How Has Residential Per Capita Water Consumption in California Changed Between 1994–2019?

Juhee Lee, Mehdi Nemati, and Ariel Dinar

Residential water consumption (gallons per capita per day) in California fell dramatically in the past three decades. These reductions are the result of various water-conservation policies and other efforts by state and local water managers. In this article, we describe California's major droughts and conservation policies between 1976 and 2020. We then estimate the reductions in residential water consumption from 1994 to 2019 and show how they vary by time, location, and water agency characteristics.

Conservation efforts and polices have substantially reduced residential water use in California.

Photo Credit: Jaycek Dylag

California has one of the most proactive urban water management systems of the many states and countries facing water scarcity. The need for urban water management has increased in California mainly because of two conditions: 1) The state's urban population has steadily increased over time, and 2) California is affected by severe and long-lasting droughts. These situations have emphasized the need for water conservation in California's urban landscape.

The state continues to invest in and encourage conservation by introducing new technologies and various policy interventions to reduce water use. To combat the chronic threat of drought, the state enacted a series of regulations during the past three decades. However, little evidence exists that documents how residential water use and its distribution has changed over time due to these efforts.

This article examines: 1) how California's urban water systems (agencies) are structured and how residential water use has changed over time; 2) how California's existing water-conservation policies have reduced residential water use over the recent decades; and 3) how conservation practices have differed among the various agencies and regions.

We collected a comprehensive dataset from different sources, including monthly residential water use (measured as residential gallons per capita per day, or R-GPCD) from 1994 to 2019, water agencies' boundaries and characteristics, weather information, and demographic data. We then conducted an in-depth analysis to improve our understanding of regional differences in conservation results, consumer characteristics and behaviors, and policy effects.

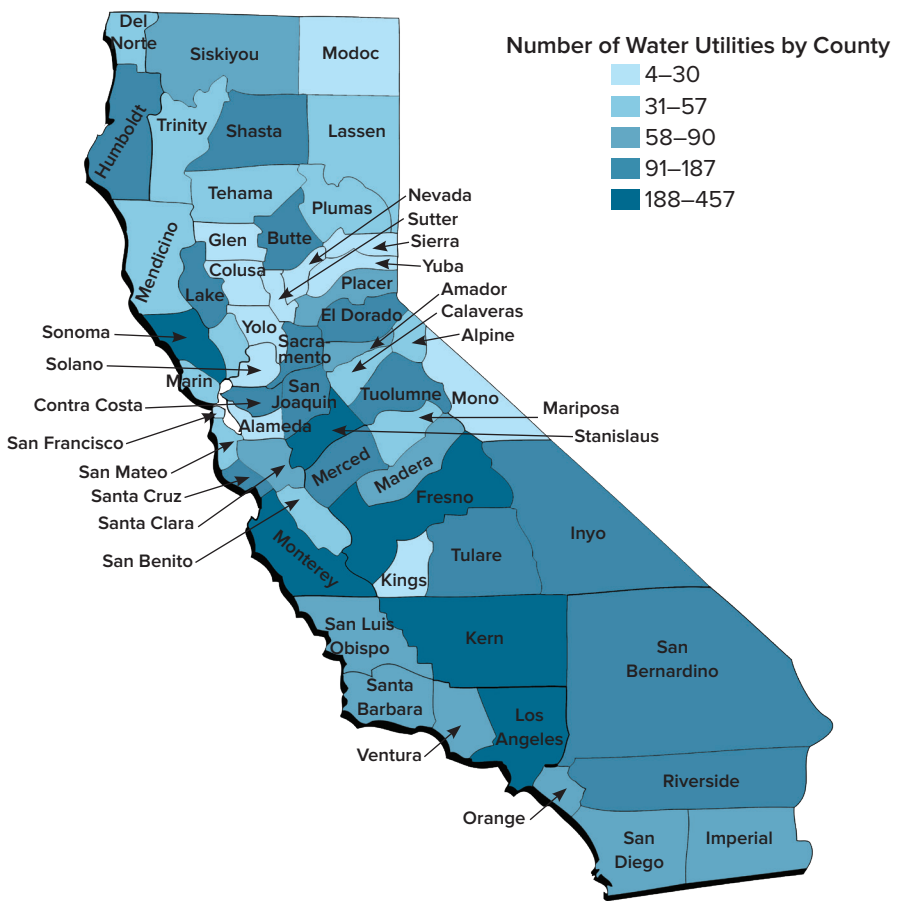
Public Water Systems

While California has more than 7,500 water agencies, nearly 50% of these agencies serve fewer than 100 customers, and about 80% serve fewer than 500. Agencies serving more than 3,300 customers constitute roughly 9% of all agencies. The majority (86%) rely on groundwater, while 14% have surface water as their primary water source. Approximately 33% of the agencies primarily serve residential areas, followed by recreation areas (18%), and industrial/agricultural areas (10%). The rest serve mobile home parks, restaurants, schools, hotels, institutions, highway rest areas, and medical facilities.

Most of California's small and medium-sized water agencies are privately owned. The majority of the larger agencies are public (owned by local governments). Figure 1 (on page 6) shows the distribution and number of water agencies in California by county. Water agencies in California are not distributed evenly across counties. Counties with a high population or high agricultural intensity tend to have more water agencies.

From the 7,500 water agencies, we obtained data on 409 urban water agencies throughout California to analyze water-use changes over time. Each of these 409 agencies serve more than 3,000 customers, or annually deliver over 3,000 acre-feet of water, making them subject to regulations by the State Water Resources Control Board (SWRCB). These agencies are required to report monthly water use to the Department of Water Resources (DWR) and recently also to the SWRCB. These 409 agencies serve 97% of California's population, and local governments own the majority (81%). We observed that 69% of these agencies mainly use surface water (which is less reliable) as a primary water source. Among the

Figure 1. Number of Water Systems by County Across California



Note: The 7,500 water agencies in California are not distributed evenly across counties. Regions with a high population or high agricultural intensity tend to have more water agencies.

agencies that use surface water, only 25% own their water source. The rest rely on purchased surface water. Most of the agencies that purchase surface water are solely retailers; only 14 (3.4%) are also water wholesalers.

Figure 2 illustrates the average R-GPCD by hydrologic region from 1994 to 2019. Our analysis is based on average monthly R-GPCD. From 1994 to 2019, R-GPCD follows a downward trend across all of the regions. The dashed line in Figure 2 indicates the average across all the regions in California. The minimum, average, and maximum R-GPCD in California in 1994 was 106, 147, and 232, respectively. These numbers decreased in 2019 to 73, 101, and 129, respectively. These findings verify that regional variation in R-GPCD fell between 1994 and 2019 (regions have become more similar over time in terms of their water consumption). This figure also indicates the regional differences in per capita residential water use. For example, although R-GPCD decreased over time, the Colorado River region has one of the highest R-GPCD levels compared to the others. These differences between the regions could be due to multiple factors such as climate conditions (e.g., the Colorado River Region has higher temperatures and less precipitation than other regions), population density and house size, regional and agency-level regulations, and water management strategies, among other things.

Urban Water Conservation Policies

California's population grew due to rapid urbanization in the early 20th century. Frequent and long-lasting droughts led to significant water scarcity levels and challenges for water resource management. From 1976 through 2019, California experienced drought periods that significantly influenced the state's water conservation policies during the past half-century (Figure 3).

The first drought period (1976–1977) triggered the Urban Water Management Planning (UWMP) Act, passed in 1983. This act imposed mandates on state agencies requiring every urban water supplier with more than 3,000 customers, or annually delivering over 3,000 acre-feet of water, to provide water management planning at least once every five years.

The second drought period (1987–1992), which resulted in significant water scarcity, expanded the existing urban water management measures. Correspondingly, the UWMP Act of 1983 was amended in 1991 to allow more comprehensive and preventive measures against short- and long-term droughts. These efforts led to initiatives to reduce short- and long-term urban water use through the 1993 Memorandum of Understanding Regarding Urban Water Conservation.

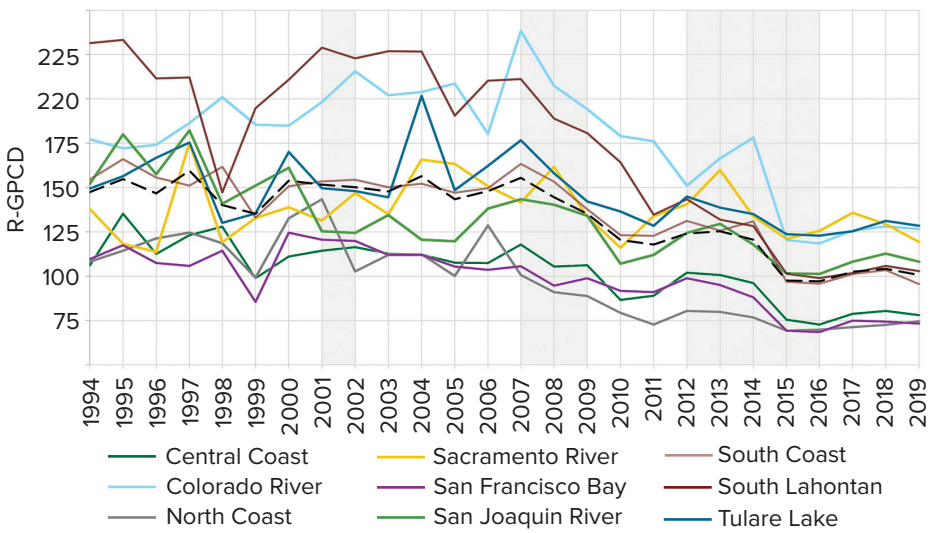
The third major drought (2007–2009) induced the Water Conservation Act in 2009 to ensure sufficient water supply. This act mandated that all water suppliers increase their water-use efficiency, targeting a 20% reduction in R-GPCD consumption by 2020 (called 20×2020).

The fourth drought (2012–2016) was the second prolonged drought period, following the previous one in 1987–1992. The continued water scarcity led to the governor's proclamation of an emergency decree in 2014 that ordered state agencies to take more aggressive water-saving actions. The order called on urban water suppliers to immediately implement their water shortage contingency plans, including the state

drinking water programs, to identify communities in danger of running out of water by extending water loss reporting requirements in 2015 to urban wholesale water suppliers.

This four-year, prolonged drought, triggered changes in public perception and increased water policy interventions with the enactment of the Water Conservation and Drought Planning legislation in 2018. This legislation required the state to have ongoing efforts to make water conservation a way of life in California through four goals: 1) use water more wisely; 2) eliminate water waste; 3) strengthen local drought resilience; and 4) improve agricultural water-use efficiency and drought planning. In addition, water suppliers must enact provisions for efficient water use by 2022.

Figure 2. Residential Consumption in Gallons per Day per Capita (R-GPCD) in California (1994–2019)



Note: Gray areas indicate droughts (2001–2002, 2007–2009, and 2012–2016). The black dashed line indicates the average across all the regions in California. The number of agencies by region in our dataset are Central Coast (32), Colorado River (15), North Coast (16), Sacramento River (43), San Francisco Bay (47), San Joaquin River (28), South Coast (175), South Lahontan (17), and Tulare Lake (31). We exclude North Lahontan, since this region has only five agencies.

Methods and Results

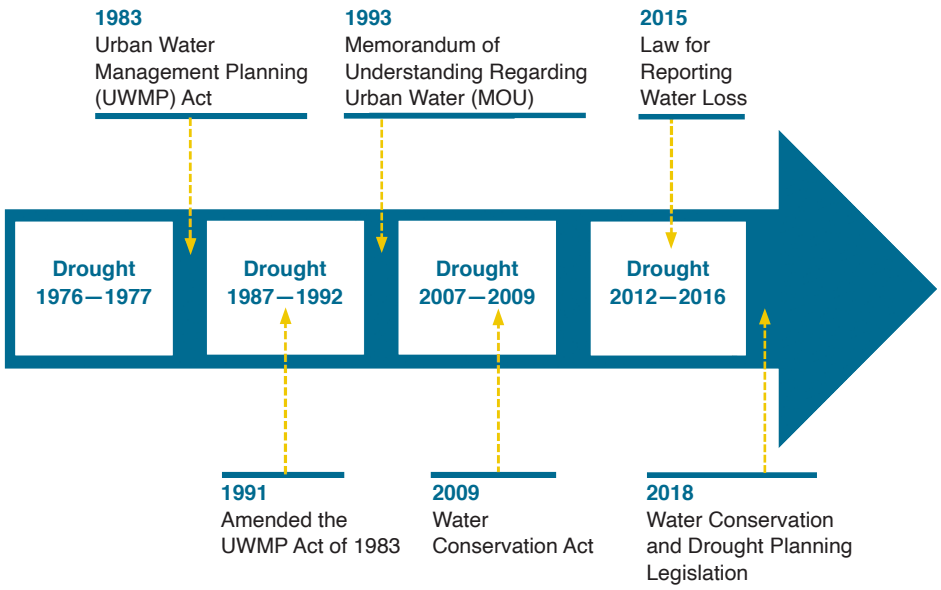
Based on our sample of 409 water agencies, we examined the changes in R-GPCD from 1994 to 2019 using statistical models where we controlled for variation in weather (precipitation and temperature) and demographics (average income and household size), along with agency-specific and calendar month-specific effects. Note that estimated effects in this article provide descriptive differences and should not be interpreted as causal effects of specific programs.

Figure 4 (on page 8) shows our statistical model results. Each point is the estimated change in R-GPCD, compared to the 1994 levels. As shown in the figure, considerable reductions in R-GPCD are realized after the 2007–2009 drought, and, later, after the 2012–2016 drought. Notably, between 1994 and 2019, residential R-GPCD decreased by 34% (47 R-GPCD). We also found that Southern and Northern California agencies reduced their R-GPCD by 39% (58 R-GPCD) and 19% (23 R-GPCD), respectively, in 2019 compared with 1994 levels.

We divided the dataset into seven periods, based on the significant drought events (and following major policy interventions) in California: Period 1 (1994–2000), Period 2 (2001–2002), Period 3 (2003–2006), Period 4 (2007–2009), Period 5 (2010–2011), Period 6 (2012–2016), and Period 7 (2017–2019). Next, we estimated water consumption changes during each period, compared to the base period, Period 1.

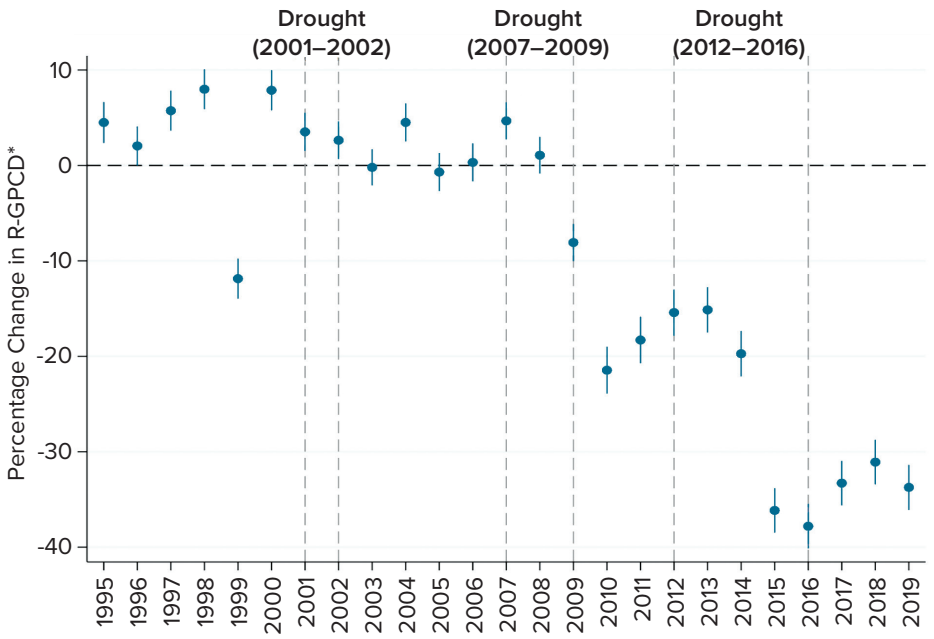
Our results show that water consumption decreased by 3.2% during 2007–2009, compared to the base period 1994–2000. After that drought, water consumption was further reduced during the 2010–2011 period that

Figure 3. Overview of the California Urban Water Conservation-Oriented Policies from 1976 to 2020



Note: This figure breaks down six policy interventions implemented by the California State Legislature according to the drought periods.

Figure 4. Estimated Residential Water Consumption Changes in Gallons per Capita per Day (R-GPCD): 1994–2019



*Note: Percent change is in comparison to 1994 levels. R-GPCD in 1994 was 142.03.

followed (up to 22.6%), mainly due to the state and local agencies' conservation policies and efforts. An extended drought occurred in Period 6 (2012–2016), leading to a 28.5% decrease in water consumption relative to the base period. For the last period, 2017–2019, water use fell by 34.8%, compared to 1994–2000. Overall, the effects are cumulative as we move from the first to the last period (i.e., 0.6% in the second period to 34.8% in the last period), indicating the continuous collective conservation efforts since 2001.

Finally, we estimated the residential water-use trends by periods, considering heterogeneity based on agency and regional characteristics. Relative to the base period, we observed a more substantial reduction in R-GPCD by local, government-owned agencies than by those owned by the private sector. In addition, we found that agencies relying primarily on surface water have a significantly higher rate of reduction than those relying primarily on groundwater. Our findings also indicated that those who rely on purchased water reduced usage by higher rates than those relying on local sources, especially in the last ten years. Reduction rates in the 2017–2019 period, compared with 1994–2000 levels, are 34.9% (48 R-GPCD) and 24.6% (36 R-GPCD), respectively, for agencies relying on purchased water versus those relying on local sources.

Regarding climatic characteristics, we found that the percent reduction in R-GPCD in summer months is similar to that in non-summer months. However, given that these are in percentage terms, the absolute values imply that the water conservation in summer is greater, since water use is relatively high due to outdoor activities, allowing greater opportunities to reduce use.

Lastly, we also found regional variation in water-use reductions. Specifically, during the 2017–2019 period, agencies in Southern California reduced usage by 33.9% (52 R-GPCD), and those in Northern California reduced usage by 20.3% (26 R-GPCD), compared with 1994–2000 levels. We also found evidence that agencies in Northern California started conservation in earlier periods (starting around 2003) than those in Southern California (starting around 2010).

Conclusions

We found that California's water use was reduced incrementally after major droughts, potentially due to state and local conservation policies, which resulted in improvements in urban water-use efficiency. We also found that these reductions vary based on the year, season, region, and agency characteristics. These findings have important implications for local and statewide water managers and policymakers to consider future conservation planning, legislation, policies, and investment strategies.

Suggested Citation:
Lee, Juhee, Mehdi Nemati, and Ariel Dinar. 2021. "How Has Residential Per Capita Water Consumption in California Changed Between 1994–2019?" *ARE Update* 24(5): 5–8. University of California Giannini Foundation of Agricultural Economics.

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For additional information, the authors recommend:

Lee, Juhee, Mehdi Nemati, and Ariel Dinar. 2021. "Historical Trends of Residential Water Use in California: Effects of Droughts and Conservation Policies." *Applied Economic Perspectives and Policy*.