The "Brown Effect"

California's Water Conservation Amidst a Record Drought

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By Allison Hornstra

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The University of Texas at Austin
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The Brown Effect: California's Water Conservation Amidst A Record Drought

ALLISON HORNSTRA
THE UNIVERSITY OF TEXAS AT AUSTIN

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ABSTRACT

Recent drought conditions have resulted in California's first-ever mandatory statewide conservation regulations. Although the current drought will eventually end, there will undoubtedly be many more in California's future. To better inform future policy decisions, it is crucial to investigate how effective these historic conservation mandates have been, and identify factors that may influence a region's ability to meet such mandates. Doing so is a vital step in learning how to best manage state-mandated water-use restrictions. In this project, the conservation mandates assigned to urban water suppliers and current conservation gaps in meeting those mandates were mapped. This study found that the geospatial pattern of conservation gaps suggests the need to modify how assigned targets are determined. Additionally, future work is outlined to determine the relative influence of various parameters of interest to conservation abilities.

1. BACKGROUND

1.1 Defining Drought

Drought is commonly defined as a deficiency in precipitation over an extended period, resulting in water shortages that adversely impact the environment and/or people. Deciding when to declare a drought is often a difficult task because droughts occur gradually, arise from a variety of factors, and lack a universal definition as to when they begin or end.

Complicating matters more, the same hydrologic conditions constituting a drought in one region within California may not constitute a drought in a different part of the state. Drought conditions can even vary amongst users who live in the same location but rely on different water supplies. Despite these localized variations, a steady decrease in carry-over supplies within reservoirs and the depletion of water levels in groundwater basins are both strong indicators of a statewide drought.

1.2 California's Water Supply

Three main water sources sustain California. They include the snowpack of the Sierra Mountains, water stored in engineered reservoirs, and water in groundwater basins. Most of California's precipitation comes from storms moving across the Pacific Ocean during winter months [1]. On average, 75 percent of California's annual precipitation occurs between the months of November and March [2]. These months are crucial in establishing a snowpack that can sustain water demands during summer months. Average precipitation is typically dependent on just a handful of storms within this time frame and a small variation in the number of winter storms can be the difference between a wet or dry water year.

1.3 Current Conditions

As of November 2015, California has endured four years of a record drought. Except for 2011, the state has had below-average precipitation every year since 2007 [3]. In 2014 (three years into the drought) the state experienced a snowpack measuring just 5% of normal [3]. By this time, the effects of drought were apparent. The water levels in reservoirs reached historical lows and withdrawals from groundwater greatly exceeded recharge rates. When Governor Jerry Brown declared a drought emergency on January 17, 2014, all of the water sources that California relies on had been dwindling from a series of dry years [4].

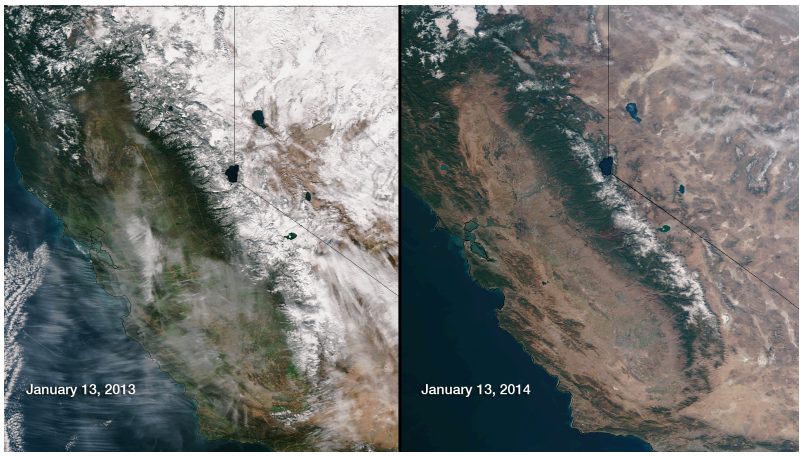


Figure 1: A comparison between the California-Nevada snowpack as of January 13th for 2013 and 2014 (NOAA National Climate Data Center)

Strained water resources are not new to California, which has an impressive infrastructure for moving and storing water across the state. However, it is clear that the state is currently pushing the limits of its ability to engineer around nature. As shown in Figure 2.0, the state's 12 main reservoirs are far below capacity, and at levels much lower than their historical averages. These reservoir conditions highlight the extent to which the state of California is running out of water.

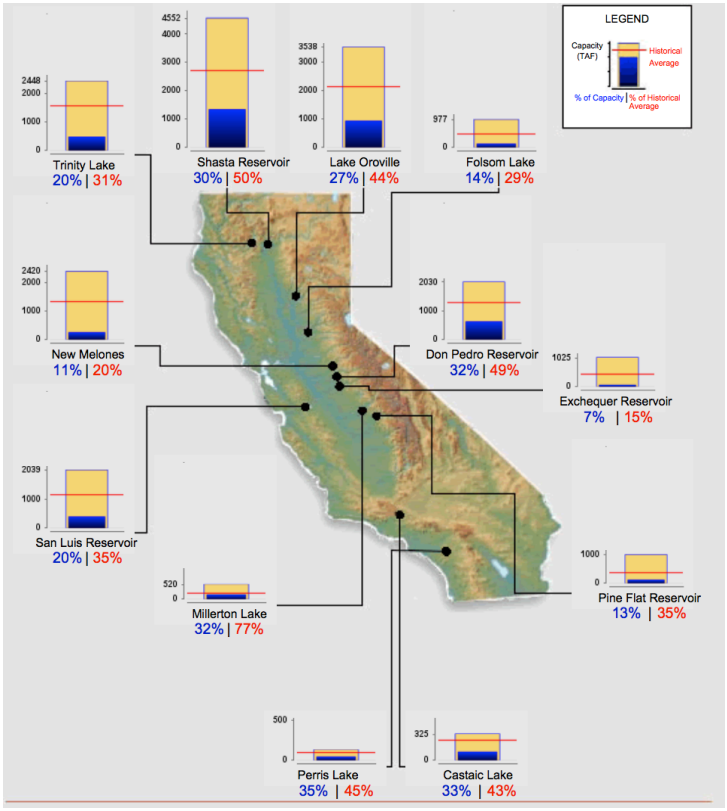


Figure 2: Conditions for selected reservoirs in the state of California. Data as of November 22, 2015. (California Department of Water Resources, California Data Exchange Center)

Figure 3: Contrasting conditions of Lake Oroville, California's second largest reservoir. The image on the left shows water level in July 2011, while the right shows July of 2014. (Getty Images)

As California's drought begins its fifth year, conditions show no sign of relenting. The 2015 water year saw the highest average temperature in 120 years, two of the most destructive wildfires in state history, and groundwater basins so depleted that the elevation in the San Joaquin Valley is sinking at an accelerated pace. Worsening conditions such as these are compounding the hardships already brought on by a four-year drought.

1.4 Regulatory Action

On January 17, 2014, California Governor, Jerry Brown, declared an Emergency Drought Proclamation in which he called for Californians to reduce their water use by 20 percent. This 20 percent target was not mandated, meaning that there would be no repercussions for failing to meet it. Among many other resolutions, the proclamation required urban water suppliers to submit monthly reporting of water production to the State Water Resources Control Board (State Water Board) [4]. These reports were established so that progress towards the target reduction could be monitored.

After a year of worsening conditions, Governor Brown issued the fourth in a series of executive orders on actions necessary to address California's severe drought conditions. On April 1, 2015, Gov. Brown signed an executive order directing the State Water Board to implement the state's first-ever mandatory water restrictions [5]. Specifically, urban areas were called to reduce potable urban water usage by 25 percent statewide. Information of enforcements by the State Water Board can be found here.

Most recently, the Governor extended his water conservation order on November 13, 2015. The newest executive order announced that if the drought continues through January, mandatory water cuts will remain in effect until October 2016.

2. PROJECT OBJECTIVES

Although this drought will eventually end, there will undoubtedly be more just like it in California's future. Water agencies in California have been asked to conserve tremendously, and the state must learn how to manage state-mandated water-use restrictions in a way that is in the best interest of the people. Thus, it is imperative to investigate how effective recent conservation mandates have been, and identify the factors that influence a region's ability to meet such mandates.

2.1 Scope of Work

The overall objective of this project can be broken down into two questions: "How is California doing when it comes to conserving water?" and "What's needed next?":

1. **How is California doing?:** Assess the effectiveness of current conservation mandates.

   Analyze water conservation successes and failures across the state of California, using ArcGIS to visually represent trends.

2. **What's needed next?:** Identify factors potentially influencing trends in conservation abilities.

   Analyze extent to which certain factors impact conservation rates.

   Use findings to better inform future water conservation regulations with fair and realistic mandates.

3. METHODOLOGY

3.1 Data Acquisition

Boundary shapefiles for California's hydrologic regions, counties, major water conveyance systems, and planning regions were obtained from the Department of Water Resources [8].

Monthly water-use reports for urban water suppliers were obtained from the State Water Board's online conservation portal [6]. The portal was established by the State Water Board to meet the Emergency Drought Proclamation requirements. It serves as a database for water-use reports beginning in June 2014 and ending in the most recent month of submissions. Reporting during 2014 required that agencies also provide monthly water-use for 2013. Therefore, data going back to 2013 was obtained.

In order to map spatial conservation trends across the state, geospatial references were needed to link agencies to their service area locations. The service area boundary layer data was obtained from the California Department of Public Health [7]. However, supplier submission of boundary shapefiles to the tool was voluntary. As a result, not all 411 urban water suppliers submitted shapefiles. This dataset also includes more than just the 411 suppliers required to submit monthly conservation data (ie: those with more than 3,000 connections). Additionally, naming discrepancies exist between the supplier names used in the State Water Board dataset and the shapefiles attribute table.

3.2 Data Processing

In order to join the two datasets, naming conventions for urban water suppliers were standardized. This required manually matching-up the names of water agencies in the State Water Board's report database to those in the attribute table of the boundary layer files. Upon completing this, the boundary layer files were mapped within ArcGIS, and a spreadsheet containing the water-use report data was joined to that of the boundary layer attribute table. During this step, only agencies present in both datasets were kept. Therefore, the boundary layers for irrelevant agencies (those without water use reports) were removed.

4. RESULTS

4.1 Conservation Mandates

The first map generated from the State Water Board's water-use database displays the mandatory conservation rates assigned to each agency. The State Water Board divided the 411 urban water suppliers into nine conservation tiers ranging from 4 – 36 percent. The tiers were based on residential water use during summer 2013 and those cities with higher residential gallons per capita per day (R-GPCD) were assigned to higher tiers. Mandates were constructed such that a statewide average of 25 percent will be achieved if all agencies meet their assigned mandate. Additional information on the State Water Board's rulemaking process can be found here.

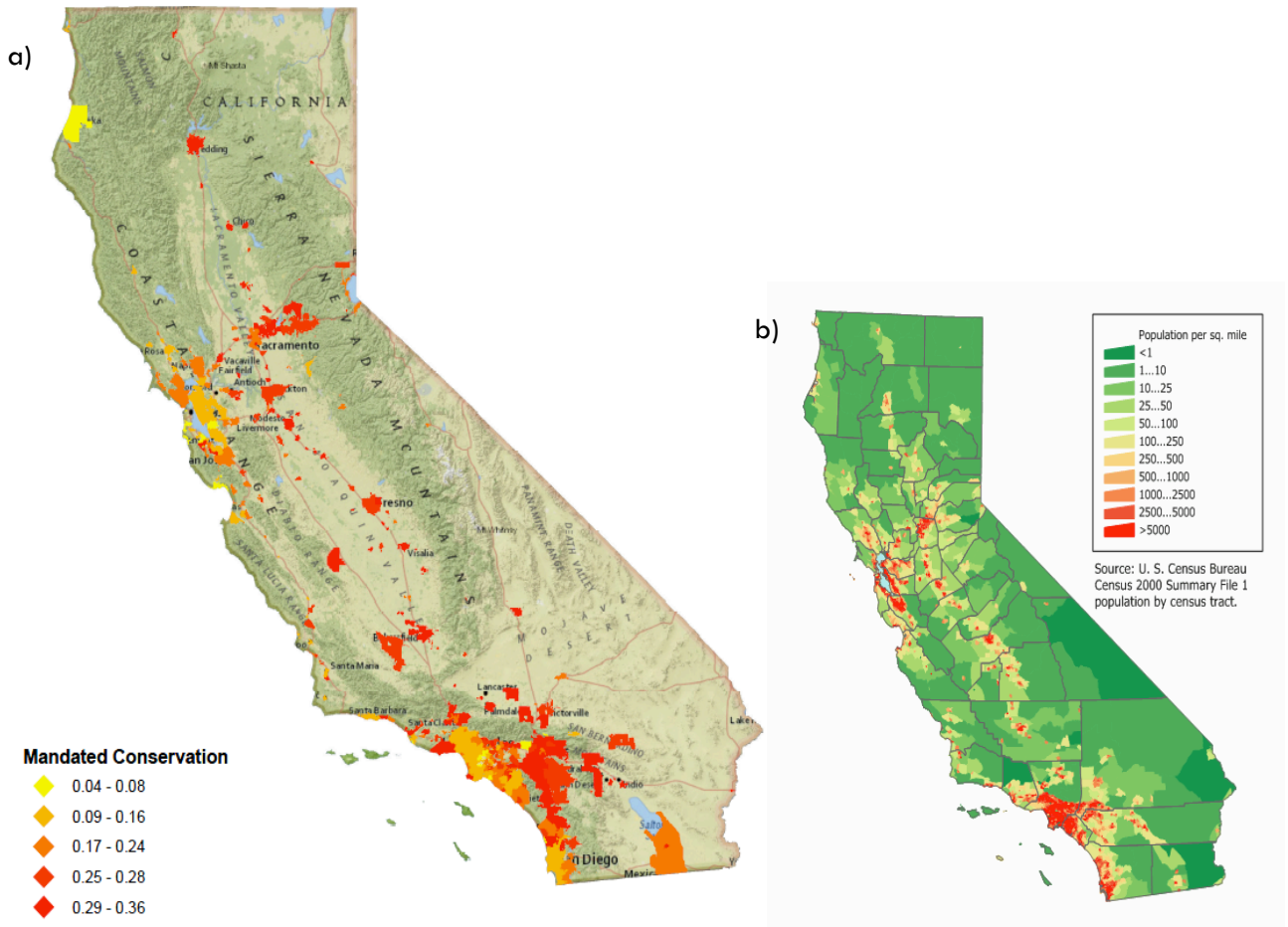


Figure 4: a) Magnitude of conservation mandates across urban water suppliers. *Please note that a total of 9 tiers were established by the SWRCB, but these were consolidated into 5 tiers for the map above.* b) Population density distribution throughout the state.

To ensure that the relatively small area covered by urban water suppliers was properly concentrated around urbanized regions within the state, the map was compared to population distribution data. As can be seen above, these were properly aligned with California's regions of highest population density. In fact, California is the most highly urbanized of the 50 states and it is estimated that 95 percent of residents live in cities [9]. As such, it was deemed appropriate to move forward with this data as a proper representation of urban water-use across the state.

4.2 Agency-Mandated Restrictions

In July 2014, 264 agencies had implemented their own mandatory restrictions, 108 agencies reported not having formal restrictions, and 15 agencies provided no response. It wasn't until the Governor's mandatory 25 percent cut that almost every agencies implement their own mandatory restrictions. In September 2015, 383 reported having their own mandatory restrictions, a drastic increase since July 2014. Additionally, only 5 agencies reported not having formal restrictions, and one did not provide a response.

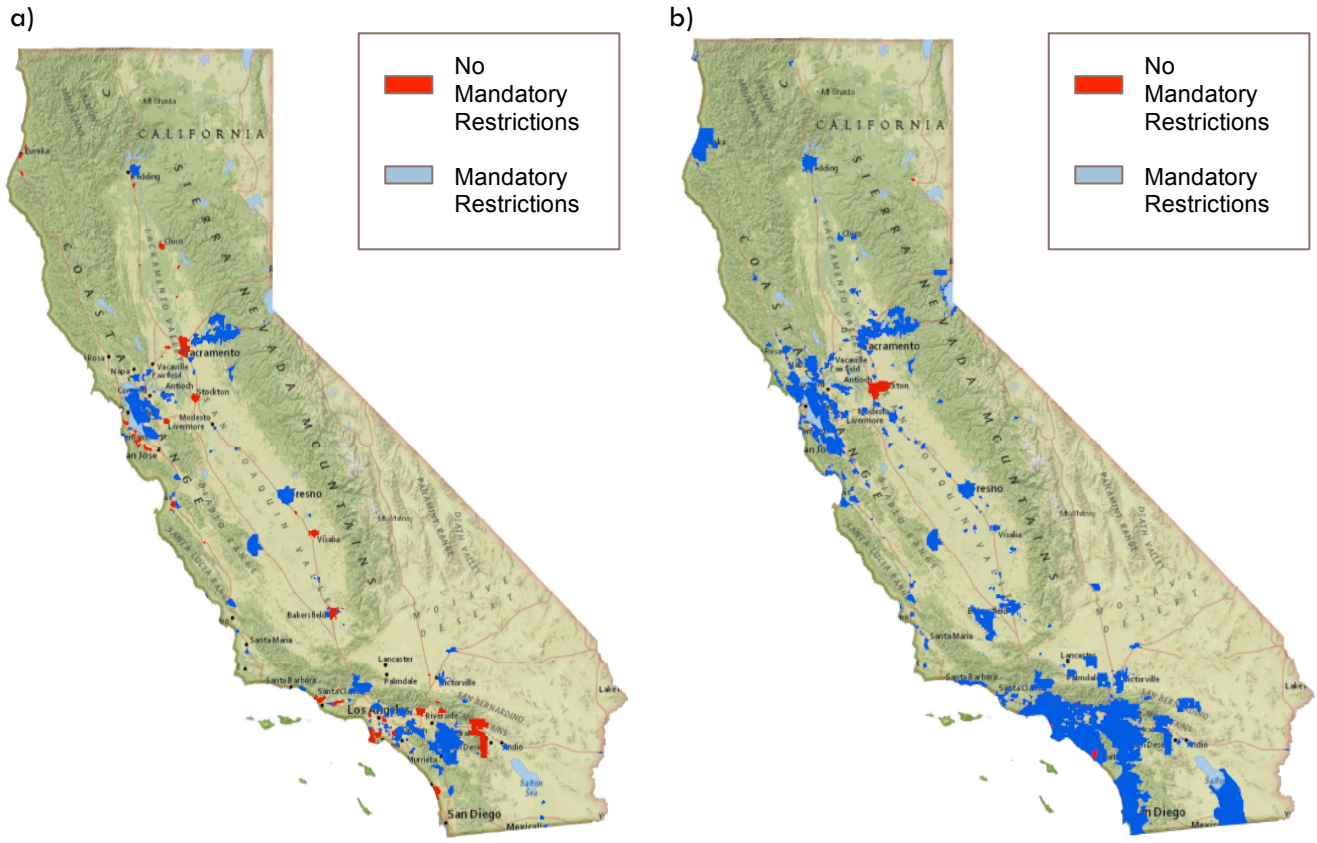


Figure 5: Urban water suppliers with and without mandatory restrictions are shown for a) July 2014 and b) September 2015

4.3 Potable Water Production by Hydrologic Region

Figure 6: Hydrologic regions of California (Base Map: National Geographic. Hygrologic Regions: California Department of Water Resources)

The ten hydrologic regions within California are shown in Figure 6. The total potable water production for each region was calculated during three time periods: June 2013 – May 2014, June 2014 – May 2015, and June 2015 – September 2015 (see Figure 7). These calculations were based on the water-use reports obtained from the State Water Board.

As depicted in Figure 7, statewide water-use is heavily concentration in the South Coast region. This region includes the highly populated counties of Los Angeles, Orange County, and San Diego. Trends also show that all hydrologic regions successfully conserved water during the initial calls for 20 percent reduction. Conservation efforts since the 25 percent mandate are shown by the grey bars, and are still in progress. Once data has been collected through May 2016, water-use during the last time interval can be compared to the two prior years.

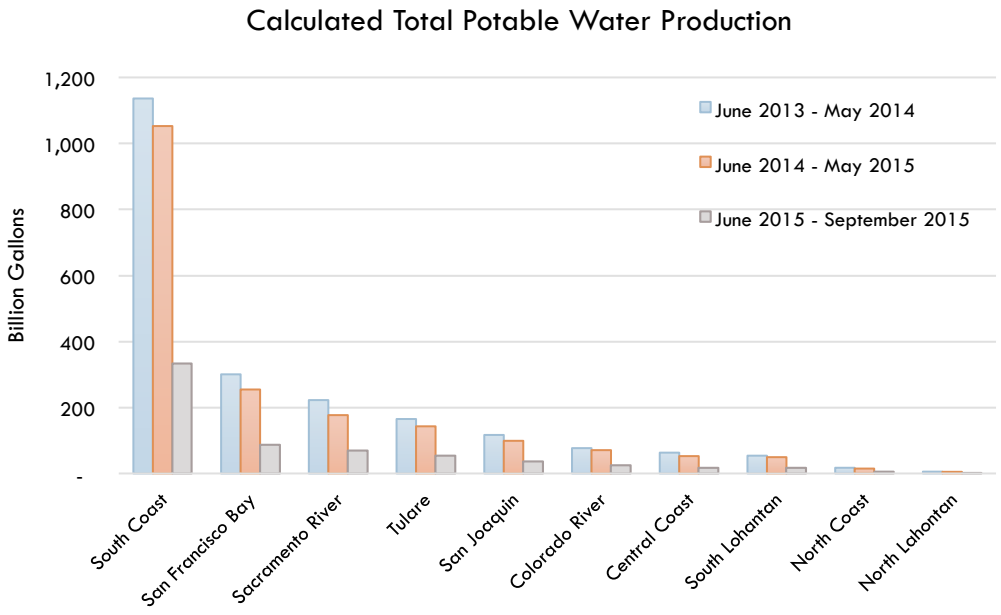
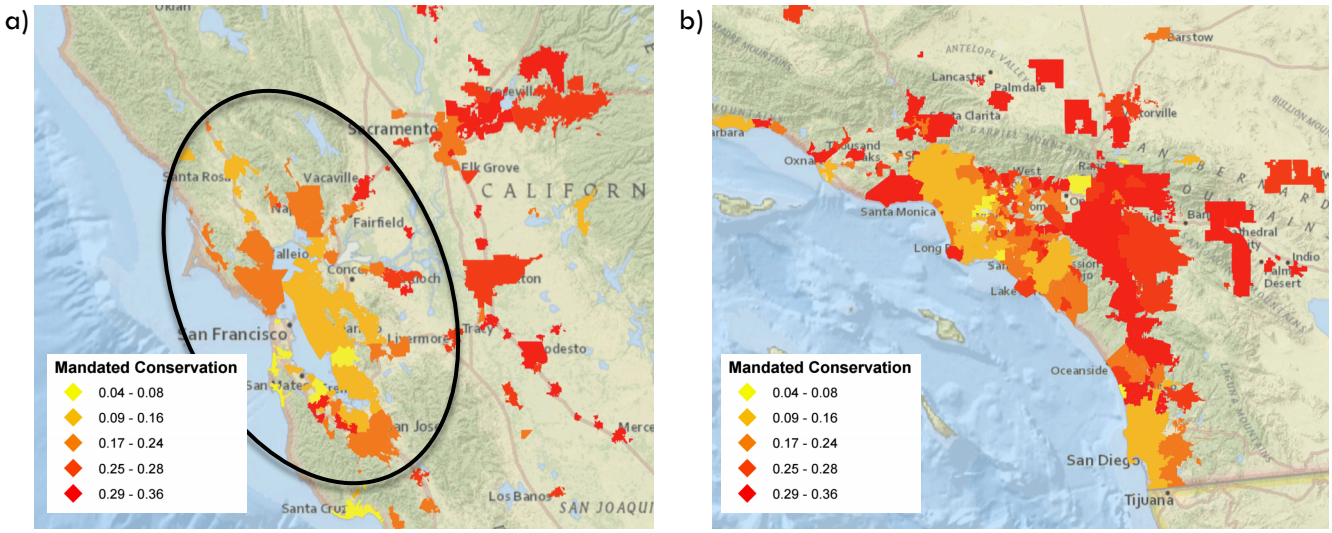


Figure 7: Calculated total potable water production for 10 hydrologic regions based on State Water Board reports. Three bars are shown for each hydrologic region, representing two complete years (June 2013 – May 2014 and June 2014 – May 2015) and one in progress (June 2015 – September 2015)

The following snapshots of Figure 4a were taken to zoom-in on the two hydrologic regions where water-use was the greatest (South Coast and San Francisco Bay).



San Francisco Bay **South Coast**

Figure 8: Mandated conservation rates for the a) San Francisco Bay and b) South Coast hydrologic regions. Conservation rates are given in decimals, and represent percentages. The San Francisco region has been circled due to its proximity to the Sacramento Region to the northeast, and the San Joaqin River to the East.

As expected, conservation mandates were higher in the South Coast region than in the San Francisco Bay region. There is a general trend of larger conservation mandates as you move inland. This means that R-GPCD values also increase as you move inland, as these were the basis for assigning

conservation mandates. This distinction explains why the San Francisco region has the second highest aggregate water-use, but received conservation mandates significantly less than those of Sacramento and the San Joaquin River. In the table below, R-GPCD values are broken down by hydrologic region over a span of 16 months. Nine out of 10 hydrologic regions report lower R-GPCD values in September 2015 compared to September 2014, and all 10 regions have reduced residential water use since September 2013.

Table 1: R-GPCD values by hydrologic region between June 2014 and September 2015

Hydrologic Region	14-Jun	14-Jul	14-Aug	14-Sep	14-Oct	14-Nov	14-Dec	15-Jan	15-Feb	15-Mar	15-Apr	15-May	15-Jun	15-Jul	15-Aug	15-Sep
Central Coast	100	95	91	89	83	66	54	61	60	65	72	72	76	77	77	79
Colorado River	235	236	218	182	169	166	116	115	128	123	160	160	167	151	169	184
North Coast	88	96	82	84	67	55	57	54	53	62	60	64	79	74	76	72
North Lahontan	162	148	131	127	94	68	72	70	62	61	66	83	115	115	119	114
Sacramento River	187	198	177	164	130	89	71	74	72	97	104	118	138	152	150	141
San Francisco Bay	99	98	91	84	77	63	53	57	56	63	65	66	70	72	72	72
San Joaquin River	197	197	174	158	130	91	72	68	70	94	106	114	130	134	135	126
South Coast	122	120	113	112	103	88	65	73	77	83	90	81	91	88	95	89
South Lahontan	189	192	180	158	133	107	72	72	75	95	113	121	133	129	146	127
Tulare Lake	201	212	189	179	148	106	80	75	75	101	127	132	155	163	164	151
Statewide	**133**	**133**	**123**	**118**	**105**	**86**	**65**	**71**	**73**	**82**	**91**	**88**	**98**	**98**	**102**	**97**

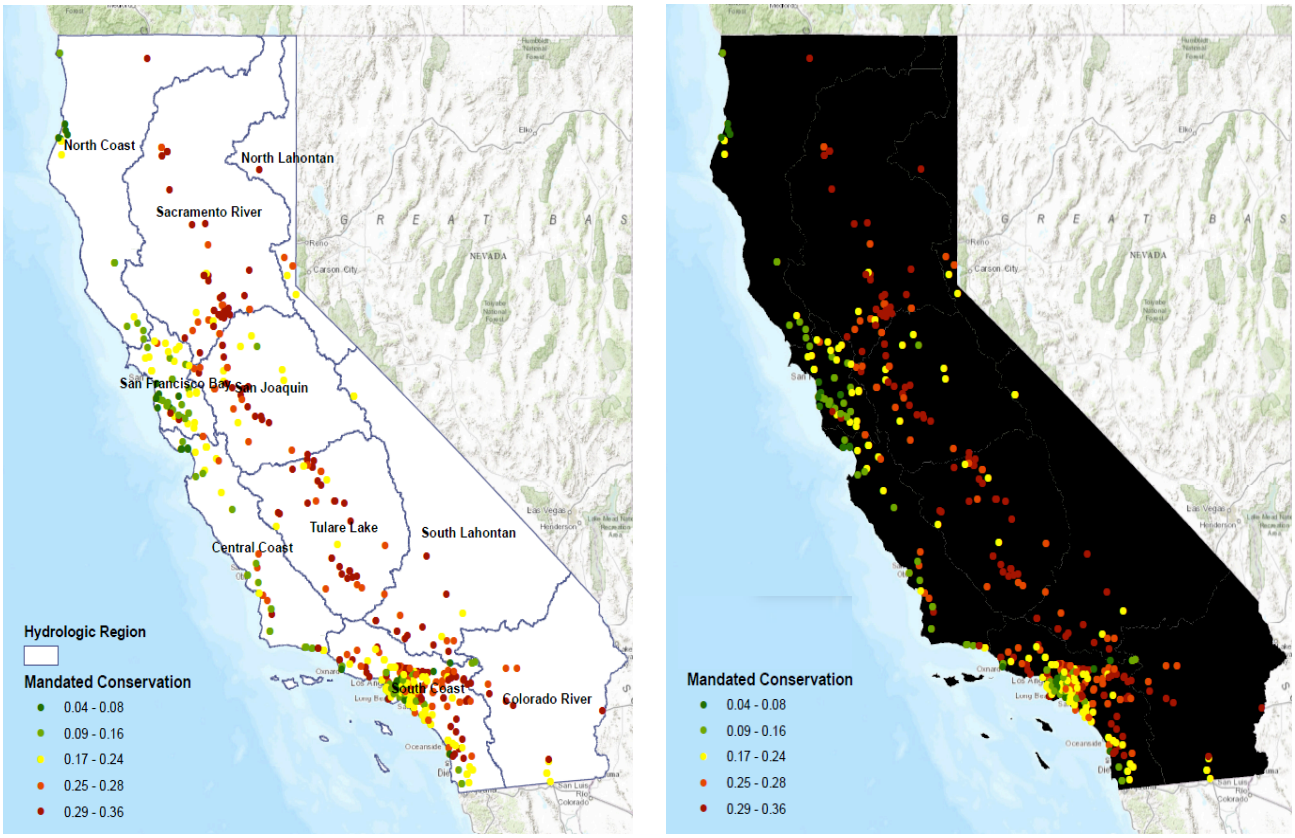


Figure 9: Mandated conservation mapped with a) hydrologic regions as a reference and b) a black background to better see trends. Mandate values are given in decimals and represent percentages.

In Figures 9a and 9b, a single marker was used to represent the conservation mandate tier of each agency. Figure 9a includes hydrologic regions as a reference, and a black background was generated in Figure 9b to better see the trends. It can be seen that big cities along the coast tend to use less (presumably due to cooler climates, higher urban density, and more rainfall) whereas inland regions tend to be hotter, drier, and have development that is more spread out, leading to higher water usage.

4.4 Statewide R-GPCD Trends

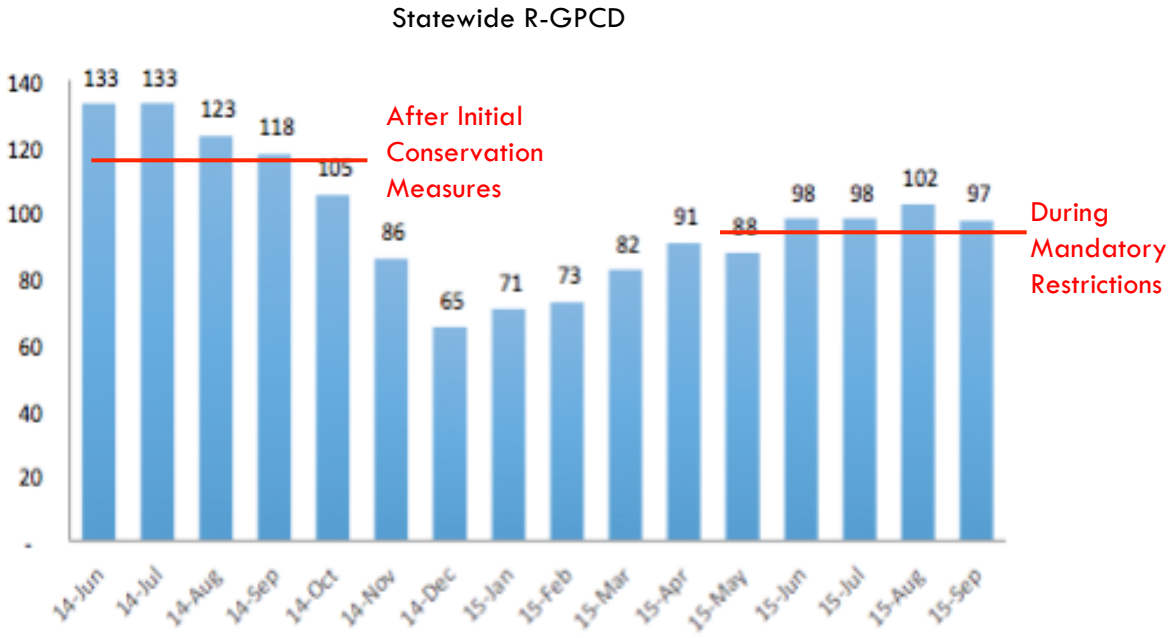


Figure 10: Trend in statewide monthly R-GPCD between June 2014 and September 2015. Data obtained from the State Water Board's Conservation Portal.

Figure 10 shows the trend in statewide R-GPCD since the start of water-use reporting to the State Water Board. The time continuous trend observed is seasonal in nature, and does not indicate that water-use has been on the rise in recent months. Rather, it is typical that R-GPCD values dip during winter months. Instead, comparisons can be made for a given month between years. Doing so indicates that R-GPCD values have decreased for all repeated months.

4.5 Conservation Gaps As of September 2015

Given the magnitude of the drought, California has done an impressive job conserving water. As of September 2015, State Water Board data indicated that statewide conservation was at 28.2 percent, which is well above the 25 percent target. In September 2015, 282 water agencies (72%) met or exceeded their mandate. Only 6 out of a total of 402 missed their mandate by more than 15 percent. The percentage by which an agency is off from its mandate is referred to as the "conservation gap". For example, those agencies that missed their mandate by 15 percent are said to have a conservation gap of 15 percent.

A spreadsheet containing each agency's conservation gap was imported into ArcGIS, joined with the boundary layer file attribute table, and mapped using a tiered marker system. The resulting map (Figure 11) shows the spatial distribution of conservation gaps for agencies throughout the state. For ease of

comparison, all agencies that have met or exceeded their mandate are indicated with a blue marker regardless of the magnitude by which they exceeded their mandate.

Noticeably, cities along the coast have been the most successful in meeting, and even exceeding their mandates. It appears that those inland, as well as those in the southern regions are struggling to meet their assigned mandates.

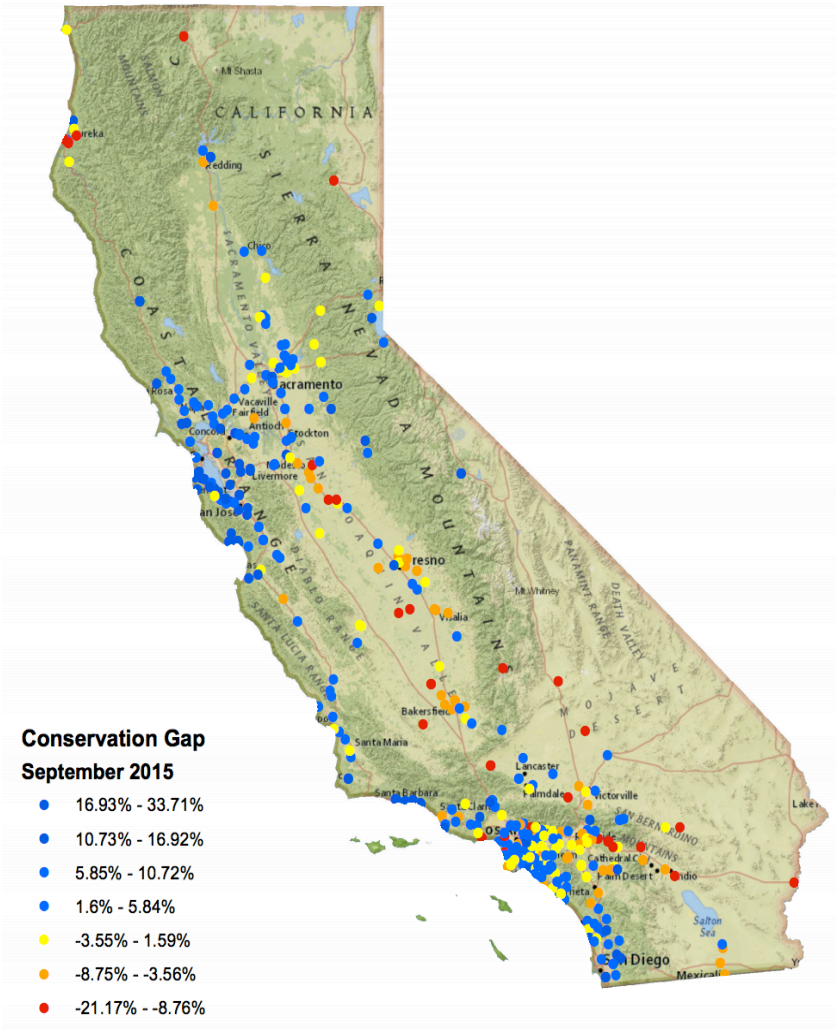


Figure 11: Conservation gaps of agencies as of September 2015

5. CONCLUSIONS AND FUTURE WORK

California is navigating mandated water restrictions for the first time in history. As is the case with any new process, there will be lessons learned with time and ways to improve upon the process will be considered. This report found that spatial trends of conservation mandates (Figure 4a) and the observed geospatial patterns of conservation gaps (Figure 11) suggest the need to modify the State Water Board's current model of setting targets.

In its initial conservation mandates, the State Water Board did not consider factors such as climate, population growth, and water conservation efforts prior to 2013. Now that California has made great

strides in conservation, it is an appropriate time to revisit the method for assigning conservation mandates and consider modifications within the existing framework. This report suggests that the following factors are further investigated:

- **Prior Conservation Efforts/Investments:** Many water agencies have been conserving water long before 2013, making the summer 2013 baselines used for conservation mandates inaccurate. This current structure hurts agencies that have been actively conserving ahead of their time. If an agency has been conserving for years, it experiences demand hardening. This means that every additional percent cut is going to be harder to come by than the previous. If the State Water Board maintains the summer 2013 baselines, it should consider giving credits to those who can prove they have invested in *successful* conservation efforts. Alternatively, baselines could be averaged over a number of years (say, 5 or 10 years) to account for these trends.

- **Regional Climate:** California's climate is highly variable both spatially and temporally. The North Coast is characterized by temperate rain forest conditions, whereas Death Valley experiences extreme aridity. Records for maximum annual precipitation range from more than 90 inches on the North Coast to a little over 2 inches in Death Valley [2]. Temperature is similarly variable across the state. Some regions rarely exceed temperatures of 90°F, while others can stay above 100°F for months at a time. The higher R-GPCD values and greater conservation gaps in some of the state's hottest regions suggest that climate plays a significant role in a region's ability to conserve.

- **Agency and Population Size:** While R-GPCD calculations normalize values and allow for water-use comparisons between regions, they rely on the assumption that no additional factors come into play with scaling. While this may be the case, it is worth investigating further. Some agencies have a couple hundred, or thousand, customers while others have well over a million. Different sized agencies have varying financial means, rules, approaches, and different tolerances to taking risks and conservation.

The factors identified above may be key in understanding the trends in conservation across California. In order to determine the degree to which one or more variables influence water-use, a regression analysis needs to be carried out. An example of a resulting regression equation is provided below, specific to the variables that have been identified.

Regression Equation:

$$\% \text{ Conservation} = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \varepsilon$$

With Explanatory Variables Defined As:

X_1 = Precipitation
X_2 =Temperature
X_3 = Population
X_4 = Number of agency connections

β values= coefficients
ε = residuals (random error)

Performing a regression analysis will help policy makers better understand California's conservation trends and possibly use that understanding to inform future regulatory decisions. It is anticipated that by doing so, the method would be expanded to account for factors that make the same conservation burden to look different as you move from highly populated coastal regions to less population inland regions.

GLOSSARY OF IMPORTANT TERMS

Demand Hardening: as a service area becomes more efficient, it becomes more difficult to reduce customer demand during a shortage or drought

Potable: suitable for drinking

R-GPCD: the number of gallons of water per person per day used by the residential customers a supplier serves. R-GPCD is calculated using the following equation:

$$R - GPCD = \frac{Total\ Monthly\ Potable\ Water\ Production \times Percent\ Residential\ Use}{Total\ Population\ Served \times Number\ of\ days\ in\ the\ month}$$

Small mutual water agencies: small water suppliers serve 15 to 2,999 service connections or deliver less than 3,000 acre-feet of water in a year. There are 2,600 of these in California.

Urban water suppliers: urban water suppliers serve more than 3,000 service connections or deliver more than 3,000 acre-feet of water in a year. There are 411 of these in California.

Water year: the 12-month period from October 1st of a given year through September 30th of the following year. The water year is designated by the calendar year in which it ends and which includes 9 of the 12 months.

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