

Urban Water Use Efficiency



A Resource Management Strategy of the California Water Plan

California Department of Water Resources

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Abbreviations and Acronyms

20x2020 Plan	20x2020 Water Conservation Plan
ACWA	Association of California Water Agencies
af	acre-feet
AMI	advanced metering infrastructure
AWWA	American Water Works Association
BMP	best management practice
CII	commercial, institutional, and industrial
CLCA	California Landscape Contractors Association
CUWCC	California Urban Water Conservation Council
Delta	Sacramento-San Joaquin River Delta
DMM	demand management measures
EPA	U.S. Environmental Protection Agency
ETo	evapotranspiration
gpf	gallons per flush
gpcd	gallons per capita per day
gpm	gallons per minute
HET	high-efficiency toilets
IWA	International Water Association
maf	million acre-feet
MOU	memorandum of understanding
MWELO	Model Water Efficient Landscape Ordinance
PRV	pressure regulating valve
SB	Senate Bill
ULFT	ultra low-flow toilets
Update 2009	California Water Plan Update 2009
UWMP	urban water management plan
WMCP	Water Management Certification Program

Urban Water Use Efficiency

During the past few decades, Californians have made great progress in urban water use efficiency. Once viewed and invoked primarily as a temporary strategy in response to a drought or emergency water shortage situation, water use efficiency has become a permanent part of the long-term management of California's water supply. At the individual level, the benefits of water use efficiency may appear small, incremental, or difficult to see, but when Californians act together as a community to conserve water, the cumulative effect is significant, and the benefits are widespread.

There are several factors that have contributed to increased water use efficiency: outreach efforts that have increased awareness and changed behaviors; urban water suppliers' implementation of demand management measures (DMMs); plumbing codes requiring more efficient fixtures; the Model Water Efficient Landscape Ordinance (MWELO); advances in irrigation technology; new technologies in the commercial, institutional, and industrial (CII) sectors; and mandates requiring that unmetered connections become metered.

But, with tighter environmental constraints on the Sacramento-San Joaquin River Delta (Delta), increasing population, and the necessity of adapting to climate change, even greater efficiencies will be needed and are achievable. When faced with an increasing demand for water, water agencies can consider options for increasing supplies or reducing demand, or a combination of both, to meet this need. Increasing water supply can be expensive and can include costs of purchasing additional water, capital cost of production and distribution systems, water supply treatment facilities, energy costs, and wastewater treatment facilities. Reducing demand through increased water use efficiency is generally lower cost and quicker to implement.

In an effort to emphasize and increase water use efficiency, the California Legislature has directed urban retail water suppliers to reduce urban per-capita water use by 20 percent by the year 2020. This legislation, the Water Conservation Act of 2009 (Senate Bill [SB] No. 7 of the Seventh Extraordinary Session, or SB X7-7), was enacted as part of a five-bill package aimed at improving the reliability of California's water supply and restoring the ecological health of the Delta. SB X7-7 had multiple urban and agricultural water use efficiency provisions. The key urban conservation measure established a statewide goal of reducing urban per-capita water use by 20 percent by 2020. Meeting this statewide goal of a 20-percent decrease in demand will result in a reduction of just over 2 million acre-feet (maf) of urban water use in 2020.

This chapter will present the practices already employed in urban water conservation, as well as describing how further efficiencies can be achieved and how the goal of 20-percent reduction by 2020 can be met.

Urban Water Use Efficiency Today in California

Demand Management Measures and Best Management Practices

DMMs shown in Table 1 and best management practices (BMPs) are practices that can be used by urban water suppliers to conserve water, and the implementation of these practices has been a major driving force behind urban water conservation in California.

Table 1 Demand Management Measures

Demand Management Measure	Description
DMM A	Water survey programs for single-family residential and multi-family residential customers.
DMM B	Residential plumbing retrofit.
DMM C	System water audits, leak detection, and repair.
DMM D	Metering with commodity rates for all new connections and retrofit of existing connections.
DMM E	Large landscape conservation programs and incentives.
DMM F	High-efficiency washing machine rebate programs.
DMM G	Public Information programs.
DMM H	School Education Programs.
DMM I	Conservation programs for commercial, industrial, and institutional accounts.
DMM J	Wholesale agency programs.
DMM K	Conservation pricing.
DMM L	Water conservation coordinator.
DMM M	Water waste prohibition.
DMM N	Residential ultra-low-flush toilet replacement.

Notes: DMM = demand management measure.

California Water Code, Section 10631 (f), requires urban water suppliers to provide a description of their demand management measures in their urban water management plans. Implementation of these measures has been a driving force behind urban water conservation in California.

The Urban Water Management Planning Act placed the DMMs in the California Water Code (Section 10631) and required urban water suppliers to include a description of their DMM implementation in their urban water management plans (UWMPs), due every five years.

These DMMs were also included in the California Urban Water Conservation Council's (CUWCC's) memorandum of understanding (MOU). The CUWCC was created to increase efficient water use statewide through partnerships among urban water agencies, public interest organizations, and private entities. The council's goal is to integrate DMMs into the planning and management of California's water resources. When the DMMs were incorporated into the MOU, they were labeled as BMPs. Water agencies that became signatories to the MOU pledged to implement the BMPs to specified levels and to report progress on their BMP implementation biannually to the CUWCC.

Originally, the CUWCC BMPs were the same as the DMMs listed in the Urban Water Management Planning Act. But in 2008, the CUWCC BMPs underwent a significant revision. The BMPs were

reorganized as either “Foundational” or “Programmatic” BMPs and re-numbered. More details on the revised BMPs can be found at <http://www.cuwcc.org>.

To be eligible for grant or loan funding from the State of California, an urban water supplier, whether a signatory to the CUWCC MOU or not, must demonstrate that its efforts in implementing each DMM or BMP will be implemented at the coverage level determined by the CUWCC MOU.

Some of the DMMs/BMPs provide quantifiable water savings, and others do not. For example, DMM N is the practice of toilet retrofits; replacing a 5-gallon-per-flush toilet with a 1.6-gallon-per-flush toilet yields water savings of 3.4 gallons per flush. Contrast that with DMM H, school education programs. Although education is critical to conservation and necessary to move people to new behaviors, it is not possible to correlate each educational effort with specific water savings.

20x2020: A New Direction

Box 1 describes the history, process, and impact of the *20x2020 Water Conservation Plan* (20x2020 Plan).

Baseline Water Use

The period used for baseline water use estimations is roughly 1996 to 2005, though suppliers could choose any 10 consecutive years from between 1995 and 2010.

After compiling baseline water use from 342 water agencies, the statewide average baseline water use was calculated to be 198 gallons per capita per day (gpcd) (California Department of Water Resources 2012).

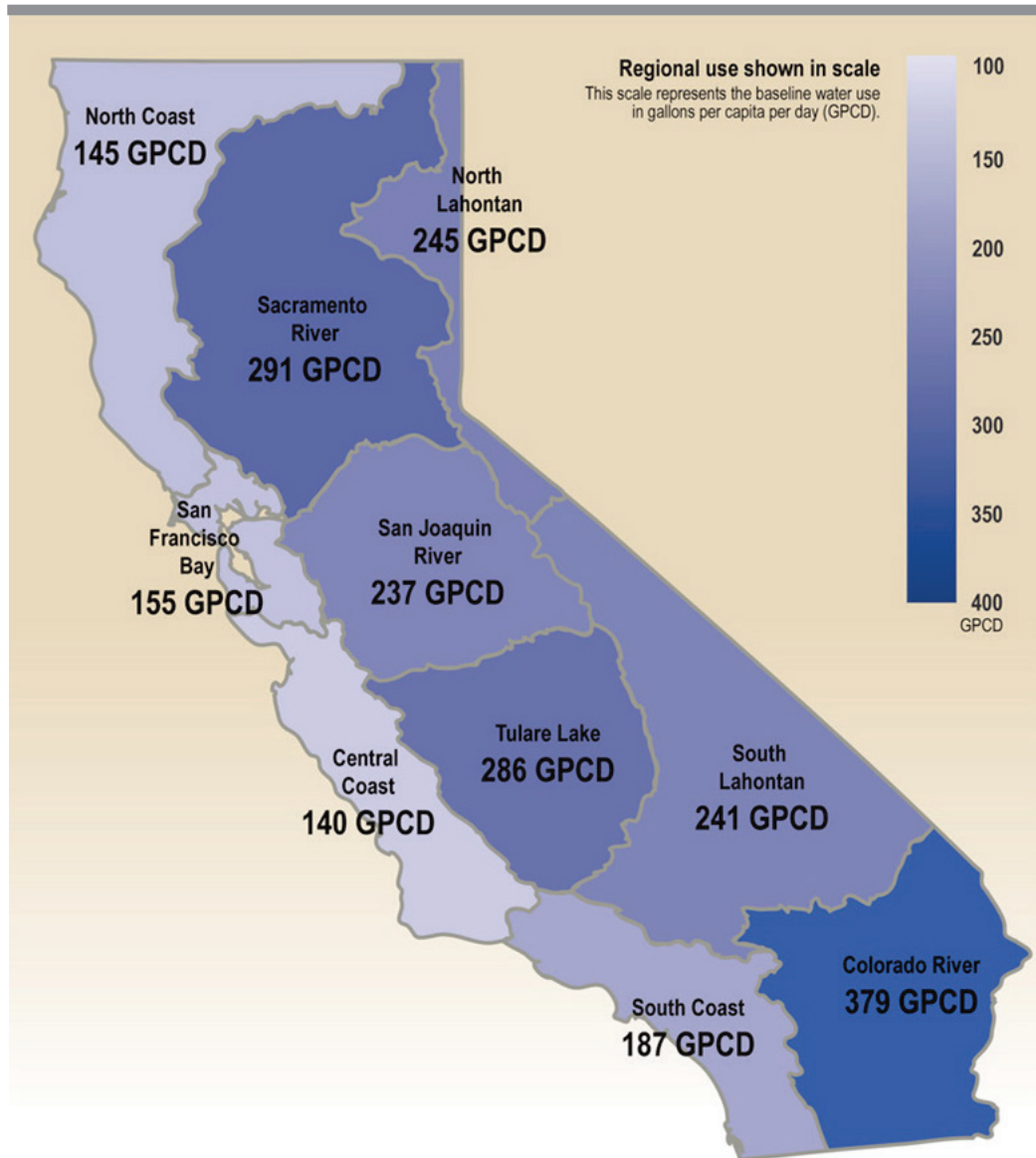
Figure 1 shows how baseline water use differs regionally across the state, and Figure 2 displays the range of per-capita water use reported by the water agencies in their 2010 UWMPs. Generally, lower water use is seen along the coast, with increasing water use in the inland valleys; however, low or high per-capita water use is not necessarily an indicator of efficiency. Climate and land use factors can have a significant effect on water use. The coastal areas generally use less water in their landscapes because the marine climate provides a lower rate of evapotranspiration and because the sizes of coastal residential landscapes tend to be smaller than those of inland areas. Increased efficiencies have also been needed on the coast, because these communities were strongly affected by the 1988-1992 drought and a number of conservation programs were implemented to improve water supply reliability.

Baseline Water Use by Sector

The total volume of urban water use, statewide, as reported in California Water Plan Update 2009 (Update 2009) is 8.8 maf per year (California Department of Water Resources 2009). This is an eight-year average for the time period of 1998-2005.

There is some variation in water use reporting between Update 2009 and the 20x2020 calculations used in UWMPs. When estimating urban water use, Update 2009 calculations included the use of recycled water, self-supplied industrial water, potable water supplied to agriculture, conveyance losses, and water used for groundwater recharge. The 20x2020 calculations used in UWMPs do not include these urban water uses.

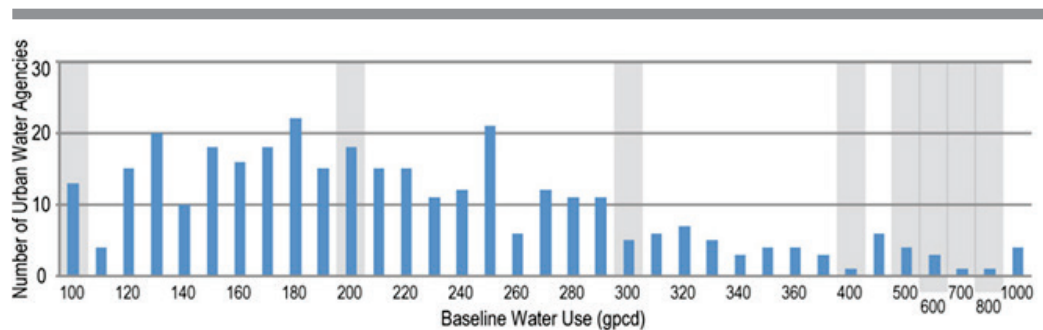
Figure 1 Average Baseline Water Use by Hydrologic Region



Source: California Department of Water Resources 2012

Note: This map displays the average water use, by hydrologic region, during the baseline period, roughly 1996 through 2005. The numbers displayed are in gallons per capita per day. The hydrologic regions near the coast generally have smaller landscapes and cooler climates compared with inland regions, which have larger irrigated landscapes and warmer climates.

Table 2 and Figure 3 show the division of the 8.8 maf of urban water use (California Department of Water Resources 2009) into water use sectors.

Figure 2 Range of Reported Baseline Water Use

Source: California Department of Water Resources 2012

Note: This figure illustrates the range of reported baseline water use. Blue bars show the number of agencies reporting a particular baseline. Gray bars indicate a separation of 100 gallons per capita per day.

Water Use in 2010 — Progress in Achieving 20-Percent Reduction by 2020

Because of the economic downturn, the 2007-2009 drought, and a cool summer in 2010, many suppliers have reported significant drops in water use in the last few years, and some are already below their 2020 water use target. These suppliers are now focused on ways to keep water use low once the economy improves and a more typical weather pattern returns.

2015 and 2020 Water Use Targets

In the 2010 UWMPs, water suppliers reported an average 2020 water use target of 166 gpcd. This target is a 16-percent reduction from the statewide average baseline of 198 gpcd, which is less than the 20-percent goal. The legislation provided four methods for calculating the 2020 target, and this allowed some suppliers to select targets lower than the 20-percent goal, but none of the methods require suppliers to select targets higher than 20 percent.

After receiving the 2015 UWMPs, DWR is required to report to the Legislature on progress toward the 20-percent reduction goal. Suppliers are expected to be halfway between the baseline and the 2020 target by 2015. If the state, overall, is not on track to meet the 20-percent target, DWR is directed to provide recommendations to the Legislature on how the goal can be achieved.

A list of the individual water supplier's baselines and targets and more information on statewide and hydrologic region averages is available in DWR's report to the Legislature on the 2010 UWMPs (California Department of Water Resources 2012).

Meeting the Targets — Potential Savings by Sector

Since the early 1990s, voluntary implementation of DMMs, new codes and regulations has increased water use efficiency in California. However, abundant opportunities still exist to increase urban water use efficiency, and many of these opportunities will need to be tapped in order for California to achieve its 20-percent reduction goal by 2020.

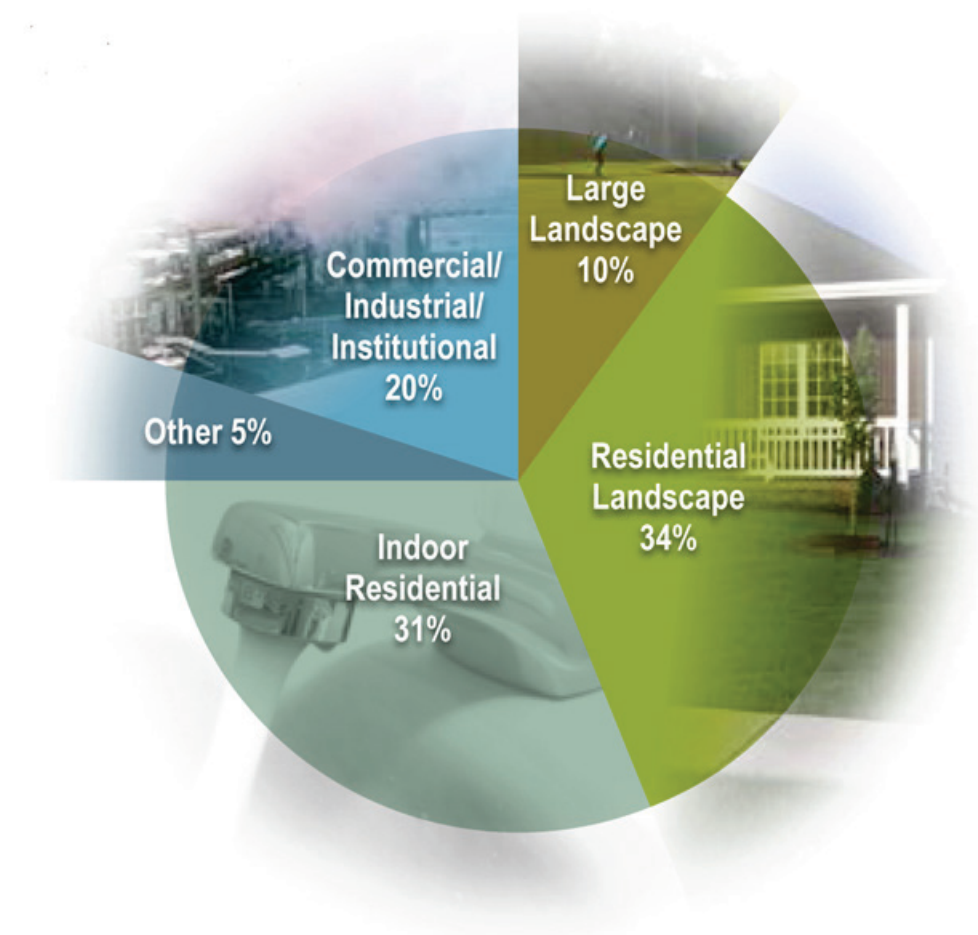
Table 2 Statewide Urban Water Uses

Sector	Percentage	Volume
Residential landscape	34%	3.0 maf
Large landscape	10%	0.9 maf
Indoor residential	31%	2.7 maf
Commercial, institutional, and industrial	20%	1.7 maf
Other	5%	0.5 maf
Total	100%	8.8 maf

Source: California Department of Water Resources 2009

Note: maf = million acre-feet

Figure 3 Statewide Urban Water Use: Eight-Year Average, 1998-2005



Source: California Department of Water Resources 2009

Note: This pie chart illustrates the relative water use of different sectors as a statewide average. The water use by sector will vary for each individual water agency.

Box 1 20x2020 Plan: History, Process, and Impact

History

In 2008, the Delta Vision Blue Ribbon Task Force called for improved water use efficiency and conservation to reduce exports from the Sacramento-San Joaquin Delta (Delta). The task force specifically recommended a statewide 20-percent per-capita reduction in water use by the year 2020. In response to this recommendation, the 20x2020 Agency Team on Water Conservation was formed. The agency team subsequently wrote the 20x2020 Water Conservation Plan (20x2020 State Agency Team on Water Conservation 2010) outlining recommendations on how statewide per-capita water use reductions could be successfully implemented to meet the goal of 20-percent reduction by 2020.

In November 2009, the Water Conservation Act of 2009, Senate Bill No. 7 of the 7th Extraordinary Session (SB X7-7), was enacted by the California Legislature (California Water Code Section 10608). The urban water conservation provisions of SB X7-7 reflect the approach taken in the 20x2020 Water Conservation Plan and set an overall goal of reducing per-capita urban water use statewide by 20 percent by 2020.

The 20x2020 Plan Process

Water suppliers play a fundamental role in carrying out the statewide water reduction goal of 20 percent by 2020. Each urban water supplier is required to set water use targets based on its historical water use, the local climate, and locally implemented conservation programs. ("Urban water supplier" is defined in California Water Code Section 10617.) The statewide goal will be met by compiling the water reductions from each water supplier.

The legislation does not require a reduction in the total volume of water used in the urban sector. That is because other factors, such as changes in economics or population, will affect water use. Rather, the legislation requires a reduction in per-capita water consumption. Water consumption is calculated in gallons per capita per day (gpcd).

As set out in the SB X7-7 legislation, and through the use of methodologies and criteria in Methodologies for Calculating Baseline and Compliance Urban Per Capita Water Use (California Department of Water Resources 2011), water suppliers:

- Must determine their baseline water use and target water uses for 2015 and 2020. Wholesale suppliers are not required to set targets but are directed to assist their retail suppliers in meeting the targets.
- Must report their gross water use during the final year of the reporting period (years 2015 and 2020). This is known as "Compliance Water Use."
- May revise their baseline water use calculations and change the method used to set their targets after submitting their 2010 urban water management plans.

Impact of the 20x2020 Plan

Projecting forward to the year 2020, with statewide population expected to be in the range of 44 million people, a decrease in per-capita water use of 20 percent would equate to an annual demand reduction of just over 2 million acre-feet of water.

The requirement that all urban retail water suppliers quantify per-capita baseline water use, set water use targets, and then show actual reductions in 2015 and 2020 has caused suppliers across California to pay particularly close attention to the effectiveness of their water conservation programs.

Descriptions of the potential for increased savings are presented below. These represent a statewide overview and are not intended as a blueprint for individual water agencies, because each agency will have its own unique strategy for achieving its 2015 and 2020 water use targets.

All water savings noted in the following sections are comparisons of potential savings by 2020 to the baseline water use reported by water suppliers in their 2010 UWMPs. Because baselines and targets are reported in gallons per capita per day, the descriptions presented below will state the current water use and potential savings in gallons per capita per day.

Landscape Irrigation

Annual water demand for residential and large landscape irrigation amounts to approximately 4 maf, or about 45 percent, of urban demand. Because this sector represents such a large portion of urban water demand and because water waste from landscapes is common — water running down street gutters, leaks, watering during rainstorms, etc. — landscape irrigation presents a significant opportunity for increasing efficiency and reducing unnecessary demand. Box 2 has more information on reducing landscape irrigation runoff.

Increased landscape water use efficiency can be accomplished with a variety of tools that are effective in any landscape sector, whether residential, commercial, or institutional. Some of these tools include regular maintenance of irrigation systems, irrigation audits to identify deficiencies, development of landscape water budgets, and selection of low-water-using plants. Some tools are available at low- or no-cost and can provide immediate and significant savings.

Urban landscapes can be divided into three categories: residential; large landscape; and CII mixed meter. Each of these uses is addressed more specifically below.

Residential Landscapes

Residential landscape irrigation represents the single largest end use of urban water, accounting for 34 percent of total urban use (California Department of Water Resources 2009).

Many factors contribute to the large amount of water used in residential landscapes, including population shifts to hotter interior regions, which often have larger residential landscapes (Hanak and Davis 2006); the prevalence of cool-season turf grasses and other high-water-use plants; irrigation systems that are inefficient and poorly maintained; and widespread overwatering of all plant types.

When comparing homeowners' actual landscape water use to a theoretical water requirement, one sees a mix of irrigation behaviors: homeowners who under-irrigate and those who over-irrigate (Irvine Ranch Water District 2011). It can be assumed that most of those who under-irrigate are nevertheless satisfied with the quality and appearance of their landscapes; otherwise, those homeowners would have increased their water use.

There are at least two possible explanations for this phenomenon: Either some landscapes require less water than previously thought, because actual plant water needs, soil conditions, and cultural factors contribute to a lower demand, or the standard used to estimate the theoretical water requirements needs to be reevaluated. It is apparent that many landscapes are successfully irrigated at rates below the current theoretical requirement.

In light of these findings, water suppliers would benefit from targeting their most resource-intensive landscape conservation efforts to water users that are over-irrigating (Irvine Ranch Water District 2011). As a marketing tool, a cost-benefit analysis based on water rates and other factors can help determine which customers would be the best candidates for intervention, both in terms of maximizing water supplier resources and customer buy-in. Furthermore, because most residential users underestimate the quantity of water used in their landscape (California Urban Water Conservation Council 2007c), education components remain a vital tool for increasing the water savings potential.

Box 2 Landscape Irrigation Runoff

Photo A shows an example of irrigation runoff, frequently seen in landscapes throughout California.

Fortunately, many opportunities exist to improve efficiency in landscape irrigation. These include the use of evapotranspiration controllers, soil moisture sensors, reduction of cool season turf, and education of water users. The Residential Runoff Reduction Study (Municipal Water District of Orange County and Irvine Ranch Irrigation District 2004) demonstrated that a combination of evapotranspiration controllers and user education can greatly reduce dry season irrigation runoff.

In this study, dry season irrigation runoff was measured from 138 residential and non-residential landscapes. After the runoff was measured, the landscapes were retrofitted with evapotranspiration controllers, and the water users were educated in efficient irrigation practices. A second set of runoff measurements was taken after the retrofit and user education.

A comparison of the first and second measurements showed that irrigation runoff had been reduced by 50 percent by the installation of evapotranspiration controllers and user education.

Photo A Irrigation Runoff



Landscape water budgets, based on landscape area and climate, are employed in the MWELo. (California Code of Regulations Title 23, Division 2, Chapter 2.7, Section 490). The MWELo formula for calculating water budgets was updated in 2010, thus lowering the amount of water in a landscape water budget. After more research is completed in plant water needs, it may be appropriate to lower the evapotranspiration adjustment factor used in the water budget calculation. Box 3 has more information on landscape water budgets.

Several water use studies (Pacific Institute 2003; Irvine Ranch Water District 2001; Hanak and Davis 2006; Irvine Ranch Water District 2011) indicate that residential landscape water demand can potentially be reduced by at least 20 percent, with some researchers estimating savings potential of 45 percent or more (Pacific Institute 2003).

The statewide average baseline water use for residential landscape irrigation is estimated at 79 gpcd. This is derived as follows: Baseline residential landscape use is 3.0 maf (Table 2), divided by a 2000 population of 33,780,000, and then converted to gpcd.

A conservative estimate of 20-percent reduction in residential landscape water use would represent a savings of 16 gpcd, equating to an annual statewide reduction of 789,000 acre-feet (af) by 2020.

Large Landscapes (Dedicated Meters)

Large landscapes are CII landscapes that are a category of landscapes set apart by the presence of dedicated irrigation meters. Dedicated metering serves the purpose of accurately measuring the water use of a landscape and making it possible to assign and monitor water budgets and detect leaks. The CUWCC landscape BMP requires water use budgets to be assigned at 70 percent of local reference evapotranspiration (ET_o).

Based on an eight-year average of DWR data (Table 2 and Figure 3), large landscapes with dedicated meters accounted for 10 percent of urban water use, equivalent to 0.9 maf. Water use through a dedicated landscape meter can be monitored by the irrigator and can provide immediate feedback on the amount of water moving through the meter. Programs such as the California Landscape Contractors Association (CLCA) Water Management Certification Program (WMCP) (California Landscape Contractors Association 2012) enable irrigation managers to monitor and track water use and manage a landscape at 80 percent of ET_o or less. Box 4 has information on dedicated water meters and California Water Code requirements.

The numbers and total acreage of sites designated as large landscapes will increase over time as mixed-use meters at existing CII landscapes are retrofitted to dedicated meters. All new CII landscapes over 5,000 square feet require a dedicated irrigation meter and are more accurately known as “large landscapes.”

A CII landscape water use efficiency study (California Landscape Contractors Association 2003) collected data from 449 CII landscapes. The results indicate that approximately 50 percent of CII landscapes were irrigated in excess of 100-percent ET_o. If those sites reduced water use to maintain a water budget of 100-percent ET_o, the author estimates a 15-percent demand reduction could be achieved.

Potential landscape efficiency gains could be much greater than 15 percent if conversions from cool-season turf to water efficient plants were included and if the water budget were reduced to 70 or 80 percent of ET_o.

Recent WMCP information from the CLCA Water Forums indicates that many sites maintained and managed under the WMCP are performing at water budgets of 80 percent of ET_o or less, with average irrigation rates of 64 percent of ET_o for the 704 sites enrolled in the WMCP in 2012 (California Landscape Contractors Association 2012).

Box 3 The Value of Landscape Water Budgets

Landscape water budgeting is a straightforward method for determining whether a site is receiving the correct amount of water to keep the plants healthy without wasting water. A water budget is calculated using local reference evapotranspiration data, an evapotranspiration adjustment factor, and the area (in square feet) of the irrigated landscape. The landscape area can be captured from landscape plans, by measuring the site, or through aerial imagery. Historically, obtaining the landscape area has been a challenge for water suppliers, especially when more than one meter may serve a parcel, but new tools and technology are becoming available that will simplify the process.

When the volume of water allowed in the water budget is compared with water use data, the irrigation manager can evaluate whether water use is on track and, if it is not, can make immediate changes to the irrigation schedule. Because weather conditions influence the water needs of plants, irrigation managers should assess compliance with the water budget weekly or at least monthly.

Water budgets are valuable communication tools. An irrigator that keeps a site within a water budget can show its customer the water savings and cost savings achieved when compared with historical use. Water suppliers can assign a water budget to an account and notify the customer and the irrigation manager when the budget is exceeded. Water budgets, coupled with tiered water rates, send a pricing signal that discourages wasteful water use.

Box 4 Dedicated Water Meters: California Water Code Section 535

Since 2008, water suppliers must install a dedicated landscape meter on new non-residential water service with a landscape area of more than 5,000 square feet. The California Green Building Standards Code requires dedicated meters, metering devices, or sub-meters to facilitate water management on non-residential landscapes from 1,000 square feet up to 5,000 square feet.

However, some water suppliers have found that after assigning water budgets and conducting outreach efforts, they are still not seeing the savings estimated in the 2003 CLCA CII landscape study, nor do they believe potential for further savings is as great (Brown pers. comm. Oct. 26, 2012). Other suppliers have seen a drop in landscape water use but attribute these savings not only to the training programs, but also to pricing, shortages, and other factors as well (Granger pers. comm. Oct. 19, 2012).

Newer study results will give a more current picture of CII landscape water use efficiency, but it is clear that sites that are actively managed by trained personnel are generally the most efficient and still retain potential for further savings.

Statewide average baseline water use for large landscapes is estimated at 24 gpcd. This is derived as follows: Baseline large landscape water use is 0.9 maf (Table 2), divided by a 2000 population of 33,780,000 and then converted to gpcd.

A conservative estimate of a 15-percent reduction in large landscape water use would represent a savings of 3 gpcd, equating to an annual statewide reduction of 148,000 af by 2020.

Commercial, Industrial, and Institutional Landscapes (Mixed-Use Meters)

Opportunities for water savings in CII landscapes with mixed-use meters are probably as high as residential landscapes; however, significant data gaps exist due to inconsistencies in water use reporting.

Suppliers voluntarily report their water deliveries and, depending on the agency, landscape water use may be included in CII, multi-family, or “other” categories. Because of these data gaps, potential water

savings in CII landscapes with mixed-use meters cannot be separated from CII water use and are included as part of CII water savings, discussed later in this chapter.

Indoor Residential Water Use

Indoor residential water use (both single and multifamily housing) accounts for about 31 percent of total urban water use in California (Figure 3 and Table 2). This equates to a statewide average baseline water use for indoor residential of 62 gpcd. This is derived by using 8.8 maf for the total annual urban water use (California Department of Water Resources 2009) and 33,780,000 for the 2000 population.

A comparison of California's baseline indoor residential water use, 62 gpcd, to a study of homes retrofitted with WaterSense and Energy Star fixtures and appliances (U.S. Environmental Protection Agency 2008), which had water use of 43 gpcd, shows that significant savings remain to be captured in this sector.

Residential indoor water is delivered through only a small number of fixtures — toilets, clothes washers, showers, faucets, and dishwashers. The percentage of water use by fixture is displayed in Figure 4. The following paragraphs address these fixtures, and potential savings, in more detail. Several regulations mandate high-efficiency fixtures. A discussion and comparison of these regulations is provided by the California Urban Water Conservation Council (2010).

Toilets

A study by American Water Works Association (AWWA) Research Foundation (1997) revealed that toilets were the biggest component of indoor water use at that time. Many older, inefficient toilets have been replaced with more efficient models since then, but, years later, it appears that toilets are still the largest user of indoor residential water use. More current studies (Pacific Institute 2003; Irvine Ranch Water District 2011) show that toilets account for 20 percent to 33 percent of indoor water use, which equates to an average of 13-19 gpcd.

Older toilets use 3.5 or 5 gallons per flush (gpf), but regulations have mandated increased efficiency. The 1992 California code required that new toilets sold in the marketplace have a flush volume of 1.6 gpf. These are called ultra low-flow toilets (ULFTs). In 2014 the code will require an even greater efficiency of 1.28 gpf. These toilets are known as high-efficiency toilets (HETs) and have been mandated in new construction since 2011.

Many existing toilets remain to be converted to efficient models. Estimates are that the saturation of ULFTs and HETs is 54 percent to 60 percent (Irvine Ranch Water District 2011; 20x2020 Agency Team on Water Conservation 2010).

The 20x2020 Plan calculates that retrofitting residential toilets, so that 81 percent are ULFT or HET, could save approximately 5 gpcd.

Clothes Washers

Clothes washers account for 14 percent to 18 percent of indoor residential water use (Pacific Institute 2003; Irvine Ranch Water District 2011), which is about 9.0-10.5 gpcd. However, according to the

Figure 4 Estimated Indoor Residential Water Use in California (Year 2000)

Source: Pacific Institute 2003

California Single Family Home Water Use Efficiency Study (Irvine Ranch Water District 2011), only about 20 percent of homes studied in 2007 were using efficient washers.

This indicates that there is great potential for decreasing per-capita water use for clothes washing through appliance replacement.

The water efficiency of clothes washers is rated using the term “water factor.” The water factor is measured by the quantity of water (gallons) used to wash each cubic foot of laundry. The lower the water factor rating, the more water-efficient the clothes washer.

Standards for the water efficiency of residential clothes washers have been put in place by the Department of Energy. These water factor standards have been moving progressively lower over several years. The most current standard will culminate in 2018 with a maximum water factor of 6.0 for standard top-loading machines and a maximum water factor of 4.5 for standard front-loading machines. For comparison, conventional washers have a water factor of 12 to 13.

The 20x2020 Plan estimated that potential savings from efficiency codes, active rebate programs, and natural turnover of clothes washers would be approximately 5 gpcd.

Leaks

Studies from Pacific Institute (2003) and Irvine Ranch Water District (2011) reveal that the water lost to leakage in the residential sector averages from 7 gpcd to 10 gpcd. This number is relatively large; however, the majority of the water loss was concentrated in a small number of homes. The median loss was found to be small, between 1.4 gpcd and 3.9 gpcd. Yet, 14 percent of the homes lost more than 17 gpcd to leaks, and 7 percent of the homes were leaking more than 34 gpcd. This variability suggests that leak reduction programs that target the homes with the highest leakage rates would be the most cost-effective for a water supplier.

Water suppliers can employ several methods to detect homes with high rates of leakage, including:

- Developing water budgets. Homes with leaks will exceed their water budgets and pay excess use rates, thus encouraging repair.
- Installing advanced metering infrastructure (AMI). AMI monitors water usage in real time, sampling hourly to every 15 minutes. Because of the frequent monitoring and collection of water use data, a constant flow (leak) can be detected quickly and efficiently. For a case study, see Box 5.
- Identifying excessive water users (by comparison of water bills with similar properties) and offering water audits to these customers.

If leaks were to be detected and repaired at homes with high leak rates, so that the average losses due to leaks were reduced to the median values (1.4 gpcd to 3.9 gpcd), the savings would be 6.0 gpcd to 7.5 gpcd (Pacific Institute 2003; Irvine Ranch Water District 2011).

Conservatively estimating that, on a statewide average, water agencies were able to work with their residential customers so that just less than half of this potential leakage could be detected and repaired, the savings would then be 3 gpcd.

Water agencies are also beginning to evaluate the water-saving potential of pressure regulating valve (PRV) replacement programs. PRVs reduce water supply pressure, protecting home appliances, while decreasing excess flows through plumbing fixtures and leaks. PRVs are typically installed when the house is built and they generally last 8 years to 12 years. Since PRVs are installed on the customer side of the meter, it is the customer's responsibility to maintain the PRV. Many water agencies already offer their customers information and technical assistance regarding PRV function and maintenance, and they are now beginning to consider additional programs to encourage PRV replacement.

Showers

Showers account for about 22 percent of indoor residential use, equivalent to about 11.8 gpcd to 13.5 gpcd. A study by Irvine Ranch Water District (2011) found that nearly 80 percent of all homes had shower heads operating at 2.5 gallons per minute (gpm) or less (the federal standard, as specified by the Energy Policy Act of 1992). WaterSense-rated showerheads have a maximum flow rate of 2.0 gpm or less, producing even greater savings. Further savings in shower water use can be achieved by continued retrofitting of inefficient shower heads and public education campaigns that include messages to take shorter showers. The 20x2020 Plan estimates that the potential water savings remaining to be captured in shower water use are approximately 1 gpcd.

Box 5 Case Study: City of Sacramento Advanced Metering Infrastructure

After installing advanced metering infrastructure (AMI) in more than 17,600 residences, the City of Sacramento reported the following successes during the two-year period of 2010-2011:

- 1,076 single-family homes showed leak alerts.
- 75 percent of leaks were verified in the field.
- 367 million gallons of aggregate annual water loss were calculated through AMI reports.
- 236 million gallons of water were saved, which equates to 12.6 gallons per capita per day.

AMI can play a major component in helping the City of Sacramento reach the State mandate of a 20-percent per-capita reduction by 2020.

2011 California Urban Water Conservation Council Advanced Metering Infrastructure Symposium, Sacramento

Faucets

Faucets account for about 18 percent of indoor use, approximately 11 gpcd to 12 gpcd.

The maximum flow rate for new faucets, set by federal standards in 1994, is 2.5 gpm, though some faucets, especially bathroom faucets, can operate as low as 0.5 gpm. The 1997 AWWA Research Foundation study estimated a 50-percent penetration of 2.2-gpm faucet aerators.

Savings in faucet water use can be achieved by continued retrofitting with low-flow fixtures and aerators and public education campaigns that include messages to “turn off the tap” when water is simply going down the drain. Box 6 has information regarding the use of sub-metering to encourage conservation in multi-family dwellings.

The California Single Family Home Water Use Efficiency Study (Irvine Ranch Water District 2011) assumes a reduction of 10 percent in faucet water use (11.5 gpcd times 10 percent = 1 gpcd). This equates to a savings of 1 gpcd.

Total Projected Savings for Indoor Residential

The statewide average baseline water use for indoor residential is estimated at 71 gpcd. This is derived as follows: Baseline indoor residential use is 2.7 maf (Table 2), divided by a 2000 population of 33,780,000 and then converted to gpcd. An East Bay Municipal Utility District pilot project used a new behavioral approach to encourage conservation (Box 7).

Adding the savings from each of the fixtures and appliances above, total projected water savings for indoor residential use is 15 gpcd, equating to an annual statewide reduction of 739,000 af by 2020 (Table 3).

Commercial, Industrial, and Institutional Sectors

The CII sectors cover a broad range of water uses, from schoolyard playgrounds and drinking faucets to bottling plants and restaurants. It is, therefore, a challenge to address these sectors, whether trying to make broad generalizations about CII water use as a whole or trying to drill down and find detailed data

Box 6 Multi-Family Dwellings and Sub-Metering

Multi-family units are often served by a single water meter, and the water bill is included as a fixed part of a tenant’s rent payment. This makes tracking individual tenants’ water use virtually impossible and removes the consumers’ incentive to conserve water in response to a high water bill.

When each dwelling unit within a multi-family property is individually metered, this is called sub-metering. A 2004 study (Aquacraft and East Bay Municipal Utility District 2004) found water savings of 15.3 percent when comparing sub-metered properties with rental properties that do not bill water separately from rent.

There are, however, numerous obstacles to capturing these savings, even in new buildings. Meter installation may lead to unacceptable pressure drop at some locations, and vertical plumbing layouts that supply water to each unit through multiple locations may make installation of traditional in-line water meters impractical. Important consumer protection issues must also be addressed if the interests of occupants dealing with water billing service companies are to be fully protected.

Sub-metering in multi-family dwellings could present an opportunity for significant water conservation in the future.

Box 7 Behavioral Water Efficiency — A New, Proven Conservation Tool

In addition to using conservation rate structures to incentivize water conservation, some water suppliers are using a new behavioral approach to encourage conservation. Based on insights from psychological research, behavioral water efficiency programs inform consumers of prevailing social norms, such as the average water use of neighbors, to drive conformity to a more efficient standard. This comparison creates a social framework in which water conservation is seen as highly valued by residents of a community.

The effectiveness of behavioral water efficiency programs has been tested in several communities, including in an East Bay Municipal Utility District pilot project. In this pilot, residents received home water reports with information about their water consumption, the consumption of similar households, and personalized recommendations on ways to save. The year-long pilot project involved 10,000 homes and a randomized control group. Households that received the home water reports reduced their water use from 4.6 percent to 6.6 percent, were more likely to participate in utility audit and rebate programs, and reported higher customer satisfaction. The unit cost of saved water was between \$250 and \$590 per acre-foot, with a mid-point cost of \$380 per acre-foot.

Table 3 Potential Savings for Indoor Residential Water Use

Use	Savings
Toilets	5 gpcd ^a
Showers	1 gpcd ^a
Leaks	3 gpcd ^c
Faucets	1 gpcd ^b
Clothes washers	4-6 gpcd ^a
Total	15 gpcd

Notes: gpcd = gallons per capita per day.

^a Source: 20x 2020 Agency Team on Water Conservation 2010.

^b Source: Irvine Ranch Water District 2011.

^c Sources: Derived from Irvine Ranch 2011 and Pacific Institute 2003.

on any particular use. The State does not currently have the data necessary to establish the baseline of use in each CII subsector, and the information needed to estimate statewide savings must await the development of baselines and metrics.

The CII sectors (not including large landscapes) use about 20 percent of urban water, which equates to 1.7 maf per year, or approximately 48 gpcd (California Department of Water Resources 2009, 2014; Pacific Institute 2003; 20x2020 Agency Team on Water Conservation 2010).

If water used for large landscapes is added to CII water use, the total CII water use would then be approximately 30 percent of urban water use. The 30-percent figure is often quoted for CII water use. However, water use for large landscapes will not be discussed in this section, as it has been addressed in the “Landscape Irrigation” section earlier in this chapter. The CII landscapes with mixed-use meters (indoor and outdoor use on one meter) are included in this section, because they are distinctly different from large landscapes, such as parks and golf courses.

Commercial, Industrial, and Institutional Water Uses

There are limited centralized data concerning how much water is used in the CII sectors. Data on the numerous end uses are even more scattered. However, water uses within the CII sectors can be grouped into the following common uses (Pacific Institute 2003; California Department of Water Resources 2014): process, restrooms, cooling, landscaping, kitchen, and laundry. With the exception of process water use, these end uses are very similar among CII users. Box 8 has information regarding process water use.

- **Process** — Process water inefficiencies include poorly adjusted equipment; leaks; use of outdated technology or equipment that is not water-efficient, or both; and use of potable water where alternatives, such as recycled or reused water, or waterless processes may be appropriate.
- **Restrooms** — Restroom usage is one of the higher end uses in CII. Inefficiencies in this area are similar to those in the residential sector; these include older toilets with high-volume flush rates and high-volume faucets. Waterless and low-flow urinals are components unique to the CII sectors, and these have brought significant savings to CII customers.
- **Cooling** — Water is used for cooling heated equipment, cooling towers, and air conditioning. Inefficiencies include improper adjustments made by system operators; system leaks; and the use of older, inefficient equipment.
- **Landscape** — Inefficiencies in CII landscape, as with other landscapes, include poorly designed and maintained irrigation systems, excessive watering schedules, and landscape designs that rely on high-water-using plants, especially cool-season turf, where low-water-using plants could provide the same benefit.
- **Kitchen** — The majority of the water used in the kitchens is for pre-rinsing, washing dishes and pots, making ice, preparing food, and cleaning equipment. Pre-rinse spray-valve retrofit programs have been, and continue to be, effective water efficiency programs. Inefficiencies in kitchen water use include usage of old machines, high-volume spray valves, and cooking practices and techniques.
- **Laundry** — Water savings can be achieved through use of more efficient washers.

Water Recycling and Reuse in the Commercial, Industrial, and Institutional Sectors

The use of recycled water (treated municipal effluent) or the reuse of process water within an industrial facility can play an important part in reducing CII water demand. With appropriate management, many non-potable water uses can be supplied with these alternate sources, such as cooling, washing, irrigation, and toilet flushing.

Box 8 Process Water

Process water is water used by industrial water users for producing a product or product content, or water used for research and development. Process water is highly specific to each industrial user.

Process water, within certain parameters, may be excluded from calculations of baselines and targets in order to avoid a disproportionate burden on another customer sector.

California Code of Regulations, Title 23, Section 596

Recycled water provides 209,500 af of fresh water a year to CII sectors, including power plants. Saline water use from coastal sources also provides additional water primarily to the mining and steam electric power plants, estimated at 14.5 maf per year (California Department of Water Resources 2014).

Water reuse opportunities exist in almost all industrial plants and are a growing focus of industry. Water reuse can range from reusing relatively clean rinse water for initial washing processes to the capture of rainwater or air conditioning condensate for use in irrigation or a cooling tower.

Water Agency Actions

Each water agency will face a unique blend of CII customers and will need to tailor the implementation of their CII water conservation program to fit local needs and opportunities. However, certain actions will assist water agencies in increasing CII water use efficiency to meet 2020 targets. These include identifying the highest users of CII water within the agency and offering or otherwise supporting water use surveys for these customers, continued and more aggressive conversions of mixed-use meters to dedicated landscape meters, and continued retrofitting of older toilets to ULFT and HET.

Commercial, Industrial, and Institutional Task Force

In response to the complexity of the CII sectors and the lack of data available on CII water use, the SB X7-7 legislation called for a CII Task Force to address CII water use efficiency, including development of alternative BMPs and metrics for water use in CII sectors, as well as identifying barriers to the use of recycled water. The CII Task Force wrote a report of its findings and recommendations to the Legislature (California Department of Water Resources 2014).

Assessment for Appropriateness of Best Management Practices

The CII Task Force identified a wide range of BMPs for use in the CII sectors. All of these BMPs are technically feasible and cost-effective in certain situations; however, the appropriateness of using any single BMP must be assessed for each site by the site operator or owner. The CII water user would need to conduct an audit of the site to determine which BMPs would be technically feasible and conduct a cost/benefit analysis to determine whether it is cost-effective to implement the BMPs. Organizations representing business and industry, water suppliers, the CUWCC, and DWR should educate CII businesses on the BMPs and approaches to doing audits and a cost-effectiveness analysis.

Commercial, Industrial, and Institutional Task Force Recommendations

The CII Task Force draft report (California Department of Water Resources 2014) includes the following recommendations:

- **Best Management Practices**
 - All stakeholders should endorse and adopt a formal process and commit to ongoing support for CII water conservation measures.
 - Technical and financial assistance and advice should be provided to those implementing the BMPs.
 - Local, sector-specific, and statewide approaches should be developed to track the success and effectiveness of BMP implementation.
 - CII water users should perform audits to identify opportunities for implementing all cost-effective BMPs.
- **Metrics and Measuring Progress**
 - CII establishments should use metrics to improve and track their water use efficiency over time.
 - Tools, guidance, and training should be provided to constituents and customers on the establishment and use of metrics-based benchmarking.
 - Efficiency standards should be set for certain water use devices.
 - Data should be collected on market penetration levels for particular devices and practices for which water use efficiency standards exist.
- **Recycled and Alternative Water Use**
 - Improve statutory and regulatory requirements to overcome barriers to the use of recycled water in a manner that is protective of public health and the environment.
 - Encourage financial and technical assistance to increase recycled and alternative water use.
- **Legislative Opportunities**
 - Provide the State with a mechanism and authority for collecting water use data for the purpose of tracking the progress of CII water use.
 - Promote plumbing code updates to encourage development and use of alternative water supplies and implementation of cost-effective BMPs.

Box 9 has information regarding how California prisons managed to become a water conservation model.

Projected Commercial, Industrial, and Institutional Savings

Because of the lack of sufficient water use data for the CII sectors, and the fact that water conservation potential varies greatly among technologies, industries, and regions, determining a value for projected savings is challenging.

However, the SB X7-7 legislation and the CUWCC MOU both point to a target savings in the CII sectors of 10 percent from the baseline. In order to maintain consistency with the legislation and the MOU, DWR will also use the value of 10 percent to project CII water savings. These potential CII water savings exclude savings from large landscapes, which are included in the “Large Landscapes (Dedicated Meters)” portion of this chapter.

The statewide average baseline water use for CII is estimated at 48 gpcd. This is derived as follows: Baseline CII water use is 1.7 maf (Table 2), divided by a 2000 population of 33,780,000 and then converted to gpcd.

Potential water savings for CII use is estimated at 10 percent, which is approximately 5 gpcd, equating to an annual statewide reduction of 170,000 af by 2020.

Box 9 California Prisons Reduced Annual Water Use by 21 Percent

By implementing a water conservation program, the California Department of Corrections and Rehabilitation (CDCR) achieved an annual water use reduction of 21 percent. The CDCR's water conservation program began in 2006, ramped up in 2008 in response to the drought declaration, and achieved a 21-percent reduction by 2009.

CDCR headquarters issued a document titled *Best Management Practices Water Management and Conservation*, which covered:

- Eliminating nonessential water use.
- Water-efficient landscaping and irrigation.
- Leak detection and repair.
- Laundries and vehicle washing.
- On-site water consumption surveys.

The CDCR enacted the following measures:

- Toilet flush meters were installed in nearly one-third of all adult institutions.
- Institutions report monthly water consumption to CDCR headquarters.
- Enacted low- or no-cost water conservation methods.

California Department of Corrections and Rehabilitation 2009

Water Loss Control in Distribution Systems

This section addresses water loss due to leaks in the distribution system of a water supplier. Leaks in the residential and CII sectors are addressed in their respective sections of this chapter.

Water loss control consists of the auditing of water supplies and implementation of controls to keep system losses to a minimum. A report by Southern California Edison (2009) estimated that 10 percent of the total volume of water supplied statewide is lost to leaks, which equals 0.88 maf. Addressing this loss is a major challenge to water suppliers, many of whom have aging water distribution systems in need of repair yet lack adequate funding for extensive water main replacement.

Audits

Water auditing is crucial to identifying the economically viable options that can be implemented for water loss control. Water utilities that do not perform water audits are most likely to be unaware of the level of real losses in their systems, making it unlikely for them to implement practices to curb these loss volumes.

A new standard method for conducting water audits was co-developed by the AWWA and the International Water Association (IWA). The AWWA/IWA water audit method is effective because it features sound, consistent definitions for the major forms of water consumption and water loss encountered in drinking water utilities. It also features a set of rational performance indicators that evaluate utilities on system-specific attributes, such as the average pressure in the distribution system and the total length of water mains.

The AWWA/IWA water audit method is detailed in the AWWA's manual *Water Audits and Loss Control Programs* (2009). The AWWA also offers free software for this auditing method that assists in tracking water consumption and losses and calculates the costs of losses, giving agencies important information for assessing the cost-effectiveness of leak reduction measures.

This new standard water audit is now a requirement for implementation of the CUWCC's MOU. All water agencies that are members of the CUWCC, as well as any agencies that seek funding from the State of California, are obligated to complete the standard water audit annually, to improve the quality of data collected on water loss, and to reduce water losses to the extent that is cost-effective.

Trenchless Pipe Repairs

Repairing leaky pipes can be an expensive and difficult proposition for agencies. Trenchless pipe repair is an emerging, cost-effective technology that offers an efficient alternative in pipe repair. Using this new technology, the damaged pipe is lined with a new cured-in-place pipe that seals all cracks, splits, and faulty joints. This trenchless technology requires no trenching or digging and can be done in much less time without large excavations, saving money, time, and labor and making repairs and maintenance more cost-effective.

Meters

Measurements of water use are a necessary component in developing water budgets and detecting leaks. Consumers and water agencies are aware of water use when it is being metered and monitored. The water use data can be mapped for trends to detect water loss.

The 2010 DWR Public Water Systems Statistics estimates that 6 percent to 7 percent of connections in California are still unmetered. There are huge potential savings by metering water use. The CUWCC, in its MOU, BMP 1.3, estimates a 20-percent savings when water meters are installed (California Urban Water Conservation Council 2009).

As of 2012, the California Water Code required full metering for customers of all urban water suppliers served by the federal Central Valley Project by 2013. Full metering is required by 2025 for customers of all other urban water suppliers with unmetered service connections.

Although water meters aid in preventing water loss, a recent study by the U.S. Environmental Protection Agency (EPA) and the Water Research Foundation (2011) shows that water meters in service lose their accuracy through use. Low flows of 1/8 gpm may go unrecorded by meters that are set to run at 1/4 gpm. Water meters often need to be recalibrated and checked. Higher accuracy standards should also be considered to capture a greater share of low flows that are indicative of leaks.

Projected Savings

The statewide average baseline water loss is estimated at 13 gpcd. This is derived as follows: Baseline losses are 0.5 maf ("Other" in Table 2), divided by the 2000 population of 33,780,000, and then converted to gpcd.

Given that the estimated water loss in California is 0.5 maf, and that 40 percent of that is estimated to be economically recoverable, the calculated water savings from cost-effective water loss control (0.5 maf times 40 percent) is 200,000 af, or 5 gpcd.

Combined Demand Reductions

Combining the estimated demand reductions from each sector, as detailed in the preceding paragraphs, the State of California could theoretically reduce demand for potable water in the year 2020 by more than 2 million af (Table 4).

Table 4 Projected Savings by Sector

Demand reduction sectors	Reduction	Projected savings in 2020
Large landscape	3 gpcd	148,000 af
Commercial, industrial, and institutional	5 gpcd	170,000 af
Residential interior	15 gpcd	739,000 af
Residential exterior	16 gpcd	789,000 af
Water loss control	5 gpcd	200,000 af
Total	44 gpcd	2,046,000 af

Notes: gpcd = gallons per capita per day, af = acre-feet.

Alternative Water Sources — Recycled Water, Desalinated Water, Gray Water, and Rainwater

Alternative water supplies are expected to further reduce statewide demand of potable water by the year 2020.

Alternative water sources vary in water quality, level of treatment, local availability, and suitability for intended uses. Recycled water and desalinated water undergo the highest level of treatment prior to use and are discussed in detail in other resource management strategy reports.

Residential rainwater capture and gray water reuse are sources of water that can be used without the high investment in infrastructure that recycled water or desalinated water require.

Rainwater capture is discussed at length in the *Urban Stormwater Runoff Management* resource management strategy report but it should be mentioned here that on-site rainwater capture, in the form of rain gardens, bioswales, pervious surfaces, and other landscape features, can reduce the amount of potable water needed for irrigation by replenishing soil moisture levels and shortening the irrigation season. A small to moderate-sized rain garden can collect thousands of gallons of water. For example, a demonstration rain garden at the Richardson Bay Audubon Center & Sanctuary in Marin County (Salmon Protection and Watershed Network 2010) can collect nearly 3,900 gallons of water in a 315-square-foot rain garden with approximately 22 inches of annual rainfall.

Although there is tremendous interest in rainwater capture with rain barrels and cisterns, California’s dry summer climate brings into question the cost-effectiveness of small rain capture devices in many regions of the state. However, cisterns and other large-volume storage devices begin to become cost-effective in areas where the rainy season extends into the irrigation season or where supplied water is very expensive,

unreliable, or difficult to convey. Unlike rainwater capture for irrigation, in which supply availability and demand are out of sync, rainwater capture for year-round indoor non-potable uses, such as toilet flushing, may be the most practical application. Rainwater standards are printed in the 2013 California Plumbing Code.

During the 2013 triennial code cycle, gray water standards were revised by the California Building Standards Commission and the Department of Housing and Community Development and were organized in Chapter 16 of the California Plumbing Code. Gray water use will increase over time, partly due to changes in the gray water standards. The revised standards make it easier for a water user to install a gray water system; simple systems supplied by clothes washers or single fixtures do not require a building permit if certain conditions are met.

In its 2010 UWMP, the Los Angeles Department of Water and Power features a case study of alternative water use by one of its residential customers. In addition to collecting rainwater in 18 rain barrels, the customer installed a gray water system using the waste water from her clothes washer. The clothes-washer-supplied gray water system generates approximately 7,000 gallons of water per year by the family of three. By adding the shower and bathroom sink to the gray water system, the water generated for landscape irrigation could exceed 53,000 gallons of gray water per year.

The California Single Family Home Water Use Efficiency Study (Irvine Ranch Water District 2011) found that the annual estimated irrigation demand averages about 90,000 gallons per year at the homes studied. Based on this assumption, this family could offset nearly 60 percent of its irrigation demand by the expanded gray water system. Under the new gray water standards, a plumbing permit is not required if the plumbing is not altered and if health and safety conditions are met.

The Importance of Conservation Rate Structures

Conservation rate structures are rates set by water agencies to provide price signals to consumers and encourage water conservation. Conservation rates are also known as volumetric rates, because the customer bill reflects the volume of water used. These structures can be applied to water supply as well as wastewater (sewer) services (Box 10).

Properly constructed rates can be significant in motivating customers to save water. When determining conservation rate structures, water suppliers must also ensure revenue stability. This is done through a combination of variable and fixed revenues, which ensure that adequate funds are provided to operate and maintain the system even when water use is declining.

Some examples of conservation rate structures include:

- Increasing block tier structures: The cost per unit of water increases as the consumer uses more water.
- Seasonal rates: Water rates are set higher during the summer months, when peak usage occurs.

Box 10 Consumption-Based Fixed Rates, City of Davis

Volumetric water rate structures provide a strong conservation incentive to customers. However, changes in customers' water use can cause a water supplier's revenue to vary, making it difficult to cover fixed costs.

Beginning in January 2015, the City of Davis will begin implementing an innovative rate structure, known as "consumption-based fixed rates." This structure introduces a method that provides revenue stability for the water agency, regardless of the volume of water sold, while also providing a conservation price signal to its customers.

This unique rate structure divides the agency's fixed costs proportionally among all its customers, based on the customers' peak use the previous year. Customers who have implemented conservation measures and reduced their water use will lower the fixed charge on their bill. The agency's variable costs are covered by including a volumetric charge on customers' bills.

More information about consumption-based fixed rates can be found at <http://cwee.ucdavis.edu/projects/CBFR>.

- Water budget structures: Each residence has an inclining block rate structure designed according to the number of occupants, landscape area, local climate, and possibly other factors. The prices of the tiers increase significantly after the base usage tier has been reached.
- Water budgets with punitive tiers when budgets are exceeded: Often the revenue generated from punitive tiers is used to fund the conservation programs.

Flat rates, where customers' bills do not reflect the volume of water used, are not considered conservation rates because they do not send a price signal to the consumer and do not encourage conservation. Box 11 has information on one successful conservation rate structure.

Conservation Rate Structures for Wastewater Services

Although roughly 90 percent of California households served by a public water supplier pay for drinking water through a volumetric rate, about 70 percent of such California households pay for sewer service through a flat, non-volumetric charge. And sewer charges can be significant: In some jurisdictions sewer charges can be equal to, or greater than, water charges. By billing sewer service at a flat rate, the price signal rewarding water efficiency is being cut in half for a majority of California households.

Water efficiency can reduce future infrastructure requirements for sewer service, and volumetric pricing for sewer service is encouraged by the EPA, the Water Environment Federation, and the CUWCC.

Installation of new hardware is generally not required in order to begin volumetric billing for wastewater, but where water and sewer are provided by different agencies, interagency cooperation is needed, and billing software modifications are likely (Chesnutt et al. 1994).

Volumetric wastewater pricing requires access to metered water consumption records and the ability to generate a customer bill. Sewer agencies currently billing fixed charges on a combined water-wastewater bill would have the fewest implementation constraints. A sewer agency with a service area that cuts across multiple water agency service area boundaries would face more implementation challenges.

A 2011 report (A&N Services Inc. 2011) presented a approximately 4-percent reduction in residential water use, with a 10-percent sewer service rate increase.

Box 11 Successful Conservation Rate Structure: Irvine Ranch Water District

The rate structure at the Irvine Ranch Water District (IRWD) signals customers when they are exceeding their water budget and signals the IRWD about which customers are in need of attention.

The IRWD sets water budgets for each customer based on a variety of factors, such as the size of a landscape area, the weather, the number of residents, or the industrial or commercial business types. When a customer exceeds his or her water budget, the price per unit of water becomes more expensive. By taking these factors into consideration, the IRWD is able to customize the water budget for each customer and ensure a fair allocation.

The IRWD also charges a monthly fixed charge based on meter size. The fixed charge covers all operating costs and related water-use efficiency programs. The IRWD operates with a stable revenue stream despite variability in the volume of water sold.

Potential Benefits

Urban Water Use Efficiency

Using water efficiently yields multiple benefits, including:

- Increased reliability of water supplies.
- Increased capacity to meet the growing water demand of California's increasing population.
- Delayed capital costs for new infrastructure to treat and deliver water.
- Reduced contaminated irrigation runoff to surface waters (Box 12).
- Reduced volume of wastewater, thus reducing capital costs and ongoing treatment costs.
- Increased availability of water for surface or groundwater storage.
- Reduced water-related energy demands and associated greenhouse gas emissions.

Climate Change

Urban water suppliers and water users may be particularly vulnerable to changes in climate because they require highly reliable water supplies and because demands for water tend to grow over time with population. While some agricultural water users may be able to temporarily reduce water use by fallowing land or changing cropping patterns, urban water uses tend to have much less flexibility. Urban water use efficiency provides a key strategy for addressing these vulnerabilities.

Key impacts of climate change that relate to urban water supplies include:

- Warming temperatures, increasing water usage, particularly for outdoor irrigation.
- Decreasing snowfall, reducing the natural water storage found in the Sierra Nevada snowpack.
- Precipitation shifting from snow to rain, requiring a change in water supply management.
- Rising sea levels:
 - Threatening water supply infrastructure in coastal communities.
 - Increasing seawater intrusion into coastal freshwater aquifers.
 - Reducing water exports from the Delta.
- Increasing frequency of floods, droughts, and wildfires damaging watersheds that provide water to urban communities.

To help address these climate-related challenges, State and federal agencies have developed several programs that provide guidance and information to urban water suppliers. In 2011, the DWR, the EPA,

Box 12 Reducing Irrigation Runoff Helps Local Waterways

Improving irrigation efficiency will prevent irrigation runoff, saving both water and energy and preventing the contamination of receiving waters by landscape pesticides, fertilizers, pet wastes, and sediment.

Sampling of the water quality in urban streams throughout California has found the universal presence of common landscape pesticides, such as diazinon, fipronil, chlorpyrifos, bifenthrin, among others. When excess irrigation water is applied, these pesticides, as well as herbicides, fertilizers, other nutrients, and pathogenic organisms, are washed into the stormwater system and local watersheds. These contaminants are toxic to aquatic organisms.

Dry-season irrigation runoff can be prevented by irrigation system maintenance, proper irrigation scheduling, and landscape design. Irrigation scheduling should be appropriate for the site conditions, when factoring in slope, soil type, and the ability of the soil to absorb the water.

Incorporation of rain gardens and vegetated swales into a landscape design will also retain runoff from irrigation and rainwater, reducing negative impacts on local waterways.

the U.S. Army Corps of Engineers, and the Resources Legacy Fund cooperatively developed *Climate Change Handbook for Regional Water Planning* (<http://www.water.ca.gov/climatechange/CCHandbook.cfm>), which provides a comprehensive resource for regional water managers but includes information that will be useful to urban water managers as well. Even more focused on urban water providers is the EPA's Climate Ready Water Utilities program (<https://www.epa.gov/crwu>) which provides guidance and tools specifically for water utilities to incorporate climate change into their planning and operations.

Adaptation

Water conservation and water use efficiency are considered primary climate change adaptation strategies — those that should be undertaken first because they are generally lower-cost and provide multiple benefits. By implementing practices that make the most of available water supplies, practices that reduce waste and increase efficiency, the urban water use sector will be better equipped to adapt to potential reductions in water supply.

Mitigation

Supplying and treating water for urban use requires a high amount of energy, which in turn contributes to greenhouse gas emissions and climate change. Reducing the amount of water used in the urban setting reduces the energy used, thus mitigating impacts to climate change. Urban water use efficiency is both a mitigation measure and an adaptation measure for climate change. Box 13 highlights the connection between urban water use, energy, and greenhouse gases.

Potential Costs

Increasing the supply of water has the same effect on water availability as decreasing the demand for water (through increased efficiency). However, historically reliable methods for increasing supply, such as building new dams for surface storage, or increasing water exports from the Delta, are less certain as California moves into the future. Many water suppliers are turning to other strategies, such as improving efficiency, to meet increasing demand. And as the costs for increasing water supply go up, even the more expensive conservation strategies may become economically viable in the future.

Box 13 Climate Change and Water Use Efficiency: The Energy-Water Nexus

California's energy and water resources are entwined. Energy is used to transport, pump, heat, cool, treat, and recycle water. And water is used to generate hydroelectricity and to cool power plants.

According to the report *California's Water-Energy Relationship* (California Energy Commission 2005), water-related energy use consumes about 19 percent of California's electricity, 88 billion gallons of diesel fuel, and 30 percent of non-power-plant natural gas, which together equate to about 12 percent of total statewide energy use. Urban and industrial water use, including conveyance, treatment, distribution, and end uses, account for about 11 percent of statewide energy use (the other 1 percent being related to agricultural water use).

When water is used efficiently, there is a corresponding savings in energy. Also, because most energy production creates greenhouse gases that contribute to climate change, water use efficiency is a method for mitigating climate change.

In 2004, California Urban Water Conservation Council members who implemented the council's best management practices reported a savings of 27 billion gallons of water. This significant water savings also saved more than 234 million kilowatt-hours of electricity and an estimated \$200 million in energy costs.

Table 5 shows some examples of costs for water use efficiency practices. These costs will vary from supplier to supplier, but they are provided here as an illustration of what can be reasonably expected.

It is conservatively estimated that a well-implemented set of water conservation programs would cost a water supplier an average of \$333 to \$500 per acre-foot (Alliance for Water Efficiency 2008). Box 14 shows the relative costs of six alternative water solutions, including conservation, using the San Diego area as an example.

Table 5 Sample Costs of Water Use Efficiency to Water Suppliers per Acre-Foot of Water Saved

Program types	Sample costs per acre-foot
Residential programs ^{a, b, c, d, e}	Toilet rebates: \$158-\$475/af Residential audits: \$236-\$1,474/af Clothes washer rebates: \$154-\$480/af
Landscape programs ^{a, b, d, e}	Landscape audits: \$58-\$896/af Equipment rebates: \$15-\$181/af Turf removal: \$274-\$717/af Water budgets: \$10-\$59/af
Commercial, industrial, and institutional programs ^{b, c, f, g}	Toilet rebates: \$242-\$1,018/af Urinal replacement: \$320-\$583/af Pre-rinse spray valves: \$78/af
Utility operations programs ^{d, h}	System audits/leak detection: \$203-\$658/af

Notes: af = acre-foot

^a Source: City of Paso Robles 2010.

^b Source: Los Angeles Department of Water and Power 2010.

^c Source: California Urban Water Conservation Council 2004, 2005a, 2006, 2007a.

^d Source: Marin Municipal Water District 2010.

^e Source: City of Sacramento 2010.

^f Source: East Bay Municipal Utilities District [date unknown].

^g Source: Alliance for Water Efficiency 2012.

^h Source: California Urban Water Conservation Council 2007b.

Box 14 San Diego: Comparing Water Source Options

A 2010 study (Equinox Center 2010) comparing the marginal costs of six alternative water solutions for San Diego concluded that conservation was the most favorable and least costly option.

Table A Cost per Acre-Foot by Water Source

Water source	Cost per acre-foot
Imported water	\$875-\$975
Surface water	\$400-\$800
Groundwater	\$375-\$1,100
Desalinated water	\$1,800-\$2,800
Recycled water	\$1,200-\$2,600
Conservation	\$150-\$1,000

These costs were determined for the San Diego area and would vary for each individual water agency

There are other important water conservation programs that cannot be quantified in terms of cost per acre-foot of water saved. These include designating and supporting a water conservation coordinator, implementing education and outreach programs, using water conservation rate structures, and developing and implementing a water waste prohibition ordinance.

Major Implementation Issues

Reduced Water Agency Revenue for Water Conservation

Because of the economic downturn, many water agencies have reduced their staff and other expenditures for water conservation. This reduction comes at a difficult time, when water agencies will need to increase, or at least maintain, the level of conservation in their districts in order to meet the 20-percent reduction by 2020.

Rate Structures and Water Agency Revenue

Providing customers with correct price signals to use water efficiently is not a simple task. The appropriate signals may vary from agency to agency and from community to community. And if the price structure is not set up correctly, the resulting water conservation can negatively affect the amount of revenue collected by a water supplier. The less water customers use, the less revenue the water supplier receives, which creates a disincentive for the water agency to encourage conservation. Also, because of seasonal variation in water use, some price structures may increase variability and fluctuation of water utility revenues.

This problem poses a hardship on the utility's ability to meet its revenue requirements and can undermine the financial viability of their systems and the ability to meet service needs and infrastructure maintenance.

The process for changing rate structures can also be challenging in and of itself. Regulations impose certain limitations, public support can be difficult to gain, and water board elections may influence the willingness of board members to agree to rate changes.

Lack of Public Awareness Regarding Landscape Water Use

Most homeowners are not aware that the majority of their water use takes place in the landscape, nor are they aware that much of that irrigation water is used inefficiently. In the 2007 Statewide Market Survey: Landscape Water Use Efficiency (California Urban Water Conservation Council 2007c), the researchers found that most respondents either had no idea how much water they used in their landscapes, or they believed their water use was below the statewide average. Coupled with the tendency to leave irrigation controllers on the default setting year round and a lack of irrigation system maintenance, a statewide education campaign is needed to educate water users and increase awareness of meaningful actions that will save water in landscapes.

Landscape Area Measurement for Water Budgets

Knowing the area of a landscape is critical to developing a water budget for the site. A water budget, in turn, will assist in determining whether the landscape is being watered efficiently.

Many water suppliers have not determined the extent of landscape area in their service area. Impediments to measuring or estimating landscape area include the high cost of physically measuring the site or purchasing satellite imagery, a lack of expertise in utilizing available satellite data, linking the parcels with customer data, segregating areas served by multiple meters, and assessing the density of vegetated canopies.

Inconsistent Implementation of the Model Water Efficient Landscape Ordinance

By the end of 2010, 333 local land use agencies had reported on the status of adoption of water efficient landscape ordinances. However, it is not known how consistently local agencies enforce water efficient landscape ordinances. Local agencies are challenged by the complexity of landscape and irrigation design requirements and a lack of staff to review and inspect landscape. The common disconnect between water suppliers and land use authorities further complicates the issue.

Data on Industrial Water Use Are Limited

The last survey published by DWR to obtain valid information on industrial water use (Bulletin 124-3) was conducted in 1979. This information is out of date, but no current data exist. The survey determined rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.

Water Loss

The amount of water lost due to leakage in the distribution system of the State's water suppliers is not well known. This is largely due to the fact that not all water suppliers perform regular water loss audits. If water audits are not conducted, it is difficult for a water agency to know the extent of its losses and unlikely that the agency will implement practices to reduce these losses.

Lack of a Standardized Efficiency Measure for California Urban Water Suppliers

One of the limitations to the development of the 20x2020 Plan goal was the lack of an effective measure of the level of water use efficiency in a supplier's service area. The gpcd is useful to track changes in water use in individual water agencies over time, but due to differences in landscape area, climate, and CII water use it is not useful as measure of efficiency. The lack of a standard measure of supplier efficiency is one reason that four different methods for setting a 2020 water use target were provided in the SB X7-7 legislation.

Recommendations

1. **Assist Utilities in Developing Sustainable Conservation Rate Structures** — DWR, in partnership with the CUWCC, the U.S. Bureau of Reclamation, the California Public Utilities Commission, the Association of California Water Agencies (ACWA), the California Water Association, and water agencies should lead an investigation to analyze and evaluate the effectiveness of rate structures in conserving water and meeting water agency revenue requirements. DWR should disseminate the findings and recommendations from the study, as well as guidance to water agencies, throughout the state by way of regional workshops and a detailed page on the DWR Web site.
2. **Expand the Save Our Water Campaign** — DWR, in coordination with ACWA, the CUWCC, water suppliers, local stakeholders, and irrigation manufacturers, should expand the statewide Save Our Water campaign. Initially, the landscape portion of the campaign should focus on cost-effective ways to improve irrigation system function and irrigation controller programming.
3. **Assist Water Agencies in Landscape Area Measurement and Water Budgets** — DWR, in coordination with the CUWCC, should assist water suppliers in finding easy and inexpensive ways to obtain landscape area data for parcels in their service areas and offer workshops that highlight successful programs. As a priority, water agencies should measure the landscape area for sites with dedicated meters first, because their landscape water use is known. A comparison of water use and water budget will determine if the landscape is being over-watered. Water agencies can then target the sites that are over-irrigating, a cost-effective method for reducing landscape irrigation demand.
4. **Increase Landscape Water Management Skills** — Water use efficiency is most easily achieved on landscapes with properly designed and installed irrigation systems and managed with water budgets. To make this possible, the Contractors State License Board should increase the emphasis and testing requirements in the C-27 Landscape Contractor's exam in the subject areas of irrigation design and installation and water budgeting to ensure landscape professionals have the needed skills. DWR, water suppliers, and the landscape industry should increase opportunities to improve water management skills of non-English-speaking workers and workers that do not hold a contractor's license.
5. **Update the Model Water Efficient Landscape Ordinance** — DWR should work with local agencies, local water suppliers, and the landscape industry to identify and remove barriers to implementation of the MWEL. The MWEL should be updated periodically based on new findings, innovation, and technological improvements.
6. **Encourage Innovation in Irrigation Equipment Design That Increases Durability, Reliability, and Ease of Use** — The irrigation manufacturing industry should work with the

- landscape industry, universities, and other industries to develop irrigation equipment, sensors, and controllers that are more durable and easier to install, maintain, and program.
7. **Update the Survey of Industrial Water Use** — Because the last published survey on industrial water use in California was conducted in 1979, and updated data are needed by local agencies and the State in order to better manage industrial water use, DWR should update the survey of industrial water use, Bulletin 124-3. The survey should provide information on the rates of industrial water use (including both water agency and self-supplied water sources), quantities of water recycled by industry, and quantities of wastewater discharged by industry.
 8. **Require Water Audits in 2015 Urban Water Management Plans** — To reduce water loss in water distribution systems, the Legislature should revise the Urban Water Management Planning Act to require water suppliers to complete the AWWA auditing program and report their water audit, water balance, and performance indicator in their 2015 UWMPs. Signatories to the CUWCC MOU are already required to perform this audit annually. Water audit data reported to the CUWCC provided valuable information on the extent of water losses that can be economically recovered by the water agencies. More on the AWWA auditing program can be found at <http://www.awwa.org/resources-tools/water-knowledge/water-loss-control.aspx>.
 9. **Develop a Standardized Efficiency Measure for California Urban Water Suppliers** — Through a public process, DWR should develop a standardized water use efficiency measure for California urban water suppliers. The measure would be used to determine efficient water use for urban water suppliers and would account for differences in irrigated landscape area, climate, population, and CII water use. The single standardized measure for supplier water use efficiency would better permit customers, utilities, and State officials to evaluate the efficiencies of California urban water suppliers across the state.
 10. **Investigate Gray Water Use in New Residential Applications** — In cooperation with water suppliers and developers, DWR should conduct a pilot study of gray water installation in new homes. The study should evaluate gray water use in landscapes and the feasibility of installing gray water systems in new homes.

Other Related Resource Management Strategies

- Water Transfers.
- Conjunctive Management and Groundwater.
- Desalination — Brackish and Sea Water.
- Municipal Recycled Water.
- Drinking Water Treatment and Distribution.
- Matching Water Quality to Use.
- Urban Stormwater Runoff Management.
- Land Use Planning and Management.
- Recharge Area Protection.
- Economic Incentives — Loans, Grants, and Water Pricing.
- Outreach and Engagement.

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