PACIFIC INSTITUTE

CALIFORNIA WATER 2030:
AN EFFICIENT FUTURE

A Report of the Pacific Institute, Oakland

Peter H. Gleick, Heather Cooley, David Groves

SEPTEMBER 2005

ACKNOWLEDGEMENTS

In many ways, this report is a continuation of work the Pacific Institute has been pursuing for more than a decade. In 1995, the Institute published a vision of sustainable water use in California, entitled “California Water 2020.” This report received an enormous amount of attention for proposing that there were affordable, attainable solutions to the state’s perennial water disputes and challenges; in a lead editorial, the San Francisco Chronicle called it “a common sense plan” for the future. Yet traditional water planners are reluctant to explore alternative visions of the future. The most recent draft California Water Plan is a case in point—several scenarios were developed for the year 2030, yet none of them tried to evaluate what a truly water-efficient future could look like, instead pushing that analysis off to 2010. We believe such a future is possible, and even desirable. And we believe that thinking about what an efficient future might look like, and how to get there, are worthy and urgent goals.

Funding for this study has come from a variety of sources that believe the Pacific Institute should have the freedom to explore unusual water paths and that solutions to water problems are possible. We thank them, especially the Flora Family Foundation, the Charles Evan Hughes Memorial Fund, and the William and Flora Hewlett Foundation. Their generosity and foresight have given us the flexibility to respond when and where we think it most important and necessary.

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All errors are, of course, our own.

ABOUT THE PACIFIC INSTITUTE

The Pacific Institute is dedicated to protecting our natural world, encouraging sustainable development, and improving global security. Founded in 1987 and based in Oakland, California, we provide independent research and policy analysis on issues at the intersection of development, environment, and security. Our aim is to find real-world solutions to problems like water shortages, habitat destruction, global warming, and conflicts over resources. We conduct research, publish reports, recommend solutions, and work with decision makers, advocacy groups, and the public to change policy. More information about the Institute, staff, directors, funders, and programs can be found at www.pacinst.org and www.worldwater.org.

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EXECUTIVE SUMMARY

WHAT COULD CALIFORNIA'S WATER situation look like in the year 2030—twenty-five years from now? The answer is, almost anything: from shortage and political conflict to sufficiency and cooperation. California water planners regularly prepare projections of supply and demand as part of the California Water Plan process, but these projections have never included a vision of a truly water-efficient future, where California's environmental, economic, and social water needs are met with smart technology, strong management, and appropriate rates and incentives. A water-efficient future is possible; indeed, it is preferable. We present a "High Efficiency" scenario here in which Californians maximize our ability to do the things we want, while minimizing the amount of water required to satisfy those desires.

Under a High Efficiency scenario, total human use of water in California could decline by as much as 20 percent while still satisfying a growing population, maintaining a healthy agricultural sector, and supporting a vibrant economy. Some of the water saved could be rededicated to agricultural production elsewhere in the state; support new urban and industrial activities and jobs; and restore California's stressed rivers, groundwater aquifers, and wetlands.

This High Efficiency scenario is not a *prediction* for the future, but a desirable and achievable *possibility*—a vision of California in which improvements in water-use efficiency are considered the primary tools for reducing human pressures on the state's precious water resources. Can such an efficient water future be achieved? Yes, given appropriate attention and effort, California's water-use practices can be substantially modified over the next quarter century, just as they have over the past 25 years. Will such a future be achieved? That is a question that only the public and our elected officials can answer. We hope this analysis will contribute to the dialogue on how to design and implement appropriate strategies for moving along this more efficient path.

Water use in 2030 could be 20 percent below 2000 levels —even with a growing population.

Highlights

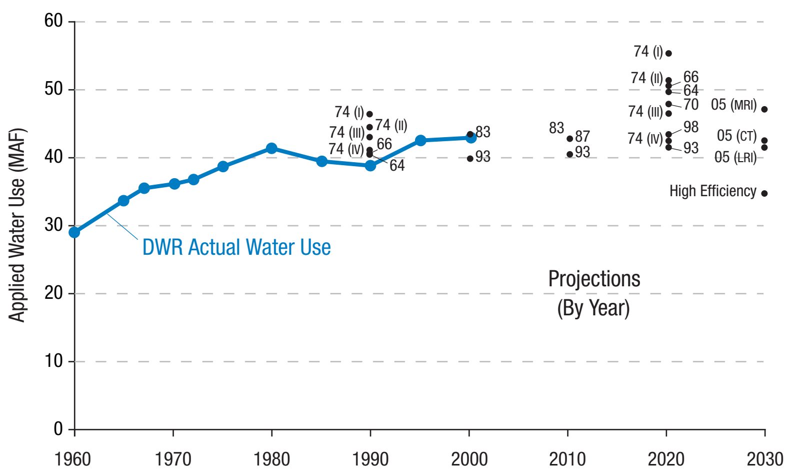
- A water-efficient future for California is possible.
- The Pacific Institute High Efficiency scenario shows that water use in 2030 could be 20 percent below 2000 levels, even with a growing population and a healthy economy.
- A water-efficient future is achievable, with no new inventions or serious hardships.
- Implementing serious efficiency improvements requires actions on the part of legislators, water managers, water districts and agencies, farmers, corporations, and all individuals.
- The sooner such actions are taken, the easier the transition to an efficient future will be.

Water Scenarios

The State of California has routinely prepared water scenarios and projections as part of long-term water planning. The principal tool for water planning at the state level is the California Water Plan, a regular analysis published by the California Department of Water Resources (DWR).[1] The newest version of the Plan was released for public review in May 2005. Figure ES-1 shows projections of future human water demands from the California Water Plans over the past four decades, together with an estimate of actual water use. As this figure shows, official scenarios routinely project substantial increases in water use over time, often far in excess of the use that actually materializes.

Figure ES-1
Projections of Total Water Demands in California

Each Water Plan Update makes one or more projections of future demand. The number next to each projection refers to the year in which the projection was made. The 1974 Water Plan Update evaluated four scenarios for future demand, represented by Roman numerals I-IV. The 2005 Water Plan Update evaluates three scenarios of future demand: Current Trends (CT), More Resource Intensive (MRI), and Less Resource Intensive (LRI).



1 The California Water Plan is also known as Bulletin 160.

The 2005 Draft California Water Plan introduced a long-term effort to develop multiple scenarios of water supply and demand. To initiate this effort, the 2005 Water Plan staff and Public Advisory Committee developed three scenarios of future water demand in California. The three scenarios developed for the 2005 version provide estimates of the quantity of water that would be used in 2030 under specified demographic, economic, agricultural, and water management conditions. Figure ES-2 and ES-3 show urban and agricultural water use for the three DWR scenarios for 2030, compared to current (year 2000) levels. The Department of Water Resources describes these scenarios as follows:

Current Trends. Water demand based on "current trends with no big surprises."

Less Resource Intensive. "California is more efficient in 2030 water use than today while growing its economy within much more environmentally protective policies."

More Resource Intensive. "California is highly productive in its economic sector. Its environment, while still important, is not the state's first priority for water management decisions. Water use in this scenario is less efficient in 2030 than it is in [the other] scenarios …" (DWR 2005).

A close analysis reveals that these scenarios are not radical, or even dramatic, departures from past analyses. All three DWR scenarios include only modest efficiency improvements achievable with current policies and programs. DWR has stated their intention to evaluate various "response packages," including greater water-use efficiency efforts, for the 2010 California Water Plan. We support that effort, but believe it is critical to begin evaluating, and implementing, stronger water-conservation and efficiency programs now. Waiting another five to ten years will make solving California's complex water challenges more difficult and expensive.

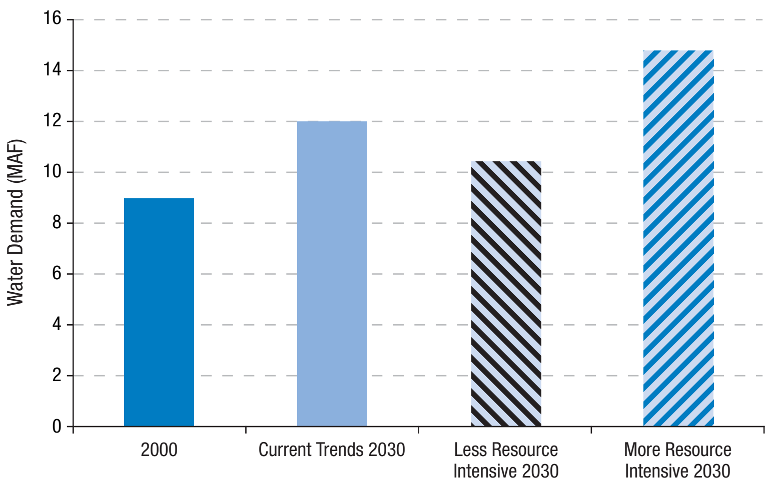
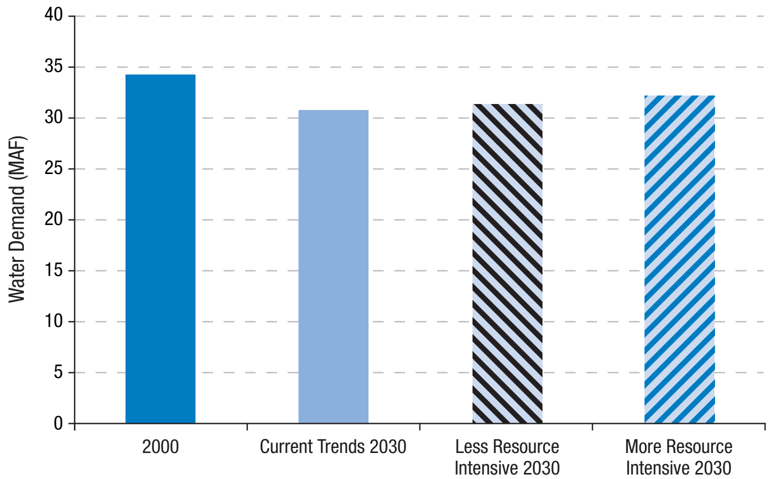


Figure ES-2
Urban Water Demand from DWR's Estimate for 2000 and for 2030 as Projected in the Three DWR Scenarios

Figure ES-3
Agricultural Water Demand from DWR's Estimate for 2000 and for 2030 as Projected in the Three DWR Scenarios



Even the most efficient DWR scenario shows increases in urban water use by 2030 of nearly 1.5 million acre-feet (MAF), and the most inefficient scenario projects urban demand to increase by a huge, and most likely unattainable, 5.8 MAF. All three scenarios project slight (5 to 10 percent) decreases in agricultural water use over the next 30 years, similar to the agricultural forecasts of the last three official California Water Plans.

We believe it is possible to foresee—and move toward—a different future. We envision a future in which California water use is highly efficient, permitting us to maintain a healthy economy and healthy ecosystems while reducing overall water use. In an attempt to describe this future, we present here an alternative, High Efficiency scenario.

Highlights of the Pacific Institute High Efficiency Scenario

A water-efficient future for California is possible.

According to our High Efficiency scenario, there is great potential for improving agricultural and urban water-use efficiency. The scenario was produced with the same model used by DWR to generate their three future demand scenarios for the 2005 California Water Plan. Our scenario adopted the same projections of population, housing distribution, agricultural land area, crop type and distribution, and income projections used by DWR. For the Pacific Institute High Efficiency scenario, we modified the assumptions about the potential for improving efficiency of water use based on more comprehensive implementation of existing technology and application of historical trends for water prices. Our analysis suggests that a water-efficient future is possible.

The Pacific Institute High Efficiency scenario shows that water use in 2030 could be 20 percent below 2000 levels, even with a growing population and a healthy economy.

The Pacific Institute High Efficiency scenario is based on widespread adoption of existing water-efficiency technologies, not on the invention of new efficiency options, and on different estimates of water prices and trends. Figures ES-4 and ES-5 show total human water demands generated by the DWR Current Trends and Pacific Institute High Efficiency scenarios between 2000 and 2030, along with estimated actual water use during the latter half of the 20th century. Overall statewide agricultural and urban water demand is projected to decline in both scenarios, but in the Pacific Institute High Efficiency scenario total human use of water declines by 8.5 MAF—a reduction of around 20 percent from 2000.

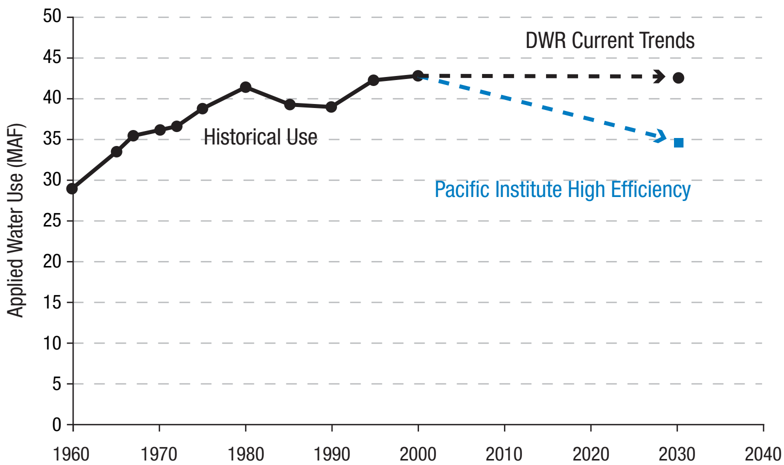


Figure ES-4
Statewide Trend in Total Urban and Agricultural Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios

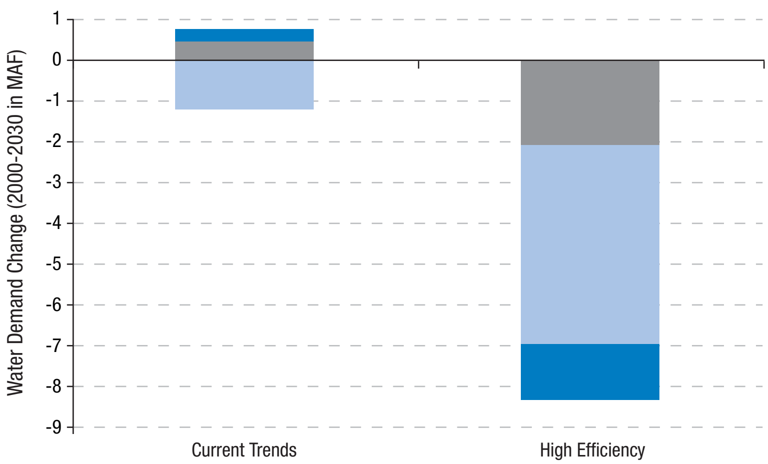


Figure ES-5
Urban and Agricultural Water Demand Change (2000-2030) by Geographic Region in the Current Trends and High Efficiency Scenarios

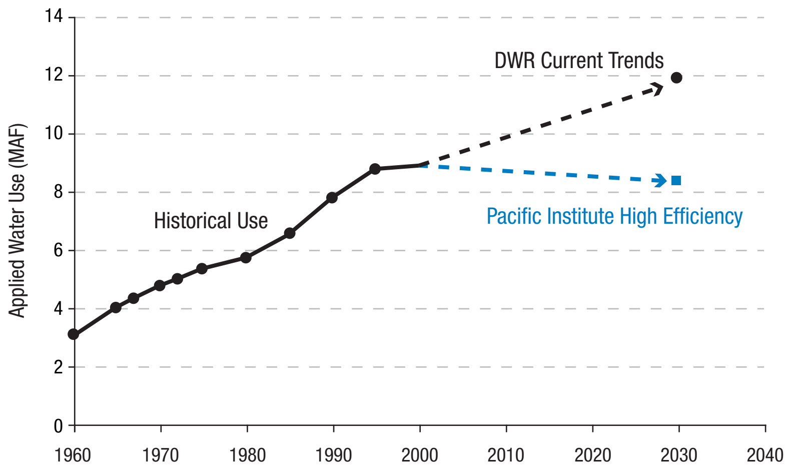
North
Central
South

A water-efficient future is achievable, with no new inventions or serious hardships.

Urban water use in the Pacific Institute High Efficiency scenario falls 0.5 MAF per year below actual 2000 levels and far below the 2030 Current Trends scenario of DWR. Demand for water in California's urban sector between 2000 and 2030 is projected to increase by 3.0 MAF in the Current Trends scenario and decrease by 0.5 MAF in the Pacific Institute High Efficiency scenario (see Figure ES-6), a difference in urban water use of over 3.5 MAF annually.

Total agricultural water use declines more than 20 percent from actual year 2000 water use in the Pacific Institute High Efficiency scenario as farmers move to more efficient irrigation methods, without reducing crop area or changing crop type from the official state Current Trends scenario. Figure ES-7 shows actual and projected agricultural water demand between 1960 and 2030 for the Current Trends and High Efficiency scenarios. Agricultural water demand is projected to decline from 2000 by ten percent (3.5 MAF) and 23 percent (8 MAF) in these two scenarios, respectively, while overall crop production remains relatively unchanged. The difference between the scenarios—approximately 4.5 MAF in water savings—is due to assumptions about irrigation technology and agricultural water prices. Even though total water use is projected to drop substantially in our scenario, total income to farmers remains effectively unchanged and total value per acre in the High Efficiency scenario slightly increases.

Figure ES-6
Statewide Trend in Urban Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios



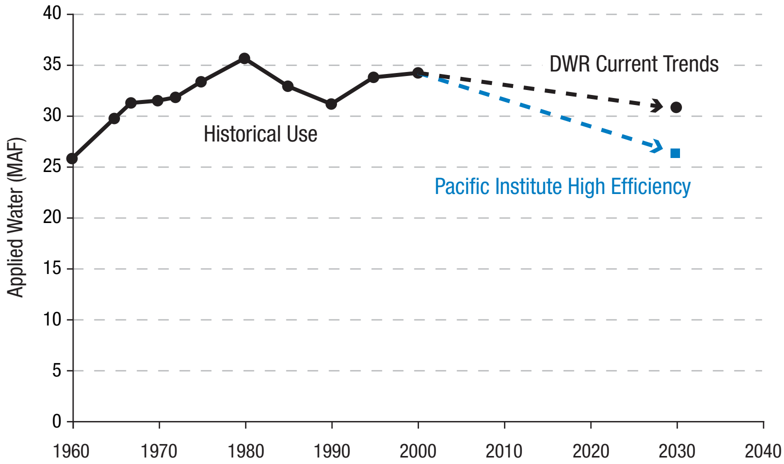


Figure ES-7
Statewide Trend in Agricultural Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios

Reaching the Pacific Institute High Efficiency future is possible, but will require serious effort on the part of California policy makers, water managers, and the public.

We believe that this efficient future is achievable, with no new inventions or serious hardships. Indeed, we believe this future is likely to be better for all Californians and the environment. But implementing serious efficiency improvements requires actions on the part of legislators, water managers, water districts and agencies, farmers, corporations, and all individuals.

The sooner such actions are taken, the easier the transition to an efficient future will be.

Delaying action on water-conservation and efficiency increases the pressure to find, build, or buy new expensive and environmentally damaging sources of water supply. In California, and much of the rest of the western United States, such sources of supply are increasingly scarce or controversial. While we do not believe a highly efficient future is necessarily easy to achieve, we think it will be easier, faster, and cheaper than any other option facing us.

Actions to Be Taken Now

Pricing policies that subsidize the inefficient use of water should be eliminated.

- Ensure that urban and agricultural water rates reflect the true cost of service, including non-market costs.
- Phase out water subsidies on the Central Valley Project, especially for low-valued, water-intensive crops.
- Implement new rate structures that encourage efficient use of water.
- Avoid inappropriate subsidies for new water-supply options.

Efforts to promote the use of water-efficient technologies and practices should be greatly expanded, in both the urban and agricultural sectors.

- Set new water-efficiency standards for residential and commercial appliances, including toilets, washing machines, dishwashers, showers, and faucets.
- Offer comprehensive rebates, including both energy and water rebates, for the purchase of water-efficient appliances.
- Require water-efficient appliances to be "retrofit on resale" for existing homes.
- Revise and expand "Best Management Practices" for urban and agricultural water agencies.
- Make "Best Management Practices" mandatory and enforceable.
- Expand development and deployment of efficient irrigation technologies and new crop types.

Legislative, regulatory, and administrative support should be given to those water transfers that improve water-use efficiency, while promoting the overall well-being of rural communities.

- Implement programs to permit water saved through efficiency improvements to be transferred and marketed, but reduce adverse impacts on rural communities and the environment from such transfers.
- A statewide system of water data monitoring and exchange should be created, especially for water use.
- Collect and make publicly available comprehensive water-use data for all users.
- Design and implement comprehensive local groundwater monitoring and management programs statewide.

Educational programs on water use, and on the potential for water-use efficiency, should be expanded.

- Label all appliances with efficiency ratings.
- Expand water-efficiency information and evaluation programs in the Agricultural Extension Services and other agricultural outreach efforts.
- Develop on-line data collection and dissemination networks to provide farmers with immediate meteorological and hydrological information on climate, soil conditions, and crop water needs.

Better combined land and water planning is needed.

- Demonstrate a secure, permanent supply of water before new urban and suburban developments are approved.
- Demonstrate water-efficient housing designs before developments are approved.
- Protect high-quality agricultural land and related watersheds from urbanization.

Conclusions

The two scenarios described here—the DWR Current Trends and the Pacific Institute High Efficiency scenarios—offer different views of urban and agricultural water use in 2030. They are the result of making different assumptions about a range of water efficiency options, policies, technologies, and decisions. Neither scenario is a prediction. How much water will be needed and used to meet urban and agricultural demands in 2030 is unknowable and uncertain, because it depends on a vast array of factors. Some of these factors are partly or completely out of the hands of Californians, such as decisions about crop production in other countries, the extent and severity of climate changes, technological developments, national policies around efficiency standards or pricing of water from federal projects, and so on.

Other factors, however, are well within our ability to influence, and some of these factors will have a huge effect on future water demands. We believe a water-efficient future is possible; indeed we believe such a future is preferable. Ultimately, which future we reach depends upon what water policies are implemented over the coming years. Experience has shown that efforts to improve water-use efficiency are consistently successful and cost-effective. If California put as much time, money, and effort into water-efficiency programs as has gone into traditional water supply development, a high efficiency future could be readily achieved—with benefits to our economy, environment, and health.

We believe a water-efficient future is possible; indeed we believe such a future is preferable.

Ultimately, which future we reach depends upon what water policies are implemented over the coming years.

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"The fact that a large portion of the whole quantity of water in most public supplies is wasted, or lost, without the knowledge of the Water Authorities or the consumers, is as incontrovertible as it appears to be difficult to conceive."

—William Hope, 1891

Introduction

WHAT COULD CALIFORNIA'S WATER situation look like in the year 2030—twenty-five years from now? The answer is, almost anything: from shortage and political conflict to sufficiency and cooperation. We present here a vision of a water-efficient future, where California's environmental, economic, and social water needs are met with smart technology, strong management, and appropriate rates and incentives. While many scenarios of water use in California have been developed over the last 40 years, including three new ones for the latest California Water Plan, no official scenarios have made an effort to look at the true potential for improving water-use efficiency and conservation. In the Pacific Institute "High Efficiency" scenario, we maximize our ability to do the things we want, while minimizing the amount of water required to satisfy those desires.

Can a water-efficient future be achieved?

Yes.

Our crystal ball is, of course, no clearer than anyone else's. Our intention is not to *predict* the future, but to offer a desirable and achievable *possibility*—a vision of California in which improvements in water-use

> "Scenarios serve as stimulants for our imagination. They help us to conceive of new possibilities, to explore wildly different alternatives, and to integrate many different factors into our thinking about the future" (Hammond 1998).

efficiency are considered the primary tools for reducing human pressures on the state's precious water resources.

The scenario presented here is just part of an overall vision for California, and part of a smart path to water, described in previous Institute reports. The changes necessary for achieving more efficient water use in California do not require "heroic" or extraordinary actions on the part of any individual or sector, nor do they require new technologies to be invented. Instead, these changes can come about by applying existing technologies; innovative governmental, industrial, and agricultural policies; an evolution in personal values; and changes in culture—all of which are already common characteristics of California's dynamic society. In addition, we make no projections of future water supply, new projects, or the impacts of climate change on water availability and quality.

Can a water-efficient future be achieved? Yes, given appropriate attention and effort, California's water-use practices can be substantially modified over the next quarter century, just as they have over the past 25 years. Will such a future be achieved? That is a question that only the public and their elected officials can answer. We hope this analysis will contribute to the dialogue on how to move along this alternative path.

Scenarios: What Are They? What Aren't They?

The future is largely unknowable. Nevertheless, humans have always thought about possible futures, explored plausible paths, and tried to identify the advantages and disadvantages associated with different choices. In recent years this has led to a growing interest in scenarios, forecasting, and "future" studies (see, for example, Schwartz 1991). Scenario planning has more than academic implications. In the water sector, expectations about future water demands and supplies drive huge financial expenditures for water-supply projects. These projects, in turn, have significant human and ecological impacts. At the same time, failing to make necessary investments can lead to the failure to meet fundamental human water needs. The challenge facing water planners is to balance the risks and benefits of these kinds of efforts.

Analysts and decision makers often construct scenarios to better understand the consequences of choices or policies on a wide range of plausible future conditions. This is particularly useful when there are great uncertainties about how the future may evolve, or when the stakes are especially high. Sometimes scenarios explore outcomes that are unlikely or incongruent with current decisions and policies. Sometimes these scenarios are purely descriptive and are designed to study outcomes that had not previously been considered. Sometimes the scenarios are quantitative and represent discrete outcomes drawn from a range of possible futures.

Recognizing that a single forecast of resource demands is unlikely to characterize the actual future demand, decision makers often evaluate a wide range of alternatives. Collectively, a set of scenarios provides a

2 Of special interest may be the Institute reports: California Water 2020: A Sustainable Vision and Waste Not, Want Not: The Potential for Urban Water Conservation in California. Both are available at www.pacinst.org. See also "Global Freshwater Resources: Soft-Path Solutions for the 21st Century," (P.H. Gleick) Science Vol. 302, 28 November 2003, pp. 1524-1528, and "The Soft Path for Water," (G. Wolff and P. H. Gleick) in The World's Water 2002-2003. Island Press, Washington, D.C.

broad look at how the future may evolve in response to (1) forces largely outside the control of policy makers, and (2) policy choices designed to shape future conditions. Such a "scenario analysis" approach can help resource managers and interested stakeholders better understand the inherent uncertainties about future management and, in turn, help reveal more innovative and successful management strategies for adapting to possible futures. Scenario analysis can also help guide more detailed assessments of particularly interesting cases using complex models.

In any effort to look into the future, it is critical to keep in mind that no matter how thoughtful any scenario analyst is, there will be surprises and unexpected events. Despite this, as Peter Schwartz has noted, we can make pretty good assumptions about how many of them will play out (Schwartz 2003).

Ultimately, the point—and power—of scenarios is not to develop a precise view or prediction of the future. It is to enable us to look at the ***present*** in a new and different way, and to find new possibilities and choices we might have previously overlooked or ignored.

Water Scenarios

Water planners are among the few natural resource managers to think more than a few years into the future. The time required to design and build major water infrastructure, and the subsequently long lifetimes of dams, reservoirs, aqueducts, and pipelines, require planners to take a relatively long view. But what will future water demands be? How can they be predicted, given all the uncertainties involved in looking into the future? At the global level, various projections and estimates of future freshwater demands have been made over the past half century, some extending out as much as 60 or 70 years. At national and regional levels, water projections typically extend two or three decades into the future, using population and economic forecasts as the major drivers.

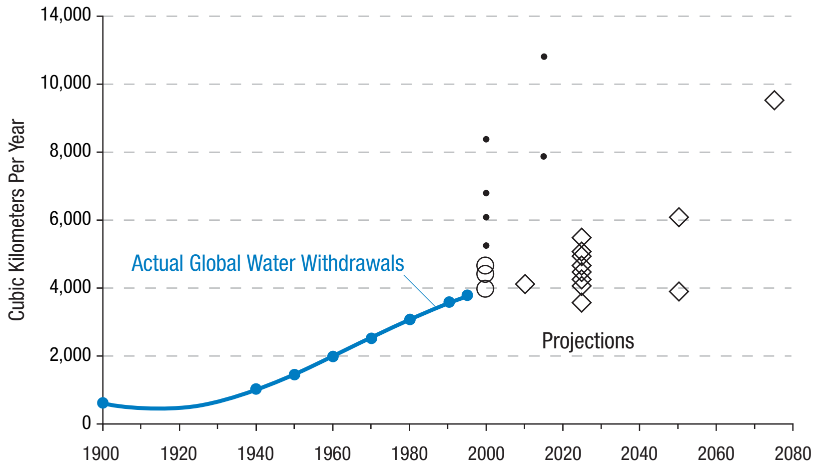
"Public policy must be not only adaptive but also anticipatory" (Davis 1990).

Most of the earliest water projections used variants on the same methodology—future water use was typically based on population projections, simple assumptions of industrial, commercial, and residential water-use intensity (e.g., water per unit population or income), and basic estimates of future crop production as a function of irrigated area and crop yield. Early planning efforts usually produced single, "business-as-usual" projections with no variants. Most estimates of future water demand ignored water requirements for instream ecological needs, navigation, hydropower production, recreation, and so on.

Almost all of these projections show increases—substantial increases—in demands for water over time. And almost invariably, these projections have turned out to be wrong. Figure 1 shows a set of over 25 water projections along with an estimate of actual global water withdrawals. As this figure shows, projections of water demands have routinely been too high.

Figure 1
Scenarios of Global Water Use, and an Estimate of Actual Global Water Withdrawals

- ● Pre-1980
- ○ 1980-1995
- ◇ Post-1995



More recently, large-scale water-use projections have become increasingly sophisticated due to the growing capability of easily accessible computers to handle significant numbers of calculations, the growing availability of water-use data, and better understanding of water management approaches and opportunities. Assessments that used to be done for continental areas or on a national basis are now being done for watersheds on smaller and smaller temporal and spatial scales. New studies have been published describing a wider range of results under a wider range of assumptions. Projections have begun to include information on actual water needs and water-use efficiencies, economic variables, dietary requirements, cropping patterns and types, and ecosystem functions. And as our ability to better evaluate options has grown, forecasts of the size of future demand have often dropped substantially. This is also true of the High Efficiency scenario for California described later in this report.

Forty Years of California Water Scenarios and Projections

The State of California has routinely prepared water projections as part of long-term water planning. The principal tool for water planning at the state level is the California Water Plan, a regular analysis published by the California Department of Water Resources (DWR). The first California Water Plan ("Bulletin 3") was released in 1957 and subsequent versions (now called "Bulletin 160") were produced in 1966, 1970, 1974, 1983, 1987, 1993, and 1998.[3] The latest version is to be released in late 2005, and a draft of this report was released in May 2005 for public comment.

Each volume of Bulletin 160 is slightly different in form, structure, and tone, reflecting the resource, economic, and political conditions of the State at the time of publication. One version of Bulletin 160 (DWR 1974) included multiple scenarios for future water demands, but all the rest of these periodic reports made a single water-demand projection based on variables such as population, per-capita water demand, agricultural production, levels of economic productivity, and so on. The forecast is

3 An interim report was also produced by DWR for internal use in 1964, but this is not considered a formal California Water Plan.

then compared to estimates of available water supplies and used to evaluate the kinds of management systems or infrastructure necessary to meet future demands.

Using fairly constant water-intensity projections (in this case water use per person) coupled with projected increases in population, DWR has routinely assumed that California water problems and policies in the future will be little changed from today. Future farmers are assumed to grow approximately the same kinds of crops on about the same amount of land. The growing urban population will continue existing patterns of water use, with relatively minor changes in some residential water-use technology and efficiency. Water used by aquatic ecosystems will remain the same or decrease as human demands grow. And the projections of total future water demands routinely exceed estimates of available supplies by several million acre-feet annually, a shortfall projected in every California Water Plan since the first.[4] The philosophy of the traditional California Water Plans can be succinctly stated as:

> "Only a substantial commitment to large-scale surface water storage and conveyance facilities would enable the major water supply problems in the State … to be brought under control in the next 30 years" (DWR 1983, pp. 175).

Even a more recently published version, Bulletin 160-98, identifies its purpose as quantifying "the gap between future water demands and the corresponding water supplies" (DWR 1998). The latest version, Bulletin 160-05, however, begins to move beyond this approach and examine California water issues more comprehensively.

Unfortunately, more sophisticated approaches have not been adopted universally. In a report released in July of 2005, the Public Policy Institute of California (PPIC) projected that urban water demand will increase by 40 percent between 2000 and 2030 (Hanak 2005). This report simply assumes that per-capita water use will remain constant between 2000 and 2030, despite recent trends in declining per-capita use. Thus the increase in water use projected in the PPIC report simply reflects the projected increase in population by 2030.

DWR's Urban and Agricultural Water Demand Projections Over Time

Figures 2 and 3 show the projections of future urban and agricultural water demands from the different versions of the Department of Water Resources Bulletin 160. In Figure 2, projections made in 1964 and 1966 for the year 2020 forecast a huge increase in expected urban water use,[5] from around 3 MAF per year in 1960 to over 14 MAF per year in 2020. Forecasts made in 1970 show 2020 urban use increasing to just less than 12 MAF—still a tripling of water use. By the late 1970s and early 1980s, however, actual urban demand for water was beginning to level off, reflecting the first efforts at conservation and efficiency. As the growth in actual demand slowed, new projections for future demand also began to drop. Bulletin 160-74 included projections of future urban demands as low as around 10 MAF by 2020, and Bulletin 160-83 actually included a projection for 2010 of fewer than 8 MAF. In part, this reduction was driven by the severe drought experienced by California in 1976 and

4 One acre-foot is equal to 1,233 cubic meters, or 326,000 gallons.

5 The 1964 version was an unofficial draft and not released to the general public.

1977, which dropped the base of urban use in 1980. The two Bulletin 160s prepared in the 1990s regressed, however, to earlier approaches and higher baselines, with single scenarios showing urban use in 2020 growing to around 12 MAF per year. The lessons of uncertainty, efficiency, and the value of multiple scenarios had been lost.

Figure 2
Projections of Urban Water Demands in California

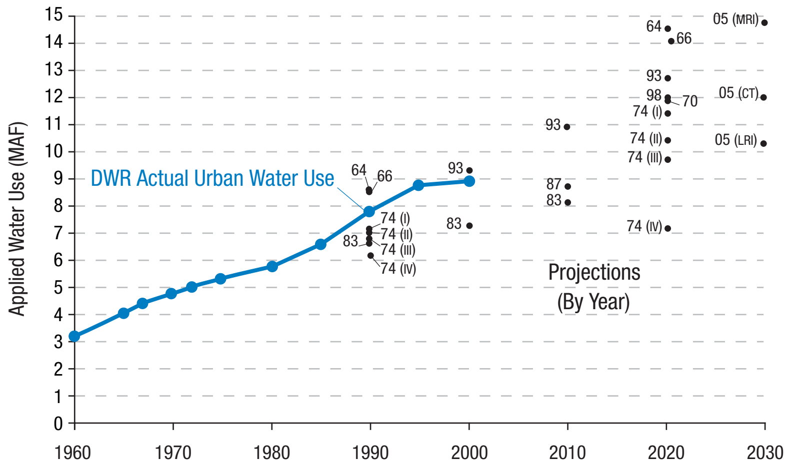
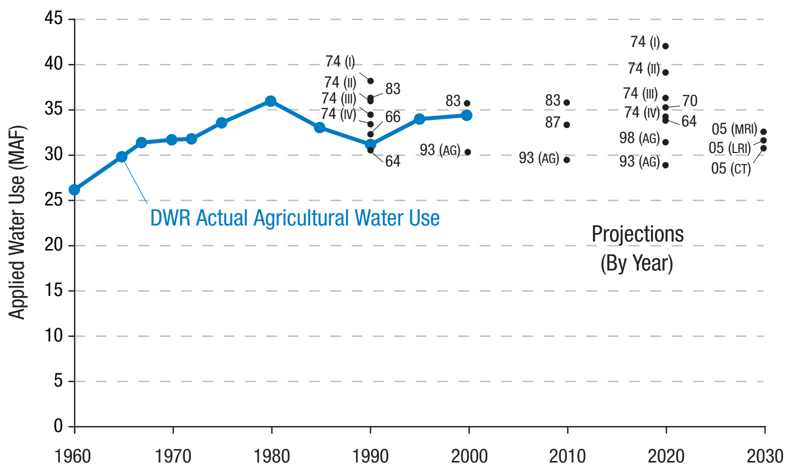


Figure 3
Projections of Agricultural Water Demand in California

Each Water Plan Update makes one or more projections of future demand. The number next to each projection refers to the year in which the projection was made. The 1974 Water Plan Update evaluated four scenarios for future demand, represented by Roman numerals I-IV. The 2005 Water Plan Update evaluates three scenarios of future demand: Current Trends (CT), More Resource Intensive (MRI), and Less Resource Intensive (LRI).



Bulletin 160 agricultural water use scenarios have typically looked a little different from the urban scenarios (Figure 3). In the early 1960s, agricultural water use was growing rapidly, as the State Water Project and federal Central Valley Project infrastructure was being built and increasing the ability to deliver large volumes of water to irrigation and some municipalities. As a result, the earliest Bulletin 160s (the 1964

Sidebar 1: Estimating Actual Water Use in California

One of the many challenges to studying water issues in California is the lack of a consistent, comprehensive, and accurate estimate of actual water use, by sector or region. Different institutions and groups track, record, and report water use in different ways and no single accepted historical record exists. Indeed, not all water uses are actually measured and monitored—thus, reported water use is a combination of measurements of use and estimates of uses not actually measured. For example, some cities still do not require residential water monitoring, especially for multifamily homes. Many agricultural groundwater withdrawals are not monitored or reported.

The Pacific Institute has tracked these different estimates over the past decade, and we conclude—to our dismay—that no single estimate is likely to be either accurate or appropriate. In the long run, we urge (as we have urged for more than a decade) that more and better data be collected. In a state with such contentious and difficult water challenges as California, it is important to account for all uses of the state's resources. This failure affects planning, policy making, and ultimately the state's economic and environmental health.

In Figure S1 we show two separate estimates of urban and agricultural water use from 1960 to 2000. One was prepared by compiling the actual water use numbers from all previous Bulletin 160 reports of the Department of Water Resources. The other data are developed from a periodic series on water use in the United States, by state, prepared by the U.S. Geological Survey (see Data Table 20 in Gleick et al. 2004). Neither is "correct"—neither is "incorrect." Both have limitations and advantages, worthy of far more discussion and analysis than is possible here. Part of the differences, however, result from different categorizations of things like power plant cooling water, self-supplied water, and groundwater use. Part of the differences result from different assumptions about crop distribution and irrigation water applications. Part of the difference is the result of decisions to "normalize" certain water-use statistics to account for changes in behavior during wet or dry years, compared to average years.

We show both here to highlight the need for better estimates of total water use and the uncertainties that exist, even today, on such a critical issue. For most of this report, however, we use the base year estimates from DWR, because they were used in the generation of the Bulletin 160 estimates over time.

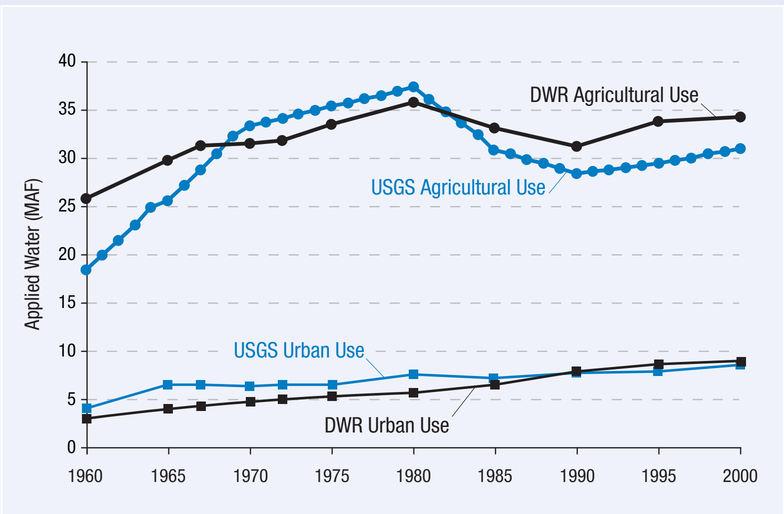


Figure S1
California Water Use Estimates

internal volume, and Bulletin 160-66) showed modest continued increases in agricultural water use through the 1990s. With few exceptions, however, all agricultural water scenarios generated in subsequent plans show a leveling off, and even a decrease, in total agricultural water use to between 30 and 35 MAF per year. One exception to this is the set of water-intensive scenarios produced in Bulletin 160-74, which projected high agricultural water use of over 41 MAF as one possible future. By Bulletin 160-93 and 98, however, projections of agricultural water use in 2020 were settling around 30 MAF per year—effectively equal to the base use in 1990.

Bulletin 160-2005: New Scenarios

After criticisms that Bulletin 160-93 and Bulletin 160-98 were inappropriately ignoring the potential for efficiency and focusing on single projections of the future (see, for example, Gleick et al. 1995), the 2005 Draft California Water Plan introduced a long-term analytic effort to develop multiple scenarios of water supply and demand. To initiate this effort, the 2005 Water Plan staff and Public Advisory Committee developed three scenarios of future water demand in California. These scenarios of water demand are primarily narrative, do not reflect any new water-management strategies (such as new water-efficiency programs), and do not touch upon any water-supply issues.

The three scenarios developed for the 2005 version provide estimates of the quantity of water demanded out to the year 2030 under specified demographic, economic, agricultural, and water management conditions. These scenarios are briefly described as:

> **Current Trends.** Water demand based on "current trends with no big surprises."
>
> **Less Resource Intensive.** "California is more efficient in 2030 water use than today while growing its economy within much more environmentally protective policies."
>
> **More Resource Intensive.** "California is highly productive in its economic sector. Its environment, while still important, is not the state's first priority for water management decisions. Water use in this scenario is less efficient in 2030 than it is in [the other] scenarios ..." (DWR 2005).

Figures 4 and 5 show urban and agricultural water use for the three DWR scenarios for 2030, compared to current (year 2000) levels. Water use in the urban sector is projected to go from 8.9 MAF in 2000 to 10.3, 11.9, and 14.7 MAF for the Less Resource Intensive, Current Trends, and More Resource Intensive scenarios, respectively. Thus, as Figure 4 shows, even the most efficient of DWR's new scenarios shows increases in urban water use by 2030 of nearly 1.5 MAF, and the most inefficient scenario projects urban demand to increase by a huge and, we believe, implausible 5.8 MAF.

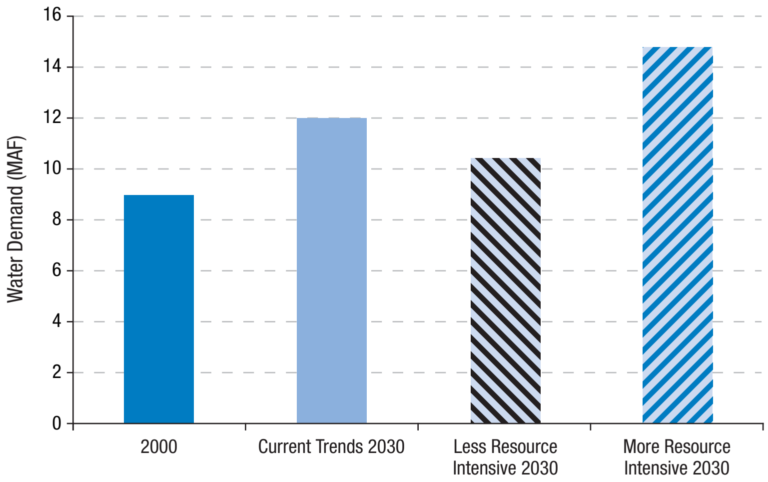


Figure 4
Urban Water Demand from DWR's Estimate for 2000 and for 2030 as Projected in the Three DWR Scenarios

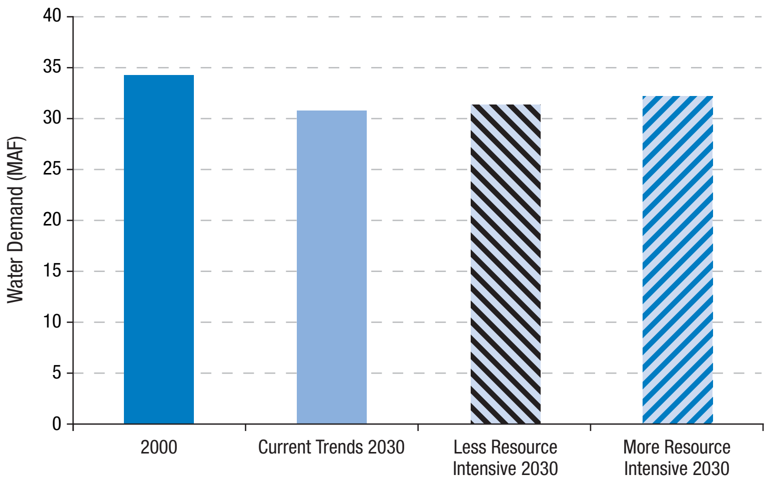


Figure 5
Agricultural Water Demand from DWR's Estimate for 2000 and for 2030 as Projected in the Three DWR Scenarios

The three DWR scenarios project slight decreases in agricultural water use over the next 30 years, similar to the agricultural forecasts of the last three Bulletin 160s. But the projected declines are small—from between a 5 and 10 percent decline. As Figure 5 shows, these three scenarios all cluster together around 32 MAF per year.

Despite the fact that the new California Water Plan offers multiple scenarios for the first time in decades, a closer analysis reveals that the methods used to develop these scenarios are not radical, or even dramatic, departures from past analyses. The Water Plan still relies primarily on demographic and economic forecasts—albeit more sophisticated forecasts—to project future urban demand; agricultural demand is still largely based on estimates of irrigated crop area and the mix of crops grown.

The current Plan intentionally includes only modest urban and agricultural efficiency improvements in its water demand estimates based on a "business as usual" approach of continuing current policies and practices. These estimates are nowhere near the levels already demonstrated to be technically achievable and largely cost-effective today. One purpose of the Pacific Institute High Efficiency scenario is to examine how reasonable levels of water-use efficiency can dramatically reduce future water needs.

In addition to providing multiple scenarios of future demand, the 2005 California Water Plan identifies eight resource-management strategies capable of providing additional supply to meet future needs. Urban and agricultural efficiency provide the largest "supply" benefit and can meet California's water needs in 2030 for two of the three scenarios in the Water Plan. Rather than include this efficiency estimate, DWR chose a much more modest estimate for the three scenarios. As a result, we believe the three DWR scenarios offer a less-than-complete picture of the true alternatives available to California. And while it is possible that one of the DWR scenarios may ultimately be a more accurate forecast of the future, it doesn't have to be.

Sensible levels of water-use efficiency can be enormously effective in moderating demand and reducing the need to identify and provide new supplies.

It is the stated intention of the DWR staff to further develop analytic tools to evaluate several quantitative scenarios of demand and supply and to evaluate how different "response packages" might perform for the 2010 California Water Plan. We support that effort, but believe it is critical to begin evaluating, and implementing, stronger water-conservation and efficiency programs now. Waiting another five to ten years will make solving California's complex water challenges more difficult and expensive.

A New Scenario: High Efficiency

We offer here a fourth scenario—a High Efficiency scenario. We don't claim to know what the future will look like, and this scenario is not a prediction. We can, however, explore, verbally and analytically, different assumptions, circumstances, and constraints for how the future could look. The Pacific Institute High Efficiency scenario projects 2030 water demand by adopting the demographic, economic, and agricultural forecasts used in the DWR's Current Trends scenario and including additional levels of efficiency that have been shown to be achievable and cost-effective using existing technology (Mayer et al. 1999, Gleick et al. 2003). Our High Efficiency scenario is then contrasted and compared with the DWR Current Trends scenario. This comparison reveals that sensible levels of water-use efficiency can be enormously effective in moderating demand and reducing the need to identify and provide new supplies. It provides an alternative vision of the future, one that can be achieved by concentrating on identifying and capturing improvements in the many ways Californians use water. Below, we describe the tool used to produce the scenario, the assumptions and methods, and the results.

Model Background and Assumptions

Software

We used the same model to develop the High Efficiency scenario as used by DWR to generate their three future demand scenarios (Groves et al. 2005). The model estimates urban, agricultural, and environmental water use for each of California's ten hydrologic regions (Figure 6). Urban water demand includes the demand by households, the commercial and industrial sectors, and public institutions. Agricultural water demand includes irrigation use, delivery and conveyance losses, and other uses. Environmental water demand reflects the amount of water that the water management system would allocate to environmental purposes. It does not necessarily reflect all environmental needs. Each scenario is based upon average current conditions that evolve over time according to scenario-specific parameters representing the major factors believed to influence future water demand. Scenarios are distinguished from one another by the specification of a unique set of factors representing various trends and parameters in the model. See Groves et al. (2005) for a thorough description of the model structure.

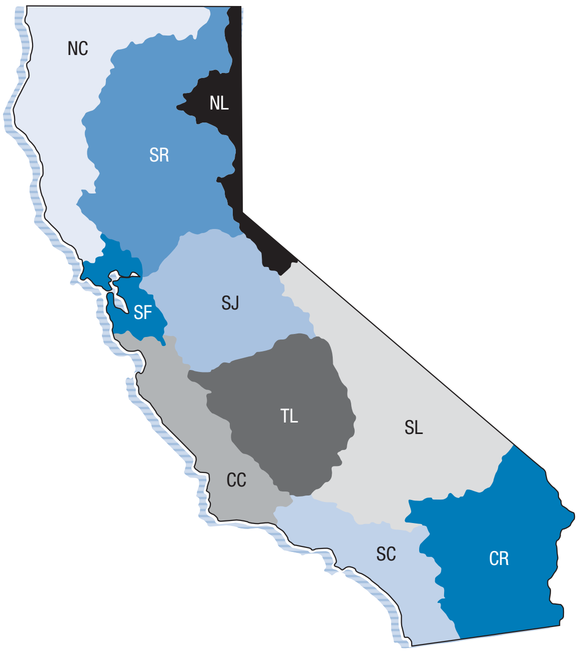


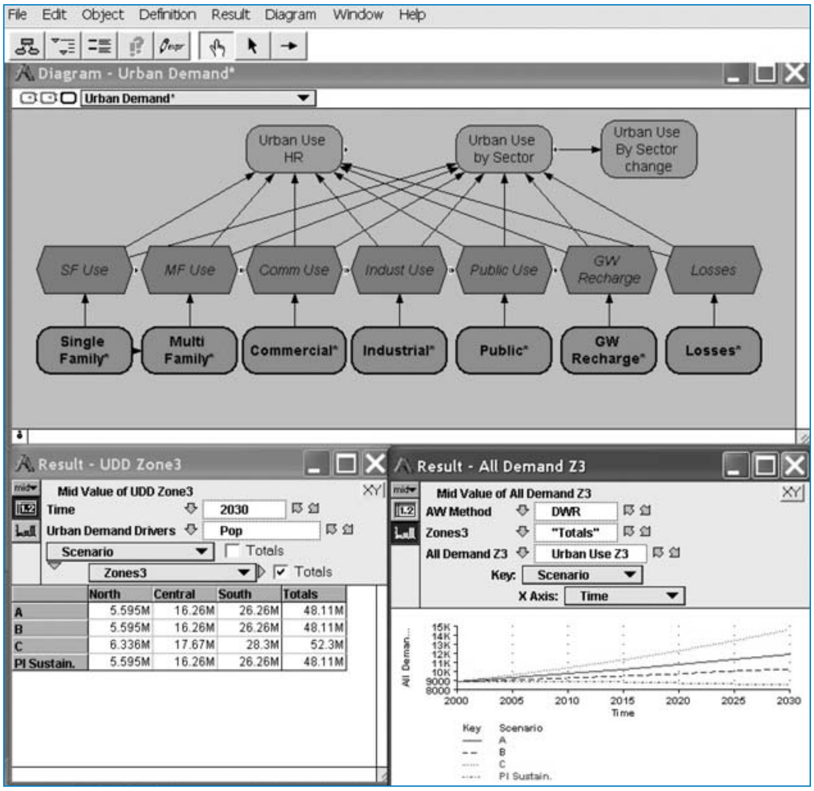
Figure 6
California's Ten Hydrologic Regions

NC: North Coast
NL: North Lahontan
SR: Sacramento River
SF: San Francisco Bay
SJ: San Joaquin River
TL: Tulare Lake
CC: Central Coast
SL: South Lahontan
SC: South Coast
CR: Colorado River

The model was implemented in a graphically based computer environment called Analytica™, available from Lumina Decision Systems (Figure 7). Water demand is estimated using a "top-down" modeling approach, aggregating individual uses of water by end user (e.g., persons in a household, employees of a business, and users of public institutions). This process is well suited for considering how changes in the number of water users and changes in their average water use will affect future demand. Alternative "bottom-up" approaches estimate future water use by multiplying the numbers of water-using devices, such as toilets, by their technical water requirements, or by estimating water-use behaviors and technical characteristics, such as numbers of showers per person per day, shower duration, and showerhead performance. This approach was used recently by Gleick et al. (2003) to assess California's water-conservation potential in the urban sector. It is particularly useful for evaluating the impact of specific technologies or water-use practices and thus can establish both state- or region-wide water-use baselines and efficiency targets.

Figure 7
Screen-Shot of the Graphical Interface of the Water Demand Model

Note: The top pane shows the various components of urban demand. In the lower left is a table showing the 2030 population for the three regions of the state underlying the scenarios. The graph on the right shows the statewide urban demand estimates for the Water Plan scenarios (A-C) as well as the Pacific Institute High Efficiency scenario.



Modeling Urban Water Demand

Urban water demand is modeled using estimates of total population, households (including both single- and multi-family housing), employees, and the per-unit demand for each from the year 2000 to 2030. Future urban water demand is then computed by multiplying these future demand units and their average water use. The paragraphs below and Tables 1 to 3 summarize the parameters used to represent each scenario.

For all of the demographic parameters, we accepted the same assumptions adopted by the DWR for their Current Trends scenario as shown in Table 1. We made no judgments about the likelihood of these population or housing trends; rather our goal was to ensure that the differences between the DWR scenario and our High Efficiency scenario were the result of differences in assumptions about water-use efficiency and water management alone.[6]

For the Current Trends and High Efficiency scenarios, annual population growth rates were developed by the California Department of Finance (DOF) by county for 2030 (DOF 2004). County estimates are aggregated into hydrologic regions by DWR. The DOF projects that California's population will reach 48.1 million by 2030. We note, however, that in April 2005, the U.S. Census Bureau projected that California's population will reach 46.4 million by 2030 (U.S. Census 2005), substantially less than the 48.1 million predicted by the DOF. This discrepancy alone suggests that water demand projections based on DOF data may overestimate urban demand.

6 Indeed, while we do not alter the population projections, it is clear that the lower the overall population, the easier it will be to address all problems associated with water scarcity, supply, transfer, and management. Efforts everywhere to address population problems should therefore be continued.

The household population, share of multifamily housing, and housing size assumptions for both the Current Trends and High Efficiency scenarios are based upon DWR housing projections (DWR 2004) calculated from DOF 2030 population projections (DOF 2004), Woods and Poole 2030 population projections (Woods & Poole Economics 2004), and 1980 to 2000 U. S. Censuses. In these assumptions, the housed population remains nearly constant from 2000 to 2030, the share of multi-family housing decreases from 35.5 percent to 33.9 percent (as a statewide average), and the household size decreases modestly for single and multi-family households. Finally, both scenarios used the same projections of mean income (in constant dollars) for each hydrologic region based on projections from Woods and Poole Economics (2004).[7]

Table 1
Urban Water Scenarios:
Demographic Assumptions for 2030

Demographic Parameter	Current Trends and High Efficiency Scenarios
Total population	48.1 million (2030)
Inland and southern (SC, SL, CR, SR, SJ, TL)	37.3 million (2030)
Coastal and northern (NC, SF, CC, NL)	10.8 million (2030)
Housed population fraction	Nearly constant (~98%)*
Multi-family housing share	35.5% to 33.9%*
Single-family house size	3.13 to 3.06*
Multi-family house size	2.41 to 2.38*
Mean income (1996 dollars)	$87,225 to $116,269*
Employment fraction	58% to 60%*

* Values for 2000 -> 2030. Trend varies by hydrologic region.

Urban water demand is also affected by a number of other factors, including water price, income, and technology. One of the important differences between the Current Trends and High Efficiency scenarios is the assumption of changes in urban water prices (in constant dollars) over the period 2000 to 2030 (as shown in Table 2). The DWR Current Trends scenario specifies a modest statewide average increase in water price over 30 years of 20 percent. Ironically, this is not the "current trend" in urban price; according to the annual urban water-price surveys in California conducted by Black and Veatch between 1991 and 2001, actual increases have been about 1.1 percent annually (in constant dollars). If this continues to compound at the same rate, urban prices will go up an average of 41 percent between 2000 and 2030. We adopted this value for the High Efficiency scenario.

Table 2
Urban Water Scenarios:
Water Price Assumptions for 2030

Water Price Parameter	Current Trends Scenario	High Efficiency Scenario
Urban water price*	2000 prices + 20%	2000 prices + 41%

* Constant dollars.

The relationships between water demand and some of the factors listed in Tables 1 and 2 are specified by elasticity factors. Elasticity is a measure of the responsiveness of one economic variable (water demand) to changes in another economic variable (water price, household size, and income). If the price doubles and water use drops 20 percent, the price elasticity of water is considered to be -0.2. Table 3 lists elasticity factor assumptions for the Current Trends and High Efficiency scenarios. For the Current

7 Income and employment data were disaggregated by hydrologic region by Marla Hambright and Richard Le of the California Department of Water Resources.

Trends scenario, the single-family price elasticity is adopted from the 1998 Water Plan Update (DWR 1998). Multi-family price, income, and household size elasticities are derived from a range recommended in a widely used urban water-demand model (IWR-MAIN from Planning and Management Consultants 1999).

Elasticity factors adopted here for the High Efficiency scenario are quite similar, but have been adjusted based on a broader survey of the literature. Our survey revealed that the household size and income-elasticity factors used in the Current Trends scenario are within the published ranges reported in field surveys. A survey of price-elasticity factors, however, suggested that those used in the Current Trends scenario underestimate the effect of *price* on water demand (Table 4). Thus, for the High Efficiency scenario, income and household elasticities are assumed to be the same as in the Current Trends scenario, while price elasticity is somewhat higher. Price-elasticity factors for single-family homes (SF); multi-family homes (MF); and the commercial, industrial, and institutional uses (CII) in the High Efficiency scenario are calculated from the average of the literature values in Table 4.

We note here that the average of the literature values may not be the most accurate method for estimating elasticity. Elasticity factors can be either long- or short-run, referring to the length of time that the individual has to respond to the change in question. They are likely to vary somewhat from place to place. They are unlikely to be constant over time. And they may be influenced by other factors, including education, new technology, and even whether or not a region has recently experienced a severe drought. Nevertheless, we believe using the observed average, as most analysts do, is a reasonable approach for this kind of forecasting.

Table 3
Residential and CII Water Demand Factors for 2030

Note:
SF: Single-family
MF: Multi-family
CII: Commercial, Industrial, and Institutional

Elasticity and Efficiency Parameter	Current Trends	High Efficiency
Price elasticity – SF	-0.16	-0.2
Price elasticity – MF	-0.05	-0.10
Price elasticity – CII	-0.085	-0.25
Income elasticity – SF	0.4	0.4
Income elasticity – MF	0.45	0.45
HH size elasticity – SF	0.4	0.4
HH size elasticity – MF	0.5	0.5
Naturally occurring conservation – interior	-10%	
Naturally occurring conservation – exterior	-10%	
Naturally occurring conservation – CII	-10%	
Efficiency – interior	-5%	-39%
Efficiency – exterior	-5%	-33%
Efficiency – CII	-5%	-39%

Table 4
Price Elasticity Factors for Single Family (SF), Multi-Family (MF), and the Commercial, Industrial, and Institutional (CII) Water Uses

Sector	Study	Elasticity
SF	Renwick et al. 1998	-0.16
SF	Manwaring 1998	-0.20
SF	Manwaring 1998	-0.28
SF	Michelson et al. 1997	-0.10
SF	Kiefer et al. 1995	-0.18
SF	Kiefer et al. 1996	-0.09
SF	Campbell et al. 1999	-0.27
SF	**Average**	**-0.20**
MF	Manwaring 1998	-0.08
MF	Manwaring 1998	-0.08
MF	Kiefer et al. 1995	-0.16
MF	Kiefer et al. 1996	-0.09
MF	**Average**	**-0.10**
CII	Manwaring 1998	-0.55
CII	Dziegielewski and Opitz 1991	-0.28
CII	Kiefer et al. 1995	-0.11
CII	Kiefer et al. 1996	-0.08
CII	**Average**	**-0.25**

Note:
SF: Single-family
MF: Multi-family
CII: Commercial, Industrial, and Institutional

The DWR Water Plan scenarios assume a level of conservation expected to occur without any new policies, such as through existing plumbing codes and continued implementation of current Best Management Practices (BMPs) in the Memorandum of Understanding (MOU) (CUWCC 2004). The Current Trends scenario uses a report prepared by A&N Technical Services (2004) on behalf of California Urban Water Agencies (CUWA) to estimate the total domestic conservation (termed the Gross effect) and the portion of total conservation due solely to the implementation of a subset[8] of BMPs (termed the Net effect).[9] The difference between the Gross and Net effects is "naturally occurring conservation" (NOC), defined as conservation that can be achieved via the implementation of existing plumbing codes. The report presents Net and Gross savings for seven of the ten California hydrologic regions at years 2007, 2020, and 2030. Over time, the Net savings (and therefore the Gross savings as well) decrease from 2020 to 2030 because of fixed life spans for conservation technology or decay rates for the conservation achieved by the BMP programs.

Using the data and assumptions contained in the A&N Technical Services report along with year 2000 DWR domestic water-use estimates, the Water Plan projects that 2030 NOC and efficiency due to the implementation of a subset of BMPs would decrease household water demand by about 10 percent and 5 percent of 2000 demand, respectively. The same estimates are used for the commercial, industrial, and institutional sectors. Because overall population rises much faster than this improvement in efficiency, total urban water use in all three of the DWR scenarios actually rises.

8 Of the 14 BMPs, only eight of them were quantified in the A&N Technical Services study.

9 A&N Technical Services (2004) estimate water savings for three different implementation scenarios: Existing Conditions, Cost-Effective Implementation, and Full Implementation.

The assumptions used in the Current Trends scenario exclude a wide range of efficiency options that we know to be both cost-effective and achievable with existing technologies (Mayer et al. 1999, Gleick et al. 2003). The BMPs represent limited efforts by water utilities and are not comprehensive in either scope or magnitude. We believe the DWR assumption also overestimates the "decay" of conservation savings, as noted in Gleick et al. (2003).

In contrast, the High Efficiency scenario developed here includes implementation of additional water-conservation programs. For the High Efficiency scenario, estimates of the conservation potential are based on the Pacific Institute's "Waste Not, Want Not" (WNWN) report (Gleick et al. 2003). This study uses a "bottom-up" approach to estimate future water use by multiplying the numbers of water-using devices, such as toilets, by their technical water requirements. The WNWN study conservatively estimated that the indoor and outdoor urban conservation potentials were 39 percent and 33 percent, respectively, from current use. The commercial, industrial, and institutional (CII) conservation potential was estimated at 39 percent, though it varied by industry and end use. Overall, this study estimated that one-third of current urban uses could be conserved cost-effectively. This is an especially conservative estimate to extend to 2030 because the report:

- Assumes no new technological developments.
- Assumes no new regulatory requirements.
- Requires no change in behaviors or "benefits" of current water use (i.e., it excludes changes like shorter showers, smaller lawns, or a ban on car washing).
- Ignores trends in the construction of more efficient homes, relative to the 2000 average.
- Assumes no further cost reductions in efficiency equipment, despite continual reductions in such costs.
- Assumes no increases in energy costs, despite recent substantial increases in such costs.

Modeling Agricultural Water Demand

Agricultural water demand is a function of many different things, ranging from climate and soil conditions to irrigation technology, crop type and area, water prices, water rights, and farmer behavior. These factors all vary over time. Indeed, there have been substantial changes in the kinds of crops grown in California over the past several decades, the areas under irrigation, water prices, and the method of irrigation. In the model used to generate the DWR scenarios, there are two sets of agricultural water demand parameters: agricultural land use and crop-water demand. Each of these sets of parameters has a number of factors that can be tested in the model. The paragraphs below and Tables 5 to 7 summarize the parameters and factors used to represent each scenario.

Agricultural land-use changes over time are comprised of two major factors: the total amount of land in production, and the kinds of crops being grown. The total amount of land in production is affected by the conversion of agricultural land to urban uses, new land brought into agricultural production, land that is retired, and changes in the amount of land on which more than one crop is grown annually—called "multi-cropping." The choice of crops planted on any given piece of land also varies over time as diets and consumer preferences change, growers respond to crop and water price trends, and technological or other resource factors change.

DWR's assumptions for these variables for 2000 and 2030 were developed using historical rates of land conversion from agriculture to urban development, tempered by increases in multi-cropping and some new lands coming into production. Tables 5 and 6 summarize the way these variables are integrated in the model and the assumptions made by DWR about the trends. Overall, the DWR Current Trends scenario assumes a modest five percent decrease in overall irrigated crop area over the next 25 years to just over nine million acres. We did not change these assumptions and adopted the DWR land-use assumptions for the High Efficiency scenario.

Table 5
Quantification of Statewide Agricultural Land-Use Changes for 2030

Agricultural Land-Use Parameters	Current Trends and High Efficiency Scenarios
Irrigated crop area (ICA) [1]	~4.9% reduction (9.5 ma ‡ 9.05 ma)*
Irrigated land area (ILA) [2]	10% reduction (9.0 ma ‡ 8.1 ma)*
Multi-cropped area (MA) [3]	80% increase (540 ta ‡ 970 ta)*

Note:
* Values for 2000 -> 2030
ma: million acres
ta: thousand acres
[1] Changes in ICA described in narrative scenarios and computed from specified changes in ILA and MA.
[2] Changes in ILA for Current Trends scenario derived from off-line regression analysis.
[3] Changes in MA specified to produce the ICA changes shown.

Agricultural land-use changes have not been uniform throughout the state over time; rather, they vary by hydrologic region and crop type. The scenario model adopts a rules-based procedure to disaggregate scenario-specific statewide changes in irrigated land, multi-cropped area, and irrigated crop area to changes at the hydrologic region and by crop type. Table 6 shows the parameters used to implement these rules. Based on discussions with DWR staff and the agricultural community, DWR set different rates of change from low-valued to high-valued crops, or in overall irrigated area, for different hydrologic regions. Upper limits were placed on the conversion from low-valued to high-valued crops, and on overall areas subject to multi-cropping. We've adopted these same assumptions for the High Efficiency scenarios.

Table 6
Agricultural Land-Use Changes by Hydrologic Region and Crop Type for Each Scenario for 2030

Note:
MA: Multi-cropped area
ILA: Irrigated land area
HR: Hydrologic region

Parameter	Current Trends and High Efficiency Scenario
Irrigated land area statewide trend (as in Table 5)	-10%
Multi-cropped area statewide trend (as in Table 5)	+80%
Hydrologic regions with low ILA change	NC, SF, NL, SL
Hydrologic regions with high ILA change	CC, SC, SR, SJ, TL, CR
Hydrologic regions with no MA change	CC
Hydrologic regions with low MA change	NC, SF, SC, NL, SL, CR
Hydrologic regions with high MA change	SR, SJ, TL
Hydrologic regions with increases in low value crops	NL
Low value crop reduction (upper limit)	50%
Potential multi-crop ratio (lower limit)	2000 potential multi-crop ratio by HR
Potential multi-crop ratio upper limit	36%

The third set of factors affecting agricultural water use is changes in crop water demand. We evaluated these in more detail for the High Efficiency scenario, with a focus on water prices and a set of "technological improvements" described in more detail below. The overall water demand of any given crop is a function of its location and the local climate, the relationship between yield and evapotranspiration, the effective precipitation, the price and price elasticity of water, irrigation technology, and irrigation technique. These variables are captured in various ways in the model, which permits us to explore the sensitivity of agricultural policy choices. These variables are listed in Table 7.

Table 7
Crop Water Demand Parameters for Each Scenario for 2030

Note:
* Value varies by crop and hydrologic region. Changes are from 2000 to 2030.
[1] In both scenarios, yields are assumed to be constant.
[2] Approximately the average long-term water price elasticity for Central Valley agriculture as reported by DWR Bulletin 160-98, Table 4A-5 (DWR 1998).

Agricultural Parameter	Current Trends Scenario	High Efficiency Scenario
Agricultural Yield	2000 values*	As Current Trends
Yield-ET Elasticity	0.2 [1]	As Current Trends
Effective Precipitation	2000 values	As Current Trends
Agricultural Water Price	2000 values + 10%	2000 values + 68%
Price-CF Elasticity	0.28 [2]	As Current Trends
ET Technique Factor	0	0
Technology CF Effects	2.5%	0%
Technological Improvement	0	See below for details

Some improvements in crop water-use efficiency result from changes in the price of water, which leads farmers to modify behavior, technology, and other factors. We assume that these improvements are cost-effective because the elasticity estimate indicates a level of conservation that by definition costs less to implement than the adjusted water price. Of course, no one is certain what the cost of agricultural products or irrigation technologies will be over the next 30 years. As a first approximation, however, our assumption about the cost-effectiveness of price-driven efficiency is valid.

In the DWR scenarios, agricultural water price is projected to rise by only 10 percent over the next 30 years. As a result, total price-driven agricultural water demand drops only modestly when this price increase is coupled in the model with the price and consumed fraction elasticities.

The High Efficiency scenario assumes that water price will change at the same rate as the historical trends, which is higher than the rate assumed in the Current Trends scenario. (As with the urban sector, this means the High Efficiency scenario for price is actually more like a real "current trends" scenario.) To project changes in agricultural water price between 2000 and 2030, we assume that recent increases in the cost of service (CoS) rates, which include operation and maintenance, capital, and deficit costs, for Central Valley Project (CVP) contractors will apply to all water supplies, regardless of source. As a baseline, we evaluated CoS rates for 120 water contractors between 1990 and 2005 (USBR 1990 and 2005) and extended this increase through to 2030. This analysis suggests that basic agricultural water rates will increase by 39 percent between 2000 and 2030. We apply this price increase to all water supplied to agricultural users.

Agricultural users served by the CVP will likely experience additional price increases. CVP contractors are currently behind on repaying the project costs. Under the original contracts, which were negotiated and signed in the late 1940s, the project was to be paid off 50 years after its construction (USBR 1988). By 2002, however, irrigators had repaid only 11 percent of the project cost (EWG 2004). According to Public Law 99-546, which was signed in 1986, all facilities built prior to the New Melones Dam and Reservoir in 1980 and all operation and maintenance deficits with interest incurred after 1985 must be fully paid by 2030. To meet this requirement, CVP contractors will be required to pay higher costs.

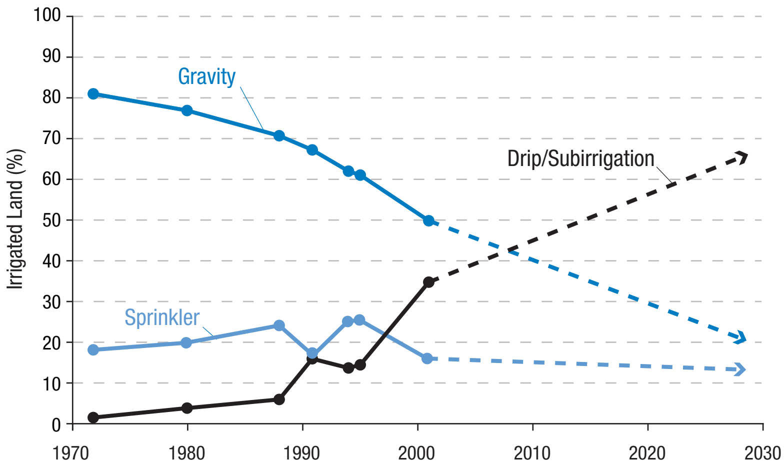
Based on an analysis of 120 CVP irrigation contracts and a review of full cost rates, which include CoS and interest on unpaid capital costs since 1982 (USBR 2000), water contractors will need to pay on average an additional 196 percent to be brought up to full cost rates. Combining the estimated price increases for CVP contractors with rising CoS rates for the remainder of agricultural water users, we project that overall agricultural water price will increase by 68 percent statewide between 2000 and 2030.

Some improvements result from changes in efficiency not captured by changes in water price ("non-price-driven efficiency"). Non-price efficiency drivers include innovation, education, rebates and incentives, regulations and ordinances, and, for agricultural users, unreliable supply. In the Current Trends scenario, non-price-driven efficiency is specified by two variables: the ET Technique Factor and Technology CF Effects. The ET Technique Factor represents reductions in evapotranspiration due to more efficient irrigation practices; the Technology CF Effects represent increases in the consumed fraction (and thus reductions in applied water) due to the adoption of more efficient irrigation technologies. The values for these variables are not well known and are used as placeholders in the model.

The High Efficiency scenario uses a different approach to estimate non-price-driven efficiency. Non-price-driven efficiency is estimated using a "bottom-up" approach based on historical changes in irrigation method by crop type and the relative efficiency of each method. Surveys of irrigation methods by crop type in California have been conducted approximately every ten years since 1972. In 2001, Orang et al. (2005) conducted an irrigation method survey throughout California. That analysis shows that for all crops combined, the use of gravity/flood irrigation and sprinklers has declined, while micro/drip and subirrigation use has increased (Figure 8).

Figure 8
Historical Data on the Percent of Irrigated Land Under each Irrigation Method Between 1972 and 2001, With Projections to 2030

Note: Historical data are represented by solid lines; projections are represented by dashed lines.



Using historical data on irrigation methods by crop type (grouped as field, vegetable, orchard, and vineyard crops) between 1972 and 2001, we use a linear trend to estimate the fraction of each crop type irrigated by each irrigation method in 2030. We then estimate the differences in water use among irrigation methods for each crop type based on data from field studies. We group studies according to crop type and calculate a relative efficiency for each irrigation method and crop type (see Appendix A for more detail). We combine the irrigation method and relative efficiency data to produce an adjusted 2030 irrigation water use. Using this approach, considerably more use of efficient irrigation technology occurs by 2030 than in the Current Trends scenario, which leads to considerably greater improvements in water-use efficiency. This is discussed in more detail in the Results section below.

A cost-effectiveness analysis was not performed on non-price-driven efficiency. More efficient irrigation technologies, however, continue to be installed throughout California, indicating that they are in fact cost-effective under many circumstances.

Modeling Environmental Water Demand

The DWR Bulletin 160 scenarios also include some rough estimates of "environmental demand" for water, defined as the official allocations of water for the environment under legal decisions or institutional operational conditions. Part of these estimates comes from an analysis prepared for the California Water plan by Environmental Defense, which produced a review of flow objectives for the year 2000 for some but not all of the major environmental objectives managed by the fisheries management agencies throughout the state (Rosekrans and Hayden 2003). While we do not evaluate environmental demands for water in this analysis, we understand how critical water is for ecosystem services, and the policy challenges for satisfying these demands. Indeed, one advantage of an "efficient" future is the opportunity to leave more water in rivers and streams for ecosystem use, or return water previously taken for urban or agricultural needs.

Results of the High Efficiency Scenario

The results of our High Efficiency scenario are presented here and compared with the DWR Current Trends scenario of the May 2005 public review draft of Bulletin 160-2005. The model computes water demands for each of the State's ten hydrologic regions, though we have little confidence in specific regional results. We focus here on the main trends and challenges facing California, with some comments about implications for the State's three major regions: north, central, and south (Figure 9). Separate results are reported for urban and agricultural water use.

Figure 9
Geographic Division of California (3 Regions)

Urban Water Demand

Trends in statewide urban water demand differ significantly among the scenarios. Demand for water in California's urban sector between 2000 and 2030 is projected to ***increase*** by 3.0 MAF in the Current Trends scenario and ***decrease*** by 0.5 MAF in the High Efficiency scenario (Figure 10), a difference in urban water use of over 3.5 MAF annually. The Current Trends scenario assumes a modest increase in efficiency of 15 percent for all sectors between 2000 and 2030. We note this refers to efficiency improvements possible with current programs and policies. The High Efficiency scenario assumes greater efficiency improvements, ranging from 33 percent for outdoor residential uses to 39 percent for indoor residential uses and commercial, industrial, and institutional uses (CII), but still assumes no new technological developments. Some of these efficiency improvements require additional conservation programs and policies. The High Efficiency scenario also assumes that water demand is more price-elastic than is assumed in the Current Trends scenario and that overall urban price continues to rise at the historical rate, which is higher than assumed in Current Trends.

Figure 10
Statewide Trend in Urban Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios

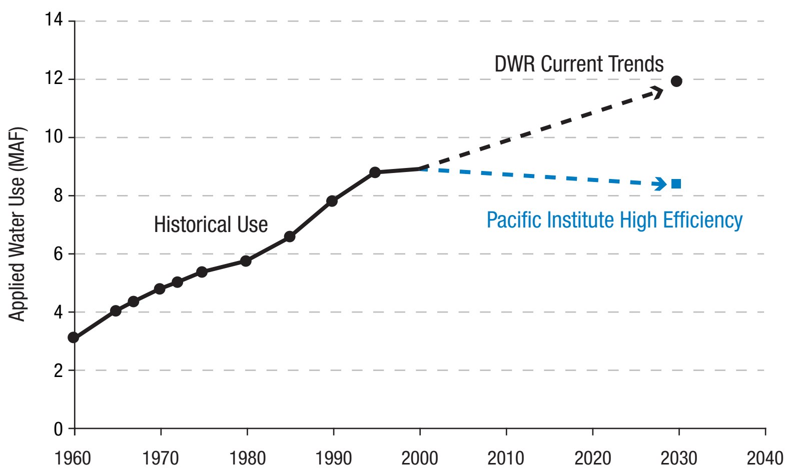


Figure 11 shows urban demand changes between 2000 and 2030 by geographic region. Urban demand increases for all regions in the Current Trends scenario, with the largest absolute increases in the southern part of California (an increase of 1.5 MAF). Although demand increases by only 0.6 MAF in the North, this change is the largest in percentage terms, nearly 60 percent over 2000 use, driven largely by assumed population and income growth in that region. In the High Efficiency scenario, a slight water demand increase in the North is offset by a modest decrease in the Central region and a larger decrease in the South. Because overall urban water use is greater in the South than in the Central or Northern regions, the efficiency gains produce the greatest absolute savings (2 MAF) in the South. Demand increases slightly in the North even in the High Efficiency scenario because its more substantial efficiency gains are still not sufficient to offset the 60 percent projected growth in population and income-driven water use.

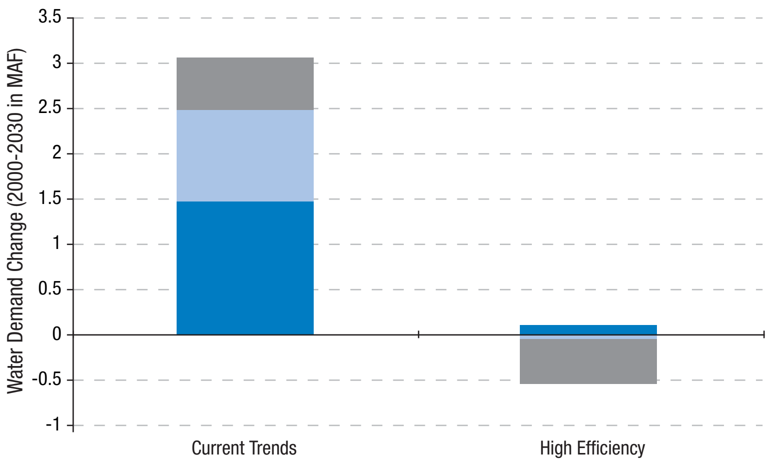


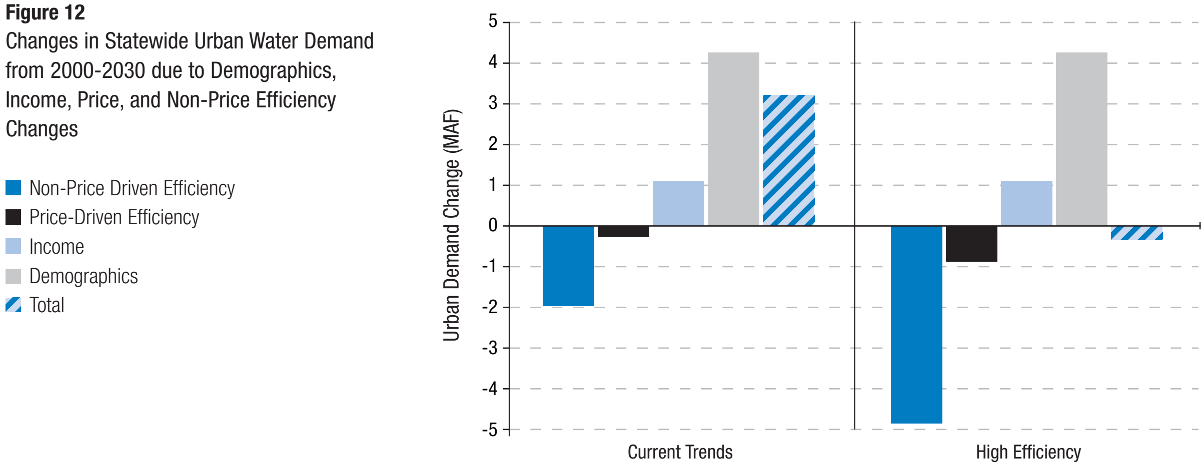
Figure 11
Changes in Urban Water Demand (2000 to 2030) by Geographic Region for the Current Trends and High Efficiency Scenarios

Total urban demand is affected by changes in population, housing factors, income, price, and non-price-driven efficiency. Figure 12 shows how total urban demand is affected by the scenario assumptions about demographic factors (population size and distribution and housing assumptions), price and non-price-driven efficiency improvements, and income elasticity. As can be seen, the demographic and income assumptions drive increases in water demand, while price- and non-price-driven factors result in improvements in overall water-use efficiency.

Assumptions about population, housing factors, and income are the same for both scenarios, thus the effect of these changes on urban demand is also the same. The difference between scenarios lies in the efficiency assumptions. Within the Current Trends scenario, price- and non-price-driven efficiency improvements lead to some reductions in the overall increases driven by growing income and population, yet total urban demand still increases by over 3 MAF per year by 2030. In the High Efficiency scenario, both price- and non-price-driven efficiency improvements are more substantial and effectively counterbalance increases in demand caused by increases in population and income, leading to an overall reduction in urban water use of around 0.5 MAF per year by 2030.

Note that non-price-driven efficiency improvements reduce 2030 demand by nearly 5 MAF. This is substantially larger than the upper range of urban efficiency savings of 2.3 MAF included in DWR's resource management strategies. Both estimates, however, are based on the Pacific Institute's "Waste Not, Want Not" report. DWR incorrectly uses the absolute value (2.3 MAF) given in the Pacific Institute report, which refers to the conservation potential in 2000, not 2030. Because conservation lowers per-capita use, population growth leads to an even greater absolute savings. By specifying efficiency as a percent of use, the High Efficiency scenario captures the additional water savings due to a growing population.

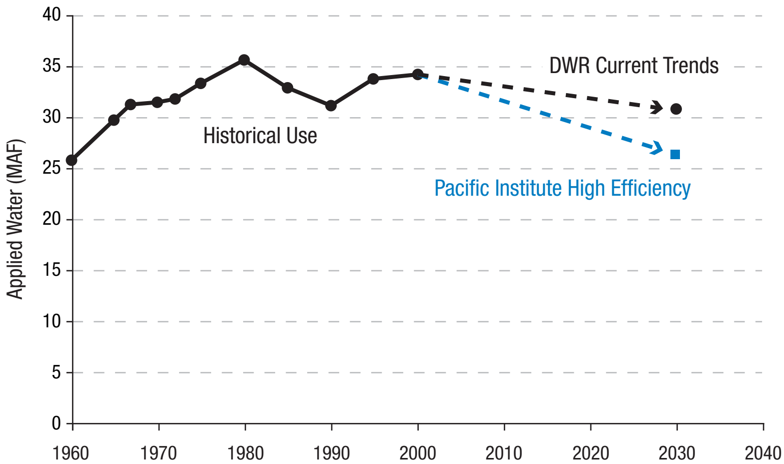
Figure 12
Changes in Statewide Urban Water Demand from 2000-2030 due to Demographics, Income, Price, and Non-Price Efficiency Changes



Agricultural Water Demand

Figure 13 shows actual and projected agricultural water demand between 1960 and 2030 for the Current Trends and High Efficiency scenarios. Agricultural water demand is projected to decline from 2000 by ten percent (3.5 MAF) and 23 percent (8 MAF) in these two scenarios, respectively, while overall crop production remains relatively unchanged. Water demand declines in both scenarios due to a reduction in irrigated crop area and changes in cropping patterns.

Figure 13
Statewide Trend in Agricultural Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios



The difference between the scenarios—approximately 4.5 MAF in water savings—is due to explicitly modeled changes in irrigation technology (1.5 MAF) and greater price-driven efficiency (3 MAF) in the High Efficiency scenario. As described in the Data Constraints section, we may be assuming greater improvements than would result from a simple extension of the historical trend because of the way the model is set up. As noted in the Model Background and Assumptions section above, we tried to adopt conservative assumptions for other aspects of the High Efficiency scenario. If all of the savings from improvements in irrigation technology—approximately 1.5 MAF—are captured by actions farmers take due to rising prices, then overall reductions in agricultural water use by 2030 could be between 6.5 and 8 MAF.

Figure 14 shows the agricultural demand changes by geographic region and scenario. Modeled reductions in agricultural demand are not distributed equally among the three regions of the State. In both scenarios, the largest absolute savings are expected in the Central region, where agricultural water use is highest and consequently potential efficiency gains are largest. A reduction in irrigated crop area of over 400,000 acres, or 7 percent, in the Central region (as assumed by DWR in the Current Trends scenario) also contributes to the expected savings. The largest savings as a percentage of 2000 use, however, are expected in the South, where the reduction in irrigated crop area due to urban encroachment is the highest among the three regions at nearly 14 percent.

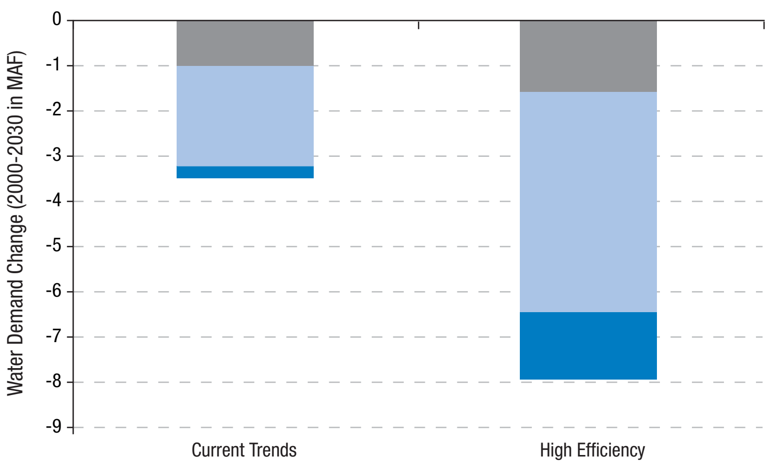


Figure 14
Agricultural Demand Change (2000 to 2030) by Geographic Region in the Current Trends and High Efficiency Scenarios

North
Central
South

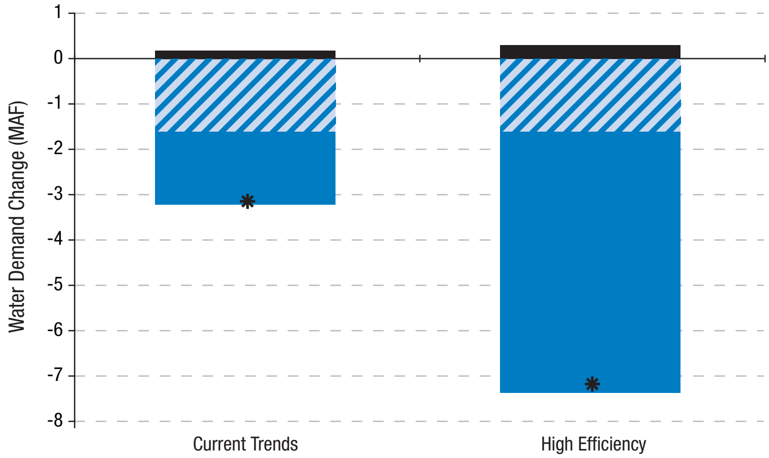
Irrigation demand is a function of irrigated crop acreage (ICA) and crop water use (CWU). Figure 15 disaggregates irrigation demand reductions into changes in these factors. Changes in crop acreage reduce irrigation demand by 1.6 MAF in both scenarios. We would expect the same amount of demand reduction from this factor, because assumptions about agricultural land use are the same in both scenarios. Changes in crop water use reduce irrigation demand by 1.6 MAF and 5.8 MAF in the Current Trends and High Efficiency scenarios, respectively. The difference between the scenarios is 4.2 MAF. This suggests that additional policies and practices that promote water-use efficiency, as assumed in the High Efficiency scenario, can reduce irrigation demand by 4.2 MAF. Note that irrigation demand reductions are less than the agricultural demand reductions described above. Agricultural demand includes irrigation demand as well as delivery and conveyance losses.

Figure 15

Disaggregated Irrigation Demand Change from 2000-2030 in the Current Trends and High Efficiency Scenarios

CWU Change
ICA Change
Residual Change
Total Demand Change

Note:
CWU: Crop water use
ICA: Irrigated crop area
The "residual change" term corrects for double-counting changes in CWA and ICA separately. See Grover et al. (2005) for details.



Assumptions about changes in agricultural land use and crop mix have economic implications for the agricultural sector. While this requires a far more detailed economic analysis than we were able to perform, we evaluated the production value of crops grown throughout the state under the different scenarios based on commodity data from 2000 (NASS 2000). We assume that farmers are price takers and that the price farmers receive for particular crops remains the same, in constant dollars. The High Efficiency scenario also assumes that improvements in irrigation efficiency do not increase total yields, but rather that farmers capture the savings by reducing total water demand. As a result, the total value per acre increases two percent between 2000 and 2030 due to shifts in crop types toward higher-valued crops, and total agricultural income declines a modest three percent, even with a five percent drop in total irrigated area and a 23 percent drop in irrigation water demand.

This is a conservative assumption: irrigation studies examined in this report suggest improvements in irrigation efficiency both save water and substantially improve crop yields. Crop yields can rise in response to a number of factors, including reduced fungal infestations, more efficient fertilizer applications, and less water lost through evaporation (and consequently more available for transpiration). This effect is not included in this study, but may offset some of the production value loss due to agricultural land-use changes. Using some of the water savings to increase production on land previously not irrigated can also offset production value loss. This is a matter of policy at both the state and local levels. The more important issue is that the net well-being of growers, as measured by income or crop production, can be maintained with a significant reduction in water use.[10]

This analysis cannot be used to examine compliance with California legislation AB2587, which requires that California be a net exporter of table food. Our analysis covers all irrigated crops grown in California and does not explicitly address table food. Nevertheless, Brunke et al. (2004) conducted an initial evaluation of various scenarios and concluded that California's agricultural sector in 2030 will likely continue to be a significant exporter of food.

10 In addition, our analysis does not include technological advances or techniques that may further increase yield or reduce water use, or both.

Total Water Demand

Figures 16 and 17 show total human water demands generated by the Current Trends and High Efficiency scenarios between 2000 and 2030, along with DWR estimates of actual water use during the latter half of the 20th century. The DWR 2000 estimates were used as the starting point/base case here. Overall statewide human water demand is projected to decline in both scenarios. In the Current Trends scenario, slight increases in the North and South are offset by decreases in the Central region (Figure 16). Water demand in the High Efficiency scenario declines by 8.5 MAF—a reduction of around 20 percent of California's total human water use in 2000—due to significant improvements in both urban and agricultural water use.

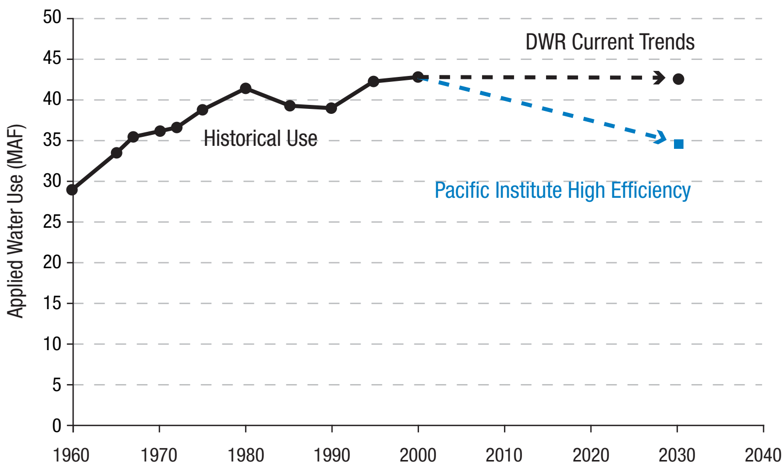


Figure 16
Statewide Trend in Total Urban and Agricultural Water Demand Between 1960 and 2000, with Projections to 2030 in the Current Trends and High Efficiency Scenarios

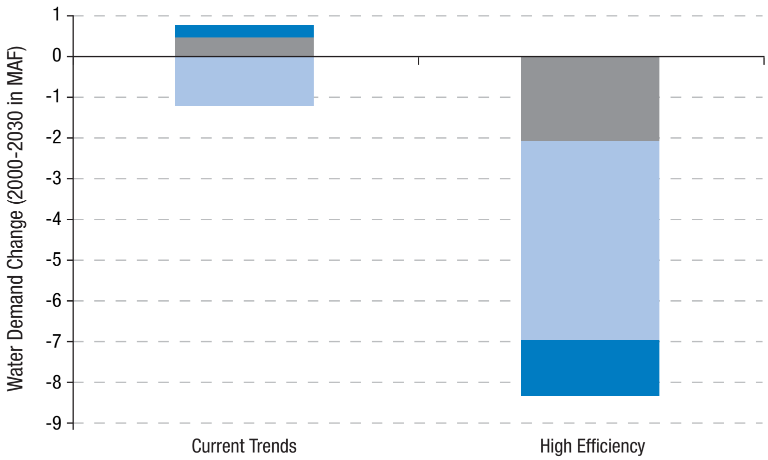


Figure 17
Urban and Agricultural Water Demand Change (2000-2030) by Geographic Region in the Current Trends and High Efficiency Scenarios

North
Central
South

Some Caveats About Scenario Results

We reiterate that these scenarios are not predictions. How much water Californians actually use in the future will depend on a very large number of uncertain factors, ranging from the total number of people in California to the nature and priorities of society a generation from now.

The results described above, therefore, are inherently uncertain. Data problems, the potential for double counting savings or missing classes of savings opportunities, risks to overall water supply such as climate change, and many more factors remain unresolved, unforeseen, or simply poorly understood. We discuss a few of these issues in a more detail below.

Data Constraints

The greatest constraints on future improvements in water forecasts now come not from computer capability but from limitations on the quality, availability, and regional resolution of water data and from difficulties in doing certain kinds of assessments. This is true for California water planning as well. Some of the most important data problems are as follows:

- **Serious gaps in regional-scale hydrological data still exist and are unlikely to be filled soon.** While precipitation, temperature, and runoff are relatively well measured in developed countries, many regions of the world suffer both from gaps in present-day instrumental coverage and from lack of any long-term records. And, even in California, pressures to cut funds for observation and monitoring stations threatens the continuity of time-series data.

- **Certain types of water-use data are not collected or reliable.** Far less data are collected on water use than on water supply and availability. Domestic water use is often not measured directly and details on how that water is used are rarely collected. A survey conducted for the American Water Works Association on U.S. domestic water use is a rare exception (Mayer et al. 1999), and even this study was limited in scope. Industrial and commercial water use are inventoried infrequently or not at all. Agricultural water-use data are even more uneven and unreliable. Groundwater withdrawals are rarely measured or regulated. Even when water-use data are collected, information on changing water-use patterns over time is often not available, making analysis of trends difficult.

- **Some water users still restrict access to water data.** Even in this era of easy Internet access, some water users refuse to share water-related data with neighbors or even local governments. In regions where water is shared or disputed, restricting information may result from a perceived (or real) political or economic advantage in doing so. In California, most data that are collected are made available, but there are still difficulties accessing certain industrial and agricultural water use data, information on water bills and prices, and groundwater pumping.

- **Some water uses or needs are unquantified or unquantifiable.** In all likelihood, some uses and needs are unlikely ever to be accurately determined or included in scenario projections. For example, ecological needs, recreational uses, water for hydropower production or navigation, and reservoir losses to seepage or evaporation are often difficult to calculate with any accuracy. Nevertheless, these water uses and activities will eventually need to be quantified and incorporated into future estimates if true water planning is to be done.

Double Counting or Missing Water

Double counting of water savings (or even missing water savings entirely) is potentially a problem for agricultural and urban water demand in both scenarios. For urban demand, the model includes both price-driven efficiency and a separate efficiency factor. Some of the water savings accounted for in the efficiency factor, however, may have been driven by price. By including both factors, we may be double counting water savings. This is also true in the agricultural sector, where some fraction of the irrigation technology effect may have been driven by price. By using conservative estimates for price- and non-price-driven efficiency, one can argue that the potential for double counting is diminished. Insufficient data are currently available to adequately address this issue.

Ultimately, which future we reach depends upon what water policies, strategies, and technologies are implemented over the coming years.

Quantifying non-price-driven efficiency also poses a problem for modeling water demand. Non-price drivers, including innovation, education, ordinances, and, for agricultural users, unreliable supply, can lead to water demand savings. A study by Michelsen et al. (1998) on price and non-price conservation programs concludes that a lack of information on the implementation of non-price conservation programs limits an evaluation of the effect of these programs on water demand.

As a result of these kinds of limitations, analysts should not assume that increasing model or scenario sophistication would lead to more accurate forecasts. In the end, even "perfect" models supplied with imperfect data are of limited value. Any scenarios must still be treated as "stories," as possible futures to be explored, with the understanding that choices we make today will determine which path we end up following and which future we move toward.

Analysis and Conclusions

The two scenarios described above—the DWR Current Trends and the Pacific Institute High Efficiency scenarios—offer different views of urban and agricultural water use in 2030. They are the result of making different assumptions about a range of water-use efficiency options, policies, technologies, and decisions. The Pacific Institute High Efficiency scenario projects that the statewide use of water will decline by 20 percent by 2030, through implementation of urban and residential water-use efficiency improvements. While we do not evaluate environmental demands for water in this analysis, we understand how critical water is for ecosystem services, and the policy challenges for satisfying these demands. Indeed, one advantage of an "efficient" future is the opportunity to leave more water in rivers and streams for ecosystem use, or return water previously taken for urban or agricultural needs.

Neither scenario is a prediction. How much water will be needed and used to meet urban and agricultural demands in 2030 is unknowable and uncertain, because it depends on a vast array of factors. Some of these factors are partly or completely out of the hands of Californians, such as decisions about crop production in other countries, the extent and severity of climate changes, technological developments, national policies around efficiency standards or pricing of water from federal projects, and so on.

Other factors, however, are well within our ability to influence, and some of these factors could have a huge effect on future water demands. Ultimately, which future we reach depends upon what water policies, strategies, and technologies are implemented over the coming years.

Experience has shown that efforts to improve water-use efficiency are consistently successful and cost-effective. If we put as much time, money, and effort into improving water-efficiency as has gone into traditional water supply development, a high efficiency future could be readily achieved—with substantial benefits to California's economy, environment, and health.

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APPENDIX

Note: The following appendix is available online at
http://pacinst.org/reports/california_water_2030

Appendix A

Agricultural Efficiency

Step 1: Calculate the percentage of irrigated land by crop type and irrigation method

Step 2: Calculate the relative efficiency of each irrigation method for each crop type

Step 3: Project the applied water for each crop and hydrologic region in 2030

Caveats and Suggested Improvements