1.0 Introduction

1.1 Purpose

The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) have jointly developed the CALSIM II planning model of Central Valley Project (CVP) and State Water Project (SWP) operations. The model represents the facilities and hydrology of these two systems and areas tributary to the Sacramento-San Joaquin Delta (Delta).

CALSIM II simulates a variety of factors that control CVP-SWP operations. One of these factors is the assessed water quality (WQ) condition in the lower San Joaquin River. The California State Water Resources Control Board specifies Electrical Conductivity (EC) standards at Vernalis, which are met by release operations at New Melones Reservoir.

New planning questions related to source-specific WQ management in the San Joaquin River Basin have necessitated improved CALSIM II representation of Vernalis salinity estimation. Reclamation's response has been to introduce mass-balance routing capabilities in CALSIM II through development of the San Joaquin River WQ Module version 1.00 (WQ Module ver1.00). The Module disaggregates the Vernalis salinity estimate (i.e. flow rate multiplied by salt concentration) into source components from Lander Avenue to Vernalis. It also provides a modeling framework that can be updated with new source information as our basin knowledge progresses.

WQ Module ver1.00 is presented herein as a first-step product. This report provides information on Module development and testing. The CALSIM II user community is invited to review this report and provide comments on Module documentation, development approach, and potential future areas of improvement. In the interim, WQ Module ver1.00 is available for near-term use in planning studies (e.g., Eastside Integrated Resource Management Plan analyses).

The next section presents a brief history of San Joaquin River WQ modeling improvements that led to the completion of WQ Module ver1.00.

1.2 History of San Joaquin River Water Quality Modeling in CALSIM II

San Joaquin River water quality modeling in CALSIM II has undergone several phases of improvement since 2002. The conceptual beginning for these improvements was featured in the Delta-Mendota Canal Recirculation Feasibility Study (Reclamation, 2002), completed by Reclamation and DWR in compliance with the 1995 Water Quality Control Plan decision. Its objective was to explore the impacts of meeting instream flow requirements at Vernalis by recirculating Delta water through the Delta-Mendota Canal (DMC) and the Newman Wasteway. The analysis required source-to-target modeling so that salinity sources above Maze could be linked to the Vernalis salinity estimate (**Figure 1.1**).

Coincidental with activities of the Recirculation Study, Reclamation was also engaged with DWR in the development of the joint agency planning model, CALSIM II, which was released publicly on September 30, 2002. These initial benchmark studies featured a method for estimating Vernalis salinity that was used in previous San Joaquin operations models (Kratzer). The key to the approach was Maze salinity estimation using a single regression equation, referred to as the Modified Kratzer equation, to estimate Maze electrical conductivity (EC) based on non-Westside flow at Maze. (Note: EC is a proxy for total dissolved solids (TDS) and serves as a measure for salt concentration in the river flow.) The approach also featured EC assumptions for below-Maze and Westside flow flow sources. These assumptions set up a Vernalis EC estimate based on mass balancing of Maze flow, Stanislaus River flow, accretions/depletions, and their respective EC conditions (**Figure 1.1**).

After release of the CALSIM II Benchmark Studies, Reclamation began working on planning questions related to source-specifc WQ management in the San Joaquin River Basin. It was recognized that CALSIM II's "Kratzer" approach was insufficient for this task. The limitation was the Modified Kratzer equation. It was calibrated to one operational environment represented by a period of historical conditions. Using these historical data, a flow-EC relationship was defined. This relationship cannot be used to infer flow-based EC conditions associated with alternative operational settings that involve changes to upstream salinity management (e.g., changes to seasonal flow or seasonal "load" (flow * EC)).

It was decided that the "Kratzer" approach needed to be replaced by source-to-target modeling in CALSIM II. This led to the development of a prototype CALSIM II mass-balance module for the lower San Joaquin River Basin. This prototype was called the "CALSIM II Link-Node Approach" (Reclamation, 2003)). The module represented the conceptual ideas proposed in the Recirculation Study. It was designed to compute salt mass-balance at various river locations from Maze up to Lander Avenue. It addressed the objectives of improving salinity estimation at Vernalis, and explaining salinity sources contributing to the Vernalis estimate. It also featured initial assumptions of source-specific EC conditions along this river reach.

One finding from the CALSIM II Link-Node Approach was that disaggregation of Westside flows contributing to the salt balance might further improve the CALSIM II estimate of San Joaquin River salinity from Lander Avenue to Vernalis. Given that Eastside San Joaquin model refinements were already underway, this finding led to the coordination of two efforts to ultimately translate the Link-Node Approach into a draft version of WQ Module ver1.00.

Both model developments were implemented within a CALSIM II D1641 single-step study, initially featuring San Joaquin logic from the September 30, 2002, Benchmark Studies. The first effort, completed by MBK Engineers and Reclamation, involved refining logic related to Eastside San Joaquin hydrology and operations from the Calaveras River to the San Joaquin River below Friant. This effort featured multiple improvements (**Attachment A**), including:

- changed Eastside demands from contracts-based to land-use based.
- verified Eastside reservoir operations at New Melones and Friant, refined operational representation for local districts, and refined floodwater routing for local districts.
- validated CALSIM II representation of the New Melones Interim Operations Plan and the San Joaquin River Agreement.
- refined San Joaquin River Basin accretion/depletion estimates at Newman and Vernalis.

The second effort, completed by Montgomery Watson Harza (MWH) and Reclamation, involved disaggregating Westside returns in preparation for WQ Module development. This effort involved implementing a modified Westside flow-disaggregation relative to what was proposed in the 2002 Recirculation Study (**Attachment B, Chapters 2 and 3**). The adjusted disaggregation was designed to be consistent with the flow architectures of other San Joaquin hydrologic modeling efforts (e.g., DSM2-SJR, WESTSIM, SJRIO).

Adjustments to the Westside flow-disaggregation and the Eastside hydrology led to a routing schematic for the WQ Module. MWH then developed EC assumptions for sources along the San Joaquin River and applied them in CALSIM II to produce a draft WQ Module (**Attachment B, Chapter 4**). This draft WQ Module allowed for CALSIM II simulation of Vernalis salinity linked to sources between Lander Avenue and Vernalis (**Figure 1.2**).

1.3 Document Organization

The overall structure of the document is as follows:

- Section 2 – additional details on preliminary development steps, completion issues, and how completion issues were addressed.
- Section 3 – sensitivity of CALSIM II results to model changes, measured at New Melones and Vernalis.
- Section 4 – key limitations affecting Module development and suggested limitations of understanding during Module application.
- Section 5 – document summary.
- Section 6 – acknowledgements.
- Section 7 – references.
- Attachment A: DRAFT "*Eastside San Joaquin Hydrology Refinements,*" December 2004, MBK Engineers and Reclamation.
- Attachment B: "*Technical Memorandum, Development of Water Quality Module*," June 2004, Montgomery-Watson Harza.
- Attachment C: "*Memorandum, Quick Summary of Suggested Revisions – CALSIM Water Quality*", 30 August 2004, Daniel B. Steiner.
- Attachment D: *WETMANSIM Assumptions*, March 2004, Nigel Quinn.
- Attachment E: *Water Quality Module WRESL File Guide*

2.0 Completion of CALSIM San Joaquin River Water Quality Module version 1.00

2.1 Preliminary Efforts for Water Quality Parameter Selection

As discussed in Section 1.2, the draft WQ Module produced by MWH served as the starting point for this completion effort. The MWH methodology for selecting water quality parameters featured several key assumptions:

- EC is a surrogate indicator for salinity.
- Salt load equals the product of EC in microSieman per centimeter (μS/cm) and flow rate in cubic feet per second (cfs).
- For any river reach, incoming salt load equals outgoing salt load (conservation of mass).

Data availability was a limiting factor for EC assignment, which was approached differently for two source groups: local creek inflow and non-local creek inflows (e.g., Westside project returns, non-project returns, accretions not attributable to local creek inflow). For non-local creek inflows, EC assignment was based on recent water quality information (i.e. historical records, previous studies, and assumptions from publically released models).

For local creek inflow, EC assignment was inferred through calibration, using a four-step process (**Attachment B, Figure 4-1**). This process was applied upstream to downstream at two locations: Newman and Vernalis.

- Step 1 - The first step occurred at the downstream location and involved characterizing a historically-based flow-EC relationship at that location. MWH used 1985-1998 observations to define these relationships at Newman and Vernalis.
- Step 2 – The second step begins with CALSIM II simulation where the Module's load sources above the downstream location are activated. Simulated flow at the downstream location and the historically-based flow-EC relationship at that location are used after simulation to compute a downstream EC for the simulation period. This EC was multiplied by the flow to compute a downstream load. Unexplained

load was then revealed as the difference between the summation of simulated upstream loads and this downstream load.

- Step 3 – This step involves assigning the load residual to local creek inflow. A decay function was assumed to describe how EC value decreases as local creek inflow increases. Parameters for this function were fit (i.e. calibrated) so that the product of local creek inflow and function-derived EC would produce a local creek load that accounts for as much of the Step 2 load residual as possible.

- Step 4 – The last step involves resimulating CALSIM II with the local creek inflow-EC function activated to compute local creek load during simulation, which then gets added to the loads above the downstream location.

It was found that calibration at Vernalis had to be performed iteratively through Steps 2 through 4. Local creek inflow produces load in this calibration from Newman to Vernalis. This load is a function of the load residual at Vernalis, and 95% of this residual was assumed to occur above Maze. It was found that the fitting of a Step 3 local creek flow-EC function based on a Step 2 residual would change New Melones operations significantly in Step 4. New Melones operations changes led to Vernalis flow conditions that were inconsistent with that used to define load residual in Step 2. However, it was found that by iterating through steps 2 through 4, Step 3 function parameters would eventually stabilize.

2.2 Completion Issues

In June 2004, the draft WQ Module was reviewed by Reclamation, MWH, MBK Engineers, and Dan Steiner in June 2004. The following completion issues were identified:

- Module calculations, assumptions, and data needed external review and verification.

- Source EC assumptions needed to be updated to reflect post-1998 basin salinity management practices. Likewise, historically-based flow-EC relationships at downstream calibration locations also need to be updated to reflect post-1998. Salinity management practices have evolved significantly since 1999 (CVOO, D. Steiner, and N. Quinn, *personal communication,* July 2004).

- Load residual assessment and calibration needed to be updated to reflect EC updates. Also, suggestions were made to move the lower calibration location from Vernalis to Maze. This move would insulate the calibration process from New Melones operations.

- After updating the EC parameters to reflect post-1998 conditions, Reclamation's Central Valley Operations Office (CVOO) needed to review CALSM II results for New Melones WQ release and compare them relative to their operational experience since 1999. CVOO also needed to review simulated Vernalis EC standard-exceedences relative to their post-1998 experience.

2.3 Completion Notes

For the sake of discussion, completion efforts described herein are referred to as Phase 4 of the development efforts, in reference to preceding phases:

- Phase 1: Refinement of Eastside San Joaquin Hydrology and Operations (**Attachment A**)

- Phase 2: Flow Dissaggregation for the Westside San Joaquin Basin (**Attachment B, Chapters 2 and 3**)

- Phase 3: EC assignment for the draft WQ Module ver1.00 (**Attachment B, Chapter 4**)

The reader is strongly encouraged to read Attachment B. It provides a thorough background on Module's development philosophy, flow-routing, variable-name conventions, EC assignment philosophy, and metadata on assigned EC values.

Phase 4 efforts addressed the completion issues above, including (a) review, data updates, and logic modification, and (b) CVOO Review of WQ Module Performance measured by simulated release at New Melones relative to their recent historical experience. Reclamation implemented logic modifications while Dan Steiner provided services to verify Module calculations and obtain post-1998 data to support EC updates relative to Phase 3.

Several main tasks took shape during Phase 4, each of which are described in the following sub-sections:

- (Section 2.3.1) Adjustment to load assumptions at the Module perimeter.

- (Section 2.3.2) Adjustment to accretion/depletion representation above Newman.

- (Section 2.3.3) Implementation of Module load residual assessment rather than calibration, noting changes relative to the Phase 3 procedure:
  - **(Section 2.3.3.1)** Decision not to implement Step 3, where unexplained load is calibrated to local creek inflow.
  - **(Section 2.3.3.2)** Updates to historical flow-EC relationships at Maze and Newman to reflect post-1998 conditions.
  - **(Section 2.3.3.3)** Treating downstream flow-EC relationships as a basis for defining "minimum load" when comparing the upstream load summation versus this downstream load.
  - **(Section 2.3.3.4)** Iterating the assessment at Newman and Maze due to interactions between Vernalis Adaptive Management Program (VAMP) operations and the assessed load residual.

<u>2.3.1 Adjustments to Source Assumptions</u>: The first set of assumption updates involves EC computations for the two Eastside rivers (Tuolumne and Merced) and the upstream San Joaquin river where they cross into the Module domain (**Figure 1.2**). CALSIM II computes EC as a function of simulated flow at these boundary locations (i.e. a flow-EC "rating curve"). In Phase 3 work, these functions were developed using pre-1999 observations of flow and EC . Per Dan Steiner's suggestion (**Attachment C**), the curve fits were updated in Phase 4 to reflect post-1999 conditions. The new curves are shown relative to the previous relationships (**Figures 2.1 through 2.3**).

The next set of assumption updates involves flow and EC patterns associated with refuge operations that send return flows through Mud and Salt Sloughs (**Figure 1.2**). Three assumptions were changed: (1) annual return volume from the Level 2 refuge operations, (2) monthly pattern of this annual return, and (3) monthly EC associated with monthly flow. Steiner suggested that CALSIM II's refuge return flows and Module parameters should be based on recent modeling of Firm Level 2 refuge operations (**Attachment C**) that was completed for the draft Exchange Contractors' Environmental Impact Statement/Report (WETMANSIM-031604-ver01.00 (Quinn 1997; Quinn 2004; **Attachment D**)). In that modeling, Firm Level 2 operations were represented separately for 10 districts tributary to Mud and Salt Sloughs. Operational assumptions were meant to reflect post-2000 operations, and were parameterized based on discussions with operators and their data-provisions (N. Quinn, *personal communication,* September 2004). The following discussions elaborate on how WETMANSIM data were used to change WQ Module inputs.

- Annual Return Volume: CALSIM II simulates annual return as a fraction of annual delivery volume. CALSIM II parameters for this annual return were updated so that simulation returns would be consistent with WETMANSIM-031604-ver01.00. The latter suggests that annual refuge returns of 170,000 af should be expected during a 100 percent refuge allocation year. This amount includes 120 TAF of annual returns from refuge operations and another 50 TAF of agricultural pass-through flows routed through Grasslands Water District. By comparison, the Phase 3 CALSIM II study simulated 84 TAF of annual returns during a 100 percent refuge allocation year.

- Monthly Return Volumes: CALSIM II computes monthly return as a fraction of annual return volume. Based on consideration of WETMANSIM's total returns from the 10 districts, a new monthly pattern of fractions was identified (**Figure 2.4**). The pattern is applied in CALSIM II for all simulation years. Applying this pattern without variation relative to hydrologic year-type is rationalized on the grounds that refuge hydrology is a delivery-driven process except for contributions from precipitation-runoff. Moreover, any precipitation-runoff passing through Mud and Salt Sloughs should be represented in the accretion development for the region above Newman (Phase 1).

- Monthly EC of Returns: The Phase 3 EC assignments for monthly refuge returns were set to equal to the values assumed in the San Joaquin River Input-Output model (SJRIO) . SJRIO includes four different 12-month patterns of EC values, one for each SJRIO year-type. Per Steiner's suggestion (**Attachment C**), monthly EC assumptions were updated to be consistent with information in WETMANSIM-031604-ver01.00. The latter reports monthly WQ of refuge returns, measured as total dissolved solids (TDS). These estimates are based on district-specific recent monitoring (Quinn, *personal communication*, September 2004). For application in this effort, a TDS-to-EC conversion factor of 1/0.64 was used to convert WETMANSIM values into EC. A flow-weighted pattern of monthly EC values was then computed to represent the 10 districts (**Figure 2.5**). This pattern applies for all simulation years.

The final set of assumptions updates stemming from Steiner's review involved Exchange Contractor returns routed through Mud and Salt Sloughs (**Figure 1.2**). Phase 3 EC values were set equal to SJRIO assumptions, which involved four 12-month patterns mapped to four SJRIO year-types. Per Steiner's suggestion (**Attachment C**), these EC assumptions were changed to reflect monthly 2000-2003 observations of Exchange Contractors' EC of return flows (summarized in **Attachment C**). The monthly maximums from this four-year observation period were selected to be the updated pattern (**Figure 2.6**).

Steiner's review also raised two miscellaneous issues. The first involved May accounting logic for New Melones WQ releases and the second involved the occurrence of EC reporting as zero for one Westside return near Vernalis (EC_R639_F). Regarding the first issue, an error was corrected in the accounting logic, where New Melones WQ releases during the May VAMP Non-Pulse period were not getting debited from the annual release allocation for Vernalis EC obligations. Regarding the second issue, the instances of EC_R639_F reporting as zero were found to be correct per Module design. When the associated return flow (i.e. R639B) approaches zero, the reported EC is set equal to zero rather than allowed to be reported as a near-infinite value (i.e. EC = source load divided by flow).

<u>2.3.2 Changes to Accretion/Depletion Representation Above Newman</u>: While implementing Steiner's suggested EC updates, a problem was found with the accretion/depletion assessment for the Above Newman region (Phase 1, **Attachment A**). Before describing the problem, it should first be noted that the variables were developed using reasonable methods with uncertainties noted:

- Gages with long periods of record were used to define upstream and downstream flow points for a historical mass balance calculation. These gages are located at the downstream location of Newman and at the upstream locations of Hidden Dam, Buchanan Dam, and Friant Dam (**Attachment A**)).

- Before comparing regional inflow to regional outflow (i.e., flow difference assessment), the regional inflow was adjusted positively for historical diversions and seepage assumptions and negatively for historical return flows. For the Above Newman region, seepage was estimated along the Fresno and Chowchilla Rivers immediately below Hidden and Buchanan Dams, and along the San Joaquin River between Bifurcation and Friant Dam (**Attachment A**).

- Comparison of the adjusted inflow and outflow revealed a time series flow residual. This net residual is "accretion" if positive and "depletion" if negative. Since precipitation-runoff isn't explicitly identified as a water budget term, it is generally accepted that the accretion instances are proxies for precipitation-runoff entering the region or occurring within the region. The depletion instances are generally viewed as proxies for unexplained channel seepage.

- These net flow residuals were then placed at the Newman node as a 1922-1998 input time series, representing upstream precipitation-runoff and unexplained seepage processes during simulation.

Review of Phase 3 simulation results revealed a that during depeletion months, the Above Newman depletion magnitude was often inconsistent with mass balance at Newman. For example, in approximately 10 percent of the simulation months, the flow leaving the San Joaquin-Merced River confluence was less than the Merced flow entering the confluence.

In retrospect, it appears data inconsistencies led to the excessive estimates of net regional depletion. This also raises questions about the accuracy of the accretion estimates. Remedies were considered; the first involving disaggregation of the water budget analysis to sub-regions. In short, local area gage information in the Above Newman region does not enable depletion estimation prior to water year (WY) 1965, whereas CALSIM II requires monthly depletion assignment to 1922-1998 simulation years. The time-extrapolation required for local area depletion estimation was viewed to be too speculative. Similar conclusions were made for other sub-regions in the Above Newman region.

Given data limitations, an alternative approach was adopted with several simplifying assumptions that determine Above Newman accretion/depletion during CALSIM II simulation:

- <u>Assumption 1 – Depletions in the San Joaquin River between Lander Avenue and Newman:</u> This river reach is approximately 12 miles long and proximate to wetlands. Noting the estimation of persistent base flow in Mud/Salt Sloughs (Phase 1 and 2 work), it is assumed that groundwater conditions prevent significant depletion from the river as it travels along this reach. Therefore, assume no depletion along this reach during simulation.

- Assumption 2 – Depletion in the Bypass Structure during Non-Flood Control Situations: This structure is named Chowchilla Bypass at its head and Eastside Bypass where it returns to the San Joaquin River. It re-routes part of the flow at Bifurcation (above Mendota Pool) during high flow periods. It also collects residual flows from the Fresno and Chowchilla Rivers. It is assumed that when the bypass structure is not re-routing flows at Bifurcation (i.e., Chowchilla Bypass has zero flow), then the Eastside Bypass is also dry. This means that when Chowchilla Bypass has zero flow, the Fresno and Chowchilla Rivers are not connected to the San Joaquin River. Therefore, full depletion of the Fresno and Chowchilla Rivers' residual flows is assumed when the Chowchilla Bypass is empty at its head and all other potential bypass accretions are also assumed to be zero.

- Assumption 3 – Depletion in the Bypass Structures during Flood Control Situations: It is assumed that when the Chowchilla Bypass is operated for flood control, depletion processes are small relative to flows passing through the Bypass and are, therefore, ignored.

- Assumption 4 – Depletion in the Mainstem San Joaquin River between Mendota Pool (Sack Dam) and Lander Avenue: It is assumed that when Sack Dam is releasing flow, it is likely to be associated with wet season flow operations and that these releases are not likely to experience significant depletion between Sack Dam and Lander Avenue.

- Assumption 5 – Accretion Placement in CALSIM II Above Newman: Accretion volumes are assumed to largely reflect precipitation-runoff processes above Lander Avenue, which is the outflow point for much of the Above Newman watershed. This placement causes the accretion flow to be added to upstream releases. Placement at Lander Avenue is appropriate because the WQ Module includes a flow-EC boundary condition at Lander Avenue (**Figure 2.1**) associated with a flow that should already reflect most of the Above Newman accretion. The fraction of accretion that might occur between Lander and Newman is ignored.

Assumption 2 was tested using a monthly water budget analysis from WY1972-1986. The water budget area includes the bypass structure and lower reaches of the Fresno and Chowchilla Rivers. The flow residual for this water budget is a local area accretion/depletion that equals Eastside Bypass Flow near El Nido minus the sum of inflows from the Chowchilla River, Fresno River, and Chowchilla Bypass at Head.

Data for Lower Chowchilla and Fresno River flows were provided by Phase 1 efforts (**Attachment A**). Additional data were obtained for Chowchilla Bypass at Head (DWR Gage BO-7802) and Eastside Bypass near El Nido (DWR Gage BO-0435). The analysis was performed on a monthly basis during months of no data gaps (i.e., October 1972-June 1973, February 1974-July 1974, October 1975-August 1978, September 1978-February 1979, and April 1979-September 1986).

Results show that Assumption 2 is correct in approximately 80 percent of the months (**Figure 2.7**). Contradictions to Assumption 2 occurred in other months when Eastside Bypass flow was measured even though the Chowchilla Bypass had no flow. During these months, Eastside Bypass flow volumes are typically small, but do exceed 10 TAF in about 5 percent of the months.

The significance of these error months is that if we apply Assumption 2 during CALSIM II simulation and force the Eastside Bypass to be "dry" when Chowchilla Bypass is "dry," then we may be missing some flow from the Chowchilla/Fresno Rivers region. This would lead to underestimation of flow at Lander Avenue and overestimation of EC at Newman and downstream locations.

Assumptions 3 and 4 produce different risks than Assumption 2. The assumptions hold that during high-flow events through the Bypass or below Sack Dam, seepage volumes are insignificant or much smaller than net channel flow volumes. However it is recognized that the contrary may be the case. If flood-control objectives require bypass operation or Sack Dam release, and if depletion processes are significant during these events, then CALSIM II would tend to overestimate flow at Lander Avenue and underestimate EC at Newman.

The risks posed by these assumptions affect the load residual assessment for the Above Newman region (described in subsequent sections). Results from the Above Newman load residual assessment then propogate to potentially affect the Maze load residual assessment. However, because of the historical flow-EC relationships defined for Maze (shown in a later section), it turns out that the Above Newman accretion/depletion assumptions are not controlling for below Maze simulation results (i.e. Vernalis and New Melones operation outcomes).

Given this finding and as long as operations above Lander Avenue are held static, these accretion/depletion assumptions do not affect the Module's applicability for effects analyses on below-Lander management alternatives. In such analyses, incremental adjustments to below-Lander management (e.g., Westside returns Above Newman) would propagate through the Module's mass-balance framework. Meanwhile the Above Newman accretion load would remain constant because there would be no change in the Lander Avenue flow attributable to accretion. However, the Lander Avenue load could change slightly as changes at Maze could affect New Melones conditions, which might then affect VAMP operations at Mendota Pool.

If the operations above Lander Avernue become a target for management alternatives, then the accretion/depletion assumptions need to be revisited. Another reason for revisiting these assumptions would be applications requiring more accurate load partitioning Above Newman between natural processes and managed processes. However, both concerns were considered to be outside the scope of WQ Module ver1.00.

<u>2.3.3 Updating the Load Residual Assessment</u>: After making updates to source flow/EC assumptions and Above Newman accretion/depletion, the Module load residuals had to be reassessed. The assessment involves identifying load not explained by the Module's source assumptions when compared against historical flow-EC relationships at various locations in the San Joaquin River (Section 2.1, Step 2 of the calibration procedure). In Phase 4 work, these assessments were located just above the Merced confluence (i.e. Above Newman) and just above the Stanislaus confluence (i.e. Maze) (**Figure 2.8**).

Once the load residual is identified, and whether or not it is calibrated to local creek inflow (Section 2.1, Step 3 of the calibration procedure), the residual is inserted as another input to the Module for CALSIM II simulation. Following Phase 3 – Step 3, the residual would be introduced at local creek inflow locations (**Attachment B, Chapter 3**). If Phase 3 - Step 3 isn't followed, then the residual would be introduced as a load not mapped to flow (but understood to be related to accretions, which is discussed later) and distributed among the Module's mainstem San Joaquin River nodes. This assignment of residual distribution to CALSIM II nodes is similar to how flow residuals (i.e. accretion/depletions) are positioned in the model.

Whether introduced into the Module with local creek inflow or as a distributed load residual, the respective inputs are held constant during any CALSIM II analyses involving salinity management changes. For example, one might wish to study the effects of changing Mud/Salt Slough's loading patterns relative to a baseline. The Module's mass-balance mechanism would route this Mud/Salt Slough change down to Maze, where it would trigger different New Melones operations and Vernalis outcomes. Let's assume that the load residuals for Above Newman and Maze are introduced with local creek inflow for these simulation. The input time series for local creek inflow and the input parameters for the local creek flow-EC function (calibrated in Phase 3 – Step 3) should be unaffected by this change and are therefore held constant. The rationale is that these residual inputs and parameters were determined when the baseline was developed, and they are meant to represent unmanaged processes in the baseline. It is assumed that these unmanaged loading processes would persist in any alternative study.

If new information arrives suggesting that the basin's status quo for salinity management has changed relative to the conditions assumed during development of the baseline (i.e. WQ Module ver1.00), then the load residuals need to be reassessed. However, this re-assessment should be confined to the period reflecting the recent change, which may create data limitations if the period is short. The re-assessment would involve a recognized date of basin, source EC conditions since that date, mainstem historical flow-EC relationships since that date, and then load residual re-assessment.

<u>2.3.3.1 Decision to Not Calibrate Load Residual to Local Creek Inflow</u>: Step 3 of the Phase 3 calibration procedure is based on the reasonable premise that precipitation-runoff events account for much of the load disparity between source assumptions and mainstem expectation. However, reasonable calibration of the local creek flow-EC curve parameters depends on the accuracy of the local creek inflow variable as a predictor.

The uncertainties of the Above Newman accretion are significant (Section 2.3.2). After netting out baseflow and tile drainage components, the results local creek inflow variable for Above Newman inherits these uncertainties. Likewise, the uncertainties of the Newman-to-Vernalis local creek inflow are also significant (**Attachment A**). Focusin on the latter, the Newman-to-Vernalis local creek inflow is allocated in the CALSIM II domain to two reaches (**Attachment B**): Newman-to-Maze (95 percent) and Maze-to-Vernalis (5 percent). A plot of the Maze load residual versus the Newman-to-Maze accretion reveals a lot of scatter (**Figure 2.9**). The variability in the accretion is largely retained in the variability Newman-to-Maze local creek inflow; the baseflow and tile drainage components are much less variable. Therefore it seems that the amount of scatter in the Newman-to-Maze local creek inflow undermines the notion that it can be used to predict an associated

EC, and that their product should equal the load residual assessed at Maze (which is the assumption of the Phase 3 – Step 3 calibration procedure).

Given the uncertainties of the accretion estimates, it was decided that the calibration portion (Step 3) of the Phase 3 approach for load residual assessment should not be implemented until the accretion/depletion flow estimates are refined. It would be desirable to have the accretion/depletions eventually based on process simulation, rather than inferred from the error term in a regional flow-balance. For completion of WQ Module ver1.00, the load residuals are distributed among the Module's mainstem San Joaquin River nodes (**Figure 2.10**).

2.3.3.2 Updating the San Joaquin River Flow-EC Relationships: As explained in Section 2.1, Step 1 of the load residual assessment is defining an historical flow-EC relationship at the downstream location relative to the region for residual assessment. In Phase 3, rating curves were developed at Vernalis and Below Newman based on 1985-1998 data (**Attachment B**). For Below Newman, one curve was developed to apply for all months. For Vernalis, separate curves were developed for each calendar month. In the Phase 4 work, the locations were changed to Above Newman and Maze. Also, following the philosophy that the WQ Module should reflect recent basin operations, post-1998 flow-EC observations were used to develop the new downstream rating curves.

At Above Newman, 2000-2004 monthly observations were pooled into three seasons for which separate curves were developed: August-November, December-March, April-July (**Figure 2.11**). The monthly flow data were computed, rather than measured, as the difference between flow downstream of the confluence (i.e. cdec.water.ca.gov, station I.D. "NEW") and just above the confluence on the Merced River (i.e. cdec.water.ca.gov, station I.D. "MST"). The monthly EC data were computed from weekly grab samples (Station H, "San Joaquin River at Hills Ferry," Central Valley Regional Water Quality Control Board). The season selections are comparable to Firm Level 2 Refuge operations' seasonal regimes for return flows through Mud/Salt Slough (WETMANSIM-031604-ver01.00).

At Maze, 1997-2003 monthly observations during "low-flow" conditions were pooled into six season for which separate curves were developed: December-January, February-March, April-May, June-July, August-September, and October-November (**Figures 2.12a and 2.12b**). In this context, "low-flow" was assumed to be less than 5000 cfs. Months with average flow greater than 5000 cfs were not considered. The monthly flow data were provided by the

CA Department of Water Resources, Division of Planning and Local Assistance (D. Steiner, *personal communication*, September 2004). The monthly EC data were computed as extrapolated monthly values from intermittent grab samples (extrapolated data by Dan Steiner, *personal communication,* September 2004). The Maze EC grab sample data were provided by the CA Department of Water Resources, Division of Planning and Local Assistance (Dan Steiner, *personal communication,* September 2004).

The season selections for Maze rating curves were driven by a desire to resolve February-March EC conditions relative to other months. CVOO suggested that February and March EC conditions at Maze in recent years are necessitating New Melones WQ releases that contrast with releases during December-June and April-May (CVOO*, personal communication, Sep 2003*). The curve fit for the February-March season supports CVOO's suggestion (**Figure 2.12b**) as it stands out relative to the December-January and April-May curve fits.

The reliability of the Above Newman curve fitting is severely limited by the WQ Module's development philosophy where WQ parameter assignment is based on recent conditions. This creates a sparse data basis for both upstream and downstream assumptions relative to the load residual assessment. Moreover, the 2000-2004 period of record does not contain higher flow occurrences which were considered to be important for curve fitting. To mitigate the latter, a decision was made to constrain the curve fit using a synthetic high flow case (**Figure 2.11**). The case is consistent with the upstream flow-EC boundary condition on the San Joaquin River at Lander Avenue. This high flow case is admittedly a critical assumption for constraining the Above Newman load error assessment. However, using the high flow case ensures the intuitive result of an attenuating relationship between EC and increasing flow.

Aside from sparse data conditions, the Above Newman curve-fitting is also limited the EC data available for curve fitting. These data are collected at the Hills Ferry location (Station H, Central Valley Regional Water Quality Control Board) which is not insulated from mixing processes at the Merced and San Joaquin Rivers' confluence. Therefore, it is questioned whether these data truly represent an estimate of Above Newman EC.

For the Maze location, the curve fitting reliability is primarily limited by sparse data conditions, similar to the Above Newman location. This spareness was exacerbated by the decision to focus on months when flow was less than 5000 cfs, primarily for affecting the February-March curve fit when most historically high-flow months occurred. The decision seem justified because including the higher flow cases produces a wet-season curve fits that were leveraged too greatly by high-flow cases, leading to underestimates of EC at lower flows, which is the critical flow regime for New Melones WQ operations. In contrast, focusing on the lower flow cases produces rating curves that underestimate EC at higher flow cases, which are believed to be less critical for simulation purposes.

The significance of theses curve-fitting uncertainties varies between Above Newman and Maze. For Maze, the curves determine load residual assessment, simulated Maze EC, and therefore New Melones WQ operations. They also determine interpretation of source disaggregation between Newman and Maze. For the Above Newman, the curves only determine interpretation of source disaggregation Above Newman. However, they are not a factor for interpretation of New Melones operations. The reason for the latter is discussed in the next section.

<u>2.3.3.3 Assuming Downstream Load as Minimum</u>: Following Step 2 of the Phase 3 residual assessment procedure, there are some situations when the summation of upstream load sources was greater than the downstream assumption based on the flow-EC rating curves. These occasions are referred to as "negative load residuals" since residuals equal downstream load minus upstream summation. Cases of negative residuals were found to be infrequent relative to positive residual cases (e.g., **Figure 2.13**).

For the instances of negative residuals, it was decided that the collection of upstream assumptions should be believed rather than the downstream assumption. This means not debiting the upstream summation by the negative residual just to comply with the downstream load value. Therefore, after constructing a 1922-1998 monthly time series of load residuals (i.e. Section 2.1, Step 2 of the calibration procedure), all instances of negative residuals were reset to have zero value before introduction into CALSIM II.

The assumption of setting negative residuals to zero is benign as long as months of reset do not coincide with months of simulated New Melones WQ release. If this coincidence occurs, then the reset assumption becomes controlling on New Melones operations. This would then necessitate reconsideration of the reset assumption's reasonability since it is a critical driver of model results.

It was found that the reset assumption was not controlling model results. CALSIM II results using WQ Module ver1.00 were evaluated. These results are based on Above Newman and Maze load residuals being developed and reset sequentially, with Above Newman reset residuals being a boundary condition on the Maze assessment (i.e. the Newman-to-Maze load summation was conservatively large promoting the chance for more negative residuals at Maze). Results show that months of New Melones WQ release only coincide with months of positive Maze load residual (**Figure 2.14**), and not with months of negative residuals from the non-reset Maze residual time series (**Figure 2.13**). (Note: Contrary to ideas proposed at Module briefing meetings during Fall 2004, it is unnessary to check for coincident occurrences of Above Newman negative residuals and New Melones WQ releases. This is because the Maze load residual was conservatively assessed with reset Above Newman residuals, and there were still no coincident occurrences between Maze negative residual and New Melones WQ release).

Another message stemming from this analysis of results is that the Maze rating curve fits are critical for Module performance in relation to simulated New Melones operations. They should therefore be viewed with scrutiny. At the very least, their fits should be updated annually as new flow and EC data become available at Maze. Assuming that basin conditions are reasonably stable relative to 1998, these annual data arrivals could be appended to the historical flow-EC data sets used to fit curves in **Figures 2.11** and **2.12a,b**.

<u>2.3.3.4 Iteration Issues:</u> It was found that iterations in load residual assessment were not altogether avoidable by moving the assessment location from Vernalis to Maze. Some degree of iteration was incurred by VAMP operations interacting with source flows above Maze.

To illustrate, consider the load residual assessment at Above Newman. CALSIM II simulates Mendota Pool VAMP operation as an explicit load source Above Newman. Load residual is then assessed at Above Newman and introduced into the domain. Running CALSIM II with this additional load error term changes downstream EC conditions, affects Maze EC and New Melones operations, which causes perturbations in Mendota Pool VAMP obligations relative to those that supported the original load residual assessment. Thus, an iteration situation is created by VAMP. **Figures 2.15 and 2.16** illustrate that approximately four iterations of assessment were necessary at Above Newman and Maze in order to arrive at stable residuals.

3.0 Sensitivity of CALSIM II Results to Implementing San Joaquin River Water Quality Module version 1.00

Release of WQ Module ver1.00 marks the completion of a significant set of of CALSIM II changes (i.e. Eastside San Joaquin hydrology, Westside returns dissaggregation, mass-balance salinity computation below Lander Avenue). These changes improve CALSIM II San Joaquin representation so that it more closely matches current operational experience in the basin. While these changes are viewed to be an improvement, there is concern that their collective effect on CALSIM II results will contradict currently held paradigms on what CALSIM II is expected to show regarding San Joaquin simulation. In particular, this concern applies to CALSIM II WQ modeling results at Vernalis and release results at New Melones.

This section presents an evaluation of model sensitivity to San Joaquin changes, focusing on two WQ output metrics:

- New Melones release for Vernalis EC obligation.
- Vernalis EC outcomes relative to standard.

CALSIM II results were tracked through six of the studies developed during the process of making San Joaquin changes, spanning the four phases of development. Results from these studies are compared against recent years of operating experience. The six studies are:

- Study 1) "OCAP Today"
    - This is a multi-step study. However, only D1641-step results are queried for comparison with Studies 2-6, which were D1641 single-step simulations. In Study 1, the San Joaquin representation is consistent with the September 30, 2002 CALSIM II Benchmark Studies: Eastside hydrology includes contract-based water demands; Westside return flow architecture is pre-disaggregation; and Maze salinity is computed using the Modified Kratzer equation, with domain indicated in **Figure 1.1**.
- Study 2) "Phase 3"
    - This is a D1641 single-step study. It reflects cumulative effects from development Phases 1 through 3 (Section 2.1). Eastside hydrology was changed in Phase 1 to reflect land-use based

demands. The development study assumes land use that reflect "existing conditions," or recent historical surveys (**Attachment A**). Westside return flows were disaggregated per Phase 2. Maze salinity is computed using a draft version of the WQ Module, with parameter assumptions completed per Phase 3 (**Attachment B**).

- Studies 3-5) "Phase 4, Iter 1", "Phase 4, Iter 2", "Phase 4, Iter 3"
    - These are all D1641 single-step studies, incorporating developments from Phases 1-3, but with completion changes noted in Section 2. "Iter" refers to iterations of the load residual assessment at Maze, when load residual was still being adjusted to be in balance with VAMP operations (Section 2.3.3.4).
- Study 6) "Phase 4, Iter 4"
    - This study reflects the final iteration of load residual assessment at Maze and contains the completed WQ Module ver1.00.

Note that this section offers preview sensitivity analysis to a larger effort that can be completed after baseline study preparations for the Eastside Integrated Resources Management Plan (Eastside IRMP). In that effort, the San Joaquin changes from Phases 1-4 have been implemented migrated from their D1641 single-step framework into the CALSIM II multi-step framework (D1485, D1641, B2, JPOD, EWA). Once those studies are finalized (early 2005), a larger cross-section of model results pertaining to San Joaquin operations can be evaluated.

3.1 New Melones Release for Vernalis EC Obligation

CALSIM II simulation of New Melones WQ release is consistent with the 1997 New Melones Interim Plan of Operation (NMIPO). Monthly water quality releases are determined after establishing releases for senior water rights holders and minimum instream flows below Goodwin Dam per the 1987 Agreement between Reclamation and the California Department of Fish and Game (1987 DFG flows). Given flow conditions associated with releases for 1987 DFG obligation, the EC condition at Vernalis is assessed and compared to standard. If the condition exceeds standard, then CALSIM II computes the additional New Melones release required to reduce the EC condition to standard, capped by the availability of remaining annual WQ allocation per NMIPO.

This section explores modeling sensitivity for New Melones WQ release using two metrics. The first is the monthly probability that CALSIM II will simulate a WQ release requirement. Probability statements are made based on modeling occurrence. The second is the average release amount during months when WQ release are made.

3.1.1 Release Occurrence: Before examining results from Studies 1-6, Reclamation operators of New Melones were interviewed to define expectations for release occurrence based on 1999-2003 experience. It was suggested that WQ release obligations should be anticipated from January through August. The monthly percentage frequency from 1999-2003 is shown on **Figure 3.1**. The data show that for January, a WQ release was made in once of those five years. In February and August, WQ releases were made in two of the past five years. And for March through July, WQ releases have occurred in three of the past five years. It may be that these percent frequencies are biased estimates of a longer term monthly likelihood because 1999-2003 represents a spell of somewhat drier years. The 1999-2003 San Joaquin WYs happened to be classified as Above Normal, Above Normal, Dry, Dry, and Below Normal according to the San Joaquin 60-20-20 Index (http://cdec.water.ca.gov/cgi-progs/iodir/WSIHIST). It is assumed that WQ releases should be more likely during drier years than in wetter years.

Figure 3.1 shows simulated release frequencies from Studies 1 through 6. These frequencies are based on much larger monthly data pools than the CVOO experience, as they represent long-term averages from 73 years of simulation (i.e., numerated as WY1922-1994). It is assumed that a monthly frequency pattern based on the long-term average might show lower frequencies than the 1999-2003 pattern if the latter does have a drier-year bias. Therefore, comparing the study frequencies against the 1999-2003 experience should involve some bias consideration, albeit subjective.

There appears to be an improving shift in CALSIM II output results toward the recent experience. Before any changes (i.e. Study 1), CALSIM II would suggest that summer release occurrence was more frequent than recent CVOO experience. In contrast, Study 1 showed relatively infrequent winter release occurrences. Following implementation of San Joaquin hydrology changes and draft WQ Module development (Study 2, "Phase 3"), the release frequencies showed a summer-to-winter seasonal shift in release occurrence, and appear to be more consistent with CVOO experience. Completion of WQ Module ver1.00 affected the magnitude of this shift, but the general pattern of more winter and fewer summer releases relative to Study 1 is still apparent.

Release occurrence from Studies 1 and 6 were analyzed in relation to San Joaquin 60-20-20 year-type (**Table 3.1**). Release occurrence was also used to estimate percentage likelihoods that CALSIM II will simulate a WQ release during a given month and year-type (**Table 3.2**). Results show that before implementation of model changes, CALSIM II would always simulate summer WQ releases during Below Normal, Dry, and Critical year-types, while virtually never simulating WQ release during winter months except during March in a few Critical years. After model changes, the summer releases during Below Normal and Dry year-types happen less than 100 percent of the time, whereas the chances increase significantly for winter releases during Below Normal, Dry and Critical years.

<u>3.1.2 Monthly Average Release given Occurrence:</u> Instances of required release from 1999-2003 were evaluated to identify general trends in expected release magnitudes given occurrence. Threshold release expectations were estimated to be 400 cfs and 200 cfs for the periods of February-March and June-August respectively, based on release experiences from 1999-2003 (CVOO staff, *personal communication,* September 2004).

Figure 3.2 shows a comparison of these flow expectations relative to model averages from Studies 1 through 6. Model averages are based on first identifying months of WQ release, and then developing monthly averages using only those months (i.e. n varied by month according to simulation results).

There appears to be an improving shift in seasonal CALSIM II results toward expectation based on 1999-2003 experience. Before changes, Study 1 ("OCAP Today") suggested summer release amounts that exceed expectation. In contrast, winter release amounts were quite low. Following changes to San Joaquin hydrology and draft WQ Module development (Study 2, "Phase 3"), there average winter release increased while the average summer release decreased. However, the winter and summer release magnitudes from Study 2 exceeded expectation based on 1999-2003 experience. Following completion of WQ Module ver1.00 (Studies 3-6), the final average release requirements still exhibit a seasonal pattern that resembles CVOO expectation. However, the average magnitudes of release are somewhat lower than expectation.

3.2 Vernalis EC Standard Exceedences

CALSIM II determines New Melones WQ release operations based on two factors: (1) an assessment of Vernalis EC condition relative to standard, and (2) an assessment of remaining New Melones supply allocated for Vernalis EC support per the NMIPO. The standard used for the first factor is 700 μS/cm April-August and 1000 μS/cm September-March. The second factor is establishes simulated release limits that are updated monthly in relation to an annual allocation updated every March. Depending on conditions, it is possible that Vernalis EC conditions will require complete consumption of the annual WQ allocation before February. If Vernalis EC persists above standard after the month when allocation is extinguished and before the next March, then the model will indicate such conditions by reporting a Vernalis EC above standard (i.e. a Vernalis EC Standard Exceedence).

The occurrence of Vernalis EC Standard Exceedence was evaluated for Studies 1 through 6 (**Figure 3.3**). Before making model changes (Study 1), CALSIM II results would show frequent occurrences of Vernalis EC Standard Exceedences during summer months. Given 73 years of simulation with results pooled by by month, the percentage frequency of exceedence occurrence was 25 percent in July, 45 percent in August, and 38 percent in September. After making model changes and completing WQ Module ver1.00 (Study 6), the percentage frequencies decreased sharply. The peak months are February an August, and their percent frequencies are still less than 10 percent.

To address the reasonability of new results, recent historical EC conditions at Vernalis were considered. Daily EC conditions from August 1999 to present were obtained from the California Data Exchange Center (http://cdec.water.ca.gov/staMeta.html, station ID: "VER"). **Figure 3.4** shows monthly average EC conditions from August 1999 through October 2004. No exceedences were observed on this basis during the historical period, implying that CALSIM II results might be reasonable relative to recent historical experience. However, the monthly averages mask exceedence occurrence at the daily level (**Figure 3.5**). These exceedences occurred during each year from 1999-2003, and seem most prevalent in the February-March and June-August periods.

The shift in exceedence frequencies from Study 1 to Study 6 is significant. The latter study's results may challenge commonly held paradigms on what CALSIM II should show in terms of Vernalis EC Standard Exceedences. However, it is emphasized that the development efforts for WQ Module ver1.00 were designed to capture basin conditions since 1999. It is assumed that salinity management has evolved significantly in these recent years relative to prior years, for which older versions of CALSIM II were more representative.

3.3 Summary

The implementation of WQ Module ver1.00 improves the seasonality of CALSIM II results relative to experience. The frequency and magnitude of WQ releases at New Melones during winter and summer seasons are more reflective of the 1999-2003 experience, relative to CALSIM II results before model changes. As noted, the model results continue to show average release magnitudes that are less than recent historical experience. Future work efforts might focus on refining release expectations and/or identifying WQ Module features that produce results that depart from these expectations.

The combined effects of changes to Maze salinity computation and the reactions of New Melones operations lead to fewer Vernalis EC Standard Exceedences in the modeling results. The new exceedence frequencies are consistent with recent historical data at Vernalis when analyzed on a monthly basis. However, monthly average exceedence frequencies can mask the occurrence of daily exceedences.

It was concluded in Section 2.3.3.3 that the Maze flow-EC rating curve-fit is the key factor in driving sensitivity results on New Melones release and Vernalis EC Standard Exceedence because the Maze load residual during months of simulated New Melones WQ release was always positive (**Figure 2.14**). Another factor is that changes in upstream flow hydrology are producing greater amounts of lower San Joaquin flow. To illustrate, the difference in average monthly Vernalis flow by year-type is shown for Studies 1 and Study 6, along with the differences (**Table 3.3**). The average annual increase from Study 1 to Study 6 in Dry and Critical years flow volume is 108 and160 TAF/year, respectively. These changes are mostly attributable to adjustments in refuge returns through Mud/Salt Slough during drier years. The average annual increase during Wet Years is 730 TAF/year, which is primarily attributable to changes in Eastside Hydrology (**Attachment A**). Increasing the flow volume at Maze decreases the Step 2 downstream EC assignment during Maze load residual assessment (see the Maze flow-EC rating curve, **Figures 2.12a and 2.12b**). This would generally decrease the magnitude of positive load residuals that were found to coincide with New Melones WQ releases during simulation. Therefore it can be said that augmented flows coded into CALSIM II per changes to Eastside Hydrology and Westside Refuges representation are contributing to reduced Maze EC conditions during simulation. Such reductions would trigger less need for New Melones WQ release and less likelihood for Vernalis EC Standard Exceedence.

4.0 Limitations

WQ Module ver1.00 should be viewed as a first-generation CALSIM II product for salinity mass-balancing along the San Joaquin River. This product's intended use is for incremental planning studies related to changes in New Melones operations in relation to changes in below-Lander salt-management practices. These studies should not be performed without consideration of key Module limitations that relate to data and Module structure uncertainties. Key module uncertainties are described below:

1) **<u>Source EC Assumptions</u>**: Only a few years of observations were used to establish source assumptions (e.g., post-2000 information for refuge and exchange contractor returns through Mud/Salt Sloughs). Basin conditions have been changing since 1999 due to evolving approaches to salt management (D. Steiner, *personal communication*, September 2004; N. Quinn, *personal communication*, November 2004). It is important to revisit these EC assumptions periodically in the coming years as basin operations continue to develop.

2) **<u>Above Newman Accretion/Depletion</u>**: Data uncertainties limited the applicability of accretion/depletions developed for the Above Newman region (Section 2.3.2). Because the calculated depletion values caused mass balance problems during simulation, they were replaced by conceptual assumptions. The calculated accretion values were moved to the Lander Avenue location to more properly represent boundary condition load at Lander.

   In reality, these conceptual assumptions are not always observed. One assumption is that the Fresno and Chowchilla Rivers are disconnected from the San Joaquin River if the bypass structure is not operated for flow diversion at Bifurcation. For months when this assumption is wrong, CALSIM II overestimates EC at Lander because flow is underestimated.

   Another key assumption is that when the bypass structure is operated for flow diversion or Sack Dam is operated for high-flow releases, then depletions en-route to Lander Avenue are insignificant relative to the scale of these flows. For months when this assumption is wrong, CALSIM II underestimates EC at Lander because flow is overestimated. It happens that the importance of these assumptions on simulated New Melones operation is small relative to the importance of the Maze flow-EC rating curve-fit (Section 2.3.3.3). However, for the purpose of partitioning load Above Newman, these assumptions are significant and should be investigated during future upper basin Module refinements.

3) **<u>San Joaquin River EC Assumption at Above Newman</u>**: Only a few years of observations were used to establish these assumptions. A synthetic high-flow case was used to steer resultant curve fits since the 2000-2004 record did not exhibit high flow conditions. In addition, the Hills Ferry Station defining Above Newman EC is poorly located relative to the mixing zone of the San Joaquin and Merced Rivers. Similar to Above Newman accretion/depletion assumptions, the uncertainty of this assumption is important for explaining load partitioning Above Newman, but happens to be of minimal importance for explaining New Melones WQ release. This is because the latter is driven by the Maze flow-EC rating curve-fit. In any case, the uncertainties of using Hills Ferry data might be avoided with future Module updates by moving the location of load residual assessment from the Newman confluence downstream to either Crows Landing or Patterson.

4) **<u>San Joaquin River EC Assumption at Maze</u>**: Only a few years of observations were used to establish these assumptions. This assumption is critical for determining CALSIM II simulation results at New Melones and Vernalis because the curve-fits always imply that positive load residual coincides with New Melones WQ release needs.

Because of how they ultimately control New Melones operations using WQ Module ver1.00, the Maze flow-EC rating curves cause WQ Module ver1.00 to have some similarity with the preceding model paradigm. In the former, the Maze EC was always determined by using a regression equation defining EC as a function of flow (i.e. Modified Kratzer). In the latter, during months of New Melones WQ release need, there is always positive Maze residual so it can be said that the Maze EC was also determined by a regression equation (**Figures 2.12a,b**). However, there are two contributions made by WQ Module ver1.00 that distinguish it from the preceding model paradigm:

- The Kratzer regression equation was calibrated to out-dated observations at Maze, whereas the updated curves represent post-1997 river conditions and basin salinity management changes since 1999 .

- The Maze flow-EC curves were only used to identify a static Newman-to-Maze load residual that is held constant during simulation and does not impair the applicability of CALSIM II for effects analyses involving below-Lander salinity management proposals. The preceding model paradigm did not enable such effects analyses because the Maze regressions were used to determine entire Maze load during simulation rather than just load residual prior to simulation.

5.0 Summary

The San Joaquin River WQ Module version 1.00 improves CALSIM II salinity estimation. Relative to the preceding approach that did not resolve load sources above Maze, WQ Module ver1.00 represents load sources from Lander Avenue to Vernalis. In doing so, CALSIM II can be used to perform effects analyses on salinity management strategies below Lander, given understanding of the limitations explained in Section 4.0.

The development of WQ Module ver1.00 required a series of changes to the San Joaquin representation in CALSIM II. The first change involved refinements to Eastside Hydrology, including implementation of land use-based water demands to replace the contracts-based demands. Schematic changes were also implemented, with attention given to deliveries and returns mapping on the Eastside. The second change involved disaggregation of Westside return flows into distinct flow sources. The final change involved developments related toWQ Module ver1.00, including definition of the Module's domain (**Figure 1.2**), assignment of EC values for flow sources, and identification of load residual at various San Joaquin River locations based on recent historical flow-EC relationships. All of these changes were implemented with the philosophy of creating a CALSIM II San Joaquin representation that reflects current basin operations.

The sensitivity of CALSIM II results to these model changes was evaluated for two results related to lower San Joaquin WQ modeling:

1. New Melones releases for Vernalis EC obligations, and
2. Vernalis EC Standard Exceedences.

For New Melones release, recent operations history was compared against simulation results before model changes, after intermediate stages of model changes, and after completing WQ Module ver1.00. Model results before changes suggested strong likelihood of release requirements during summer months and very little release needs during winter months, contrary to operational experience. After completion of WQ Module ver1.00, the simulated release requirements are seasonally consistent with experience. However, the average magnitude of simulated release, when required, may be low relative to recent observations (CVOO, *personal communication,* September 2004).

For Vernalis EC Standard Exceedence, the before-changes modeling showed frequent exceedences during summer months. After changes, simulated exceedences were rare in the results. The after-changes results seem reasonable relative to observed monthly-mean EC conditions at Vernalis from 1999-2003. However, it is acknowledged that CALSIM II is a monthly model and shouldn't be construed to represent the possibility of daily exceedences like those observed in the 1999-2003 record.

CALSIM II with WQ Module ver1.00 is expected to be used to support near-term planning studies (e.g., Eastside IRMP, exploration of below-Lander salt-management strategies). These studies should not be performed without consideration of key Module limitations related to several key uncertainties (Section 4). Those uncertainties relate to how data sparse conditions were used to support perimeter EC and mainstem EC assumptions, and how conceptual assumptions were made to represent Above Newman accretion/depletion.

Improving the WQ Module is an ongoing effort. While the EC development framework for the Module has been established, further assumption development efforts should be explored. Future improvements to the WQ Module might be targeted to the following areas:

- **Near-Term Improvements:**
    - Refine water quality estimates for Eastside agricultural returns.
    - Work with CVRWQCB to refine understanding on SJRIO input development where SJRIO assumptions control Module EC assumptions.
    - Develop location-dependent EC-TDS conversion factors to replace the general rule of thumb used in the current Water Quality Module. For example, the Module currently assumes an EC->TDS conversion factor for Refuge Returns of 0.64 when relating WETMANSIM-031604-ver01.00 TDS output to Module EC input. This conversion factor may need to be revisited (Quinn, *personal communication*, November 2004).
    - Extend the module's upstream boundary from Lander Avenue to Mendota Pool. This will enable water quality analysis for Mendota Pool operation changes in the Upper San Joaquin River Basin Storage Investigation.

- **Long-Term Improvements:**
  - Incorporate Westside groundwater pumping information from WESTSIM (currently in calibration stage) and available groundwater quality information into CALSIM II. Currently, Westside groundwater pumping is a missing component for CALSIM II. Incorporation of these data will change the water balance along the San Joaquin River and will require recalibrating CALSIM II and the Water Quality Module.
  - Continue field monitoring and data collection. Analysis of field data will provide additional insight into the modeling effort.
  - Reintroduce Step 3 of the load residual calibration procedure proposed in Phase 3 (Section 2.1, or **Attachment B - Chapter 4**) as a means to map positive load residuals assessed at Above Newman and Maze to the accretion terms associated with regions above these locations. Implement this calibration procedure after accretion/depletion variables are re-defined to be process representations rather than "flow residuals" from regional water balances.
  - Develop an integrated surface-subsurface process model that can be used to quantify basin-wide hydrologic and water quality processes. Then use parallel simulations of this model and CALSIM II to develop linear response functions that CALSIM II would reference during simulation to infer process-simulated subsurface flow and water quality conditions. This approach would be analogous to how CALSIM II uses ANN-derived linear response functions to infer delta water quality conditions that would have been simulated by DSM2 given the same Delta boundary conditions.

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