A Strategic Analysis Framework

for

Managing Water in California

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***Ad hoc* Committee on Long-Term Model and Data Development**

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Summary

Today's water management problems differ significantly from those of the past. To solve today's problems, new analytical perspectives are needed to serve more contemporary and decentralized decision-making processes. The success of California's complex water system depends on how well the water community develops and uses data and models to address water management problems. Development of water-related databases and models must be undertaken with explicit involvement from local, regional, and statewide interests and diverse expertise. It must be transparent and subject to stringent quality control. This report advocates a broadly based, broadly supported, and comprehensive approach to this problem.

Current and emerging water management problems require more sophisticated models. For example:

a) State and Federal Investments: What can a specific water management investment achieve for environmental, urban, and agricultural purposes under different scenarios?

b) Urban Water Supply Reliability: What is the best approach to secure a reliable water supply to meet urban needs and promote economic growth, consistent with environmental protection and agricultural prosperity?

c) Agricultural Water Security: How can agricultural water supply be managed to allow farms to remain productive and profitable while protecting the environment and urban prosperity?

d) Environmental Restoration: How can California use water most effectively for environmental purposes while protecting agricultural and urban prosperity?

e) Climate Change: How should local, regional, and statewide water managers plan for likely changes in demand and hydrology due to changing climate?

f) Floods: What strategy for flood management should California adopt given floodplain urbanization, climate change, multiple demands on reservoirs, and limitations in flood forecasting?

g) Water Right, Contract, Transfer, and Regulatory Accounting: How much water can a particular water right or water contract provide under different scenarios and regulations? How feasible are complex water transfer options?

The California water community is asking these questions in an increasingly decentralized decision-making environment with interacting local, regional, and statewide management alternatives. This decentralized situation differs fundamentally from the centralized and isolated development of data and models in the past. To provide reliable and well documented technical analyses, California needs to develop a coherent set of databases and models that meets the following criteria:

- Strategy – Data, models and communications tools should be developed and integrated as part of a broadly-based strategic effort focusing on likely future water problems in California. This strategy should be documented, updated, and coordinated with major modeling and stakeholder groups.

- Transparency – Data and models should be documented in a self-critical way so limitations are better known and considered. Documentation should be available to public scrutiny.
- Technical Sustainability – Data and model development are long-term efforts that must incorporate advances in scientific knowledge and the water communities' understanding of water problems as they become available. Models and data should be developed in a strategic modular way.
- Coverage – Water management in California involves not only statewide activities and processes, but also local and regional activities and processes. Consequently, California needs a statewide concerted effort to integrate the problems, resources, opportunities, and expertise available at the local and regional levels.
- Accountability and Quality Control – To improve the quality and transparency of model applications, models must be ground-truthed with the help of local experts. Protocols for model use and documentation, including limitations, must be developed.

The development of such databases, models, and communications tools will require a concerted, long-term effort and a broadly based strategic analysis framework for water problems in California. The major components for a framework are:

- Purpose and objectives
- Data review and management
- Models and communication tools
- Principles for data and model development
- Institutional and financial support

The development and implementation of a strategic analysis framework will require considerable time, resources, and dedication, and will complement ongoing policy and modeling efforts that address immediate needs. To begin this process, the California Water and Environmental Modeling Forum proposes the following immediate activities:

1) Purposes and Objectives

   Through a collaborative process with key responsible agencies, identify, review and revise, if necessary, the Strategic Analytical Framework's long-term purpose and objectives.

2) Data Review and Management
   a) Critically review the achievements and lessons of data development efforts both within and outside of California.
   b) Critically review existing databases in California and assess uncertainties in these data.

3) Modular Models and Communication Tools
   a) Critically review development efforts both within and outside of California.
   b) Revise and update the 2000 Modeling Forum report *Modeling Protocols for Water and Environmental Modeling* to provide more specific technical and procedural guidance consistent with the principles identified in this report.

4) Institutional and Financial Support

   Continue discussion with agencies to establish an institutional and funding basis for developing and implementing a strategic analysis framework for water management in California. This is the single most important activity in the immediate term since the success of the entire effort depends on it.

PREFACE

At its 2004 annual meeting, the California Water and Environmental Modeling Forum (Modeling Forum) initiated a discussion on the need for a comprehensive strategic analysis framework to guide the development of databases and models for managing water in California. An *ad hoc* committee on long-term modeling and data development was formed and embarked on an effort to identify (1) the key issues that the California water community will need to address in the next ten years and (2) the types of database and models needed to support future water policy, planning, and operation decisions. The committee solicited input from California water professionals through (1) a questionnaire consisting of four open-ended questions, (2) two half-day technical workshops conducted in the summer of 2004, (3) a plenary session at the Modeling Forum's 2005 annual meeting, and (4) comments received through other forums.

This report discusses the results from these efforts and proposes the development of a strategic framework for water management in California. This framework will guide the development of databases and models to provide reliable quantitative information under a broad range of scenarios. The framework is broad-based and involves agencies and expertise from all levels. It is technically focused and designed to support a variety of policy, planning, and management applications. A complete, integrated quantitative description of all aspects of California's water system is an ambitious goal, and broad stakeholder support for the framework is necessary to begin serious progress.

The Modeling Forum's Steering Committee accepted this report at its September 2005 regular meeting. However, this report does not necessarily represent the views of the member agencies or individual members of the Modeling Forum.

The Steering Committee thanks the many colleagues who contributed to this report through their participation in workshops, responses to surveys, and discussions. Many of their ideas are incorporated throughout this report. The Modeling Forum plans to continue this dialog with stakeholders and welcomes input and further discussions with interested parties.

I. INTRODUCTION

The long-term success of California's complex water system depends on how well the California water community collects, manages, and uses data and models to support operations, planning, and policy development. Recognizing this need, the California Water and Environmental Modeling Forum (Modeling Forum) promoted discussions on how to improve information and analysis for water management and decision-making. The result of this effort is a proposed Strategic Analytical Framework for the long-term development of data and models to manage water in California. While the results of this work might be useful for current planning and policy deliberations, it is specifically focused on a ten-year or more horizon. This allows the Strategic Analytical Framework to (1) focus on the technical environment of greatest long-term value, (2) avoid too much emphasis on current (but sometimes transient) problems, and (3) avoid confining the water community to existing data and models.

This Strategic Analytical Framework is intended as a basis for further discussion and action. While it cannot address the entire list of long-term water problems that California may face, its fundamental principles can be applied, extended, and modified to aid in understanding and managing the wide variety of evolving California water problems.

This report is organized as follows: Section I is the Introduction. Section II discusses recent developments in California water management that increase the role of technical analysis in management decisions. Section III summarizes key management issues that pose specific long-term challenges to technical analyses. It also defines the modeling requirements for adequate and reliable analyses of these issues. Section IV summarizes key requirements for a strategic framework. Section V discusses the initial steps towards the development of a framework. In particular, it proposes pilot projects that could proceed with modest resources. Appendices A through E provide additional background information.

II. PROBLEM SETTING

In recent decades, California's water problems have evolved substantially because of greater and more diverse demands on California's water system, increasing operational complexity of the system, increasing roles of local and regional agencies, and higher expectations of technical analyses.

- ***The technical complexity of California water management is increasing.*** Technical aspects of water policy, planning, and operations have become much more complex. For example, water quality requirements, which add a new dimension to management decisions, have become more demanding, especially for drinking water uses. Increasing and diversifying demands and regulatory complexity have led water managers to explore and adopt new water management options in addition to the traditional water storage and conveyance facilities, such as:
    - conjunctive use of surface and ground water
    - coordinated operation of reservoirs and pumping facilities of different projects
    - water markets (including long-and short-term options, transfers, and exchanges); and
    - wastewater reuse

  - improvements in water use efficiency

  Effective water system management requires careful coordination of such new options with traditional water management strategies.

- ***Institutional aspects of California water management have become more complex.*** Water management initiatives are no longer limited to the state and federal levels. Local and regional leadership and financing are increasing. Operations of this myriad of water projects affect each other, and they must be coordinated to meet environmental regulations, water quality concerns, and other requirements. Management of water purchases and sales, local conjunctive use, water use efficiency, and water reuse must be increasingly coordinated with different agencies to meet water deliveries, conveyance, and storage constraints. In recent years, local, regional, statewide, and federal water management institutions have shown increasing flexibility and coordination of their water planning and operation decisions more closely than ever before.

- ***California's demands and expectations for technical analysis are increasing***. The increasing number of parties and interests involved in water management raises the level of scrutiny and expectations on technical analyses. The credibility of modeling results supporting water management decisions is questioned more often. The highly pluralistic, complex, and flexible nature of water management in California poses a challenge to technical analyses. At the same time, recent legislation has led to modeling results taking on an accounting function in assuring local water supplies required for new urban developments, leading to still greater scrutiny of modeling results.

Water management in California involves many interests. Negotiations, contracting, and operation planning could all benefit from reliable, consistent, and well-documented quantitative analyses. A higher confidence in modeling results allows managers and policy-makers at all levels to make local, regional, and statewide decisions with a better understanding on how different systems would affect each other. The development of a comprehensive set of reliable data and modeling tools is often beyond the capabilities of any single agency. It requires involvement from many parties (Close et al 2003; Ferreira et al. 2004, 2005).

A comprehensive strategic analysis framework is critical as a guide to the development of data and models to support water resources management, planning, and policy. What are the requirements on data and models to assure effective technical analyses? How should such models be developed and used to support the increasingly difficult and controversial policy, planning, and operational decisions at local, regional, and statewide levels? Appendix A discusses the more fundamental needs for technical analyses that would provide guidance in addressing these questions.

The performance of California's water system depends on how well the water community collects, manages, and uses data and models for California's complex and decentralized system. The development of models must be undertaken with explicit involvement from local, regional, and statewide interests. This report is a first effort to address these issues in a comprehensive manner.

III. FUTURE WATER MANAGEMENT ISSUES

California faces many water management challenges, each requiring specific data and modeling to address. Participants in a Modeling Forum workshop in August 2005 identified the key California water management issues:

A) State and Federal Investments: What can a specific water management investment achieve for environmental, urban, and agricultural purposes under different scenarios? The California Water Plan, the CALFED process, and other planning efforts identify and analyze investment options to address California's water-related problems. These proposals require detailed quantitative analyses of alternative operations and management of infrastructure options. The system these studies address are more complex than the more centralized State Water Project (SWP) and the Central Valley Project (CVP) system existing models were designed to simulate. At the same time, how local and statewide water systems can be coordinated to improve their overall performance poses a challenging question.

B) Urban Water Supply Reliability: What is the best approach to secure a reliable water supply to meet urban needs and promote economic growth, consistent with environmental protection and agricultural prosperity? As water demand increases, local and regional water suppliers will be asked to provide firm and well-substantiated water supply guarantees for new developments. Recent California Senate Bills SB610 (Costa) and SB221 (Kuehl) in the 2001-2002 Session are perhaps forerunners of more demanding legal requirements of a reliable water supply. Assurances of water supply are likely to be challenged unless supported by consistent and transparent quantification, including contingencies. Accounting for the reliable sources of local water supplies is not simple for most growing areas in California. Estimating the available water, especially during droughts, is difficult given inter-regional dependencies for water supply and water quality. California does not have the type of data and models that allow these types of questions to be answered on a consistent basis across regions.

C) Agricultural Water Security: How can agricultural water supply be managed to allow farms to remain productive and profitable while protecting the environment and urban prosperity? Agricultural water supply will continue to become integrated with environmental and urban water uses. Recent water market transfers between farmers and cities illustrate the high level of economic and supply dependency that is evolving among different water users. How can water be better managed so that farms and rural areas remain viable without adversely impacting environmental restoration and urban economic prosperity, especially during droughts? What facilities, operational changes, water use changes, and institutional arrangements could provide a cost-effective basis for securing long-term agricultural productivity?

D) Environmental Restoration: How can California use water most effectively for environmental purposes while protecting agricultural and urban prosperity? Water management in California remains focused on independently meeting water supply, water quality, and environmental needs. A more integrated management of environmental uses and other beneficial uses of water could increase the overall utility of water for all beneficial use sectors. Models needed to explore such coordination are currently unavailable.

E) Climate Change: How should local, regional, and statewide water managers plan for likely changes in demand and hydrology due to changing climate? Management of water in California will need to change as the climate changes. However, we do not have a quantitative understanding on how different climate change scenarios affect the water supply, water demand, and environmental needs in California. We are unable to provide consistent recommendations to local and regional authorities. Reliable predictions of hydrological sequence from regional climate models will likely remain unavailable into the foreseeable future. What approaches and analyses can be taken when only the general hydrologic trend is known?

F) Floods: What strategy for flood management should California adopt given floodplain urbanization, climate change, multiple demands on reservoirs, and limitations in flood forecasting? Flooding is a persistent problem in California and is expected to worsen. Flood control is closely tied with water supply, environmental, and other water management priorities. Reliable cost-benefit analyses of flood control options require greater technical capability than is currently available.

G) Water Right, Contract, Transfer, and Regulatory Accounting: How much water can a particular water right or water contract provide under different scenarios and regulations? As water demands continue to increase and water market transfers become more prevalent, a consistent approach to establish the quantities and timing of water delivery under contractual rights and applicable regulations will become critical. How reliable could complex water transfer options be analyzed under multiple constraints? California lacks the tools for consistent and adequately accurate accounting.

These issues pose many challenges to water management in California. From the modeling perspective, they add to the complexity in quantitative analyses. Each one of these issues must be properly accounted for in a reliable and consistent manner. For example:

- **Real-time, flexible environmental requirements** could only be simulated if management triggers in flexible, real time operations are properly accounted for.
- **Biological models** must be linked or integrated with hydrological and water quality (e.g., temperature) models to be useful to management decision processes.
- **New facilities** require a realistic simulation of changes in the operation of existing facilities under the new system.
- **Integrated system operations** require accounting for water deliveries and operations in different systems, such as the Colorado River, Tulare Lake Basin, San Joaquin Valley, and Sacramento Valley projects. Operational coordination within each valley poses an additional challenge.
- **Water transfers, options, exchanges, etc.** require integration of economic considerations and system limitations (e.g. conveyance capacity and regulatory standards) of each entity and accounting for the cumulative effects of multiple transfers.
- **A wide range of available water management options** creates a need to understand how to combine and integrate options to improve system performance. This is difficult to do without adequate models. Appendix B provides a list of the major water management options available to most water agencies in California.
- **The Environmental Water Account (EWA)** requires simulation of ill-defined operation criteria for the SWP/CVP system. The impacts of EWA on the market for water transfers require modeling capabilities covering multiple disciplines.

- **Conjunctive use** requires simulation of system capacity limitations under multiple demands and political constraints.
- **Climate change** requires analyses beyond the historical hydrology. Potential changes in drought sequences, flood control requirements, and Delta salinity changes due to sea level rise all require new modeling capabilities.
- **Catastrophic events** could disrupt normal operations in large areas of the state for six months or more. Water project operations after major catastrophes, such as a massive earthquake-induced Delta levee failure, will likely be chaotic without adequate planning and feasibility analyses. A systematic evaluation of plausible scenarios requires additional flexibility in the modeling tools.
- **Uncertainty** in modeling results and questions about their reliability are legitimate concerns for water managers and policy makers. Modeling results are subject to error and bias for a variety of reasons (Satkowski *et al*, 2000). How should the performance of water management options be evaluated when there could be considerable uncertainty and variability in the modeling results for water availability, water demands, and costs? How should uncertainty analyses be conducted for operations, planning, and policy studies? Multiple-scenario studies are desirable, but how should these be conducted, presented, and interpreted? Currently, formal uncertainty analysis is rarely done in modeling studies for California water management.

Existing models and data sets were not originally designed to address these contemporary and emerging needs. .The credibility of modeling results is critical to management decisions. How can water policy, planning, and management discussions benefit from technical analyses? The technical basis supporting most policy discussions is fragmented and insufficient for the types of policy questions the water community are asking. If modeling results fail to gain wide acceptance, their roles and value in management decisions are diminished accordingly. A credible and broadly accepted data and modeling approach would greatly enhance the ability of water managers to explore and develop innovative solutions to water problems. If inadequacies in modeling capabilities are not addressed, the role of technical analyses in water policy and management decisions will decline. Without sound scientifically based analyses, operations, planning, and policy decisions would have to rely more on educated guesses and political considerations, becoming less transparent and efficient and more controversial and litigious.

Complex water issues take a long time to resolve. Development of a new facility or policy requires considerable time for institutional negotiations, compliance with legal requirements, financial arrangements, as well as construction. California must plan for future water problems and prepare for the challenge. Being able to use appropriate data and models broadens the variety of alternatives that the water community can evaluate with confidence.

IV. STRATEGIC ANALYSIS FRAMEWORK

The previous section highlights the need for a strategic analysis framework to guide the development of an appropriate database and a set of modular, linkable models to address increasingly complex water management challenges. Models and data sets must be designed and implemented to work well together to allow integrated evaluation of the types of water management problems expected in the future. This section describes the key steps of a strategic analysis framework.

A strategic analytical framework is a set of standards and protocols that allow data and models to be developed and combined in a transparent and systematic way to address defined problems. The technical development of an analytical framework for data and model integration requires a detailed planning and design process. Once a conceptual blueprint of the framework is developed, the design and development of the actual data management systems and models could proceed with a focus.

Several efforts have been made to develop integrated analysis frameworks for water management studies. These efforts have been focused on different problems, in different regions, and have met with various degrees of success. A first step in our effort is to learn from these past and ongoing efforts and to adapt appropriate components into our own development for water resources management in California. Major on-going efforts consulted include:

- U.S. Army Corps of Engineers
  - Hydrologic Engineering Center water management models and databases, CWMS (www.hec.usace.army.mil, USACE 2005)
  - Institute for Water Resources planning models
  - Basin-specific shared vision modeling
  - Central Valley Comprehensive Flood Control Study (USACE 2002)
- State of Texas Water Availability Management System (www.twdb.state.tx.us/rwpg/planning_page.asp, Wurbs 2005)
- Center for Advanced Decision Support for Water and Environmental Systems (U.S. Bureau of Reclamation, Tennessee Valley Authority, University of Colorado, cadswes.colorado.edu)
- European Union's Water Framework Directive (HarmonIT, www.harmonit.org)
- Federal Emergency Management Agency (FEMA) Mapping Information Platform (www.hazards.gov/resources/outreach/mip.htm, www.fema.gov/fhm/ctp_overtxt.shtm)
- Spain's national and regional modeling efforts (www.upv.es/aquatool/)

Review of these efforts and stakeholder input suggest that a framework must include the following five basic components:

1. Purpose and Objectives

California faces a wide variety of water management problems. A clear purpose and a concise set of objectives are necessary to guide the design and development of a strategic analysis framework. What are the most important questions the analysis framework will be asked to evaluate? Given the dynamic nature of California water, these questions should be fairly broad. Narrowly focused questions are less likely to retain their policy relevance over the long term. Major objectives will need to be identified in enough detail to provide guidance to the designers of the databases, models, and communication tools. However, detailed objectives will be developed only after the institutional and funding arrangements are defined. The applications discussed in Section III and in Appendix A provide a starting point for discussion.

2. Data Review and Management

A well-organized data management system supports major modeling objectives by providing well-documented, searchable descriptions of water, environmental resources, and infrastructure information. The conceptual blueprint for the strategic analysis framework would include detailed specifications for a data management system.

This data review and management effort differs fundamentally from most other existing water data activities intended for monitoring, hypothesis-testing, and compliance purposes. It would be developed with modeling applications as the key purpose. It would focus on the development, documentation, and testing of data sets that are used as input to models and for verifying model accuracy. These focuses differ from those of databases designed for monitoring or enforcement purposes. Error characteristics of data used for modeling purposes are especially important for several reasons. Systematic bias in the data over an extended period (for example, when maintenance for a sensor or recording instrument lagged and data quality deteriorated) would make model calibration and validation difficult. Equally important, the error characteristics of field data must be quantified if they are to be used for comparison with model output, error analysis of model results, or data quality improvement efforts. Furthermore, errors in input data will propagate, and possibly magnify, when different models are used sequentially.

The spatial representation and resolution in the database are important design criteria. The data structure should allow various spatial levels of representation, be GIS-based, and be searchable based on various hydrologic definitions. Presentation of analytical output on a GIS map, possibly with animation, will facilitate the analysis of model results. The temporal resolution is also an important issue, as operations and economic models operate on different temporal scales. How data of a coarser temporal resolution should be interpolated, if it could be interpolated, for input to models with a finer temporal resolution must be addressed.

A plan for data coverage must be part of the initial design. Data documentation, transparency, quality control, and uncertainty are important parts of the design criteria. Data quality problems are generally well known among data collectors, but they are rarely documented in a systematic way to data users. A scheme for characterizing data uncertainty and systematically improving data coverage and quality must be incorporated. Maintenance and data access protocols are essential.

3. Modular Models and Communications Tools

The strategic analysis framework must define an integrated set of models that provides adequate information to address policy, planning, and management questions of interest to local, regional, and statewide planning. Communications tools should be developed as companions to these "number crunching" tools to better allow policy-makers and their staffs to understand analytical results. The information conveyed should include a discussion of the uncertainties in (1) modeling results due to uncertainties in future scenarios, (2) water communities' understanding of the system, (3) input data, and (4) approximations used in the model algorithms. The models and communications tools will be designed based on technical feasibility into the foreseeable future.

The Modeling Forum is not aware of any integrated database <u>and</u> set of models developed for statewide water management in other states and countries. The CalSim-II model covers the federal Central Valley Project and the State Water Project, but does not include major parts of

California's water supply system. The Corps of Engineers, the State of Texas, and others have developed such analytical systems for particular projects or regions. The closest example for California may be the integrated databases and economic-engineering optimization model CALVIN, developed at the University of California, Davis (Draper et al 2003; Jenkins et al 2001). This research and screening tool has provided a proof-of-concept for the value of integrated databases and analysis, but has many well-documented limitations (Jenkins et al 2001).

The preliminary conceptual design must cover several currently disconnected technical domains, including operations, surface hydrology, groundwater, urban economics, agricultural economics, water quality, biology, ecosystem, and social studies. Appendix C describes the wide range of technical domains that must be included to develop a comprehensive strategic analysis framework. Models in each of these domains must be developed with spatial and temporal representations and input and output specifications allowing them to be systematically linked to or integrated with other models in "upstream," "downstream," or feed-back relationships, such as surface hydrology model results becoming inputs to water quality, fish population, or operations models. Models with variable spatial and temporal resolution and coverage would be of particular interest.[1] The experience of the European Union's Water Framework Directive, the HarmonIT Project, and the U.S. Army Corps of Engineers' (water management models and databases) CWMS effort could provide useful insights and ideas for adoption in California.

The design of screening tools, whether for simulation or optimization purposes, should be based on more detailed models. These tools are needed to identify promising alternatives from a large number of options within a reasonably short time frame. The promising alternatives can then be refined and tested with the more detailed and carefully verified models.

Another aspect of the conceptual design of models will be the development of preliminary protocols and guidelines for model development and use. A previous effort of the Modeling Forum (Satkowski *et al* 2000) could be revised for this purpose. In addition, models should be designed such that new research results and improved understanding of the system could be easily incorporated into the model algorithms and/or input data.

4. Institutional Support and Funding

A wide variety of institutional forums are potentially available to develop, implement, and adapt a strategic analysis framework. Texas has developed an extensive and integrated approach to quantify understanding of that state's water availability, demands, and management (see www.twdb.state.tx.us/rwpg/planning_page.asp; Wurbs 2005, in press).

Texas' analytical framework consists of a set of standardized regional models for surface water availability, groundwater availability, and water demands. While this approach has limitations, Texas is well ahead of California in the types and consistency of information being developed. The following excerpt outlines Texas' approach to groundwater management:

> "During the 76th Legislative Session, the Texas Legislature, recognizing the importance of accurate groundwater availability estimates, approved initial

[1] The feasibility to use detailed, accurate models as screening tools by reducing the spatial resolution and/or coverage (to reduce computation time) would be a highly desirable feature. Alternatively, two sets of tools could be considered. Each approach has advantages and disadvantages.

> funding for the Groundwater Availability Modeling (GAM) program. The GAM program's goal is to provide reliable and timely information on groundwater availability to the citizens of Texas. The GAM program will result in standardized, thoroughly documented, and publicly available groundwater models. These models will be important tools for Regional Water Planning Groups and Groundwater Conservation Districts to evaluate water-management strategies and to assess present and future groundwater availability under normal and drought conditions.
>
> Stakeholder involvement is critical to the success of the GAM program. Stakeholders, participating in Technical Advisory Groups (TAGs), are relied upon to voice concerns and provide information. Stakeholder input ensures that the models address the important water-resource issues concerning them for each major aquifer. TAGs typically consist of representatives from Regional Water Planning Groups, Groundwater Conservation Districts, the Texas Natural Resource Conservation Commission, the Texas Department of Agriculture, the Texas Parks and Wildlife Department, industry, water utilities, higher education, agriculture, and private landowners."
> (From: www.twdb.state.tx.us/publications/newsletters/waterfortexas/wftwinter00/article4.htm)

As pointed out in the Texas example, any framework development process should be broad-based, involving agencies and expertise from all levels. Policy and technical committees representing major technical and policy expertise for California's water management will help ensure that the framework and products are comprehensive, enjoy a broad consensus among stakeholders, and are likely to become standard for water management analysis. Spain has a somewhat similar approach to developing analytical capability for its national and regional water plans, where a single academic developer provides most of the software and modeling technical support (Andreu, et al. 1996).

Various institutional support and funding options can be explored. Some options include:

i) Consortium of agencies

Create a stand-alone data and model development organization consisting of a consortium of data and model development institutions. This consortium would report to a Board of Directors and not directly to any single agency manager. The products from this consortium would be the authoritative data and models for all water related management purposes in California. This consortium could begin by focusing on a limited scope of data and model domains, which can later on be expanded if the initial effort is successful. The Consortium would adopt, maintain, and implement a strategic analysis framework, and oversee the development of data and models and protocols for their applications.

ii) Analysis coordination group ("Consortium Lite")

Establish a small formal coordination group consisting of major modeling agencies, with a small, but mostly senior staff. This coordination group would direct and oversee all major data and model development for local, state, and federal purposes. The group would report to a Board of Directors consisting of major agencies and stakeholders.

iii) Independent research and development unit hosted by a research institution
Similar to some aspects of Texas' and Spain's approach, an academic institution (e.g., the University of California) or a research institute would host an independent research and development unit with staff and support from participating agencies. This alternative is similar to the consortium approach, except that another institution would host that unit. This arrangement might be better suited to attract and retain data and modeling expertise and to establish public/private partnerships, especially those that deal with information technology.

iv) State modeling program
The state legislature would specify an institutional structure for the development of a standard set of models and databases and protocols for their applications. The discussion on the Texas Groundwater Availability Modeling Program above provides an example of this approach.

v) MOU of modeling BMPs, with an enforcement/inspection mechanism
A set of best management practices (BMPs) for data and analytical tool development and use would be established and agreed upon by the major agencies in a Memorandum of Understanding (MOU). The MOU will also address how data and model developments in different agencies will be coordinated.[2] It would be overseen by an independent group. This approach is currently used in urban water conservation effort, in which the California Urban Water Conservation Council (CUWCC) oversees the MOU of best management practices.

vi) CBDA analysis coordination group
The California Bay Delta Authority (CBDA) would establish an analysis coordination group, similar to the CBDA "Ops Group," to coordinate data and model development, standards, and protocols among agencies and other stakeholders. While the CBDA would require the use of these standards for CBDA studies, they are likely also to become the standard for other agency studies.

vii) Legislative requirements for funding recipients to adhere with data and modeling principles
State and federal budget acts, and state bond funding legislations would require funding data and modeling recipients to adhere to a set of principles (see section IV.5 below).

viii) New DWR Division for data and models development
The California Department of Water Resources (DWR) would reorganize and form a Division of Analytical Services. This new Division would manage all data and model activities. The Division would consult with an external advisory board consisting of stakeholders from different sectors. This alternative provides DWR with consistent data and model development with explicit input from external stakeholders.

ix) DWR analysis coordinator and committee
A DWR coordinator supported by limited staff would report to DWR's Director. The coordinator would be a deputy director or senior manager responsible for budgets and technical direction for data and model development within DWR. S/he will be advised by an external committee as a channel for input from non-DWR stakeholders. This alternative is a scaled-down version of the previous alternative.

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[2] An example is the federal framework for facilitating cooperation and coordination on environmental models (www.iscmem.org/Memorandum.htm).

x) Expansion of DWR-USBR cooperation to other groups and modeling domains
The recent collaborative effort between DWR and the US Bureau of Reclamation (USBR) to develop the operations planning model CalSim-II has been successful. This state-federal cooperation would be expanded in phases to include other major data and modeling efforts and include other modeling domains.

xi) Continued and expanded Modeling Forum efforts
The Modeling Forum would expand its work to facilitate voluntary coordination of data and modeling activities. The Modeling Forum has been and will continue to be an active forum for the discussion of technical issues and peer-review efforts. It could take on strategic and implementation roles if the major agencies so prefer and authority and resources are delegated accordingly.

xii) No change. Each agency proceeds at its own pace and interest
This is the no action alternative where each agency develops and uses data and models at its own pace and interest. We are all familiar with how this works.

xiii) Other Alternatives / Combinations of the above alternatives
Since the alternatives discussed above are not mutually exclusive, some combinations could be pursued at the same time. A superior alternative might emerge from brainstorming sessions involving technical staff, managers, and policy makers.

There are advantages to a framework that is non-dictatorial and does not stifle innovation. At the same time, it must encourage convergence and consistency in technical work. In addition to defining a clear arrangement of authority, funding, expertise, and activities, the institutional framework should also support the development, education, and improvement of modeling professionals.

5. Principles for Model and Data Development

The issues discussed in sections IV.1 through IV.4 have been summarized into a set of common principles (CWEMF 2004). These principles apply to all major model and data developments and applications. They provide a foundation for both technical analyses and the use of the results for policy decisions. They define expectations of analytical work which technical and scientific professionals, water managers, and policy-makers can all understand and adhere to.

The 17 principles fall into five key areas, summarized in Table 1 and further discussed in Appendix D. While the exact vision of desirable technical analysis capability has yet to be fleshed out, the Modeling Forum believes such principles can help structure our long-term technical thinking, provide basic understanding between technical staff and water managers, policy-makers, and stakeholders, and provide directions to help move the data and models from what we have today to what we would like to have in the future, regardless of the particular technical problems to be addressed.

Table 1: Principles for Development and Use of Analytical Tools and Data

Strategy:

1) Data and analytical and communications tools should be based on expected long-term water problems and the decision-making processes they are expected to inform.
2) A strategic analysis framework should identify the technical objectives, roles, and responsibilities of major data collection efforts and models.
3) Strategic documents should be prepared and made available to the public. They should undergo periodic internal and external review, with substantial input from stakeholders, to identify needs for additional analytical tool and data development.
4) A frequently updated implementation document should outline short-term and long-term efforts, budgets, and responsibilities for continuous improvement of models and data. A sustained process for stakeholders input should be defined and adopted.

Transparency:

5) All data and models should have sufficiently detailed documentation.
6) Known limitations and appropriate applications should be documented.
7) Model applications should include explanatory & self-critical discussions of results, including uncertainty analyses.
8) Data, models, and major reports should be in the public domain, available on the web, and regularly updated.
9) A common glossary of key terms and acronyms should be maintained.

Technical Sustainability:

10) Modularity: Major models should be designed and implemented to fit modularly in the larger strategic analysis framework, allowing models to be tested, refined, updated, and replaced without major adjustments to other components.
11) Adaptive information management framework: Major data and information efforts should fall within a larger information management framework, including protocols for data documentation and updating, and documentation of limitations.

Coverage:

12) The spatial coverage of the basic data and analytical framework should be statewide and encompass a wide variety of water management options and processes.
13) Local and regional water management interests and resources should be explicitly represented to allow consistency among local, regional, and statewide studies.

Accountability and Quality Control:

14) Explicit testing should be done, documented, and available for major models.
15) Protocols and guidelines for model use should be developed and adhered to.
16) Major analytical products should be reviewed by both external experts and local agencies whose systems are included in the model(s).
17) In developing and maintaining models, serious efforts should be made to involve local agencies and stakeholders, including users groups or other cooperation mechanisms.

The five principal areas are:

- Strategy – Data, models and communication tools should be developed and integrated as part of a broadly based strategic effort focusing on likely future water problems in California. This strategy should be documented, updated, and coordinated with major modeling and stakeholder groups.
- Transparency – Data and models should be documented in a self-critical way so limitations are better known and considered. Documentation should be available to public scrutiny..
- Technical Sustainability – Data and model development are long-term efforts that must incorporate advances in scientific knowledge and the water communities understanding of water problems as they become available. Models and data should be developed in a strategic modular way.
- Coverage – Water management issues in California involves not only statewide activities and processes, but also local and regional activities and processes. Consequently, California needs a statewide concerted effort to integrate the problems, resources, opportunities, and expertise available at local and regional levels.
- Accountability and Quality Control – To improve the quality and transparency of model applications, models must be ground-truthed with the help of local experts. Protocols for model use and documentation, including limitations, must be developed.

V. PROPOSED ROAD MAP

The development of a strategic analysis framework for data and model development and integration requires a detailed planning and design process. These processes require institutional and financial support. To a large extent, the institutional and funding arrangements shape the detailed objectives and the blueprint for the framework development. Once the blueprint is complete, the specification of the data management system, models, and more detailed institutional and financial arrangements can be developed.

The Modeling Forum will continue to work with the water community to further develop alternatives and build support for institutional and financial arrangements. In the mean time, a few small, but significant first steps could be taken. These immediate goals require relatively modest financial resources, and the Modeling Forum will work with interested agencies to further develop and implement these projects where feasible. The Modeling Forum will continue to organize workshops to share information and solicit further input as progress warrants. As a start, technical workshops will be organized to review recent efforts to develop coherent data and models for major infrastructure management enterprises, and how these approaches may be adapted for a state-wide modeling framework.

At the same time, the Modeling Forum will continue to seek funding for several tasks that are fundamental to long-term models and data development in California, but require substantially more resources. The Modeling Forum is open to participating as lead, co-lead, collaborator, or resource in these efforts.

The next steps include both immediate goals and longer-term efforts in the following four categories.

1) Purpose and objectives

<u>Immediate Goal 1: Stakeholder Process</u>

The Modeling Forum will continue a process to define long-term purpose and objectives through workshops and discussions with stakeholders and agency staff with long-term interests in water management. Input will be sought from users of technical information from water agencies (including local, regional, state, and federal), environmental interests, and other stakeholder groups. The Modeling Forum will strive for concurrence and endorsement from key responsible agencies to assure their support and collaboration. Sufficient details will be developed to allow designers of databases, models and communication tools to assess the feasibility of the framework.

Deliverable: A written purpose and objectives document.

Resource needs: Active participation from Modeling Forum members is essential. Contact persons and assistance from key agencies would greatly facilitate the process.

2) Data review and management

<u>Immediate Goal 2A: Review data management efforts</u>

The Modeling Forum will work with interested agencies to develop, and implement where feasible, a project to review the achievements and lessons learned in developing large databases in other states and countries. For example, multi-million dollar efforts were made to compile data collected in the Snake River, Idaho, the Colorado River, and Tampa Bay, Florida. This project will aim to document the successes and problems encountered in these efforts based on input from the developers of individual databases. The findings will aid development efforts in California.

Deliverable: A report describing selected database developments in other states and countries.

<u>Immediate Goal 2B: Data Quality Assessment</u>

The Modeling Forum will work with interested agencies to develop, and implement, where feasible, a project to assess the quality of data available in California's major publicly accessible databases. This effort will document known problems and estimate data accuracy based on input from data collectors and users. The goal is to identify the sources of error and quantify their magnitudes. If possible, automated procedure(s) to identify faulty data will be proposed. The effort also will evaluate each data program with regard to its conformity to applicable principles in data development discussed in Section IV.5 and Appendix D.

Several efforts to inventory existing databases have been made recently. For example, DWR's Municipal Water Quality Investigations Program compiled a list of water quality measurement programs in the Central Valley, Delta, and San Francisco Bay (DWR, 1998). In addition, the California Water Plan has set up a web page for information exchange (the "Water PIE," at www.waterplan.water.ca.gov/waterpie/index.cfm), which lists major California databases that are publicly accessible. Unfortunately, most of these databases provide only the raw data, with little or no documentation of data quality and error. Whereas problems in data quality may be well known among data collectors, they are rarely disclosed systematically, and data users often have to learn about them the hard way.

Deliverable: A searchable web page documenting the quality of data in major California databases.

Resource needs for immediate goal 2A and 2B: Both efforts would be appropriate for Master's thesis level work in a graduate school program. Matching funds from other agencies will be sought, and the available funds will determine the level of effort. Alternatively, the work could be performed by agency staff or consultants with the appropriate expertise.

Additional tasks contingent upon external funding

a) Assemble and further develop GIS-based land-use data for water demand and hydrologic inputs for statewide water management. Several broad areas of data needs have been identified in previous efforts. A GIS-based database of California's water system will allow various spatial levels of representation of hydrologic data. Spatial representation of modeling output will also be developed.

b) Develop a more refined conceptual design for data management within an institutional framework. This design includes identifying major data needs and a setup that would allow continuous updates and data sharing among different databases throughout California. The databases will provide a quantitative, electronically documented, and searchable description of water and water management for identified modeling purposes. Data documentation, quality control, and uncertainty estimates will be important parts of the design.

3) Modular models and communication tools

Immediate Goal 3A: Review model and data communications tools

The Modeling Forum will work with interested agencies to develop, and implement where feasible, a project to review the achievements and lessons learned in developing modular modeling and communication tools in other states and countries. During the last ten years, many agencies have investigated modular modeling and communication tools (see list in the introduction in Section IV), including the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the Federal Emergency Management Agency, and the European Union. Their experience and work products could offer insights into the feasibility and promising approaches of modular modeling and communication tools.

Immediate Goal 3B: Further develop modeling protocols and guidelines

The Modeling Forum will update and further develop its previous report on the protocols for water and environmental modeling (Satkowski *et al*, 2000). The goal is to provide more specific technical and procedural guidance to develop and use models, consistent with the principles discussed in Section IV.5 and Appendix D.

Deliverables: A written report for each of the two projects.

Resource needs for immediate goal 3A and 3B: The first project will be appropriate for one or more Master's thesis in a graduate school program, depending on the scope of work. Active participation from Modeling Forum members is essential for the second project. Available resources will determine the level of effort. Alternatively, the work could be performed by agency staff or consultants with the appropriate expertise.

Additional tasks contingent upon external funding

Develop preliminary technical designs and specifications for an integrated set of models and communication tools, and a plan for their development. This would consist of a set of integrated models to provide decision support for policy, planning, and management questions of local, regional, and statewide importance. An important aspect of this design is to quantify uncertainties in future scenarios and in the water communities' understanding of the system. The types of models developed would depend on what is technically feasible in a ten-year or longer time frame.

The preliminary conceptual design must cross several currently independent technical domains, including operations, surface hydrology, groundwater, urban economics, agricultural economics, water quality, biology, and ecosystems. In particular, California must develop models in each of these domains with spatial and time scales and input/output specifications that allow them to be systematically linked with other models in "upstream," "downstream," or feedback modes.

4) Institutional and financial support

Immediate Goal 4: Stakeholder process

The Modeling Forum will continue discussions with major parties to establish long-term institutional support and funding to develop and implement a strategic analysis framework for water management in California. It will continue discussions with stakeholders and data management and modeling groups to generate support for integrated data management and analytical tool development and improvement. Through workshops and other communications, the Modeling Forum will update stakeholders and interested parties on the progress of ongoing data and modeling efforts, and the feasibility of the framework.

The success of the effort depends on many factors. The Modeling Forum would make every effort to:

- Respond to stakeholders' long-term modeling needs
- Promote the modeling principles discussed in Section IV.5 and Appendix D to stakeholders and technical interests
- Attract broad technical staff participation from local, regional, and statewide interests and agencies
- Work with key agencies to develop institutional and financial supports.

Institutional governance and financial support are the most challenging aspects of the proposed framework. They require broad buy-ins and compromises. However, the success of the effort would depend on an arrangement that:

- Establishes the legitimacy of the approach and broad institutional support
- Secures at least a quasi-independent institutional arrangement
- Develops the ability to contract and supervise external expertise in the academic and in both private and public sector
- Attracts and retains technical staff

- Educates technical staff on the data and models used to analyze and understand California's complex water system

Deliverable: Report with a feasibility analysis in sufficient details to allow for legislation and policy developments.

Resource needs: Active participation from Modeling Forum members is essential. Contact persons and assistance from key agencies would greatly facilitate the process.

VI. CONCLUDING THOUGHTS

Hope is like a road in the country;
there was never a road,
but when many people walk on it,
the road comes into existence.

– Lin Yutang

An analysis framework is like a path in the country,
there was never a path,
but when many people walk on it,
the path comes into existence.

The path could lead far, or just go round and round,
it's up to the people who walk it,
to decide if they want it to lead somewhere.

– Pete Pivo

Let the work begin!

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Appendix A

Why Use Quantitative Analysis for Managing Complex Systems?

Data and models are essential for managing large complex systems. They support operational decisions and planning processes in all major transportation, industrial, or utility systems. Southwest Airlines, Dell, and Boeing are examples of private enterprises that have increased their effectiveness and lowered their costs with extensive and intensive use of quantitative analysis for operational, planning, and policy purposes. In large decentralized utilities such as electric power and water resource systems, data and models quantify the interactions among semi-sovereign but interdependent system components. Data and models serve many purposes including the following:

1) Forum for integrated learning about the system. A computer model is an integrated representation of our understanding of a system. As such, it forces us to assemble a self-consistent replicable quantitative description of a system. An analysis framework allows decentralized expertise on individual aspects of the system to be formally integrated.

2) System to progressively test hypotheses and improve understanding. Our understanding of large, complex, decentralized systems will always be limited, and our strategies to operate the system must address many uncertainties. Computer modeling allows system managers to experiment with different aspects of the system to better understand the system's components and their relationships, and how uncertain future conditions affect various processes and solution approaches. It is easier to learn from mistakes (or unexpected results) if our understanding of the system is formalized and can be tested quantitatively.

3) Aid in developing alternative management solutions. Integrated understanding of a system is essential for developing management solutions. Modeling results allow potential solutions to be explored without the time, expense, coordination, logistics, and risks required for testing in the actual system. Models also provide a more controlled environment than field testing.

4) Basis for comparing management alternatives. The formal comparison of alternatives and their performance is fundamental to making rational choices. Computer models support expeditious, cost-efficient, standardized, and consistent comparison of alternatives.

5) Accounting framework for contracts, agreements, and regulations. Some infrastructure systems are too complex for operational accounting to be based directly on field monitoring. Comprehensive field monitoring is often too costly and unreliable to form a basis for binding contracts and agreements. Computer modeling provides a consistent basis for operational accounting, if the models are sufficiently accurate.

6) Quality assurance. Modeling allows alternatives to be analyzed in an objective and systematic manner. Data and modeling studies could be a cornerstone in a formal and documented decision process that could be understood by all interested parties.

Appendix B

Water Management Options and Integrated Management

Local, regional, and statewide water managers are using a variety of water management options that are further complicated by decentralized decision-making. Table B provides a list of these options. This complexity makes the use of modeling essential to the development and implementation of water management options.

Table B. Summary of Available Water Supply Management Options

Demand Management and Allocation

<u>General</u>
Pricing
Subsidies, Taxes
Regulations (allocation, water quality, contract authority, rationing, etc.)
Water transfers, options, markets, exchanges (within and/or between regions/sectors)
Insurance (drought insurance)

<u>Demand Sector Options</u>
Urban water use efficiency
Urban water scarcity (reduce demand through pricing or rationing)
Agricultural water use efficiency
Agricultural water scarcity
Ecosystem restoration/improvements (dedicated flow and non-flow options)
Ecosystem managed water use efficiency
Environmental water scarcity
Recreation water use efficiency
Recreation improvements
Recreation scarcity

Supply Management

<u>Operations Options (Water Quantity and/or Quality)</u>
Conjunctive use of surface and ground water
Surface water storage facilities (new or expanded)
Cooperative operation of surface facilities, operational changes
Conveyance facilities (new or expanded)
Conveyance and distribution facility operations

<u>Supply Expansion Options (Water Quantity and/or Quality)</u>
Supply expansions through operations options (e.g. reduced losses and spills)
Agricultural drainage management
Urban water reuse (recycling)
Water treatment and desalination
Urban runoff/stormwater collection and reuse (in some areas)

Appendix C

Domains of Data and Models

Water management in California is becoming more complex and involves many physical, water quality, biological, ecological, economic, and institutional processes that interact at different time and geographic scales. This poses challenges to the analyses and developments of water management alternatives and requires quantitative models that span different technical domains. The range of these domains is illustrated in Table C. Temporal and spatial scales and uncertainty estimates in models from different domains must be compatible when these models are used in an integrated analysis.

Table C. Technical domains of data and models

1. Water Demands (including economic, biological, and other performance valuation)

Agricultural	Recreation
Environmental	Land use (GIS)
Urban	Others?
Hydropower	

2. Facilities (capacities, connectivity, water losses, variable costs; essentially a database)

Surface reservoirs	Treatment
Aquifers	Wastewater reuse
Conveyance (streams, aqueducts)	Desalination
Pumping	Artificial recharge
Hydropower	Junctions

3. Hydrology
   - Surface Water – rim flows; local inflows
   - Groundwater

4. Water quality

Estuary	Lake/reservoir
Groundwater	Return flow and local source
River and canal	Treatment

5. Water Management/operations (how to operate facilities: local, regional, statewide)

Water deliveries – spatial	Water operations – temporal

6. Experimental domains (Ecosystem processes; fluvial geomorphology, etc.)
7. Multi-domain models (spanning several domains)
8. Post-processor(s), graphics, and visualization for presenting and comparing results
9. Post-processor for evaluation of alternatives on performance objectives
10. GIS interface (Land use depiction of results, display of assumptions, and pre-processing and post-processing of data)
11. Data management, quality control, and documentation
12. Interpretation, synthesis and communication to various audiences

Appendix D

Principles for Analytical Tool and Data Development and Use

The interim report in this Modeling Forum effort (CWEMF 2004) proposed 17 principles for long-term model and data development. While detailed requirements for technical analysis have yet to be developed, the proposed principles serve to frame the strategic plan and provide a common understanding between technical staff, water managers, policy-makers, and stakeholders. They provide a framework to map out the steps it would take to get to where we would like to be in the future, even though specific water management issues and data and models have yet to be defined in detail. The principles fall into five categories and are discussed below.

Strategy:

1) Data and analytical and communications tools should be developed based on expected long-term water problems and the decision-making processes they are expected to inform.

2) An official strategic analysis framework should identify the technical objectives, roles, and responsibilities of major data collection efforts and models.

3) Strategic documents should be prepared and made available to the public. They should undergo periodic internal and external review, with substantial input from stakeholders, to identify needs for additional analytical tool and data development.

4) A frequently updated implementation document should outline short-term and long-term efforts, budgets, and responsibilities for continuous improvement of models and data. A sustained process for stakeholders input should be defined and adopted.

Data, models, and communications tools are resource-intensive to develop and maintain. They would have more lasting value if they are designed to address a defined set of problems that decision-makers and stakeholders expect to have long-term importance. Strategic planning documents for data and models provide the general water community with a clear statement of the purpose of data and models. However, since problems, data, understanding, and modeling techniques change with time, strategic thinking should be adaptive and amended periodically.

Aside from informing stakeholders and decision makers of a particular model's purpose, strategic documents provide a common understanding on what could be expected of models and data. Strategic documentation also serves to educate technical newcomers to better understand (1) the strengths, weaknesses, and limitations of the data and models, and (2) the intended context of their application.

The responsibility for developing and maintaining a strategy should be placed on an agency with a mandate for statewide water planning and accounting. The California Department of Water Resources would be a logical lead agency. However, input and close collaboration with all interested parties (e.g., through a multi-agency advisory group) would be critical to a sound strategy with broad support.

Transparency:

5) All data and models should have sufficiently detailed documentation.

6) Known limitations and appropriate applications should be documented.

7) Model applications should include explanatory and self-critical discussions of results, including uncertainty analyses.

8) Data, models, and major reports should be in the public domain, available on the web, and regularly updated.

9) A common glossary of key terms and acronyms should be maintained.

Analysis of water systems as complex and extensive as California's will never be totally transparent, and will never be simultaneously simple and correct. No one person can understand this entire system, so it seems unrealistic for any one person to understand the entire set of models and data that represent the system. Nevertheless, greater and more systematic efforts at transparency in technical activities are needed to:

Enhance quality. Transparency allows analytical methods to be better understood, allows limitations to be more readily identified and addressed, and facilitates broader input for improvements.

Enhance credibility. Technical credibility rests on the assurance that each step in the analytical process has an empirical or derived basis and that each of these steps is well-reasoned and is discoverable, testable, and replicable.

Enhance sustainability. Technical personnel rarely work on technical details of the same model for more than a few years. However, models and data sets often have much longer life spans. Without systematic and detailed documentation, institutional memory for data and models may be lost, making it difficult for new technical staff to become sufficiently knowledgeable about specific details of the model or understand how the reasons behind specific approximations. This hampers further improvements and updates of a model, and gradually erodes the model's value and credibility.

Self-critical discussion of a model and model results is essential to making useful and credible insights from unavoidably imperfect model results and provide a basis for improvements in data and models.

Technical Sustainability:

10) Modularity: Major models should be designed and implemented to fit modularly in the larger strategic analysis framework, allowing models to be tested, refined, updated, and replaced without major adjustments to other components.

11) Adaptive information management framework: Major data and information efforts should fall within a larger information management framework, including protocols for data documentation and updating, and documentation of limitations.

The complexity and changing nature of California's water problems calls for a flexible and adaptive integration of data and model development. In a strategic analysis framework, individual models are modular and are (painstakingly) designed to have consistent assumptions and data structures. Well-defined algorithms are developed to interpolate or aggregate model output and field data between different temporal and spatial resolutions. Modularity allows one part of an analytical framework to be improved without having to modify the other aspects of a complex modeling system. Modularity also facilitates modeling at different levels of detail. Recent advances in object-oriented design make modular design much more attainable now than when many of the existing models were developed.

Confidence in model results depends in large part on the amount and quality of data available for model input, calibration, and validation. A comprehensive plan for data development and documentation is an integral part of a strategic analysis framework. The plan identifies and defines the process to collect additional data needed for long-term modeling activities.

Coverage:

12) The spatial coverage of the basic data and analytical framework should be statewide and encompass a wide variety of water management options and processes.

13) Local and regional water management and resources should be explicitly represented to allow consistency among local, regional, and statewide studies.

Water management problems in California have become highly interconnected. Conjunctive use and water conservation efforts in one part of the state are often tied to water use decisions elsewhere, with implications to water management operations in the areas in between. A statewide framework is essential to an adequate analysis.

Development of statewide coverage must be a cooperative enterprise. A comprehensive system can be constructed over time if local, regional, and statewide agencies all adhere to a consistent data and modeling framework and set of protocols. A coordinated approach could promote local and regional investments to improve quantitative capability throughout the state. A statewide framework provides a standardized and more credible basis for management studies for local and regional projects. It also provides a forum for local agencies and stakeholders to be involved and improve representations of their respective areas for regional and statewide analysis.

Accountability and Quality Control:

14) Explicit model testing should be undertaken, documented, and made available for major models.

15) Major analytical products should undergo review by external experts and local agencies whose systems are included in the model(s).

16) Protocols and guidelines for model use should be developed and adhered to.

17) In developing and maintaining models, significant efforts should be made to involve local agencies and stakeholders, including users groups or other cooperation mechanisms.

Quality control is essential for good technical work. The general public and policy-makers perceive the quality of data and models by examining the formal testing, documentation, use, and review procedures. These formal evaluations may be performed at different levels of detail and sophistication, depending on a particular model application.

Appendix E

Existing Data and Modeling Activity

Data and models are developed at state, federal, and local agencies for their water management needs with little coordination. Table E lists some of the major entities whose water management modeling activities would affect or require input from other systems.

Table E. Some of the major efforts to develop databases and models in California

Department of Water Resources SWP Modeling Support Branch	Operations planning - CalSim-II Delta hydrodynamics & quality - DSM2 Groundwater – CVGSM/IGSM2
Department of Water Resources Department of Planning and Local Assistance	Economics - CALAG, LCPSIM Urban water demand - IWR-MAIN Agricultural water demands – SIMETAW Real-time forecasting – DSM2 Municipal Water Quality Investigation Program
Department of Water Resources Environmental Services Division	Suisun Marsh hydrodynamics & quality – DSM2 and RMA
Department of Water Resources Operations	Operations planning - CalSim-II & DSM2
Department of Water Resources Flood Management	Runoff modeling and flood models
U.S. Bureau of Reclamation	Operations planning - CalSim-II, GIS, Temperature modeling, salinity drainage
U.S. Army Corps of Engineers	Real-time operations and flood control, flood mapping, risk assessment
California Bay-Delta Authority (CBDA)	Financial support for data and modeling efforts
California Department of Fish and Game	Instream flow modeling (particularly related to temperature)
Interagency Ecological Program	Raw data collection
Metropolitan Water District of Southern California	Operations planning – IRPSIM Urban water demand – MWD-MAIN
State Water Resources Control Board	Water rights data, Water quality data
Department of Health Services	Drinking water source and system inventory, Drinking Water Source Assessment and Protection
San Diego Water Authority	Planning models
Contra Costa Water District	Outflow-salinity model (the “G-Model”)
Santa Clara Valley Water Authority	Planning and operations planning models
California Urban Water Conservation Council (CUWCC)	Water conservation BMP implementation and water demand effects
U.C. Davis Information Center for the Environment (ICE)	GIS data Urban land use models for Central Valley
U.C. Davis CALVIN group	Screening, facilities, & operations planning - CALVIN
Local and regional water districts	Planning models and operational data