  61.12;  59.84;   1.29;   1.69;   1.41
OCT 16  DEC 31;   2318;  53.80;  52.82;   0.98;   1.52;   1.19
year;  12443;  56.71;  56.22;   0.49;   1.28;   1.00
```

Excel

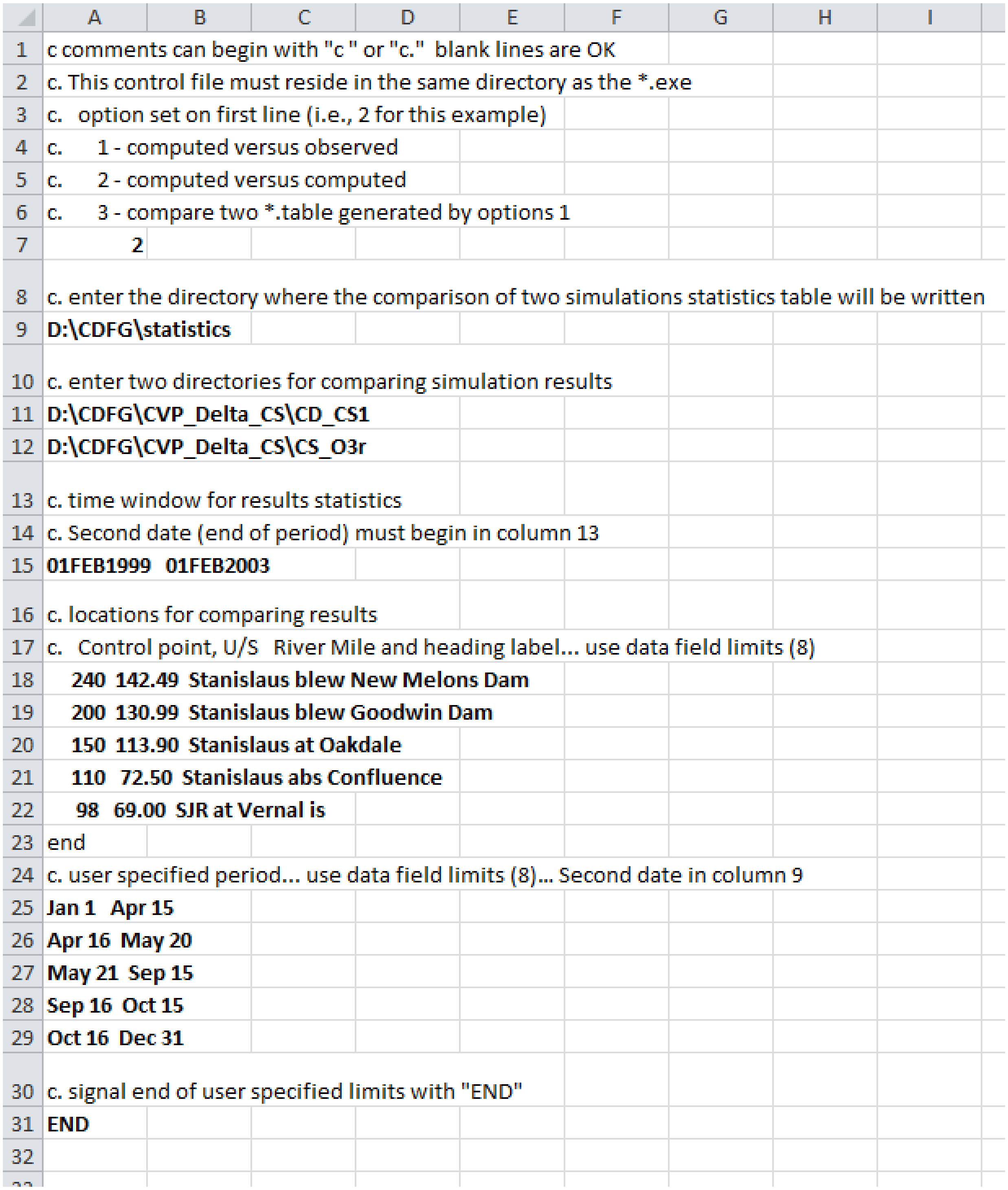
/STANISLAUS_R/OAK_REC_DS_H120_OAKR1/TEMP/

Element mid-point river mile: 112.65

Observations from 01Feb2000 to 30Dec2010

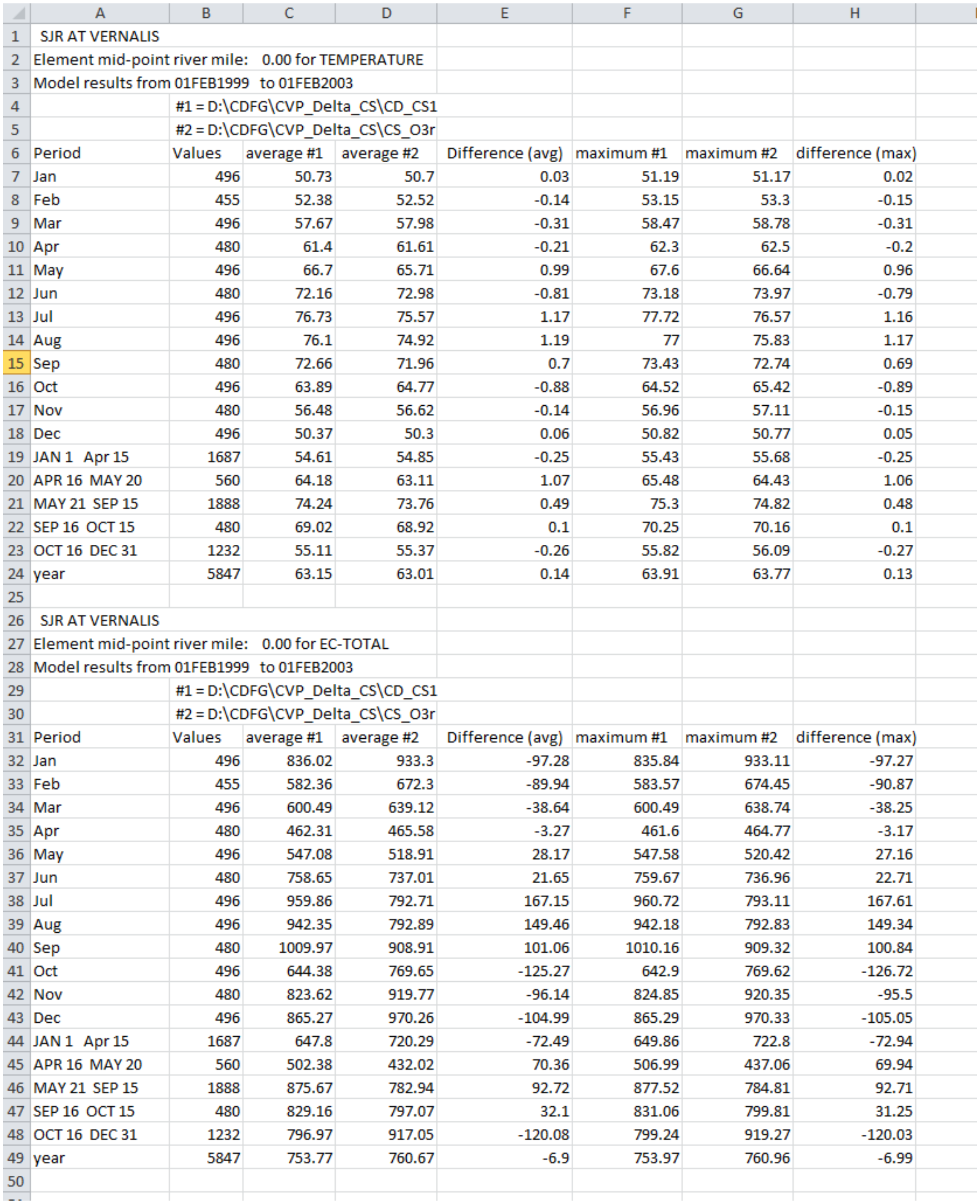
Period	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif|
Jan	1070	50.28	49.65	0.63	1.23	0.96
Feb	1031	51.42	50.99	0.43	1.08	0.87
Mar	1233	54.62	54.17	0.45	1.07	0.85
Apr	1200	55.01	54.86	0.15	0.92	0.71
May	1190	55.92	56.16	-0.25	1.10	0.83
Jun	1063	60.14	60.42	-0.27	1.14	0.91
Jul	862	63.25	63.16	0.10	1.12	0.92
Aug	921	64.47	63.81	0.66	1.30	1.03
Sep	1075	62.89	61.77	1.11	1.66	1.33
Oct	960	58.52	57.30	1.22	1.63	1.33
Nov	845	54.56	53.35	1.20	1.61	1.32
Dec	993	51.60	50.86	0.73	1.41	1.07
JAN 1 Apr 15	3934	52.71	52.26	0.45	1.11	0.88
APR 16 MAY 20	1394	55.15	55.12	0.03	0.83	0.66
MAY 21 SEP 15	3782	62.06	61.87	0.18	1.29	1.01
SEP 16 OCT 15	1015	61.12	59.84	1.29	1.69	1.41
OCT 16 DEC 31	2318	53.80	52.82	0.98	1.52	1.19
year	12443	56.71	56.22	0.49	1.28	1.00

Figure F-3. Typical option 1 statistical output, text and Excel.



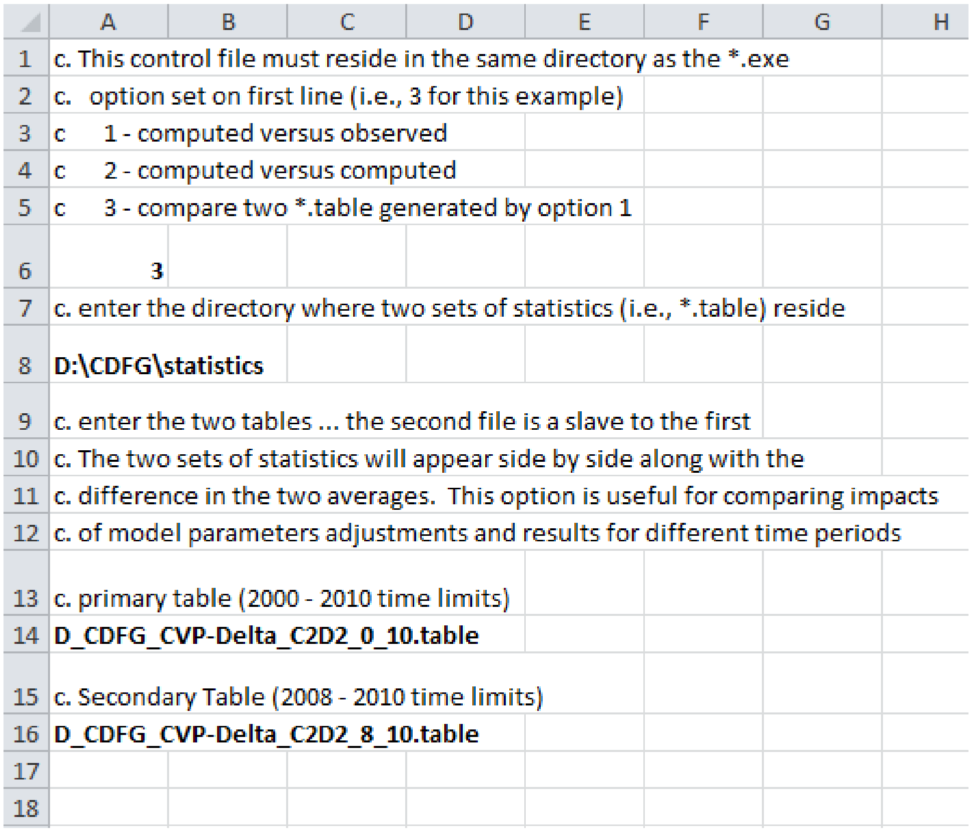
```
c comments can begin with "c " or "c."  blank lines are OK
c. This control file must reside in the same directory as the *.exe
c.  option set on first line (i.e., 2 for this example)
c.      1 - computed versus observed
c.      2 - computed versus computed
c.      3 - compare two *.table generated by options 1
           2
c. enter the directory where the comparison of two simulations statistics table will be written
D:\CDFG\statistics
c. enter two directories for comparing simulation results
D:\CDFG\CVP_Delta_CS\CD_CS1
D:\CDFG\CVP_Delta_CS\CS_O3r
c. time window for results statistics
c. Second date (end of period) must begin in column 13
01FEB1999  01FEB2003
c. locations for comparing results
c.  Control point, U/S  River Mile and heading label... use data field limits (8)
   240  142.49  Stanislaus blew New Melons Dam
   200  130.99  Stanislaus blew Goodwin Dam
   150  113.90  Stanislaus at Oakdale
   110   72.50  Stanislaus abs Confluence
    98   69.00  SJR at Vernal is
end
c. user specified period... use data field limits (8)... Second date in column 9
Jan 1   Apr 15
Apr 16  May 20
May 21  Sep 15
Sep 16  Oct 15
Oct 16  Dec 31
c. signal end of user specified limits with "END"
END
```

Figure F-4. Example control file for option 2 of the statistical analysis utility.



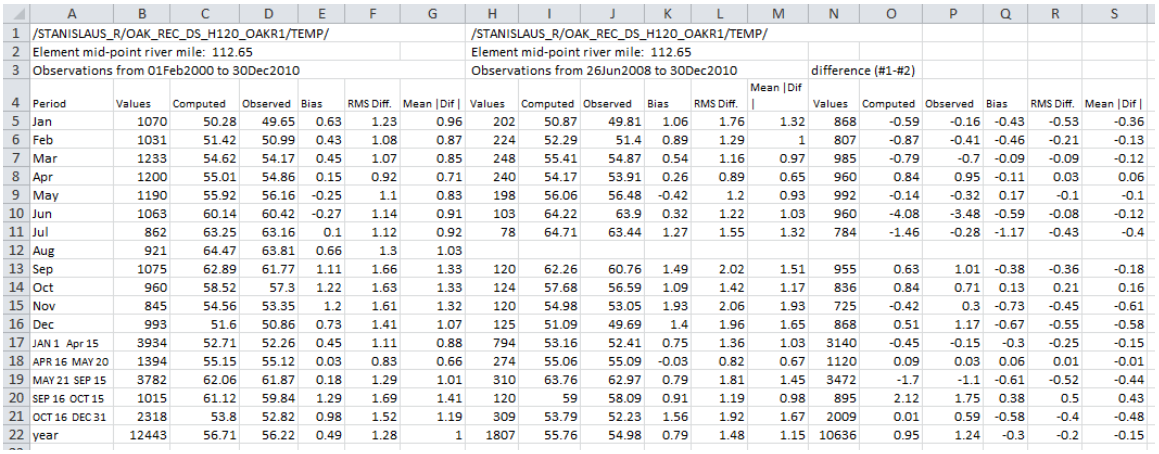
	A	B	C	D	E	F	G	H
1	SJR AT VERNALIS							
2	Element mid-point river mile: 0.00 for TEMPERATURE							
3	Model results from 01FEB1999 to 01FEB2003							
4		#1 = D:\CDFG\CVP_Delta_CS\CD_CS1						
5		#2 = D:\CDFG\CVP_Delta_CS\CS_O3r						
6	Period	Values	average #1	average #2	Difference (avg)	maximum #1	maximum #2	difference (max)
7	Jan	496	50.73	50.7	0.03	51.19	51.17	0.02
8	Feb	455	52.38	52.52	-0.14	53.15	53.3	-0.15
9	Mar	496	57.67	57.98	-0.31	58.47	58.78	-0.31
10	Apr	480	61.4	61.61	-0.21	62.3	62.5	-0.2
11	May	496	66.7	65.71	0.99	67.6	66.64	0.96
12	Jun	480	72.16	72.98	-0.81	73.18	73.97	-0.79
13	Jul	496	76.73	75.57	1.17	77.72	76.57	1.16
14	Aug	496	76.1	74.92	1.19	77	75.83	1.17
15	Sep	480	72.66	71.96	0.7	73.43	72.74	0.69
16	Oct	496	63.89	64.77	-0.88	64.52	65.42	-0.89
17	Nov	480	56.48	56.62	-0.14	56.96	57.11	-0.15
18	Dec	496	50.37	50.3	0.06	50.82	50.77	0.05
19	JAN 1 Apr 15	1687	54.61	54.85	-0.25	55.43	55.68	-0.25
20	APR 16 MAY 20	560	64.18	63.11	1.07	65.48	64.43	1.06
21	MAY 21 SEP 15	1888	74.24	73.76	0.49	75.3	74.82	0.48
22	SEP 16 OCT 15	480	69.02	68.92	0.1	70.25	70.16	0.1
23	OCT 16 DEC 31	1232	55.11	55.37	-0.26	55.82	56.09	-0.27
24	year	5847	63.15	63.01	0.14	63.91	63.77	0.13
25								
26	SJR AT VERNALIS							
27	Element mid-point river mile: 0.00 for EC-TOTAL							
28	Model results from 01FEB1999 to 01FEB2003							
29		#1 = D:\CDFG\CVP_Delta_CS\CD_CS1						
30		#2 = D:\CDFG\CVP_Delta_CS\CS_O3r						
31	Period	Values	average #1	average #2	Difference (avg)	maximum #1	maximum #2	difference (max)
32	Jan	496	836.02	933.3	-97.28	835.84	933.11	-97.27
33	Feb	455	582.36	672.3	-89.94	583.57	674.45	-90.87
34	Mar	496	600.49	639.12	-38.64	600.49	638.74	-38.25
35	Apr	480	462.31	465.58	-3.27	461.6	464.77	-3.17
36	May	496	547.08	518.91	28.17	547.58	520.42	27.16
37	Jun	480	758.65	737.01	21.65	759.67	736.96	22.71
38	Jul	496	959.86	792.71	167.15	960.72	793.11	167.61
39	Aug	496	942.35	792.89	149.46	942.18	792.83	149.34
40	Sep	480	1009.97	908.91	101.06	1010.16	909.32	100.84
41	Oct	496	644.38	769.65	-125.27	642.9	769.62	-126.72
42	Nov	480	823.62	919.77	-96.14	824.85	920.35	-95.5
43	Dec	496	865.27	970.26	-104.99	865.29	970.33	-105.05
44	JAN 1 Apr 15	1687	647.8	720.29	-72.49	649.86	722.8	-72.94
45	APR 16 MAY 20	560	502.38	432.02	70.36	506.99	437.06	69.94
46	MAY 21 SEP 15	1888	875.67	782.94	92.72	877.52	784.81	92.71
47	SEP 16 OCT 15	480	829.16	797.07	32.1	831.06	799.81	31.25
48	OCT 16 DEC 31	1232	796.97	917.05	-120.08	799.24	919.27	-120.03
49	year	5847	753.77	760.67	-6.9	753.97	760.96	-6.99
50								

Figure F-5. Example Option 2 comparison of simulated temperature and EC imported to Excel (flow comparison not shown).



	A	B	C	D	E	F	G	H
1	c. This control file must reside in the same directory as the *.exe							
2	c. option set on first line (i.e., 3 for this example)							
3	c 1 - computed versus observed							
4	c 2 - computed versus computed							
5	c 3 - compare two *.table generated by option 1							
6	**3**							
7	c. enter the directory where two sets of statistics (i.e., *.table) reside							
8	**D:\CDFG\statistics**							
9	c. enter the two tables ... the second file is a slave to the first							
10	c. The two sets of statistics will appear side by side along with the							
11	c. difference in the two averages. This option is useful for comparing impacts							
12	c. of model parameters adjustments and results for different time periods							
13	c. primary table (2000 - 2010 time limits)							
14	**D_CDFG_CVP-Delta_C2D2_0_10.table**							
15	c. Secondary Table (2008 - 2010 time limits)							
16	**D_CDFG_CVP-Delta_C2D2_8_10.table**							
17								
18								

Figure F-6. Example control file for option 3 of the statistical analysis utility.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	/STANISLAUS_R/OAK_REC_DS_H120_OAKR1/TEMP/							/STANISLAUS_R/OAK_REC_DS_H120_OAKR1/TEMP/											
2	Element mid-point river mile: 112.65							Element mid-point river mile: 112.65											
3	Observations from 01Feb2000 to 30Dec2010							Observations from 26Jun2008 to 30Dec2010						difference (#1-#2)					
4	Period	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif |	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif |	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif |
5	Jan	1070	50.28	49.65	0.63	1.23	0.96	202	50.87	49.81	1.06	1.76	1.32	868	-0.59	-0.16	-0.43	-0.53	-0.36
6	Feb	1031	51.42	50.99	0.43	1.08	0.87	224	52.29	51.4	0.89	1.29	1	807	-0.87	-0.41	-0.46	-0.21	-0.13
7	Mar	1233	54.62	54.17	0.45	1.07	0.85	248	55.41	54.87	0.54	1.16	0.97	985	-0.79	-0.7	-0.09	-0.09	-0.12
8	Apr	1200	55.01	54.86	0.15	0.92	0.71	240	54.17	53.91	0.26	0.89	0.65	960	0.84	0.95	-0.11	0.03	0.06
9	May	1190	55.92	56.16	-0.25	1.1	0.83	198	56.06	56.48	-0.42	1.2	0.93	992	-0.14	-0.32	0.17	-0.1	-0.1
10	Jun	1063	60.14	60.42	-0.27	1.14	0.91	103	64.22	63.9	0.32	1.22	1.03	960	-4.08	-3.48	-0.59	-0.08	-0.12
11	Jul	862	63.25	63.16	0.1	1.12	0.92	78	64.71	63.44	1.27	1.55	1.32	784	-1.46	-0.28	-1.17	-0.43	-0.4
12	Aug	921	64.47	63.81	0.66	1.3	1.03												
13	Sep	1075	62.89	61.77	1.11	1.66	1.33	120	62.26	60.76	1.49	2.02	1.51	955	0.63	1.01	-0.38	-0.36	-0.18
14	Oct	960	58.52	57.3	1.22	1.63	1.33	124	57.68	56.59	1.09	1.42	1.17	836	0.84	0.71	0.13	0.21	0.16
15	Nov	845	54.56	53.35	1.2	1.61	1.32	120	54.98	53.05	1.93	2.06	1.93	725	-0.42	0.3	-0.73	-0.45	-0.61
16	Dec	993	51.6	50.86	0.73	1.41	1.07	125	51.09	49.69	1.4	1.96	1.65	868	0.51	1.17	-0.67	-0.55	-0.58
17	JAN 1 Apr 15	3934	52.71	52.26	0.45	1.11	0.88	794	53.16	52.41	0.75	1.36	1.03	3140	-0.45	-0.15	-0.3	-0.25	-0.15
18	APR 16 MAY 20	1394	55.15	55.12	0.03	0.83	0.66	274	55.06	55.09	-0.03	0.82	0.67	1120	0.09	0.03	0.06	0.01	-0.01
19	MAY 21 SEP 15	3782	62.06	61.87	0.18	1.29	1.01	310	63.76	62.97	0.79	1.81	1.45	3472	-1.7	-1.1	-0.61	-0.52	-0.44
20	SEP 16 OCT 15	1015	61.12	59.84	1.29	1.69	1.41	120	59	58.09	0.91	1.19	0.98	895	2.12	1.75	0.38	0.5	0.43
21	OCT 16 DEC 31	2318	53.8	52.82	0.98	1.52	1.19	309	53.79	52.23	1.56	1.92	1.67	2009	0.01	0.59	-0.58	-0.4	-0.48
22	year	12443	56.71	56.22	0.49	1.28	1	1807	55.76	54.98	0.79	1.48	1.15	10636	0.95	1.24	-0.3	-0.2	-0.15

Figure F-7. Example of Option 3 comparison of simulated versus observed temperature statistics that are generated under Option 1.

Appendix G. Temperature Calibration Plots

This section contains temperature calibration plots that complement the statistics presented in Appendix F.

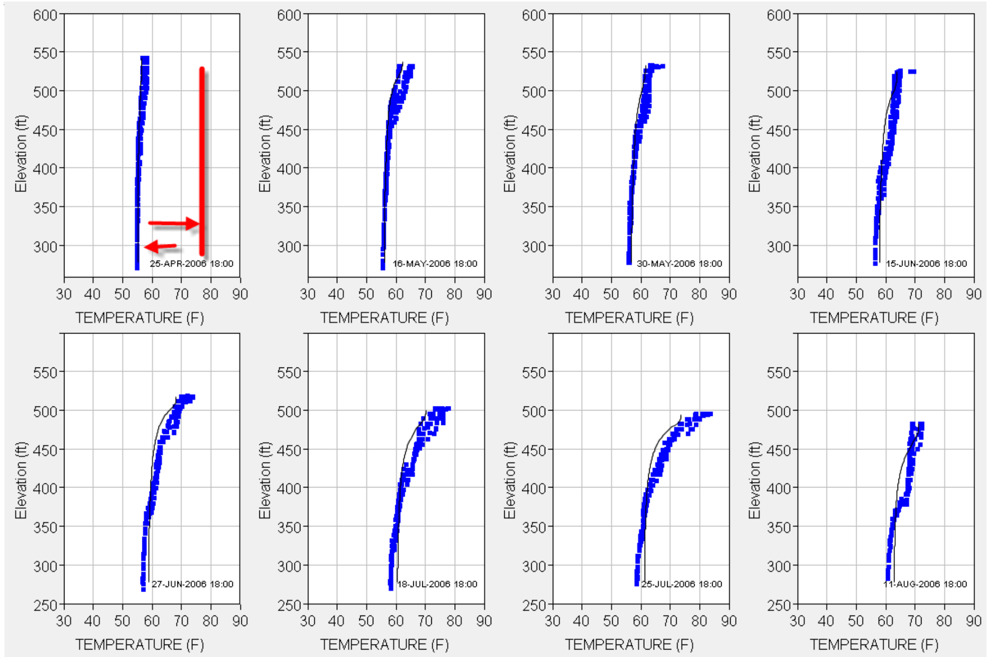


Figure G-1. SWP-CVP Facilities: San Luis Reservoir 2006. (The vertical red line indicates that the pump-back will seek a level of like density considering entrainment)

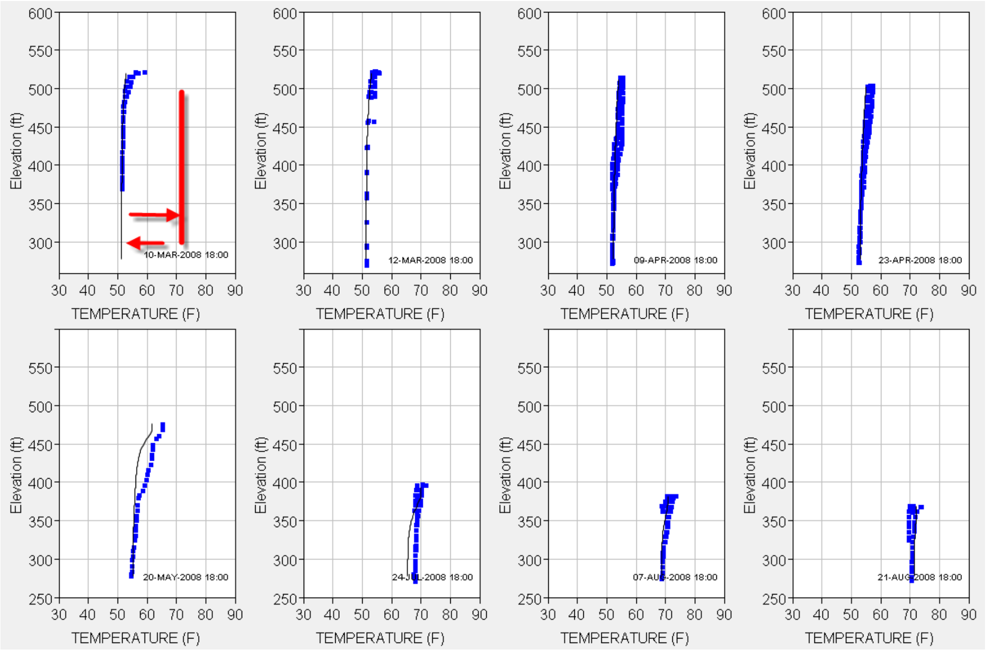


Figure G-2. SWP-CVP Facilities: San Luis Reservoir 2008.

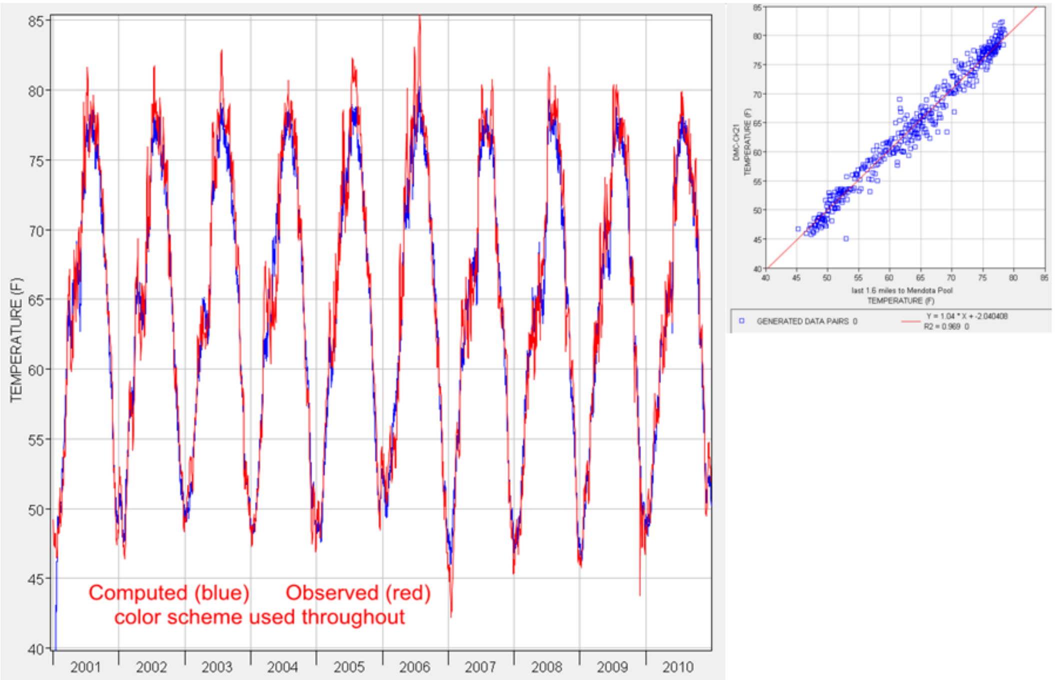


Figure G-3. SWP-CVP Facilities: DMC above the Mendota Pool (Check 21).

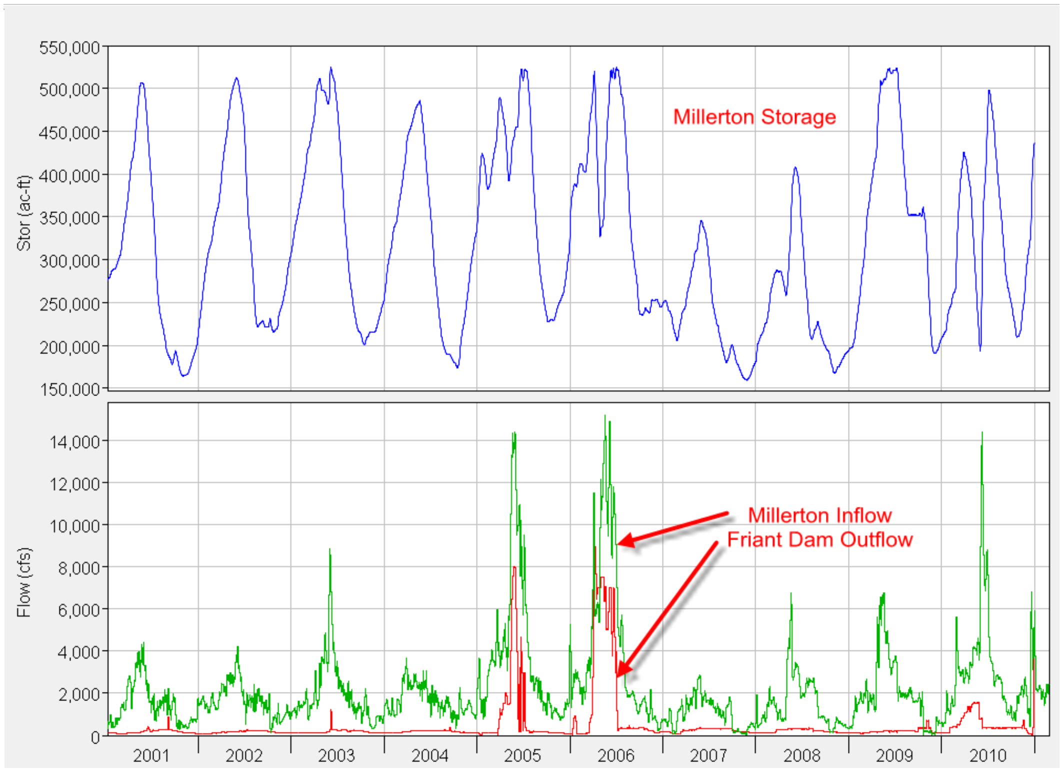


Figure G-4. Millerton inflow and Volume San Joaquin flow below Friant Dam.

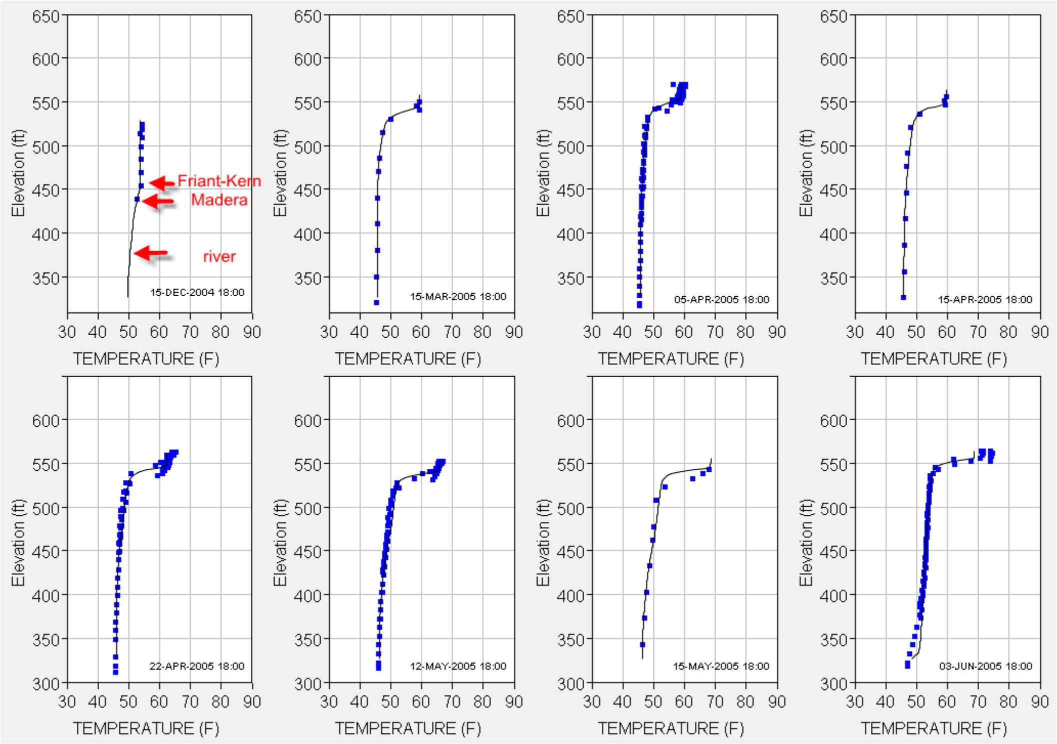


Figure G-5. Millerton Lake: 2005 - 2006 (1 of 4).

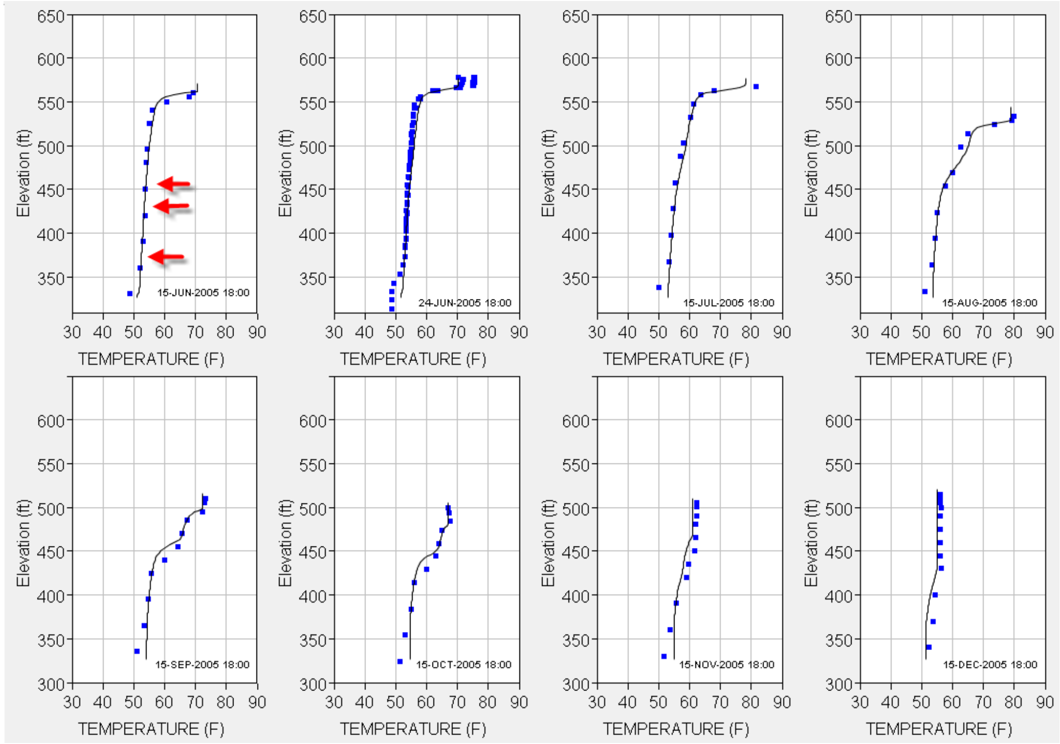


Figure G-6. Millerton Lake: 2005 - 2006 (2 of 4).

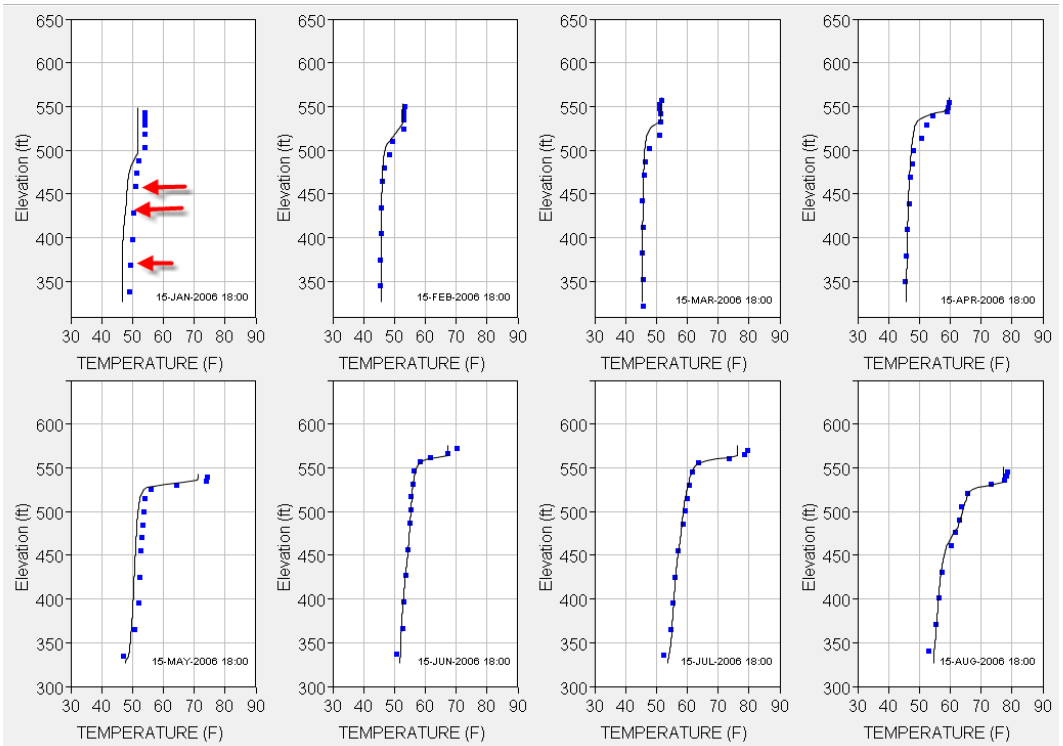


Figure G-7. Millerton Lake: 2005 - 2006 (3 of 4).

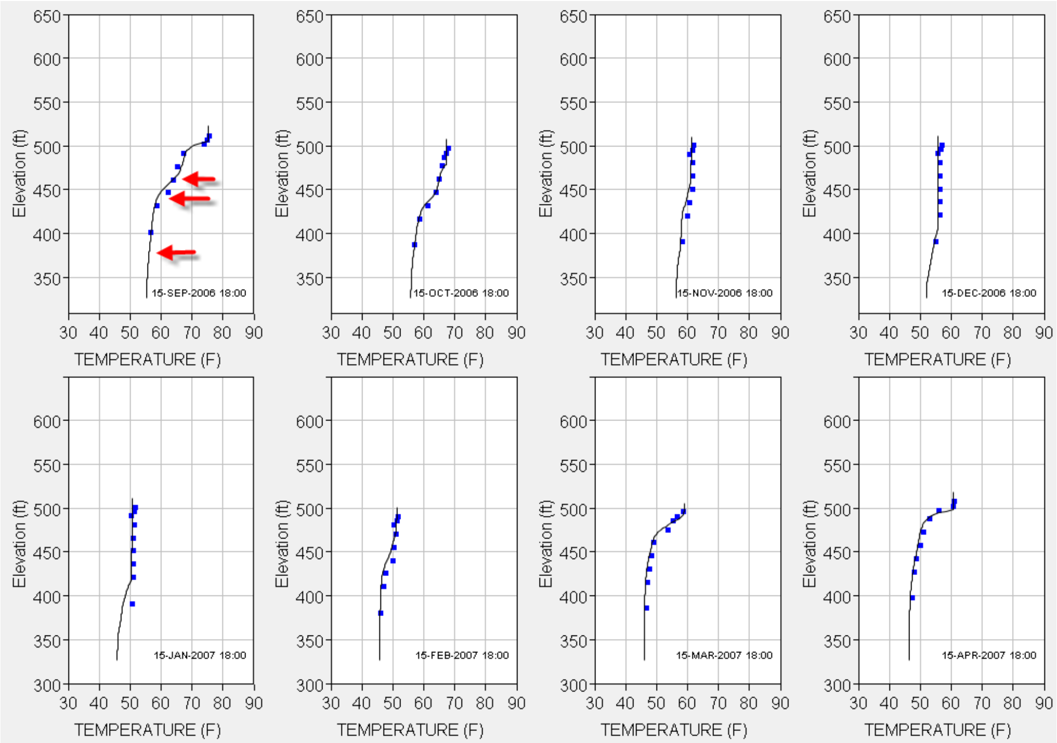


Figure G-8. Millerton Lake: 2005 - 2006 (4 of 4).

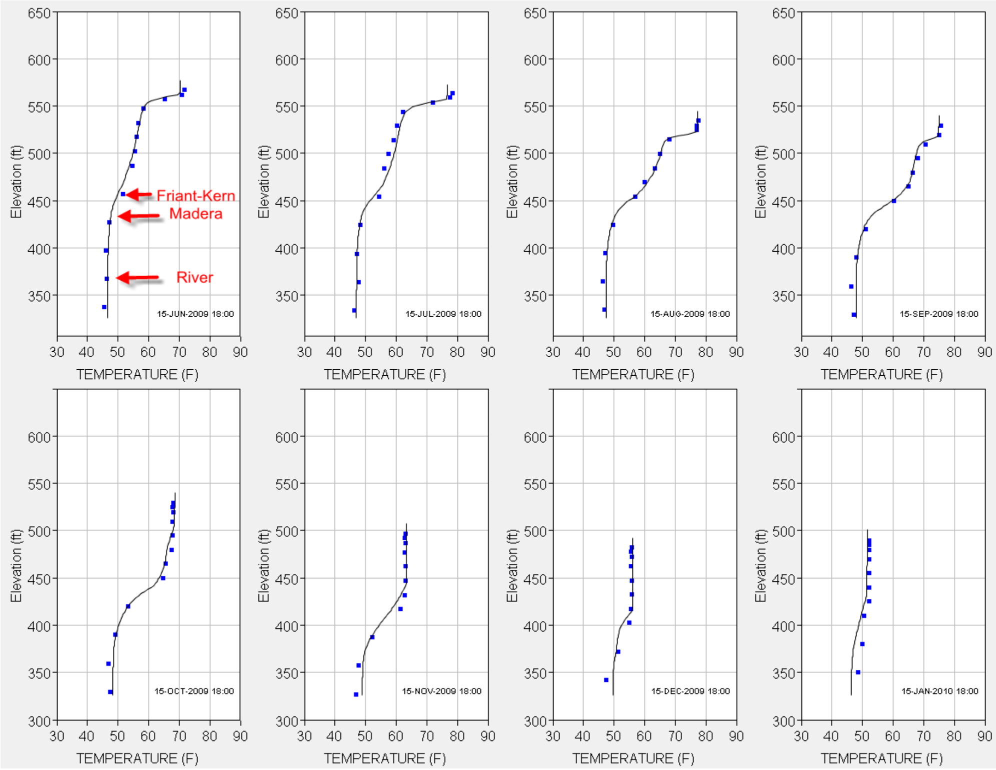


Figure G-9. Millerton Lake: 2009 – 2010 (1 of 2).

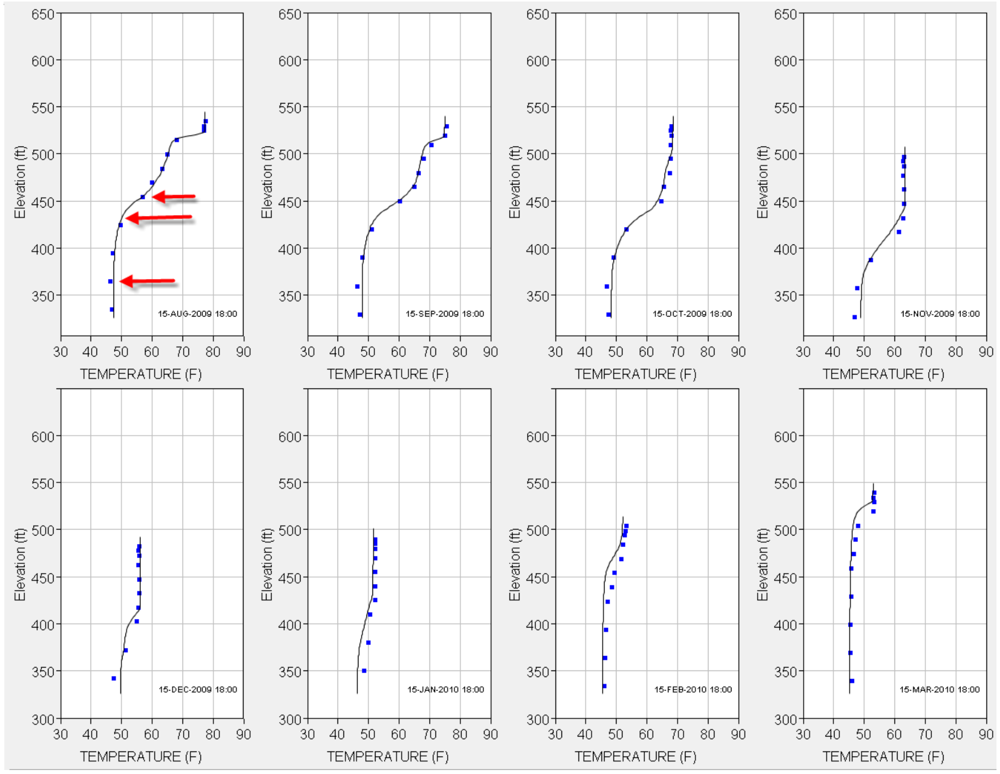


Figure G-10. Millerton Lake: 2009 – 2010 (2 of 2).

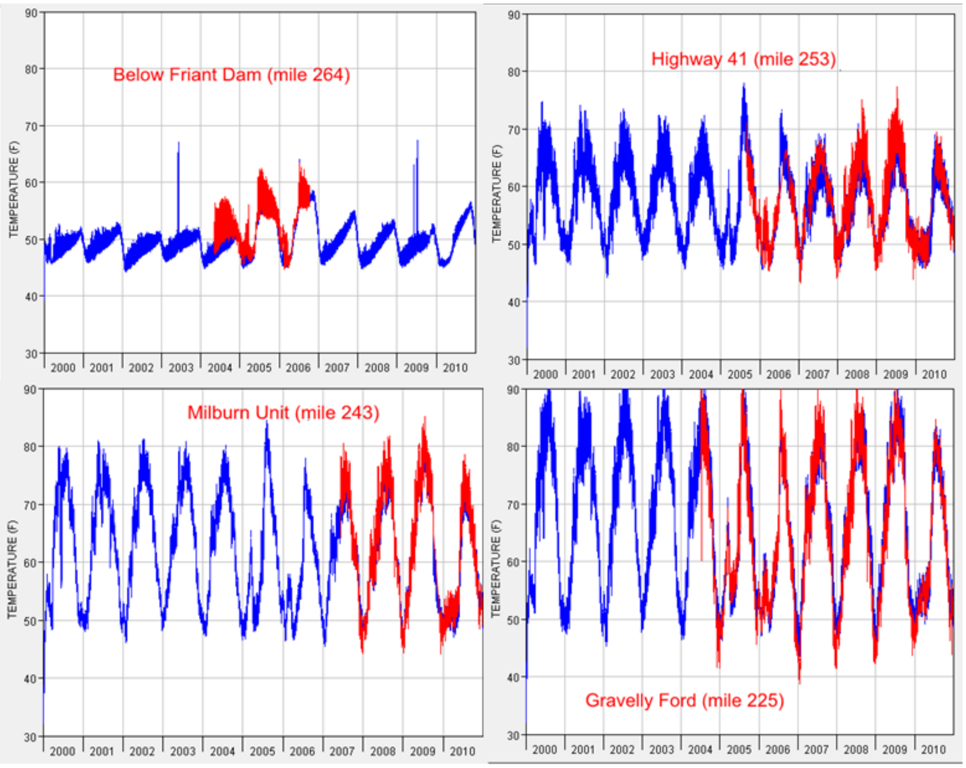


Figure G-11. San Joaquin River above Mendota– computed and observed temperature figures.

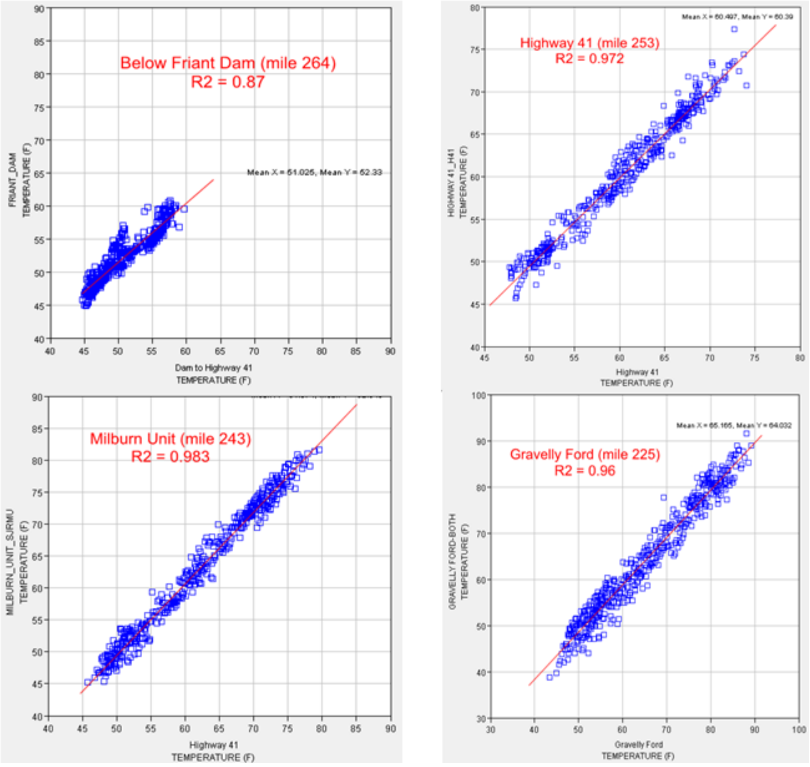
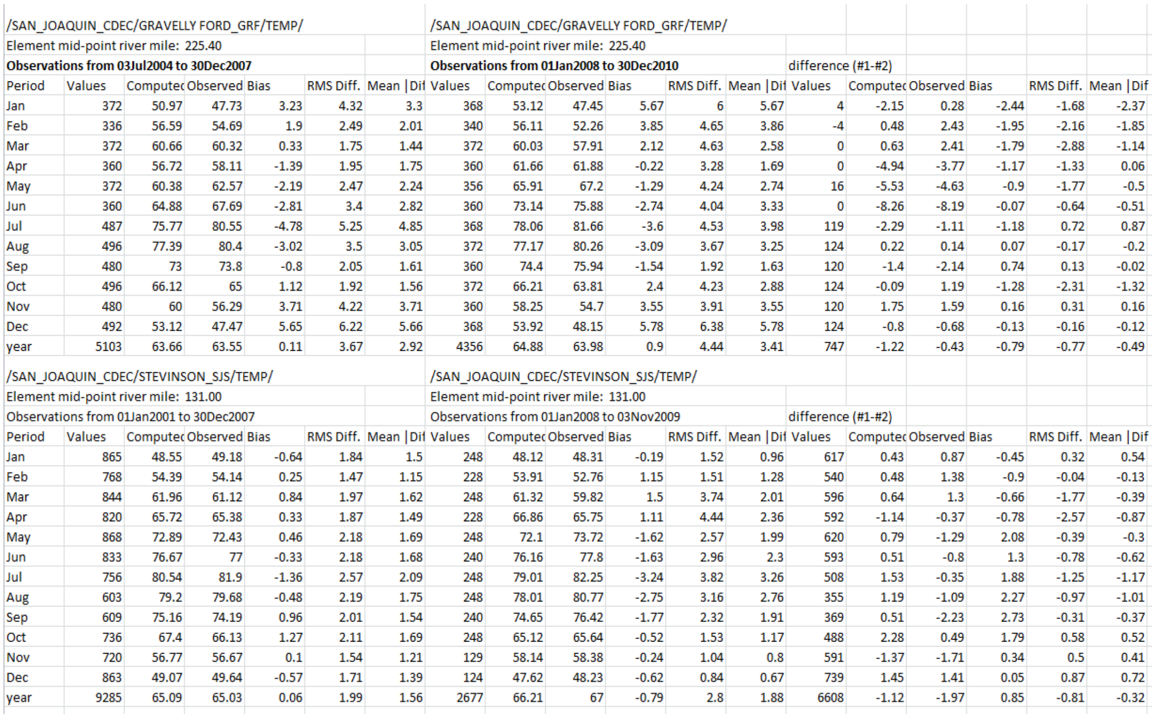


Figure G-12. San Joaquin River above Mendota– computed versus observed temperature statistics.



/SAN_JOAQUIN_CDEC/GRAVELLY FORD_GRF/TEMP/							/SAN_JOAQUIN_CDEC/GRAVELLY FORD_GRF/TEMP/											
Element mid-point river mile: 225.40							Element mid-point river mile: 225.40											
Observations from 03Jul2004 to 30Dec2007							**Observations from 01Jan2008 to 30Dec2010**						difference (#1-#2)					
Period	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif
Jan	372	50.97	47.73	3.23	4.32	3.3	368	53.12	47.45	5.67	6	5.67	4	-2.15	0.28	-2.44	-1.68	-2.37
Feb	336	56.59	54.69	1.9	2.49	2.01	340	56.11	52.26	3.85	4.65	3.86	-4	0.48	2.43	-1.95	-2.16	-1.85
Mar	372	60.66	60.32	0.33	1.75	1.44	372	60.03	57.91	2.12	4.63	2.58	0	0.63	2.41	-1.79	-2.88	-1.14
Apr	360	56.72	58.11	-1.39	1.95	1.75	360	61.66	61.88	-0.22	3.28	1.69	0	-4.94	-3.77	-1.17	-1.33	0.06
May	372	60.38	62.57	-2.19	2.47	2.24	356	65.91	67.2	-1.29	4.24	2.74	16	-5.53	-4.63	-0.9	-1.77	-0.5
Jun	360	64.88	67.69	-2.81	3.4	2.82	360	73.14	75.88	-2.74	4.04	3.33	0	-8.26	-8.19	-0.07	-0.64	-0.51
Jul	487	75.77	80.55	-4.78	5.25	4.85	368	78.06	81.66	-3.6	4.53	3.98	119	-2.29	-1.11	-1.18	0.72	0.87
Aug	496	77.39	80.4	-3.02	3.5	3.05	372	77.17	80.26	-3.09	3.67	3.25	124	0.22	0.14	0.07	-0.17	-0.2
Sep	480	73	73.8	-0.8	2.05	1.61	360	74.4	75.94	-1.54	1.92	1.63	120	-1.4	-2.14	0.74	0.13	-0.02
Oct	496	66.12	65	1.12	1.92	1.56	372	66.21	63.81	2.4	4.23	2.88	124	-0.09	1.19	-1.28	-2.31	-1.32
Nov	480	60	56.29	3.71	4.22	3.71	360	58.25	54.7	3.55	3.91	3.55	120	1.75	1.59	0.16	0.31	0.16
Dec	492	53.12	47.47	5.65	6.22	5.66	368	53.92	48.15	5.78	6.38	5.78	124	-0.8	-0.68	-0.13	-0.16	-0.12
year	5103	63.66	63.55	0.11	3.67	2.92	4356	64.88	63.98	0.9	4.44	3.41	747	-1.22	-0.43	-0.79	-0.77	-0.49

/SAN_JOAQUIN_CDEC/STEVINSON_SJS/TEMP/							/SAN_JOAQUIN_CDEC/STEVINSON_SJS/TEMP/											
Element mid-point river mile: 131.00							Element mid-point river mile: 131.00											
Observations from 01Jan2001 to 30Dec2007							Observations from 01Jan2008 to 03Nov2009						difference (#1-#2)					
Period	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computed	Observed	Bias	RMS Diff.	Mean |Dif
Jan	865	48.55	49.18	-0.64	1.84	1.5	248	48.12	48.31	-0.19	1.52	0.96	617	0.43	0.87	-0.45	0.32	0.54
Feb	768	54.39	54.14	0.25	1.47	1.15	228	53.91	52.76	1.15	1.51	1.28	540	0.48	1.38	-0.9	-0.04	-0.13
Mar	844	61.96	61.12	0.84	1.97	1.62	248	61.32	59.82	1.5	3.74	2.01	596	0.64	1.3	-0.66	-1.77	-0.39
Apr	820	65.72	65.38	0.33	1.87	1.49	228	66.86	65.75	1.11	4.44	2.36	592	-1.14	-0.37	-0.78	-2.57	-0.87
May	868	72.89	72.43	0.46	2.18	1.69	248	72.1	73.72	-1.62	2.57	1.99	620	0.79	-1.29	2.08	-0.39	-0.3
Jun	833	76.67	77	-0.33	2.18	1.68	240	76.16	77.8	-1.63	2.96	2.3	593	0.51	-0.8	1.3	-0.78	-0.62
Jul	756	80.54	81.9	-1.36	2.57	2.09	248	79.01	82.25	-3.24	3.82	3.26	508	1.53	-0.35	1.88	-1.25	-1.17
Aug	603	79.2	79.68	-0.48	2.19	1.75	248	78.01	80.77	-2.75	3.16	2.76	355	1.19	-1.09	2.27	-0.97	-1.01
Sep	609	75.16	74.19	0.96	2.01	1.54	240	74.65	76.42	-1.77	2.32	1.91	369	0.51	-2.23	2.73	-0.31	-0.37
Oct	736	67.4	66.13	1.27	2.11	1.69	248	65.12	65.64	-0.52	1.53	1.17	488	2.28	0.49	1.79	0.58	0.52
Nov	720	56.77	56.67	0.1	1.54	1.21	129	58.14	58.38	-0.24	1.04	0.8	591	-1.37	-1.71	0.34	0.5	0.41
Dec	863	49.07	49.64	-0.57	1.71	1.39	124	47.62	48.23	-0.62	0.84	0.67	739	1.45	1.41	0.05	0.87	0.72
year	9285	65.09	65.03	0.06	1.99	1.56	2677	66.21	67	-0.79	2.8	1.88	6608	-1.12	-1.97	0.85	-0.81	-0.32

Figure G-13. Monthly and yearly statistics in the San Joaquin River at Gravelly Ford and Stevinson - Pre 2008 and 2008 thru 2010.

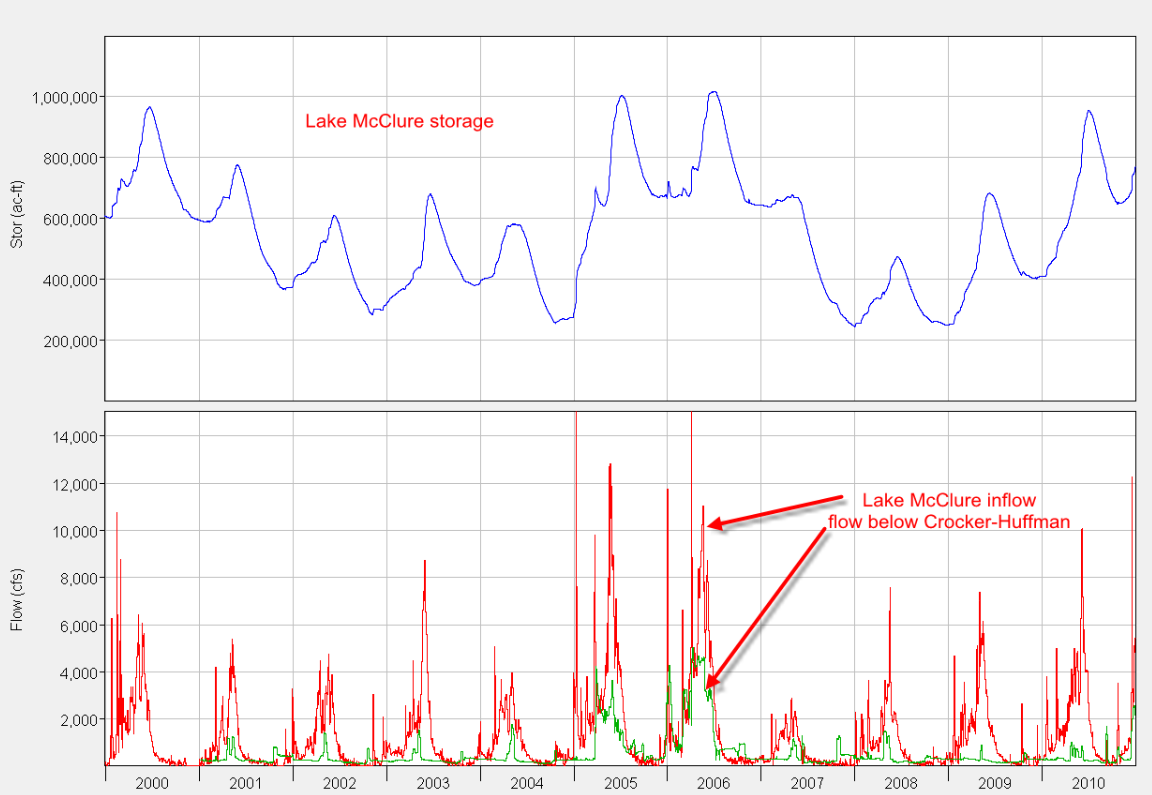


Figure G-14. Lake McClure storage and inflow Merced flow below Crocker-Huffman Dam.

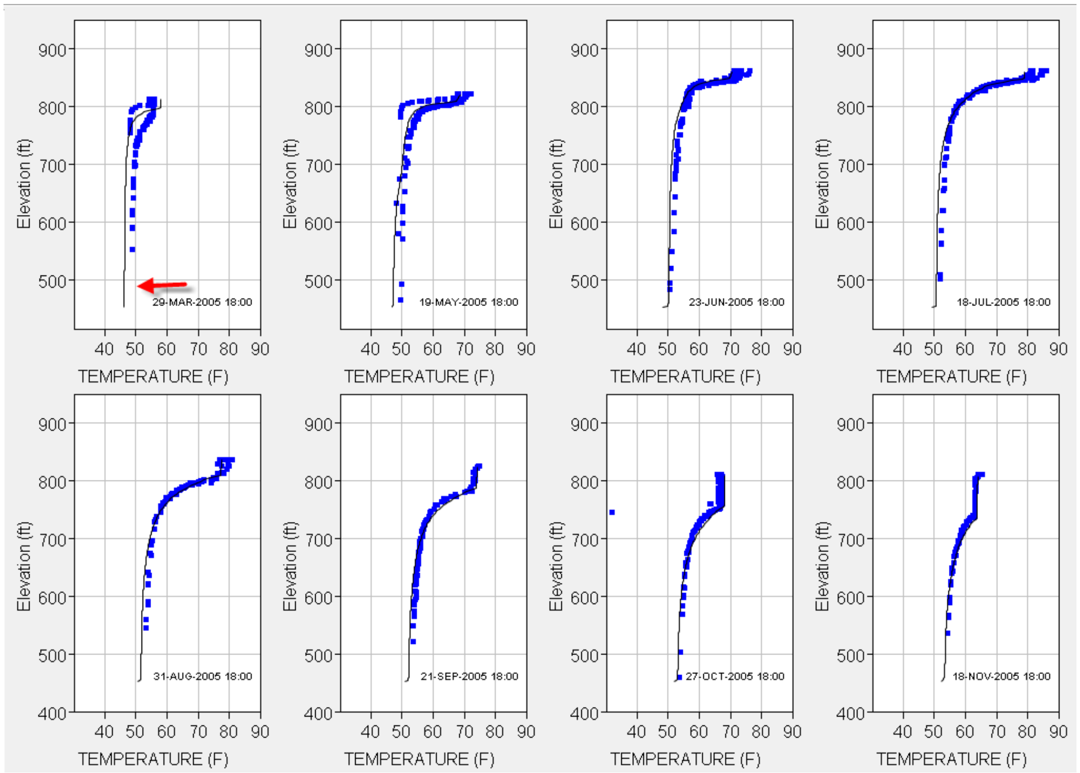


Figure G-15. Lake McClure – 2005.

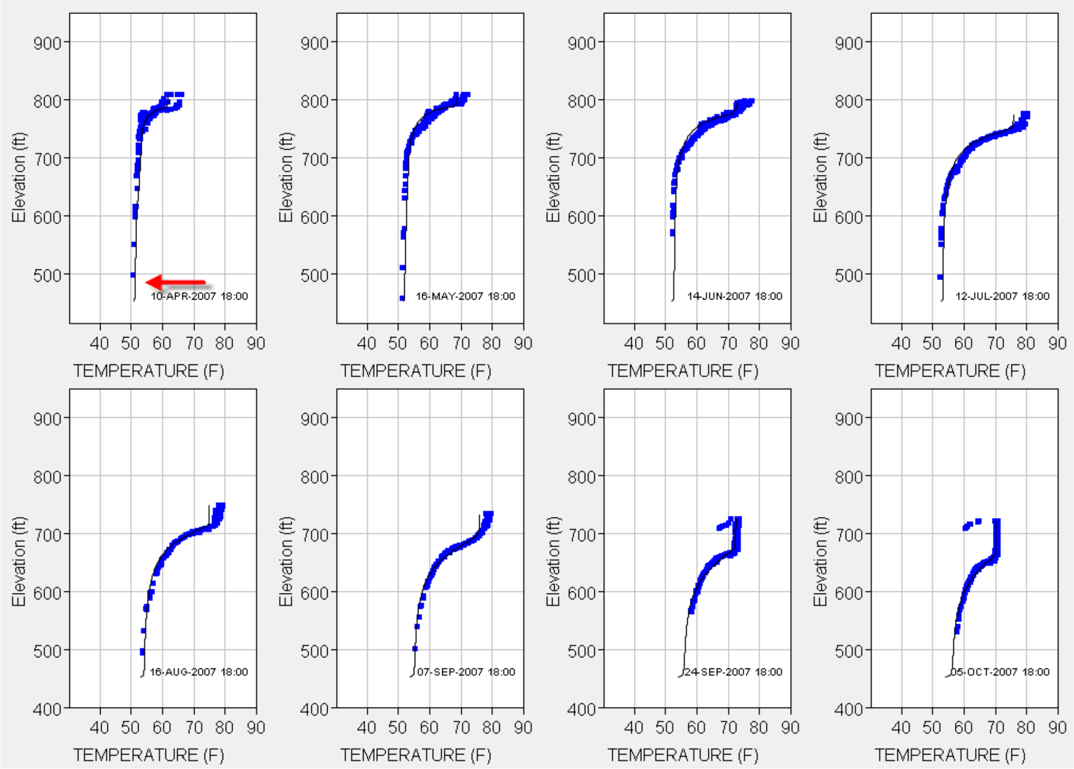


Figure G-16. Lake McClure – 2007.

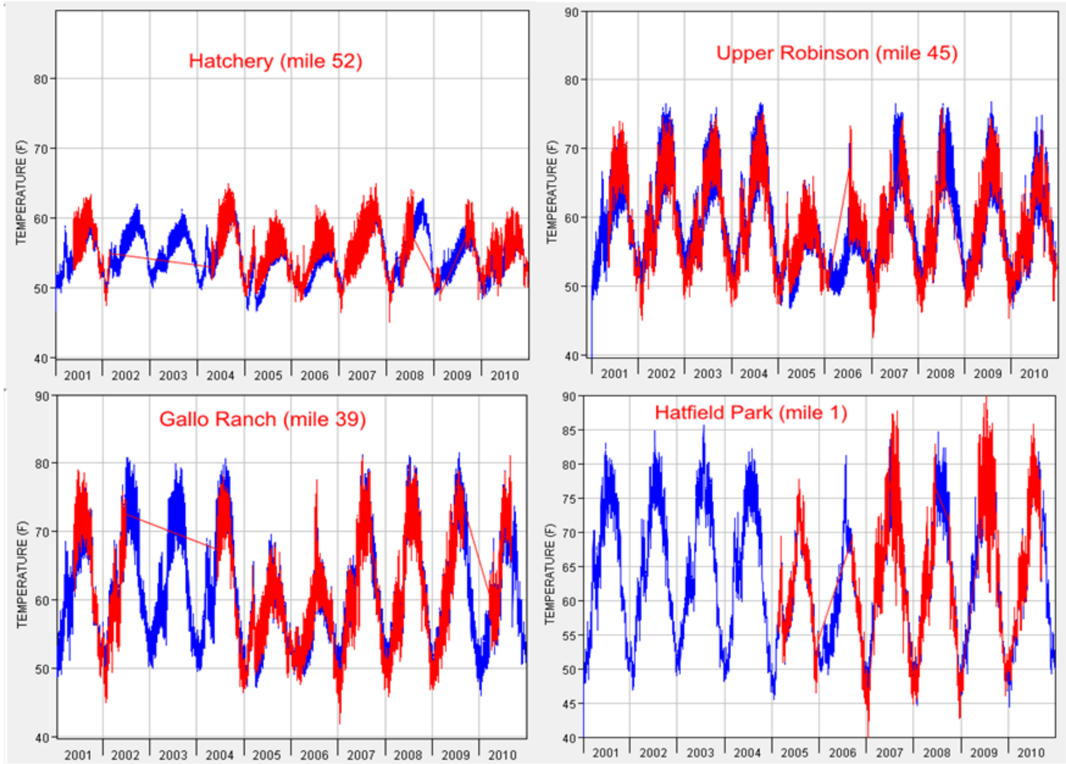


Figure G-17. Merced River – computed and observed temperature figures.

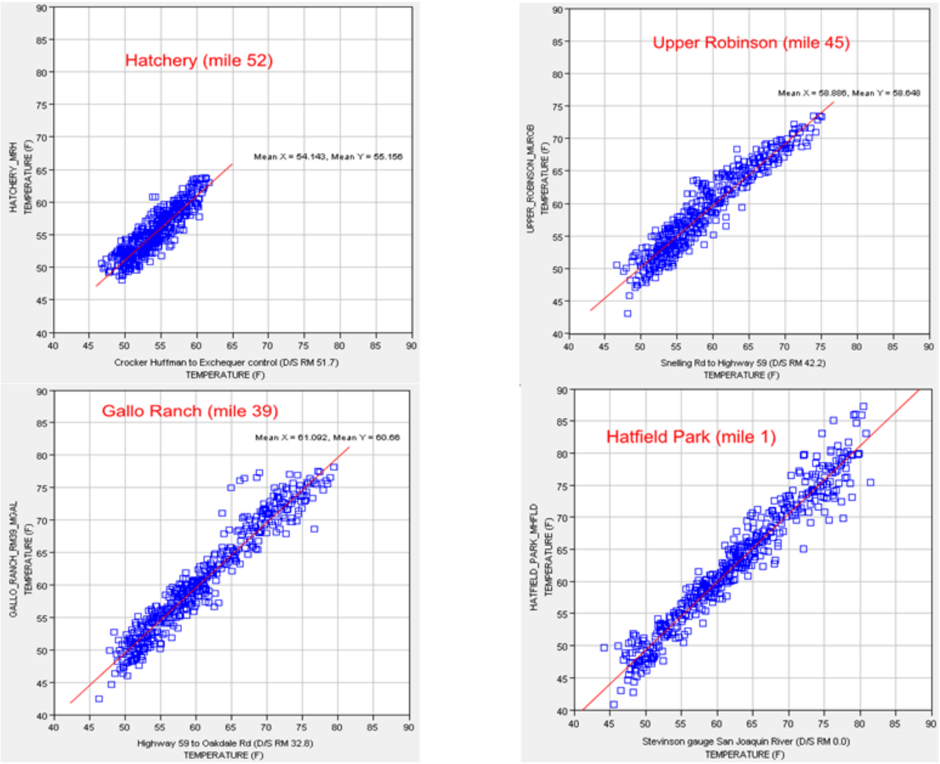
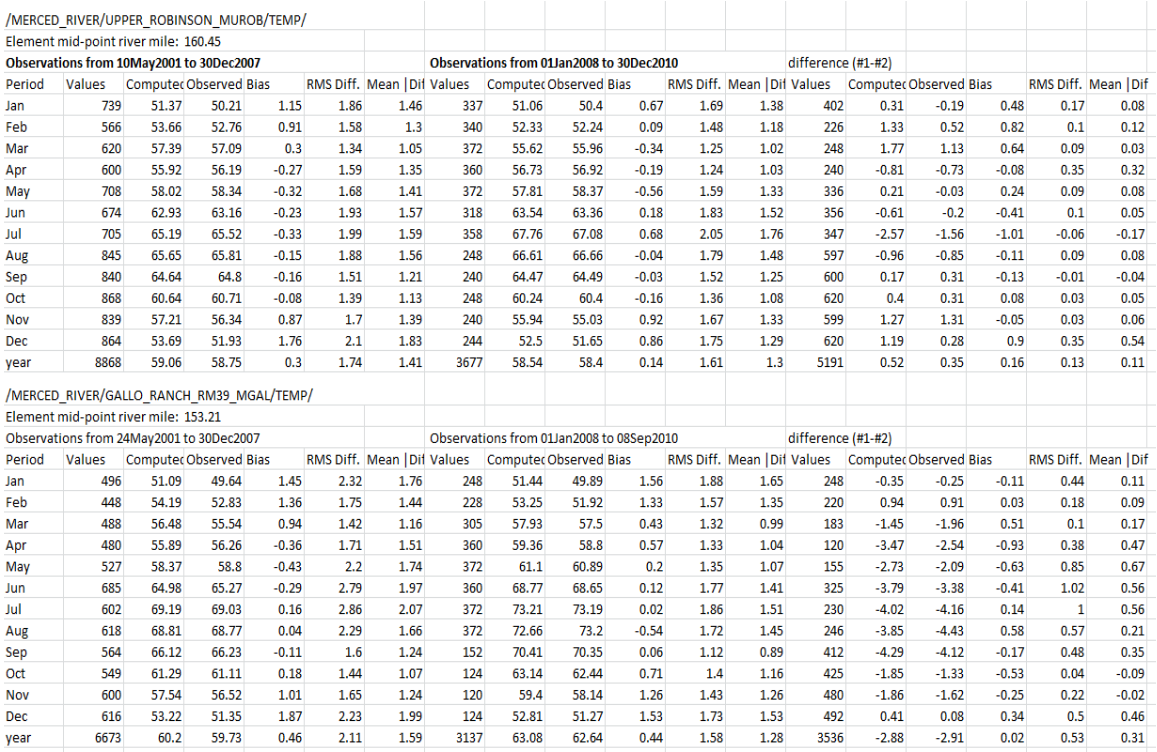


Figure G-18. Merced River – computed and observed temperature statistics.



/MERCED_RIVER/UPPER_ROBINSON_MUROB/TEMP/

Element mid-point river mile: 160.45

Observations from 10May2001 to 30Dec2007							Observations from 01Jan2008 to 30Dec2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	739	51.37	50.21	1.15	1.86	1.46	337	51.06	50.4	0.67	1.69	1.38	402	0.31	-0.19	0.48	0.17	0.08
Feb	566	53.66	52.76	0.91	1.58	1.3	340	52.33	52.24	0.09	1.48	1.18	226	1.33	0.52	0.82	0.1	0.12
Mar	620	57.39	57.09	0.3	1.34	1.05	372	55.62	55.96	-0.34	1.25	1.02	248	1.77	1.13	0.64	0.09	0.03
Apr	600	55.92	56.19	-0.27	1.59	1.35	360	56.73	56.92	-0.19	1.24	1.03	240	-0.81	-0.73	-0.08	0.35	0.32
May	708	58.02	58.34	-0.32	1.68	1.41	372	57.81	58.37	-0.56	1.59	1.33	336	0.21	-0.03	0.24	0.09	0.08
Jun	674	62.93	63.16	-0.23	1.93	1.57	318	63.54	63.36	0.18	1.83	1.52	356	-0.61	-0.2	-0.41	0.1	0.05
Jul	705	65.19	65.52	-0.33	1.99	1.59	358	67.76	67.08	0.68	2.05	1.76	347	-2.57	-1.56	-1.01	-0.06	-0.17
Aug	845	65.65	65.81	-0.15	1.88	1.56	248	66.61	66.66	-0.04	1.79	1.48	597	-0.96	-0.85	-0.11	0.09	0.08
Sep	840	64.64	64.8	-0.16	1.51	1.21	240	64.47	64.49	-0.03	1.52	1.25	600	0.17	0.31	-0.13	-0.01	-0.04
Oct	868	60.64	60.71	-0.08	1.39	1.13	248	60.24	60.4	-0.16	1.36	1.08	620	0.4	0.31	0.08	0.03	0.05
Nov	839	57.21	56.34	0.87	1.7	1.39	240	55.94	55.03	0.92	1.67	1.33	599	1.27	1.31	-0.05	0.03	0.06
Dec	864	53.69	51.93	1.76	2.1	1.83	244	52.5	51.65	0.86	1.75	1.29	620	1.19	0.28	0.9	0.35	0.54
year	8868	59.06	58.75	0.3	1.74	1.41	3677	58.54	58.4	0.14	1.61	1.3	5191	0.52	0.35	0.16	0.13	0.11

/MERCED_RIVER/GALLO_RANCH_RM39_MGAL/TEMP/

Element mid-point river mile: 153.21

Observations from 24May2001 to 30Dec2007							Observations from 01Jan2008 to 08Sep2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	496	51.09	49.64	1.45	2.32	1.76	248	51.44	49.89	1.56	1.88	1.65	248	-0.35	-0.25	-0.11	0.44	0.11
Feb	448	54.19	52.83	1.36	1.75	1.44	228	53.25	51.92	1.33	1.57	1.35	220	0.94	0.91	0.03	0.18	0.09
Mar	488	56.48	55.54	0.94	1.42	1.16	305	57.93	57.5	0.43	1.32	0.99	183	-1.45	-1.96	0.51	0.1	0.17
Apr	480	55.89	56.26	-0.36	1.71	1.51	360	59.36	58.8	0.57	1.33	1.04	120	-3.47	-2.54	-0.93	0.38	0.47
May	527	58.37	58.8	-0.43	2.2	1.74	372	61.1	60.89	0.2	1.35	1.07	155	-2.73	-2.09	-0.63	0.85	0.67
Jun	685	64.98	65.27	-0.29	2.79	1.97	360	68.77	68.65	0.12	1.77	1.41	325	-3.79	-3.38	-0.41	1.02	0.56
Jul	602	69.19	69.03	0.16	2.86	2.07	372	73.21	73.19	0.02	1.86	1.51	230	-4.02	-4.16	0.14	1	0.56
Aug	618	68.81	68.77	0.04	2.29	1.66	372	72.66	73.2	-0.54	1.72	1.45	246	-3.85	-4.43	0.58	0.57	0.21
Sep	564	66.12	66.23	-0.11	1.6	1.24	152	70.41	70.35	0.06	1.12	0.89	412	-4.29	-4.12	-0.17	0.48	0.35
Oct	549	61.29	61.11	0.18	1.44	1.07	124	63.14	62.44	0.71	1.4	1.16	425	-1.85	-1.33	-0.53	0.04	-0.09
Nov	600	57.54	56.52	1.01	1.65	1.24	120	59.4	58.14	1.26	1.43	1.26	480	-1.86	-1.62	-0.25	0.22	-0.02
Dec	616	53.22	51.35	1.87	2.23	1.99	124	52.81	51.27	1.53	1.73	1.53	492	0.41	0.08	0.34	0.5	0.46
year	6673	60.2	59.73	0.46	2.11	1.59	3137	63.08	62.64	0.44	1.58	1.28	3536	-2.88	-2.91	0.02	0.53	0.31

Figure G-19. Monthly and yearly statistics in the Merced River at Upper Robinson and Gallo Ranch - Pre 2008 and 2008 thru 2010.

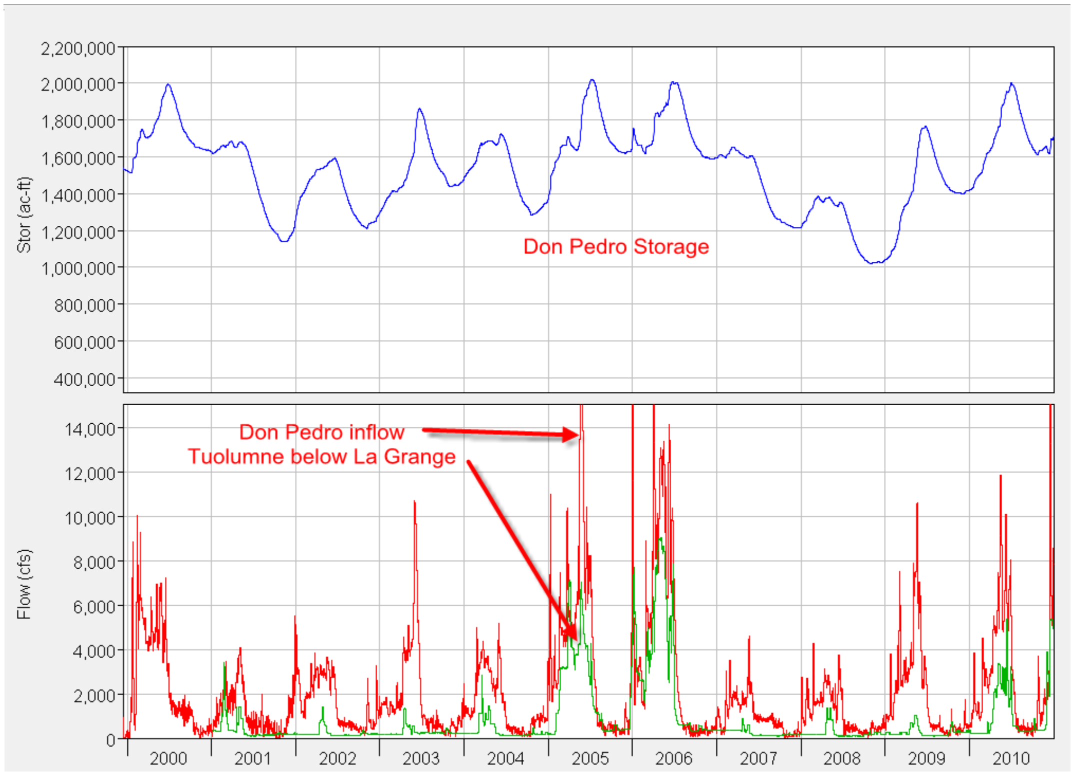


Figure G-20. Don Pedro storage and inflow Tuolumne flow below La Grange Dam.

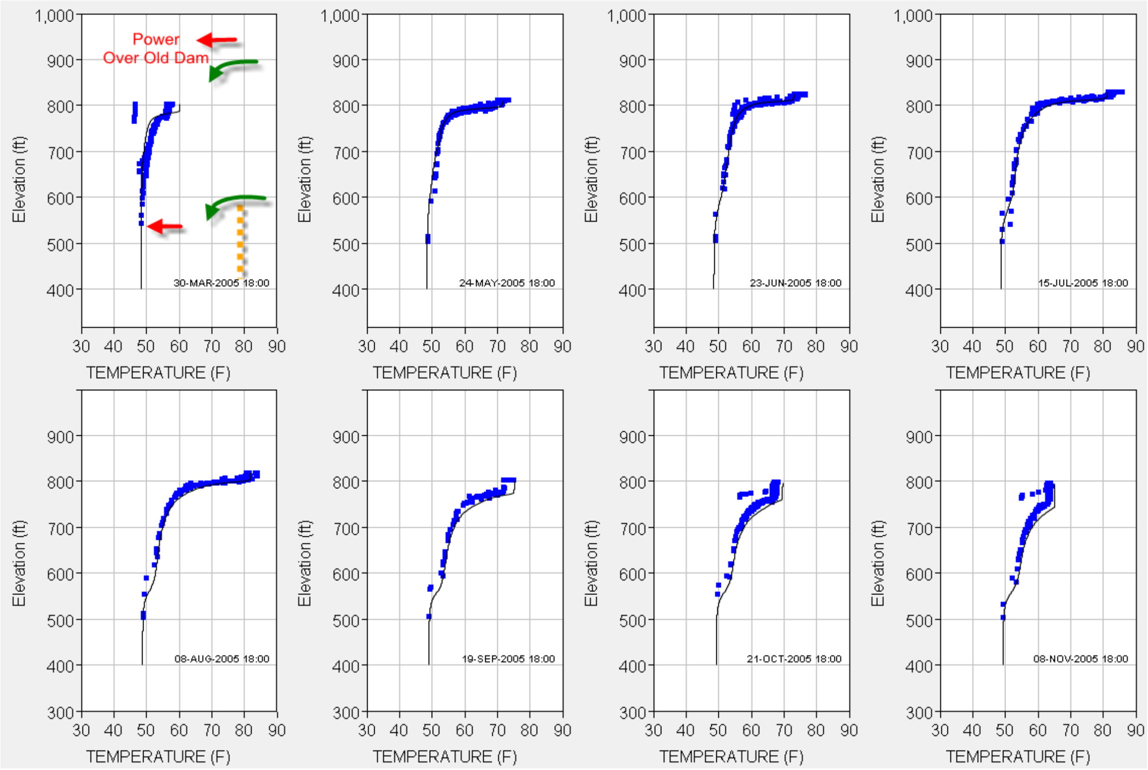


Figure G-21. Don Pedro – 2005.

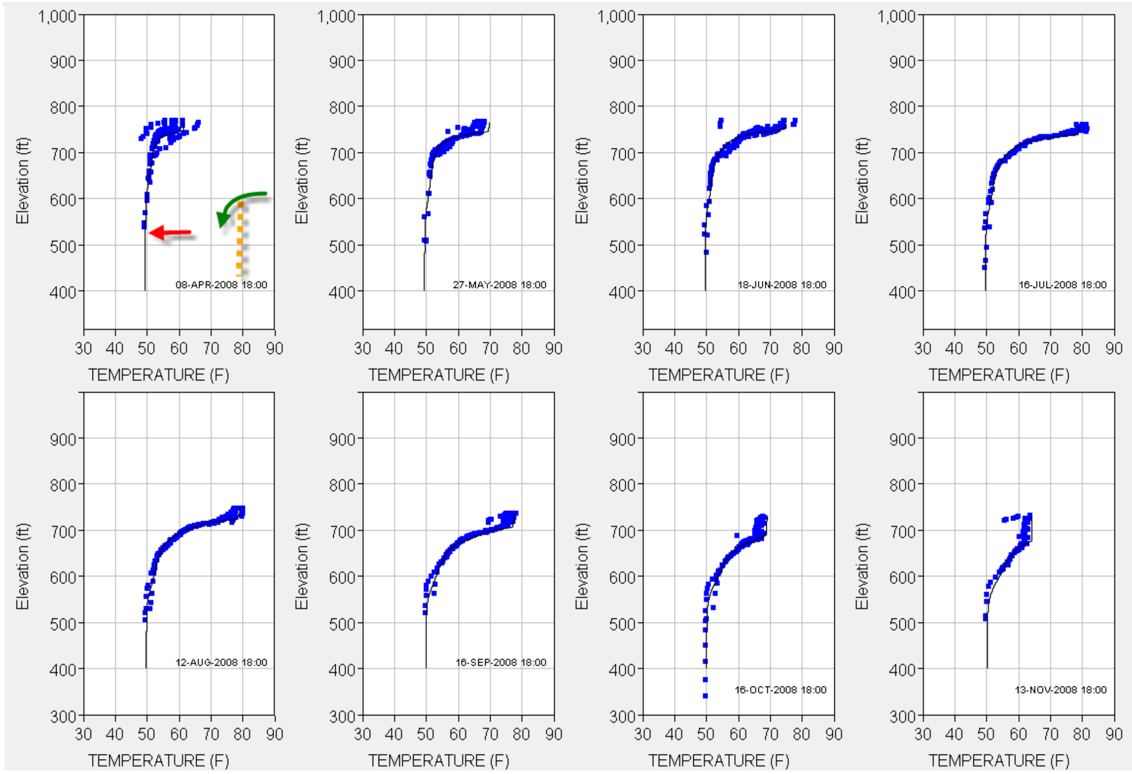


Figure G-22. Don Pedro – 2008.

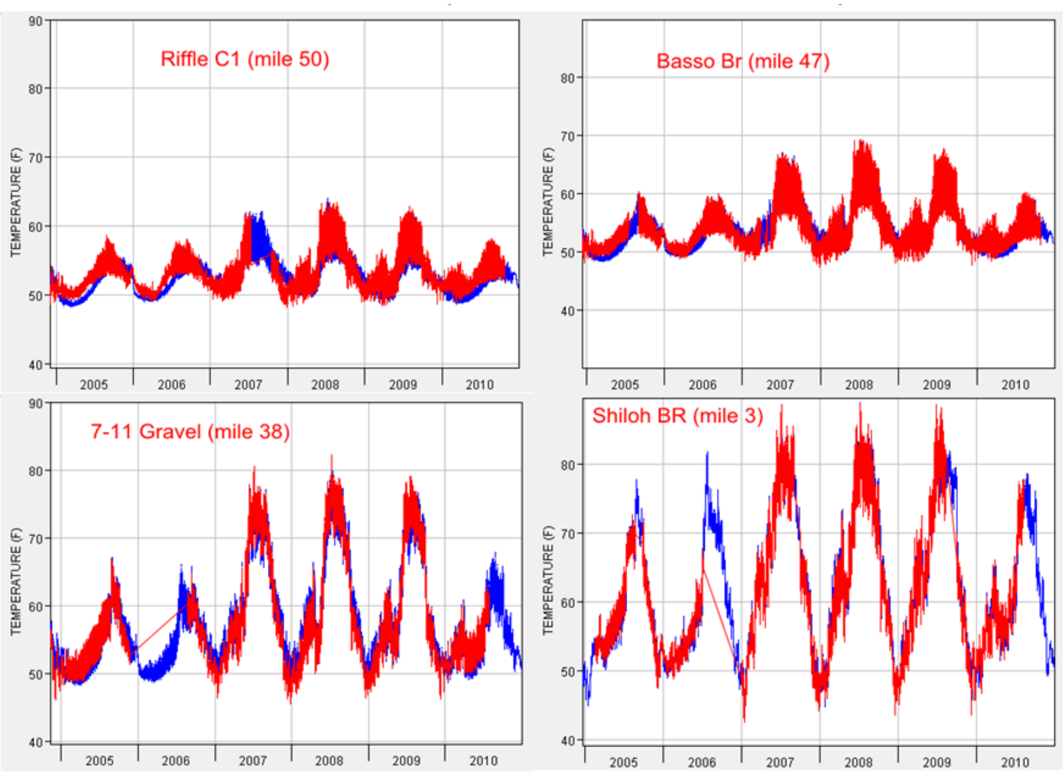


Figure G-23. Tuolumne River – computed and observed temperature figures.

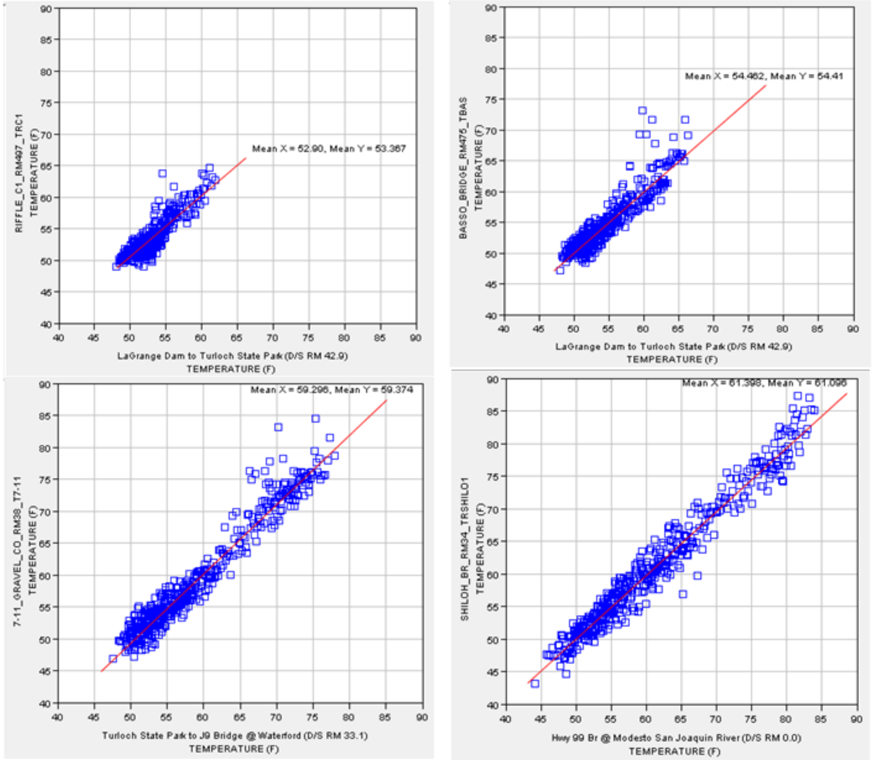
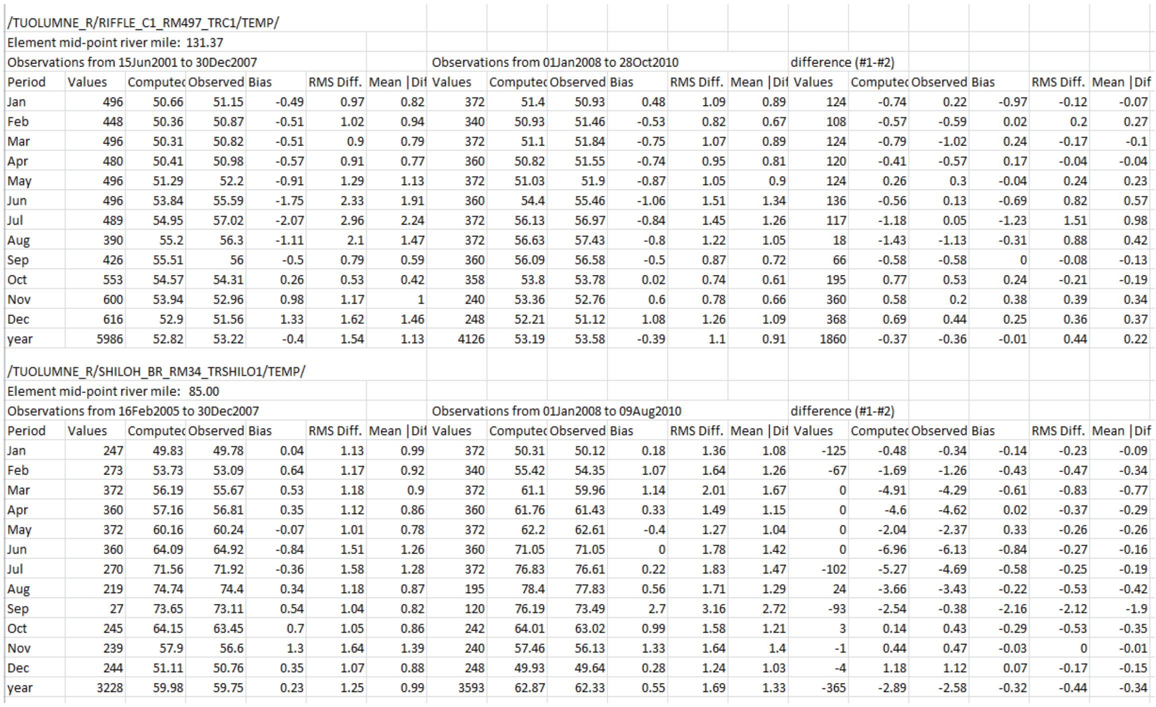


Figure G-24. Tuolumne River – computed and observed temperature statistics.



/TUOLUMNE_R/RIFFLE_C1_RM497_TRC1/TEMP/

Element mid-point river mile: 131.37

Observations from 15Jun2001 to 30Dec2007							Observations from 01Jan2008 to 28Oct2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	496	50.66	51.15	-0.49	0.97	0.82	372	51.4	50.93	0.48	1.09	0.89	124	-0.74	0.22	-0.97	-0.12	-0.07
Feb	448	50.36	50.87	-0.51	1.02	0.94	340	50.93	51.46	-0.53	0.82	0.67	108	-0.57	-0.59	0.02	0.2	0.27
Mar	496	50.31	50.82	-0.51	0.9	0.79	372	51.1	51.84	-0.75	1.07	0.89	124	-0.79	-1.02	0.24	-0.17	-0.1
Apr	480	50.41	50.98	-0.57	0.91	0.77	360	50.82	51.55	-0.74	0.95	0.81	120	-0.41	-0.57	0.17	-0.04	-0.04
May	496	51.29	52.2	-0.91	1.29	1.13	372	51.03	51.9	-0.87	1.05	0.9	124	0.26	0.3	-0.04	0.24	0.23
Jun	496	53.84	55.59	-1.75	2.33	1.91	360	54.4	55.46	-1.06	1.51	1.34	136	-0.56	0.13	-0.69	0.82	0.57
Jul	489	54.95	57.02	-2.07	2.96	2.24	372	56.13	56.97	-0.84	1.45	1.26	117	-1.18	0.05	-1.23	1.51	0.98
Aug	390	55.2	56.3	-1.11	2.1	1.47	372	56.63	57.43	-0.8	1.22	1.05	18	-1.43	-1.13	-0.31	0.88	0.42
Sep	426	55.51	56	-0.5	0.79	0.59	360	56.09	56.58	-0.5	0.87	0.72	66	-0.58	-0.58	0	-0.08	-0.13
Oct	553	54.57	54.31	0.26	0.53	0.42	358	53.8	53.78	0.02	0.74	0.61	195	0.77	0.53	0.24	-0.21	-0.19
Nov	600	53.94	52.96	0.98	1.17	1	240	53.36	52.76	0.6	0.78	0.66	360	0.58	0.2	0.38	0.39	0.34
Dec	616	52.9	51.56	1.33	1.62	1.46	248	52.21	51.12	1.08	1.26	1.09	368	0.69	0.44	0.25	0.36	0.37
year	5986	52.82	53.22	-0.4	1.54	1.13	4126	53.19	53.58	-0.39	1.1	0.91	1860	-0.37	-0.36	-0.01	0.44	0.22

/TUOLUMNE_R/SHILOH_BR_RM34_TRSHILO1/TEMP/

Element mid-point river mile: 85.00

Observations from 16Feb2005 to 30Dec2007							Observations from 01Jan2008 to 09Aug2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	247	49.83	49.78	0.04	1.13	0.99	372	50.31	50.12	0.18	1.36	1.08	-125	-0.48	-0.34	-0.14	-0.23	-0.09
Feb	273	53.73	53.09	0.64	1.17	0.92	340	55.42	54.35	1.07	1.64	1.26	-67	-1.69	-1.26	-0.43	-0.47	-0.34
Mar	372	56.19	55.67	0.53	1.18	0.9	372	61.1	59.96	1.14	2.01	1.67	0	-4.91	-4.29	-0.61	-0.83	-0.77
Apr	360	57.16	56.81	0.35	1.12	0.86	360	61.76	61.43	0.33	1.49	1.15	0	-4.6	-4.62	0.02	-0.37	-0.29
May	372	60.16	60.24	-0.07	1.01	0.78	372	62.2	62.61	-0.4	1.27	1.04	0	-2.04	-2.37	0.33	-0.26	-0.26
Jun	360	64.09	64.92	-0.84	1.51	1.26	360	71.05	71.05	0	1.78	1.42	0	-6.96	-6.13	-0.84	-0.27	-0.16
Jul	270	71.56	71.92	-0.36	1.58	1.28	372	76.83	76.61	0.22	1.83	1.47	-102	-5.27	-4.69	-0.58	-0.25	-0.19
Aug	219	74.74	74.4	0.34	1.18	0.87	195	78.4	77.83	0.56	1.71	1.29	24	-3.66	-3.43	-0.22	-0.53	-0.42
Sep	27	73.65	73.11	0.54	1.04	0.82	120	76.19	73.49	2.7	3.16	2.72	-93	-2.54	-0.38	-2.16	-2.12	-1.9
Oct	245	64.15	63.45	0.7	1.05	0.86	242	64.01	63.02	0.99	1.58	1.21	3	0.14	0.43	-0.29	-0.53	-0.35
Nov	239	57.9	56.6	1.3	1.64	1.39	240	57.46	56.13	1.33	1.64	1.4	-1	0.44	0.47	-0.03	0	-0.01
Dec	244	51.11	50.76	0.35	1.07	0.88	248	49.93	49.64	0.28	1.24	1.03	-4	1.18	1.12	0.07	-0.17	-0.15
year	3228	59.98	59.75	0.23	1.25	0.99	3593	62.87	62.33	0.55	1.69	1.33	-365	-2.89	-2.58	-0.32	-0.44	-0.34

Figure G-25. Monthly and yearly statistics in the Tuolumne at Riffle C1 and Shiloh Bridge - Pre 2008 and 2008 thru 2010.

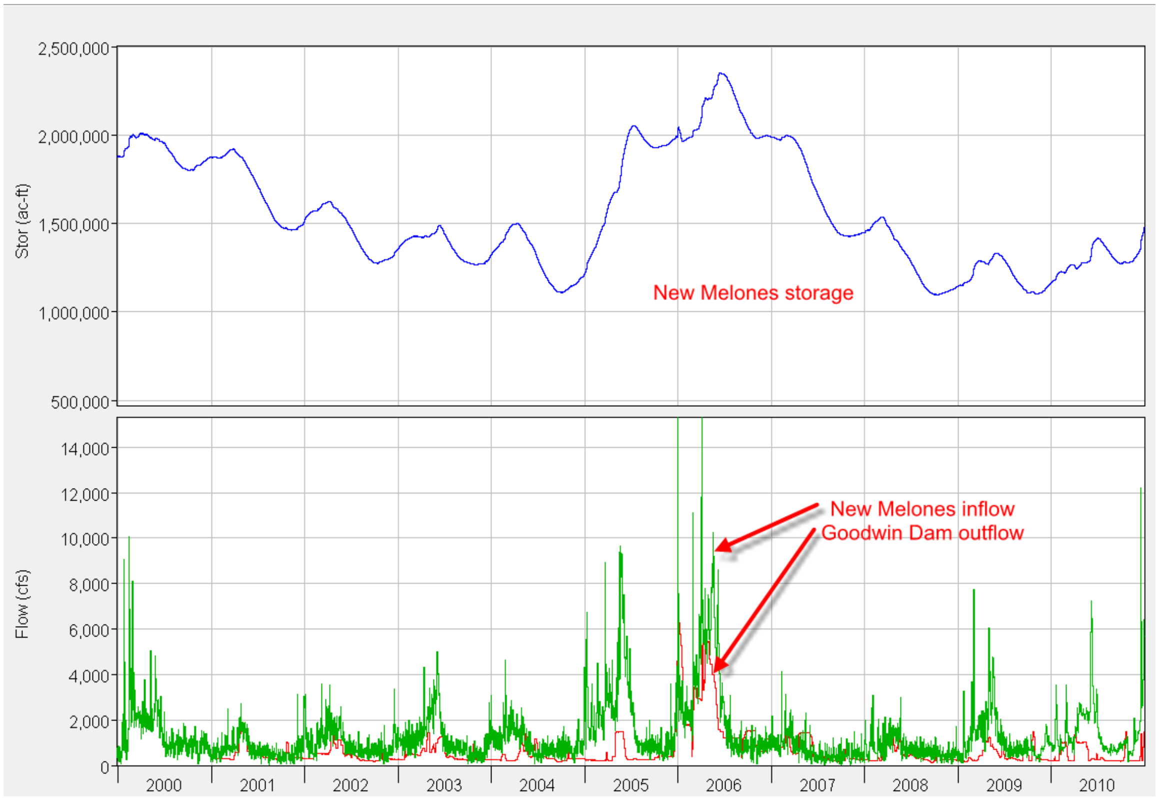


Figure G-26. New Melones storage and inflow Stanislaus below Goodwin Dam.

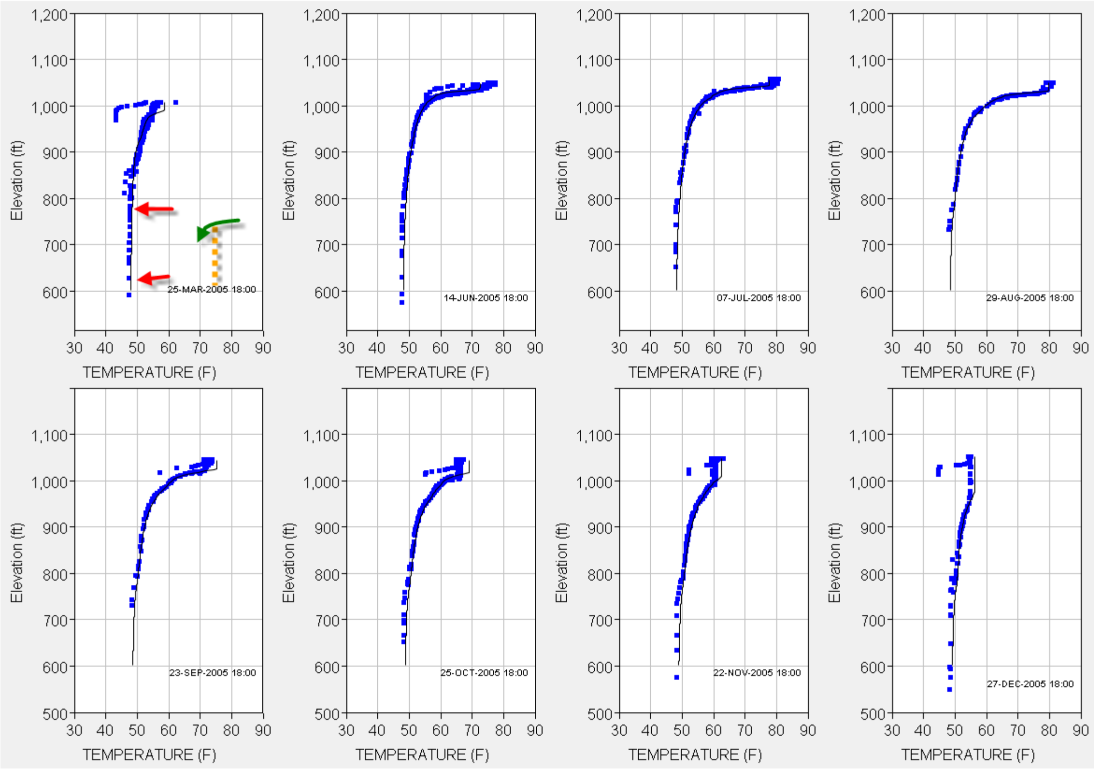


Figure G-27. New Melones – 2005.

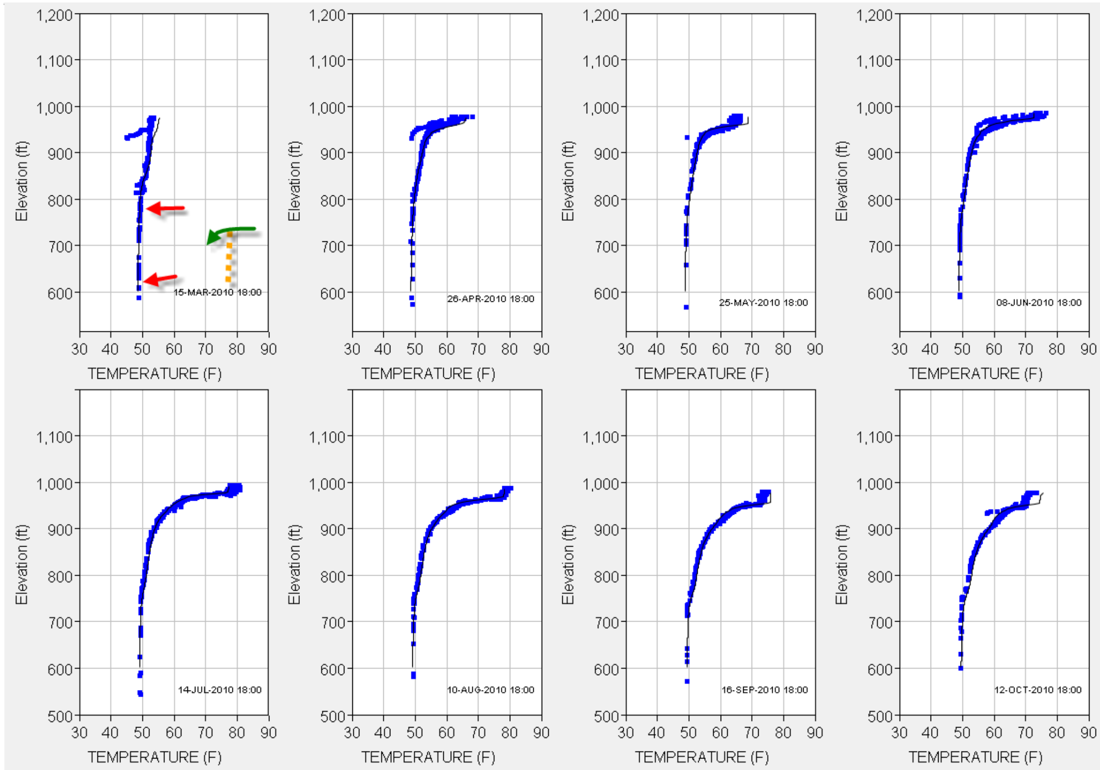


Figure G-28. New Melones – 2010.

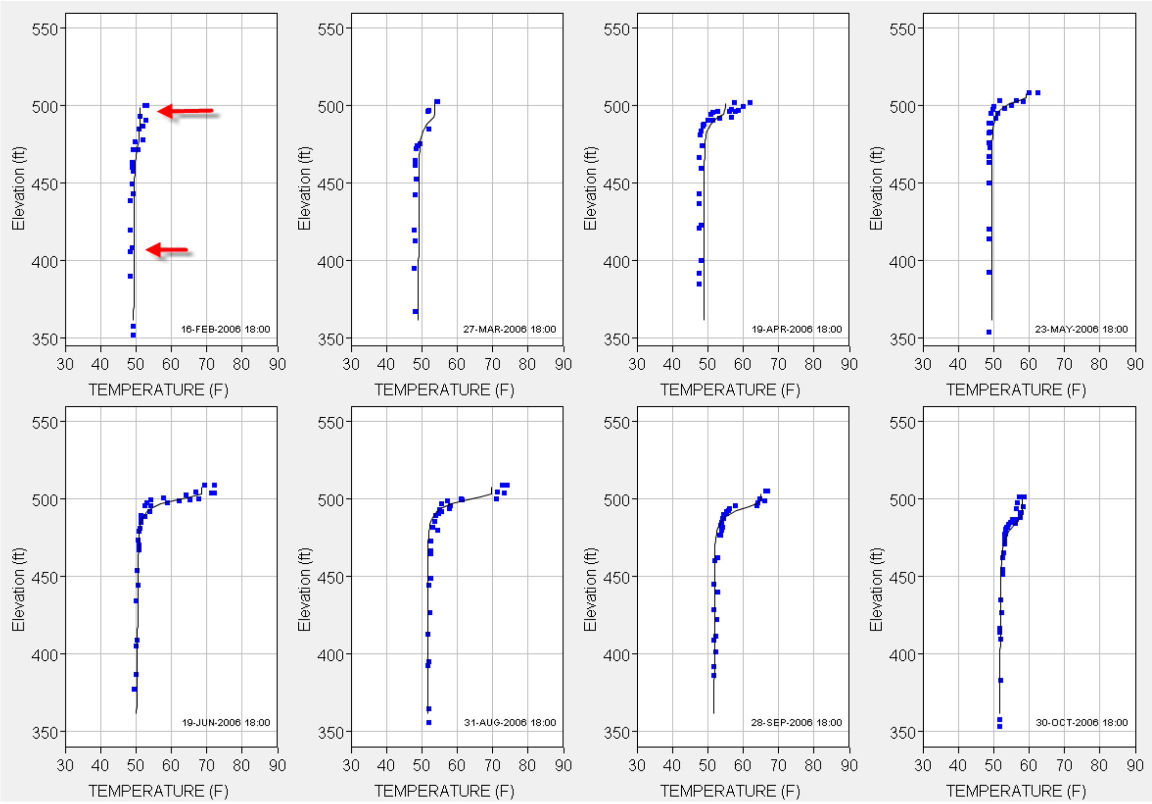


Figure G-29. Tulloch – 2005.

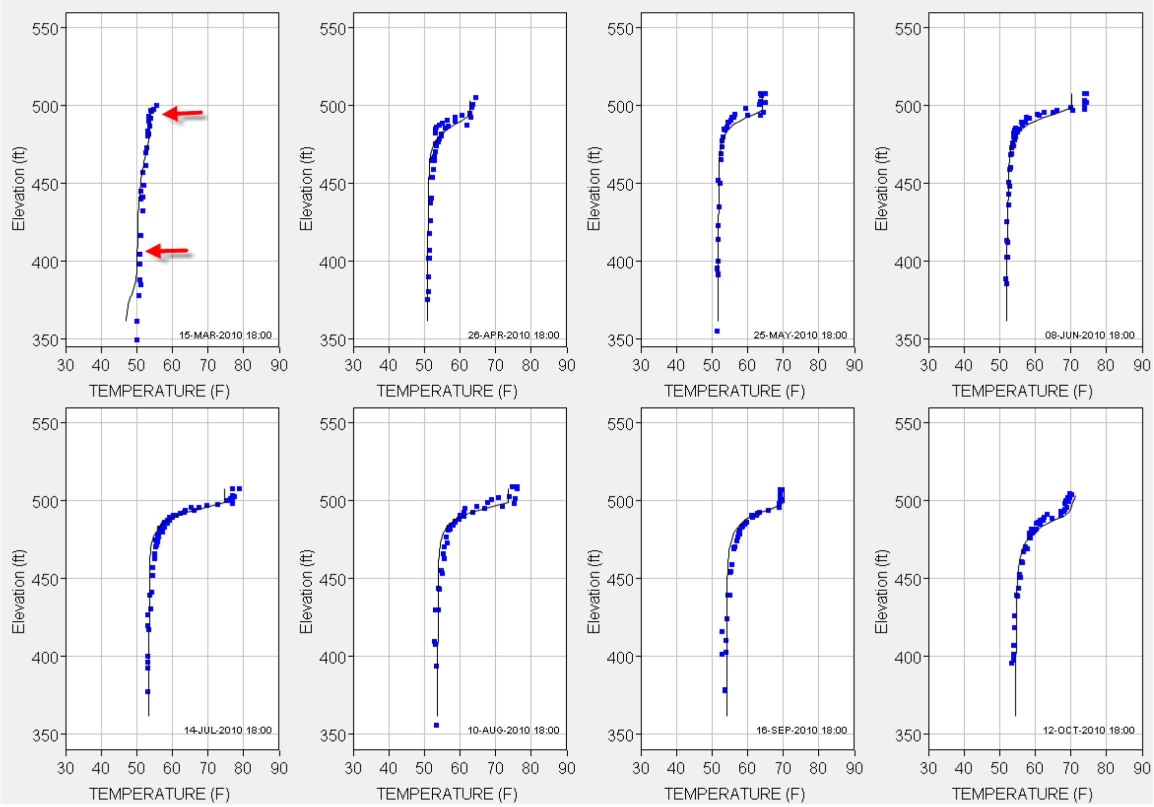


Figure G-30. Tulloch – 2010.

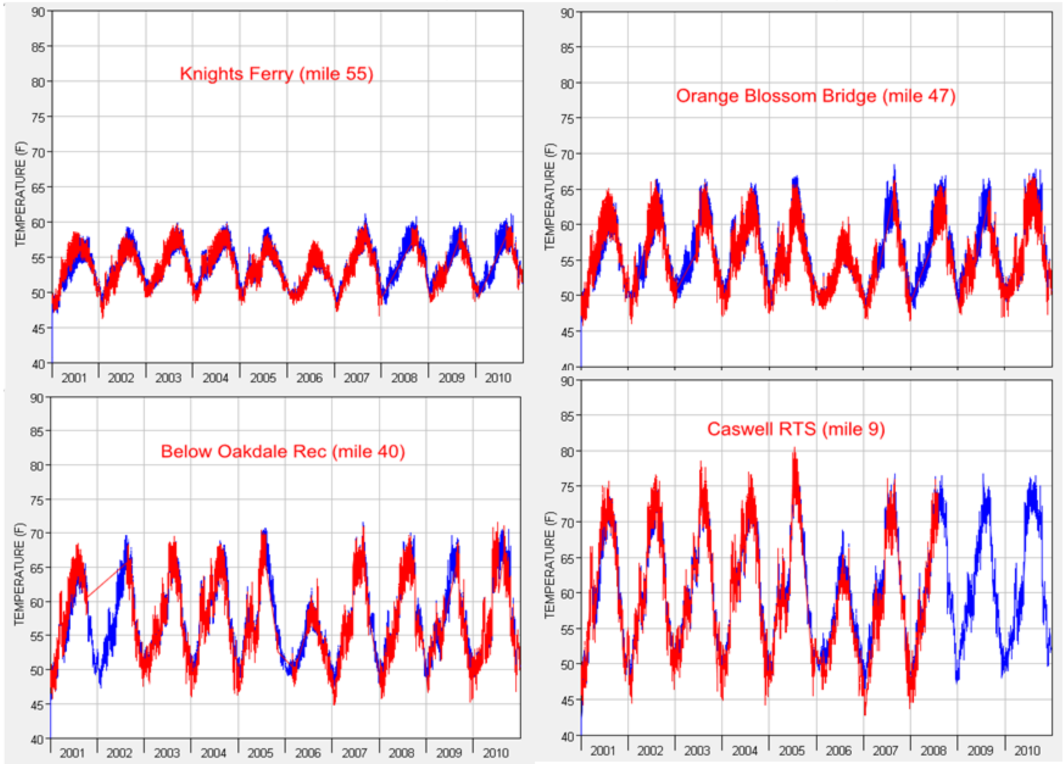


Figure G-31. Stanislaus River– computed and observed temperature figures.

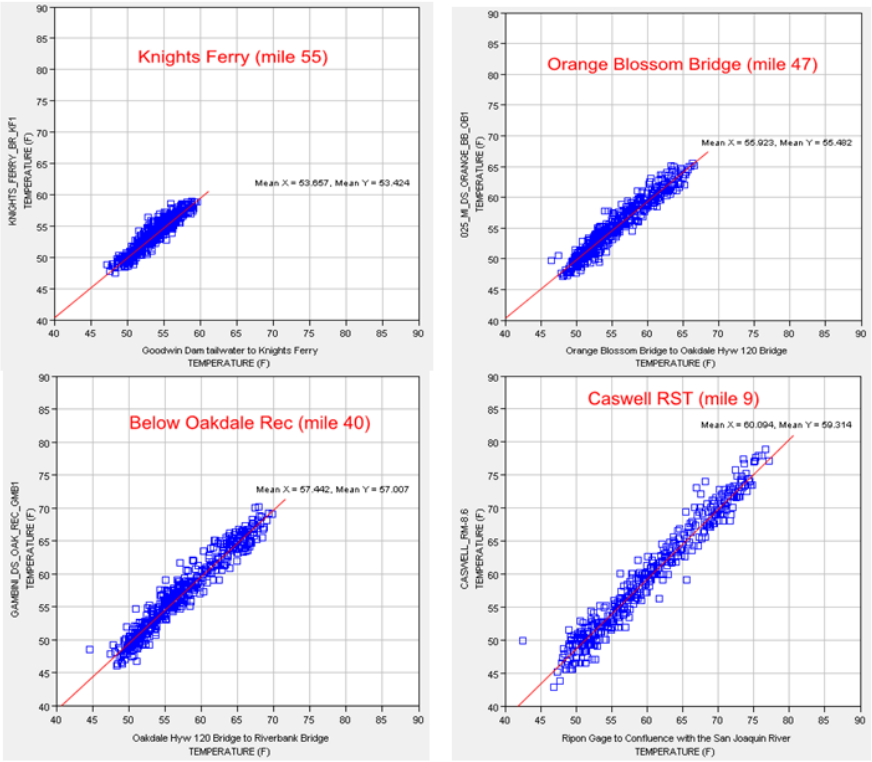
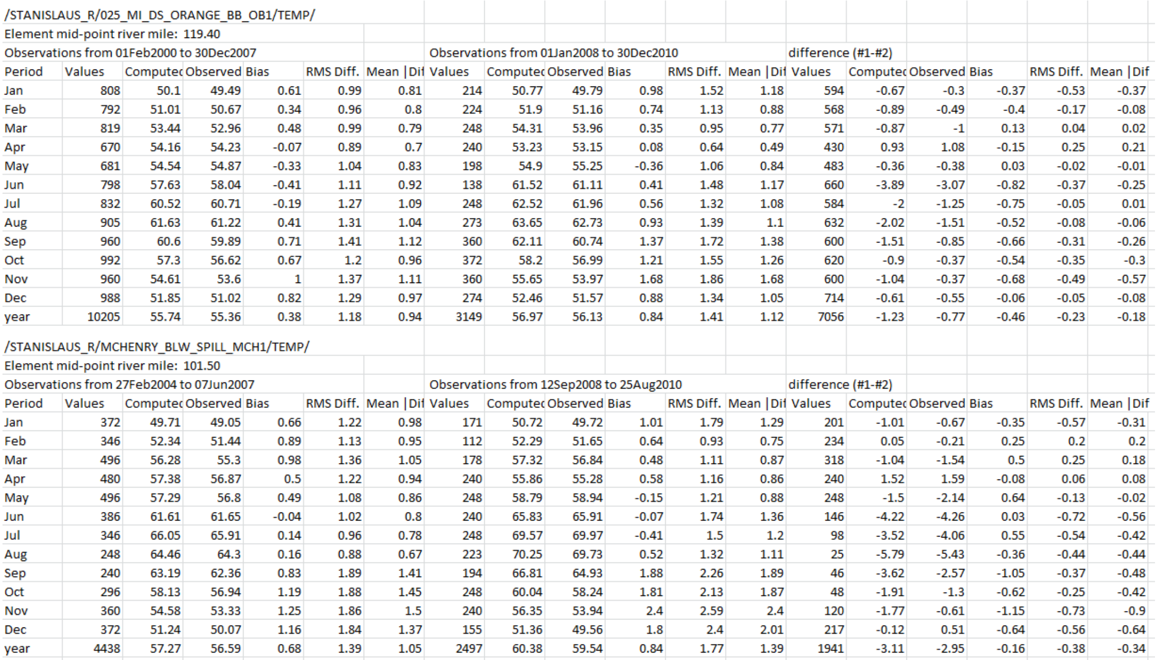


Figure G-32. Stanislaus River– computed and observed temperature statistics.



/STANISLAUS_R/025_MI_DS_ORANGE_BB_OB1/TEMP/
Element mid-point river mile: 119.40

	Observations from 01Feb2000 to 30Dec2007						Observations from 01Jan2008 to 30Dec2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	808	50.1	49.49	0.61	0.99	0.81	214	50.77	49.79	0.98	1.52	1.18	594	-0.67	-0.3	-0.37	-0.53	-0.37
Feb	792	51.01	50.67	0.34	0.96	0.8	224	51.9	51.16	0.74	1.13	0.88	568	-0.89	-0.49	-0.4	-0.17	-0.08
Mar	819	53.44	52.96	0.48	0.99	0.79	248	54.31	53.96	0.35	0.95	0.77	571	-0.87	-1	0.13	0.04	0.02
Apr	670	54.16	54.23	-0.07	0.89	0.7	240	53.23	53.15	0.08	0.64	0.49	430	0.93	1.08	-0.15	0.25	0.21
May	681	54.54	54.87	-0.33	1.04	0.83	198	54.9	55.25	-0.36	1.06	0.84	483	-0.36	-0.38	0.03	-0.02	-0.01
Jun	798	57.63	58.04	-0.41	1.11	0.92	138	61.52	61.11	0.41	1.48	1.17	660	-3.89	-3.07	-0.82	-0.37	-0.25
Jul	832	60.52	60.71	-0.19	1.27	1.09	248	62.52	61.96	0.56	1.32	1.08	584	-2	-1.25	-0.75	-0.05	0.01
Aug	905	61.63	61.22	0.41	1.31	1.04	273	63.65	62.73	0.93	1.39	1.1	632	-2.02	-1.51	-0.52	-0.08	-0.06
Sep	960	60.6	59.89	0.71	1.41	1.12	360	62.11	60.74	1.37	1.72	1.38	600	-1.51	-0.85	-0.66	-0.31	-0.26
Oct	992	57.3	56.62	0.67	1.2	0.96	372	58.2	56.99	1.21	1.55	1.26	620	-0.9	-0.37	-0.54	-0.35	-0.3
Nov	960	54.61	53.6	1	1.37	1.11	360	55.65	53.97	1.68	1.86	1.68	600	-1.04	-0.37	-0.68	-0.49	-0.57
Dec	988	51.85	51.02	0.82	1.29	0.97	274	52.46	51.57	0.88	1.34	1.05	714	-0.61	-0.55	-0.06	-0.05	-0.08
year	10205	55.74	55.36	0.38	1.18	0.94	3149	56.97	56.13	0.84	1.41	1.12	7056	-1.23	-0.77	-0.46	-0.23	-0.18

/STANISLAUS_R/MCHENRY_BLW_SPILL_MCH1/TEMP/
Element mid-point river mile: 101.50

	Observations from 27Feb2004 to 07Jun2007						Observations from 12Sep2008 to 25Aug2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	372	49.71	49.05	0.66	1.22	0.98	171	50.72	49.72	1.01	1.79	1.29	201	-1.01	-0.67	-0.35	-0.57	-0.31
Feb	346	52.34	51.44	0.89	1.13	0.95	112	52.29	51.65	0.64	0.93	0.75	234	0.05	-0.21	0.25	0.2	0.2
Mar	496	56.28	55.3	0.98	1.36	1.05	178	57.32	56.84	0.48	1.11	0.87	318	-1.04	-1.54	0.5	0.25	0.18
Apr	480	57.38	56.87	0.5	1.22	0.94	240	55.86	55.28	0.58	1.16	0.86	240	1.52	1.59	-0.08	0.06	0.08
May	496	57.29	56.8	0.49	1.08	0.86	248	58.79	58.94	-0.15	1.21	0.88	248	-1.5	-2.14	0.64	-0.13	-0.02
Jun	386	61.61	61.65	-0.04	1.02	0.8	240	65.83	65.91	-0.07	1.74	1.36	146	-4.22	-4.26	0.03	-0.72	-0.56
Jul	346	66.05	65.91	0.14	0.96	0.78	248	69.57	69.97	-0.41	1.5	1.2	98	-3.52	-4.06	0.55	-0.54	-0.42
Aug	248	64.46	64.3	0.16	0.88	0.67	223	70.25	69.73	0.52	1.32	1.11	25	-5.79	-5.43	-0.36	-0.44	-0.44
Sep	240	63.19	62.36	0.83	1.89	1.41	194	66.81	64.93	1.88	2.26	1.89	46	-3.62	-2.57	-1.05	-0.37	-0.48
Oct	296	58.13	56.94	1.19	1.88	1.45	248	60.04	58.24	1.81	2.13	1.87	48	-1.91	-1.3	-0.62	-0.25	-0.42
Nov	360	54.58	53.33	1.25	1.86	1.5	240	56.35	53.94	2.4	2.59	2.4	120	-1.77	-0.61	-1.15	-0.73	-0.9
Dec	372	51.24	50.07	1.16	1.84	1.37	155	51.36	49.56	1.8	2.4	2.01	217	-0.12	0.51	-0.64	-0.56	-0.64
year	4438	57.27	56.59	0.68	1.39	1.05	2497	60.38	59.54	0.84	1.77	1.39	1941	-3.11	-2.95	-0.16	-0.38	-0.34

Figure G-33. Monthly and yearly statistics in the Stanislaus River at Orange Blossom Bridge and McHenry Spill - Pre 2008 and 2008 thru 2010.

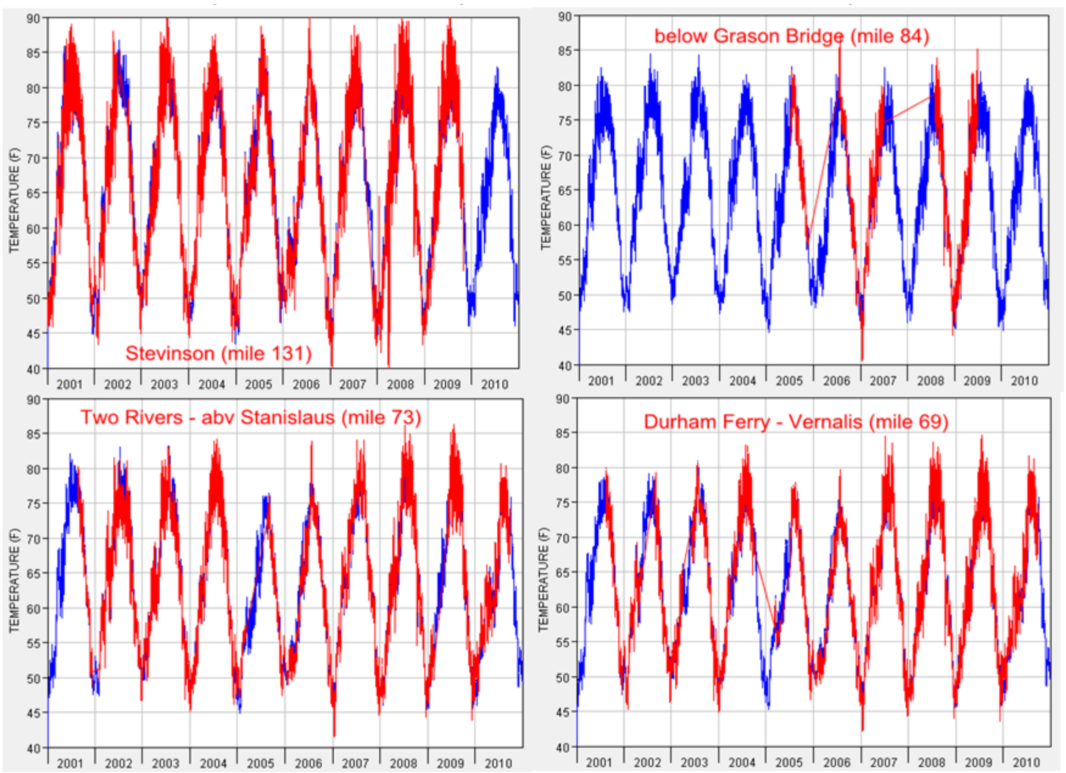


Figure G-34. San Joaquin River– computed and observed temperature figures.

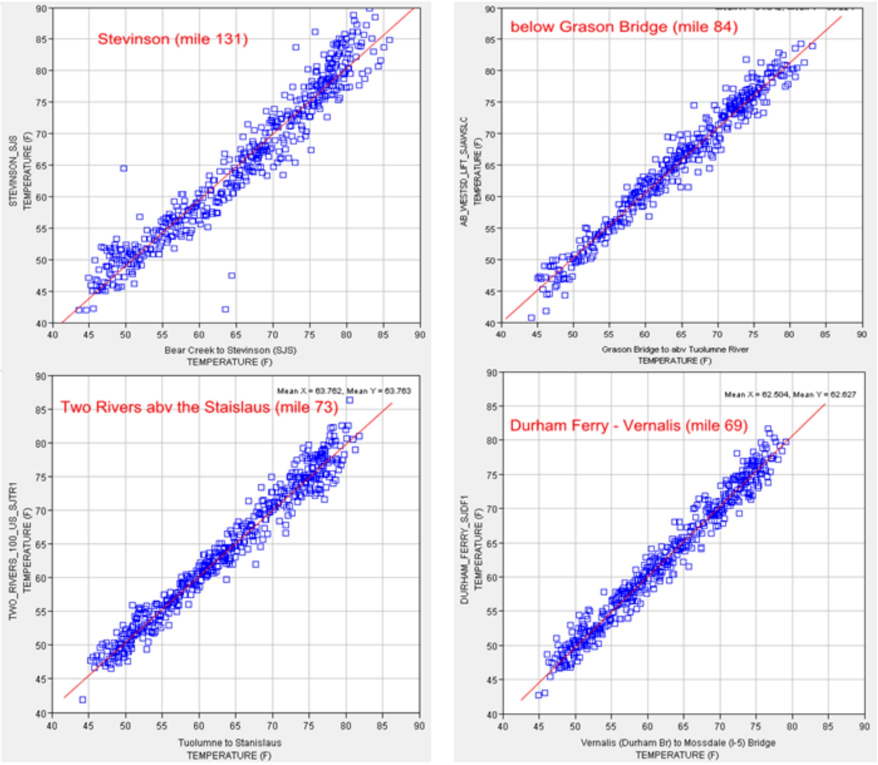
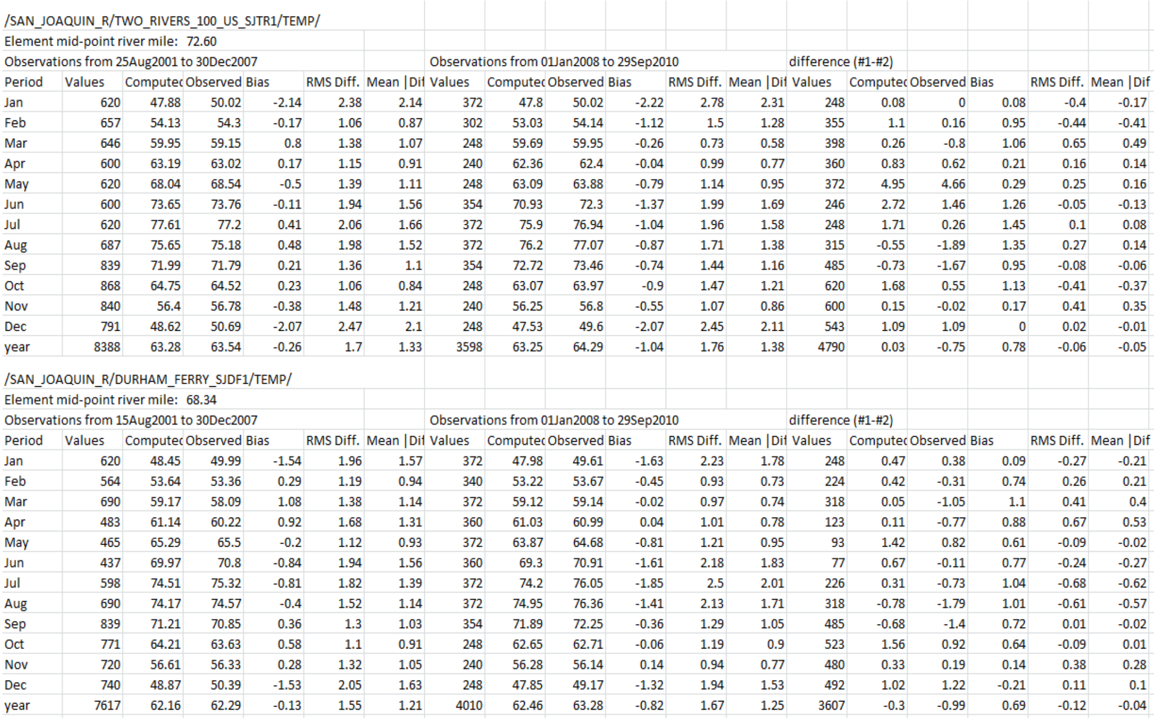


Figure G-35. San Joaquin River – computed versus observed statistics.



/SAN_JOAQUIN_R/TWO_RIVERS_100_US_SJTR1/TEMP/

Element mid-point river mile: 72.60

Observations from 25Aug2001 to 30Dec2007							Observations from 01Jan2008 to 29Sep2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	620	47.88	50.02	-2.14	2.38	2.14	372	47.8	50.02	-2.22	2.78	2.31	248	0.08	0	0.08	-0.4	-0.17
Feb	657	54.13	54.3	-0.17	1.06	0.87	302	53.03	54.14	-1.12	1.5	1.28	355	1.1	0.16	0.95	-0.44	-0.41
Mar	646	59.95	59.15	0.8	1.38	1.07	248	59.69	59.95	-0.26	0.73	0.58	398	0.26	-0.8	1.06	0.65	0.49
Apr	600	63.19	63.02	0.17	1.15	0.91	240	62.36	62.4	-0.04	0.99	0.77	360	0.83	0.62	0.21	0.16	0.14
May	620	68.04	68.54	-0.5	1.39	1.11	248	63.09	63.88	-0.79	1.14	0.95	372	4.95	4.66	0.29	0.25	0.16
Jun	600	73.65	73.76	-0.11	1.94	1.56	354	70.93	72.3	-1.37	1.99	1.69	246	2.72	1.46	1.26	-0.05	-0.13
Jul	620	77.61	77.2	0.41	2.06	1.66	372	75.9	76.94	-1.04	1.96	1.58	248	1.71	0.26	1.45	0.1	0.08
Aug	687	75.65	75.18	0.48	1.98	1.52	372	76.2	77.07	-0.87	1.71	1.38	315	-0.55	-1.89	1.35	0.27	0.14
Sep	839	71.99	71.79	0.21	1.36	1.1	354	72.72	73.46	-0.74	1.44	1.16	485	-0.73	-1.67	0.95	-0.08	-0.06
Oct	868	64.75	64.52	0.23	1.06	0.84	248	63.07	63.97	-0.9	1.47	1.21	620	1.68	0.55	1.13	-0.41	-0.37
Nov	840	56.4	56.78	-0.38	1.48	1.21	240	56.25	56.8	-0.55	1.07	0.86	600	0.15	-0.02	0.17	0.41	0.35
Dec	791	48.62	50.69	-2.07	2.47	2.1	248	47.53	49.6	-2.07	2.45	2.11	543	1.09	1.09	0	0.02	-0.01
year	8388	63.28	63.54	-0.26	1.7	1.33	3598	63.25	64.29	-1.04	1.76	1.38	4790	0.03	-0.75	0.78	-0.06	-0.05

/SAN_JOAQUIN_R/DURHAM_FERRY_SJDF1/TEMP/

Element mid-point river mile: 68.34

Observations from 15Aug2001 to 30Dec2007							Observations from 01Jan2008 to 29Sep2010						difference (#1-#2)					
Period	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Di	Values	Computec	Observed	Bias	RMS Diff.	Mean |Dif
Jan	620	48.45	49.99	-1.54	1.96	1.57	372	47.98	49.61	-1.63	2.23	1.78	248	0.47	0.38	0.09	-0.27	-0.21
Feb	564	53.64	53.36	0.29	1.19	0.94	340	53.22	53.67	-0.45	0.93	0.73	224	0.42	-0.31	0.74	0.26	0.21
Mar	690	59.17	58.09	1.08	1.38	1.14	372	59.12	59.14	-0.02	0.97	0.74	318	0.05	-1.05	1.1	0.41	0.4
Apr	483	61.14	60.22	0.92	1.68	1.31	360	61.03	60.99	0.04	1.01	0.78	123	0.11	-0.77	0.88	0.67	0.53
May	465	65.29	65.5	-0.2	1.12	0.93	372	63.87	64.68	-0.81	1.21	0.95	93	1.42	0.82	0.61	-0.09	-0.02
Jun	437	69.97	70.8	-0.84	1.94	1.56	360	69.3	70.91	-1.61	2.18	1.83	77	0.67	-0.11	0.77	-0.24	-0.27
Jul	598	74.51	75.32	-0.81	1.82	1.39	372	74.2	76.05	-1.85	2.5	2.01	226	0.31	-0.73	1.04	-0.68	-0.62
Aug	690	74.17	74.57	-0.4	1.52	1.14	372	74.95	76.36	-1.41	2.13	1.71	318	-0.78	-1.79	1.01	-0.61	-0.57
Sep	839	71.21	70.85	0.36	1.3	1.03	354	71.89	72.25	-0.36	1.29	1.05	485	-0.68	-1.4	0.72	0.01	-0.02
Oct	771	64.21	63.63	0.58	1.1	0.91	248	62.65	62.71	-0.06	1.19	0.9	523	1.56	0.92	0.64	-0.09	0.01
Nov	720	56.61	56.33	0.28	1.32	1.05	240	56.28	56.14	0.14	0.94	0.77	480	0.33	0.19	0.14	0.38	0.28
Dec	740	48.87	50.39	-1.53	2.05	1.63	248	47.85	49.17	-1.32	1.94	1.53	492	1.02	1.22	-0.21	0.11	0.1
year	7617	62.16	62.29	-0.13	1.55	1.21	4010	62.46	63.28	-0.82	1.67	1.25	3607	-0.3	-0.99	0.69	-0.12	-0.04

Figure G-36. Monthly and yearly statistics in the San Joaquin River above the Stanislaus and at Vernalis - Pre 2008 and 2008 thru 2010.