Integrated Data and Analysis

Chapter photo. CIMIS station. The California Irrigation Management Information System is a program in the California Department of Water Resources that manages a network of over 120 automated weather stations in the state of California.

Contents

Figures

Boxes

Chapter 6. Integrated Data and Analysis

About this Chapter

Chapter 6 Integrated Data and Analysis describes a roadmap and key actions needed to improve water resources information and analysis for integrated water management by State government, particularly the Department of Water Resources (DWR), and by the many other research institutions, and federal, Tribal, regional, and local water management entities. This chapter is organized into the following sections.

- Purpose and Motivation
- Specific Water Management Information and Analytical Needs
- Recent Studies and Forums for Improving Water Management Information and Analysis
- Implementing Long-term Technical Improvements through Shared Vision Planning
- Implementing Analytical Improvements for Water Plan Update 2009
- Quantification of Scenarios and Resource Management Responses

Purpose and Motivation

Investment in our analytical capabilities lags far behind the growing challenges facing water managers and resource planners. We need significant new investment in our technical capabilities to advance integrated water management, to improve sustainable management of the Sacramento-San Joaquin River Delta (the Delta), and to prepare for future impacts of climate change, extended droughts, and flood events. Improving communication between technical experts and decision-makers goes hand in hand with improving our technical capabilities because sound technical information is critical to making difficult and robust policy decisions and making decisions for sustainable outcomes in light of uncertainty. Needed technical improvements are described for two essential capabilities:

- Decision-making in light of uncertainties
- Supporting integrated water management, including integrated flood management, regionally and statewide

Improving communication between technical experts and decision-makers goes hand in hand with improving our technical capabilities.

Improving Technical Support for Decision-making in Light of Uncertainties

Decision-makers often take action on issues that affect water management even when there is significant uncertainty either about the basic scientific understanding of the water management system or about the political or social acceptance of particular water management alternatives. For example, today scientists cannot describe precisely what

Analytical approaches need to be improved to effectively quantify where scientific uncertainties exist, allow for collaborative decision-making to help overcome political and social disagreements, and identify actions that will have sustainable outcomes.

long-term climate change will mean for water and flood management in California. However, enough is known about the potential impacts that decision-makers have enacted a series of measures to reduce greenhouse gas emissions and implement adaptation strategies.

Analytical approaches need to be improved to effectively quantify where scientific uncertainties exist, allow for collaborative decision-making to help overcome political and social disagreements, and identify actions that will have sustainable outcomes. As discussed later, Shared Vision Planning is a collaborative approach for using technical information with decision support tools to seek informed and consensus-based solutions.

Improving Technical Support for Integrated Regional Water Management

Integrated water management is becoming a foundation of water planning in California and is the theme of this California Water Plan update. This is a multi-objective approach that encourages using a mix of resource management strategies to provide broad benefits particularly to regions. These strategies include water use efficiency, water recycling, desalination, and storage as well as strategies for protecting and improving water quality; managing floodplains, runoff, and watersheds; and restoring ecosystems. Update 2009 (Volume 2) identifies 27 strategies to help meet regional and statewide water management objectives. Communities can plan, invest, and diversify their water portfolios using these management strategies to become more self-sufficient with local supplies and minimize conflicts with other resource management efforts and other regions.

Unfortunately, many Integrated Regional Water Management Plans are only integrated conceptually and not quantitatively. California needs better water management information and analytical tools to produce useful and more integrated information on water quality, environmental objectives, economic performance, social equity objectives, and surface water and groundwater interaction. Today, it is difficult to compare, much less integrate, information from different local entities to understand and resolve regional water management issues, and even more difficult to understand the statewide linkages.

California needs to create a new water information exchange and management system and more integrated analytical tools that can be used to document and share knowledge.

To make significant progress toward a more comprehensive scientific understanding, California needs to create a new water information exchange and management system and more integrated analytical tools that can be used to document and share knowledge as it is developed. Investments in information exchange and integrated analytical tools will help facilitate consensus-based decision-making that is a key part of integrated water management.

Specific Water Management Information and Analytical Needs

California lacks a consistent framework and standards for collecting, managing, and providing access to information on water and environmental resources.

Several factors have led DWR to rethink how it evaluates California's future water conditions. Policy-makers and the public need more detailed quantitative information about the costs, benefits, and tradeoffs associated with different water management strategies. Water resources information, analytical tool development, and information management and exchange have not kept pace with growing public awareness of the complex interactions among water-related resources. Finally, California lacks a consistent framework and standards for collecting, managing, and providing access to information on water and environmental resources essential for integrated water management. For example, four separate statewide surveys of urban water use by different entities result in duplicative efforts by those reporting the information and often with inconsistent responses. More accurate water resources information and analytical tools and better information management can reduce many uncertainties about the state's current and future water resources: how water supplies, demands, and water quality respond to different resource management strategies; how ecosystem health and restoration can succeed; and how we can adapt our water systems to reduce controversy and conflicts.

Information Gaps and Limitations

Completing regional flow diagrams and water balances requires more detailed land and water use data, the ability to differentiate between applied and consumptive water uses, and better surface water and groundwater data.

Today's water resources problems are much more complex than in the past. A large amount of information is needed not only to analyze water demands and supplies, but also to evaluate ecosystem restoration options, adapt to long-term climate change, and implement integrated regional water and flood management solutions. The Water Plan describes much of the current water resource information requirements in regional waterflow figures (see Volume 3 Regional Reports and Volume 5 Technical Guide). Flow diagrams characterize a region's hydrologic cycle. Completing regional flow diagrams and water balances requires more detailed land and water use data, the ability to differentiate between applied and consumptive water uses, and better surface water and groundwater data. The following categories of information are not available or are very expensive to compile.

- Statewide land use—native vegetation, urban footprints, nonirrigated and irrigated agriculture
- Groundwater[1]—total natural recharge, subsurface inflow and outflow, recharge of applied water, extractions, groundwater levels, pumping-induced land subsidence, and water quality
- Surface water—natural and incidental runoff, local diversions[2], return flows, total streamflows, conveyance seepage and evaporation, runoff to salt sinks, and water quality

1 Senate Bill 6, enacted in November 2009, provides a significant improvement in access to groundwater information by requiring local agencies to monitor groundwater levels.

2 Senate Bill 8, enacted in November 2009, provides for improved accounting of location and amounts of surface water diversions.

- Consumptive use—evaporation and evapotranspiration from native vegetation, wetlands, urban runoff, and nonirrigated agricultural production
- Soil moisture characteristics—water saturation, porosities, and field capacities
- Environmental/biological data—species monitoring and their habitat and water requirements
- Land elevations and channel bathymetry
- Current and future price of water by supply source

Information is available for some regions and not others. For example, methods and data to estimate natural runoff are available for regions like the Sacramento Valley where the Delta is a central outflow measurement. In areas like the South Coast Hydrologic Region, with no central point for outflow measurement and substantial groundwater, the natural runoff is more difficult to estimate. In addition to natural obstacles, existing data are not easily gathered or split apart to provide convenient access for all areas of interest. And budget constraints limit the data collection and management necessary to quantify and track all the water in the state.

Much of the new water management projects and activities over the last 20 years have been developed and funded by local and regional water agencies. And new State laws have been passed to encourage California regions to become more self-sufficient with their water supplies.

Technical Challenges of Integrated Water Management

Update 2005 highlighted and encouraged California's regions to take a leadership role in solving many of California's water management challenges. This is a reflection of what has been happening for many years. Much of the new water management projects and activities over the last 20 years have been developed and funded by local and regional water agencies. These include water conservation programs, new surface water and groundwater storage, and water recycling projects. California voters have passed several statewide bond measures during this time providing billions of dollars to support local and regional water management activities. And new State laws have been passed to encourage California regions to become more self-sufficient with their water supplies.

New tools must be developed that allow for inclusion of economic, environmental, and social (equity) benefits and impacts using project life-cycle analysis.

Integrated regional water management is a multi-objective approach that encourages using a mix of resource management strategies to provide broad benefits to regions. Technical analysis performed for multi-objective planning often seeks to minimize total economic costs or maximize the total economic benefits for the entire region when implementing a set of resource management strategies. This analysis requires a detailed and dynamic representation of the water management system. However, water managers often lack detailed information or analytical tools to represent groundwater pumping, dynamic relationships between surface water and groundwater, ecosystem benefits and stressors, and ambient water quality. In addition, it is difficult to represent many of these factors in economic terms and to characterize uncertainty. New tools must be developed that allow for inclusion of economic, environmental, and social (equity) benefits and impacts using project life-cycle analysis. The following highlights three examples of analysis performed for integrated regional water management that have significantly increased the need for improved water management information with robust and transparent technical analysis.

Integrated Flood Management

Integrated flood management seeks to include both structural and nonstructural methods to manage high water events and seeks to enhance the ability of undeveloped floodplains and open spaces to reduce the incidence of flood events and the implementation of land use practices that minimize the risk to lives and property while enhancing environmental stewardship. This multifaceted approach to flood management relies on the integration of multiple strategies to achieve the broad goal of improving flood management. Analysis of flood management strategies requires water management information and analytical tools that are useful to daily or hourly time scales. It also requires accurate information on levee construction details, channel capacities, effects of in-channel vegetation and structures, and existing and future land uses in floodplains.

Ecosystem Restoration

Ecosystem restoration can include changing the flows in streams and rivers; restoring fish and wildlife habitat; controlling waste discharge into streams, rivers, lakes, or reservoirs; or removing barriers in streams and rivers so anadromous fish like salmon and steelhead can reach spawning areas. Ecosystem restoration improves the condition of our modified natural landscapes and biotic communities to provide for the sustainability and for the use and enjoyment of those ecosystems by current and future generations. Scientists often only qualitatively estimate environmental benefits of restoration projects because of scientific uncertainty about the effects of proposed projects and how species respond to different environmental factors such as waterflow and water temperature. In addition, usually only limited historical data are available on ecosystems and their relative health.

Adapting to Climate Change

As a result of climate change, California's future hydrologic conditions are changing from patterns observed over the past century. There is much scientific uncertainty about how each of the widely varying regions in California will be affected by climate change. Predictions include increased temperatures, reductions to the Sierra snowpack, earlier snowmelt, and a rise in sea level, although the extent and timing of the changes remain uncertain. These changes could have major implications for water supply, flood management, and ecosystem health. (See the climate change adaptation white paper and the climate science white paper in Volume 4 for a discussion of these changes.)

An article in the San Francisco Estuary & Watershed Science recommends a series of strategic responses to address climate change challenges facing water managers.

Scientists and engineers require significant improvements in water management information and analytical tools to effectively examine how California's water infrastructure and natural systems can be managed to accommodate or adapt to climate change. An article in the San Francisco Estuary & Watershed Science (Dettinger and Culberson 2008) recommends a series of strategic responses to address challenges facing water managers. The following are some of the strategic responses associated with improving the basic science and analysis:

- Additional emphasis on long-term monitoring of restoration and resource management activities
- Support multidisciplinary, integrated science
- Encourage multivariate climate monitoring and modeling
- Ensure consistency of observational and analytical methods
- Develop and maintain integrated models that include important subsystems

The need for concerted improvements in our water management information and analysis is not a new revelation.

Recent Studies and Forums for Improving Water Management Information and Analysis

The Shared Vision Planning approach can transcend the individual efforts to provide long-term improvements to our technical infrastructure.

This section highlights a few of the studies and forums closely associated with the California Water Plan that recommend specific new investments in our technical capabilities. Numerous related efforts by federal, State, and local entities have developed similar recommendations. The need for concerted improvements in our water management information and analysis is not a new revelation. Scientists and engineers involved in water resources planning and management agree that investments in collecting reliable water resources information and developing improved analytical procedures has not kept pace with the need. Information from the following studies and forums are the basis of the Shared Vision Planning approach proposed later in this chapter that can transcend the individual efforts to provide long-term improvements to our technical infrastructure.

Update 2005, Volume 1, Chapter 4

California Water Plan Update 2005 (DWR 2005) introduced several new concepts within the analytical approach for evaluating statewide and regional water conditions (as compared to previous water plan updates). They included the development of multiple scenarios of the future, the shift from using average or normalized data when describing current water management conditions, and the development of specific criteria to evaluate the expected performance of potential water management strategies. Although not fully implemented in Update 2005, these new concepts helped define the long-term direction for the Water Plan. DWR worked extensively with the Water Plan Advisory Committee to outline the improved quantitative deliverables that are at the core of the analysis performed for the California Water Plan.

CWEMF. *California Water and Environmental Modeling Forum is a nonprofit, nonpartisan organization whose mission is to increase the usefulness of models for analyzing California's water-related problems with emphasis in the San Francisco Bay, Sacramento-San Joaquin Delta, and Central Valley system (Bay-Delta Watershed).*

CWEMF (California Water and Environmental Modeling Forum) Strategic Analysis Framework

The California Water and Environmental Modeling Forum developed a Strategic Analysis Framework (CWEMF 2005) for the long-term development of data and models to manage water in California (see it in Volume 4 Reference Guide). The CWEMF framework describes the important water management challenges that California faces and promotes the development of better integrated and modular analytical tools to evaluate alternative solutions to these challenges. CWEMF considered several efforts within the United States and abroad when it developed the framework. The framework also describes several potential institutional and funding options that California should explore to improve the technical foundation for the state's water planning and management studies. Several of these options include an important role for DWR.

San Francisco Estuary & Watershed Science

The paper "Internalizing Climate Change - Scientific Resource Management and the Climate Change Challenges" (Dettinger and Culberson 2008) includes recommendations for strategic improvements in scientific research and collaboration needed to respond to climate change. In particular, the paper identifies seven important climate change-related challenges and a number of strategic responses that should be undertaken by the technical community. These strategic responses include improving monitoring commitments, supporting multidisciplinary science, and better integrating our water resources information and analysis. (Read the article in Volume 4 Reference Guide.)

Many of the recommended strategies call for more integrated management of state and local water supply and flood systems and are incorporated in Update 2009 objectives and related actions.

DWR Climate Change Adaptation White Paper

In October 2008, DWR published Managing an Uncertain Future: Climate Change Adaptation Strategies for California's Water. The primary purpose of this white paper is to identify some of the important challenges of long-term climate change that California faces and to recommend water management adaptation strategies to respond to the effects of climate change. Many of the recommended strategies call for more integrated management of state and local water supply and flood systems, and are incorporated in Update 2009 objectives and related actions (see Chapter 7 Implementation Plan). The white paper also identifies the need for additional investment in scientific information used to support decisions about adaptation strategies.

This climate science paper includes specific recommendations for research and improvements to analytical tools and data for evaluating climate impacts.

DWR Climate Science White Paper

DWR with input from the Climate Change Technical Advisory Group developed (2009) a white paper on the state of climate-related science. "The State of Climate Change Science for Water Resources Operations, Planning, and Management" describes the current understanding of potential climate-related impacts to our water supply, water use, and water management infrastructure and makes a series of recommendations to advance the science. (Read the paper in Volume 4 Reference Guide.) This paper includes specific recommendations for research and improvements to analytical tools and data for evaluating climate impacts.

DWR convened the Statewide Water Analysis Network, a standing technical advisory group known as SWAN, to assist with formulating recommendations on technical improvements needed to support the Water Plan.

SWAN (Statewide Water Analysis Network)

Water Plan Update 2005 recommended that DWR and other State agencies improve data, analytical tools, and the exchange of information needed to support regional integrated resource plans. In response, DWR convened the Statewide Water Analysis Network, a standing technical advisory group known as SWAN, to assist with

Box 6-1 Shared Vision Planning Workshop

On April 22, 2008, the California Department of Water Resources and the California Water and Environmental Modeling Forum, in collaboration with the US Army Corps of Engineers' Institute for Water Resources, sponsored a one-day workshop to introduce the topic of Shared Vision Planning to an audience of natural resource planners, scientists, and engineers.

Stakeholders identified the opportunities for use of Shared Vision Planning concepts that have the greatest potential for improving the utility of, and confidence in, the analytic tools used to study water management problems. By developing higher level, transparent screening tools, developing common planning scenarios, and sharing data and data collection efforts, the Water Plan process will build long-term relationships, increase awareness and support for collaborative planning processes, and build trust in the planning process. Additional near-term steps include a communications plan for Update 2009 that includes Shared Vision Planning and touches on the many competing programs that deal with water.

Participants identified the need for two levels of detail in analytical tools used for water planning: detailed analytical tools and simpler Shared Vision Planning tools. Detailed analytical tools are needed to capture the complex system dynamics as realistically as possible. These more complex tools are used to ground truth the simpler Shared Vision Planning tools. Proponents of Shared Vision Planning need to show a bridge to the development of the detailed analytical tools that support the Shared Vision Planning tools to justify long-term funding commitments.

A workshop summary can be found in Volume 4 Reference Guide.

formulating recommendations on technical improvements needed to support the Water Plan. SWAN is a voluntary collection of scientists and engineers and met several times during development of Water Plan Update 2009 to provide advice on the quantitative deliverables for the Water Plan including the recommendations contained in this chapter. See http://www.waterplan.water.ca.gov/swan for additional information about the activities of SWAN.

Implementing Long-term Technical Improvements through Shared Vision Planning

Shared Vision Planning integrates tried-and-true planning principles, systems modeling, and collaboration into a practical forum for making water resources management decisions.

DWR is pursuing the approach and methods of Shared Vision Planning (SVP) in the Water Plan to achieve these technical goals and outcomes:

- Achieve better integration and consistency with other planning activities
- Obtain consensus on quantitative deliverables
- Build a common conceptual understanding of the water management system
- Improve transparency of Water Plan information

SVP integrates tried-and-true planning principles, systems modeling, and collaboration into a practical forum for making water resources management decisions. The term is most closely associated with the US Army Corps of Engineers, Institute for Water Resources which has been implementing the approach and methods since the National Drought Study in the 1990s (See www.SharedVisionPlanning.us for additional information).

SVP addresses the need for broad involvement of stakeholders by actively involving them in the technical analysis. Aside from the intensive and continuous collaboration, what defines SVP is the use of collaboratively developed decision-support models that serve as the primary tools for plan formulation and evaluation. These SVP models are designed to be transparent and easy-to-use and integrate hydrologic simulations with economic, environmental, and other considerations relevant to understanding the system. Benefits of SVP are a shared understanding and vision of the system, identification of alternatives that are both technically and politically feasible, and reduced resistance to implementation of any decisions.

Benefits of SVP are a shared understanding and vision of the system, identification of alternatives that are both technically and politically feasible, and reduced resistance to implementation of any decisions.

DWR working with SWAN believes that the SVP approach can be expanded beyond its current emphasis on model building at the watershed scale to the broader concept of improving our technical analysis infrastructure (methods and tools) through greater interactions with stakeholders and decision-makers. Through SVP the needs of stakeholders can inform the development of the analytic tools so that they are more relevant to current and future problems. Current data and analytical tools are not sufficient to provide answers to important questions from decision-makers, water managers, and resource planners. DWR working through SWAN applied SVP in preparing this Water Plan (See Box 6-1 Shared Vision Planning Workshop). DWR, CWEMF, the CALFED Science Program, and others have proposed specific activities to ensure that California continues to improve our water management information and analysis for making crucial decisions about water resource investments. Achieving these advances requires significant investments in better information management systems; additional data collection; and more sophisticated, transparent, and accessible analytical tools.

Achieving these advances requires significant investments in better information management systems; additional data collection; and more sophisticated, transparent, and accessible analytical tools.

Critical Near-term and Long-term Activities

Several agencies and institutions are engaged in long-term efforts to improve California's water management information and analytical capabilities (See Box 6-2 Entities Engaged in Long-term Technical Improvements for Statewide Water Management). These efforts are focused on detailed models that form the backbone of water management analysis in California. Development of simpler SVP or decision support tools ultimately must be verified against these detailed models. Each of the entities in Box 6-2 has long-term strategic plans for technical improvements for their particular area of responsibility.

Missing are the crosscutting actions that transcend the individual efforts to provide widespread integration of water resources information and analysis. This section describes five of these currently unmet crosscutting actions that are critical for the long-term improvement of our technical capabilities.

Missing are the crosscutting actions that transcend the individual efforts to provide widespread integration of water resources information and analysis. This section describes five of these currently unmet crosscutting actions that are critical for the long-term improvement of our technical capabilities.

DWR working with SWAN recommends these critical activities to support a long-term vision for integrated water management information and analysis (e.g., the Strategic Analysis Framework envisioned by CWEMF in its 2005 report).

- Develop a Strategic Plan to Improve Water Management Information

Box 6-2 Entities Engaged in Long-term Technical Improvements for Statewide Water Management

- The US Geological Survey is active in a wide range of surface water and groundwater monitoring, development of analytical tools, and analysis of water resources problems.
- The US Army Corps of Engineers is responsible for developing numerous analytical tools used for watershed and flood management analysis.
- DWR maintains several water monitoring programs and is responsible for the development of analytical tools of the Sacramento-San Joaquin Delta.
- DWR and the US Bureau of Reclamation jointly maintain an analytical tool of the Central Valley Water Management System.
- Researchers of the University of California develop and maintain numerous analytical tools as part of specific research projects.

- Improve Integration of Water Management Information
- Develop Common Schematics of the Water Management System
- Develop a Common Conceptual Understanding of the Water Management System
- Establish Modeling Protocols and Standards

Involvement of stakeholders in these five technical activities will support an SVP approach to the Water Plan. These activities were determined to be priority, based on advice received at SWAN workshops and the recommendations of key studies mentioned earlier in this chapter. Although significant resources are needed to implement them, these activities would greatly enhance the ability of scientists and engineers to support integrated water management and decision-making in light of uncertainties. They must be viewed as long-term commitments to our technical infrastructure.

Develop a Strategic Plan to Improve Water Management Information

The limitations and gaps in water management information under our current institutional arrangements are described in an earlier section. California water and resource managers and planners have a critical need for a strategic plan describing the specific information needed to support water management activities and the institutional arrangements for collecting and maintaining the information. A strategic plan for improving water management information would identify the range of different program needs to respond to flood and drought management, climate change, ecosystem restoration, water quality improvement, and integrated management objectives. Based on program needs the strategic plan would:

- establish standards and protocols to ensure the widest utility and efficient use of resources,
- identify the optimal location of monitoring stations,
- prioritize long-term improvements in the monitoring network, and
- ensure long-term maintenance and accessibility to water management information.

The Water Plan does not have a fully transparent linkage between the information collected from local entities and reported at the hydrologic region.

Improve Integration of Water Management Information

Water management information is collected and maintained by a multitude of local, regional, State, federal, and Tribal governments, agencies, and organizations. Some entities like the Metropolitan Water District of Southern California have made inroads into effective integration of information from its water retailers. However, development of the Water Plan requires a labor-intensive process of collecting relevant information and converting it into a useful format for the Water Plan. The Water Plan does not have a fully transparent linkage between the information collected from local entities and reported at the hydrologic region. DWR has proposed three activities to improve integration of water management information; they are described below. Some initial planning and pilot studies for these activities have occurred, but DWR does not currently have the resources to implement them as proposed.

Integrating Data from Urban Water Management Plans, Integrated Regional Water Management Plans, and the California Water Plan

Local agency Urban Water Management Plans and the California Water Plan are required by State law to be updated in five-year cycles. Both plans require significant resources to develop information about current and future water uses and water supplies. Both plans are also used to make significant planning and policy decisions about how and how much to invest in our local and statewide water management systems. Better integration is needed to ensure that both plans are using the best available and consistent information so that decision-makers can have confidence in water policy decisions and the public can have confidence in their investments.

DWR is leading a collaborative effort to explore how information can more effectively be integrated among local, regional, and statewide water planning and management activities. The initial focus of this effort is to improve how information produced for Urban Water Management Plans can be used more effectively to support Integrated Regional Water Management Plans and the California Water Plan while streamlining reporting requirements. This initial focus will require looking beyond these plans to consider related activities that collect urban water planning and management information.

DWR is building, and plans to maintain, an online information exchange system—called the Water Planning Information Exchange (Water PIE).

Water Planning Information Exchange

DWR is building, and plans to maintain, an online information exchange system—called the Water Planning Information Exchange (Water PIE)—to share water management information between State, regional, and local agencies and governments. This type of online information exchange system is being designed to support regional partnerships by providing a common way of developing and sharing information. It will support streamlined development of Integrated Regional Water Management Plans by providing a common vocabulary and basic information needed to develop an effective plan. An information management system such as Water PIE will also enhance the opportunities for collaboration with academic and research institutions by improving access to the

A prototype system called the Integrated Water Resources Information System (IWRIS) is operational as the first step for Water PIE.

Box 6-3 Integrated Water Resources Information Systems – A Working Information System

In May 2008, DWR launched a working prototype of the Water Planning Information Exchange (Water PIE) called the Integrated Water Resources Information System (IWRIS). IWRIS is a data management tool for water resources data. It is a web-based GIS application that allows users to access, integrate, query, and visualize multiple sets of data. Some of the databases include DWR Water Data Library, California Data Exchange Center (CDEC), USGS streamflow, Local Groundwater Assistance Grants (AB303), as well as data from local agencies. IWRIS can be accessed at http://www.water.ca.gov/iwris/.

most current information throughout the state. A prototype system called the Integrated Water Resources Information System (IWRIS) is operational as the first step for Water PIE (see Box 6-3 Integrated Water Resources Information System—A Working Information System).

Regional Synthesis of Water Management Information

Preparation of the Water Plan scenarios, regional reports, and regional water portfolios requires a significant amount of research and analysis to develop quantitative estimates of current and future water management conditions. For the Water Plan, information obtained from local water planning entities is aggregated up to 10 hydrologic regions, the Mountain Counties area, and the Delta region. DWR staff cannot now fully review and evaluate every statewide and regional planning document with useful water planning information.

However, DWR, SWAN members, and other Water Plan stakeholders are interested in exploring ways of more effectively using this wealth of information in the Water Plan. Example studies include:

- local and regional agency water planning and policy studies;
- DWR and US Bureau of Reclamation modeling studies of the State-federal Central Valley water management system operations, the Delta, climate change, and additional surface storage;
- DWR water portfolios and water supply, demand, and modeling studies; and
- California Energy Commission-sponsored studies of climate change.

Develop Common Schematics of the Water Management System

Development of common schematics will allow integration with other models and sources of information.

Numerous existing schematics of California's water management system are used by local, State, and federal agencies to perform water planning studies. These schematics are embedded in several planning models that provide incomplete, overlapping, and often inconsistent representations of California's water management system. For example models like CALSIM, CALVIN, Water Evaluation and Planning System (WEAP), and Statewide Agricultural Production Model (SWAP) represent water management in portions of the Central Valley, but it is difficult to share data between them and determine whether they use information consistently. These models often

Figure 6-1 Conceptual model of water management system

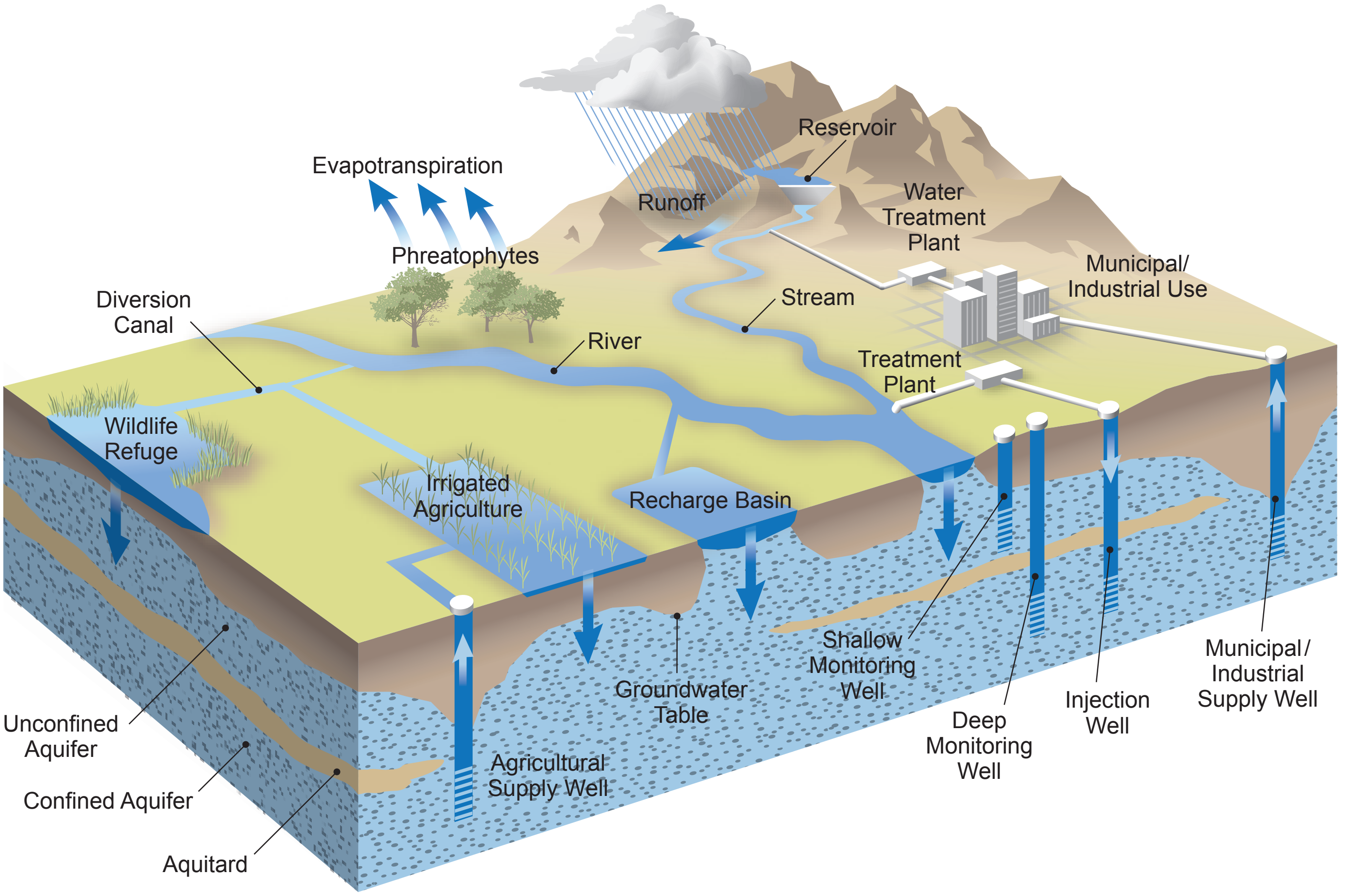


Figure 6-1 shows a conceptual model of the water management system with relationships between its components.

represent the water management system at a coarse level and do not always provide information at the scale needed for planning by a local water agency.

Development of common schematics will allow integration with other models and sources of information on water quality, ecosystem functions, flood management, climate change and other parts of integrated regional water management. DWR will take the lead in developing common water management system schematics at different spatial scales by coordinating with other technical experts and the wide array of local, regional, and statewide water planning entities.

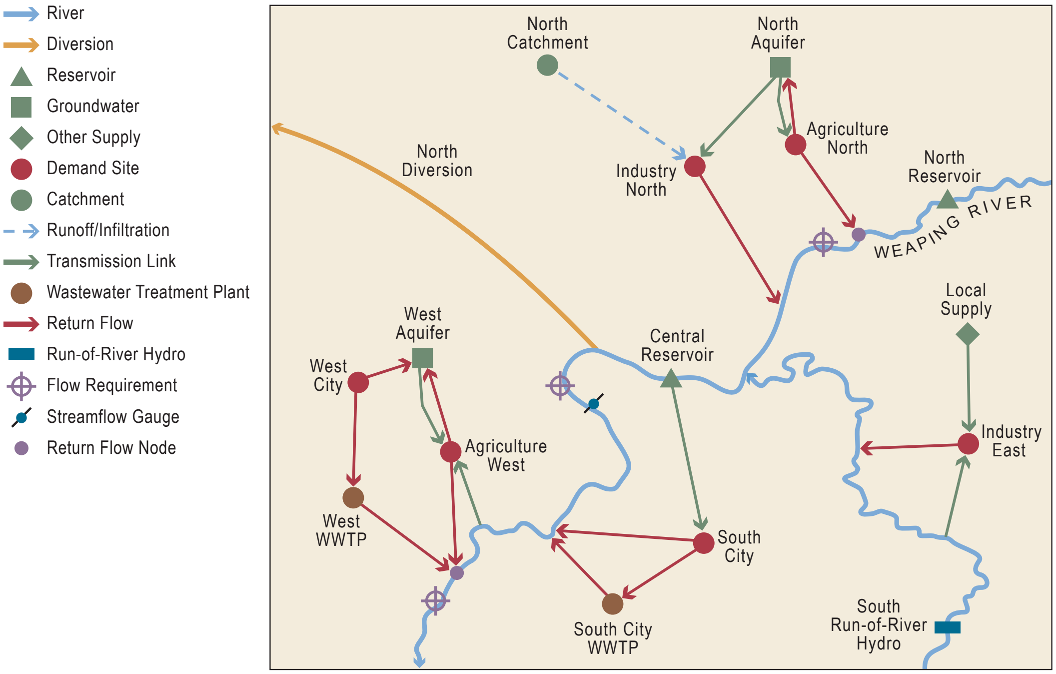
What is needed is a common and consistent way to conceptually describe the different pieces of the water management system and how the pieces interact with each other. DWR is promoting the use of an iterative development process used widely in the software development industry.

Develop a Common Conceptual Understanding of the Water Management System

One of the greatest obstacles to quantifying consensus-based water management strategies is the lack of a common way to clearly and in a concise manner describe the water management system and its complexities. The result is that technical experts, decision-makers, and stakeholders have an extremely difficult time communicating how to include critical details of the water management system. On one hand, the detailed

Figure 6-2 represents a sample schematic of the water management system from the Water Evaluation and Planning System model. This figure and Figure 6-1 on previous page represent alternative views of the water management system.

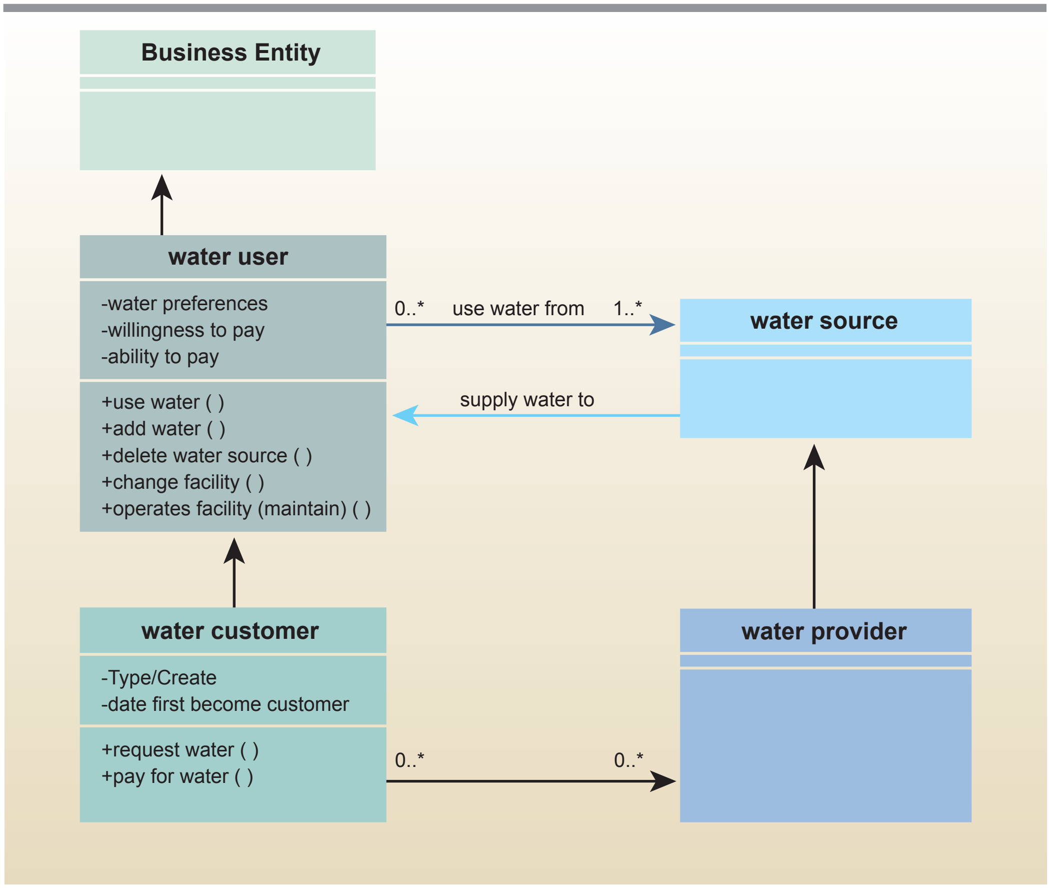
Figure 6-2 Sample schematic of water management system



Source: WEAP (Water Evaluation And Planning system)
http://www.weap21.org

Figure 6-3 shows an example describing the relationships between water users and water providers using Unified Modeling Language standard notation.

Figure 6-3 Example diagram using Unified Modeling Language standard notation



analytical tools are too obscure for nontechnical people. On the other hand, decision-makers and stakeholders often have a general understanding of only parts of the water management system.

What is needed is a common and consistent way to conceptually describe the different pieces of the water management system and how the pieces interact with each other. DWR is promoting the use of an iterative development process used widely in the software development industry to assist with the development of a conceptual model of the water management system. This iterative approach is based on object-oriented thinking and allows a team to identify and describe the relevant aspects of the real world that should be represented in an analytical tool. The conceptual model will be developed collaboratively to document the requirements of the system and a shared understanding of the water management system. For example, Figure 6-1 shows a conceptual model of the water management system with relationships between its components. Figure 6-2 represents a sample schematic of the water management system from the Water Evaluation and Planning System model (see www.weap21.org). These two figures represent alternative views of the water management system.

One method for documenting the products developed through an iterative process uses the Unified Modeling Language, which is a visual modeling language.

One method for documenting the products developed through an iterative process uses the Unified Modeling Language, which is a visual modeling language based on standard notation to describe systems in terms of objects, relationships, interactions, sequence diagrams, and state changes. Figure 6-3 shows an example describing the relationships between water users and water providers using Unified Modeling Language standard notation.

A critical part of integrated analysis is the development of modeling protocols and standards to allow analytical tools to be linked to each other or used in concert more effectively.

Establish Modeling Protocols and Standards

The movement toward integrated water management has increased the desire and need for integration of water management information and analysis. A critical part of integrated analysis is the development of modeling protocols and standards to allow analytical tools to be linked to each other or used in concert more effectively. This is very similar to the need for standards and protocols for information exchange as described in a previous section. CWEMF developed modeling protocols (CWEMF 2000) that need to be updated and implemented by the entities responsible for model development activities. The objective of the CWEMF modeling protocols is to provide guidance to water stakeholders and decision-makers, and their technical staff as models are developed and used to solve California's water and environmental problems. CWEMF identified the following benefits that would be achieved by California's water community from adherence to modeling protocols:

- Improved development of models
- Better documentation of models and modeling studies
- Easier professional and public access to models and modeling studies
- More easily understood and transparent models and modeling studies
- Increased confidence in models and modeling studies.

Box 6-4 Quantitative Deliverables for the California Water Plan

- **Water portfolios** that describe annual, regional water balances for 1998-2005.
- **Future scenarios** that describe alternative, plausible base conditions of future water use and water supply throughout California. Scenarios are distinguished from each other by different assumptions used for key factors over which water managers have little control, like population growth, land use changes, and climate conditions.
- **Response packages** of resource management strategies that are designed to improve performance of the water management system with regard to management objectives. The expected system performance of alternative response packages are analyzed under each future scenario using evaluation criteria.

Implementing Analytical Improvements for Water Plan Update 2009

Update 2009 has built upon Update 2005 by including additional years in the water portfolios, refining the representation of future scenarios, including hydrologic variability and climate uncertainty, and more fully describing water management response packages.

Update 2005 introduced several new concepts within the analytical approach for evaluating statewide and regional water conditions. These new concepts help define the long-term direction for the update process. DWR worked extensively with the Water Plan Update 2005 Advisory Committee to outline three groups of quantitative deliverables (described in Box 6-4 Quantitative Deliverables for the California Water Plan) that are the core of the analysis performed for the California Water Plan. Due to resource and schedule constraints, Update 2005 did not fully implement all three of these quantitative deliverables. However, with each successive Update, DWR will move to this more comprehensive analysis. Update 2009 has built upon Update 2005 by including additional years in the water portfolios, refining the representation of future scenarios, including hydrologic variability and climate uncertainty, and more fully describing water management response packages.

Approach for Quantifying Future Scenarios for Update 2009

The ultimate goal is to quantitatively integrate the Water Plan with Integrated Regional Water Management Plans to provide consistency in the information used to guide both regional and statewide water management decisions.

In this volume, Chapter 5 Managing an Uncertain Future describes the basics behind the development of future scenarios for Update 2009 and some of the statewide drivers and presents three narrative scenarios for conditions through 2050. This section describes the analytical approach used to quantify the scenarios including regional drivers of demand, regional water management response packages, and the performance of these response packages. In the long run, the five activities (described under the earlier section Critical Near-term and Long-term Activities) for improving technical capabilities will also support the continued refinement of scenario analysis used in the Water Plan. The ultimate goal is to quantitatively integrate the Water Plan with Integrated Regional Water Management Plans to provide consistency in the information used to guide both regional and statewide water management decisions.

Using the Water Evaluation and Planning System (WEAP) to Quantify Future Scenarios

For Update 2009, DWR with input from SWAN chose to apply WEAP as a tool to help quantify different future scenarios and alternative water management responses. (See www.weap21.org for additional information about the WEAP tool.) During and after the completion of Update 2005, DWR evaluated several possible approaches to quantify future scenarios for Update 2009, including the Analytica tool used for Update 2005. In 2005, DWR participated in a study with the Stockholm Environment Institute (SEI) funded by the US Environmental Protection Agency to apply the WEAP tool to understand the potential effects of climate change on the Sacramento Valley. DWR chose the WEAP tool for Update 2009 because WEAP:

- has a friendly graphical user interface that supports collaboration,
- requires a shorter learning curve than alternatives,
- was successfully applied by the RAND Corporation to evaluate climate scenarios for the Inland Empire Utilities Agency, and
- received positive feedback from SWAN and other Water Plan stakeholders.

Summary of Update 2009 Proposal

At the September 2007 SWAN meeting, SEI presented how the WEAP tool could support scenario analysis for the Water Plan. Following positive feedback and suggestions for implementation by both stakeholders and DWR staff, MWH, SEI, and RAND Corporation in fall 2007 provided DWR a proposal for developing a quantitative scenario analysis tool of water management responses under uncertainty for Update 2009. As described later, the WEAP proposal was presented at several public forums, including two technical workshops of the SWAN in December 2007 and June 2008. The WEAP proposal has undergone several revisions in response to stakeholder comments and was accepted and funded by DWR.

The WEAP proposal completes and builds on work begun in Update 2005 and other studies by employing the WEAP modeling tool to simulate and evaluate more refined integrated water management scenarios for Update 2009. The WEAP proposal both quantifies a small set of hand-crafted narrative scenarios developed by the Water Plan update staff and Water Plan Advisory Committee and generates a larger ensemble of plausible scenarios to systematically evaluate the performance of various regional water management response packages in the face of a number of critical uncertainties, including climate change. Work is under way in pursuit of the following specific objectives:

- Develop an integrated scenario analysis modeling framework
- Use this framework to assess the full spectrum of uncertainties that confront water planning in California, including global climate change, land use and demographic changes, hydrologic variability, and others
- Evaluate the results of these analyses against an appropriate set of performance metrics, introducing the notions of robustness and risk as part of the evaluation process

DWR used WEAP to develop a low-resolution regional demand representation for each of the 10 hydrologic regions in California.

- Develop a strategy to evaluate the most promising regional water management responses

Update 2009 Scenario Analysis Performed at Two Scales

A pilot study used WEAP at a smaller spatial scale suitable to capture the major hydrologic flows, represent major demographic and land use trends, and to evaluate the effects of water management responses.

For Update 2009, most of the scenario analysis was performed at the hydrologic region scale. DWR used WEAP to develop a low-resolution regional demand representation for each of the 10 hydrologic regions in California. For this analysis, indoor urban demand is represented in a manner similar to that used for Update 2005. The representation of outdoor urban and agricultural water demand is improved using evapotranspiration (ET) requirements and irrigation patterns, and variable monthly scenarios of precipitation and temperature based on 12 available scenarios representing future climate change.

As a pilot study, Update 2009 also presents a more detailed analysis of scenarios and water management response packages for the Sacramento River and San Joaquin River hydrologic regions. The pilot study used WEAP at a smaller spatial scale suitable to capture the major hydrologic flows, represent major demographic and land use trends, and to evaluate the effects of water management responses. In general, the model is organized by DWR Planning Areas—there are 11 PAs in the Sacramento River Hydrologic Region and 10 in the San Joaquin River Hydrologic Region. For the four PAs covering the southern Cascade and northern and central Sierra Nevada ranges, the PAs are further disaggregated along watershed boundaries and elevation bands to reflect major reservoir operations and elevation-dependent hydrologic processes. For the remaining 17 PAs, located primarily on the floor of the Central Valley, water demands and water supplies are specified at the PA level, and only disaggregated when necessary to properly reflect usage of different supplies or to evaluate scenarios and response packages of greater interest. See Volume 4 for the article describing this WEAP pilot study.

Review of WEAP Proposal by SWAN and Other Water Plan Stakeholders

The Water Plan provided significant opportunities for stakeholders to participate in reviewing and refining the WEAP proposal. Box 6-5 (DWR Scenario-related Workshops) lists workshops and meetings conducted by DWR to obtain feedback on the development of scenarios and on the WEAP proposal. At the June 2008 SWAN workshop, information was presented on how the Water Plan might quantify climate change, flood management, environmental water, and water quality as part of the scenario analysis. Workshop participants identified several strengths and limitations associated with the WEAP proposal. Some of the identified weaknesses are the inability to properly track floodflows and operations because of the coarse monthly time step used and limited representation of water quality. All feedback helps DWR identify where to focus future investments in the scenario analysis. See Volume 4 for a copy of the WEAP proposal and see www.waterplan.water.ca.gov/swan for the comments received. Meeting summaries for the workshops in Box 6-5 are posted at www.waterplan.water.ca.gov/calendar/calendar.cfm.

The key factors of uncertainty affecting future water demand are future land use patterns, future population and other demographic patterns, level of background water conservation, and future climate (precipitation and temperature).

Box 6-5 DWR Scenario-related Workshops

Date	Workshop Purpose and Scenario Content
9/17/2007	SWAN – Case studies in implementing scenarios for regional planning
10/22/2007	Plenary – Role and themes of scenarios
11/29/2007	General - Narrative themes for future baseline scenarios
12/10/2007	SWAN - Quantification of scenarios for California Water Plan Update 2009
12/19/2007	Advisory Committee - Quantification of scenarios for Update 2009
4/22/2008	SWAN – Shared Vision Planning
6/3/2008	All Regions Forum – Quantifying scenarios and response packages
6/19/2008	SWAN – Quantifying climate change, flood management, environmental water, and water quality for Water Plan Update 2009 and beyond
2/11/2009	SWAN – Preliminary scenario demands
6/16/2009	General – Graphics for Water Portfolios and Future Scenarios
10/08/2009	SWAN — Regional and Statewide Water Management Responses to an Uncertain Future

Regional Drivers of Water Demand and Available Supply

Chapter 5 Managing an Uncertain Future describes three narrative scenarios developed for Water Plan Update 2009 and some of the high level statewide and regional results. Here, we describe the underlying methods for quantifying factors of uncertainty that can drive future water demand and available supply. The key factors of uncertainty affecting future water demand are future land use patterns, future population and other demographic patterns, level of background water conservation, and future climate (precipitation and temperature). Future land use patterns affect how much land is devoted to irrigated agriculture or landscaping. Higher density urban development or water-wise landscaping practices can result in less water applied to landscape irrigation. Future population growth also has a significant effect on future water requirements. Future climate including occurrence of drought and wet years will affect the availability of supply and the additional water required to grow crops and maintain plants used in landscaping.

The irrigated agricultural land use estimates are based on potential urbanization of agricultural land, changes in crop mix, and changes in multicropping.

Agricultural Land Use

For Update 2009, three different scenarios of irrigated agricultural land use were developed corresponding to the Current Trend, Slow & Strategic Growth, and Expansive Growth scenarios described in Chapter 5. The irrigated agricultural land use estimates are based on potential urbanization of agricultural land, changes in crop mix, and changes in multicropping. The reduction in irrigated land area was based partially on the 2003 study, "How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint through the Year 2100", conducted for the Natural Resources Agency (Landis and Reilly 2003). The Landis study ties future population growth with future

Box 6-6 Abbreviations and Acronyms Used in this Chapter

CAT	Climate Action Team
CWEMF	California Water and Environmental Modeling Forum
DOF	California Department of Finance
DWR	California Department of Water Resources
PPIC	Public Policy Institute of California
SEI	Stockholm Environment Institute
SVP	Shared Vision Planning
SWAN	Statewide Water Analysis Network
SWAP	Statewide Agricultural Production model
Water PIE	Water Planning Information Exchange
WEAP	Water Evaluation and Planning system

urban development for the years 2020 and 2050. Landis developed a GIS urbanization model and created spatial urban footprints starting from the California Department of Conservation 1998 urban footprint. These urban footprints were used with the current irrigated agricultural land footprint to estimate irrigated land in the future.

The level of future multicropping area assumed for each of the three scenarios was developed using trends of historical multicropping area, irrigated land area, and results from the Landis study for 2020 and 2050. For Update 2009, relationships were developed between the Landis study and three recent estimates of projected 2050 population corresponding to Water Plan scenarios to quantify irrigated land area and multicropped area for each scenario by decade from 2010 to 2050. Land use was interpolated between decades.

Demographic Information

- **Population.** Three different estimates of future population growth to 2050 were developed for the three Water Plan scenarios. The Current Trends scenario follows population projections by the California Department of Finance (DOF). Population for the Slow & Strategic Growth and Expansive Growth scenarios are respectively based on low and high population growth scenarios developed by the Public Policy Institute of California as described in "Population projections for California climate change scenarios" (article in Volume 4 Reference Guide). The PPIC study was conducted for the Governor's Climate Action Team 2008 Biennial Climate Assessment Report. Some minor changes were made to the PPIC high population growth to distinguish it from the DOF projections.
- **Housing and housing density.** The three estimates of future population growth described above were used to develop estimates of future housing and housing density for the three Water Plan scenarios. Future population was used with demographic information from Woods and Poole (2007) to develop estimates of future single- and multiple-family households and household size. Estimates of future single- and multiple-family households and household size for the Current

Trends, Slow & Strategic Growth, and Expansive Growth scenarios are consistent with the DOF, PPIC Low, and PPIC High population projections, respectively.

- **Commercial and Industrial employment.** Similar to the housing factors, commercial and industrial employment for the Current Trends, Slow & Strategic Growth, and Expansive Growth scenarios are consistent with the DOF, PPIC Low, and PPIC High population projections, respectively, and are based on demographic information from Woods and Poole (2007).

Unmet objectives are objectives that have been identified by regulatory agencies or court decisions, but are not yet required by law.

Unmet Environmental Water Objectives

This information was updated for Update 2009 to include information from 1998 to 2007 and to consider additional objectives.

The three Water Plan scenarios include additional water needed in the future to meet currently unmet objectives for additional instream flow needs and deliveries for managed wetlands. Unmet objectives are objectives that have been identified by regulatory agencies or court decisions, but are not yet required by law. The first step of the analysis was to evaluate unmet objectives for existing streams and managed wetlands based on recent historical information following the methods described in the Volume 4 Reference Guide article by Environmental Defense, "Recommendations Regarding Scenarios and Application of Environmental Water 'Demands' in the State Water Plan Update & Quantification of Unmet Environmental Objectives in State Water Plan 2003 Using Actual Flow Data for 1998, 2000, and 2001." This information was updated for Update 2009 to include information from 1998 to 2007 and to consider additional objectives from the May 2008 report by the California Department of Fish and Game, "Flow Recommendations to the State Water Resources Control Board," which also can be found in Volume 4.

The second step in the analysis was to estimate future unmet environmental water objectives. For each hydrologic region, unmet objectives vary from year to year based on future precipitation projections from each of the 12 climate scenarios used by the Climate Action Team as described in the next section. The values for each year are derived from the historical unmet objectives and vary between scenarios. For example, for a future "wet" year type, the Current Trends scenario uses the average of the historical "wet" years; the Slow & Strategic Growth scenario uses the maximum of the historical "wet" years, and the Expansive Growth uses the minimum of the historical "wet" years. See Table 5-3 in Chapter 5 for the historical and scenario values for unmet environmental water objectives.

The Water Plan team coordinated efforts to quantify future climate with the ongoing work of the Climate Action Team (CAT). The result is 12 different time scenarios of future climate that the Water Plan applied for each of the three Water Plan scenarios.

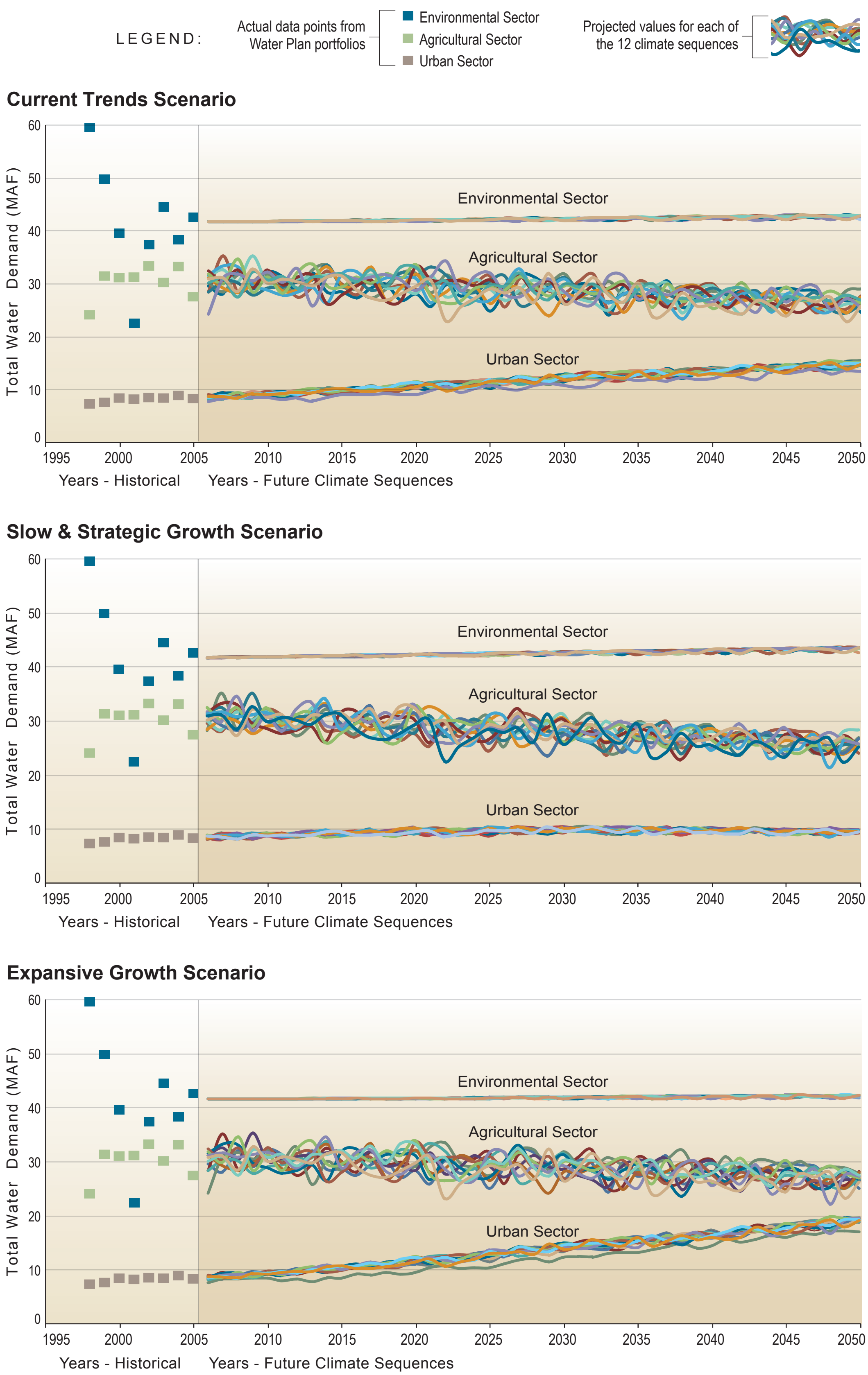
Future Climate

The Water Plan team coordinated efforts to quantify future climate with the ongoing work of the Climate Action Team (CAT) initiated by the Governor. The CAT completed a second biennial assessment of potential climate change impacts in the state. At the core of this effort is climate-change scenarios derived from six global climate models:

- From France: CNRM CM3
- From USA: GFDL CM2.1
- From Japan: MIROC3.2 (med)
- From Germany: MPI ECHAM5

Figure 6-4 shows annual statewide water demands for all sectors. The left side of each chart shows historical water use information for 1998 through 2005 from the Water Plan Water Portfolios. The right side of each chart shows 12 plausible scenarios for future water demand from 2005 to 2050 for 12 different scenarios of future climate superimposed on a single baseline growth scenario considering the effects of future population growth, land use changes, and background water conservation.

Figure 6-4 Statewide annual water demand under 12 future climate scenarios



- From USA: NCAR CCSM3
- From USA: NCAR PCM1

These models were chosen on the basis of the availability of detailed outputs for use in various parts of the assessment process and upon consideration of certain aspects of their performance. The CAT used each of the six global climate models with two separate greenhouse gas emission scenarios developed by the Intergovernmental Panel on Climate Change. The result is 12 different time scenarios of future climate (temperature, precipitation, and relative humidity) that the Water Plan applied for each of the three Water Plan scenarios. Please refer to Volume 4 Reference Guide article "Overview of Climate-change Scenarios being Analyzed" for additional information on the CAT climate scenarios.

Quantification of Scenarios and Resource Management Responses

Statewide Water Demands

Chapter 5 describes the statewide change in total water demands by 2050 under 3 scenarios and by each sector (urban, agriculture, and environmental). Here we provide more detailed results showing the aggregate impact of the regional drivers described in previous section on future water demands over time. Figure 6-4 shows the relative magnitude of water demands for each sector by showing historical information from the Water Plan water portfolios (Volume 5 Technical Guide) and annual statewide water demand results generated for 2005 to 2050 using the WEAP analytical tool.

In Figure 6-4, the left side of each line chart shows historical water use information for 1998 through 2005 from the Water Plan water portfolios. The right side of each chart shows 12 plausible scenarios for future water demand from 2005 to 2050 for 12 different scenarios of future climate superimposed on a single baseline growth scenario considering the effects of future population growth, land use changes, and background water conservation. Each line chart, one for each scenario, presents environmental, agricultural, and urban water demand separately. Total environmental demands are assumed to ramp up gradually over time from the 1998-2005 average, but vary from year to year depending on the climate. For each scenario, statewide agricultural water use varies considerably from year to year based on the climate for that year, and declines generally over time due to decreases in irrigated crop area associated with urbanization as well as additional background water conservation. Urban demands also show the influence of future climate, but are more dampened by indoor demands, which are not assumed to be influenced by climate. However, the impact of future population growth on increasing water demand is particularly evident under the Current Trends and Expansive Growth scenarios.

The long-term goal for the California Water Plan is to allow for an integrated quantification and evaluation of regional resource management responses.

Quantifying Resource Management Responses

To help bridge the technical gap in Update 2009, DWR held a SWAN workshop to solicit feedback on recent studies exploring the effectiveness of regional and statewide water management responses to uncertainties facing California water managers.

The long-term goal for the California Water Plan is to allow for an integrated quantification and evaluation of regional resource management responses. This is to be implemented as part of the quantitative deliverables described in Box 6-4 that includes water portfolios, future scenarios, and response packages. Building on Update 2005, Update 2009 applied the WEAP model to quantify future scenarios of water demand at two levels of detail. In addition, Volume 2 describes and, where possible, quantifies benefits from 27 resource management strategies that should be considered by water managers as part of integrated resource planning. This work will be expanded during preparation of Update 2013 to begin quantifying and evaluating regional water management strategies.

These studies highlight our current technical capabilities and limitations for describing future uncertainties and providing decision-makers with insights into the challenges and opportunities facing water managers.

To help bridge the technical gap in Update 2009, DWR held a SWAN workshop on October 8, 2009, to solicit feedback on recent studies exploring the effectiveness of regional and statewide water management responses to uncertainties facing California water managers. Studies were presented that offer different perspectives on how climate change, population growth, droughts, and other uncertainties may impact regional water management systems and operations of the Central Valley Project and State Water Project. These studies highlight our current technical capabilities and limitations for describing future uncertainties and providing decision-makers with insights into the challenges and opportunities facing water managers. See Volume 4, Data and Analytical Tools category, for the workshop summary.

The following is a summary of the three studies presented at the workshop:

- **Water Management Lessons for California from State-wide Hydro-economic Modeling (Lund et al. 2009, University of California, Davis)**
  Researchers at the University of California, Davis presented the results of a decade of quantification and analysis of California's water management system from a hydro-economic perspective. The study focused on the general approach, management and policy insights, and promising directions that consistently emerge from these analyses. Limitations and suggestions were presented for improving hydro-economic modeling for providing insights into contemporary and future water management problems in California. Listed below are the study's key conclusions.
  1. It is possible to significantly improve statewide integrated water management and policy studies in California using hydro-economic modeling.
  2. Most water management entities in California benefit from being connected to a wide variety of water sources and other water users, facilitating more adaptable water management and water markets.
  3. The Delta is the weakest link in California's water supply system.
  4. There is rarely a shortage of water, only a shortage of cheap water.
  5. Integrated portfolio solutions of traditional and new options tend to be the most cost effective and robust.
  6. Of traditional infrastructure, expansions of selected conveyance and aquifer recharge are typically much more beneficial if water operations are well managed.

7. We have fragmented our technical and scientific capabilities and understanding of the system. Better integration and flexibility is needed for our water management system to adapt in coming decades to changed population, land use, climate and ecosystem threats.

The study provides a preliminary assessment of the future performance of the Central Valley Project and State Water Project systems and describes and quantifies challenges related to Delta health, climate change, and drought.

- **CalSim-II Modeling Efforts on Water Resources Challenges and Potential Management Responses and Uncertainties Facing Management of the Central Valley Project and State Water Project (DWR 2009)**
  DWR staff conducted a preliminary analysis of current water resources challenges facing the State and potential management responses using existing data and analytical tools. The study provides a preliminary assessment of the future performance of the Central Valley Project and State Water Project systems and describes and quantifies challenges related to Delta health, climate change, and drought. This evaluation is ongoing, and recommendations are included for completing the assessment and providing comprehensive information for decision makers and the public. Listed below are the study's key conclusions.
  1. New conveyance provides greatest benefits during average hydrologic conditions.
  2. New storage provides the greatest supply reliability benefits under drought or climate-induced conditions.
  3. New groundwater storage performs similarly, with even greater drought year performance and with climate change.
  4. A range of integrated regional water management actions in the South Coast Hydrologic Region do not appear to significantly affect Delta operations or deliveries.
  5. The relative frequency of dead storage conditions in upstream reservoirs indicate that significantly modified operations will be required with climate-induced conditions.

Metropolitan is using IRPSIM to assist in its current integrated resources planning efforts ... to estimate the region's future water demands and to evaluate different water supply development scenarios ... additional uncertainties in its analytical studies such as demographics and climate change.

- **Regional Water Management Responses using IRPSIM**
  Staff from the Metropolitan Water District of Southern California presented information from over a decade of studies conducted for their integrated water resource plan, which began in 1996 and was updated in 2003. IRPSIM is Metropolitan's primary tool for evaluating regional reliability, storage operations, and resource opportunities. Metropolitan is using IRPSIM to assist in its current integrated resources planning efforts. The presentation covered how IRPSIM is used to estimate the region's future water demands, and to evaluate different water supply development scenarios. It also provided an overview of Metropolitan's efforts to incorporate additional uncertainties in its analytical studies such as demographics and climate change. IRPSIM uses a modeling method known as sequentially indexed Monte-Carlo simulation. In short, the model integrates projections of Metropolitan's demands and imported water supplies for each forecast year and adjusts each independent projection up or down, based on an assumed pattern of future weather drawn from the historical record.

Summary

California needs significant improvements in its analytical tools and data to effectively evaluate the costs, benefits, and trade-offs of alternative water management strategies and support decision-making. These improvements must be done in a way that promotes integrated water planning and fosters collaboration. A tremendous amount of work needs to be done to provide the desired quantitative deliverables for future Water Plan updates. This work will have to be done with limited budgets and considerable uncertainty related to the health of the Delta, future climate change, and droughts. Achieving these advances requires significant investments in better information management systems; additional data collection; and more sophisticated, transparent, and accessible analytical tools.

This chapter describes some of the critical activities undertaken recently to improve our technical information and identifies several critical activities that must be conducted for the next Water Plan update to continue progress.

It concludes with a summary of the technical accomplishments from Water Plan Update 2009 and summarizes other recently completed studies that highlight our current technical capabilities and limitations for describing future uncertainties and to provide decision-makers with insight into the challenges and opportunities facing water managers.

References

[DWR] California Department of Water Resources. 2005. California Water Plan Update 2005: A Framework for Action. http://www.waterplan.water.ca.gov/

[CWEMF] California Water and Environmental Modeling Forum. 2005. "Final Report on Strategic Analysis Framework for Managing Water In California., Sep. See www.cwemf.org

[CWEMF] California Water and Environmental Modeling Forum (Formerly Bay Delta Modeling Forum). 2000. "Protocols for Water and Environmental Modeling." Jan. See www.cwemf.org

Dettinger, Michael D. and Steven Culberson. 2008. "Internalizing Climate Change - Scientific Resource Management and the Climate Change Challenges." June. San Francisco Estuary & Watershed Science.

Landis, Paul and Michael Reilly. 2003. How We Will Grow: Baseline Projections of the Growth of California's Urban Footprint through the Year 2100. Institute of Urban and Regional Development University of California, Berkeley.

Lund, Jay R., Richard E. Howitt, Josué Medellín-Azuara, Marion W. Jenkins. 2009. Water Management Lessons for California from State-wide Hydro-economic Modeling, a Report for the California Department of Water Resources. Davis: University of California. Unpublished.

Woods and Poole Economics. 2007. "County Projections to 2030, State Profiles". Washington DC: Woods and Poole Economics.