An aerial photograph of a large dam and reservoir. In the foreground, a multi-lane highway bridge crosses the water. To the left of the bridge, there is a large concrete dam structure. In the background, a long dam with several spillways stretches across the horizon. The surrounding landscape is green and hilly, with a clear blue sky above.

# **PEER REVIEW RESPONSE:**

**A Report by DWR/Reclamation in Reply to the  
Peer Review of the CalSim-II Model  
Sponsored by the CALFED Science Program  
in December 2003**

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**August 2004**

**California Department  
of Water Resources**

**U.S. Bureau  
of Reclamation**

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**This report was prepared jointly  
By the  
Department of Water Resources  
And  
U.S. Bureau of Reclamation**

**August, 2004**

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*Table 1. Summary of Peer Review Comments*

*Table 2. Development Priorities*

# 1. Introduction

The California Department of Water Resources (DWR) and the U.S. Bureau of Reclamation (Reclamation) have jointly developed a computer model called CalSim-II that simulates much of the water resources infrastructure in the Central Valley of California and Delta region. CalSim-II provides quantitative hydrologic-based information to those responsible for the planning, managing and operating the State Water Project (SWP) and federal Central Valley Project (CVP).

CalSim-II is a particular application of software developed primarily by DWR called CalSim. CalSim is a generalized water resources tool that can be applied to most reservoir-river basin systems. CalSim was recently renamed by DWR and Reclamation to WRIMS (Water Resources Integrated Modeling System). For consistency, however, the name CalSim rather than WRIMS will be used throughout this report.

In 2003, the CALFED Science Program commissioned an external review panel to provide an independent analysis and evaluation of the strengths and weaknesses of CalSim and CalSim-II. Specifically the review panel was asked (Strategic Review, p3) to answer the following questions below: (note: The Strategic Review report used the upper case “CALSIM” for the engine and the upper case “CALSIM II” for the application. In the seven questions below, as extracted from that report, the word “CALSIM” appears to imply both the engine CALSIM and, more importantly, the application CALSIM II. For consistency in this report, the words CalSim will be used for the engine and CalSim-II for the application)

1. Is CALSIM a reasonable modeling approach for current and proposed applications and problems?
2. Do other modeling approaches show similar or greater promise and flexibility for such problems?
3. What are the major comparative strengths and weaknesses of the current CALSIM approach and alternate approaches?
4. What are the major scientific, technical, and institutional limitations, uncertainties, and impediments for current and proposed applications of CALSIM?
5. What model, software, and data developments, special studies or tests would be beneficial to improve CALSIM for current and proposed uses?
6. How might CALSIM development and applications be managed and overseen to improve the quality assurance of the model results for current and proposed applications?
7. What are the panel suggestions for long-term use, development, or replacement of the current suite of models and data available for the current and proposed uses of CALSIM?

The Peer Review was held November 13-14, 2003. The panel’s responses to the above questions were published in “*A strategic review of CALSIM II and its uses for water planning, management, and operations in central California*” (Strategic Review, December 4, 2003), herein referred to as the Strategic Review. This report is a response from DWR and Reclamation to the Strategic Review. The following information clarifies issues raised by the Peer Review, outlines the priority of development, and addresses current and future development work.

## **2. Goals of CalSim-II Development**

The Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) strive to develop, maintain, and apply CalSim-II as the simulation model of the State Water Project and Central Valley Project best representing the two projects for planning and management studies. It is intended to serve organizations with an interest in the CVP/SWP management with the goals of developing and maintaining the best available technical tools for planning and management studies.

### 3. Summary of Response Goals and Priorities

DWR and Reclamation share the view that our response priorities need to be steered by a philosophy for carrying out the goals of CalSim-II development. This philosophy begins with the overarching goal of maintaining trust and credibility of CalSim-II among the user community. A complimentary goal of equal priority is assuring quality of CalSim-II data, assumptions and results. With credibility maintained and quality assured, we adopt secondary goals of implementing obvious and feasible enhancements of CalSim-II and providing service to the evolving needs of the user community with advancements that go beyond the present application of CalSim-II.

Given this philosophy of meeting the goals of CalSim-II development, DWR and Reclamation suggest the following prioritization of response projects. Many of these projects have already been initiated (independent of this prioritization, see Table 2). Each response item is discussed in more detail in section 4 and the Appendices. Items are listed in order of priority:

1. Establish Credibility and Trust
  - a. Uncertainty and Sensitivity Analysis (*section 4.4.2, 4.4.3*)
  - b. Documentation (*section 4.2.13, 4.3.4.1, Appendix D*)
  - c. Establish formal schedule of Training Classes and User Group meetings (*section 4.3.5.6*)
2. Hydrology Enhancement (priority order beginning after 1., implemented over a longer term)
  - a. Sacramento Valley (*section 4.2.1, 4.2.2, 4.2.11, Appendix E, F*)
  - b. West Side San Joaquin (*Appendix F*)
3. Software Development Needs – Part 1 (priority order after 2., although many of these projects have been initiated (Table 2)).
  - a. Version Control (*section 4.3.4.14*)
  - b. (Meta) Data Control (*section 4.3.2, 4.3.3*)
  - c. Error Checking (*section 4.3.4.2*)
  - d. Solver Reliability/Infeasibility Handling (*section 4.3.1, 4.3.4.5*)
  - e. Graphical Network Builder (*section 4.3.4.4*)
4. CalSim-II Module Enhancements (priority order after 3., although many of these projects have been initiated (Table 2))
  - a. CalSim Allocation Module (CAM) (*section 4.2.8, 4.3.1, 4.3.4.8, Appendix B*)
  - b. Water Quality Modules for the MWD-related facilities and the San Joaquin Valley (*section 4.2.7, 4.3.4.15, Appendix B*)
5. Software Development Needs – Part 2 (priority order after 4, although many of these projects have been initiated (Table 2)).
  - a. Modularity (*section 4.3.4.7*)
  - b. Runtime (*section 4.3.4.11*)
  - c. Ability to Link Linear Optimization and Non-Linear Extensions (*section 4.3.4.12*)

6. Application/Software Extensions (priority listed in order after 5, although many of these projects have been initiated (Table 2)).
  - a. Modular Application of CalSim (*section 4.2.6*)
  - b. Demand Management and Supply Augmentation Schemes (Conjunctive Use) (*section 4.2.9*).

DWR and Reclamation plan to explore partnerships with stakeholder groups and outside resources to support implementation of some of these priority items in a comprehensive manner.

## 4. DWR/Reclamation Response to Specific Issues

### 4.1. Summary of Comments and Responses

Table 1 is a matrix of the various comments raised in the Strategic Review. The comments have been grouped into categories. The column on the far right-hand side of Table 1 refers to DWR and Reclamation's response to each individual comment as summarized below:

- 1 DWR and Reclamation do not agree with the comment stated.
- 2 DWR and Reclamation agree with the comment stated.
- 2a DWR and Reclamation agree with the comment stated and staff is currently working on it as part of our immediate needs for CalSim-II. A work plan is being developed by both DWR and Reclamation and will be shared with the public in the very near future.
- 2b DWR and Reclamation agree with the comment stated and consider it important to address in the short term with a target date of January 2007.
- 2c DWR and Reclamation agree with the comment stated but considers it should be addressed on a longer term with a target date of January 2011.

Where there is agreement (i.e., 2) then DWR and Reclamation attempt to fit the response within their projected timelines. Sometimes there is agreement and disagreement on an issue (e.g., 1, 2) indicating disagreement with portions of the comment but agreements on other parts.

### 4.2. Conceptual Level

The scope of a model should be defined in relation to its intended purpose. CalSim-II was originally conceived as a model of the CVP-SWP system to be used for planning purposes and comparative analysis of *project* alternatives. CalSim-II is now being advocated for analysis of more general water management issues. The Strategic Review (p2) states that:

*“As the official model of those projects, CalSim-II is the default system model for any inter-regional or statewide analysis of water in the Central Valley of California.”*

*“California needs a large-scale relatively versatile inter-regional operations planning model and CalSim-II currently serves that purpose reasonably well.”*

Clearly, CalSim-II has evolved from being a CVP-SWP specific model. Yet, its wider role and purpose has not been clearly stated. The Strategic Review contains many recommendations relating to the wider (non CVP-SWP) role of the model. DWR/Reclamation agrees in principal to most of these recommendations. Any planner would wish for additional capabilities. However, implementation of these recommendations is constrained by the limited resources available to DWR and Reclamation.

It is necessary to examine the applicability of CalSim-II to a wider range of water related questions and to plan how further model development can support future planning activities associated with California water. The following is a set of modeling policy statements that DWR/Reclamation support and advocate to help direct future model development.

- Model users and decision-makers need to have confidence in CalSim-II for both absolute and comparative analysis (Strategic Review, p9)

- CalSim-II should evolve toward a more consistent representation of the rules that govern annual and real-time operations planning (Strategic Review, p8)
- CalSim-II needs to evolve from a model of the CVP-SWP system to a model of California’s inter-connected water system (Strategic Review, p24)
- CalSim-II needs to explicitly represent a wide range of water management options, that include water conservation, reuse, water transfers, and groundwater conjunctive use management (Strategic Review, p21)
- Groundwater needs to be more fully represented in CalSim-II (Strategic Review, p19)

The Strategic Review (p2) agrees that CalSim is an appropriate approach for the modeling of the CVP-SWP-Central Valley system. The following sub-sections discuss particular issues raised in the Strategic Review that would broaden the model’s applicability.

#### **4.2.1. Geographical Scope**

Development of CalSim-II beyond the needs of the SWP/CVP systems and the Sacramento-San Joaquin drainage area may go further than the current purpose of the model. Widening the geographic scope encompassing the Tulare Basin and Southern California would require considerable additional resources and greater support and involvement of local agencies. DWR, however, is currently working on the calibration of CVGSM2 (an application of IGSM2 to the Central Valley which includes Tulare Basin). DWR and Reclamation expect to use CVGSM2 or an alternative tool as the principal tool for developing the hydrology, modeling surface water – ground water interaction, and modeling ground water flow.

DWR and Reclamation support the development of CalSim models of the upstream watersheds, and the integration of these models with CalSim-II. An example of this cooperation is the development of the CalSim Yuba model that is supported by Yuba County Water Agency, and development of a daily time-step model of Upper American River operations (above Folsom Lake), commissioned by Reclamation. DWR and Reclamation support the vision of CalSim providing a common platform for water resources analysis in California.

#### **4.2.2. Groundwater**

Modeling groundwater in CalSim has evolved from the simpler Depletion Analysis approach to the current multiple-cell approach used in the Sacramento Valley. As part of its short-term goals, DWR is working on enhancing the modeling of groundwater flow and the surface water – groundwater interaction through the use of CVGSM2 (Central Valley Groundwater – Surface water Model) or its variants. CVGSM2 is the application to the Central Valley of the IGSM2 (Integrated Groundwater – Surface water Model) model. IGSM2 is currently developed and supported by DWR. A brief description of IGSM2 is given in Appendix F. One clarification: Page 8 of the Strategic Review lists a series of weaknesses model users would like addressed. These concerns were identified in a survey of stakeholders conducted by the University of California at Davis, prior to the Peer Review during the summer 2003. One of the concerns is stated as:

*“Groundwater resources are assumed infinite, i.e., there is no upper limit to groundwater pumping”*

This is a mischaracterization of the model. Groundwater pumping is constrained in CalSim-II, and is also only available to meet local agricultural or urban demands. A full description of how groundwater pumping is modeled is given in Appendix A.

### **4.2.3. Hydropower**

Reclamation has incorporated project hydropower generation and use directly into a version of CalSim-II, but hydropower is not included as an objective. Reclamation and DWR are currently using post-processing spreadsheets to analyze hydropower operations in CalSim-II. The Reclamation post-processing spreadsheet was originally designed for and approved by the Western Area Power Authority (WAPA). The WAPA spreadsheet currently represents all the CVP facilities. DWR uses a spreadsheet that was originally designed for DWRSIM (predecessor to CalSim-II) and applies to all SWP facilities. In the near future, the SWP plans to adopt a methodology for approximating hydropower that is similar to the WAPA spreadsheet.

DWR may consider integrating hydropower as a decision variable or objective in SWP operations as part of its long-term planning for CalSim-II. This will also be dependent on the availability and/or development of trade-off curves between hydropower generation and surface water deliveries.

### **4.2.4. Local Projects**

Similar to the geographical extension of CalSim-II, DWR and Reclamation welcome and support, as far as possible, the use of CalSim by local agencies to develop planning models of their local facilities. These detailed models should be ‘collapsible’ so that they can be included in CalSim-II in an aggregate form, and so that CalSim-II can provide the local boundary conditions for more detailed local planning. This approach is consistent with the modular approach advocated by the Strategic Review.

### **4.2.5. Analyzing Future Scenarios**

The Strategic Review (p22) recommends that capability to analyze a greater range of future scenarios be enhanced. Long-term planning for California may be best served by considering the notion other than that of a certain future, and implementing plans that best position the State to respond to a range of possible futures. This approach has been adopted by the California Water Plan Update, and DWR is evaluating the use of CalSim-II for future quantitative analysis. DWR and Reclamation agree that this is a desirable approach. However, the current hydrology development process is too unwieldy to efficiently produce a suite of possible land use, water supply and demand scenarios. DWR and Reclamation agree that, as part of the near term future model development the agencies examine ways to streamline the development of alternate futures, and restructuring of code to allow users to quickly change key input assumptions.

### **4.2.6. Modular Approach**

The Strategic Review (p2) identifies a ‘*common tension between those who wish for greater detail and those who want less detail from the model.*’ The successful implementation of an expanded role for CalSim-II depends on the adoption of a modular approach to modeling. This should allow the quick construction of different CalSim-II versions, ranging from a very simple system representation for preliminary screening analysis or educational purposes, to a

detailed and complex model that includes many local project operations. Modularity can be addressed at three levels: hierarchical, spatial, and temporal. An example of hierarchical level is a screening version of CalSim (as compared to a detailed representation of the system). DWR and Reclamation are also considering that the CalSim-II code be restructured to implement the modular approach before more detail is added to the model to represent local project operations in the Sacramento and San Joaquin Valleys.

#### **4.2.7. Operational Objectives**

Operational objectives in CalSim-II are either flow or storage related (minimum instream flows, storage targets, deliveries). Although water quality in the Delta is a constraint on project operations, it is not an objective. The Strategic Review (p8) suggests the capability of CalSim-II to analyze economic, water quality and groundwater issues be improved. Reclamation has developed a San Joaquin River Westside Drainage module for CalSim-II that disaggregates electrical conductivity (EC) source components that contribute to simulated Vernalis EC, which is an integral first step of future San Joaquin water quality investigations involving the main stem of SJR, Westside irrigation activities, and Upper/Eastside San Joaquin tributary operations. DWR is currently working with the Metropolitan Water District of Southern California (MWD) to add water quality functionality to the CalSim software. Using economic drivers for initial screening analysis has been discussed. Reclamation has worked with UC Davis on the development of the CALVIN model, which uses prescriptive optimization techniques and economic drivers to manage California's water system. Both agencies remain interested in adding CALVIN-type capabilities to CalSim-II. This work would probably best be implemented by the University of California, supported by DWR and Reclamation as part of the long-term strategy.

#### **4.2.8. Real-Time Operations**

Both DWR and Reclamation share the modeling vision to narrow the gap between their respective operations models and CalSim-II. One key area where operations and planning tools overlap is that the former is used to set allocation targets and the latter must represent the *process* of setting allocation targets. In actual operations, the DWR and Reclamation spreadsheet operations models are applied by operators to establish annual allocation levels; these levels evolve through the snowmelt season. In planning application within CalSim-II (i.e. during a multi-year simulation), the *process* of setting annual allocations is currently emulated in a very simplified manner that considers stored-water inventory and forecast hydrology at the time of allocation setting.

This simplified representation stands to be improved greatly through the application of the CalSim Allocation Module (CAM), which is being developed by DWR in collaboration with Reclamation. CAM was developed to mimic the procedure used by operations staff. This includes using forecasted hydrology for a 12 month time horizon and a simplified representation of the system (as compared to CalSim-II). Operating guidelines are being developed in consultation with SWP/CVP operators to reflect the procedures used in real-time operations. Use of multi-period optimization simplifies the required simulation rules by relying on the MIP solver to optimize the monthly reservoir release/export decisions subject to the system constraints and operating guidelines of the project reservoirs. Linking CAM with CalSim-II

takes advantage of both model approaches and improves the ability of the planning tool to mimic real-time operations.

#### **4.2.9. Water Management Options**

The Strategic Review (p21 & 23) states that CalSim-II should more explicitly model many demand management and supply augmentation options. The demand management options require that CalSim-II represent demands in greater detail and more explicitly. DWR and Reclamation will consider if modeling of these options may best be achieved through better linkages of CalSim-II to its agricultural (CALAG) and urban (IWR-MAIN, LCPSIM) demand counterparts. This will include how data inputs and outputs can be more easily communicated between these models. Also for consideration is revising urban demands in CalSim-II so as to represent them in their entirety rather than limiting representation to outdoor (consumptive) urban demand.

#### **4.2.10. Objective Function**

The Strategic Review (p4) raises an important issue regarding the characterization of reservoir operators' behavior.

*“Most successful applications of optimization that attempt to simulate the behavior of a system have calibrated their objective function so that the model results correspond to what actually happens or would happen under a particular hydrologic and demand scenario.”*

A good example of this approach is the positive mathematical programming technique used in DWR's agricultural production models CVPM and CALAG. The lack of calibration is one reason why the *CalSim-II Simulation of Historical SWP/CVP Operations* study was unable to mimic historical project carryover storage during drought conditions.

In the past, DWRSIM and CalSim-II had a prescriptive rather than a descriptive approach in defining reservoir operation rules. For example, carryover storage targets were developed that maintained minimum storage levels during a prolonged drought while trying to minimize shortages in any particular year. While this is a valid approach, it may lead to over-optimistic model results due to discrepancies between model and actual operators' decisions.

DWR and Reclamation are engaged with their respective project operators to reduce these discrepancies. The difficulty in calibrating CalSim-II to past behavior is that the behavior is dynamic. Reservoir operations continually evolve due to changing regulatory conditions, changing systems demands, and requests from project contractors. The agencies modeling staff, reservoir operators and contractors are working together to develop a CalSim-II module (CAM) that can be used to determine present month decision variables (e.g., allocation levels, expectations on future carryover or fill targets) based on foreseen operations determined through multi-period optimization and hydrologic foresight. If successful, this approach will be extended to other model rule curves, such as balancing north and south of Delta storage.

#### **4.2.11. Land Use**

Projected-level land-use in CalSim-II is assumed constant. It is an exogenous input derived from the Central Valley Production Model (CVPM). Land use projections result from assumptions regarding farmer's long-run response to long-term average annual surface water and

groundwater availability and associated cost. Evidently, farmer's planting decisions will vary in the short-run due to annual variation in supply. This short-term response is not modeled in CalSim-II, although it can be modeled using CVPM (or its successor CALAG). DWR has developed an internal memorandum on how such a response could be represented in CalSim-II. However, modeling land-use variation is considered secondary to a more general revision and update of the CalSim-II hydrology development (Appendix E).

#### **4.2.12. Hydrologic Uncertainty**

The Strategic Review states that there needs to be *'a better capacity to accommodate other approaches to representing hydrologic uncertainty and variability besides simply simulating 70-plus years of record.'* DWR and Reclamation believe that the use of explicitly stochastic techniques or the use of synthetic hydrologic data would not be a useful contribution at this time. Assembling a reasonable representation of auto- and cross-correlation of inflows for a large-part of California is a daunting task. Preservation of the persistence of drought phenomena is very difficult. Even harder would be gaining public acceptance of such an approach. Nonetheless, DWR and Reclamation do believe that there are alternatives to the reliance on a single hydrology. Underlying the use of historical flows is the belief that the past is a good indicator of the future. DWR and Reclamation are currently working with the Scripps Research Institute to develop alternate hydrologies that may be more likely to occur due to global climate change. DWR and Reclamation are also considering the use of rainfall-runoff models as part of the hydrology development, which offer a more flexible approach to modeling extreme events beyond the recent historical record.

#### **4.2.13. Documentation**

Over the last two years DWR and Reclamation have worked together to document the model system representation and logic. As part of the September 30, 2002 Benchmark release, the agencies issued a 156 page model description and a document summarizing the simulation output. Since the release, DWR and Reclamation have dedicated time and resources to the following documentation activities:

- Creation of the CalSim-II Review and Documentation Team
- Development of WRESL code commenting protocol
- Implementation of commenting protocol for the September 30, 2002 Benchmark (review and revision of existing comments)
- Development of CalSim reference manual outline
- Development of CalSim documentation management system strategy

Despite the coordinated effort, documentation activities have often been given second priority to the production of model studies. Both DWR and Reclamation acknowledge the need to prioritize and supplement the Review and Documentation Team effort with additional resources to complete the documentation task. A brief description of the proposed CalSim-II documentation management system is given in Appendix D.

## 4.3. Implementation Level

### 4.3.1. Numerical Approach

CalSim uses mixed integer linear programming (MIP) to route water through a network of nodes and links in accordance to a user-defined set of priorities and constraints. The Strategic Review states (p4) that this approach is similar to other state-of-the art modeling tools such as ARSP, MODSIM, OASIS, REALM, Riverware and WEAP. However, the peer review does warn that optimization “*has the potential to produce inaccurate and overly optimistic results.*”

The Strategic Review recommends (p5) that the current strategy of single-step optimization should be supplemented by:

- Multi-period optimization to guide decisions with impacts that stretch beyond the current time-step,
- Detailed simulation of some system elements, allowing modeling of non-linearities, and potential reduction in run time.

DWR and Reclamation are currently implementing these recommendations in various ways. These fall under categories for enhancing and streamlining the numerical procedure. Enhancements to the numerical procedure of CalSim will allow expanded functionality, including

- Iterative solution of a cycle. A cycle will repeatedly be solved until the user-specified convergence criteria are met (or maximum number of iterations). This will increase the ability to model nonlinear aspects of the system.
- Automation of writing decision variables and constraints for multi-period optimization. The CAM model (briefly described in Appendix B) uses a time-consuming manual process for defining the MIP for multi-period optimization. This may be automated by introducing arrays for decision variables and constraints.
- Dynamic computation of decision variable weights. This will allow increased flexibility of the MIP.

Streamlining of the numerical procedure of CalSim will reduce run-times and simplify software maintenance. Items include the following:

- Streamlining of cycling MIP solutions. Cycles will be streamlined to eliminate the need for separate “Single Study Runner” and “Multi-Study Runner”. This will allow a single GUI to be used for all CalSim simulations.
- Expanded use of DSS pathnames. A single DSS output file may be used for all “multi-step” studies. Transfer files may be eliminated, reducing time-consuming reading/writing to hard drive.
- Allowing State Variables to be written to DSS. Currently only Decision Variables are written to the DSS output file. Allowing State Variables to be directly written to the DSS file will eliminate the current practice of sending these parameters through the MIP solver and unnecessarily increasing the overhead on the solver.

### **4.3.2. Data**

Concern of the quality of data in CalSim-II, is one of the most recurrent themes of the Strategic Review. For example (p20): *“There has not been sufficiently systematic, transparent, and accessible approach to the development and use of hydrologic, water demand, capacity and operational data. The administration of data development is fragmented, disintegrated, and lacks a coherent technical or administrative framework.”*

The validity of data inputs impacts both model results and model credibility. The greatest concern is the validity of the hydrologic inputs and parameters. Concern is compounded by the current lack of complete documentation. Over the last two years DWR and Reclamation have attempted to document model inputs. Reclamation is currently documenting the current CalSim-II hydrology procedures. This effort needs to be extended and updated.

It is worth noting that the restructuring of the CalSim software as part of release 2.0 allows metadata describing the source of model inputs to be stored with the actual data. A brief description of the proposed CalSim-II data and documentation management system is given in Appendix D.

### **4.3.3. Data Management**

The Strategic Review (p.58) identified data management as a critical aspect for CalSim. A web-based version control software (Perforce) is used by DWR modelers for managing the text-file input files of the current version of CalSim (v1.2). Adoption of a public domain relational database management system is under development for the next version of CalSim (v2.0). This database will provide a central repository that will contain documentation in addition to the model input/output data (time series data may continue to be stored in HEC-DSS). This will provide a full-featured client/server database including version control, integrity of data, documentation (including metadata), and ease of dissemination.

### **4.3.4. Software**

In general, DWR agrees with the recommendations of the Strategic Review regarding the CalSim software. Many of these recommendations have been adopted and are being implemented for the next version of CalSim (v2.0). Given the growing use of CalSim outside of the two agencies, DWR accepts the need for extensive discussion and input from the wider modeling community and extensive beta-testing before the release of the next version of CalSim (v2.0). New software developments must take into account the considerable familiarity represented by the body of existing software users. It is important that major changes to the structure and look of the CalSim software benefit from feedback from this user-pool.

The following sections answer specific points raised in the Strategic Review. A brief general description of the next version of CalSim (v2.0) is given in Appendix B. In general, DWR’s goal is to cease development work on the current release of CalSim (v1.2), and to implement improvements discussed below for the next version of CalSim (v2.0).

#### **4.3.4.1. Documentation**

Three documents are currently available to the CalSim user: the CalSim User’s Guide, the CalSim Manual, and the WRESL Language Reference. These documents offer the minimum required help to the CalSim novice. DWR accepts that these documents need to be updated and

expanded. Initially DWR supported a web-based software bug reporting and archiving system. This system needs to be reactivated. DWR and Reclamation intend to publish a list of frequently asked questions (FAQ). This will eliminate many wasted hours of model user's time due to minor software bugs and idiosyncrasies. DWR accepts the need to provide centralized support. Given the agencies current workload and resource constraints it seems that it may be best to contract this to a third party.

#### **4.3.4.2. Error Checking**

The Strategic Review identified automated error (p5) and input/output (p24) checking for increased productivity. Staff from DWR, Reclamation, and other agencies or consultants has developed several spreadsheets for such purposes. A short-term goal of DWR is to collect, refine, and develop such spreadsheets into a series of standard pre and post processors that become a standardized set of tools. In addition, development of the next version of CalSim (v2.0) software may include expanding the solvers capability to track potential errors in setting up input data.

#### **4.3.4.3. Gaming**

Stakeholder participation will be sought to develop a gaming interface for the next version of CalSim (v2.0).

#### **4.3.4.4. GUI**

A CalSim-II geo-referenced network schematic is under development by Reclamation. The primary purpose of this project is to provide a communication tool between CalSim-II users, agency management, project managers, and the public. Geo-referencing the network provides quality control and a spatial connection between the system and the topography. The general CalSim GIS toolbox can be applied in any geographic location and features drag and drop icons with connector linkages for easy modifications. CalSim-II network schematic developments also anticipate future integration options. GIS is capable of generating CalSim code based on the network representation to run an application, storing pertinent meta data and coverage information, and has online integrated mapping system capabilities. In addition, the CalSim GIS toolbox has been applied to the SWP and CVP system and is now under review. Alternative options (public domain) for schematic generation are also in discussion.

#### **4.3.4.5. Infeasibilities**

DWR recognizes that the solver report of an infeasible solution is a periodic, but potentially very time-consuming problem. Tools do exist currently in CalSim to identify the causal constraints, but they are not well documented. The current LP solver in CalSim is XA (by Sunsoft, Inc). Users may use the XA reporting options in CalSim to help identify the problem. In many cases XA will report which constraints it has not been able to satisfy, and by how much it would need to relax the constraint to find a solution. However, in some cases XA fails to identify the problematic constraints. The Strategic Review (p24) recommends overcoming the infeasibility problem, which adds slack and surplus auxiliary variables to each constraint. High penalty values assigned to the auxiliary variables would assure that they would be non-basic (i.e. have a value of zero) unless the solution would otherwise be infeasible. The auxiliary variables would only be added to the MIP problem if an infeasible solution were obtained, so as not to

increase run-time There is merit to this approach ,which is currently used in CalSim to assure that the continuity constraint for storage nodes can always be met.

DWR is working with Lawrence Berkeley Laboratories on an alternate approach to develop analysis tools for infeasible and non-unique solutions (Section 4.3.4.10).

#### **4.3.4.6. LP Output**

CalSim currently provides limited output from the MIP solver. For successful solutions, only final decision variable values are reported. These include Lagrange multipliers (a.k.a. dual variables, shadow prices, trade offs) which indicate the sensitivity of the objective function to each decision variable, slack variables which indicate the sensitivity of decision variable bounds on the solution, and basic and non-basic variables which are used internally by the solver. These output parameters may help users understand the complex nature of the multiple constraints on the system and how they interact with the MIP.

#### **4.3.4.7. Modularity**

The Strategic Review (p21) indicated modularity of data components will help to alleviate the conflicts of different users requiring both a less complicated and more details system representation (p21). Included in the next version of CalSim (v2.0) is the ability to store data in modules. This functionality may be used in several ways, which the CalSim user community should establish protocols for their use. Possibilities include various levels of geographic resolution (ranging from simple to complex), modularizing regulations into distinct packages and/or representing hydrologic processes in different levels of complexity. These various components may be linked together in a simulation to form various distinct models suitable to the user and purpose of simulation.

#### **4.3.4.8. Multi-Period Optimization**

CalSim-II uses the MIP to route water through the system on a single time step. Simulation rules are used to bind the optimization solver for monthly decisions. The Strategic Review suggested use of multi-period optimization may provide a useful platform to represent the system and interact with the simulation model (p5, 8, 38). The CalSim Allocation Module (CAM, Appendix B) uses this methodology for a remainder-of-Calendar-Year optimization window (e.g., twelve months if initiated in January). During the multi-month optimization window the solver is allowed to determine the optimal pattern of reservoir releases, channel flows, and exports relative to storage and release constraints that represent operator sensibilities during allocation planning, rather than specifying simulation rules. CAM was developed within the existing CalSim software by writing the system constraints manually. DWR will automate implementation of multi-period optimization by allowing the next version of CalSim (v2.0) GUI to essentially write and interpret arrays. This functionality will facilitate the exploration of multi-period optimization within the CalSim environment.

#### **4.3.4.9. Post-Processing**

The CalSim software has some limited functionality to analyze and interpret model results. This is primarily the viewing and comparison of base and alternate time series data using charts and tables. While DWR and Reclamation acknowledge the need for better post-processing tools, it is the belief of both agencies that this functionality is best provided by third-party tools such as Excel. There are currently many different post-processing tools used by CalSim users to import HEC-DSS data into Excel and subsequently to manipulate the data for interpretation.

DWR and Reclamation recommend that resources be invested into pooling the availability of these tools with further investment in their development. In addition to automated generation of charts and tables within Excel, it has been shown that for developed gaming models MS-Excel can be a good visualization tool.

#### **4.3.4.10. Public Domain**

DWR is following a policy of adopting public domain software for CalSim. This includes:

- Elimination of the FORTRAN compiler,
- Replacement of the XA proprietary MIP solver, and
- Search for a public domain GUI for the construction and editing of the river basin topology.

DWR is currently testing the public domain solver GLPK for use in CalSim. At this time, individual CalSim cycles have been solved by GLPK, and, so far, it reproduces the proprietary XA solver solutions. The next version of CalSim (v2.0) is being modified to use GLPK for further testing. Based on initial tests, GLPK is not as efficient in solving CalSim type problems as the XA solver. Solve time is approximately three times greater with GLPK. Lawrence Berkeley Laboratory (LBL) is working on improving the efficiency of GLPK. LBL has also been asked to add other utilities to GLPK such as analysis tools for infeasible and non-unique solutions.

#### **4.3.4.11. Run Time**

Advances in computer processing speeds are steadily reducing model run times. However long run time remains a problem, precluding for example sensitivity analysis on model inputs. Much of the problem relates to inefficient coding of the MIP problem in which large parts of the system are unnecessarily simulated multiple times in each time step. To reduce run times DWR and Reclamation are adopting the following strategy:

- Eliminate unnecessary variables from the LP problem (e.g. use of alias statements),
- Restructure the WRESL code to eliminate repetitive calculations,
- Optimize the reading and writing of data to HEC-DSS.

#### **4.3.4.12. Simulation**

The Strategic Review (p5) suggests that linking of linear multi-period optimization procedures to non-linear simulation models might both increase the accuracy of the model, and possibly decrease run time. The optimization module would be run each time some type of 'optimal' decision needs to be made e.g. annual allocations, reservoir releases or other management decisions. More detailed simulation at a shorter time step would subsequently implement these decisions, and define the consequences, routing water through the network according to a set of rules.

The peer review panel was not unanimous in this view. Most of the panel agreed that single time-step optimization is needed to reduce the dependence on operating rules. The use of multi-period optimization is discussed in Section 4.3.4.8. DWR, however, does agree that greater use of simulation might reduce run-time. The CalSim software should be modified to permit

simulation both at the end and beginning of each time-step. Subsequently the CalSim-II code should be reviewed so as to eliminate variables from the MIP problem that could be defined through simple arithmetic calculations .

#### **4.3.4.13. Time-Step**

CalSim-II is a monthly planning model of a geographically extensive system. Aggregation in time and space, by necessity, simplifies or omits many operational details. Of particular concern has been the error that a monthly time-step may introduce in representing the Delta.

- Project export capability may be over-estimated due to monthly averaging of Delta inflow,
- A monthly time-step may poorly represent regulatory requirements, such as X2, which may be met on the basis of 14-day running average EC, or 3-day running average Net Delta Outflow Index.

DWR has developed a daily time-step version of CalSim-II for the Sacramento Valley and Delta (Appendix B).

DWR and Reclamation heed the warnings of the Strategic Review (p24) that shortened time steps pose problems of run-time, data development and model interpretability, amongst others. DWR proposes to conduct a study to evaluate the errors introduced by using a monthly time-step. The study will compare project exports from CalSim-II to the daily Delta CalSim model. In the first part of the study the daily model will be run with the daily Delta inflow set equal to the average monthly inflow as determined by the monthly CalSim-II model, i.e. with no day-to-day flow variation. In the second part of the study the daily model will be re-run, but imposing a daily fluctuating flow pattern on the Delta inflow. This two-stage approach will distinguish between the impacts of modeling Delta regulations at a daily time scale to the impacts due to the varying daily flow pattern. A technical report of this evaluation will be published.

At this time DWR does not anticipate further extension of the daily-time step model or the introduction of routing into CalSim-II.

#### **4.3.4.14. Version Control**

Good quality control is essential given the complexity of CalSim-II, the enormous data requirements and the number of model developers. Good quality control is a key component to model credibility. Without it the accuracy or reliability of CalSim-II could quickly degenerate. The Strategic Review (p37 & 58) makes detailed recommendations relating to quality control. It cannot be achieved solely through software innovations. Protocols for data management and model development need to be written, published and adhered to.

Quality control needs to start with the central storing and sharing of data and the implementation of a version control system. This version control system should at a minimum:

- Keep track of model changes
- Facilitate the storage of metadata regarding those changes
- Allow any previous version of the model to be recovered

- Allow multiple developers to work simultaneously
- Alert model users to model changes

DWR and Reclamation have implemented a version control system for CalSim-II's text-based input files. The system allows model users web-based access to a central database. Model studies can be downloaded from the database, changes made locally to the model, and the revised data input stored back in the central location. The system has not been fully adopted, due in part to the lack of in-place model development/model management protocols. The current text-based version control system will be replaced by an analogous version-control feature with the release of the next version of CalSim (v2.0) that is centered on a relational database. DWR and Reclamation agree that it is a high priority to develop enterprise database capabilities for the next version of CalSim (v2.0), so that central data management and version control can be implemented.

#### **4.3.4.15. Water Quality**

DWR is currently working with MWD to develop a water quality module for CalSim. The first-phase of the project would permit the user to specify inflow concentrations, and concentrations for agricultural and urban return flows for various conservative constituents. CalSim would calculate the resulting water quality throughout the network using constituent mass balance. Water quality calculations would be post-processed at the end of each time-step. A second phase of development would allow the model user to specify water quality targets as drivers in the optimization procedure.

#### **4.3.4.16. Weights**

The objective function weights establish the priority for releasing water from storage and making deliveries to different parts of the network. DWR and Reclamation accept that the process of weight setting is as much an art as a science. Currently the creation of a successful set of weights requires a sophisticated model user or a very patient one that is willing to submit to a time consuming trial and error process. A systematic and standardized approach is needed to generate weights, once the user has defined relative priorities (Strategic Review, p24). The acceptability of CalSim-II results and ease of model use are subject to some debate and concern, partly due to the current difficulties in weight setting.

DWR and Reclamation support the idea of research into a method of automatically assigning values to individual weights to represent the underlying water right-based allocation rules, contractual and institutional requirements, regulatory policy layers and operating rules simulated in CalSim-II.

### **4.3.5. Administrative Issues**

#### **4.3.5.1. Resources**

DWR and Reclamation will explore and work with other public agencies; at local, regional, state or federal level, to seek needed resources to continue the development work proposed in this response plan.

#### **4.3.5.2. Model Management**

DWR and Reclamation will also seek new opportunities and avenues, both private and public, to broaden the management base for the existing and future model developments. Currently there is an interagency team coordinating this effort.

#### **4.3.5.3. Peer Review**

DWR and Reclamation believe that peer review enhances the acceptability of the modeling tool. The agencies may suggest peer reviews of modeling components it deems necessary.

#### **4.3.5.4. Public Involvement**

DWR and Reclamation will work with all interested parties, both public and private, to seek technical input in developing and enhancing the current and future modeling components.

#### **4.3.5.5. Sustainability**

The proposed Model Management Team (DWR, Reclamation and others) will work to develop a strategy in this important area.

#### **4.3.5.6. Training and Education**

The agencies modelers will continue to support, to the extent resources permit, to broaden the model users' base for appropriate use of models. The Proposed Model Management Team may also be charged with this responsibility.

### **4.4. Model Testing**

#### **4.4.1. Calibration and Validation**

Model calibration is the process of fine-tuning the value of various model parameters, so that model results match the observed data. Validation is the subsequent testing of the model against data that has not been used in the calibration to obtain an independent assessment of the model's accuracy.

The need for testing, calibration and validation of CalSim-II is one of the most controversial issues raised in the Strategic Review. Some of the peer review panel recommended that further validation of the model is required through the comparison of model results to recent historical data. However some in the modeling community express their doubts on the usefulness of such a comparison (CalSim-II in California's Water Community – Musing on a Model, p158). The Strategic Review (p129) notes that for the Murray-Darling Basin model, validation is considered to be less important. The Murray-Darling Basin model is calibrated using a long period of data. In contrast validation is carried out using only two to three years of data.

In discussing the merits of calibration it is important to distinguish between physical parameters that remain essentially constant (e.g. stream-bed conductance), and behavioral parameters that may change and adapt (e.g. reservoir operating policy). Water use parameters such as irrigation efficiency may fall somewhere in between these two extremes. Where possible the value of parameters should be determined from direct observation. This may not be possible for some parameters such as regional scale reuse of water.

DWR and Reclamation believe that model calibration to determine the value of physical parameters, and parameters such as irrigation efficiency, is a valuable exercise, and benefits model accuracy and model credibility. However, DWR and Reclamation suggest that a more reasonable approach to defining behavioral parameters is through discussions with system operators to define *current* operational policy or rules. California's water system, especially with regard to the Delta, has undergone many changes in the 1990s (Delta Water Quality Control Plan, CalFed, ESA actions, CVPIA (b)(2), Environmental Water Account) so that calibration to historical practice has limited value. It would appear more reasonable to define operating rules in conversations with operators and subsequently use a recent wet, normal and dry year in a validation exercise.

The debate on calibration stems partly from a misunderstanding of the hydrology development. The CalSim-II hydrology is tied to historical stream gage data. The following points explain what calibration has been undertaken for the Sacramento Valley:

- The accretions and depletions between the project reservoirs and the Delta *are* calibration terms. They have been determined so that at a historical level CalSim-II will exactly match historical gage data if reservoir releases are fixed at their historical level and groundwater pumping and stream-aquifer interaction are fixed at their assumed historical values.
- Calibration of groundwater use has not been carried-out due to the lack of historical data.
- The stream-aquifer model in CalSim-II is calibrated to the more sophisticated Central Valley Groundwater Surface Water Model (CVGSM).
- The CalSim-II hydrology is calibrated to net consumptive use rather than stream diversions and return flows. CalSim-II may therefore not simulate well diversions to particular irrigation districts.
- The hydrology adjustment to account for the impact of land-use change on rainfall-runoff has not been calibrated or validated.
- Calibration or validation of district-scale diversions in CalSim-II cannot be undertaken without increasing the resolution of the model.

DWR and Reclamation recommend the following approach to CalSim-II calibration and validation:

- DWR and Reclamation modeling staff continue to work with project operators to define operating rules that correctly capture current (rather than historical) operational policies.
- Following re-calibration of CVGSM<sup>1</sup>, the CalSim-II groundwater model is refined and re-calibrated.
- DWR and Reclamation develop methods to validate assumptions regarding land use change impacts on rainfall-runoff.

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<sup>1</sup> Major revisions to the underlying IGSM software and the input data sets to CVGSM have been made by DWR since the development and calibration of the CalSim-II groundwater module.

- DWR and Reclamation work with local irrigation districts and their consultants to refine the spatial scale of CalSim-II and calibrate/validate local projects operations through comparison of model output with historical data,
- Modeling groundwater pumping is modified to a land-use based approach. DWR has identified through land use surveys areas that are dependent on groundwater, areas that rely on surface water and areas that use groundwater as a contingent supply. The spatial resolution of CalSim-II should be refined to distinguish between these three land types.

After the completion of the above, CalSim-II should undergo a limited validation exercise using different recent year types.

Validation of local project operations has been shown to work well with the recent model enhancements to the San Joaquin Valley. Working with local districts has resulted in successfully calibrated hydrologic parameters so that CalSim-II has matched recent historical storage and flow data.

#### **4.4.2. Sensitivity Analysis**

The primary goal of CalSim-II sensitivity analysis is three-fold: (1) to verify if the key model input parameters are working properly within their reasonable range of variations; (2) to determine the impact of each parameter on selected model results; and (3) to set up priorities for potential refinements of model input parameters. Some of the parameters being evaluated are: SWP demands, target carryover storages, reservoir inflows, agricultural and urban water use, water use efficiencies, Delta water quality requirements etc. This sensitivity analysis had been undertaken by DWR and will be coordinated with Reclamation.

#### **4.4.3. Uncertainty Analysis**

Uncertainty analysis uses probabilistic descriptions of model inputs to derive probability distributions of model outputs and system performance indices (Strategic Review, p73). CalSim-II users need not only stand alone for absolute model results but also the degree of confidence they can place them. For example, what is the 95% confidence limit on the exceedence curve of project exports from the Delta? Hydrologic uncertainty is expressed through the use of a 73-year time series. There is currently no measure of data input uncertainty. Appendix H of the Strategic Review focuses on ways to identify and quantify uncertainty.

DWR and Reclamation agree that a method of implementing uncertainty analysis for CalSim-II needs to be defined. One approach is to simulate historical operations and use the statistics of goodness of fit to identify the uncertainty. An alternate approach is to identify plausible ranges of input parameters and to repeat model runs using high and low values of complimentary parameters (e.g. low efficiency in conjunction with high demands). This approach is more akin to the multiple future scenarios adopted by the California Water Plan Update.

#### 4.4.4. CalSim-II Historical Operations Study

The primary purpose of the *CalSim-II Simulation of Historical SWP/CVP Operations Study* (DWR, 2003) was to evaluate the ability of CalSim-II to represent CVP and SWP operations, in general, and the delivery capability of the projects, in particular, when compared with a recent historical 24-year period. The following paragraphs discuss issues regarding this study raised in the Strategic Review.

##### 4.4.4.1. Overestimation of Project Deliveries (Strategic Review, p68)

Comments in the Appendix E of the Strategic Report suggest that CalSim-II Historical Operations Study overestimates Project deliveries. The reviewers observe that CVP deliveries in the validation study are higher than historic; and the SWP deliveries taken from a model study conducted at 2001 level of development, are higher than the average of the last ten years. We do not believe this will be the case when compared with appropriate studies.

The Historical Operations Study was designed to simulate historical deliveries to evaluate how well other components of the system (such as reservoir storage, river flows, Delta outflow) compare with historical values. In this study, a simplistic demand assumption was made for the CVP. For each year of the simulation, CVP demands were fixed at the contractual amounts for north and south-of-delta contractors. It appears this assumption is the main reason for the overestimation of CVP deliveries. The historical data show that for most years during the study period of 1975-1998, especially during 1980s and early 1990s, CVP contractors received 100 percent of what was requested. If the CVP demand assumption could be refined for each year of the historical simulation, then, of course, the CVP overestimation is significantly reduced.

The reviewers observe the SWP deliveries also appear overestimated. This observation is not based upon the Historical Operations Study because the SWP demands in that study are artificially set at the values for historical deliveries during non-dry years when contractors received 100 percent of what was requested. The comment is based on comparing actual average annual deliveries for the last 10 years (2385 taf/yr) with the modeled 73-year average annual deliveries (3090 taf/yr) from a study conducted at 2001 Level of Development, based on current entitlement request. Note that this study was conducted for a different purpose for use in the *SWP Delivery Reliability Report, 2003*. DWR does not believe 2001 level study overestimates SWP deliveries. For dry periods, the results are very close to historical because the deliveries are limited by supply. The modeled average annual south-of-delta deliveries for the recent drought of 1987-1992 compare well with the actual values. The average annual values for SWP deliveries during this period are 1,930 taf/yr for the 2001 level study and 2,030 taf/yr historical. Similarly, the average south-of-Delta CVP deliveries are 2,340 taf/yr for 2001 level study and 2,320 taf/yr historical. In the wetter years, the demand (2001 level) is higher than the historical demand, so estimated deliveries are higher than the historical amounts.

When long term deliveries are compared among appropriate studies, the average annual values for SWP during the 23 year period are 1810 taf/yr for the Historical Operations Study and 1790 taf/yr actual historical deliveries for the same period. Similarly, the average south-of-Delta CVP deliveries are 2650 taf/yr for Historical Operations Study and 2490 taf/yr actual historical.

#### **4.4.4.2. Allocation to Project Contractors (Strategic Review, p68)**

Real-time allocation rules are moving targets that are year-specific and are based on entitlement requests, hydrology forecasts, initial storage conditions (both north and south of the Delta), and many other operational considerations. As such, allocation rules are very closely tied to each historical year's operation, and are not easily amenable to general mathematical formulations under a wide range of hydrologic conditions for use in the CalSim-II modeling studies. Knowing this, DWR does agree in general with the reviewers' observation that current allocation rules in the model tend to deliver water more uniformly over the dry period. Current allocation rules in CalSim-II have been designed to operate the system at a fixed level of development, present or future, which tend to maximize long-term deliveries while protecting the average annual deliveries during the historical dry periods of 1987-1992 and 1928-1934. This rule reduces the potential variability of deliveries from year to year. During the dry period of 1987-1992, more water was delivered by the SWP and the CVP during the first years of the drought and less during the latter part when compared to the delivery values of the Historical Operations Study. Although CalSim-II does not capture the potential variability of deliveries during dry periods, the simulations are useful for quantifying the total amount of deliveries over dry periods and providing information for more detailed analyses designed to address this variability. At this time, DWR will continue with the method currently used in CalSim-II for allocating water.

#### **4.4.4.3. San Luis Reservoir Operations (Strategic Review, p69)**

DWR acknowledges the reviewer's statement that San Luis Reservoir storage in the Historical Operations Study is consistently underestimated during the 1987-1992 drought when compared to the historically observed storage and that this can significantly effect the results for the pattern of flow in the Delta, opportunities for wheeling and pumping under Article 21, and accounting under the Coordinated Operations Agreement. It is also acknowledged that users of CalSim-II output need to be confident that the rules adopted by the model for determining how water is moved from north of the Delta to south of the Delta reflect the way San Luis Reservoir will be operated in the future.

DWR and Reclamation agree this component of the model merits additional review and plan to review CalSim-II's operation criteria for San Luis Reservoir with project operators and stakeholders.

#### **4.4.5. Comparative vs. Absolute Predictions**

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

Traditionally both DWR and Reclamation have assumed that model assumptions are less significant in a comparative study than an absolute study. All of the assumptions are the same for

both the "with-action" and "without-action" model runs, except the action itself, and the focus of the analysis is the differences in the results. The Strategic Review (p9), however, suggests that the assumed relative accuracy of a comparative analysis may be incorrect as:

*"...it relies on the assumption that the model errors which render an absolute forecast unreliable are sufficiently independent of, or orthogonal to, the change being modeled that they do not similarly affect the forecast of change in outcome; they mostly cancel out."*

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

The relative accuracy of a comparative analysis can be demonstrated through sensitivity analysis. Sensitivity to model inputs can be compared between a stand-alone study and a comparative analysis. In the comparative sensitivity analysis, a unit change of input to both the "with" and "without" project model, results in a change in the difference in the model outputs.

CalSim-II is constantly improving. DWR and Reclamation will consider, through discussions with stakeholders, the relative priorities of (1) refining the current model to improve its accuracy, and (2) quantifying the level of accuracy of the current CalSim-II model.

## **5. Development Priorities**

Table 2 summarizes current CalSim/CalSim-II development projects and recommends priorities for future development. These are categorized according to immediate needs, short-term priorities, and long-term priorities. The time frame for the short and long-term priorities is January 2007 and January 2011, respectively. Comments and references in Table 1 can be matched (in general) with those in Table 2.

## **6. Summary and Conclusions**

### **6.1. Summary**

#### **6.1.1. Model Scope**

The Strategic Review identified many areas in which the scope of CalSim-II could be extended to support a wider range of planning activities. In its current form it is predominantly a model of the CVP-SWP system. The coarse spatial resolution of the model and the limited integration of groundwater limit its usefulness in other planning forums. Nonetheless DWR and Reclamation believe that CalSim-II is an adequate model for planning studies for new storage and conveyance facilities in the CVP & SWP systems.

DWR and Reclamation support further development of CalSim-II to broaden its applicability to California water planning issues other than those relating to the CVP-SWP. DWR and Reclamation intend to work with stakeholders to produce a model strategy for future model development. In the near-term, DWR and Reclamation believe that the geographical and conceptual extension of CalSim-II to non-project areas and issues should be secondary to a technical audit/peer review of the existing model data input and logic, and completion of application documentation.

Future model extension should be modular. A more complete groundwater model for the Sacramento and San Joaquin valleys is an essential component. Other important modules that should be added include:

- 1) Water transfers
- 2) Groundwater banking, and conjunctive use
- 3) Water conservation options
- 4) Water quality
- 5) Economic drivers

Consideration should also be given to extending land use based demands to the west side of the San Joaquin Valley and to areas in the Tulare Basin served by the two projects.

DWR is evaluating the use of CalSim-II to analyze a broad range of future scenarios for the California Water Plan Update. DWR will examine ways to streamline the development of alternate water supply and demand input data. DWR and Reclamation will also examine ways to better integrate CalSim-II with the Department's other planning models (CVGSM, CALAG, LCPSIM) that would benefit both agencies.

#### **6.1.2. Data and Documentation**

Model credibility is viewed as the most immediate concern. Unless the credibility of CalSim-II stays above a certain threshold, the continued development and use of the model will be threatened. The issue of credibility stems partly from the complex representation of California's water system, exasperated by incomplete documentation. It also stems from the limited efforts to demonstrate that CalSim-II's water accounting is unbiased and reasonably

accurate. Many of the data concerns relate to the input hydrology. Priorities for the two agencies are:

- 1) Documentation of the CalSim-II's conceptual model and associated data inputs
- 2) Overhaul of the CalSim-II hydrology, with the development of updated hydrologic inputs supported by calibration and or validation
- 3) Integration of CalSim-II and CVGSM2 (or alternative) system representation and data set
- 4) Extension of hydrologic data to 2002 or beyond
- 5) Validation of CalSim-II using different year types
- 6) Uncertainty analysis

### **6.1.3. Software**

Improvements to the CalSim software should focus on the release of the next version of CalSim (v2.0). This represents a major restructuring of the model, with the replacement of text input files with a relational database. This will provide the functionality to implement many of the Strategic Review recommendations: modularity, version control, and documentation (metadata). The database will allow users to quickly query constraint sets and decision variables, and more easily follow model coding logic. Elimination of the FORTRAN compiler and the use of a public domain solver will make the software more accessible. Other important software development goals are:

- 1) Development of a GUI for construction of reservoir river-basin topology and the input and output of data
- 2) Creation of a common post-processing utility (using third-party tools such as Microsoft Excel) that streamlines the comparison of model results across model runs
- 3) Update and expand the CalSim user's manual and provide centralized support to CalSim/CalSim-II users
- 4) Reduce model run times by implementing better data transfer efficiency, increased modularity, and a more efficient solver
- 5) Develop a stripped-down CalSim-II for training of new users
- 6) Develop and automated procedure for weight setting
- 7) Develop multi-period optimization capabilities

### **6.1.4. Long-term Development**

Models take time to develop. Substantial thought should be given to the problems and type of analysis that CalSim will have to address in the next five to ten years, and the likely available resources within DWR and Reclamation. DWR and Reclamation will seek involvement from local agencies in model development. With modeling needs clearly defined, a strategy should then be devised for how to go from the current state of the model to the desired state of the model within the given timeframe.

## 6.2. Conclusions

The following remarks are extracted from the CalSim-II peer review panel

*“A unique aspect of CALSIM II is the high degree of cooperation between federal (i.e. U.S. Bureau of Reclamation) and State (i.e. California Department of Water Resources) interests in its development. This kind of cooperation is rare, and in fact this may be the only such example of such coordination for a system of this scale and complexity.....CALSIM II can provide a showcase for other states as to what can be accomplished with Federal and state cooperation for river basin management.” (Strategic Review, p18):*

*“We believe the use of an optimization engine for simulating the hydrology and for making allocation decisions is an appropriate approach and is in fact the approach many serious efforts of this kind are using.” (Strategic Review, p2)*

*“... CALSIM II represents a state-of-the-art modeling system that is similar in general concept, while differing in specific details, to other data-driven river basin modeling systems such as ARSP, MODSIM, OASIS, REALM, RiverWare, and WEAP.” (Strategic Review, p4)*

DWR and Reclamation believe that CalSim-II is an adequate model for planning studies for new storage and conveyance facilities in the CVP & SWP systems. For certain applications of CalSim-II as described in section 4.4.5, absolute values of CalSim-II results are required as projected estimates of future system performance. For such applications of CalSim-II, full discussion of all pertinent assumptions and careful examination of input data must accompany presentation of CalSim-II results. Many enhancements described in this Response Plan, when properly implemented, will greatly improve the performance of CalSim-II, thereby expanding the applicable scope of the model and enhancing the level of public acceptance. Sustained effort will be required to accomplish the planned enhancements. Periodic review and updates of the planned enhancements will also be part of this sustained effort.

# APPENDIXES

# **Appendix A. Representation of Groundwater Pumping**

## **Modeling of Groundwater Resources**

In CalSim-II, groundwater in the Sacramento Valley is used to meet both agricultural and urban demand. The volume of groundwater pumping varies according to the availability of surface water, and spring precipitation. In modeling groundwater, the developers of CalSim-II had a choice: (1) to restrict the volume of groundwater pumping in drier years to, for example, an estimate of the installed pumping capacity for a particular sub-basin; or (2) to assume groundwater pumping continues until demand is fully met. In either case, the impact of groundwater extraction can be measured by the impact on groundwater storage of each sub-basin, which is explicitly modeled in CalSim-II. Average annual groundwater pumping over and above the natural and artificial recharge will result in depletion of the basin. Once a groundwater basin is fully depleted, CalSim-II will no longer run. Model developers selected option (2) above, which gave rise to the concern of unlimited groundwater pumping voiced by the peer review. It is important to note, however, that CalSim-II does not include local ground water inventories. Currently the multiple-cell approach mimics the CVGSM model, which in itself is an “approximation” of built-in inventories (based on the historical calibration).

CalSim-II attempts to mimic farmers pumping decisions over the recent historical period. Groundwater extraction in CalSim-II is limited in several ways:

- The total of stream diversions and groundwater pumping must be less than the land use based demand. This demand is calculated from an assumed cropping pattern and monthly crop evapotranspiration, and takes into account the monthly and annually varying precipitation.
- The assumed cropping pattern used for CalSim-II is based on an agricultural economic production model that is calibrated to recent observed water use and cropped acreage. As such, CalSim-II implicitly accounts for the cost of groundwater pumping, which limits farmer’s willingness to pump water.
- For areas that have access to both surface water and groundwater, groundwater is the secondary or contingent resource. Groundwater pumping occurs only after the model has tried to maximize service water deliveries given the various operational constraints (minimum instream flows, Delta water quality requirements, minimum reservoir levels and reservoir carryover storage targets).
- Groundwater pumping may only be used to satisfy the demands of overlying landowners. No groundwater is exported from the overlying watershed (except in the form of surface water return flow or tailwater that results from irrigation using groundwater).

The above bulleted items are discussed in more detail in the following sections.

## **Land Use Based Demands**

Demands in the Sacramento River Basin (including the Feather and American River basins) and Delta are determined based on land use and vary by month and year according to hydrologic conditions. Land use-based demands are calculated using DWR’s Consumptive Use

(CU) model. The CU model simulates soil moisture conditions for 13 different crop types over the historical period. Irrigation demand is triggered when soil moisture falls below a specified minimum. The CU model calculates the crop consumptive use of applied water. The consumptive use is subsequently multiplied by water use efficiency factors to obtain a regional water requirement to be met from stream diversions or groundwater pumping. Agricultural demands in the Delta are represented more simply as an overall mass balance between precipitation and crop evapotranspiration.

### **Central Valley Production Model**

The Central Valley Production Model (CVPM) predicts cropping patterns, land use, and water use within the Central Valley by considering land availability, water availability and cost, irrigation technology, market conditions, and production costs. CVPM was used in the California Water Plan Update (Bulletin 160-98) to forecast future agricultural acreage. CVPM has recently been updated and extended into a statewide model, known as CALAG.

CVPM is a regional model of irrigated agricultural production and economics that simulates the decisions of agricultural producers (farmers) in the Central Valley. The model assumes that farmers maximize profit subject to resource, technical, and market constraints. Farmers sell and buy in competitive markets, and no one farmer can affect or control the price of any commodity. To obtain a market solution, the model's objective function maximizes the sum of producers' surplus (net income) and consumers' surplus (net value of the agricultural products to consumers).

The model is calibrated using recent historical irrigated acreage, applied surface water and groundwater pumping for 21 sub-regions in the Central Valley. The model includes information on pumping depth and pumping costs.

### **Matching of Demands and Supply**

Within the Sacramento Valley CalSim-II always meets the land use based demand.

### **Groundwater Pumping Logic**

In the Sacramento Valley demand is met by a mix of surface water and ground water. Farmers and urban municipalities may have access to either one or both of these supplies. In CalSim-II a minimum groundwater pumping is specified to represent those demands that only have access to groundwater. The CalSim-II code is written so that demands are first met by groundwater pumping, up to the minimum specified volume. It is subsequently met by surface water diversions up to the contract amount for project demands and up to its availability for riparian demands. Any difference between demand and supply is finally met by additional pumping. No shortages occur. Minimum groundwater pumping volumes are based on water years 1981-1993 of the historical CVGSM run.

### **Groundwater Export**

There are a total of seven basins that represent the Sacramento Valley floor north of the Delta. There is no export of groundwater from the sub-basin. Groundwater is pumped only to meet the demands within each sub-basin. The CalSim-II logic allows a certain percentage of pumped groundwater applied as irrigation to flow to the stream network as return flow.

### **Results from CalSim-II Historical Operations Study**

DWR recently released a report describing the results of a CalSim-II Historical Operations Study. The purpose of the Historical Operations Study was to evaluate the ability of

CalSim-II to represent CVP and SWP operations, in general, and the delivery capability of the projects, in particular, through the simulation of recent historical conditions (water years 1975-1998). The following is an extract from that report.

*Does CalSim-II overestimate the availability of surface water in the Delta by meeting Sacramento Valley in-basin use through excessive groundwater pumping?*

*The mix of surface water and groundwater used by the model to meet Sacramento Valley consumptive demands depends primarily on project water allocation decisions and levels of minimum groundwater pumping that are specified in the model. Over the 24-year period average annual net groundwater extraction in CalSim-II as compare to estimates based on the Central Valley Groundwater Surface water Model (CVGSM) is lower by 378 taf. The average annual net stream inflow from groundwater in CalSim-II is 190 taf greater than estimated by the CVGSM for the same period. The combined affect of dynamically modeling groundwater operations in CalSim-II (pumping, recharge and stream-aquifer interaction) leads to 188 taf/yr less water being available to the Delta. For the 1987-92 period the combined effect results in 46 taf/yr additional water being available to the Delta.*

Thus the Historical Operations Study concludes that the current representation of groundwater in CalSim-II results, on average, in an underestimate of the water available at the Delta.

## **Appendix B. Current CalSim / CalSim-II Development Projects**

### **CalSim Software**

#### **Version Control**

Good quality control is essential given the complexity of CalSim-II, the huge data requirements and the number of model developers. Good quality control is essential to model credibility. Without it, the accuracy or reliability of CalSim-II could quickly degenerate. The Strategic Review (p37 & 58) makes detailed recommendations relating to quality control. It cannot be achieved solely through software innovations. Protocols for data management and model development need to be written, published and adhered to.

Quality control needs to start with the central storing and sharing of data and the implementation of a version control system. This version control system should at a minimum:

- Keep track of model changes
- Facilitate the storage of metadata regarding those changes
- Allow any previous version of the model to be recovered
- Allow multiple developers to work simultaneously
- Alert model users to model changes

DWR and Reclamation have implemented a version control system for CalSim-II's text-based input files. The system allows model users web-based access to a central database. Model studies can be downloaded from the database, changes made locally to the model, and the revised data input stored back in the central location. The system has not been fully adopted, due in part to the lack of in-place model development/model management protocols. The current text-based version control system will no longer work with the release of the next version of CalSim (v2.0) that is centered on a relational database. DWR and Reclamation agree that it is a high priority to develop enterprise database capabilities for the next version of CalSim (v2.0), so that central data management and version control can be implemented.

#### **Geographically Referenced Network Schematic**

DWR and Reclamation are working cooperatively to develop a GIS based geo-referenced schematic of CalSim-II which would allow a user to interactively query attributes (e.g., reservoir or channel physical characteristics or all references to a node or link in the WRESL files), and time series data.

#### **Public Domain Solver**

DWR is currently working with the LBL to investigate the possibility of replacing the current XA solver in CalSim with a public domain solver.

## **CalSim-II Applications**

### **Geographical Expansion**

Over the last four years DWR and Reclamation have worked to develop CalSim models for the mountain watersheds in the Sacramento Valley. Models for Stony Creek, Yuba River, Bear River, and Upper American River have been successfully developed. These models require a technical peer review before being integrated into CalSim-II. The Yuba River model is currently being reviewed by Yuba County Water Agency's consultants, and is expected to be an integral part of the next CalSim-II benchmark study release.

### **Global Climate Change**

CalSim-II is being used by a joint DWR-Reclamation Climate Change Work Team to investigate impacts of climate change on California's water resources. Currently downscaled projections of future climates are being used to generate reservoir inflow time series for use in CalSim-II to investigate impacts on water allocation and Delta water quality. The work is an extension of previous studies conducted at UC Berkeley. Future work will focus on incorporating probabilistic risk analysis. Initial assessments focus on potential climate change impacts on SWP and CVP yield, carry-over reservoir storage, Delta outflow and compliance with Delta water quality standards.

### **East-Side San Joaquin Operations/Hydrology**

The representation of the east-side of the San Joaquin Valley has been substantially revised. Modifications include:

- Use of land use based demands
- Refine spatial resolution
- Revised reservoir operational logic for local projects
- Revised accretions and depletions

This effort is currently being extended to the Delta east-side streams.

## **CalSim-II Modules**

### **Daily Time Step Model**

DWR has created a daily time-step CalSim Delta Model as part of the evaluation of the proposed In-Delta Storage Project. This model was used in conjunction with the CalSim-II monthly model. The entire system's operation was simulated for a one month period with the CalSim monthly model and then the information on inflows to the Delta and south-of-Delta delivery amounts were passed on to the Daily Delta Model. The Daily Delta Model was used to re-simulate the operations in the Delta and the export facilities.

The monthly CalSim-II model provides monthly flows for various Delta locations. However, the daily model requires daily flow data as its input. Thus, a disaggregating model,

which was trained using historical observations, was used to generate the daily flows from the monthly flows. While the daily inflow hydrograph was patterned after the historically recorded inflow, the total volume of the inflow to the Delta provided by the monthly model was preserved. The results of the Daily Delta Model are provided to the monthly model as the initial conditions for the following month's simulation. The operation of the upstream reservoirs is re-simulated, and any gains or losses of water are reflected in Delta outflow and storage at San Luis Reservoir. The next month's simulation is then started with the modified end-of-month storage in San Luis Reservoir and the state of the Delta as simulated by the Daily Delta Model.

Since its use for evaluating the In-Delta storage Project, the daily model has been extended upstream to include the Sacramento Valley downstream of the major project reservoirs.

### **Water Quality Module**

MWD is taking the lead to develop and implement a water quality mass-tracking algorithm in the CalSim-II model. The implementation will track water quality constituent mass through arcs and reservoirs with the assumptions that the constituent is conservative and that perfect and instantaneous mixing occurs over the time step. Linearization of the mass balance relationship, by using source concentrations from beginning of time step, may be necessary for efficient implementation in CalSim-II. Linkage of Delta flow-salinity results to the south-of-Delta water quality mass tracking will be included.

### **CalSim Allocation Module**

The CalSim Allocation Module (CAM) was developed to help integrate the CalSim-II planning model with operational models used by the CVP and SWP. Specifically it was created to help operators:

- Define project reservoir carryover storage targets
- Define what hydrologic probabilities should be used in making projections
- Investigate how late the projects should make adjustments to annual allocations

CAM uses multi-period optimization to make annual allocation decisions based on imperfect hydrologic forecasts. By necessity this requires a much simpler representation of the system compared to CalSim-II. At the beginning of the contract year, CAM is run to define an initial annual allocation decision. The period of optimization is from the current month to the end of the September. The resulting allocation decision, based on maximizing deliveries for a given carryover storage target, is passed to the full CalSim-II model, which simulates in greater detail the response of the system for the current month. Updated forecasts and storage conditions from CalSim-II are subsequently passed back to CAM. CAM model is rerun to obtain an updated allocation. This process is continued until annual allocation decisions become firm, usually in the month of May.

On-going work for CAM includes the refinement of hydrologic forecasts, and developing better Delta required outflow projections.

### **San Joaquin River West-Side Drainage WQ Module**

Reclamation is working with consultants and DWR to complete development of a water quality mass-balance module that maps source loads of electrical conductivity associated with

the San Joaquin River irrigation activities to electrical conductivity conditions in the main stem of the San Joaquin River. The purpose of the module is to improve the CalSim-II salinity estimate at Vernalis through: (1) San Joaquin River westside flow disaggregation; (2) salt balance along the San Joaquin River main stem (nodes between Lander Avenue and Vernalis) by assigning EC values to the disaggregated flows.

### **CalSim Water Transfers Tool (Screening Model)**

The Water Transfers Tool (WTT) currently being developed for DWR will be a separate, smaller application from CalSim-II but will incorporate the major hydrologic, SWP/CVP system, and operational features of the larger model. Changes in the land use-based diversion requirements included in the model -by Depletion Study Area (DSA)- will serve as a surrogate for a variety of fallowing, crop change, conservation, and groundwater substitution transfers. Stored water transfers will be simulated through a surrogate reservoir concept at the location of the transfer and limited to upstream storage capacity availability. The WTT will be developed through a layering approach to allow for a large number of transfers at varying priorities for purchase and conveyance.

## **Appendix C. Software Development Proposed Plan**

The original CalSim 1.0 program was initially released to the public in 1999. Since that time, updates have been made to refine the original software and add capabilities as required by users. In that time the manner in which CalSim based modeling has been used has grown in terms of the number of users, the complexity of the regulatory environment needed to be simulated, and an increase in the scope and detail of the system required to be modeled. These and a number of other concerns led to the recognition that in order to achieve a robust and fully acceptable model of the current CalSim (v1.2) program required improvement.

The development of the next version of CalSim (v2.0) is intended to create a more robust modeling environment for the increasing number of users and complexity of system representation. These improvements fall under three categories of data management, a graphical user interface, and the solution controller.

### **Data Management**

Proper data management is an essential component for applications relying on large amounts of data. The text-based structure of the current CalSim application is sufficient for small numbers of users. However, as the complexity of the model and number of users increases, the greater the chances are for mismanagement of data. Integration of a relational database management system for CalSim's data storage formalizes the collection of data into a state-of-the-art management tool. Version control, integrity of data (validity of data is still required on the user side), reduction of duplicated data, and ease of linking with a graphical user interface are all advantages of using a relational database system.

Client/server functionality of the database provides for a central repository of benchmarked and finalized projects. Users may connect as a client to the database server to send and receive updates. The client may keep a local copy of the database on their computer and update with the server as desired.

Incorporation of metadata into the relational database is a significant step forward in automated documentation. As data is entered or manipulated the author and date is automatically recorded. A text area is also available for user comments and documenting the source of the data. Protocols on what users should record in this field have been developed by the CalSim-II Review and Documentation Team.

A tool will be developed that will ease the adoption of the next version of CalSim (v2.0) by automating the transfer of existing text files into the database.

### **Graphical User Interface**

With the incorporation of a relational database management system there needs to be a user interface for entering, manipulating and viewing the information. An integrated graphical

user interface (GUI) is being developed for this purpose. All data required for running CalSim simulations is interfaced through this single menu-driven GUI using standard windows features.

A hierarchical visualization of the relation of Projects, Simulations, and Cycles is the main component of the GUI. Properties of these components are viewable/editable through a standard point-and-click window. WRESL and Lookup tables are viewable/editable through similar standard windows. Standard editing features such as searching and copy/paste will also be provided.

The next version of CalSim (v2.0) GUI controls the management of projects which encapsulate any number of simulations. User privileges defined in the database allow for management of projects and simulations by controlling who may modify such data.

## **Solution Controller**

A JAVA based solution controller has replaced the current FORTRAN package. Adoption of object-oriented programming into the controller allows for more robust techniques. This increases not only the longevity of the management of source code but provides a simpler context for probable future modifications to the solution package.

Additional features of the new solution controller include the following:

- Elimination of the FORTRAN compiler. Reduces cost.
- Investigation of alternative MIP solvers. Potential cost reduction.
- Streamlining relationship of 'projects', 'simulations', and 'cycles'.
- Embedded 'cycles'. Replaces the Multi-Study Runner by allowing 'cycles' to contain other 'cycles'.
- Introduction of 'layers'. Collection of data (WRESL, tabular lookup, etc.) that allows for modularity of data across 'projects'. Cycles may contain any number of 'layers'. Layers are overlaid one on top of the other and may overwrite previously defined data. Protocols will be developed for sufficient need of using 'layers' (i.e. geographic subsystems, regulatory components, etc.).
- Iteration of a 'cycle'. A single 'cycle' may iterate on its solution until convergence criteria is met.
- Increased use of DSS path names. Using the 'cycle' name in one of the DSS path names facilitates the use of embedded cycles and eliminates the need for the costly run-time transfer files.
- Pre/Post-MIP 'state variables'. Some 'state variables' are functions of 'decision variables'. These are evaluated after the MIP solver but remain on the current time step.
- Direct writing of 'state variables' to the results file. Eliminates the need to send unnecessary decision variables and constraints to the solver to get 'state variables' in the results file.
- Dynamic calculation of 'decision variable' weights. Increases ability to control the MIP for each 'cycle' and time step.

- Introduction of ‘watch variables’. Allows results from the simulation to be dynamically viewed while the simulation is running.
- Facilitation for an interactive schematic. Development of GIS or other tools is being investigated.
- Facilitation of multiple-period optimization. GUI-assistance in writing WRESL that will span multiple time periods

## **Appendix D. Documentation Proposed Plan**

The most recent release of CalSim-II application documentation accompanied the September 30, 2002 benchmark. This literature is contained within the Benchmark Assumptions Document and Study Results, a summary of the simulation output. Criticisms to the documentation include a deficiency in: explaining how the model works, the underlying assumptions, limitations, and applicability to planning and management issues (Strategic Review, p 8). In addition, CalSim-II documentation is hampered by three factors: protocol has been mostly absent, maintenance is difficult and the knowledge of the vast SWP and CVP systems resides in many different individuals. Both DWR and Reclamation realize the importance of documenting information. However, more often than not, documentation has been placed at a lower priority or overlooked as an integral task to data and logic development or modification.

Despite the difficulties and challenges both agencies face to complete documentation of the CalSim-II application, a consorted effort has been initiated to remedy the deficiencies identified by both internal and external criticisms. DWR and Reclamation have proposed to develop a CalSim documentation management system. The purpose of the documentation management system is to

- Institute documentation protocol
- Provide a convenient method for documentation updates
- Flexible media products for users

This documentation system will become fully integrated within the next version of CalSim (v2.0) data management system and will be linked to the CalSim logic and data. The data management system will require a standardized set of documentation fields and meta data. Finally, the management system will be capable of generating a variety of media products with graphics, linking, indexing and searching options.

### **Documentation Management**

The current documentation techniques are cumbersome for the CalSim-II modeling community to maintain. A variety of formats such as text documents, comments in the code, spreadsheets, supporting model reports, and PDFs are housed in several different locations. The formats and locations make it almost impossible to update all aspects of a modification with absolute certainty.

Therefore, a documentation management system is proposed that utilizes a database to organize and maintain the information. The system will be used as a “central-file” for all model documentation. The new system will track and maintain a documentation history similar to features in the next version of CalSim (v2.0) data management system. Existing documentation will also be rolled into the new management system.

The key features of the documentation management system include:

- Documentation linked to the code
- Tiered levels of detail
- New topics of documentation not yet covered
- Links to source documents (e.g. PDFs or spreadsheets)
- Documentation of state, initial, and decision variables
- Documentation of lookup tables
- Documentation of logic and system control files
- Data confidence rating
- Distinction between actual practice and implementation
- Flexible report templates
- Advanced query options
- Electronic, hard-copy and Help File applications

It is anticipated that the organized and centralized documentation management system will be the new standard for CalSim documentation procedures. Linkages between the documentation and the code will eliminate undocumented or overlooked topics. New documentation coverage will address deficiencies and multi levels of detail will support both the novice and expert. The document management system is also expected to be an integral and priority component of the CalSim work effort.

## **Appendix E. Surface Water Hydrology Enhancement Proposed Plan**

The term hydrology development is used to describe: (1) the conceptual (node-link) model of the Central Valley, (2) the calculation of water supply and demand inputs and (3), water use parameters (efficiencies, losses, minimum groundwater pumping, etc.). Many of the methods used in the hydrology development were originally formulated in the 1960s and 1970s. This section proposes a major overhaul of the surface water hydrology, particularly for the Sacramento Valley, which provides approximately 80% of the inflow to the Delta.

The redevelopment of the surface water hydrology is to meet the following goals:

- Integrate the hydrology development with other statewide data collection and analysis efforts, in particular the land and water analysis carried-out by DWR's Division of Planning and Local Assistance (DPLA) regional offices
- Allow for spatial and temporal aggregation/disaggregation
- Provide a common approach for other agency planning models (CalSim-II, IGSM, CALAG)
- Easy to understand and implement
- Facilitate the use of CalSim-II to support other CalFed, DWR and Reclamation planning processes: e.g. Water Use Efficiency Program
- Refine estimate of Sacramento Valley 'in-basin use'
- Correct minor conceptual errors in existing methods

Both DWR and Reclamation agree on modifying and enhancing the hydrology development for CalSim-II. At this time, different proposals are being considered; but no agreement has yet been finalized (including the approaches discussed below).

### **Conceptual Model**

Water supplies and demands are currently represented in CalSim-II in a very aggregate form. For example, in the Sacramento Valley floor water supplies (other than inflows from the surrounding foothills) and agricultural and urban demands are lumped into only seven Depletion Study Areas (DSAs). The typical representation for each DSA is shown in Figure 11-1. A single inflow arc typically represents total regional inflow from minor ungaged streams and direct runoff. This flow is an unimpaired inflow. Any irrigation demands associated with these minor streams are met by proxy by diversions from the principal stream running through the DSA (the Sacramento River, the Feather River and the American River). A single land use based demand is calculated for each DSA using DWR's Consumptive Use (CU) model<sup>2</sup>. This demand is subsequently disaggregated into project and non-project demands using a constant fraction or percentage. Project demands may be met from releases of stored water from project reservoirs, but are constrained by the annual project allocation/contract entitlement. Non-project demands

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<sup>2</sup> The CU model estimates irrigation demands by simulating monthly soil moisture conditions in the root zone for 13 crop types.

are not constrained by contract, but are constrained by the availability of stream flow, unimpaired by project operations. Both project and non-project diversions are constrained by the land use based demand.

It is assumed that a certain percentage of demand must be met from groundwater pumping to represent areas that have no access to groundwater. Above a specified minimum pumping, demand is met from surface water supplies up to its availability or allocation. Supplemental groundwater pumping meets any unmet demand.

Land use based demands are at the resolution of the DSA. However, contract entitlements represented in CalSim-II are at a more disaggregated scale, typically at the level of the larger irrigation districts. To resolve this discrepancy in resolution, CalSim-II disaggregates demand by assuming it is proportional to the contract entitlement.

The aggregation of demand by DSA leads to assumptions about project and non-project water use that may not be entirely accurate.

- Project and non-project demands have identical efficiencies
- Project and non-project demands have the same monthly pattern of diversion requirements (implicitly the same cropping pattern)
- Project and non-project demands have similar dependency on groundwater (as represented by the assumed minimum groundwater pumping)

Non-project demands are predominantly located on the minor streams tributary to the Sacramento River. These supplies may be more restricted in dry years. The DSAs are currently not consistent with DPLA's proposed new Planning Areas used for land use planning and economic analysis. The boundaries of the DSAs make hydrologic mass balance calculations difficult in some areas (e.g. the Colusa Basin)

## **Spatial Representation**

There is a proposal to replace the existing DSAs with new water management areas so that demand units are associated with their correct water supply sources. Demands would be distinguished according to:

- Source of water,
- Contract type,
- Cropping pattern, and
- Water use efficiency.

The proposed new water demand areas are shown in Figure 11-2. Both project and non-project demands may be present in one planning area. Different project demands in a single planning region may be differentiated according to their water source, type of contract (with the CVP, SWP or local project), type of use (M&I vs. agriculture), cropping pattern, and water use efficiency. However non-project demands within a planning region are represented as a single aggregated unit. This proposed refinement of CalSim-II's spatial resolution could lead to greater engagement of local irrigation districts and water agencies.

## **Water Use Efficiency**

DWR's CU model calculates the irrigation water required to meet crop evapotranspiration while maintaining soil moisture above some minimum threshold. A 'basin efficiency' factor is subsequently used to calculate the water demand at a regional level. The basin efficiency factors are based on field measurements conducted by DWR during 1969-1974. These efficiencies were derived for use in DWRSIM (CalSim-II's predecessor). DWRSIM modeled groundwater as a net extraction from the aquifer, rather than explicitly modeling pumping and subsequent recharge from irrigation activities. The original basin efficiencies therefore had to be modified to account for losses from deep percolation. Use of a lumped efficiency factor, rather than explicitly representing losses at different scales, leads to assumptions and potential inaccuracies:

- Water use efficiencies are independent of the source of water, although most groundwater pumping is at farm/field level, and significant conveyance losses may be associated with stream diversions
- Project contractors and non-project diverters have identical water use efficiencies (conveyance losses, farm efficiencies, reuse, etc.)
- The project non-project demand split does not account for differences in water use efficiency so may be incorrect
- It is difficult to assess the impacts of on-farm and in-district water conservation measures due to the poor representation of efficiencies, losses and return flows
- The representation of demands in CalSim-II, CALAG/CVPM and CVGSM are difficult to reconcile since efficiencies and losses are represented in different ways
- CalSim-II demands are not related to applied water demands at the farm level and demands at the district level, although most of the available data is at these scales rather than at a regional level

It is also proposed to replace the existing representation of agricultural demand with an explicit representation of on-farm applied water demands, reuse (both intra-district and inter-district), conveyance losses, and operational spills. Different conveyance loss factors would be applied to the different contractors and non-project diverters according to their water source. The proposed approach is shown diagrammatically in Figure 11-3.

### **Rainfall-Runoff Modeling**

CalSim-II uses the historical hydrology to represent the possible range of water supply conditions that could occur at a future point in time (level of development). This enables future water supply reliability to be expressed in probabilistic terms. DWR and Reclamation recognize that this approach poses several problems. The historical stream flow record is incomplete. Flow data, where it exists, is impaired by historical diversions and return flows. Lastly historical stream flows are affected by the stream-aquifer interaction, a process that CalSim-II models dynamically. The current hydrology development uses a 'depletion analysis' to estimate the historical and projected level flows. The aggregate stream inflow for each DSA is calculated as the closure term of a hydrologic mass balance. Subsequently, historical flows must be adjusted to account for the impact of land use change on runoff. While this approach has its advantages, there are also disadvantages:

- The need to define historical land use, and historical consumptive use resulting from irrigation
- The need to define historical groundwater pumping and recharge
- The need to define the historical stream-aquifer interaction
- The need to define historical water transfers (imports and exports) across the model boundary
- The absence of a good measure of the associated error (errors are encompassed in the closure term)

With increasing demands for details, the depletion analysis approach (while serving its original intent) is becoming more difficult to use, requiring a detailed knowledge of the basin. It is very time-consuming to develop new hydrologies for different levels of development or to extend the period of simulation. To model historical water use also imposes considerable constraints on modernizing the approach. For example, representing changes in rice irrigation requirements due to changes in planting dates, shorter-growing crop varieties, winter flooding for rice straw decomposition all have to be represented as phased changes over time rather than simply considering today's practices. Lastly, the current depletion analysis does not lend itself to the modular approach advocated by the Strategic Review (p21).

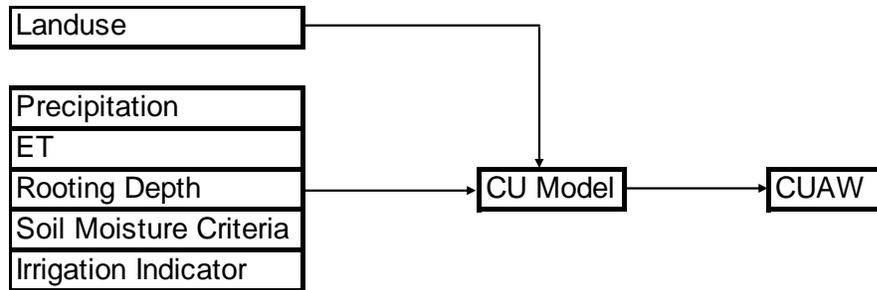
Under consideration is proposed work that a more modern and flexible rainfall-runoff approach to estimating local hydrology and rim inflows for use in CalSim-II would have considerable advantages. The rainfall-runoff approach has been successfully implemented for use in other planning models. The benefits of rainfall-runoff modeling include:

- Easier to field verify
- Easier to update hydrology for changing land use conditions (or climate conditions)
- Easier to document and sustain with personnel changes
- Easier for various model users and hydrologists to understand and use
- Easier for more groups of hydrologists (agencies and consultants) to contribute to model upgrades and refinements
- Easier to apply consistently across basins
- Provides a framework for keeping land use, water demand, surface hydrology, and groundwater hydrology assumptions consistent
- Provides consistency with CVGSM/IGSM (or alternative model) representation of groundwater hydrology
- Easier to change modeling time-step
- Easier to modify spatial coarseness
- Easier for state, regional, and local agencies to employ for a wider range of hydrologic, planning, and management studies (such as local water supply, flooding, and restoration problems)

## **Consumptive Use Model**

The Consumptive Use (CU) model was originally developed by DWR to create input for the water resources planning model DWRSIM. Its role in CalSim-II is essentially unchanged. The CU model simulates monthly soil moisture conditions in the root zone using simple mass balance accounting. For a given land use, the model calculates:

- Monthly agricultural and outdoor urban water use (consumptive use of applied water)
- Monthly precipitation that is used consumptively through evapotranspiration.



The time series of CUAW is aggregated by DSA and multiplied by efficiency factors to obtain the land use based target demands used in CalSim-II. The consumptive use of precipitation on developed areas compared to pre-development is used to calculate the effects of land use change on runoff. These adjustments are required to estimate the local water supplies or accretions in CalSim-II.

A main limitation of the CU model is that it does not integrate soil moisture accounting with rainfall-runoff and deep percolation. The separate estimation of rainfall runoff, evapotranspiration and deep percolation in CalSim-II can lead to errors. One approach under consideration is:

- Replace CU model with a soil moisture accounting model (e.g., Sacramento Watershed Model framework, implemented by CA-NV RFC) that directly estimates runoff and deep percolation
- Structure new model so that it can be directly incorporated into IGSM or alternative model
- Integrate new model's current work on irrigation model development such as DPLA's CUP and SIMETAW

## Modularity

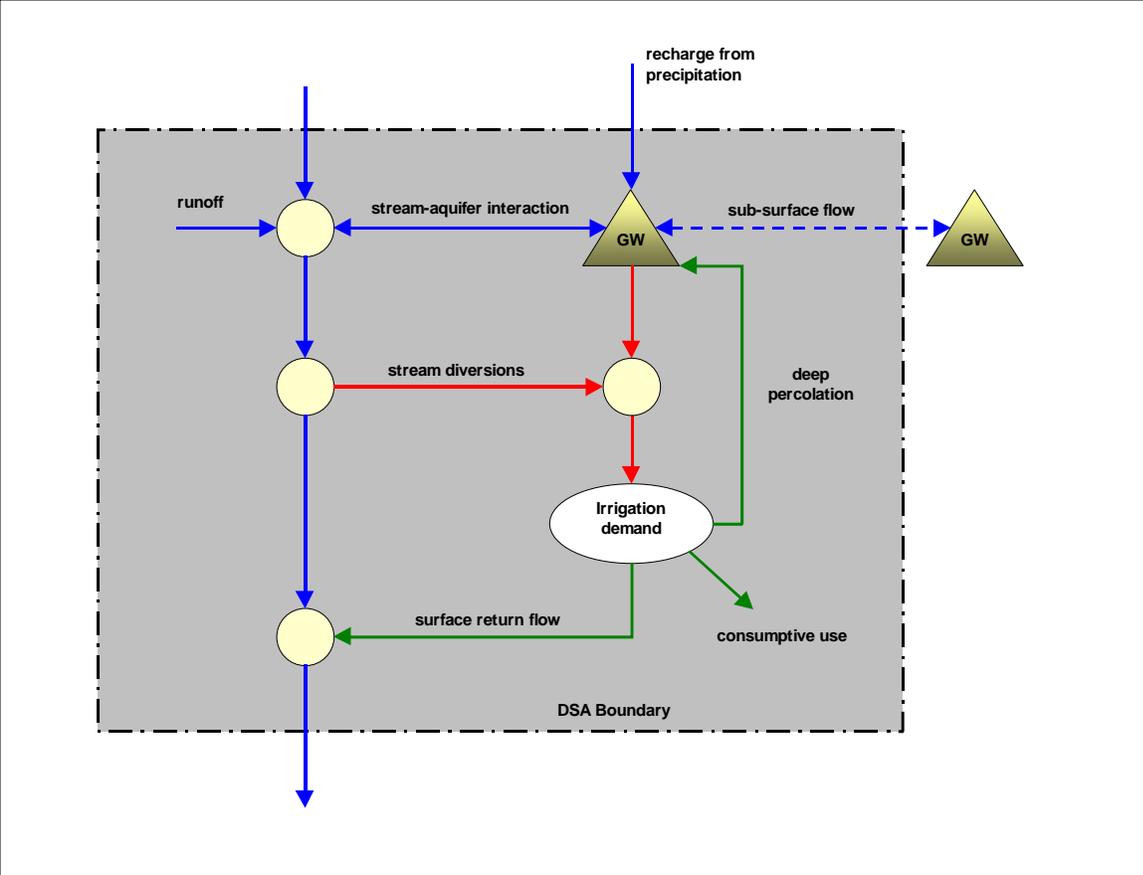
The refinement of the CalSim-II spatial resolution should go hand-in-hand with implementation of the modular concept of modeling. For example, agricultural areas in the Sacramento and San Joaquin Valley could be represented as a black box with boundary flows linking the black box to the major stream and groundwater system. The boundary flows are:

- Diversion arc(s) from the stream network with associated monthly demands and monthly weights

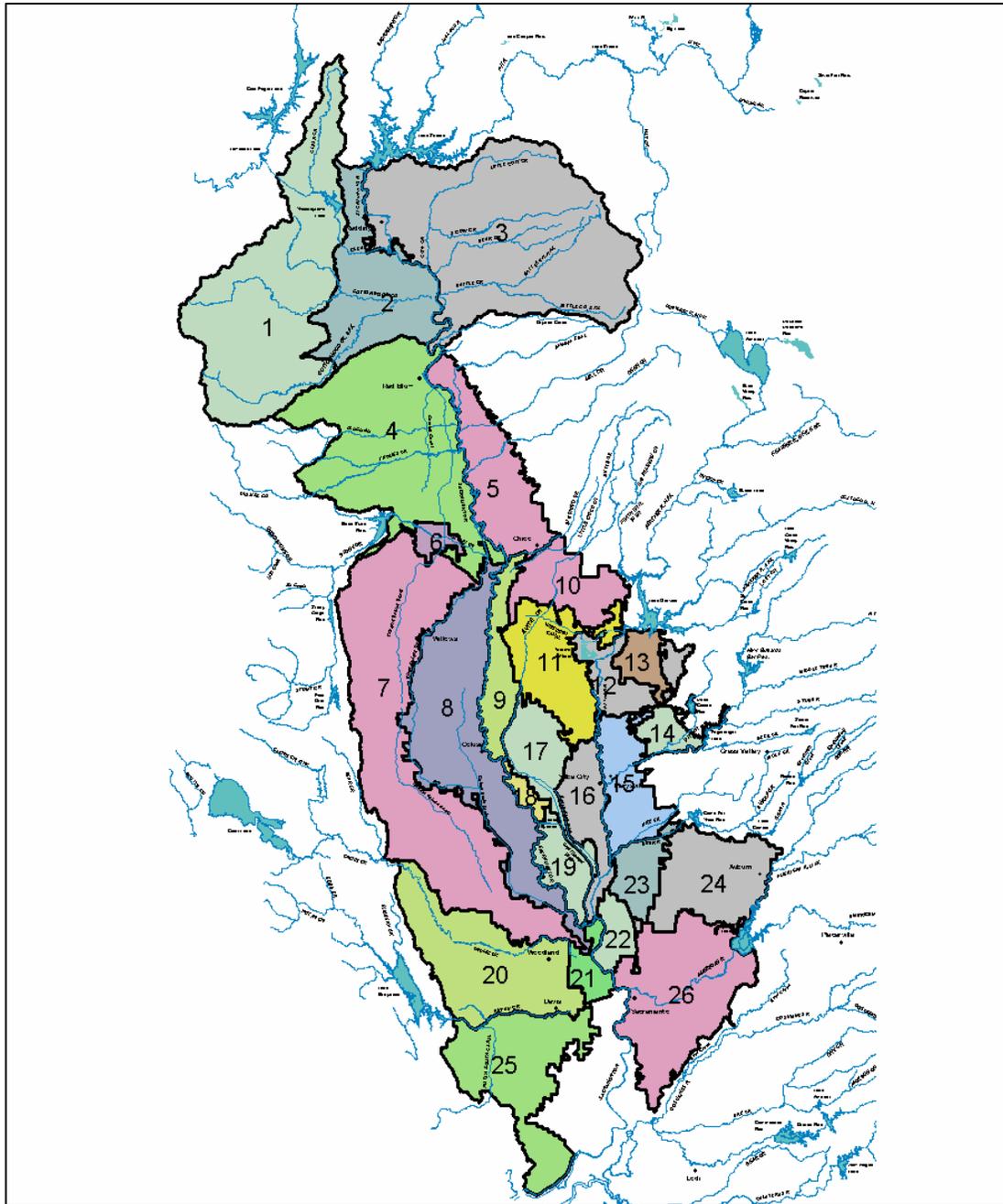
- Return flow arc(s) to the stream network, with flow calculated as a piecewise linear function of the flow in the diversion arc
- A groundwater pumping arc, with flow calculated as a piecewise linear function of the flow in the diversion arc
- An inflow arc to the groundwater system representing recharge from deep percolation (given a fixed land use, flow in this arc could be constrained to a fixed time series)

Alternatively, a region may be represented in more detail, broken-down into constituent irrigation districts with arcs showing conveyance losses, reuse, and operational spills. This more detailed representation is required for defining the relationship between surface water deliveries, groundwater pumping and return flows. Once these relationships have been established, the detailed model can be switched to the 'black box' representation to simplify the CalSim-II model and reduce run-times. The more detailed model can be used for analyzing impacts of water conservation measures.

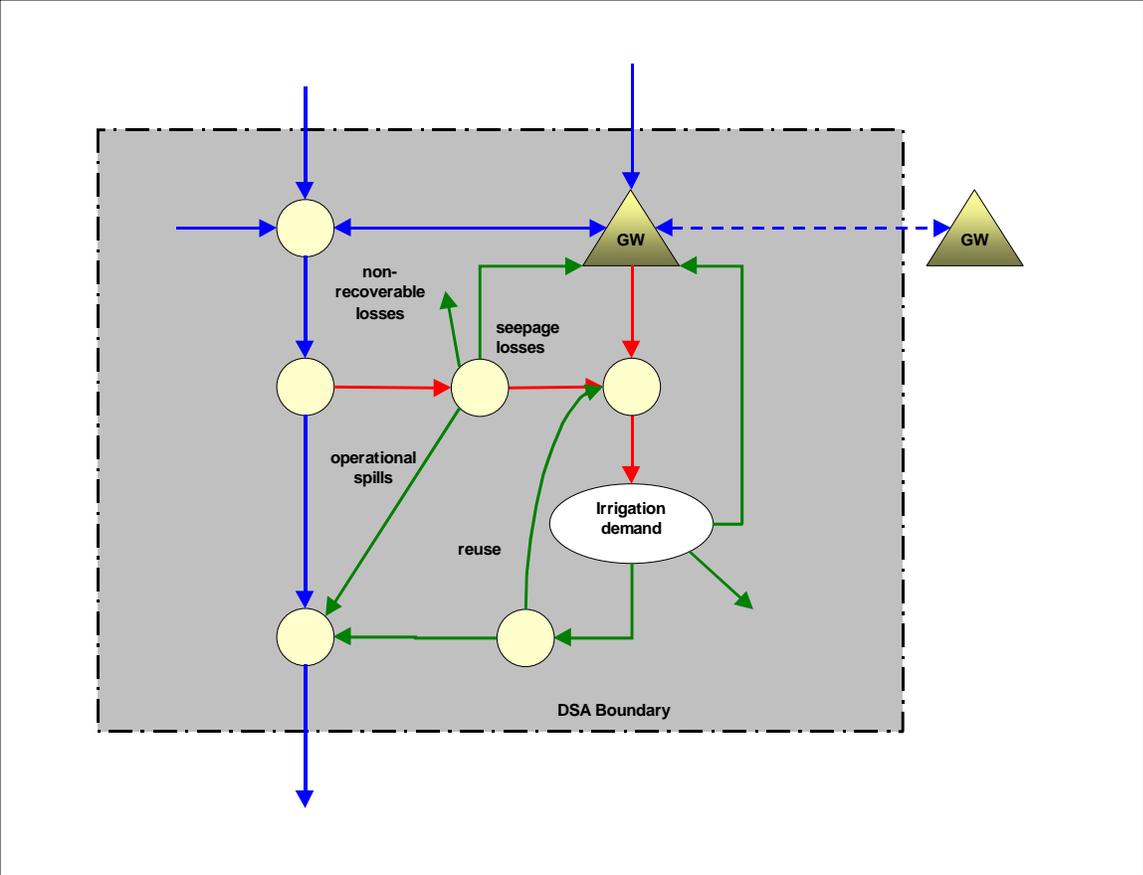
DWR is considering implementing this dual modular approach for a test area, such as the Feather River Basin, that has a very complex internal structure of diversions from different sources and reuse between irrigation districts.



**Figure E-1 Existing Conceptual Water Use Diagram**



**Figure E-2 Proposed New Water Management Areas**



**Figure E-3** Proposed Conceptual Water Use Diagram

## Appendix F. Groundwater Modeling Proposed Plan

Current representation of groundwater (inventories and impacts) in CalSim-II is approximate and limited. Both DWR and Reclamation recognize the strong need to enhance the modeling of groundwater in CalSim-II and a more realistic impact of recharge and pumping on local ground water resources. One model under consideration is the Integrated Groundwater – Surface water Model IGSM2 (Figure 12-1) the latest version of which was developed and is supported by DWR. The application of IGSM2 to the Central Valley is called the Central Valley Groundwater – Surface water model CVGSM2 (Figure 12-2). However, other models will also be investigated, including how the model is used (e.g, directly, or mimicked through approximate methods such as response functions).

One approach for meeting such an objective is the coupling of CalSim-II and IGSM2/CVGSM2 (or alternative model or mimicked version) for hydrology development, ground water representation and assessment in future versions of CalSim-II. This new approach could be used calculating the hydrology input to CalSim-II, the accounting for surface water – ground water interaction, and the modeling of groundwater flow. The type of “linkage” between CalSim-II and CVGSM2 (or alternative) would depend on what hierarchical level of CalSim-II is being used. For example, at its simplest formulation CalSim-II as a screening model of the SWP/CVP system may use an emulation of CVGSM2 (or alternative) to account for the accretions and surface water – groundwater interaction (e.g, through the use of response functions that would be developed based on CVGSM2 or alternative model runs). At a different level, resolution at a planning area level may be sufficient. At another level, interactions at the finite element level of CVGSM2 may be important. This hierarchical approach of CalSim-II and the associated form of using CVGSM or alternative (direct, indirect, or by emulation) is still being investigated by DWR and Reclamation.

There are many benefits for linking CalSim-II with IGSM2 (or alternative):

- The hydrology at future levels of development would be integrated in the simulation and developed on-the-fly allowing for modifications to land use (especially during dry periods) and/or modifications for meeting demands from surface water and groundwater.
- The spatial resolution would be enhanced, and allow for GIS technologies for use in calculating water demands by element of CVGSM (or alternative), rather than DSA.
- The accretions calculations will be more physically based, and would eliminate the use of the CU model and the Depletion model and their limitations for the valley floor areas. Currently IGSM2 uses the NRCS (SCS) method for calculating rainfall/runoff components.
- There would be a marked theoretical improvement in modeling groundwater flow and the surface water - ground water interaction, and allow for carrying conjunctive use studies.
- The extent of the simulation areas would be extended to include Tulare Basin.

In modeling California’s complex water resources, it is important that key elements reflecting hydrologic processes be accounted for either directly or indirectly in the model itself, its assumptions, or input. Key elements to consider in modeling surface hydrologic processes include: rainfall, snowfall, snowmelt, interception, retention, detention, infiltration, evaporation, surface runoff, return flows, artificial recharge, land and water use, water quality, and water rights. Key elements that need to be considered in modeling subsurface hydrologic processes include saturated flow, unsaturated flow in the

vadose zone, ground water pumping, evapotranspiration, water quality, and water rights. The interaction between the two processes occurs through streams, rivers, canals, lakes, reservoirs, and land surface. The IGSM2 incorporates most of the processes listed. Other models exist also, but the focus of this section is to use IGSM2 as a surrogate model.

IGSM2 is a regional scale model developed by DWR for the simulation of groundwater elevations, surface flows and surface-subsurface flow interactions. It is a completely revamped version of its predecessor IGSM version 5.0. IGSM was originally developed by consultants for Reclamation, DWR and other agencies. The first major public release of IGSM was in 1991. The first public release of CVGSM was also in 1991. Since its 1991 version, IGSM has undergone various upgrades by different groups based on specific applications to numerous basins in California, Colorado, Wisconsin, and Florida. In January 2001, DWR began the development of IGSM2 that included an extensive review and revamp of the theory, simulation methodologies and the source code used in IGSM. Based on this work, IGSM2 Version 1.0 that utilized enhanced/modified theory and simulation techniques was made available to public in December 2002. IGSM2 Version 2.0 was released in December 2003.

IGSM2 simulates groundwater elevations in a multi-layer aquifer system and the flows among these layers. The depth-integrated conservation equation is solved for horizontal flows in each layer and an approximate method is utilized to compute vertical flows among layers. The Galerkin finite element method is used to solve the non-linear conservation equation for each aquifer layer. A mixture of confined and unconfined aquifer layers that are separated by semi-confining layers can be modeled. The changing aquifer conditions (confined to unconfined and vice versa) as well as subsidence, and effect of tile drains, injection and pumping wells can also be modeled.

Stream flows, lake storages, and their interaction with the aquifer system are also modeled in IGSM2. Stream flow simulation is similar to that used in MODFLOW 2000. Conservation equations for streams, lakes and aquifer system are solved simultaneously to compute the interaction among these components accurately.

The distribution of four land use types (agricultural with specified crops, urban, native and riparian vegetation) dictate the evapotranspiration, surface runoff and infiltration characteristics (calculated using the NRCS method) as well as the demand for agricultural and urban water supply. The infiltrated water is routed vertically through root and vadose zones to compute the recharge to the groundwater. Stream diversions and groundwater pumping can be specified and distributed to meet agricultural and urban water requirements, and also adjusted dynamically to balance supply and demands. DWR staff also provides technical support of IGSM2.

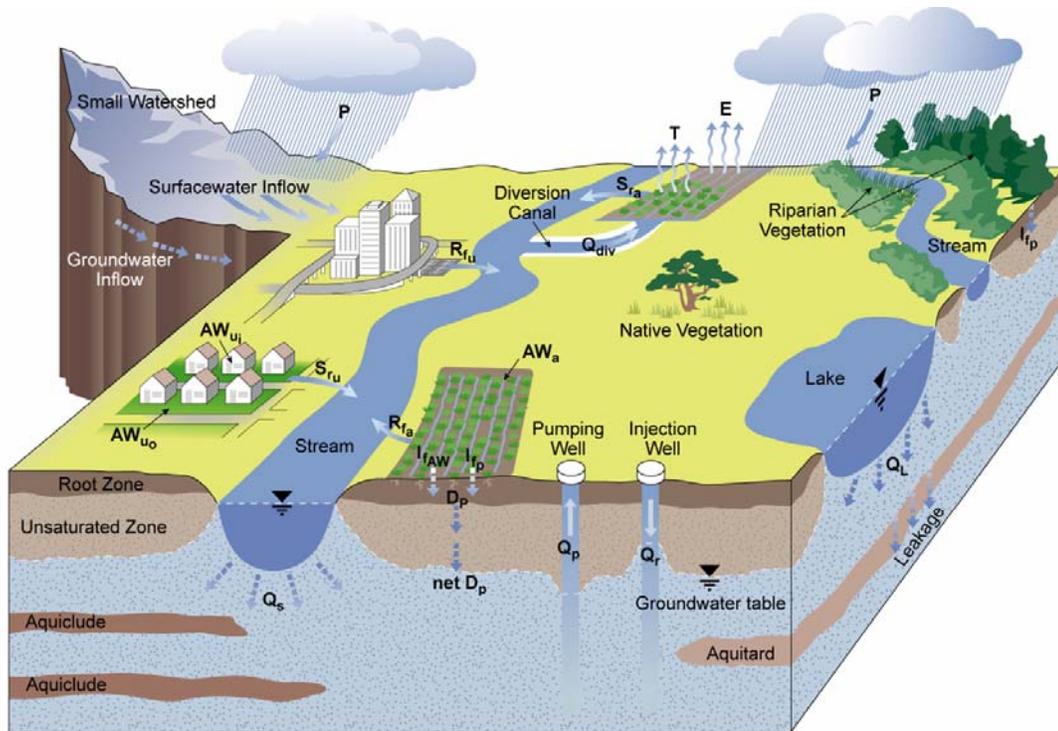
Hydrologic input to the CalSim-II model includes WY1922-1994 time series for reservoir inflows, local accretions, and projected land-use based demands. The land use based demands are using the Consumptive Use CU model, and local accretions and reservoir inflows are calculated using the Depletion Analysis approach. The CU model is a monthly soil moisture accounting model using known precipitation, crop and urban acreages, and crop soil moisture characteristics to calculate monthly demands (Diversion Requirements) by Depletion Study Area DSA. It calculates monthly demands for both historical (time-varying land use) conditions and projected (constant future land use) demands. Inflows into the reservoirs are calculated using the Depletion Analysis approach developed by both DWR and Reclamation. The procedure begins with measured historical outflows at gauged streams of a DSA which are unimpaired for historical conditions by adding back the historical calculated land-use based demands from the CU model, and re-impairing the flows by subtracting out the future level demands from the CU model. Local accretions are calculated using simple budget analysis, and the results are used as input to CalSim-II.

Local water supply computations (accretions) are currently pre-processed for CalSim-II. The CU model is used to calculate land-use based applied water demands at both historical and projected levels of

development. A simple water budgeting approach by DSA then allows for calculating local water supplies (accretions).

The accounting of groundwater in CalSim-II (and its predecessor DWRSIM) has undergone an evolutionary process. In the past the Depletion Model was used to calculate the additional groundwater pumping (above historical) required at a future level of development, along with future recharge of the past-pumped water using simple specified rules. This implicitly also fixed the historical surface-ground water interaction at future levels of development. In the current CalSim-II for the Sacramento Valley, a multiple-cell MC approach was used (each DSA represented by one cell), allowing for the interaction between cells and streams. The MC approach used actually emulated CVGSM in a very simple form, but allowed for ground water elevation accounting, and the stream-aquifer interaction.

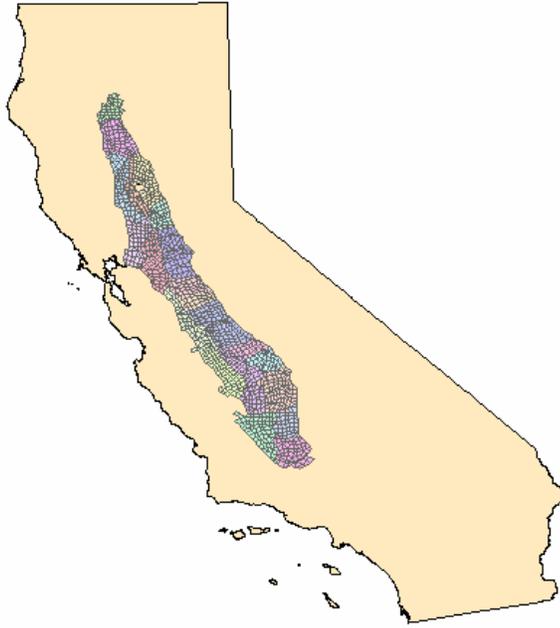
With IGSM2/CVGSM2 (or alternative) it is possible to enhance the hydrology input and the modeling of groundwater resources in CalSim-II, by eliminating the use of the CU model and the depletion analysis approach. DWR and Reclamation will investigate the different options of how best to achieve this objective.



**LEGEND**

- |  |   |  |
|--|---|--|
| P.....Precipitation                                  | $I_{fAW}$ ..... Infiltration of applied water                 | $net D_p$ .....Recharge to the groundwater aquifer |
| $AW_a$ ..... Water applied to agricultural lands     | $Q_{div}$ ..... Surface water diversion                       | $Q_p$ .....Pumping from groundwater aquifer        |
| $AW_{ui}$ ..... Water applied to indoor urban lands  | $S_{fa}$ ..... Agricultural runoff                            | $Q_r$ ..... Recharge to groundwater aquifer        |
| $AW_{uo}$ ..... Water applied to outdoor urban lands | $S_{ru}$ ..... Urban runoff                                   | $Q_s$ ..... Stream-groundwater interaction         |
| E.....Evaporation                                    | $R_{fa}$ ..... Agricultural return flow                       | $Q_L$ ..... Lake-groundwater interaction           |
| T.....Transpiration                                  | $R_{ru}$ ..... Urban return flow                              |  |
| $I_{fp}$ ..... Infiltration of precipitation         | $D_p$ ..... Deep percolation of water to the unsaturated zone |  |

**Figure F-1 Hydrologic Processes Modeled in IGSM2**



**Figure F-2** CVGSM2 Finite Element Grid and Subregions

**Table 1. Summary of Peer Review Comments**

| <b>CONCEPTUAL LEVEL</b>    |   |           |            |            |          |                 |
|----------------------------|---|-----------|------------|------------|----------|-----------------|
| <i>Type</i>                | <i>Comment</i>  | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> | <i>#</i> | <i>Response</i> |
| Local Projects             | Efforts to model local projects should be continued and expanded  | 19        | 2.1        | 9          | 1        | 2b,2c           |
| Geographic Scope           | Include Friant System, Tulare basin, Southern California, Colorado River. Hierarchical decomposition approach would allow development of separate models that can be linked through iterative process.  | 27        | 3.7        | 2          | 2        | 2b,2c           |
|                            | CalSim-II should be expanded to include major non-CVP/SWP areas, especially the Tulare Basin, the Colorado River, and Southern California.  | 21        | 2.2        | 4          | 3        | 2b,2c           |
| Management Scope           | CalSim-II does not explicitly represent many of the management options in which policy makers are interested  | 23        | 2.2        | 6          | 4        | 1,2             |
|                            | CalSim-II should be expanded to include local management options such as water conservation, reuse, water transfers, groundwater and conjunctive use management.  | 21        | 2.2        | 4          | 5        | 2a,2b           |
| Modular Approach           | Common tension for those who wish for greater detail and those who want less detail from the model. Need for more flexible, modular approach to modeling.   | 2         | 1          | 2          | 6        | 2               |
|                            | Too complex. Not sufficiently detailed. Develop linkable modules of different complexity.   | 7         | 5.2        | 2          | 7        | 2               |
|                            | CalSim-II should be modular.  | 21        | 2.2        | 4          | 8        | 2b,2c           |
| Real-time Operations       | Improve capabilities for real-time operations, gaming, ag demands, water transfers, Delta storage, carryover contract rights, refuge water demands, updated operations for Feather, Stanislaus, Upper American, San Joaquin, Yuba.  | 8         | 5.2        | 3          | 9        | 2a,2b           |
| Model Purpose              | For CalSim-II to remain a model of only the CVP and SWP seems technically and politically untenable. California's water system asked to be operated in an increasingly integrated manner. Widen geographical and functional scope of model. Better parameterize local supplies and demands. | 24        | 2.2        | 10         | 10       | 2a,2b,2c        |
| Hydropower                 | CalSim-II should include risk-based power capacity evaluation and incorporation of indexed sequential hydrologic modeling. Hydropower should not be after-the-fact calculation, but explicitly included in system objectives.   | 25        | 3.3        | 1          | 11       | 2b              |
| Groundwater                | Efforts to include groundwater should be continued  | 19        | 2.1        | 9          | 12       | 2a,2b           |
| Analyzing Future Scenarios | Need to examine greater range of long-term scenarios with respect to hydrology, demands, and operational uncertainty  | 22        | 2.2        | 4          | 13       | 2b              |
| Operational Objectives     | Better capabilities for analyzing economic, water quality and groundwater issues.   | 8         | 5.2        | 3          | 14       | 2a,2b,2c        |
| Documentation              | Documentation required that describes applicability of model to different problems.   | 8         | 5.2        | 3          | 15       | 2a,2b           |

| <i>Type</i>            | <i>Comment</i>  | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> | <i>#</i> | <i>Response</i> |
|------------------------|---|-----------|------------|------------|----------|-----------------|
| Objective Function     | Need to calibrate the CalSim-II objective function so that CalSim-II model decisions correspond to those operators would make. Unless calibrated the model may produce overly optimistic answers. | 4         | 3          | 1          | 16       | 2b              |
| Hydrologic Uncertainty | Need other approaches to representing hydrologic uncertainty and variability besides using historical record.   | 22        | 2.2        | 4          | 17       | 2b,2c           |
| Groundwater            | Limited representation. Infinite resource.  | 8         | 5.2        | 3          | 18       | 1,2             |
| DWRSIM/PROSIM          | Remove ties to DWRSIM and PROSIM  | 24        | 3.1        | 1          | 19       | 2               |
| Rule Curves            | Documentation required.   | 27        | 3.6        | 1          | 20       | 2a,2b           |
|                        | CalSim-II rule curves should reflect operator's behavior.   | 29        | 3.9        | 1          | 21       | 2b,2c           |
| Land Use               | Consider a land use that changes over time or responds to hydrologic conditions   | 8         | 5.2        | 3          | 22       | 2b              |
| Model Improvements     | Develop protocols and records for identifying and correcting model errors and making model improvements.  | 40        | 6.10       | 1          | 23       | 2b,2c           |

**Note: The keys to the "Response" column is on page F-10**

| IMPLEMENTATION LEVEL |   |    |     |     |
|----------------------|---|----|-----|-----|
| Numerical Model      |   |    |     |     |
| Type                 | Comment   | Pg | Sec | Prg |
| Daily Operations     | Inclusion of routing requires look-ahead optimization ability. Daily releases are head dependent.   | 26 | 3.4 | 1   |
| Groundwater Model    | Consider use of response functions. A dynamically linked CalSim-II -CVGSM is not necessary to obtain accurate groundwater predictions. It would also lead to greater run times. | 27 | 3.5 | 9   |
|                      | Possibility of using ANN for groundwater.   | 27 | 3.7 | 3   |
| Soil Moisture        | Soil moisture is not dealt with in a realistic manner within the CU model.  | 27 | 3.5 | 10  |

| #  | Response |
|----|----------|
| 24 | 2a,2b,2c |
| 25 | 2b,2c    |
| 26 | 2b       |
| 27 | 1,2b     |

| Data                 |  |    |     |     |
|----------------------|--|----|-----|-----|
| Type                 | Comment  | Pg | Sec | Prg |
| Required Accuracy    | Model developers should recognize the requirement that CalSim-II provide absolute values. Additional calibration required.   | 25 | 3.2 | 1   |
|                      | Need to improve CalSim-II's comparative as well as absolute capabilities.  | 8  | 5.2 | 3   |
| Data Development     | There has not been sufficiently systematic, transparent, and accessible approach to the development and use of hydrologic, water demand, capacity and operational data. The administration of data development is fragmented, disintegrated, and lacks a coherent technical or administrative framework. Needs to be greater coordination of data collection and analysis between different administrative units within DWR. | 20 | 2.2 | 2   |
|                      | Develop protocols for data documentation and development.  | 70 | G   | 3   |
| Groundwater          | Details of GW calibration should be available. The San Joaquin system should be added to the multi-cell model. The accuracy of using a coarse representation should be assessed. Better historical groundwater pumping data is needed to confirm whether the use of groundwater in CalSim-II is accurate.  | 26 | 3.5 | 5   |
| Hydrologic Data      | Needs updating.  | 20 | 2.2 | 2   |
|                      | Develop documentation and testing regime for developed data.   | 38 | 6.5 | 1   |
| Agricultural Demands | Update data. Use of economic factors in estimation of water demands. Preferred spatial scale for economic modeling is irrigation district scale.   | 23 | 2.2 | 5   |
| Documentation        | Documentation required that describe assumptions and limitations.  | 8  | 5.2 | 3   |
| Metadata             | Provide metadata for data inputs   | 58 | E   |     |
| DWRSIM/PROSIM        | Remove ties to DWRSIM and PROSIM   | 24 | 3.1 | 1   |
|                      |  |    |     |     |
|                      |  |    |     |     |
|                      |  |    |     |     |

| #  | Response |
|----|----------|
| 28 | 2a,2b    |
| 29 | 2a,2b,2c |
| 30 | 2a,2b    |
| 31 | 2a,2b    |
| 32 | 2a,2b    |
| 33 | 2a,2b    |
| 34 | 2a,2b    |
| 35 | 2b,2c    |
| 36 | 2a,2b    |
| 37 | 2a,2b,2c |
| 38 | 2        |

| <b>Data Management System</b> |  |           |            |            |
|-------------------------------|--|-----------|------------|------------|
| <i>Type</i>                   | <i>Comment</i>   | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> |
| Accountability and            | Need for quality control and documentation   | 2         | 1          | 2          |
| Quality Control               | Need for version control, quality control, calibration, and verification.            | 8         | 5.2        | 3          |
|                               | Develop an explicit quality control program.   | 37        | 6.2        | 1          |
| Model runs                    | Input and output data sets from model runs should be archived in a central location. | 58        | E          |            |

| <i>#</i> | <i>Response</i> |
|----------|-----------------|
| 46       | 2a,2b           |
| 47       | 2a,2b           |
| 48       | 2a,2b           |
| 49       | 2a,2b           |

| <b>Software</b>           |   |           |            |            |
|---------------------------|---|-----------|------------|------------|
| <i>Type</i>               | <i>Comment</i>  | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> |
| Error Checking            | Create automated mass balance checking procedure.   | 5         | 4          | 2          |
|                           | Automated input and output checking is needed.  | 24        | 2.2        | 10         |
| Non-Linearity             | Link linear optimization model with non-linear simulation models.   | 5         | 4          | 3          |
| Public Domain             | Switch to public domain software for optimization, visualization, file management and data base support.  | 5         | 4          | 4          |
|                           | Eliminate FORTRAN compiler, use public domain MIP solver.   | 24        | 2.2        | 10         |
| Multi-period Optimization | Introduce multi-period optimization for decision making based on uncertainty information.   | 5         | 4          | 3          |
|                           | Multi-period optimization could replace rule curves.  | 8         | 5.2        | 3          |
|                           | Performance based optimization should be added to WRIM's capabilities   | 38        | 6.7        | 1          |
| Modularity                | Ability to change geographic scope, spatial resolution, temporal resolution as required for the analysis.   | 8         | 5.2        | 3          |
| Documentation             | Improve software documentation.   | 8         | 5.2        | 3          |
| GUI                       | Improved GUI for facilitating model input, setting of constraints and weights, operating the model, displaying and analyzing results.   | 9         | 5.2        | 3          |
|                           | CalSim lacks a comprehensive, graphical user interface for constructing and editing the river basin system topology. The complexity of CalSim would be greatly reduced with development of an object-oriented graphical user interface. | 18        | 1.1        | 5          |
|                           | Develop GUI tied to databases with GIS display.   | 24        | 2.2        | 10         |
| Time-Step                 | Consider use of shorter time-step for some aspects of the model.  | 24        | 2.2        | 10         |
| Post-Processing           | Need for better post-processing tools   | 24        | 2.2        | 10         |
| Version Control           | Need for version control, and database management software and protocols.   | 24        | 2.2        | 10         |
| Weights                   | Need systematic and objective method of setting weights.  | 24        | 2.2        | 10         |
|                           | Need capability to dynamic vary weights, as a function of the state of the system.  | 27        | 3.6        | 1          |
| Run Time                  | Long run times preclude sensitivity analysis. Update solver to gain from efficiency improvements in the Branch and Bound algorithm and better sparse matrix analysis.   | 29        | 4.1        | 1          |
| Gaming                    | Improve capabilities for gaming involving stakeholders.   | 8         | 5.2        | 3          |
| Output                    | Provide access to Lagrange multipliers, identification of binding constraints and value of slack variable   | 24        | 2.2        | 10         |

| <i>#</i> | <i>Response</i> |
|----------|-----------------|
| 50       | 2a,2b           |
| 51       | 2a,2b           |
| 52       | 2b              |
| 53       | 2a,2b,2c        |
| 54       | 2a,2b           |
| 55       | 2b,2c           |
| 56       | 2b,2c           |
| 57       | 2b,2c           |
| 58       | 2b,2c           |
| 59       | 2a,2b           |
| 60       | 2b,2c           |
| 61       | 2b,2c           |
| 62       | 2b,2c           |
| 63       | 2b,2c           |
| 64       | 2a,2b,2c        |
| 65       | 2b              |
| 66       | 2b              |
| 67       | 2b              |
| 68       | 2b,2c           |
| 69       | 2a              |
| 70       | 2a              |

|                 |  |    |     |    |    |       |
|-----------------|--|----|-----|----|----|-------|
|                 | Develop output for a wider set of variables other than CVP_SWP e.g. groundwater depletion, water quality, supply reliability for non-project users, hydroelectric generation, indicators of ecological health. | 28 | 3.8 | 1  | 71 | 2a,2b |
| Infeasibilities | Add capability for automated debugging of infeasibilities.   | 24 | 2.2 | 10 | 72 | 2a,2b |

| <b>Administrative</b> |   |           |            |            |
|-----------------------|---|-----------|------------|------------|
| <i>Type</i>           | <i>Comment</i>  | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> |
| Model Peer Review     | Shortness of 2003 CalSim/CalSim-II Peer Review precluded technical analysis of CalSim-II. Such a technical review should be carried-out.  | 3         | 2          | 6          |
|                       | A peer review is required for each separate element of the model  | 2         | 1          | 2          |
|                       | CalSim-II should be subject to a systematic and frequent review and testing program   | 21        | 2.2        | 4          |
| Sustainability        | Develop strategy on how to sustain software development.  | 5         | 4          | 5          |
|                       | Produce strategic document that outlines short-term and long-term efforts, budgets, and responsibilities for model and data improvements, with policy for local agency and stakeholder involvement. | 70        | G          | 3          |
| Public Involvement    | Local agencies, system operators, and consulting firms should be actively involved in the development and application of CalSim-II.   | 21        | 2.2        | 3          |
| Financing             | The financing for CalSim/CalSim-II development should be wider than CVP/SWP projects. Funding should be forthcoming from local and regional agencies  | 38        | 6.6        | 1          |
| Staff                 | Not enough knowledgeable modelers   | 21        | 2.2        | 4          |
| Model Interpretation  | Stakeholders and policy makers are poorly guided in how to interpret model results.   | 23        | 2.2        | 8          |
|                       | Studies have not contained the kind of written discussion and interpretation of results that would demonstrate that the authors have thought about the results and drawn conclusions.               | 23        | 2.2        | 9          |
| Model Management      | CalSim-II should no longer be solely responsible to CVP-SWP managers but a broader range of technical managers from additional interests.   | 23        | 2.2        | 7          |
|                       | Create a broader interagency modeling consortium for developing operations planning models. Might require steering committee or governing board.  | 35        | 5          | 3          |
| Training & Education  | Hold seminars on CalSim-II to increase public confidence in model.  | 36        | 6.1        | 1          |
|                       | Develop a formal common regimen to train CalSim-II users.   | 29        | 4.2        | 3          |
|                       | Provide centralized support.  | 37        | 6.3        | 1          |
|                       | Develop a users group   | 8         | 5.2        | 3          |
|                       |   | 37        | 6.1        | 1          |

| <i>#</i> | <i>Response</i> |
|----------|-----------------|
| 73       | 2b,2c           |
| 74       | 2a,2b,2c        |
| 75       | 2a,2b,2c        |
| 76       | 2a,2b           |
| 77       | 2a,2b           |
| 78       | 2a,2b           |
| 79       | 2a,2b           |
| 80       | 2a,2b           |
| 81       | 2               |
| 82       | 1,2             |
| 83       | 1,2             |
| 84       | 2               |
| 85       | 2               |
| 86       | 2a,2b           |
| 87       | 2a,2b           |
| 88       | 2b              |
| 89       | 2a              |

| <b>MISCELLANEOUS</b> |  |           |            |            |
|----------------------|--|-----------|------------|------------|
| <i>Type</i>          | <i>Comment</i>   | <i>Pg</i> | <i>Sec</i> | <i>Prg</i> |
| Supporting Models    | Documentation, calibration, testing, peer review should be extended to other models that provide data input for CalSim-II. | 38        | 6.4        | 2          |

| <i>#</i> | <i>Response</i> |
|----------|-----------------|
| 90       | 2b,2c           |

| <b>CALIBRATION AND VALIDATION</b> |   |           |            |            | <b>#</b> | <b>Response</b> |
|-----------------------------------|---|-----------|------------|------------|----------|-----------------|
| <b>Type</b>                       | <b>Comment</b>  | <b>Pg</b> | <b>Sec</b> | <b>Prg</b> |          |                 |
| Calibration                       | CalSim-II should be calibrated, tested, and documented for absolute and comparative use.  | 40        | 6.9        | 1          | 39       | 1,2a,2b,2c      |
| Validation Report                 | Evaluation of CalSim-II by comparison with historical operations should be more rigorous.   | 40        | 6.9        | 3          | 40       | 2a,2b           |
|                                   | Comparison of simulated and historical deliveries suggests that the model over-estimates project deliveries                       | 68        | F          | 3          | 41       | 1               |
|                                   | Model rules on carryover storage during drought should be examined so that they reflect the system will be managed in the future. | 68        | F          | 4          | 42       | 2a,2b           |
|                                   | Comparison of simulated and historical deliveries suggests that the model underestimates storage in San Luis Reservoir.           | 69        | F          | 6          | 43       | 1,2             |
| Sensitivity Analysis              | Need for sensitivity and uncertainty analysis.  | 8         | 5.2        | 3          | 44       | 2a,2b,2c        |
| Advisory Board                    | Create external technical advisory body as part of a quality control program.   | 37        | 6.2        | 1          | 45       | 2a              |

**Keys to the “Response” column of Table 1:**

- 1 DWR and Reclamation do not agree with the comment stated.
- 2 DWR and Reclamation agree with the comment stated.
- 2a DWR and Reclamation agree with the comment stated and staff is currently working on it as part of our immediate needs for CalSim. A work plan is being developed by both DWR and Reclamation and will be shared with the public in the very near future.
- 2b DWR and Reclamation agree with the comment stated and consider it important to address in the short term with a target date of January 2007.
- 2c DWR and Reclamation agree with the comment stated but considers it should be addressed on a longer term with a target date of January 2011.

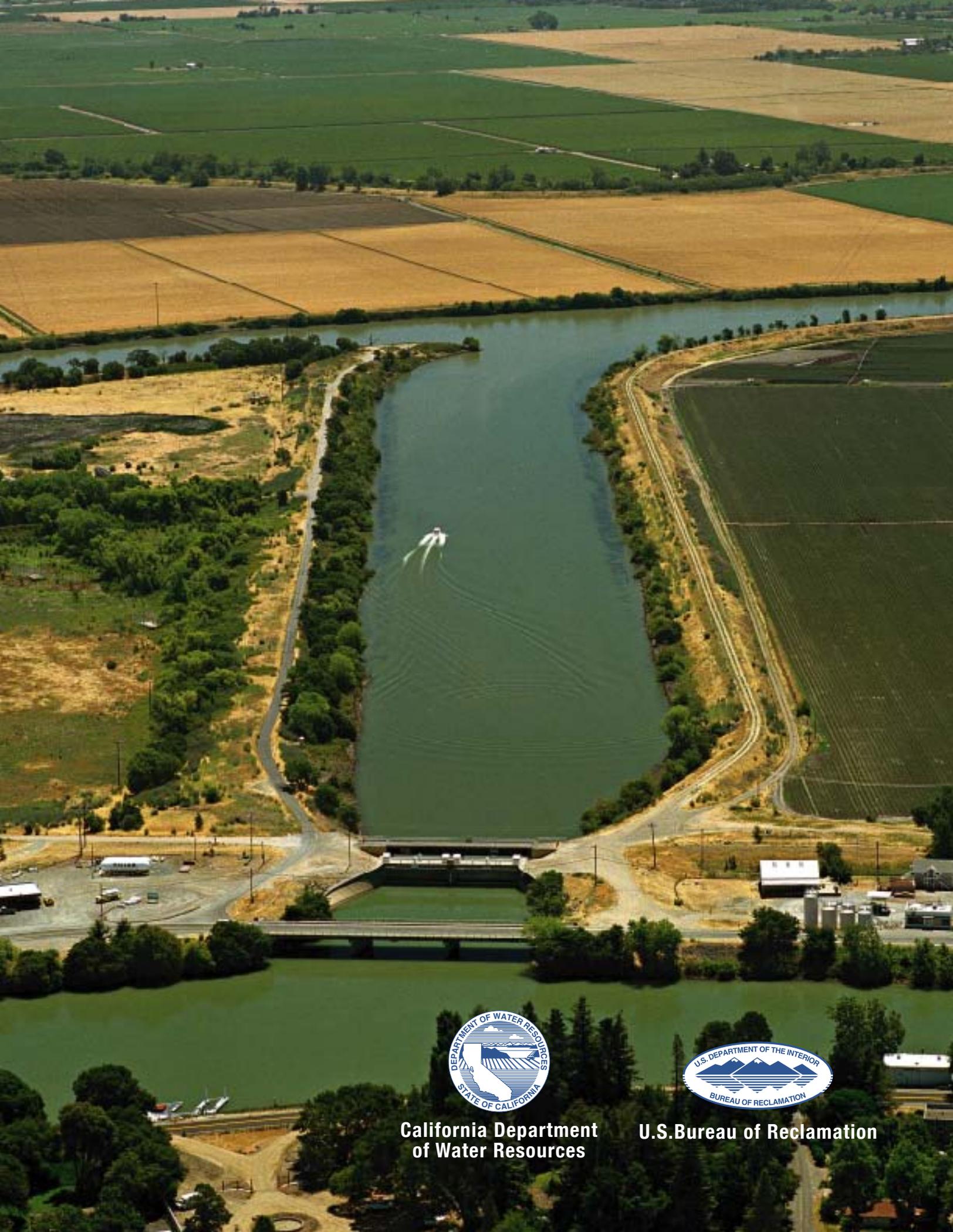
**Table 2 Development Priorities**

| CONCEPTUAL LEVEL                           |  |  |  |  |
|--|--|--|--|--|
| Task                                       | Current Development  | Immediate Needs  | Short-Term Development<br>Target January 2007  | Long-Term Development<br>Target January 2011 |
| Representation of local projects           | Explicitly represent major irrigation districts on the East-Side of the San Joaquin Valley | Explicitly represent major irrigation districts and water agencies in the Sacramento Valley        |  |  |
| Extended geographic scope                  | Model Friant System  |  |  | Model Colorado River system                  |
|  | Model Yuba River   |  |  | Expand representation of southern California |
|  | Model Bear River   |  | Model Upper Feather River  |  |
|  | Model Upper American   |  |  | Tulare Basin                                 |
|  | Model Stony Creek  |  |  |  |
| Representation of water management options | Develop module for water transfers   | Improve capability to model water conservation measures  |  |  |
|  |  | Improve capability to model conjunctive surface water and groundwater operations                   |  |  |
| Development of a modular approach          |  | Develop modular approach for irrigation and urban demands in the Sacramento and San Joaquin Valley |  |  |
| Real-time operations                       | Integrate planning and operational models  | Develop gaming model   |  |  |
| Hydropower                                 | Post-processing of hydropower operations   |  | Add risk-based power capacity evaluation   |  |
| Groundwater                                | Calibration of CVGSM   | Refine groundwater representation in the Sacramento Valley   | Add groundwater model for the San Joaquin River Valley                                 |  |
| Analyzing Future scenarios                 |  |  | Develop alternate future demand and water use scenarios. Develop alternate hydrologies |  |
| Operational objectives                     | Water quality module for the lower San Joaquin River                                       |  | Use of economic and water quality drivers and performance measures                     |  |
| Documentation                              | .  | Document applicability and limitations of CalSim-II  |  |  |
| Objective function                         | Work with operators to define current operating rules and objectives                       |  |  |  |
| Hydrologic uncertainty                     | Model global climate change study  |  | Develop alternate approaches to representing hydrologic uncertainty and variability    |  |
| Groundwater                                | Develop strategy to more comprehensively model groundwater                                 |  |  |  |
| Land use                                   |  |  | Dynamic variation of agricultural land use (demand) in response to water supply        |  |

|                                    |                                  |   |   |                    |
|------------------------------------|----------------------------------|---|---|--------------------|
| Model improvements                 |                                  | Develop protocols and records for identifying and correcting model errors and making model improvements.                    |   |                    |
| Daily time step                    |                                  | Assessment of errors due to monthly time step   |   |                    |
| Documentation                      | Document model logic             | Document development of rule curves   |   |                    |
| <b>IMPLEMENTATION LEVEL</b>        |                                  |   |   |                    |
| <b>Numerical Model</b>             |                                  |   |   |                    |
| MIP solver                         | Improve computational efficiency |   |   |                    |
| Daily operations                   |                                  |   | Add look ahead optimization functionality   | Hydrologic routing |
| Groundwater model                  | Link of CalSim-II and CVGSM      |   | Refinement of groundwater model in CalSim-II (unit response function, ANN, or multi-cell model) |                    |
| Soil moisture accounting           |                                  |   | Replace CU model  |                    |
| <b>Data</b>                        |                                  |   |   |                    |
| Required accuracy                  |                                  | Improve CalSim-II's absolute predictive capability  |   |                    |
| Data development                   |                                  | Develop protocols for data documentation and development  | Develop systematic, transparent and accessible approach to the development of hydrologic data   |                    |
| Hydrologic Data                    |                                  | Update hydrologic data. Broaden range of expertise involved in hydrology data development. Develop testing regime for data. |   |                    |
| Spatial resolution                 |                                  | Gather data for finer spatial resolution  |   |                    |
| Documentation                      |                                  | Document derivation of all data input   |   |                    |
| Metadata                           |                                  | Provide metadata for data inputs  |   |                    |
| <b>Data Management System</b>      |                                  |   |   |                    |
| Accountability and Quality Control |                                  | Develop version control for model input data  |   |                    |
|                                    |                                  | Develop an explicit quality control program   |   |                    |
| Model runs                         |                                  | Archive data sets from model runs in a central location   |   |                    |

| Software                  |  |  |  |  |
|---------------------------|--|--|--|--|
| Error checking            |  |  | Automate mass balance checking procedure               |  |
|                           |  |  | Add automated algorithms for checking input and output |  |
| Simulation                |  |  | Improve simulation functionality                       |  |
| Public domain software    | Elimination of FORTRAN compiler  |  |  |  |
|                           | Adoption of public domain solver.  |  |  |  |
| Multi-period optimization |  | Add automated multi-period optimization functionality  |  |  |
| Modularity                |  | Facilitate ability to change geographic scope, spatial and temporal resolution                                     |  |  |
| Documentation             | Add ability to store metadata  | Update and expand user's manual  |  |  |
| GUI                       | Create geo-referenced network schematic  | Develop GUI for constructing and editing river basin system topology, facilitating model input, displaying results |  |  |
| Time-step                 | Increase flexibility to switch between daily and monthly time steps                                  |  |  |  |
| Post-processing           |  | Improve third-party post-processing tools  |  |  |
| Version control           | Use version control for text based inputs  | Create centralized database for version control management   |  |  |
| Weights                   | Add functionality for dynamic conditional setting of weights   | Develop automated weight generating algorithm  |  |  |
| Run-time                  | Restructure WRESL code to eliminate redundant/repetitive calculations                                |  |  |  |
|                           | Add capability to output intermediate of state variables (rather than their addition to MIP problem) |  |  |  |
|                           | Improve solver computational efficiency  |  |  |  |
| Gaming                    |  | Create gaming model for stakeholder participation  |  |  |
| Output                    |  | Output of (Lagrange multipliers, basic and non-basic variables, including slack variables)                         |  |  |
|                           |  | Develop more comprehensive standard output of model variables  |  |  |
| Water quality             |  | Add water quality input tables and post-processor  | Add functionality to specify water quality objectives  |  |
| Infeasibilities           | Automate debugging of solver infeasibilities   |  |  |  |
|                           |  |  |  |  |

| <b>Administrative</b>               |  |  |   |  |
|-------------------------------------|--|--|---|--|
| Peer Review                         |  | Complete technical reviews of CalSim-II components   |   |  |
| Sustainability                      |  |  | Develop strategy on how to sustain software development.  |  |
|                                     |  | Produce strategic document that outlines short-term and long-term efforts, budgets, and responsibilities for model and data improvements |   |  |
| Public Involvement                  |  |  | Actively engage local agencies, system operators, and consulting firms in the development and application of CalSim-II. |  |
| Financing                           |  |  | Seek wider financing for CalSim/CalSim-II development   |  |
| Model Management                    | CWEMF modeling strategic vision committee                            |  | Create broader interagency modeling consortium for developing operations planning models.                               |  |
| Training &                          |  | Hold seminars on use and interpretation of CalSim-II for managers and policy staff   |   |  |
| Education                           |  | Develop a formal common regimen to train CalSim-II users.  |   |  |
|                                     |  | Provide centralized support.   |   |  |
|                                     |  | Develop a users group  |   |  |
| <b>MISCELLANEOUS</b>                |  |  |   |  |
| Supporting Models                   | Create documentation of model linkages (model map)                   | Documentation, calibration, testing, and peer review of supporting models  |   |  |
|                                     | Facilitate communication between models (CalSim-II-CALAG translator) |  |   |  |
| <b>CALIBRATION AND VERIFICATION</b> |  |  |   |  |
| Calibration                         |  | Calibrate hydrologic parameters using historical data  |   |  |
| Sensitivity Analysis                | Carry-out sensitivity analysis                                       | Carry-out uncertainty analysis.  |   |  |



**California Department  
of Water Resources**



**U.S. Bureau of Reclamation**