Research Brief

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Identifying and Reducing Climate-Change Vulnerabilities in Water-Management Plans

When agencies draft their water-management plans, they commonly assume that their region's future climate and all its variability will be similar to that experienced over the past several decades. Unfortunately, this planning assumption seems increasingly unlikely to hold in the future. In California, according to scientific information compiled by the University of California, climate change will likely lead to higher temperatures, altered precipitation patterns, and less snow pack to supply state and federal water projects. Climate change may also alter the frequency and severity of extreme events, such as droughts and floods. In addition, western water agencies will continue to face many other difficult planning challenges, such as anticipating future water needs and sustainably managing such local and regional resources as groundwater basins.

This rapidly changing, difficult-to-predict environment poses a major challenge for many water-management agencies.

Abstract

Climate change will affect water supplies in California, but few water-management agencies in the state have formally included climate change in their water-management plans. RAND researchers have worked with Southern California's Inland Empire Utilities Agency to help it identify vulnerabilities related to climate change in its long-term water plans and to evaluate its most effective options for managing those risks. This analysis has proved very helpful to IEUA and can easily be adapted to address the challenges that other water-management agencies face.

New Approach to Climate-Change Vulnerability Assessment and Options Analysis

The RAND Corporation is working with California water agencies to help them better manage this new and challenging planning environment. Building on RAND's long experience in strategic planning and climate change, as well as on the latest advances in uncertainty management, RAND researchers have deployed new decision-support methods that can help water agencies identify near- and long-term actions that can perform well over a wide range of plausible future conditions.

These methods integrate four key components:

- **Simulation models** that represent the water flows in an agency's service area, the implementation and effectiveness of the agency's plan, and consideration of myriad planning uncertainties, including trends in water-demand factors, response of local and regional resources (including groundwater basins) to changes in climate, consumer response to conservation and other water-management programs, and the reliability of external supplies
- **State-of-the-art, regional climate-change projections** that provide weather sequences for the service area reflective of trends and patterns from the latest global and regional climate models
- **Statistical vulnerability assessments** that examine an agency's plan performance over multiple scenarios and then identify those combinations of assumptions most likely to cause the plan to miss its performance goals
- **Options analyses** that evaluate alternative actions to make an agency's plans more resilient to the most challenging scenarios—in particular, identifying alternatives that the agency ought to implement over time in response to new information.

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These tools employ a robust decisionmaking (RDM) approach for planning under conditions of deep uncertainty, which allows planners to assess their plans over many scenarios, identify vulnerabilities, and evaluate the most effective means to address those vulnerabilities. RAND researchers have deployed RDM in a variety of public-policy analysis settings, ranging from education policy to terrorism-risk insurance.

Work with the Inland Empire Utilities Agency: Invest Now or Later?

In one application that was part of a multiyear research project sponsored by the National Science Foundation, RAND researchers have used these RDM methods to help Southern California's Inland Empire Utilities Agency (IEUA) consider and respond to the effects of climate change on its long-range urban water-management plan (UWMP).

To accommodate rapid population growth in the coming decades, IEUA's *2005 Regional Urban Water Management Plan* aims to increase its local supplies through an expanded groundwater-replenishment program and a significant increase in the use of recycled urban wastewater. IEUA's plan envisions increasing groundwater use by 75 percent and reusing about 70,000 acre-feet of recycled water (a more than six-fold increase) by 2025. As of 2005, IEUA received slightly more than half its supply from its local groundwater basin, a third from imports, and only about 1 percent from recycling. While the agency is confident that its plans would perform well under historical climate conditions, it had not yet considered its potential vulnerabilities from future climate change.

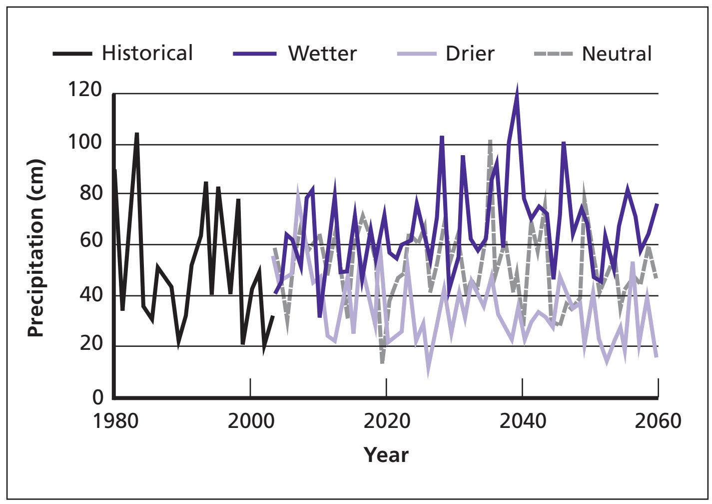
RAND researchers helped IEUA identify these vulnerabilities and assess options for reducing them. In particular, they helped the agency consider what actions it should take now and which it could defer until later.

To address these questions with the RDM approach, the research team first customized the Water Evaluation and Planning (WEAP) system for the IEUA region. Developed by the Stockholm Environment Institute, WEAP is a water-balance simulation tool that can be used to evaluate the performance of an agency's water-management plans under a wide range of planning assumptions. For instance, for IEUA, the team considered plausible weather conditions and other planning assumptions, such as the timing for achieving resource-development milestones (e.g., extent of a wastewater-recycling or groundwater-replenishment program), groundwater hydrology (such as rates of percolation), water intensity of future urban development, the effects of climate change on imported water supplies, and the future costs of specific supplies and water-use efficiency programs.

The team worked with the National Center for Atmospheric Research (NCAR) to develop weather data for use in the WEAP model that reflect state-of-the-art climate projections for the IEUA region. NCAR colleagues first created probabilistic regional projections for the U.S. Southwest by combining the climate projections from 21 atmosphere-ocean general-circulation models, which suggested that the region's average summer temperature is virtually certain to rise by 2030, increasing by between 0.1 and 2 degrees C, and that winter precipitation could rise by roughly 10 percent but is more likely to fall by up to 20 percent. NCAR colleagues next used sophisticated statistical techniques to develop hundreds of time sequences of future monthly weather parameters for the IEUA region consistent with this range of future temperature and precipitation trends. These data enabled the RAND researchers to consider many uncertain possibilities about climate-change effects over the region.

Figure 1 shows examples of three such time sequences, one reflecting a future climate that is wetter than that of previous decades, one that is drier than that of previous decades, and one that is neutral. For contrast, historical values from 1980 to 2003 are shown in black.

Figure 1
How Precipitation Trends Play Out for the IEUA Region

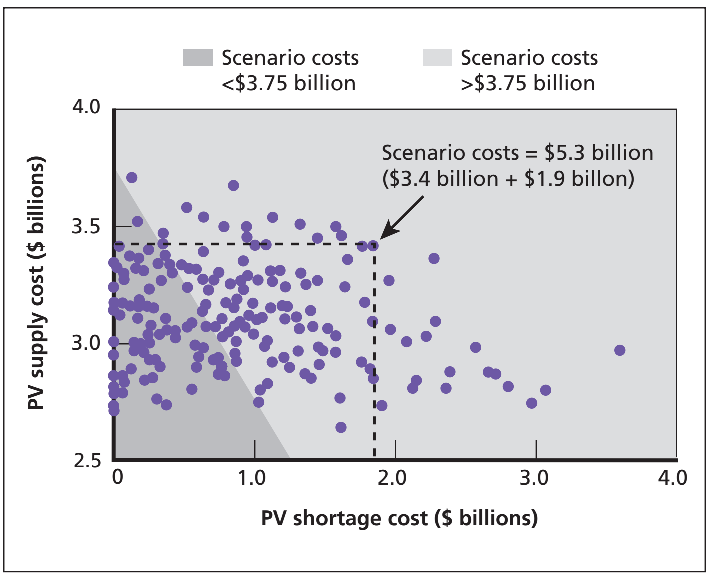


As expected, these climate projections and the WEAP simulations confirm that IEUA's plan performs well if the region's climate remains unchanged or grows wetter but that it can suffer significant shortages if the drier-climate projections come to pass.

To better understand IEUA's vulnerabilities and response options, the RAND team next used the WEAP model to evaluate hundreds of scenarios that explore assumptions about future climate change, resource-development milestones, groundwater hydrology, urban development, program costs, and future import costs. It used statistical methods to ensure that the scenarios efficiently sampled the plausible combinations of these assumptions. It then evaluated the scenarios using a variety of measures, including the cost of supplying water to the agency's end users under different combinations of response options, plus the costs of incurring any shortages through the simulated time horizon (2040). Shortage costs were estimated as the likely cost of purchasing additional imported water during drought years, about 2.5 times as high as current import costs.

Figure 2 shows the present-value (PV) costs of 200 scenarios that IEUA faces if it follows its current plan for the next 35 years (UWMP forever). (For this analysis, we evaluated only scenarios in which precipitation declines.) Each dot indicates the cost of supplying water in a scenario and the cost of any shortages; total costs are the combination of both costs for the scenario, as shown by the example marked by the dotted line. The dots in the darker shaded area show total 35-year costs under $3.75 billion, a sum that is within 20 percent of the cost expected under UWMP forever if all the agency's planning assumptions remain valid. Scenarios in the lighter shaded area would impose costs on IEUA above this threshold, an amount considered unacceptably high.

Figure 2
How UWMP Forever Plays Out Across 200 Scenarios



What combinations of uncertain factors are most important in generating these high-cost scenarios? Statistical "scenario-discovery" analysis of the 200 cases shown in Figure 2 indicates that three future conditions must hold simultaneously for UWMP forever to be likely to lead to large costs for IEUA: (1) large precipitation declines, (2) large climate-change effects on imports, and (3) small or large reductions in natural percolation into the Chino groundwater basin.

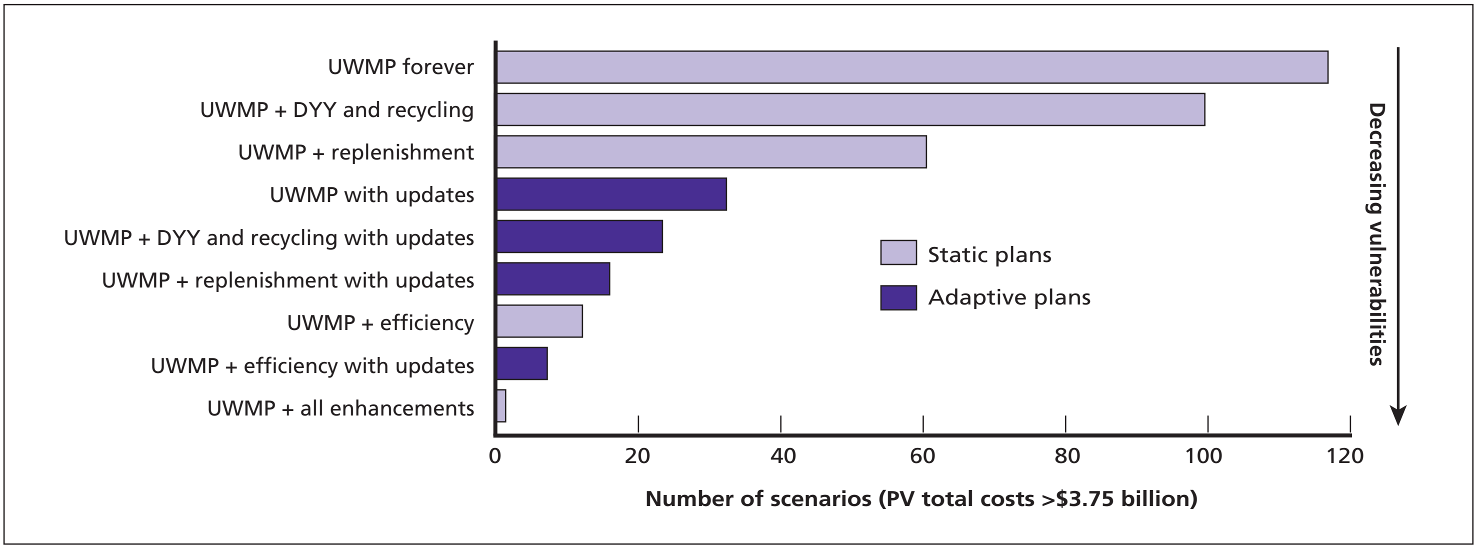
How can IEUA mitigate these vulnerabilities? In particular, what actions should it take now, and which can it defer until later? IEUA identified several options for enhancing UWMP forever, including expanding its dry-year yield (DYY) program with Metropolitan Water District of Southern California, meeting recycling goals sooner, gaining approval to increase groundwater replenishment with more recycled water, capturing more storm water to replenish groundwater, and meeting increased water-efficiency goals.

The RAND team used the WEAP model to evaluate four "static" modifications to UWMP forever that each augment the plan with some combination of these actions now and make no further modifications to the plan through 2040. It also evaluated four "adaptive" strategies that implement the plan and some additional actions now, monitor IEUA's supply reserves (the difference between potentially available supply and demand), and then take additional actions (specifically, implementing more efficiency and capturing more storm water for groundwater replenishment) in the future if the average five-year supply reserve level drops below a specified threshold.

Figure 3 shows the number of scenarios in which each of the nine plans would impose costs greater than $3.75 billion on IEUA. Consistent with Figure 2, UWMP forever generates this undesirable outcome in nearly 120 of the 200 cases in which precipitation declines. If IEUA were to implement all the considered enhancements now—expanded DYY program, increased replenishment with storm water, faster implementation of the recycling program, and increased urban water-use efficiency (the UWMP + all enhancements plan in Figure 3)—it eliminates almost all the vulnerability, as shown in the figure. However, just allowing UWMP forever to update—that is, add actions in response to observed declines in the five-year average surplus—reduces the number of vulnerable scenarios from about 120 to 30 (the UWMP with updates plan in Figure 3). A mixture of current actions and updates reduces the number of vulnerable scenarios even further.

Figure 3 suggests that IEUA has a range of options for reducing its future vulnerabilities, depending on the degree to which it wishes to mitigate the risk. Each of these options improves IEUA's ability to accommodate climate change and other planning uncertainties in different ways. Expanding the DYY program, for example, reduces the extent and frequency of shortages during temporary drought periods, but it does not help under conditions in which precipitation systematically declines. Replenishing groundwater by allowing more recycled water and capturing storm water increases supplies under most climate conditions. In general, implementing these improvements sooner reduces the region's vulnerability to the more adverse changes in future climatic conditions.

Figure 3
Options Anaysis for IEUA

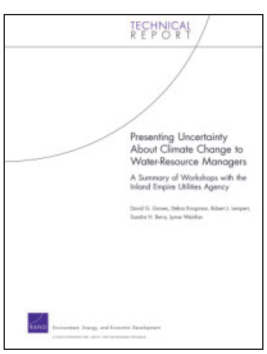


IEUA estimates that many local resource development options (including increasing efficiency) will be cheaper in the future than acquiring imported supplies; thus, implementing local resource options not only reduces the severity and costs of shortages but also reduces costs of meeting the region's water needs. As a result, the agency is in a fortuitous position: Taking more aggressive near-term actions not only reduces climate vulnerability but also lowers its near-term financial costs and vulnerability to other supply disruptions. While Figure 3 suggests that the most aggressive near-term options will most reduce future vulnerabilities, IEUA managers may find that such aggressive early action imposes less quantifiable burdens, such as excessive staff time and political capital with the community. The information summarized in Figure 3 helps IEUA balance these opportunities and costs.

Implications

IEUA has already begun to use the results described here to better understand and counter its future climate risks. In particular, it has used these results to highlight the benefits of the actions laid out in its current plan to stakeholders and partner agencies and to articulate the reasons for implementing the more aggressive actions evaluated in this project.

Like those at IEUA, water managers across the United States and beyond face a new, rapidly changing, difficult-to-predict environment. Traditional planning assumptions, such as assuming future climate to be similar to that of the past, will likely prove inadequate. RAND's approach provides a powerful set of tools that can help water agencies identify, evaluate, and communicate their climate-change and other vulnerabilities and the best means for reducing them. ■



This research brief describes work done for RAND Infrastructure, Safety, and Environment and documented in *Presenting Uncertainty About Climate Change to Water-Resource Managers: A Summary of Workshops with the Inland Empire Utilities Agency*, by David G. Groves, Debra Knopman, Robert J. Lempert, Sandra H. Berry, and Lynne Wainfan, TR-505-NSF, 2008, 100 pp., $20, ISBN: 978-0-8330-4398-6 (available at http://www.rand.org/pubs/technical_reports/TR505/); and *Preparing for an Uncertain Future Climate in the Inland Empire: Identifying Robust Water-Management Strategies*, by David G. Groves, Robert J. Lempert, Debra Knopman, and Sandra H. Berry, DB-550-NSF (available at http://www.rand.org/pubs/documented_briefings/DB550/), 2008, 118 pp., $36, ISBN: 978-0-8330-4405-1. The RAND Corporation is a nonprofit research organization providing objective analysis and effective solutions that address the challenges facing the public and private sectors around the world. RAND's publications do not necessarily reflect the opinions of its research clients and sponsors. **RAND**® is a registered trademark.

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