


The Untapped Potential of California’s Urban Water Supply: Water Efficiency, Water Reuse, and Stormwater Capture

Heather Cooley, Anne Thebo, Sonali Abraham
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EXECUTIVE SUMMARY

Water is the lifeblood of California, providing for the household needs of nearly 40 million people and supporting one of the most productive agricultural regions in the world, the health and viability of the state's aquatic and terrestrial ecosystems, and an economy that would make it the fifth wealthiest country in the world after the United States, China, Japan, and Germany.

Persistent water challenges, the ongoing severe drought, and the intensifying effects of climate change all highlight the vulnerability of California's water systems, but they also offer a new opportunity to rethink the state's water policies and strategies. The good news is that we are already seeing communities throughout the state rethink water "supply" and "demand." There has been tremendous progress across California in reducing water use through water conservation and efficiency and augmenting local supplies through water reuse and stormwater capture. Without these efforts, our current challenges would be much worse, demands on limited water supplies would be even higher, and ecosystem destruction would be more severe.

In this assessment, we quantify the potential for a range of water strategies in urbanized parts of California to both reduce inefficient and wasteful water uses and expand local water supplies. This assessment finds that urban water-use efficiency improvements could reduce statewide urban water use by 2.0 million to 3.1 million acre-feet per year (AFY). The reuse potential of municipal wastewater is 1.8 million to 2.1 million AFY, and the stormwater capture potential is 580,000 AFY in a dry year to as much as 3.0 million AFY in a wet year. Previous assessments have shown that these efficiency and supply options are more cost effective than traditional – and increasingly hard to implement – options to expand supply. Programs to tap this potential would tremendously help solve California's long-standing water problems.

URBAN WATER EFFICIENCY POTENTIAL

Greater urban water conservation and efficiency can reduce unnecessary and excessive demands for water, save energy, reduce water and wastewater treatment costs, and eliminate the need for costly new infrastructure. Between 2017 and 2019, California's urban water use averaged 6.6 million AFY, far below previous levels. Despite past improvements, California's water efficiency potential remains large. **We estimate that adopting proven technologies and practices could reduce urban water use in California by 2.0 million to 3.1 million AFY, or by 30% to 48%.** Water efficiency opportunities can be found across the state but are highest in the South Coast hydrologic region, followed by the San Francisco Bay and Sacramento River hydrologic regions. Water savings are greatest for the residential sector, followed by the commercial, industrial, and institutional sectors and reducing losses in the water distribution system. Additionally, savings can be found inside and outside but are slightly higher outside homes, businesses, and institutions.

WATER REUSE POTENTIAL

Water reuse is a reliable, local water supply that reduces vulnerability to droughts and other water-supply constraints. It can also provide economic and environmental benefits by reducing energy use, diversions from rivers and streams, and pollution from wastewater discharges. There is a significant opportunity to expand the reuse of municipal wastewater in California. An estimated 728,000 AF of municipal wastewater is already beneficially reused in the state each year. Onsite reuse—including the use of graywater—is also practiced across California, although data are not available to estimate its extent. **We estimate that an additional 1.8 million to 2.1 million AFY of municipal wastewater is available for reuse in California.** Nearly three-quarters of this water is currently being discharged to marine environments and is recognized as a high priority for future reuse projects. Water reuse opportunities can be found across the state but are highest in the South Coast and San Francisco Bay hydrologic regions, the two most populated regions in the state. Continued reductions in indoor per capita use can reduce the amount of water available for reuse, although population growth and increased economic activity could offset those reductions.

URBAN STORMWATER CAPTURE POTENTIAL

As water resources have become increasingly constrained, there is new interest in capturing urban stormwater runoff as a sustainable source of supply, with the added benefits of reducing flooding and protecting surface water quality. While no estimate of current stormwater capture exists, a growing number of communities, including Los Angeles and Fresno, are integrating stormwater into their water supply portfolios. In California, there are substantial opportunities to use stormwater beneficially to recharge groundwater supplies or for direct use in non-potable applications. **We estimate that the urban stormwater capture potential in California ranges from 580,000 AFY in a dry year to 3.0 million AFY in a wet year in urban areas overlying public supply aquifers.** This potential exists across scales—at the community, neighborhood, and even parcel or household scale—each of which will be essential for successfully capturing the full potential of this local water supply.

CONCLUSIONS AND RECOMMENDATIONS

California can fill the gaps between water supply and use with strategies that are technically feasible, cost effective, and compatible with healthy rivers and groundwater basins. Water efficiency options include the adoption of more comprehensive efficiency improvements that allow us to continue to provide the goods and services we want, with less water. New supply options include expanding water reuse and stormwater capture. These alternatives can provide effective drought responses in the near-term, permanent water-supply reliability in the long-term, and other co-benefits for the state. Efforts in these areas have been underway in California for decades, and laudable progress has been made, but much more can be done.

This assessment has identified the untapped potential to expand nontraditional supply options and increase urban water-use efficiency savings in California. This is the first step in tackling California's water problems, but it is also critical to adopt effective policies and programs to capture this potential. Here, we offer recommendations for helping to realize the untapped potential of water efficiency, reuse, and stormwater capture.

Expand Efforts to Improve Water Use Efficiency and Water Loss Control. There are significant opportunities to improve the efficiency of water use in California homes, businesses, and institutions and to reduce losses in water distribution systems. These improvements will make communities more resilient to climate impacts, cut water and energy costs, and provide additional co-benefits. Greater funding, combined with new and greater enforcement of regulations, expanded education and outreach, and additional technical assistance programs are needed to capture this untapped potential.

Expand the Supply and Use of Recycled Water. California has made considerable progress in expanding the reuse of high-quality treated wastewater, but large volumes of municipal wastewater continued to be discharged unused to local waterways, marine and estuarine environments, and land. A range of new actions and policies are needed to expand the supply and use of recycled water.

Increase Efforts to Capture and Use Stormwater. The variability of precipitation in California produces, at times, large volumes of stormwater that could be captured, used, or stored, expanding total water supply. This will require changes in local infrastructure and updated state and local policies and programs.

Improve State and Local Planning to Support Integration of Water and Non-Water Benefits into Water Management and Investment Decisions. Capturing the untapped potential for water efficiency, water reuse, and stormwater capture would benefit from broader improvements in state and local planning. In particular, efforts to incorporate multiple benefits—both water and non-water—into water management and investment decisions can improve a project's financial viability and public acceptance while helping to minimize adverse and unintended consequences.

Support State-Level Data Collection Efforts and Integration Across and Within State Agencies. Data from two large-scale data collection efforts (Electronic Annual Reports and Volumetric Annual Reporting) were key to our analysis of the potential for efficiency and reuse in California. Consistently reported data collected at regular time intervals is an essential component of making informed projections about water use, water availability, and investment needs.

Investigate Research Gaps to Improve Effectiveness of Water Efficiency, Water Reuse, and Stormwater Capture. There remain outstanding scientific questions that must be addressed for effective implementation of these supply options. State agencies, academics, water agencies, and community organizations all have a role to play in filling research gaps.

INTRODUCTION

California is a land of hydrological extremes, from water-rich mountains and redwood forests in the north to some of the driest deserts in North America in the south. It is also subject to damaging storms and floods and severe, persistent droughts. California suffered the worst five-year drought in 1,200 years between 2012 and 2016, and as of the completion of this study, is experiencing what is at least another two-year extreme drought (Griffin and Anchukaitis 2014). In 2020 and 2021, precipitation was well below average, and the mountain snowpack was extremely limited. Soil moisture and runoff in major rivers and water levels in the region's major reservoirs fell to record low levels. Agricultural lands have been fallowed and groundwater continues to be overpumped. Endangered fish species are threatened with extinction from high water temperatures and low flows.

Persistent challenges and the ongoing severe drought have shined a new spotlight on the vulnerability of California's water systems, but they also offer a new opportunity to rethink the state's water policies and strategies. The good news is that we are already seeing communities throughout the state rethink water "supply" and "demand." A 2014 study, led by the Pacific Institute in partnership with researchers at UC Santa Barbara and the Natural Resources Defense Council, found that urban and agricultural water-use efficiency improvements could reduce statewide annual water use by 8.5 million to 11.8 million acre-feet (AF), while reuse and stormwater capture could augment local water supplies by 1.6 million to 2.4 million acre-feet per year (AFY). Together, these alternatives could provide effective drought responses in the near-term *and* permanent water-supply reliability benefits for the state while reducing pressure on rivers and aquifers, lowering energy use and greenhouse gas emissions, and creating new business and employment opportunities. Since that assessment was completed, California has experienced several events affecting water-use patterns and the potential for additional water-supply alternatives. Some, such as the ongoing implementation of appliance standards and severe prolonged droughts that have prompted the replacement of inefficient water-using appliances with more efficient options, may have reduced the remaining water efficiency and reuse potentials. However, other factors, like more intense precipitation events, continued population growth, and newer efficiency technologies and practices, may have increased them.

In this study, we provide a new assessment of the potential for a range of water strategies in urbanized parts of California to both reduce inefficient and wasteful water use and expand local water supplies.[1] We provide an overview of current imbalances in water use and supply in California. We then describe our methods and the results of our analysis of opportunities in three key areas: increased urban water-use efficiency, expanded reuse of municipal wastewater, and improved capture of urban stormwater runoff. Additionally, we discuss the co-benefits associated with these strategies that can make them even more economically, environmentally, and socially valuable. Finally, we offer conclusions and a set of policy recommendations that can help federal, state, and local agencies move more quickly and effectively to capture this potential.

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[1] An earlier analysis by the Pacific Institute identified extensive savings potential in the agricultural sector (Cooley et al. 2014), and some of these approaches are being implemented. While the potential to improve water use efficiency in the agricultural sector remains large, a new assessment of this sector is needed but was beyond the scope of this study.

CURRENT WATER USE AND SUPPLY CONDITIONS

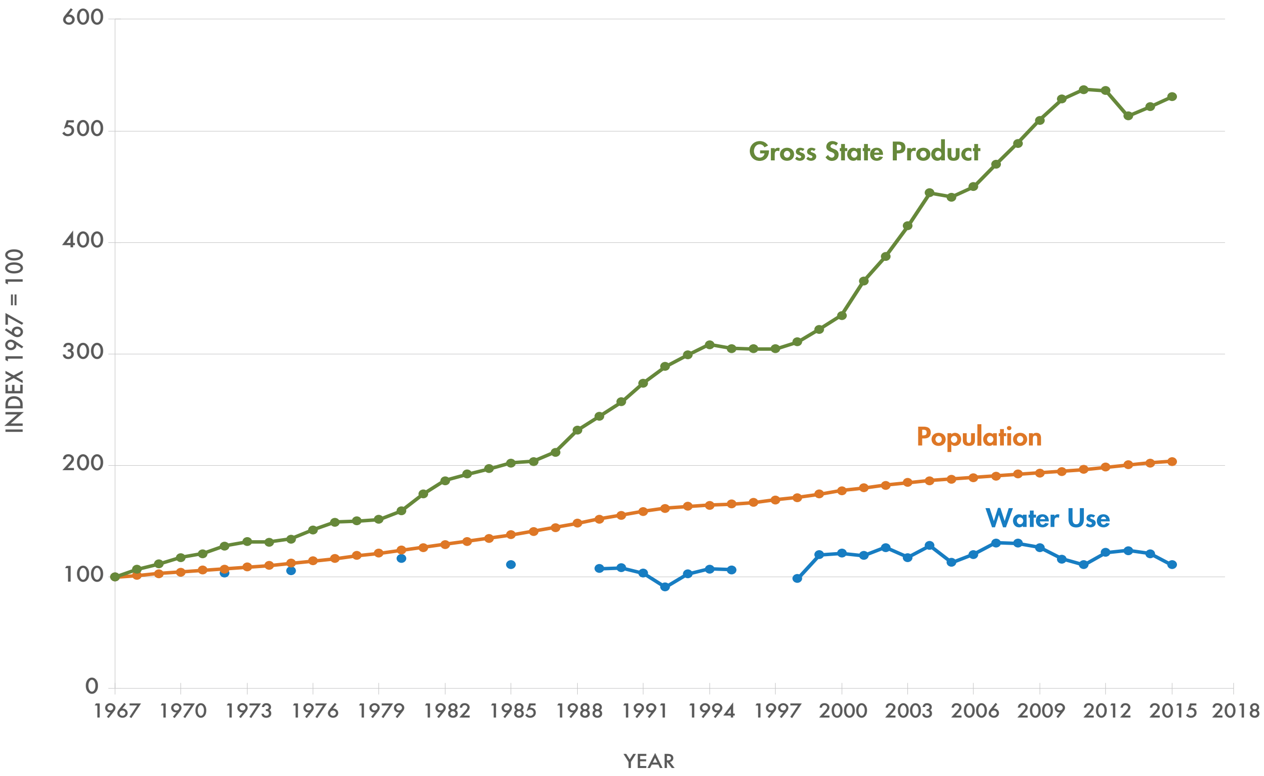
California's water situation is out of balance, with deep mismatches between water supply and use, inequitable allocations among diverse users, and deteriorating ecosystem health. Human-caused climate changes are also affecting both the supply and demand for water in ways that water managers have failed to anticipate or prepare for.

WATER USE TRENDS

Water use is a function of the state's population, choices about how much land to farm, what to grow, and how to irrigate it, the nature of industrial and commercial water use, and the efficiency of water-using technologies in our homes and cities and on farms. California water use has seen a dramatic "decoupling" from population and economic growth in the past 40 years (Cooley 2020). Between 1967 and 2016, gross state product grew by a factor of five and population more than doubled, but water use increased by only 13% (Figure 1). This trend was due to improvements in urban and agricultural efficiency, as well as shifts to higher-value crops and less water-intensive commercial and industrial activities.

Figure 2 shows the total amount of water used by people and businesses, including on farms, in California between 1960 and 2016, with drought periods shaded in yellow. Agriculture accounts for about 80% of statewide water use, with the remaining 20% used by homes, businesses, and institutions in urbanized areas across California.

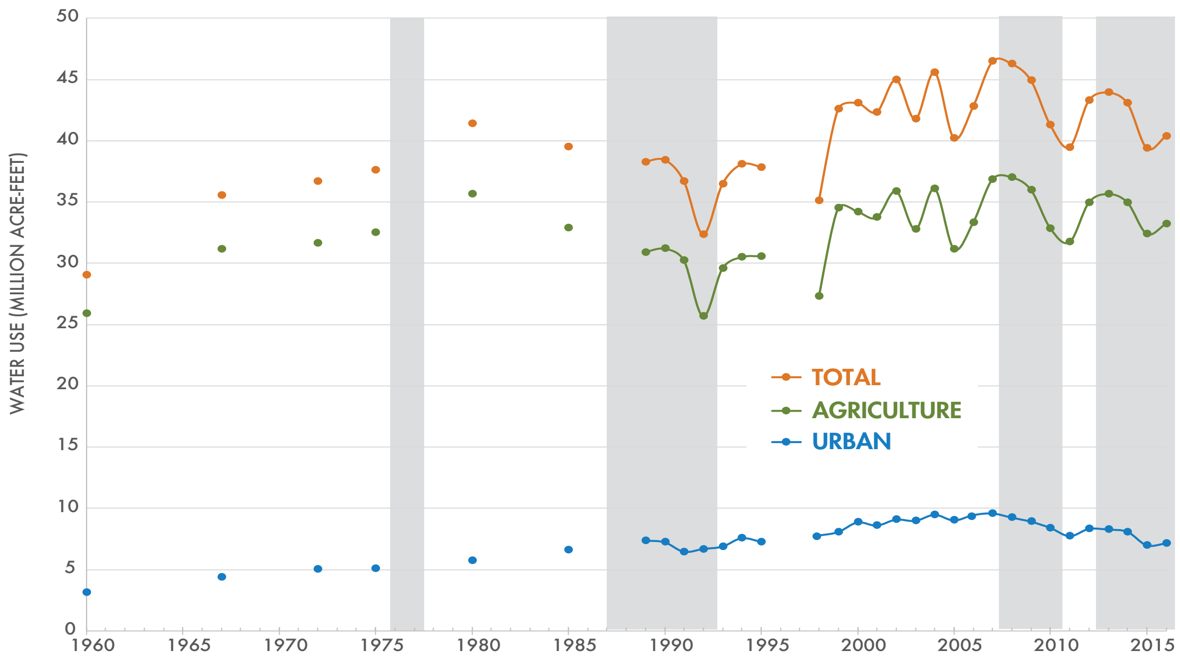
Figure 1. California Population, Gross State Product, and Water Use Indices, 1967-2016



Note: All values are indexed to their 1967 values to allow for comparison. Statewide water use data are not yet available for 2017 through the present.
Data sources: Water use data from California Department of Water Resources (DWR) 1964; 1970; 2018a; 2019b. Population data from California Department of Finance 2018. Gross state product from United States Bureau of Economic Analysis 2019.

Since the mid-1960s, agricultural water use has typically ranged from about 30 million to 37 million AFY. While water use has changed little over this period, the economic productivity of water—the economic value produced per unit of water applied—has increased dramatically due to a shift toward higher value crops and more efficient irrigation technologies and practices. In the 1960s and early 1970s, the economic productivity of water was less than $600 per AF but has exceeded $1,200 per AF since 2013 (Cooley 2020). While not the focus of this study, numerous studies point to additional agricultural water-use efficiency opportunities through, for example, the use of drip irrigation and irrigation scheduling technologies and development of healthy soils (CALFED Bay-Delta Program 2000 and 2006; Christian-Smith, Cooley, and Gleick 2011).

Figure 2. Total, Urban, and Agricultural Water Use in California, 1960-2016



Note: Statewide multi-year droughts are shown in shaded grey areas.
Data Source: Water use data from California Department of Water Resources 1964; 1970; 2018a; 2019b.

Urban water use has changed dramatically over the past several decades (Figure 2). In 1960, total urban water use was 3 million AF, or 177 gallons per capita per day (gpcd). Statewide urban water use, both total and per capita, steadily increased between 1960 and 1990. The 1987-1992 drought resulted in a dramatic reduction in urban water use, although that use began to increase again after the drought ended, reaching nearly 10 million AFY in the mid-2000s. However, while water use increased, per-capita water use stayed relatively flat. Since 2007, both total and per-capita urban water use have declined dramatically such that total urban use in 2016 was 7.1 million AF—a level not seen since the early 1990s.

Using data submitted by water suppliers in their electronic annual reports (EAR), we estimate that urban water use in California averaged 6.6 million AFY between 2017 and 2019.[2] Of that amount, most was used in and around homes, with residential water use accounting for nearly two-thirds of total urban use, or 4.2 million AFY (Figure 3). Together, commercial businesses (such

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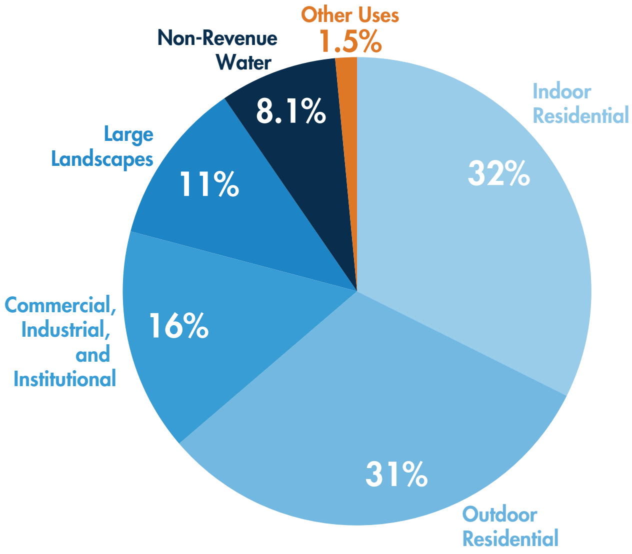
[2] Details about the dataset and approach are discussed in Appendix A.

as hotels, restaurants, and office buildings), industrial manufacturing, and institutions (such as schools, prisons, and hospitals) accounted for 16% of California's urban water use, or 1.0 million AFY. Large landscapes served by a dedicated irrigation meter accounted for an additional 11%, or 0.74 million AFY. Non-revenue water accounted for 8.1% of urban water use, or 0.53 million AFY.[3] Finally, other miscellaneous uses, such as street cleaning and temporary meters, accounted for 1.5% of urban use.

Statewide urban per-capita water use averaged 152 gpcd between 2017 and 2019 and ranged from a low of 103 gpcd in the North Coast hydrologic region (HR) to a high of 205 gpcd in the Colorado River HR (Table 1 and Figure 4). This regional variability is driven by several factors, including climate, land use, water-use efficiency, and economic activity. Residential water use in California averaged 94 gpcd between 2017 and 2019, evenly split between indoor and outdoor uses at 47 gpcd for each. While less variable than total urban use, residential per-capita use ranged from a low of 65 gpcd in the North Coast HR to a high of 117 gpcd in the Colorado River HR. In the South Coast HR, the most populated region in California, residential use was 96 gpcd, slightly higher than the statewide average. By comparison, residential use in the San Francisco Bay HR was 70 gpcd, due to lower indoor and outdoor use.

Figure 3. Urban Water Use in California, 2017-19



Note: Other refers to miscellaneous uses, such as street cleaning and temporary meters. Non-revenue water includes real losses (e.g., physical losses through leaks), apparent losses (e.g., meter inaccuracies, billing errors, or theft), and authorized unbilled uses (e.g., a fire department taking water from a hydrant).
Data Source: Based on data from State Water Resources Control Board electronic annual reports (EARs)

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[3] Non-revenue water is water that has been produced but is "lost" before it reaches the customer and does not generate revenue for the utility. These losses can be real losses (e.g., physical losses through leaks), apparent losses (e.g., meter inaccuracies, billing errors, or theft), and authorized unbilled uses (e.g., a fire department taking water from a hydrant).

Table 1. Urban and Residential Per Capita Water Use in California, 2017-19

Hydrologic Region	Urban Per Capita Water Use (gpcd)	Residential Per Capita Water Use (gpcd)		
		Total	Indoor	Outdoor
Central Coast	116	75	44	31
Colorado River	205	117	50	66
North Coast	103	65	41	24
North Lahontan	164	93	52	41
Sacramento River	179	114	46	68
San Francisco Bay	113	70	42	28
San Joaquin River	156	99	51	48
South Coast	148	96	50	47
South Lahontan	153	99	49	50
Tulare Lake	184	112	44	67
Statewide Average	**152**	**94**	**47**	**47**

Data Source: Based on data from State Water Resources Control Board EARs.

Figure 4. Urban (Left) and Residential (Right) Per Capita Water Use by Hydrologic Region

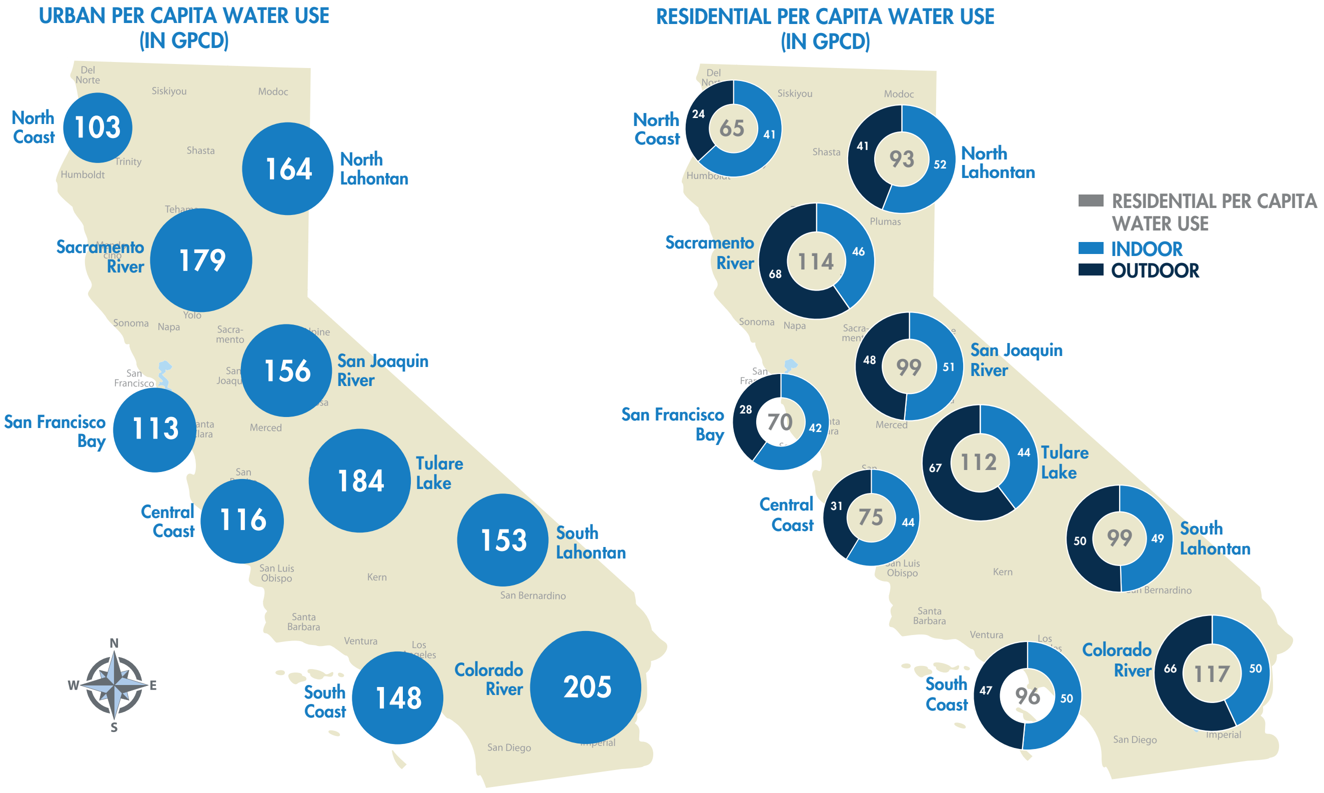
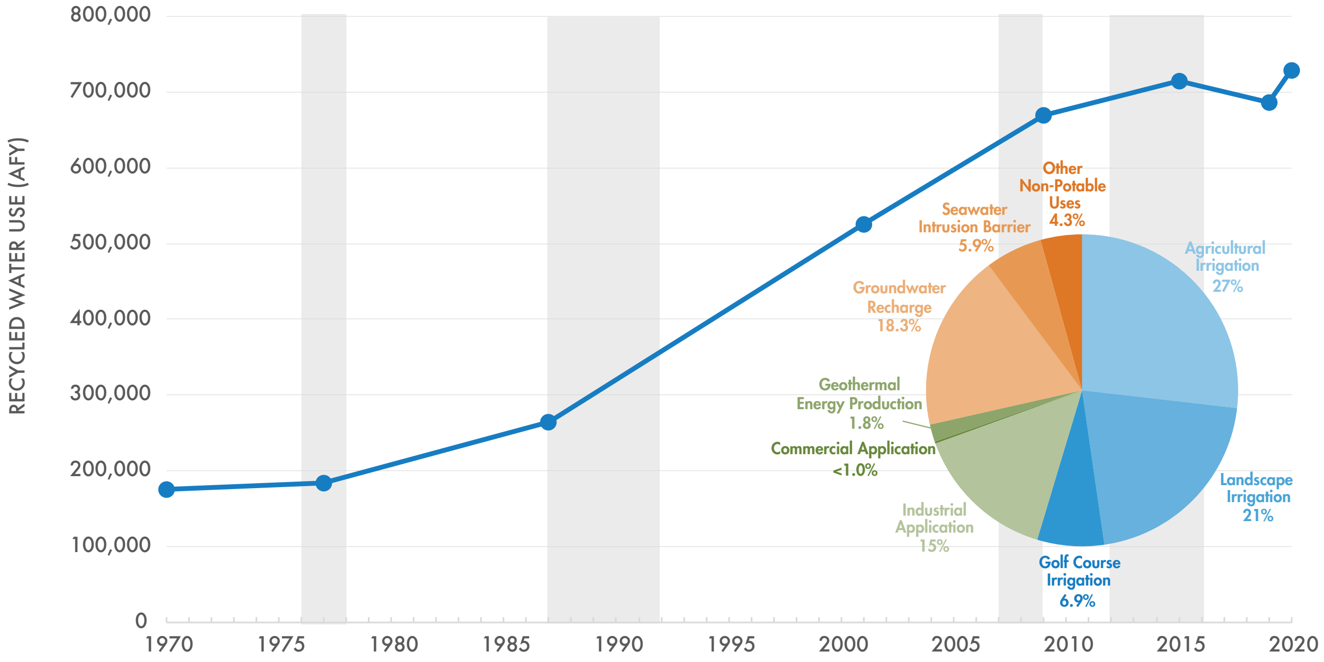


Figure 5. Trends in Recycled Water Use in California and (Inset) Title-22 Recycled Water Use by End Use in 2020



Notes: Gray bars indicate periods of drought. Past recycled water surveys and current volumetric annual reporting data to the California State Water Resources Control Board accounts for reuse of municipal wastewater by wastewater treatment plants and recycled water producers. Onsite water reuse is not currently included in these data.
Data Source: California State Water Resources Control Board recycled water surveys and Volumetric Annual Reporting (multiple years).

WATER SUPPLY TRENDS

California has also made significant progress to diversify water supplies through non-traditional sources like water reuse and stormwater capture. For example, the earliest recycled water survey, conducted in 1970, found that an estimated 175,000 AF of municipal wastewater was beneficially reused annually, about two-thirds of which was for agriculture (Newton et al. 2010). Since 1970, the quantity of water reused in California has increased by more than 300%, with most of those gains occurring over the past 30 years (Figure 5). In 2020, the most recent year for which data are available, recycled water use for Title-22 purposes was 728,000 AF.[4,5] An additional 285,000 AFY of treated wastewater was reserved for instream flow and other environmental purposes. Current use of recycled water in California spans a diverse range of geographies and scales (Figure 6), including at numerous small facilities. Substantive investments in new and expanded recycled water projects are occurring in nearly all hydrologic regions.

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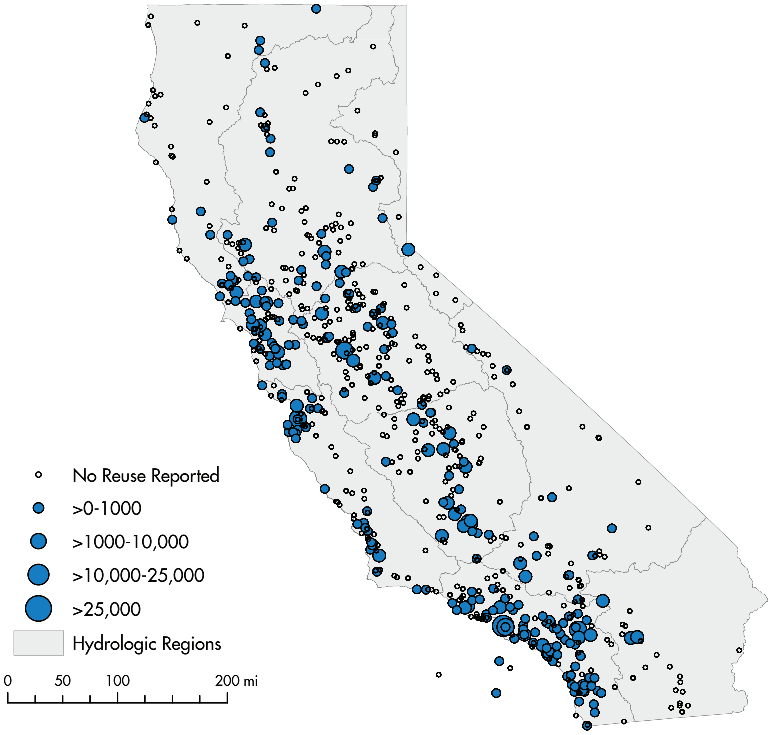
[4] Title-22 includes a list of specific beneficial uses and the regulations around the use of each of these classes of water. Some environmental uses of wastewater effluent and recycled water, such as augmenting instream flows, are not currently included in the current list of designated beneficial uses.

[5] As periodic recycled water surveys moved to volumetric annual reporting in 2019, the way some agricultural projects classified their use of recycled water shifted (i.e., from "other non-potable" to "agricultural irrigation"), resulting in an increase in reported agricultural reuse between 2019 and 2020. This, coupled with overall increases in landscape irrigation and groundwater recharge, led to the slight differences and overall increase in total reuse between 2015, 2019, and 2020.

Figure 6. Current Reuse Volumes Reported by Facilities in California



Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

Data Source: Based on data from the California State Water Resources Control Board Volumetric Annual Reporting.

A growing number of communities are also integrating stormwater into their water supply portfolios. While there is currently no statewide estimate of the amount of stormwater captured and reused in California, new projects are being developed across the state.[6] For example, the California Department of Water Resources (DWR) identified 78 unique urban stormwater capture projects funded at least in part by the state that were to be completed by 2020, and another 70 projects by 2035 (California Department of Water Resources 2018b). Together, these projects were expected to capture more than 200,000 AF of stormwater per year for recharge and another 40,000 AFY for irrigation and other direct uses. In Los Angeles, centralized facilities capture an average of 29,000 AF of stormwater annually for recharge in water-supply aquifers, and an additional 35,000 AF is captured incidentally (Mansell et al. 2016). Moreover, Los Angeles residents overwhelmingly approved a parcel tax in 2018 that is expected to generate $300 million annually for stormwater projects.

WATER USE AND SUPPLY IMBALANCES

Together, efficiency and non-traditional water sources can reduce reliance on traditional water sources. Figure 7 shows the sources of water for the Metropolitan Water District of Southern California's service area from 1976 to 2020. Water conservation and efficiency efforts across the service area was a major contributor to reductions in water use in 2020 to levels not seen since the late 1970s, despite continued population growth. Likewise, local supplies, which include recycled water and groundwater recharge from stormwater capture, have steadily increased since the mid-1970s. The net effect of these changes is reduced reliance on water imported from the Colorado River and Northern California and through the Los Angeles Aqueduct.

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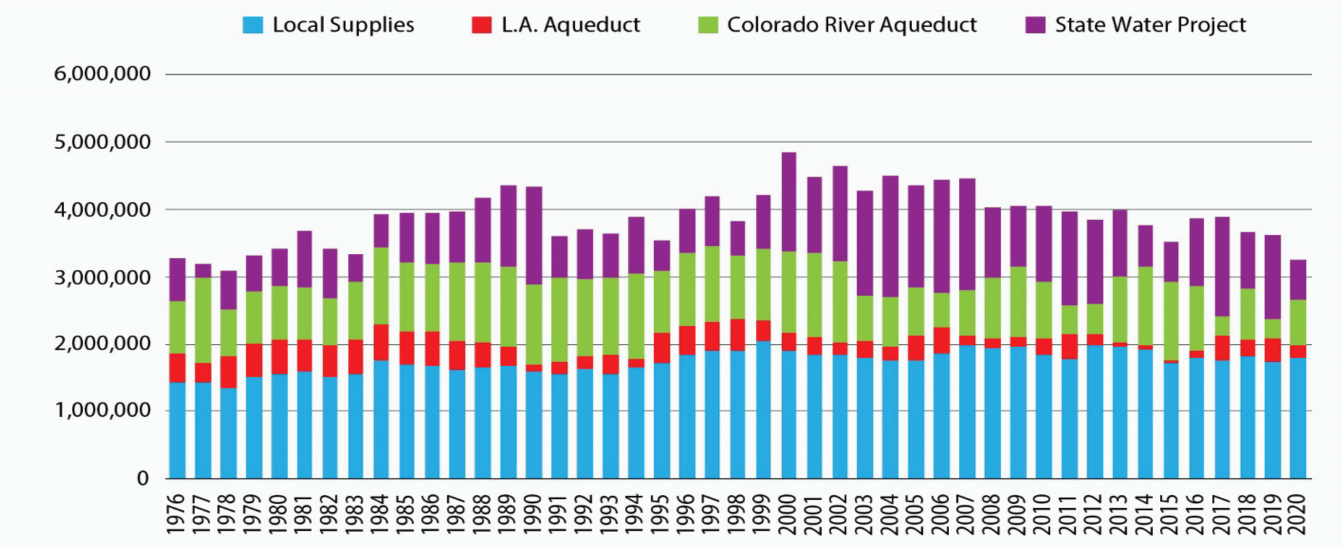
[6] Work is underway at the State Water Resources Control Board to quantify stormwater capture at the state scale (Fassman-Beck, Schiff, and Apt 2020).

Figure 7. Water Supply Trends for the Metropolitan Water District of Southern California's Service Area, 1976-2020



Notes:

1. Not including system losses.
2. Colorado River Aqueduct supplies are gross Havasu diversions less return flows, deliveries to USBR, Mexico, and storage.
3. State Water Project Supplies include Table A, Art. 21, Art. 14(b), Art. 12(d), Art. 12(e), Art. 55, draws from storage & carryover, DWCV & other exchanges, transfers, Drought Water Bank and Dry Year Pool Purchases, Pools A&B, Flood Water, wheeling, Port Hueneme lease, and SBVMWD Purchases.
4. Local Supplies includes local groundwater, surface water, recycled water, groundwater recovery, and seawater desalination used for MI, AG, SW or GW recharge in MWD service area. Include Santa Ana River Baseflow at Prado Dam for groundwater recharge. Based on best available data at the time of publication, subject to updates without notice. Data for 2020 not available and is estimated based on historical data.

Source: Metropolitan Water District of Southern California (MWD) 2021.

Despite progress that has been made in reducing water use and diversifying California's water supply portfolio, by any measure, water use exceeds water supply. For example, the Sacramento-San Joaquin River Delta is where the state's two major rivers come together. It is the heart of what used to be a vibrant natural wetland and is home to hundreds of species of plants, birds, fish, and other wildlife, including two-thirds of the state's salmon population and at least half of the birds that migrate along the Pacific Flyway (United States Fish & Wildlife Service 2001). It is also where massive pumps pull water to aqueducts that supply farms and cities in the south. Assessments by the State Water Resources Control Board found that we take nearly five million AFY more water out of the Delta, even in an average water year, than is compatible with a healthy system (California State Water Resources Control Board and California Environmental Protection Agency 2010). The net result has been a serious deterioration in the ecological health of the entire system, as reflected in plummeting populations of both commercially valuable and non-commercial native fish species.

Likewise, groundwater overdraft continues to persist and even worsen. Groundwater provides nearly 40% of the state's water, even in average years; when there is a drought and reduced surface water availability, groundwater becomes even more important. The Department of Water Resources estimates the state's annual groundwater overdraft—the amount of water withdrawn that exceeds recharge—is approximately 2 million AF. Across the state, 21 groundwater basins, of which 13 are in the Central Valley, have been designated as critically overdrafted. Overdraft of groundwater has led to land subsidence and damage to infrastructure, drying up of local wells, depletion of streamflows, and decreased water quality. While plans are now being developed, as required by the Sustainable Groundwater Management Act, to bring groundwater basins into long-term balance, groundwater overdraft continues to be severe and has even worsened in parts of California.

CALIFORNIA'S UNTAPPED POTENTIAL

California has great potential to reduce the mismatch between water supply and water use in all sectors, with strategies that are known to work, are cost-effective, and would provide resilience and flexibility during droughts that are becoming more frequent and severe as climate change intensifies. These options include greatly expanded water treatment and reuse, more comprehensive and consistent stormwater capture, and expanded efforts to improve urban water-use efficiency. In this section, we evaluate the potential of these options for urbanized areas in California.

URBAN WATER EFFICIENCY POTENTIAL

The good news is that over the past several decades, California communities have improved the efficiency of their water use. For example, the City of Los Angeles uses about 15% less water today than it did in 1970 while serving 1.2 million more people (LADWP 2020). Likewise, San Francisco uses less water today than it did in 1965 (SFPUC 2020). And the City of Fresno used the same amount of water in 2020 as it did in 1990 despite a population increase of 32% (City of Fresno Department of Public Utilities 2021). Without these past efforts, our current challenges would be much worse, demands on limited water supplies would be much higher, and ecosystem destruction would be more widespread.

Water efficiency measures, by definition, reduce water use without affecting the services and benefits that water provides. These measures include a variety of technologies and practices, such as replacing old, inefficient toilets, showerheads, and clothes washers with high-efficiency models, as well as replacing lawns with climate-appropriate plants, improving outdoor irrigation efficiency, and reducing losses in the water distribution system.

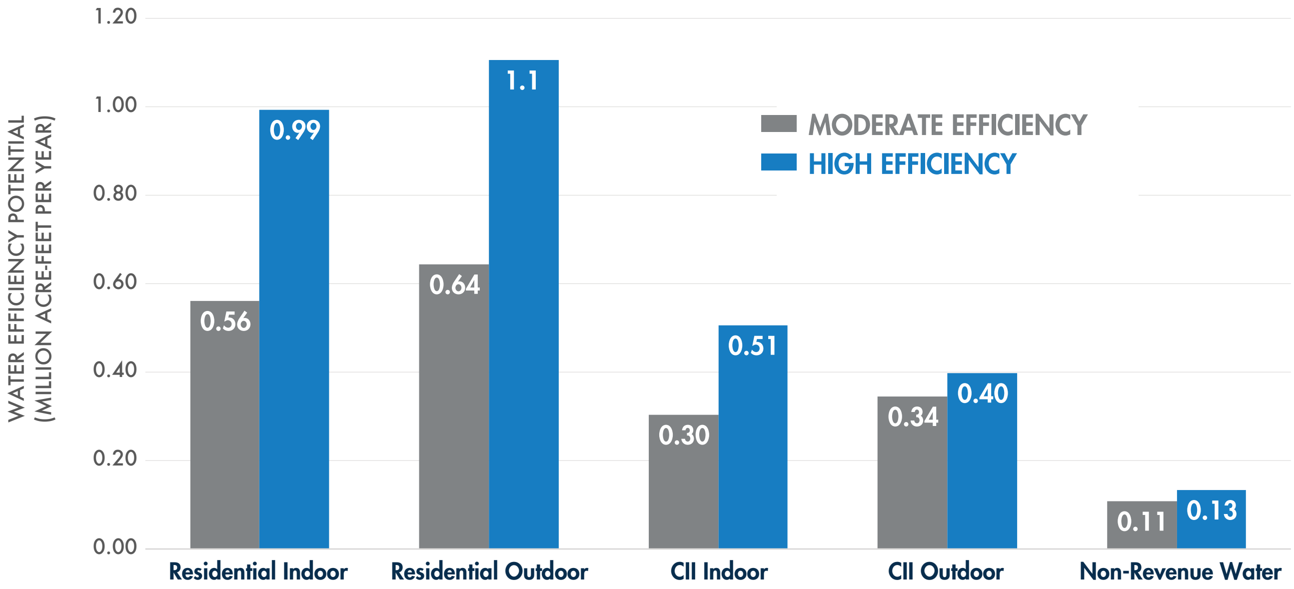
Previous analyses have evaluated California's water conservation and efficiency potential. For example, Gleick et al. 2003 found that up to one-third of California's urban water use—more than 2.3 million AF—could be saved using existing technology. Subsequently, Heberger, Cooley, and Gleick 2014 found that statewide urban water use could be reduced by 2.9 million to 5.2 million AF by adopting water-efficient technologies and practices that met existing standards at that time. In this analysis, we update these estimates using new data to assess the effect of past uptake of water-efficient technologies and practices, as well as the development of new water-saving devices.

This study focuses on water efficiency opportunities in homes, businesses, institutions, and in the water distribution system. For each, we estimate current and efficient water use, with the difference between these values representing the water efficiency potential. Current water use was based on the EAR datasets for the years 2017, 2018, and 2019, the most recent years for which data were available (California State Water Resources Control Board 2021a). Efficient indoor residential use was based on appliances and fixtures that meet current California standards (a moderate estimate) and on leading-edge technologies that are available but not yet mandated (a high estimate). Efficient outdoor water use was based on urban landscape compliance with the Model Water Efficient Landscape Ordinance (a moderate estimate) and complete conversion of urban landscapes to climate-appropriate plants and efficient drip irrigation (a high estimate). Commercial, industrial, and institutional (CII) water savings were based on estimates in the literature, including policy documents, case studies, and water audits. Finally, water savings from water loss control measures were based on data from 2017-2020 for a water loss performance standard developed pursuant to California Water Code Section 10608.34. Additional detail on the methods can be found in Appendix A.

Water Efficiency Potential by Sector

Urban water use in California averaged 6.6 million AFY between 2017 and 2019. We estimate here that available technologies and practices could reduce current water use by 2.0 million to 3.1 million AFY, or by 30% to 48% (Figure 8). Between 61% and 67% of the potential water savings, or 1.2 million to 2.1 million AFY, are in the residential sector. An additional 28% to 31%% of the savings, or 0.65 million to 0.9 million AFY, come from efforts to improve efficiency among the CII sectors. Reducing real losses in the water distribution system to meet water loss performance standards would save 0.11 million to 0.13 million AFY statewide.

Figure 8. California's Urban Water Efficiency Potential by Sector

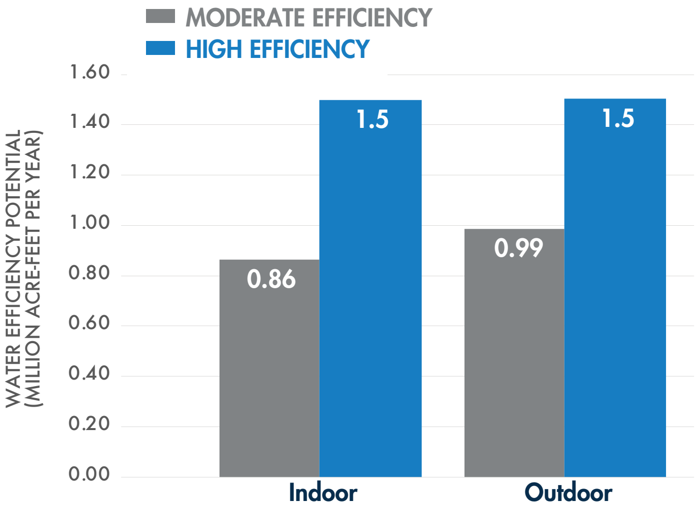


Indoor and Outdoor Water Efficiency Potential

We estimate that 44% of all urban water used in California, or 2.8 million AF, is used outdoors for landscape irrigation, washing cars or sidewalks, and for filling pools and spas. Moderate landscape conversions from turf to less water-intensive alternatives could save 1.0 million AFY, while more extensive landscape conversion could save 1.5 million AFY (Figure 9). The largest outdoor savings potential is at residences (0.64 million to 1.1 million AFY), while outdoor savings from CII landscapes range from 0.34 million to 0.4 million AFY.

While earlier water-efficiency efforts have emphasized indoor efficiency, our analysis suggests there are still significant indoor water-savings opportunities. We find that statewide indoor efficiency opportunities in California range from 0.86 million to 1.5 million AFY. The greatest indoor savings potential is in residences (0.56 million to 1.0 million AFY), although there are also considerable savings opportunities in businesses and institutions, ranging from 0.3 million to 0.5 million AFY.

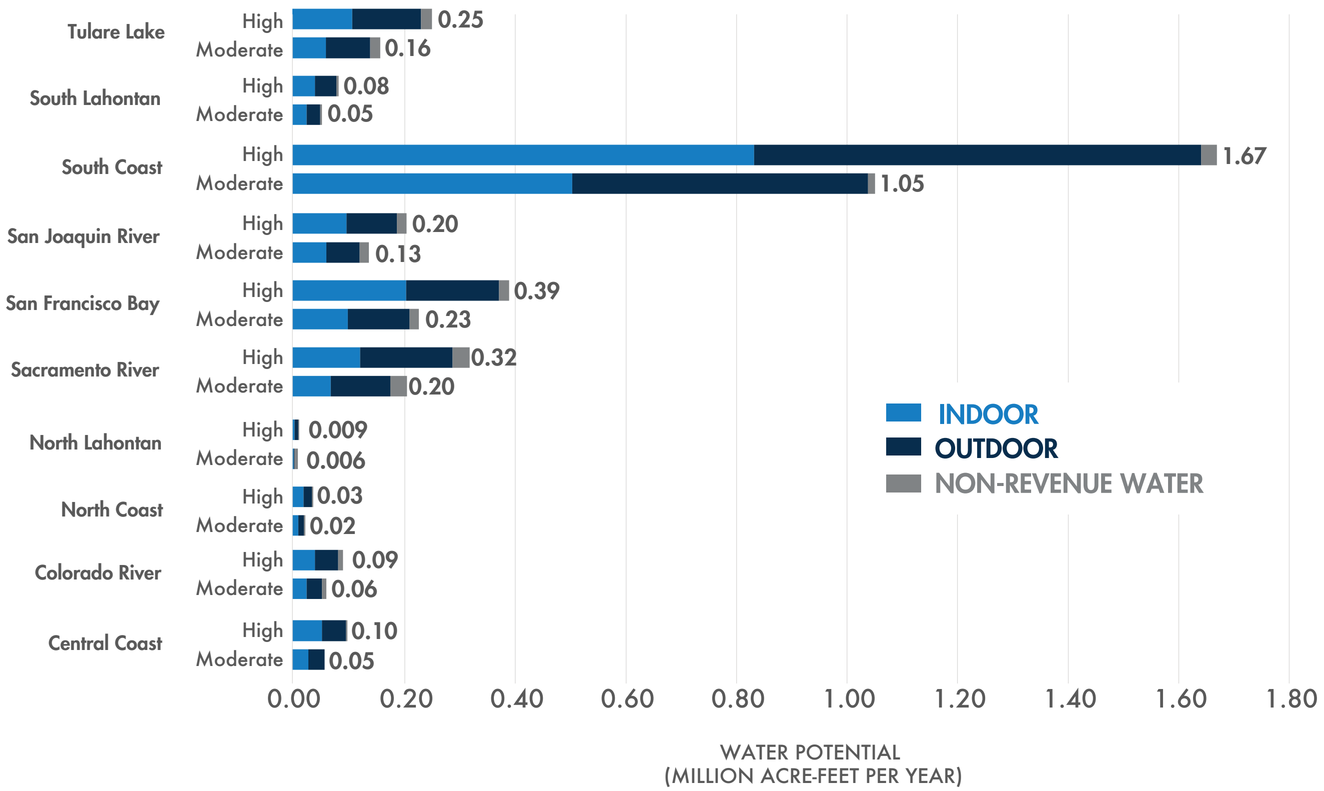
Figure 9. Indoor and Outdoor Water Efficiency Potential



Regional Water Efficiency Potential

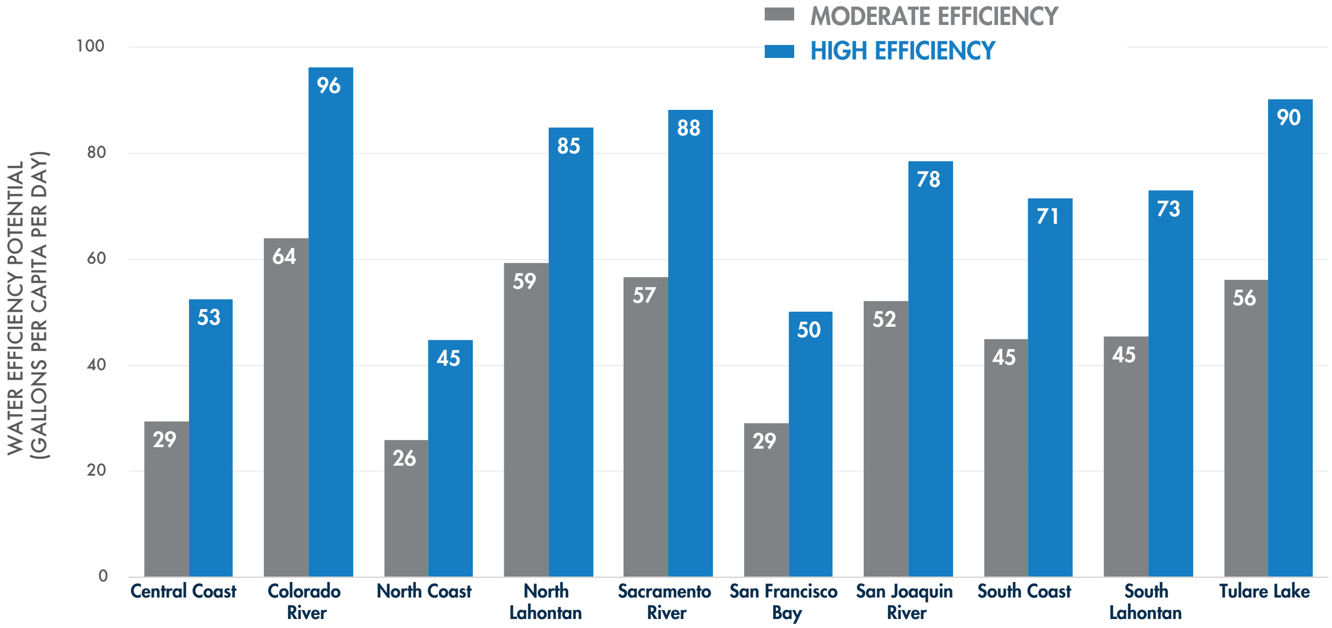
The South Coast HR has the highest potential water savings, across all sectors. By implementing available efficiency measures, the region could save between 1.1 million and 1.7 million AFY of water (Figure 10), or about 50% of the total statewide water savings potential. San Francisco Bay HR has the second-highest potential savings, between 0.23 million and 0.39 million AFY, followed closely by the Sacramento River HR at 0.20 million to 0.32 million AFY.

Figure 10. California's Urban Water Efficiency Potential by Hydrologic Region



Average statewide water savings range from 46 gpcd to 73 gpcd. On a per-capita basis, the greatest water savings are in the Colorado River HR, where daily savings ranged from 64 to 96 gallons per person (Figure 11). The South Coast HR has the highest total water savings due to the large number of people living in the region, but water savings per person were equivalent to the statewide average. San Francisco Bay, the Central Coast, and the North Coast HRs have the lowest current per-capita water use in the state and consequently the least amount of savings potential per person.

Figure 11. California's Per-Capita Urban Water Efficiency Potential by Hydrologic Region



WATER REUSE POTENTIAL

California has a long history of reusing treated municipal wastewater, with early guidance from the State Board of Health dating back to 1907. Over the past several decades, interest in wastewater reuse has grown with the realization that new sources of water were increasingly unavailable or costly, greater public acceptance, and improvements in treatment technology that permitted high-quality water to become available for different water uses. Several state laws, including the Water Reuse Law of 1974 and the Water Recycling Act of 1991, established reuse/recycling as a priority for state water resources management. California's initial focus was on providing guidance for agricultural water reuse, but regulations have evolved to include groundwater recharge, landscape irrigation, and other beneficial uses. Regulations continue to advance with new science on relative risks, treatment efficacy, and the establishment of new monitoring criteria, such as the inclusion of monitoring criteria for contaminants of emerging concern in groundwater recharge projects in the 2013 Recycled Water Policy Update, ongoing work on onsite non-potable reuse systems, and an expected Recycled Water Policy Update including direct potable water reuse in 2023.

Several previous estimates have been made of the potential for additional reuse of municipal wastewater in California. In 2003, the California Recycled Water Task Force estimated that 1.9 million to 2.3 million AF of wastewater could be recycled by 2030—approximately 23% of the estimated available wastewater (Recycled Water Task Force 2003). The 2013 California Water Plan from the DWR similarly estimated that 1.8 million to 2.3 million AF of wastewater reuse was possible (California Department of Water Resources 2014). In Cooley, Gleick, and Wilkinson (2014), we estimated a total potential of 1.2 million to 1.8 million AF above the 670,000 AF already being recycled at the time. Two-thirds of the water reuse potential identified in Cooley et al. was located in coastal areas, primarily the South Coast and San Francisco Bay HRs. Our 2014 estimate quantified the amount of water potentially available for reuse based on projections of future water use even with a high degree of indoor efficiency improvements.

This section provides an updated assessment of the quantity of municipal wastewater potentially available for reuse in California as a function of multiple factors, including the volume of effluent produced, its quality, and the existing allocation of wastewater effluent for instream flow requirements. The volume of effluent available is affected by population, indoor water use, leakage into and out of sewers, and adoption of water-efficiency measures. In this assessment, we rely on the State Water Resources Control Board's 2020 Volumetric Annual Reporting data to develop estimates of wastewater effluent, current reuse, and the total amount of water potentially available for reuse.

Volumetric Water Reuse Potential

In 2020, the most recent year for which data are available, 3.1 million AFY of municipal wastewater was produced within the State of California.[7] Around 728,000 AFY, or about 23% of the wastewater produced, is directly recycled at wastewater treatment plants or by a dedicated recycled water producer (Figure 9). An additional 286,000 AFY of municipal wastewater effluent supports ecosystems via instream flow requirements and discharges to wildlife refuges and other natural systems. Of the remaining wastewater produced in 2020, we estimate that approximately 1.8 to 2.1 million AFY is potentially available for reuse.[8]

Of the 2.1 million AFY of water potentially available for reuse, 1.0 million AFY is produced at 259 facilities al-

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[7] Wastewater production appeared to decline in 2020 from 2019 levels, but Title-22 recycled water production increased slightly, from 668,000 AF in 2019 to 728,000 AF in 2020 (California State Water Resources Control Board 2021c). Additional years of data are needed to understand long-term trends in wastewater and recycled water production.

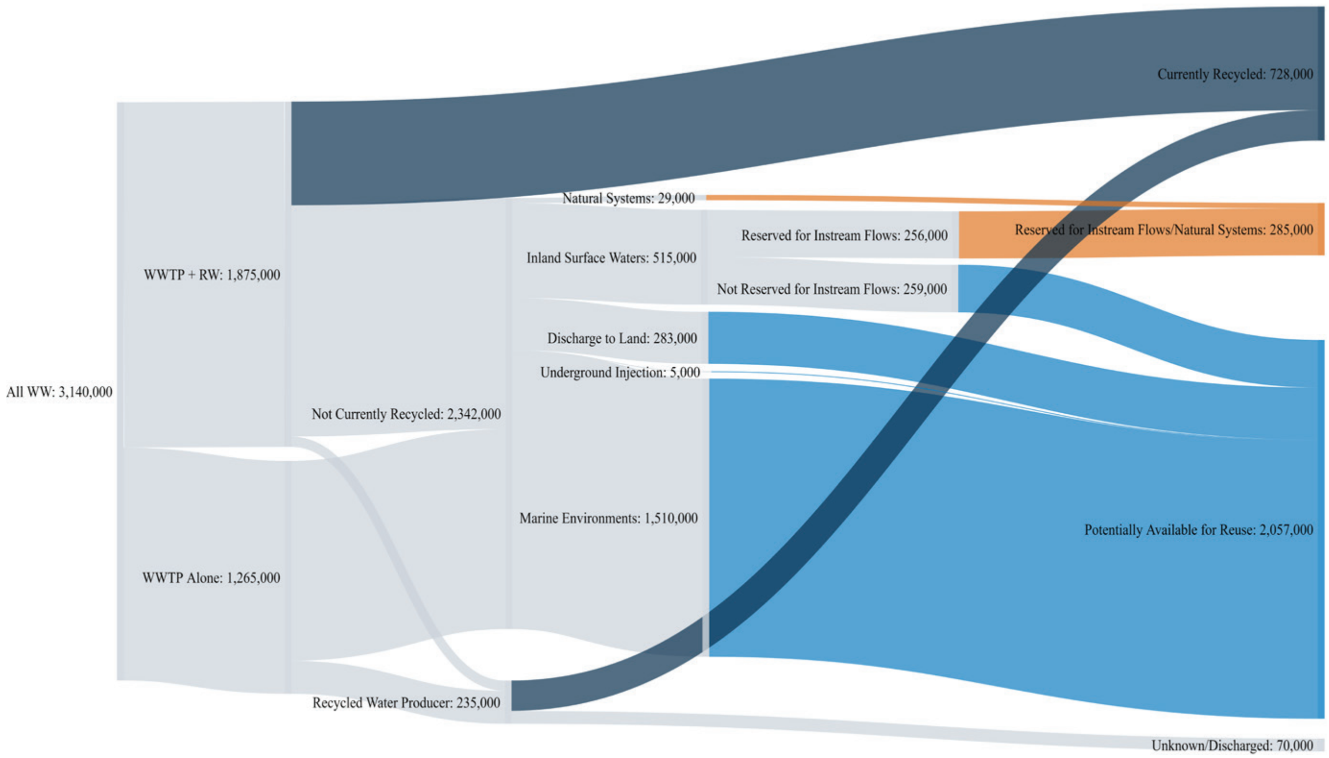
[8] The lower estimate (1.8 million AFY) excludes all discharges to inland surface waters, while the higher estimate (2.1 million AFY) includes discharges to inland surface waters not currently allocated for instream flows or natural systems. These flows (259,000 AFY) may be subject to additional water-rights related limits on reuse (discussed later in this section). The subsequent figures in this section are based on the 2.1 million AFY estimate.

ready supplying recycled water, while the remaining 1.1 million AFY is produced at the 390 WWTPs that are not (Figure 9). In both cases, the potential to increase water reuse depends on factors such as the local demand for recycled water; whether recycled water is of suitable quality for local needs; public perceptions of recycled water; and local technical, managerial, and financial capacity to support recycled water projects.

About 1.5 million AFY, or 73% of the 2.1 million AFY potentially available for reuse, is discharged to marine environments (Figure 9). Effluent discharged to marine environments does not have an alternate beneficial use (but may be important in managing salinity in estuarine environments) and is recognized as a high priority for future reuse projects (State Water Resources Control Board 2018). Fourteen percent (283,000 AFY) is currently discharged to land, and 13% (259,000 AFY) is discharged to inland surface waters and not currently reserved for instream flows. We classified these sources of water as "high potential" candidates for future recycled water projects, though there are important local contextual factors, such as demand for recycled water and local water rights, that affect the degree to which the potential can be fully realized (Sheikh et al. 2019).

The potential for reuse of water discharged to inland surface waters is especially dependent on local context. Limiting nutrient discharges during sensitive or low-flow periods to aid National Pollutant Discharge Elimination System (NPDES) permit compliance is a common driver of water reuse projects in the Central Valley (Thebo 2021). However, existing wastewater flows may already be indirectly used by downstream communities and/or contribute to maintaining instream flows within these river systems (Luthy et al. 2015). Reuse of any effluent discharged to inland surface waters is required to get approval from the State Water Resources Control Board Division of Water Rights, which includes a review of the existing beneficial uses of these waters. The potential for reuse of these waters (259,000 AFY) will vary on a case-by-case basis. Of the 515,000 AFY discharged to inland surface waters in California, about half, or 256,000 AFY, is currently reserved for the protection of instream flows (Figure 12).

Figure 12. Flow Diagram Showing Wastewater Effluent, Discharge Locations, and the Quantities of Water Currently Recycled, Potentially Available for Reuse, and Reserved for Instream Flows or Natural Systems



Note: There was an apparent reporting error in the effluent quantity data provided by one Bay Area facility. We excluded this facility from our tabulation of wastewater produced. However, because this facility supplied water to a separate recycled water producer, we were able to capture the quantity of effluent currently reused from this facility. The difference in average dry weather flows from this facility and the water currently reused is approximately 3,000 AFY.

Differences in Current and Potential Reuse Across Hydrologic Regions

Patterns of reuse and the quantity of water potentially available for reuse varies widely across regions of the state (Figure 13 and Table 2). Volumes of potentially reusable water are highest in the two most populous regions, with 497,000 AFY potentially reusable in the San Francisco Bay HR and 1.1 million AFY in the South Coast HR. The most water-abundant HR (North Coast) reused the highest proportion of their effluent (52%), though the total volumes of effluent produced in this region are comparatively small (41,000 AFY). Reuse in other less populous regions ranged from 31% to 48% of effluent. Of the more populous regions, the South Coast currently reuses 473,000 AFY (29% of effluent) while the Bay Area only reuses about 49,000 AFY (9% of effluent).

Regional motivations for reuse vary widely. Fifty-four percent of water supplies in the South Coast HR are imported over long distances at great expense and are subject to cuts in supply during periods of scarcity (California Department of Water Resources 2016). Importing water into Southern California also requires considerable energy and its associated greenhouse gas emissions, and supplies imported over long distances are also more vulnerable to supply disruptions due to system damage or power disruptions through earthquakes, flooding, and other disasters. These vulnerabilities have motivated regional investments in alternative supplies, efficiency, and stormwater capture (City of Los Angeles 2019). In contrast, much of the water supplied in the Bay Area arrives via the San Francisco Public Utilities Commission (SFPUC) regional water system. While these supplies also travel over long distances and are subject to changes in the form and timing of precipitation in the Sierra Nevada, SFPUC is a senior water rights holder on the Tuolumne River, which has historically made these supplies a bit more reliable and created less of an imperative to invest in alternative supplies, though recent droughts, wildfires, and other challenges have highlighted the value of local supplies and redundancy throughout the state.

Figure 13. Current Water Reuse, Water Potentially Available for Reuse, and Effluent Reserved for Instream Flows or Natural Systems, by Hydrologic Region

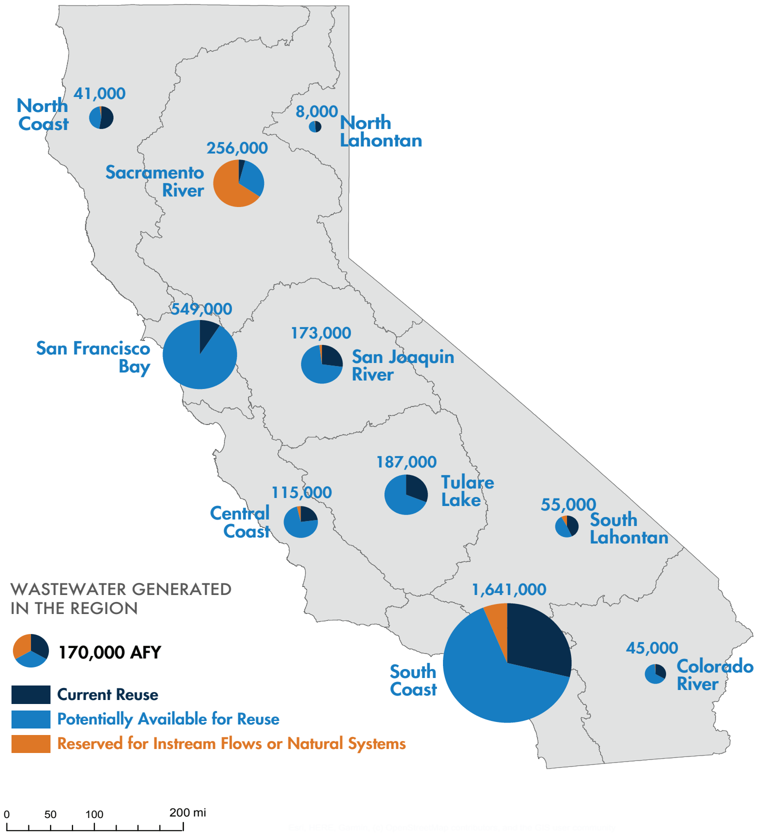


Table 2. Effluent Currently Reused, Reserved for Instream Flows or Natural Systems, or Potentially Available for Reuse, by Hydrologic Region

Hydrologic Region	Currently Reused (AFY)	Effluent Reserved for Instream Flows or Natural Systems (AFY)	Potentially Available for Reuse (AFY)	TOTAL Effluent (AFY)	Currently Reused (%)	Potentially Available for Reuse (%)
Central Coast	26,000	4,000	84,000	**115,000**	23	73
Colorado River	15,000	0	30,000	**45,000**	33	66
North Coast	21,000	1,000	18,000	**41,000**	52	45
North Lahontan	4,000	0	4,000	**8,000**	48	51
Sacramento River	11,000	168,000	78,000	**256,000**	4	30
San Francisco Bay	49,000	3,000	497,000	**549,000**	9	90
San Joaquin River	47,000	4,000	123,000	**173,000**	27	71
South Coast	473,000	101,000	1,067,000	**1,641,000**	29	65
South Lahontan	24,000	4,000	27,000	**55,000**	43	49
Tulare Lake	58,000	0	129,000	**187,000**	31	69
TOTAL	**729,000**	**285,000**	**2,057,000**	**3,071,000**	**24**	**67**

Notes: Not available for reuse is defined as water allocated to instream flows or natural systems. Value of total effluent in this table differs from Figure 12 because of reporting discrepancies between water supplied to recycled water producers and the quantity of water recycled water producers reported reusing.

Future Changes in the Quantity of Water Available for Reuse

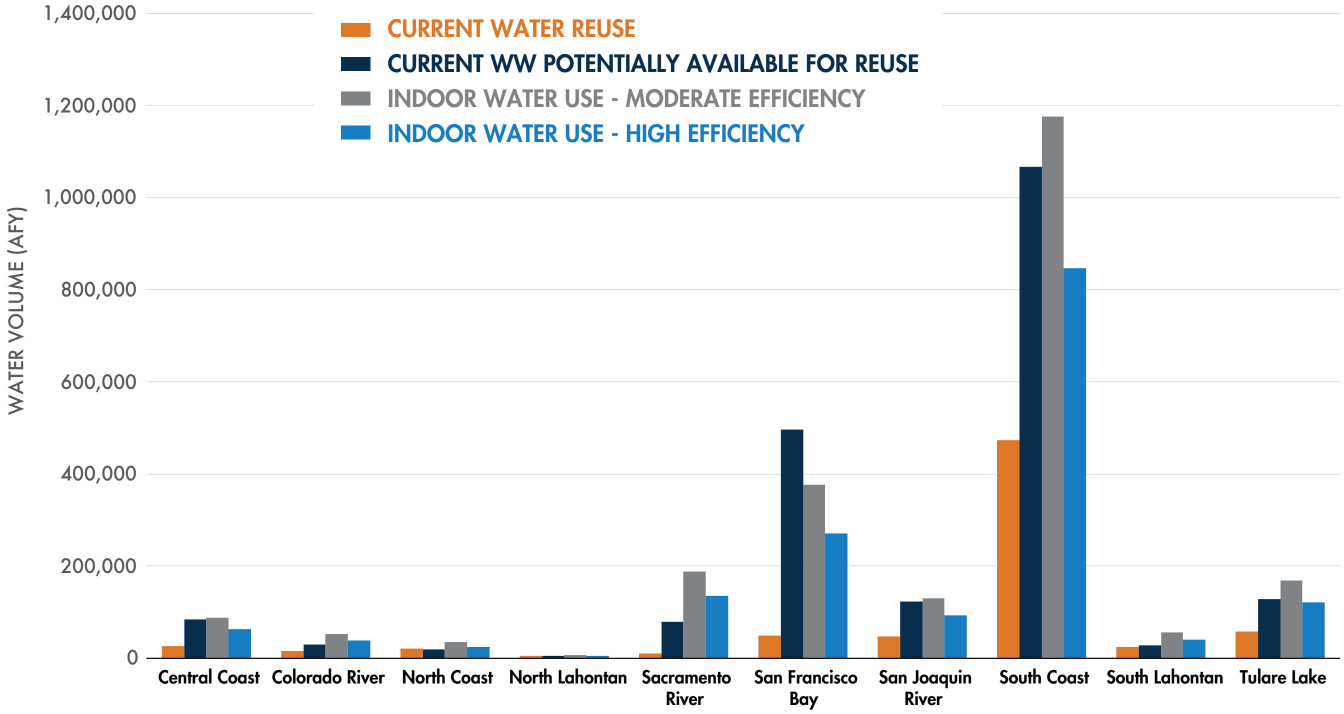
Current volumes of wastewater effluent available are not necessarily predictive of future supplies. Sustained improvements in indoor water-use efficiency are expected to continue reducing per-capita residential and CII water use in coming years. Likewise, increased adoption of onsite treatment systems could impact the distribution and concentration of wastewater flows within a region. However, these changes are balanced against shifts in population and economic activity, which are expected to vary substantially within and across California (Bohn, Lafortune, and Cuellar Mejia 2020). One aim of the state's volumetric annual reporting data is to assess long-term trends in wastewater production, reuse, and the quantities of water available for reuse in communities across the state. The current volumetric annual reporting data only includes information on reuse by NPDES and Waste Discharge Requirements permittees at centralized facilities. Most existing onsite reuse at industrial facilities is not included but can be locally significant.

Detailed modeling of the dynamics between these factors (efficiency gains, population and economic changes, and wastewater production) was beyond the scope of this analysis. However, as an illustrative example, we compare current reuse, anticipated indoor water use under the efficient and highly efficient water-use scenarios developed in this report, and wastewater potentially available for reuse for each of the state's ten HRs (Figure 14). Through this comparison we examine two metrics: (1) The potential for future indoor water use to supply enough wastewater influent to meet current recycled water commitments; and (2) a rough comparison of potential future changes in wastewater inflows relative to the current volumes of wastewater potentially available for reuse.

Across the state, future indoor water use in both the efficient and highly efficient scenarios is still substantially higher than existing reuse projects, suggesting that current recycled water commitments could continue to be met at the HR scale. However, future indoor water use was 26% lower than current wastewater volumes in the efficient water use scenario and 47% lower in the highly efficient scenario, though there was considerable variation between regions. Practically, these differences indicate that total wastewater production volumes are likely to decrease in many regions as improvements in water-use efficiency continue and population and current levels of economic development hold steady (Figure 14).

These findings highlight the need to consider anticipated changes in future indoor water use and the timing of these changes relative to infrastructure lifespans, population, and regional economic activity when planning future recycled water projects. A recent study by the Pacific Institute and SPUR unpacked some of these dynamics. That analysis estimated water use in 2070 as a function of three water-use efficiency and two population and economic growth scenarios, finding, at a high level, that current water-use levels would be maintained or reduced slightly in the efficient and highly efficient scenarios evaluated due to continued growth and development in the Bay Area (Feinstein and Thebo 2021).

Figure 14. Comparison of Current Reuse, Current Volume of Wastewater Effluent Potentially Available for Reuse, and Estimated Indoor Water Use with Moderate and High Efficiency



Note: Current reuse and current volume of wastewater effluent potentially available for reuse are based on data from the State Water Resources Control Board's 2020 Volumetric Annual Reporting, and the estimated indoor water use with moderate and high efficiency are based on estimates presented in this report.

Role of Water Quality in Assessing the Potential for Reuse

Treated wastewater can be used in a wide variety of ways, depending on the level of treatment, as defined by the State of California's Title 22 Regulations.[9] For example, some non-food crops, such as fodder crops, can be irrigated with undisinfected secondary treated effluent while disinfected tertiary treated water is required for uses where human contact is more likely (e.g., toilet flushing and recreational impoundments). Indirect potable reuse via surface water augmentation and aquifer recharge typically requires full advanced treatment. State regulations for direct potable reuse (DPR) are not yet known but are expected in 2023.

Figure 15 shows the level of treatment received by the wastewater potentially available for reuse. Of the 2.1 million AF of wastewater potentially available for reuse annually, 200,000 AFY (or 10%) is currently treated to primary standards, which essentially involves the removal of solids and typically occurs at facilities practicing land application or discharging to deep marine outfalls. Seventy-one percent (or 1.5 million AFY) of California's wastewater is treated to secondary standards, meaning it is only suitable for low-contact beneficial uses like agricultural irrigation. Secondary treatment provides additional removal of biodegradable organic matter and, in some cases, disinfection.[10] The remainder receives tertiary (383,000 AFY, or 19%) or full advanced treatment (11,000 AFY, 0.5%). Water treated to tertiary standards is suitable for less restrictive uses, such as irrigation of parks and cooling towers.

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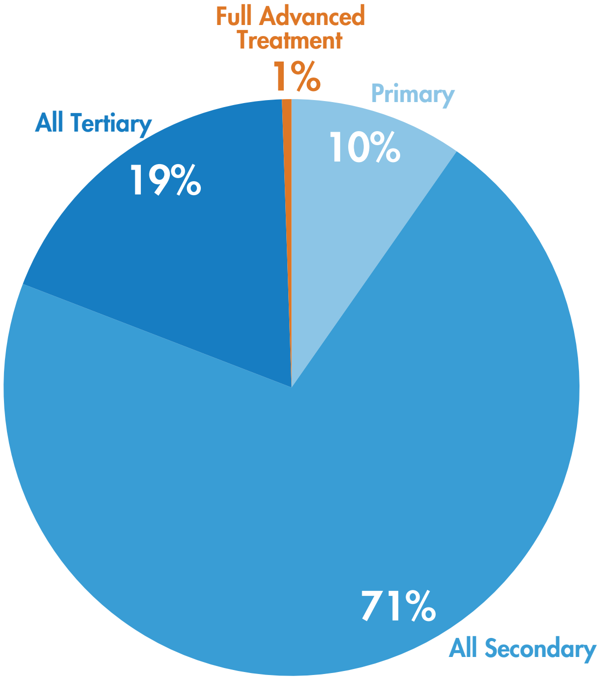
[9] California's Title 22 Regulations specify the level of treatment, monitoring, and engineering design standards required to use recycled water for each type of beneficial use. These standards were developed using a risk-based approach.

[10] The Volumetric Annual Reporting data only include information on disinfection as part of the reporting on the quantities of "Title-22" water produced. It is likely that many more facilities are practicing disinfection than was captured in the Volumetric Annual Reporting data. Disinfection is a mandatory treatment step for all classes of "Title-22" water except "Undisinfected Secondary."

Communities can invest in treatment to increase the quality of their effluent to make it usable for a broader range of beneficial uses, but there typically needs to be demand for the higher quality water, regulatory requirements, or financial incentives such as low-interest loans or grants to motivate these investments. It is yet to be seen how upcoming direct potable reuse regulations will affect demand for recycled water and in which communities potable reuse will be adopted, but there are multiple DPR projects, such as Operation NEXT in the City of Los Angeles, currently in planning stages.

Figure 15. Quality of Water Potentially Available for Reuse



STORMWATER CAPTURE POTENTIAL

While communities have been managing stormwater for a long time, intentional capture and reuse of this resource is a more recent phenomenon in California. Stormwater, here defined as runoff created from precipitation that falls on impermeable surfaces in urban areas, is commonly viewed as a nuisance or hazard. It carries pollution from roads and other urban surfaces to rivers, lakes, estuaries, and the ocean, threatening both aquatic life and public health. It can also lead to flooding, causing property damage and risks for communities. But, in a state with growing water scarcity, stormwater is increasingly seen as an opportunity for augmenting water supplies and enhancing resilience.

Several previous estimates have been made of the potential for capture and reuse of stormwater in California. The Natural Resources Defense Council (2009) found that stormwater capture at new building projects and redevelopment projects for residential and commercial properties in urbanized Southern California and the San Francisco Bay Area could increase overall water supplies by up to 405,000 AFY by 2030. Garrison et al. (2014) estimated that the stormwater capture on existing impervious surfaces in the urbanized coastal San Francisco Bay Area and Southern California could increase water supplies by 420,000 to 630,000 AFY. Most recently, using a GIS tool and method it developed, 2NDNature estimated that California's urban stormwater potential exceeds 2.0 million AFY, with approximately 50% of the potential in urban areas underlain by mapped groundwater basins (2NDNature 2021).

This section provides an updated assessment of the quantity of stormwater available for capture and reuse from existing impervious surfaces in urban and suburban landscapes across California. Volumetric capture potential is based on a GIS analysis of impervious surface cover and estimated runoff during a high (i.e., wet), medium, and low (i.e., dry) precipitation year. Volumes are calculated twice, first, as the total volume available from all impervious surfaces in urban areas, and second, as the total volume available from impervious surfaces in urban areas above groundwater aquifers currently used for municipal water supply, such that infiltration would add to an existing supply source.[11] We also estimate the statewide volume of stormwater available for capture at the household level in rain barrels.[12] While dry-weather runoff from irrigation systems may be a meaningful supply source that can be captured by stormwater systems, it was not a focus of this analysis.[13]

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[11] Aquifer location from California Department of Water Resources (2020). Public supply well locations from State Water Resources Control Board (2016).

[12] Single-family detached household count from US Census Bureau (2019).

[13] Recent work by Jacobs (2021) for Las Virgenes Municipal Water District details existing and future potential for dry-weather runoff capture in Southern California.

Volumetric Stormwater Capture Potential

We estimate stormwater capture potential across all urban areas in the state is 770,000 AF in a dry year, 2.0 million AF in a medium precipitation year, and 3.9 million AF in a wet year (Table 3). The volume of urban stormwater available is a function of the amount of precipitation and impervious surface area. In all years, the South Coast HR has the greatest potential for stormwater capture, ranging from 370,000 AF in a dry year to 1.9 million AF in a wet year. Despite receiving relatively little precipitation compared to other parts of the state, the South Coast has large expanses of pavement and other impervious surfaces. It also shows significant variability between wet and dry years, with a wet year generating more than five times more runoff than a dry year. Stormwater capture potential is also large in the San Francisco Bay HR (from 120,000 AF in a dry year to 670,000 AF in a wet year), followed by the Sacramento River HR (110,000 to 450,000 AF). While less water may be available for stormwater capture in other HRs, stormwater potential could still provide a significant new addition to local and regional water supply portfolios.

Table 3. **Volume of Urban Stormwater Potentially Available for Capture and Reuse, by Hydrologic Region, in Low, Medium, and High Precipitation Years**

Hydrologic Region	Urban Stormwater Capture Potential (AFY)		
	Low Precipitation	Medium Precipitation	High Precipitation
Central Coast	24,000	110,000	170,000
Colorado River	12,000	12,000	37,000
North Coast	35,000	91,000	150,000
North Lahontan	3,000	8,000	13,000
Sacramento River	110,000	310,000	450,000
San Francisco Bay	120,000	440,000	670,000
San Joaquin River	46,000	130,000	200,000
South Coast	370,000	860,000	1,900,000
South Lahontan	13,000	27,000	71,000
Tulare Lake	35,000	91,000	180,000
Total	**770,000**	**2,000,000**	**3,900,000**

Notes: Aquifer locations were not incorporated for this estimate. Numbers are rounded to two significant figures. Totals may not equal column sums due to rounding.

Aquifers used for public water supply are the best option for storing stormwater for later use. While there are technical and regulatory difficulties in conveying and pre-treating stormwater prior to delivering it to these aquifers, many places across the state are currently working on solutions to those challenges. When we constrain our analysis of stormwater capture potential to focus on urban areas above public supply aquifers, we find that the statewide stormwater capture potential is 580,000 AF in a dry year, 1.6 million AF in a medium precipitation year, and 3.0 million AF in a wet year (Table 4 and Figure 16). As with the analysis above, the greatest stormwater capture potential is in the South Coast HR, followed by the San Francisco Bay and Sacramento River HRs.

Table 4. Volume of Urban Stormwater Potentially Available for Capture and Reuse in Urban Areas Above Public Supply Aquifers, by Hydrologic Region, in Low, Medium, and High Precipitation Years 🔎

Hydrologic Region	Urban Stormwater Capture Potential (AFY)		
	Low Precipitation	Medium Precipitation	High Precipitation
Central Coast	20,000	89,000	140,000
Colorado River	11,000	11,000	36,000
North Coast	31,000	82,000	130,000
North Lahontan	3,000	7,000	10,000
Sacramento River	84,000	250,000	350,000
San Francisco Bay	85,000	300,000	460,000
San Joaquin River	40,000	110,000	170,000
South Coast	260,000	620,000	1,400,000
South Lahontan	12,000	23,000	63,000
Tulare Lake	34,000	90,000	180,000
Total	**580,000**	**1,600,000**	**3,000,000**

Notes: Numbers are rounded to two significant figures. Totals may not equal column sums due to rounding.

Stormwater Capture Potential by Scale

Stormwater capture can occur at various scales. For example, large spreading basins located above existing public supply aquifers can capture and recharge tens of thousands of AF per year, sourcing from areas that cover multiple square miles. Mid-size capture, also sometimes called neighborhood scale, can be done with retention basins or underground storage tanks that source from one or two adjacent acres of land; these can recharge the water into local aquifers or store it for non-potable applications like toilet flushing. CII landowners that manage large parcels with impervious areas can also create medium- to small-scale stormwater for onsite reuse. At site-scale, stormwater can be redirected into rain gardens or bioswales, or stored in rain barrels or cisterns for irrigation.[14]

The stormwater capture potential estimates in Tables 3 and 4 do not consider the scale at which the stormwater can be captured. To better understand household-level opportunities, we developed a high-level estimate of the stormwater capture potential from rain barrels installed in detached single-family households in urban areas in California. We assume that each of the approximately 7 million occupied urban homes in California (US Census Bureau 2019) has two rain barrels that collectively store 110 gallons of water with two usable refill events each year. We estimate that approximately 4,700 AF of stormwater can be captured at these homes, collectively.

Stormwater capture in single-family households represents a small fraction of both the available stormwater in California and household non-potable water demand. It can, however, save households money, reduce runoff that carries pollution into nearby waterways, and support green space in and around homes. We conclude that effectively capturing the stormwater capture potential will require additional decentralized and centralized options.

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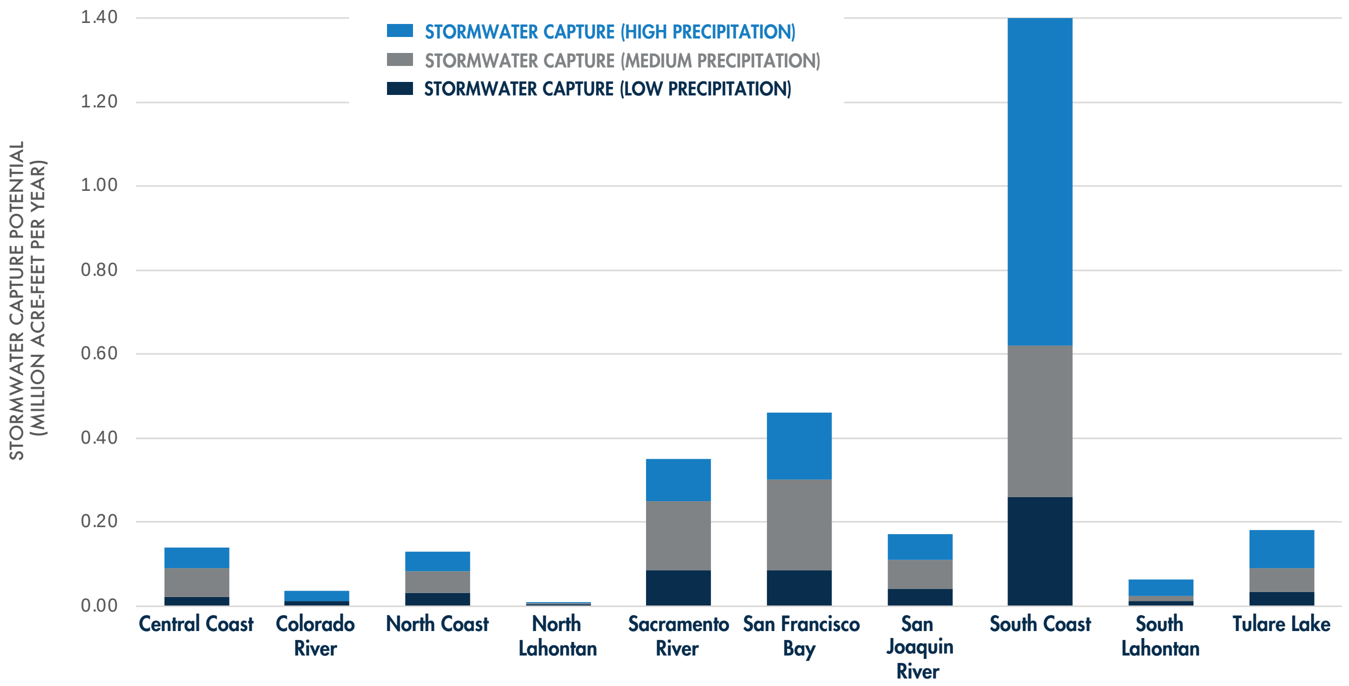
[14] Onsite treatment of stormwater for reuse for anything other than outdoor irrigation is currently prohibited in California. However, by December 2022, California Water Code section 13558 requires the State Water Resources Control Board to adopt regulations for risk-based water quality standards for onsite treatment and reuse of non-potable water for non-potable end uses in multifamily residential, commercial, and mixed-use buildings (California State Water Resources Control Board 2021b). These regulations are expected to expand the opportunities for small-scale onsite stormwater capture and reuse.

Figure 16. Stormwater Capture Potential by Hydrologic Region

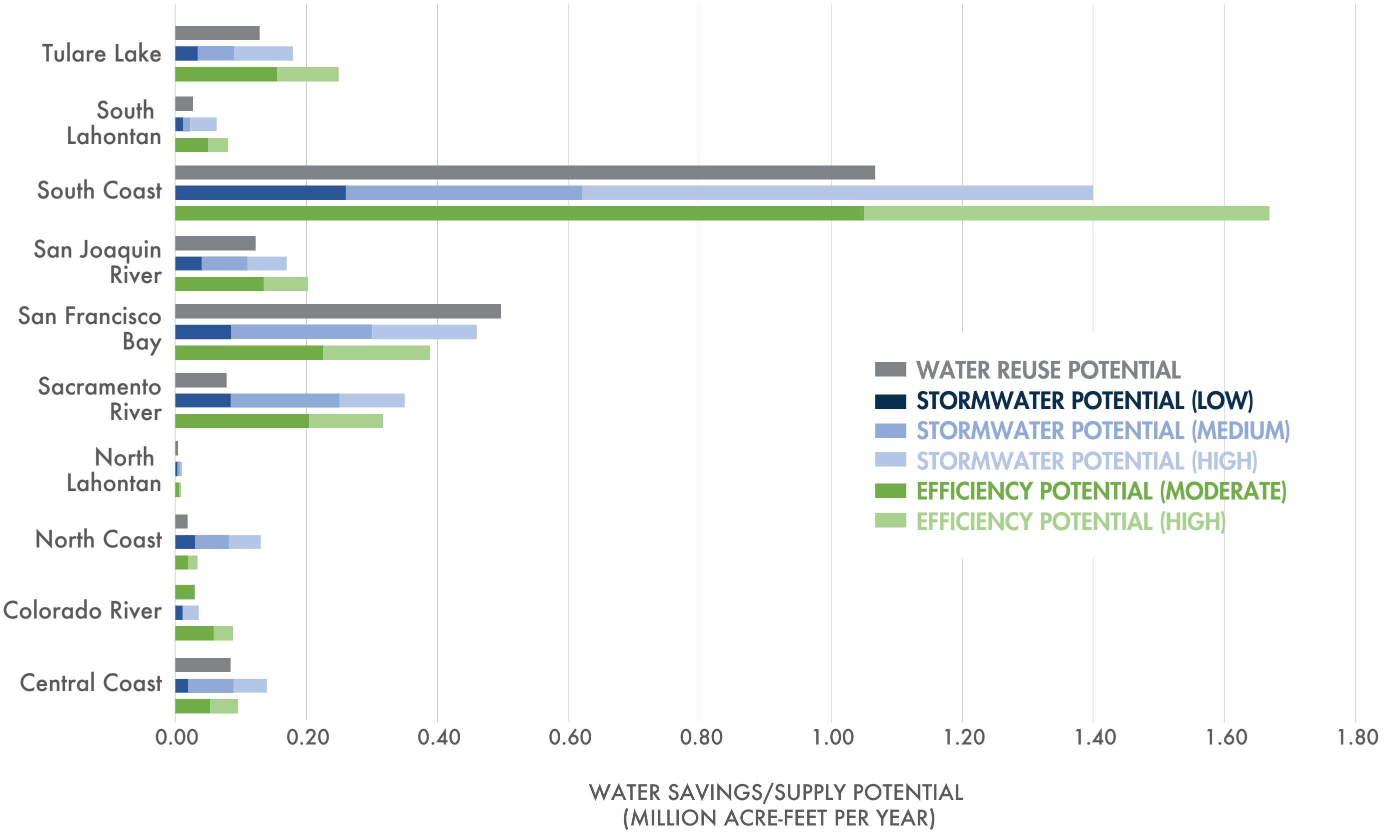


REGIONAL SUMMARY

All regions have the potential to save water through water efficiency improvements and to augment local supplies through water reuse and stormwater capture (Figure 17). In terms of the total volume of water, the greatest potential for efficiency, reuse, and stormwater capture is in the South Coast, followed by the San Francisco Bay and the Sacramento River HRs. These regions have the highest population and represent the largest urban uses of water in the state.

However, the relative importance of the efficiency and supply augmentation potentials vary across the state. In six of the ten regions, water efficiency shows the greatest potential. In three of the regions, i.e., the North Coast, Central Coast, and Sacramento River, stormwater capture holds the greatest potential. And in the San Francisco Bay Area, water reuse holds the greatest potential.

Figure 17. Water Efficiency, Water Reuse, and Stormwater Capture Potential by Hydrologic Region 🔍

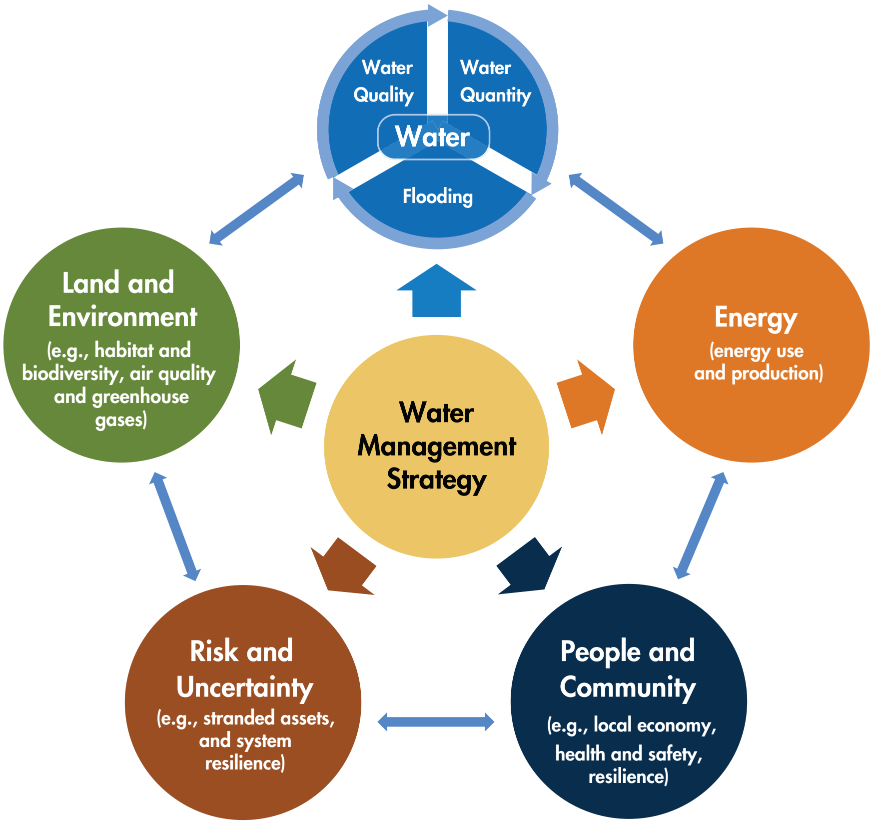


COSTS AND BENEFITS OF WATER EFFICIENCY, WATER REUSE, AND STORMWATER CAPTURE

A key factor in the adoption of water efficiency, water reuse, and stormwater capture is their economic feasibility. Cooley, Phurisamban, and Gleick (2019) evaluated the costs of alternatives for urban water supply options based on data for California. The authors found that water efficiency measures were almost always less costly than other water supply options except for some of the most expensive landscape water reduction options. Water reuse and urban stormwater capture projects were more costly per unit of water produced but still less expensive than seawater desalination—the most expensive option evaluated. Further, the authors note that many of these options provide additional co-benefits, such as improving water quality in nearby waterways, reducing greenhouse gas emissions, and providing green space, that can make them even more financially attractive.

Government agencies, businesses, and others are increasingly acknowledging the importance of the co-benefits of alternative water strategies and the potential they offer to help build partnerships, leverage resources, and garner public support (Diringer et al. 2019). In this section, we describe the key co-benefits of water efficiency, water reuse, and stormwater capture. We do not *quantify them, as this would require project-specific information. However, we urge local, regional, state, and federal policymakers to explicitly integrate co-benefits into decision-making processes and criteria when evaluating water strategies and implementing policy.* Diringer et al. (2019) presents key themes that should be addressed in any such assessment (Figure 18), and Diringer et al. (2020) provides guidance for water managers conducting these assessments.

Figure 18. Benefit Themes for Identification of Relevant Benefits of Water Management Strategies



Source: Diringer et al. 2019

WATER RESILIENCE BENEFITS

Improved water resilience is critical to advancing California's water future in the face of growing variability and uncertainty. The Pacific Institute defines "water resilience" as the ability of water systems to function so that nature and people, including those on the frontlines and disproportionately harmed, thrive under shocks, stresses, and change (Brill et al. 2021). While climate change is a primary driver of this focus, water resilience addresses a wide range of environmental, social, economic, and political pressures on water. Expanded water efficiency, water reuse, and stormwater capture will enhance California's water resilience in several fundamental ways:

1. **Robustness:** Water efficiency and reuse enhance the robustness of water systems, permitting them to continue to provide services under adverse conditions. For example, water efficiency and reuse reduce vulnerability to drought by reducing the level of water demand, which allows a water system to continue to provide water services for longer periods under adverse conditions.
2. **Redundancy:** Water efficiency and reuse help reduce supply-demand imbalances while also providing additional capacity within the system to respond to variability and uncertainty in water supplies. Some of the water saved from these efforts can be used to meet new demands, or it can be returned to the natural system to provide ecological benefits. Additionally, water-use efficiency and distributed reuse can take pressure off centralized systems and provide additional capacity during a stress or shock.
3. **Flexibility:** Water efficiency and reuse provide flexibility when traditional sources are constrained due to drought, ongoing water scarcity, or other water-supply disruptions. They can also be implemented in a modular fashion, starting small and expanding as needed, to confer operational flexibility.

In addition to supporting water resilience, these strategies can provide additional co-benefits to communities and the environment. In this section, we explore some of the additional co-benefits and trade-offs of water efficiency, stormwater capture, and water reuse.

WATER BENEFITS

Water-supply, water-quality, or flood-management improvements are typically the focus of water-management decisions. There is now a growing awareness of the relationships among them due, in part, to recent frameworks, such as Integrated Water Resources Management and One Water, leading water managers to develop approaches to capturing multiple water-related objectives in a single project.

Stormwater management has traditionally focused on the single objective of collecting or diverting stormflows away from urban centers through drains, tunnels, and pipes to reduce flooding. This approach has helped to reduce flood risk but increased the flows of oils, heavy metals, salts, and trash into nearby waterways. New interest in green infrastructure seeks to provide flood management benefits while also reducing pollution and augmenting local water supplies. Managed aquifer recharge (MAR), for example, consists of routing stormwater, surface water, or floodwater to a groundwater recharge area. Perrone and Rohde (2016) described the multiple economic, water supply, flood protection, and water-quality benefits of a set of MAR projects in California; these projects must be designed with source water quality and other site-specific parameters in mind. Stormwater capture systems, especially those devised with broader goals in mind, can also capture dry-season runoff from irrigation, helping to reduce pollutant loads to waterways and potentially providing water for recycling.

Water-efficiency improvements are usually implemented to reduce water demands, but they also offer additional water-supply benefits. Southern California efficiency projects were shown to reduce demand for both surface and groundwater, allowing reservoirs to retain water longer and for local groundwater levels to rebound even during the severe 2012-2016 California drought (Metropolitan Water District of Southern California (MWD) 2021b; Inland Empire Utilities Agency 2016). Landscape efficiency improvements reduce urban runoff, preventing fertilizers and pesticides from being discharged into local waterways (Municipal Water District of Orange County and Irvine Water District 2004).

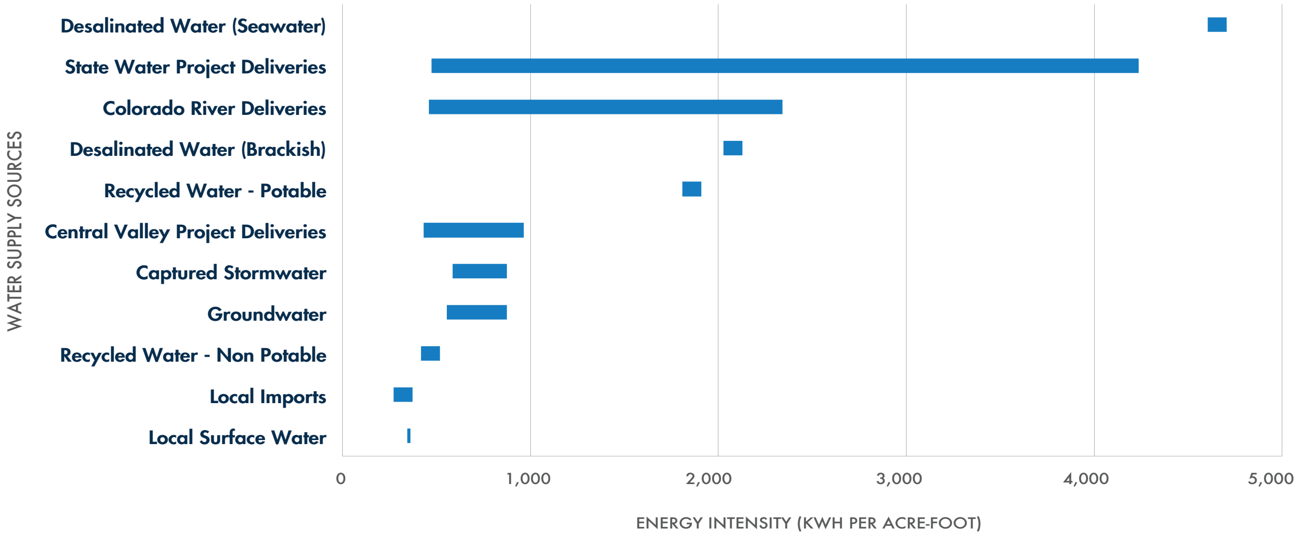
ENERGY AND CLIMATE BENEFITS

California's water system, like all water systems, includes an energy cost to operate. Substantial amounts of energy are required to collect, distribute, treat, and especially use water, and to collect and treat wastewater. Prior studies have estimated that about 20% of California's total statewide electricity use, a third of non-power plant natural gas consumption, and 88 billion gallons of diesel consumption are related to water—from collection and treatment to use and wastewater management—with a large share associated with using water in homes and businesses and on farms (Klein et al. 2005). By carefully considering the energy implications of water policies, policies can be chosen that simultaneously improve California's water situation and reduce the energy cost of the water system.

By reducing water demands, water-efficiency programs also reduce the energy required for treating and delivering water, heating and/or pressurizing the water for use, and treating wastewater. For example, California instituted mandatory drought restrictions in 2015 that reduced urban water usage by nearly 25% compared to 2013 levels. Spang, Holguin, and Loge (2018) found that those water conservation mandates reduced electricity use by 1,830 GWh, 11% greater than the savings from the efficiency programs run by all the investor-owned utilities in California combined, and reduced greenhouse gas emissions by 524,000 metric tons of carbon dioxide equivalents.

A push to expand water reuse and stormwater capture may or may not produce an energy savings, depending on the energy intensity of the water source that is displaced or that would have been developed. Water reuse and stormwater capture may require additional energy to treat the water prior to use; however, the energy requirements can be less than some water supply alternatives, such as seawater desalination and importing water over long distances and steep terrain (Figure 19). Additionally, reuse can be coupled with energy recovery, partially or even fully offsetting its energy requirements. Likewise, stormwater capture could raise groundwater levels and/or improve groundwater quality, reducing energy requirements for pumping and treating groundwater prior to use. To maximize this co-benefit, planners must assess and analyze the energy implications of the water strategies they propose.

Figure 19. Range of Energy Intensity of Water Sources across California



Note: In urban areas of California, the energy intensity of water from the State Water Project and Colorado River are at the higher end of the ranges shown. *Data Source:* Based on data from Szinai et al. 2021.

LAND AND ENVIRONMENT BENEFITS

Water is directly connected to land and the environment, including ecosystem health, biodiversity, air quality, climate, and soil health. Research on ecosystem services has advanced dramatically over the past several decades, and there is a growing body of literature on indicators and metrics for assessing the benefits and trade-offs of water management projects.

Healthy ecosystems require an adequate amount and quality of water at the right time. Because water management strategies can affect these, careful design and evaluation of projects can provide environmental co-benefits. For example, traditional wastewater treatment is designed to reduce contaminants released into the environment. Water reuse projects can also reduce pollutant flows into nearby waterways, improving surface water quality and aquatic ecosystem health. However, in some instances, water reuse can reduce water availability for instream flows and downstream users (Zoltay, Kirshen, and Vogel 2007).

Stormwater capture also reduces contaminant loading into nearby waterways. Urban runoff is a major source of impairment for rivers, lakes, reservoirs, and estuaries. The International Stormwater Best Management Practices database provides data on practices for reducing contaminant loads and can help to quantify the expected water quality benefits of these projects (BMP Database 2018).

Outdoor water efficiency measures save water, but also can provide environmental benefits by leaving water in streams and reducing the use (and ultimately runoff) of pesticides and fertilizers that are typically applied on turfgrass-dominated landscapes. Certain kinds of water-efficient landscapes also provide habitat for local flora and fauna, improving local biodiversity.

PEOPLE AND COMMUNITY BENEFITS

The alternative water efficiency and supply strategies discussed in this assessment can also provide benefits to people and communities by, for example, improving livability of urban environments (urban cooling, beautification of streets and neighborhoods); reducing costs for water, wastewater, and stormwater management services; and promoting more equitable access to water services.

A recent assessment found that water efficiency and alternative supply options, including the ones assessed here, are often a far more cost-effective way to secure "new supplies" than traditional efforts to build more surface storage or transfer more water from distant watersheds and aquifers (Cooley, Phurisamban, and Gleick 2019), improving household level affordability and reducing water rates. A study by the Alliance for Water Efficiency found that water conservation and efficiency reduced water rates in Tucson and Gilbert, Arizona by 11.7% and 9.0% respectively (Mayer 2017a; 2017b).

There is growing recognition that water planning and management decisions must incorporate equity considerations, defined here as the just distribution of costs and benefits among stakeholders. While equity is increasingly cited as a desired benefit of specific water management strategies, the strategies themselves are not inherently equitable or inequitable. Rather, it's their implementation. It is important to examine the distribution of benefits and costs among affected stakeholders and to prioritize incentives and technical assistance to low-income households and communities. This also requires increasing the transparency of decision-making and ensuring that communities have a voice in local decisions.

CONCLUSIONS AND RECOMMENDATIONS

Growing pressures on California's water supply from many factors, including population growth and intense periods of drought exacerbated by climate change, are leading to the unsustainable use of surface water and groundwater. There are deep mismatches between water supply and demand, and human-caused climate changes are exacerbating these challenges and creating new ones for water managers across the state. In this study, we provide a new assessment of the potential for a range of water strategies in urbanized parts of California to both reduce inefficient and wasteful water demands and expand local water supplies. Expanded implementation of these alternatives would provide both effective drought responses in the near-term and permanent water-supply reliability and other co-benefits for the state.

This assessment finds that urban water-use efficiency improvements could reduce statewide annual water use by 2.0 million to 3.1 million acre-feet. The reuse potential of municipal wastewater is 1.8 to 2.1 million AFY, and the stormwater capture potential is 580,000 AFY in a dry year to as much as 3.0 million AFY in a wet year. Efforts in these areas have been underway in California for decades, and laudable progress has been made, but much more can be done. We conclude that California can fill the gaps between water supply and demand with a wide range of strategies that are technically feasible, cost effective, and compatible with healthy rivers and groundwater basins.

RECOMMENDATIONS

This report has identified the untapped potential to expand nontraditional supply options and increase urban water efficiency savings in California. This is the first step in tackling California's water problems, but it is also critical to adopt effective policies and programs to tackle real and perceived barriers communities face in realizing this potential. In this section, we offer recommendations for helping to realize the untapped potential of water efficiency, reuse, and stormwater capture.

Expand Efforts to Improve Water-Use Efficiency and Water-Loss Control. There are significant opportunities to improve the efficiency of water use in California homes, businesses, and institutions and to reduce losses in water distribution systems, making communities more climate resilient, reducing waste, cutting costs, and reducing the gap between water supply and water demand. Greater funding, combined with new and greater enforcement of regulations, expanded education and outreach, and additional technical assistance programs, are needed to capture this untapped potential.

- State and federal agencies should increase funding, including through grants and low-interest loans, for local water-efficiency and water-loss control programs to levels consistent with other water-supply investments, and provide planning grants and technical assistance to help small and disadvantaged communities apply for funds.
- Local agencies should expand customer incentive programs for water-efficiency measures, including installing high-efficiency appliances and fixtures, devices to monitor household water use and identify leaks, and sustainable landscapes, and improve education and outreach strategies for households and businesses.
- State and local agencies should make efficiency programs more accessible to low-income and multi-family households through targeted support, such as direct-install programs and partnerships with trusted local nonprofit and community groups.

- State, local, and regional agencies and/or non-governmental organizations should provide education programs and technical support for landscape professionals, residents, and businesses on installing and maintaining sustainable landscapes.
- State and/or local agencies should follow Las Vegas' lead in banning non-functional grass at businesses and institutions and in large housing developments.
- State and local agencies should provide funding for Model Water Efficient Landscape Ordinance compliance education and job training programs that support a transition to water-efficient landscapes.
- State and/or local agencies should adopt ordinances requiring residential and commercial buildings to install water-efficient devices, consistent with Senate Bill (SB) 407, when they undergo alterations, improvements, or sale, as well as mechanisms to monitor compliance.
- Water suppliers should partner with energy utilities on water efficiency and water loss programs that save water and energy and reduce greenhouse gas emissions.
- State agencies should provide technical support to water utilities and financial support to smaller utilities to help meet newly adopted water-loss and water-efficiency standards under SB 555 and Assembly Bill (AB) 1668/SB 606.

Expand the Supply and Use of Recycled Water. California has made considerable progress in expanding the reuse of high-quality treated wastewater, but large volumes of municipal wastewater continue to be discharged to local waterways, marine and estuarine environments, and land. A range of new actions and policies are needed to expand the supply and use of recycled water.

- State and local agencies should aggressively work to take advantage of new federal funding for water reuse potentially available from the Infrastructure Investment and Jobs Act of 2021.
- State agencies should make more low-interest loans and grants available to support recycled water projects of all types in California, prioritizing projects that provide multiple benefits and create regional water supply and environmental solutions.
- State agencies should provide financial and technical resources to support community efforts to communicate about the benefits and safety of water reuse.
- The State Water Resources Control Board should continue developing regulations that support direct potable reuse of recycled water and onsite non-potable water systems, with suitable public health safeguards.
- The State Water Resources Control Board should clarify and regularly re-evaluate water recycling regulatory frameworks to advance fit-for-purpose concepts, address any gaps, and adjust treatment standards to protect public health and the environment while not imposing unnecessary treatment and management costs.
- Local and regional agencies should conduct assessments of the supply of and demand for treated wastewater based on improving efficiency, declining per-capita water use, and changes in population, regional economic activity, and land use.
- Local and regional agencies should conduct regional assessments of demand for recycled water that incorporate quality of water needed by potential recycled water customers.
- Water managers and consultants should design recycled water projects sensitive

to communities' long-term economic, technical, financial, and managerial capacity to support the long-term operation and maintenance of recycled water projects.

- The State Water Resources Control Board should develop new recycled water goals based on a quantitative assessment of the potential for water reuse and include those goals in the next update of the state's Recycled Water Policy.

Increase Stormwater Capture Opportunities at Various Scales. The variability of precipitation in California produces, at times, large volumes of stormwater that could, under certain circumstances, be captured, used, or stored, expanding total water supply. This will require changes in local infrastructure and updated state and local policies and programs.

- The state and/or research entities should create a framework to support urban communities in identifying the optimal mix of centralized and decentralized stormwater capture projects to maximize water supply and other co-benefits.
- State and local entities should pursue ordinances and NPDES municipal stormwater permitting provisions that strongly promote the use of low-impact-development and stormwater and greywater outdoors, with a multi-benefit lens.
- DWR and the State Water Resources Control Board should develop state and/or regional coordination policies and programs that facilitate public-private stormwater projects, such as through alternative compliance options for municipal and industrial stormwater permits.
- Policymakers should reduce the onerous voter-approval requirements for stormwater services. While SB 231 could help local agencies develop dedicated funding sources, additional policies that increase long-term funding and cover operation and maintenance expenses are needed.
- Water providers, local agencies, and community organizations should provide incentives for households and other properties to encourage adoption of on-site stormwater capture.
- Local agencies and organizations should partner to provide stacked incentives, i.e. incentive programs co-funded by two or more entities, to drive multi-benefit stormwater projects.
- The state should clarify how and when existing health and safety water quality standards apply to stormwater to efficiently ensure local agencies are clear on how to treat and monitor stormwater capture for reuse.
- The State Water Resources Control Board should develop stormwater capture goals based on a quantitative assessment of its potential and track progress toward those goals.

Improve State and Local Planning to Support Integration of Water and Non-Water Benefits into Water Management and Investment Decisions. Capturing the untapped potential for water efficiency, water reuse, and stormwater capture would benefit from broader improvements in state and local planning. In particular, efforts to incorporate multiple benefits—both water and non-water—into water management and investment decisions can improve a project's financial viability and public acceptance while helping to minimize adverse and unintended consequences.

- State agencies should use existing programs, such as the Safe and Affordable Funding for Equity and Resilience (SAFER) program, to provide financial and technical support for feasibility studies of water efficiency, reuse, and stormwater capture opportunities.
- Researchers and others should develop tools and resources to support communities in accounting for the co-benefits of efficiency, reuse, and stormwater capture projects, such as case studies and a library of project-level cost-benefit analyses.

- State and local water managers should expand the types of benefits and trade-offs evaluated in water management decisions, and meaningfully engage with stakeholders in these evaluations.
- State and local water managers should evaluate the distribution of costs and benefits of a project to promote more equitable distribution. Equity should serve as an essential lens for evaluating water management strategies.
- State agencies should provide more incentives for drinking water, wastewater, stormwater, flood control, and local land use managers to collaborate on water projects and planning.

Support State-Level Data Collection Efforts and Integration Across and Within State Agencies. Data from two large-scale data collection efforts (EAR and Volumetric Annual Reporting) were key to this report's analysis of the potential for efficiency and reuse in California. Consistently reported data collected at regular time intervals is an essential component in making informed projections about water demand, water availability, and investment needs.

- The State should continue to support robust, long-term data collection efforts on water supply, use, wastewater production, and reuse. Continually improve data quality and usability while remaining mindful of the importance of retaining comparability of specific variables across years.
- State agencies should consider accounting for wastewater effluent legally reserved for instream flows and other environmental purposes in assessments of potential reuse to facilitate a more comprehensive understanding of the multiple benefits wastewater effluent and reuse provide for society and the environment.
- State agencies should examine synergies between ongoing data collection efforts and use these insights to improve data quality (e.g., compare the quantity of recycled water use reported by water suppliers in the EAR to the quantity of recycled water supplied by recycled water producers and wastewater treatment plants reported in the Volumetric Annual Report).

Investigate Research Gaps to Improve Effectiveness of Water Efficiency, Water Reuse, and Stormwater Capture. There remain outstanding scientific questions that must be addressed for effective implementation of these supply options. State agencies, academics, water agencies, and community organizations all have a role to play in filling research gaps.

- The State should assess current CII water use and end-uses within specific subsectors to provide better information for estimating future water demand and identifying efficiency and reuse opportunities.
- The State should conduct statewide water end-use and saturation studies, potentially in combination with ongoing energy studies, for homes, businesses, and institutions to help identify which water uses hold the greatest savings opportunities.
- Researchers and others should examine behavior change and other strategies for encouraging greater uptake of water efficiency, water reuse, and stormwater capture.
- Researchers and others should identify real and perceived barriers institutions face in pursuing water efficiency, reuse, and stormwater capture projects and co-develop resources to support overcoming these barriers.
- Researchers and others should identify the potential effects of and ways to mitigate stormwater capture and recharge impacts on the water quality of California's public supply aquifers.

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