CHAPTER 10

CONCLUSIONS

1. *The complexity, controversy, interdependence, and importance of California's water supply system have grown to require new approaches to their analysis.*

California's water issues are interconnected statewide; water management and use in one area commonly affects water use in other areas. Surface water and groundwater systems are highly connected. Almost the entire system is complex and controversial. Most current analysis models used in California were developed at an earlier time to examine surface water management for a specific water project over a limited area with fairly inflexible operations. These models have been expanded like a rambling old house to accommodate new analytical requirements, but have become increasingly uncomfortable to live with. More modern analysis methods can help with these problems, providing a more integrated representation of the entire problem, improved indicators of system performance, more efficient solution procedures, and a wider range of problem solutions.

2. *Economics should have a greater role in analysis of California's water system.*

The greater controversy, variability, and diversity of water uses and supplies in California's water system have made economic indicators of system performance increasingly desirable. Economics-based analysis and economic measures of performance provide a fairly direct basis for:

- Evaluation and comparison of alternatives;
- Developing new economically promising structural and non-structural alternatives;
- Financial and willingness-to-pay studies;
- Cost or benefit effectiveness studies;
- Development and evaluation of integrated effects of multiple water management options;
- Quantifying trade-offs among system objectives; and
- Quantifying benefits to society and users of changes in facilities, environmental flow requirements, and institutional policy constraints.

Traditionally, "water supply yield" has been used to indicate water system performance. However, "yield" has become an increasingly obsolete and contentious indicator of performance, given its wide hydrologic variability, neglect of important water quality and economic considerations, and sensitivity to detailed assumptions (Linsley et al. 1992). Economic measures of performance are generally more important to people and help to characterize water supply reliability in terms meaningful to society. As economic measurement methods have improved, using the economic value of water deliveries has become a more reliable and direct indicator of system performance that can better incorporate reliability and water quality concerns.

This work, in developing and applying an improved agricultural economic production model (SWAP) and an elasticity-based urban water demand model, has produced preliminary estimates of the economic value of monthly water deliveries to agricultural and urban users throughout

California. These results and the analysis methods are presented in Chapter 6 and Appendices D and E. These economic models extend economic valuations of agricultural and urban water use used in the Draft CVPIA-PEIS and CALFED work (USBR 1997; CALFED 1999d). While improvements in these estimates are desirable, there is sufficient data and professional consensus to use these economic methods in long-term water planning.

3. *Advances in computing and software provide substantial opportunities to modernize and improve the analysis of California's water resources*.

Computers are much less expensive and more available and capable than when most current models and analytical methods were developed. Software for computing, storing, organizing, displaying, and optimizing is far more available and usable than in the past. Data of all sorts, while always lacking and imperfect, is available, sufficient, and improving for more extensive and detailed studies than have been done. The internet makes it possible for data, models, and computing resources to be shared and communicated among a wide range of users and interests, hopefully helping educate us all about problems and potential solutions.

The California water community is at an unusual point in time where the limitations of old methods and the promise of new technologies are both abundantly apparent. This is a pivotal time for the California water community to develop new approaches, methods, tools, and data for planning, managing, and operating water statewide over the long term. Development of such methods, software, and data are a vital strategic need for all parts of California's water community. Without such modernization, proposed solutions are less likely to perform effectively, and are therefore more likely to become controversial, discredited, and short-lived. DWR and USBR have moved energetically in this direction with the development of the CALSIM simulation model, which provides a platform for additional modernization efforts.

This project has demonstrated the feasibility and desirability of several more modern approaches to large-scale water system analysis. These include:
- More transparent data-driven modeling;
- Database documentation of model assumptions and parameters;
- Large-scale economic optimization; and
- Structures for automated computer management of modeling data.

The primary advantages of these techniques are to speed development and analysis of alternatives and to increase the transparency of modeling assumptions and results.

4. *California can choose from a wide variety of structural and non-structural options for addressing its pressing water resource problems.*

Chapters 3, 4, and 5 present a diversity of structural and non-structural options available to local, state, and federal agencies, firms, and water users. Traditional structural options include new or expanded surface water reservoirs, canals, and aqueducts. New structural options include groundwater storage and advanced (and expensive) treatment options to utilize wastewater, brackish water, and even seawater. Nonstructural options include water transfers and markets, water conservation, conjunctive use of surface and ground waters, and improved coordination of water storage, distribution, and treatment facility operations. Additional water conservation options are included in the economic value functions used in CALVIN. The finance of these options, most of which are costly, can also be accomplished in a variety of ways, as reviewed in Chapters 4 and 5, ranging from self-financing and bonds to privatization and joint ventures among agencies.

Nonstructural options are especially important and are necessary complements to structural options. In highly interconnected systems, such as California, the benefits of new water facilities are often reduced unless accompanied by complementary changes to the operations and management of other water facilities. Such changes in operations and management can be accomplished by cooperative operating agreements among facility owners, water transfers or markets, or changes in contracts or other agreements. Operations also can change by modifying user demands through various water conservation or transfer options. Nonstructural options provide many opportunities and might be cost-effective, especially in conjunction with structural measures. However, it is typically difficult to study, develop, and integrate nonstructural options using conventional simulation models, prompting the need to use newer and more flexible analytical techniques. The need to integrate all manner of water management options further motivates the use of more modern system analysis methods.

5. *Groundwater must be integrated into the analysis of California's water supplies, even though we know relatively little about it.*

Groundwater provides about thirty percent of California's agricultural and urban water supplies in an average year. In drought years, use of groundwater increases greatly, and provides California's greatest source of drought water storage. Groundwater overdraft is also one of the greatest manifestations of water shortage in California. While there is relatively less knowledge and regulation of California's groundwater, this has not made groundwater less important for managing California's water supplies. Realistic analysis of California's water supplies must include explicit integration of groundwater. In addition to providing more realistic analysis, such integration will support development of promising conjunctive use projects and accelerate development of improved understanding of the state's groundwater systems.

6. *Economic-engineering optimization models are feasible and insightful for California's water problems.*

This study has demonstrated the capability of a new analysis approach for California water, the CALVIN model. CALVIN is an economics-based engineering optimization model of California's water supply system. Given economic values developed for agricultural and urban water supplies, environmental flow constraints, inflow hydrologies, operating costs, and facility capacities, CALVIN suggests economic-benefit-maximizing operations of the statewide system, integrating all resources and options. This phase of work has proven the data availability and software performance required for CALVIN and the feasibility of implementing such a modeling approach.

Sample runs of statewide models demonstrate some of the desirable features of economic-engineering analysis of California's statewide water supply problems, as presented in Chapter 8. Values of facility expansions and new water are produced. The willingness of water users to pay for additional water and new facilities also is produced. The costs of environmental and other policy or operating constraints on the system can be quantified. Economically optimal and integrated facility operations are produced.

The application to California of this economic-engineering optimization approach embodied in CALVIN is the largest of its kind, with over 75 surface water and groundwater reservoirs. However, this approach has also been applied to other large water systems by the US Army Corps of Engineers (Columbia River system, Missouri River system, and Panama Canal system) and the World Bank.

7. *New optimization modeling analysis will almost always require more focussed and detailed simulation modeling to refine and test solutions*.

As good as optimization models have become, they do suffer some limitations and require sometimes important simplifications relative to simulation models. (CALVIN, for instance, has fairly crude methods of representing water quality.) Optimization model solutions provide promising solutions for refinement and testing by simulation studies. Use of optimization avoids the need to make and interpret many thousands of simulation model runs to explore the wide range of alternative solutions, a virtually impossible simulation task for large and complex systems. This allows simulation efforts to focus on the detailed analyses they are better suited for. For large, complex, and controversial systems, simulation and optimization methods complement each other.

8. *Better data is needed in some areas to allow better solutions to be realized.*

In assembling and developing input data for the CALVIN model, we identified some areas which merit greater long-term data development. These areas include:
- Surface water and groundwater hydrology;
- Operations and costs for local water facilities;
- Urban water demands and economics; and
- Water quality economics.

CALFED, DWR, and USBR are devoting effort to improving data in some of these areas, particularly regarding surface water and groundwater hydrology in the Central Valley.

9. *CALVIN needs more work.*

While this first phase of work has proven the concept of applying economic-engineering optimization to California's water system, much data checking and development is needed before useful policy-relevant results can be produced. Additional work in this regard is being undertaken with support from CALFED.