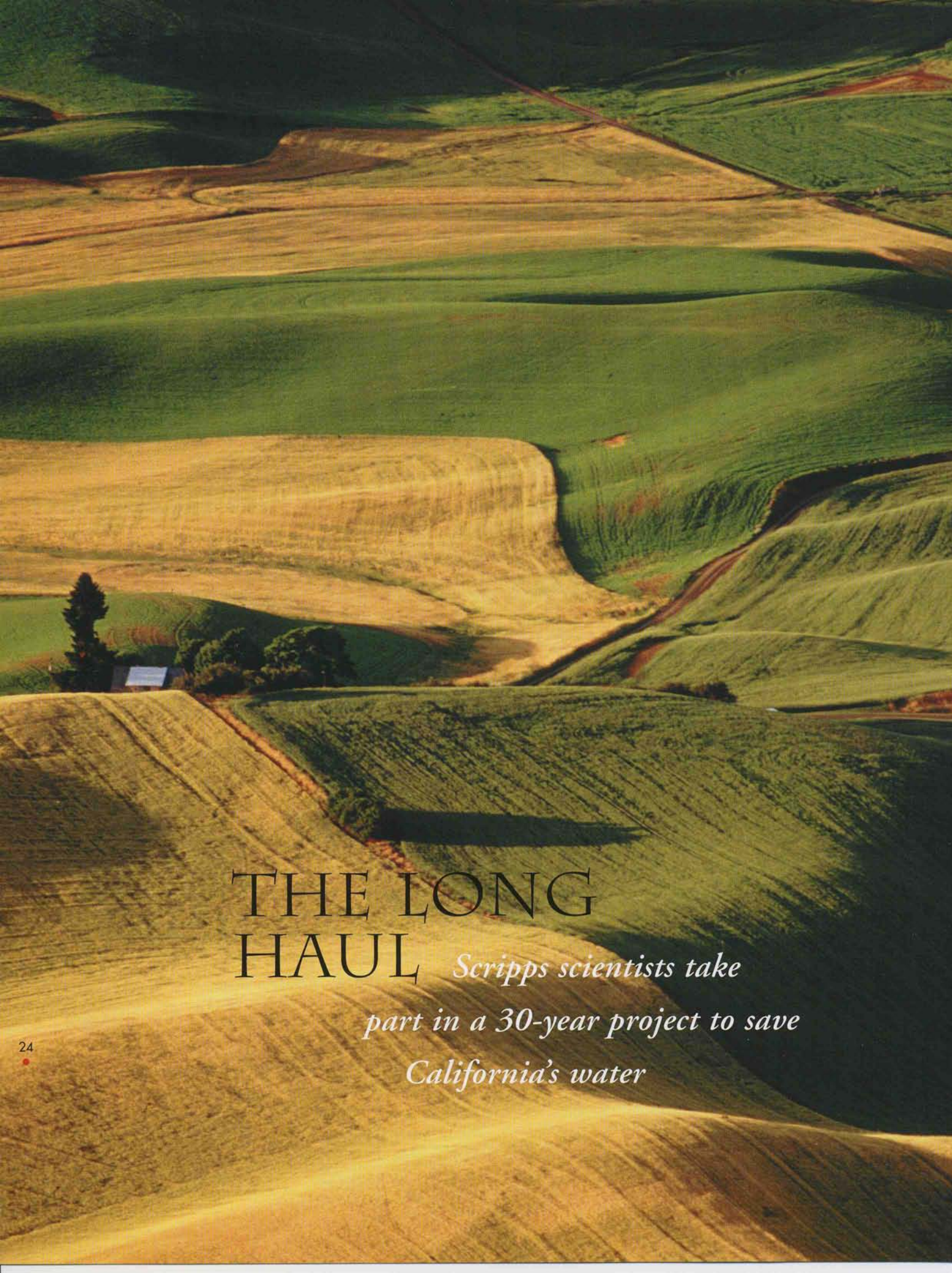


THE LONG HAUL

Scripps scientists take part in a 30-year project to save California's water

APPLICATION

BY ALLISON ZUMBER

THE SANTA ANA SUCKERFISH and the quality of your neighborhood drinking water have intertwined fates. Their common future rests in the hands of politicians, environmentalists, and scientists collaborating on a project that began as an effort to save an endangered fish but became an overhaul of one of the world's most complicated water-management systems.

The California Bay–Delta Program began six years ago as a response to several species being added to the endangered list—including the suckerfish. The fish is found in the San Francisco Bay/Sacramento–San Joaquin Delta, the largest estuary on the West Coast. But the fight to preserve the species revealed a web of water-management problems throughout the state. The threat to the suckerfish was part of a syndrome that included increasingly salty water in San Francisco Bay, crumbling levees in Sacramento, and, in several areas of the state, declining drinking water quality. It became clear to state officials that saving the endangered fish was not possible without a more comprehensive effort.

Since then, the California Bay–Delta Program has evolved from an environmental effort into an organization that is helping plan for California's future water supplies. Twenty local, state, and federal agencies that are participating in the program are redrafting water-use priorities and setting up ambitious objectives to be carried out over three decades. Two Scripps climatologists are providing the science to guide such political decisions.

One of them is Mike Dettinger, who recalls first hearing of the program and wondering what provisions its operators were making for climate-change analysis. To him and Dan Cayan, director of the Climate Research Division at Scripps, incorporating knowledge about the state's hydrologic future seemed a given—but the scientists were surprised to learn that this was not the case. Dettinger, a research associate at Scripps, contacted officials and received answers along these lines: "Our problems are much too pressing to worry about something that's going to happen in 20 or 50 years."

The Bay–Delta Program's science board eventually gave prominence to climate-change issues and the undeniable influence they will have on water systems; officials say they had hoped that these issues would eventually take their rightful place in decision making.

"Climate science has always been in the plans," said Kim Taylor, the program's deputy director for science. "The science was not given much attention until recently when a system was developed to give scientists a voice."

SUPPLY AND DEMAND

Cayan and Dettinger, both U.S. Geological Survey scientists as well as Scripps researchers, see their role as helping decision makers anticipate long-term changes that will affect the plumbing of the third-largest state in the union. Three-fourths of California's rain falls north of San Francisco, but more than three-fourths of the state's water is used south of that city. From northern California lakes and reservoirs through the Sacramento River, water is channeled south hundreds of miles to supply irrigation water for agriculture in the Central Valley and drinking water for 22 million people in southern California.

"In the old days, the primary conflict in terms of management was whether you use your reservoirs for flood control or water supply," Dettinger said. "The water agencies had gotten very good at supplying water when and where it was needed."

But with the realization that saltier waters and water-pumping practices were creating an ecological crisis, the federal government invoked the Endangered Species Act in 1994, introducing a new and challenging variable into water management.

Management schemes had to be restructured to protect fisheries. State agencies, including the California Resources Agency and the California Environmental Protection Agency, joined federal agencies such as the Army Corps of Engineers, the Department of the

Interior, and the Department of Agriculture in an interdisciplinary huddle to create the California Bay–Delta Program. Four primary objectives were drafted in order to shore up the water system.

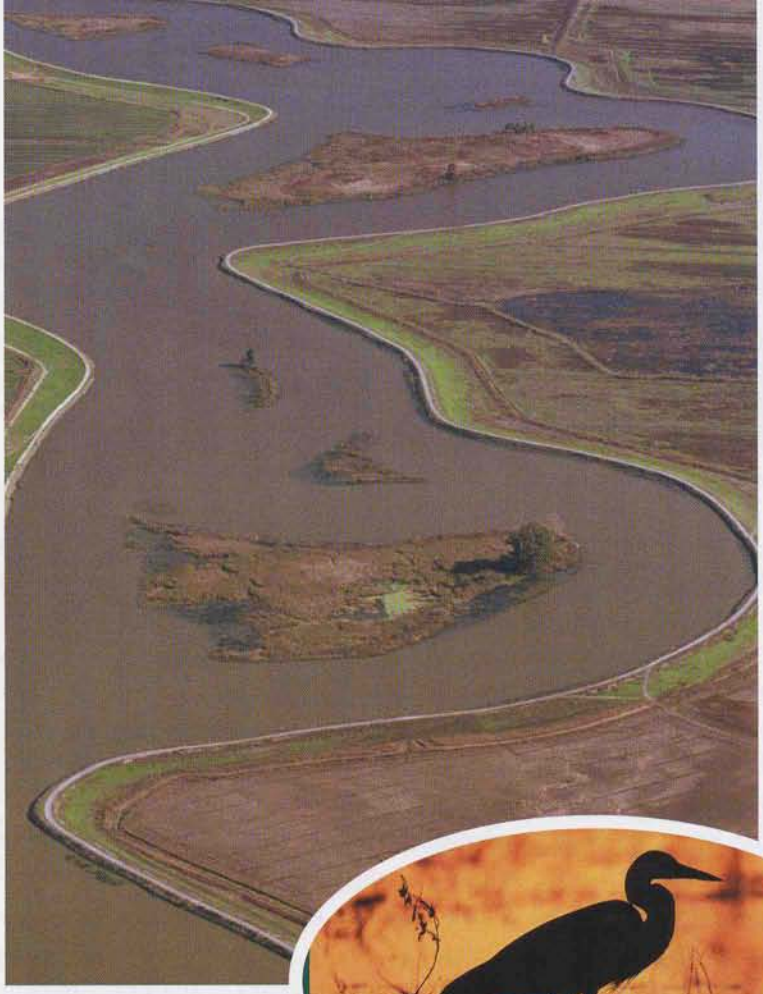
First, make the water-supply system more reliable by reassessing allocation to users, increasing water conservation efforts in southern California, and replacing dams.

Second, improve water quality, a move that benefits households as well as fisheries.

Third, restore ecosystems (surveys suggest that 95 percent of natural wetlands in northern California have been ruined).

Fourth, stabilize delta levees. Farmland in the delta sits behind hundred-year-old levees and is mostly below sea level. A levee breach would mean a salty, stagnant brown lake taking the place of green and red tomato fields.

Seemingly contradictory, the California Bay–Delta Program's objectives are in fact interdependent. Improved water quality requires functioning levees. A vibrant ecosystem cleans water by filtering out contaminants and bacteria.



Left, *Bay–Delta program managers must find a way to balance the seemingly contradictory water needs of wildlife and people.* **Far left,** *Merced River floodplain and ecosystem restoration.*

"You need some of all of them," Dettinger said. "Determining what the mix should be is the real conundrum."

IN PURSUIT OF "EVERYONE'S BEST HOPE"

Dettinger and Cayan have been have been keeping close tabs on developments within California water management—its policy and practice—and have been called on to brief state officials on their latest conclusions about climate variability. The two anticipate receiving funds from the California Bay–Delta Program for studies that will further increase relevant scientific knowledge, such as an upcoming study of tree-ring records in the Central Valley, which will shed light on precipitation patterns in past centuries. Their conclusions could reshape the Bay–Delta Program. Dettinger notes that the program's "adaptive management" approach will allow the flexibility to address new findings over its 30-year duration.

Despite the program's decades-long timeframe, an eon in political terms, Cayan and Dettinger's conclusions about climate lend a tone of urgency. Climate change itself is a near certainty, as is continuing population growth in the state. Highly probable is a 1.5 to 3.0 degrees Celsius (2.7 to 5.4 degrees Fahrenheit) increase in the average temperature in California throughout the next hundred years. Along with this warming, the sea level is expected to rise,

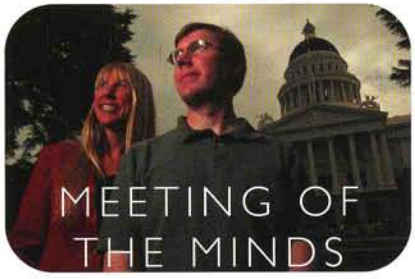
making it easier for saltwater to enter the delta and render it a brackish hazard to wildlife and industry alike. Additionally, evidence indicates that there will be less snowpack and earlier snowmelt, and flood risks will increase with the warming.

What Dettinger calls "the big kahuna" of unknowns is whether California will be wetter or drier in the future. Most climate models predict that the change in precipitation will be small—increases or decreases of about 10 percent or less. A decrease would only aggravate California's already stressed water supply and actually make flooding more likely as torrential rain replaces snow.

Still other possibilities lurk. Cayan and Dettinger's previous paleoclimatalogical studies of California present the chilling specter of a "mega-drought" lasting 70 to 80 years. There is evidence that, as recently as medieval times, California experienced such a prolonged dry spell, resulting in 30 percent less rain than the yearly average the state gets now. Remnants of ancient trees have been found underwater in the lakes of the eastern Sierra Nevada in places where they could not grow now, but could have in the past when water levels were significantly lower than they are today.

Above, *Dan Cayan (left) and Mike Dettinger are providing scientific input to the Bay–Delta program.* **Right,** *Dettinger examines a flowmeter readout near Yosemite.*

Even without such daunting scenarios, population growth alone is reason enough to make climate part of the Bay–Delta Program's decision-making process. The program is off to as good a start as could have been expected, said Dettinger. "The water systems that got us through the twentieth century will not necessarily get us through the twenty-first century," he said. "The California Bay–Delta Program is everyone's best hope."



MEETING OF THE MINDS

Left, *Scripps visiting scholar Anne Steinemann and climate scientist David Pierce take science to Sacramento.* **Above,** *Steinemann and Pierce address California Energy Commission staffers.*

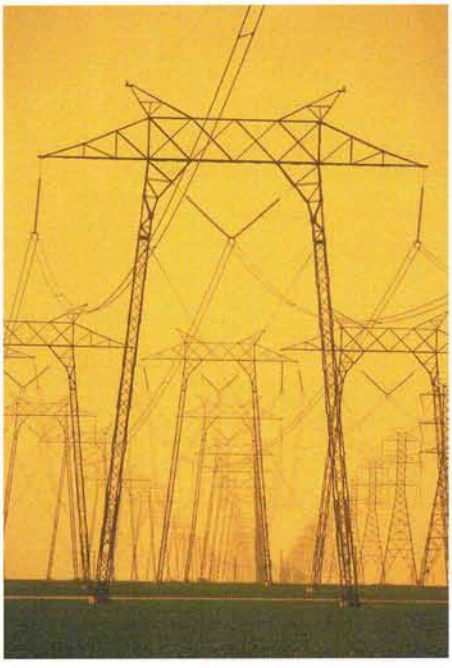
Suppose you're an electric company manager trying to predict when power usage will surge in the hot summer months. You would be interested not only in the predicted increase in temperature, but also in the geographic spread of temperatures. There are times when it is extremely hot, for instance, in San Francisco, San Jose, and the Central Valley all at once. Knowing in advance that such a situation is likely would allow for the development of plans to satisfy electricity demands.

Scripps scientists are creating forecast tools tailored to the needs of water, electric, and natural gas utilities in the new program, CalEnergy. With funding from the National Oceanic and Atmospheric Administration, the Scripps team needs to show that its climate predictions can be of use to utilities and state agencies, said Scripps climate scientist David Pierce.

"It's sort of a back and forth between academics and industry people," Pierce said. "The industry people are going to identify some key decisions that could be influenced by weather or climate, and then we'll see how accurately we can predict those kinds of things."

Long-term prediction is a new concept in the war rooms of power providers, whose crystal balls can usually see only one to two weeks into the future, the typical limit of weather forecasts. Crucial information like the cyclical appearance of El Niño, which can radically alter everything from air conditioner use to hydroelectric power production, has not been fully considered. Only recently has climate forecasting achieved a level of reliability that enables its use as a management tool.

As important as the quality of the predictions themselves, which are based on Scripps-operated climate models, is making them useful to energy officials. Joining Pierce and project leader Tim Barnett is Anne Steinemann, a Scripps visiting scholar who acts as an intermediary between the scientists and California state energy officials. She identifies the forecasting needs of agencies like the California Energy Commission then delivers forecast products and estimates of their benefits.



With the power crisis of 2000–2001 fresh in their minds, energy officials, Steinemann finds, are interested in the potential of a new forecasting resource.

"I've been impressed by the expertise and commitment from our energy partners," Steinemann said. "They are key to the success of this project."

The California Energy Commission is the main state agency partnering with Scripps. Interest in the potential of climate forecasting has grown steadily, said Guido Franco of the commission's Public Interest Energy Research Program. The next step will be to demonstrate to energy commissioners the benefits of long-range advance weather forecasts, he said.

"We hope in six to eight months, we'll be able to assess this," Franco said.

—Robert Monroe

MARGIN OF DIFFERENCE

Why should a reservoir manager learn to use a complex, abstract forecast model? The recent demonstration of a hydrologic prediction tool suggests that there could be millions of reasons.

The Integrated Forecast and Reservoir Management (INFORM) program began a five-year run in the summer of 2003. A joint initiative of the Hydrologic Research Center (HRC) in San Diego and the Georgia Water Resources Institute of Atlanta, INFORM's goal is to create models that incorporate cutting-edge climate and hydrologic forecasting technologies. Operators of major northern California dams could then use the models, translated from scientific language to the operational codes they use, to select how much water to release and when.

Above, *Shasta Dam in northern California.*

Given the number of users who rely on reserves of water from Folsom, Trinity, Oroville, and Shasta lakes, reservoir managers have to delicately balance the risks posed by releasing too much water versus the risks of releasing too little. The INFORM demonstration at Folsom Lake, which was proof of the concept for the $2-million INFORM project, showed that leveraging even small forecasting skill for the operations can make a big difference.

"Managers have to make decisions at the margins of the huge capacities of these reservoirs," said Konstantine Georgakakos, HRC director and a Scripps adjunct professor. "Because the cost of extreme events to reservoir management is so disproportionately large, even that slight edge is worth it."

The key to successful reservoir management is maintaining enough water to get a thirsty state through the summer but not so much that a swollen feeder river overwhelms the dam and causes devastating flooding in the spring. Along the way, that reservoir is expected to generate power as well as sustain wetlands and wildlife. Decisions about releasing water are considered months in advance. The consequences of a poor decision could play out in slow motion for the better part of a year or on one catastrophic day.

Dam operators usually rely on a few decades' worth of sometimes sketchy precipitation and riverflow records to try to predict future water needs. The INFORM feasibility studies using approximate reservoir management scenarios showed that science-based climate and hydrologic forecasts can substantially improve benefits. A 40-percent decrease of wasteful spillage was predicted for the Folsom reservoir, with a five-percent increase in energy production and a very significant reduction in flood likelihood.

Throughout a 30-year climatic cycle studded by El Niños and other extreme weather events, the potential water savings represented by INFORM translate to savings of several million dollars to utility operators. In addition, more efficient use of the water would allow for enhanced environmental benefits downstream.

—Robert Monroe