PIER Energy-Related Environmental Research
Environmental Impacts of Energy Generation, Distribution and Use

Improving Water Forecasting for Better Hydropower Production

Contract #: 500-02-008
Contractor: Hydrologic Research Center
Contract Amount: $300,000
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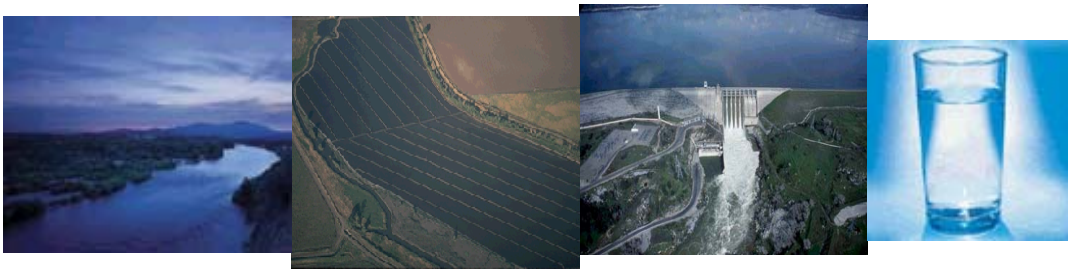

The Issue

Hydropower—our lowest cost, emissions-free, renewable energy source—encompasses the two public resource issues most crucial to Californians: electricity and water supply. Although the electricity shortages that the state experienced years ago have been resolved, the search for sufficient clean electricity sources to supply California's growing population continues to challenge the state.

Similarly, the state's demand for freshwater supplies is outstripping its existing resources. In fact, the California Department of Water Resources estimates that the state is likely to suffer from severe water shortages by 2020.[1] A key element of the state's water supply system is the several large multi-purpose reservoirs that capture runoff to supply water for urban and agricultural uses, provide protection from flooding, support recreation and generate hydroelectricity. As freshwater becomes scarce and competing demands increase, a better balance of those uses becomes imperative.

One method for doing so is to produce hydroelectricity more efficiently. California's in-state hydropower facilities constitute 27% of its generation capacity and supply the state with an average of 15% of its electricity each year.[2] However, the amount of electricity that a hydro plant can generate in any given year is based on California's variable climate (which determines the amount and timing of rainfall and snowpack runoff) and competing municipal, agricultural, and environmental needs. Although the amount of rainfall and snowpack can differ greatly from year to year, both electricity and water demand continues to climb.

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[1] PIER Interagency Agreement with Hydrologic Research Center.
[2] Ibid.

To generate as much power as possible from hydroelectric facilities, managers must be able to estimate the most efficient use of water on a daily, weekly, monthly, and yearly basis. If those estimates are based on incomplete information, one or more sectors may be shortchanged. For example, in anticipation of increased runoff, reservoir water could be released to reduce potential flooding. However, if that release was unnecessary, that water—which could produce electricity or enhance stream habitat later in the year, when it is needed the most—is lost.

Management of California's freshwater reservoirs is not as efficient as it could be, because current water use protocols do not directly account for climatic variability. To meet the state's increasing electricity needs and water demands, this variability must be incorporated into these protocols. Such efforts have already proven fruitful. An integrated forecasting system that was developed to support more efficient water management in Folsom Reservoir identified potential hydroelectric production increases of up to 18%, and also showed that increases of as much as 50% in water supplies could be possible.[3]

PIER Program Objectives and Anticipated Benefits for California

This project will offer numerous benefits and meet the following PIER program objectives:

- **Environmentally sound electricity.** The impact of hydropower dams on downstream aquatic life and habitats can be significant. Implementing a decision support system that effectively evaluates competing water uses will provide water managers with better information to assess the environmental impacts of operational decisions. In addition, electricity produced by hydropower generation displaces the need for electricity that would otherwise most likely be generated by fossil-fuel generating plants. As a result, California's air is cleaner.

- **Reliable electricity.** Better water use forecasting should enable hydropower plant managers to maintain or even increase hydropower production at California hydropower facilities. Using this fuel-free, in-state source bolsters the state's energy reliability and independence. Hydropower can also be put online quickly, which can help alleviate shortages elsewhere.

- **Affordable electricity.** Hydroelectric generation is among the lowest-cost means of generating electricity. By increasing the efficiency of hydropower plants, this project will help California maintain this supply of inexpensive electricity.

Project Description

In this three-year project, PIEREA and the Hydrologic Research Center implemented an integrated management system for reservoir operation that incorporated global climate model forecasts at the Folsom, Oroville, Shasta, and Trinity reservoirs. Researchers then demonstrated and quantified the improved efficiency of water management for hydropower production, water supply, and flood control in California.

The purpose of this Integrated Forecast and Reservoir Management Demonstration for Northern California (INFORM) was to conduct research to support the development and demonstration of

[3] Ibid.

methods and technologies for increasing hydroelectric generation with other water demands and requirements.

First, the project established an Interagency Oversight Committee to oversee the research and provide technical guidance. The research team used global climate change model simulations with historic climate information to validate those models for Northern California, and then used the models to develop hydrologic forecasts of runoff within the four reservoirs and watersheds.

The project also developed an interlinked Sacramento River Decision Support System (SRDSS) of models for the four reservoirs, including an integration of climate and ensemble hydrologic upstream forecasts and long-range decision modeling for the entire Sacramento system. To facilitate the evaluation of impacts from reservoir site release decisions, researchers assembled and formulated hydrologic models as needed for the downstream Sacramento River.

Once the SRDSS was used and validated, researchers developed and included a policy assessment model in the system. The model quantifies the system response for a specified inflow sequence, streamflow forecasting scheme, and operational policy. At the completion of the forecast-decision-simulation process, the program generates sequences of all relevant system performance measures, including reservoir levels, releases, energy generation, flood stages, instream flow conditions, and water supply deficits, if any. These sequences could be used to compare the benefits and consequences of various inflow scenarios, forecast-decision configurations, and operational policies.

In addition to modeling, the project examined the accuracy of downscaling global climate model data for smaller-scale applications. Researchers developed, tested, and refined a method to downscale information from global climate models to a scale suitable for the hydrologic forecast models and generated validation tables for the downscaled climate forecasts.

Results

After creating the Oversight and Implementation Committee, the research team completed the following activities:

- Developed, implemented, and performed validation of:
  - climate and weather INFORM components for Northern California with historical data and real-time data;
  - hydrologic INFORM reservoir-inflow forecasts with historical and real-time data for all major reservoirs of Northern California; and
  - decision INFORM components with historical and real-time data for the Northern California water resources management system.
- Integrated INFORM system climate, hydrology, and decision components and performed initial operational tests producing real-time ensemble forecasts out to lead times of 16 days four times daily for the 2005–2006 wet season.

- Performed assessments of the integrated forecast-decision system value via retrospective simulation experiments.
- Held INFORM design, assessment, and training meetings with operational forecast and management agency staff.

Researchers drew several technical and specific conclusions from the project outcomes, in the areas of meteorology/climate, hydrology, and decision science, and they are detailed in the report. Most important, the project showed that with available real-time availability of forecast information from the National Centers for Environmental Prediction and real-time observed precipitation and temperature (and hydrologic model state values from the California Nevada River Forecast Center), integrated forecast-management systems can be effective operational decision-support tools for management and planning of California water resources. Such systems help water managers to translate forecasts and their uncertainty into a range of effective risk-based policies. In addition, these systems can advance current operational practices by (1) incorporating forecast uncertainty in decisions on a range of time scales, and (2) allowing for regional coordination of management decisions.

The research team recommended that INFORM demonstration experiments continue for two or three additional operational seasons beyond the system "dry run" wet season of 2005–2006, in continued close collaboration with the forecast and management partner agencies in Northern California, to further evaluate the INFORM system performance and utility. The team also recommended that the INFORM system be used in stand-alone mode for climate change simulations.

Final Report

This project's final report, *Integrated Forecast and Reservoir Management (INFORM) for Northern California: System Development and Initial Demonstration* (CEC-500-2006-109) is on the California Energy Commission's website, at www.energy.ca.gov/pier/final_project_reports/CEC-500-2006-109.html.

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