Building Drought Resilience in California's Cities and Suburbs

Technical Appendix C: Water Use Patterns and Trends within the Service Areas of California Water Service

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Supported with funding from California Water Service, the S. D. Bechtel, Jr. Foundation,
and the US Environmental Protection Agency

Contents

Summary 3

An Overview of Districts Served by Cal Water 5

Figure C1 6

Table C1 7

Figure C2 8

Figure C3 8

District-level Response to the Drought: Analysis across Customer Classes 9

Figure C4 11

Figure C5 11

Table C2 12

Figure C6 14

Figure C7 16

Figure C8 18

Figure C9 19

Figure C10 19

Figure C11 20

Table C3 22

Figure C12 24

Figure C13 25

Variation in Drought Response within Single Family Residential Customer Class 26

Table C4 28

Table C5 29

Table C6 31

Table C7 33

Table C8 34

Table C9 35

Table C10 36

Variation in Drought Response between LIRA and non-LIRA Customers 38

Table C11 39

Figure C14 40

Table C12 42

Supplementary Materials 44

Table C13 44

Table C14 45

Table C15 46

Figure C15 47

Figure C16 48

Figure C17 49

Figure C18 50

Figure C19 51

Figure C20 53

Figure C21 53

Figure C22 54

Figure C23 54

Figure C24 55

Table C16 56

Table C17 57

Table C18 58

This publication was developed with partial support from Assistance Agreement No.83586701 awarded by the US Environmental Protection Agency to the Public Policy Institute of California. It has not been formally reviewed by EPA. The views expressed in this document are solely those of the authors and do not necessarily reflect those of the agency. EPA does not endorse any products or commercial services mentioned in this publication.

Summary

This appendix reports on findings from an analysis of water use during the latest drought in the 24 districts managed by California Water Service (Cal Water), an investor-owned utility supplying water service to more than 1.7 million Californians. Cal Water is comprised of a diverse set of districts scattered across California that provide water for residential use, including single and multi-family households, as well as governmental, industrial, and commercial use. In this analysis, we look at how water savings within the Cal Water system compared both across these different customer classes and across single-family households. We examine these patterns during both the voluntary and mandatory phases of the statewide effort to reduce urban water use in 2014–15 and 2015–16, respectively. Generally, our findings are consistent with those based on statewide district-level data reported in Technical Appendix A.

From January 2014 through April 2015, the state requested individual water districts to voluntarily reduce water use by 20 percent relative to 2013. This voluntary request was followed by a statewide conservation mandate that was announced on April 1, 2015 and adopted on June 1, 2015. The conservation mandate aimed to reduce statewide urban water use by 25 percent relative to 2013 by assigning mandatory conservation levels to individual local districts. Statewide, these mandate levels ranged from 4 percent to 36 percent. For Cal Water, the levels ranged from 8 percent to 36 percent, and Cal Water's average mandate was only slightly above the statewide 25 percent average. Our analysis of district-level water savings finds that Cal Water districts reduced water use by approximately 12 percent during the voluntary conservation period and 29 percent during the mandate period. While there was substantial variation in the degree to which district-level savings exceeded the mandate levels, we find a general negative relationship between the conservation mandate level and the proportion of districts meeting the mandate. For example, eight of the nine districts that confronted a conservation requirement of 20 percent or less met or exceeded the mandate while only five out of the nine districts that confronted a mandate of greater than 30 percent achieved compliance.

We find that the composition of customers also affects the ability of a water district to meet its conservation mandate. Single-family residential consumption not only comprises the bulk of water use across Cal Water districts, but also is responsible for a disproportionately large share of water savings relative to its use compared to other customer classes. Indeed, single family residential customers were responsible for the largest water savings of any customer class in all 24 districts analyzed and contributed to more than half the overall water savings in 18 of these districts. The governmental sector also was responsible for relatively large savings across districts. Compared to commercial, industrial, or multi-family residential customers, these two customer classes have relatively more outdoor water use—a less essential use that may be easier to cut back on during droughts. This helps to explain why single family and governmental classes regularly met or exceeded district-level mandates whereas the other customer classes often did not.

Efforts to identify factors that might drive differences in water savings rates (e.g., income, population, or precipitation) were mostly uninformative in explaining variability at the district level, although seasonality and the imposition of the conservation mandate had clear associations with water savings. There was significantly more savings in the summer months relative to the winter months, except for the industrial use customer class, and savings spiked immediately following the adoption of the mandate.

In addition to savings rates, we also examined compliance rates: the degree to which districts achieved their prescribed mandate levels. At lower mandate levels, compliance is relatively high. But as the mandate levels increase, the savings rate does not increase as fast, and the compliance rate decreases. This suggests that the marginal cost of saving is increasing: the more one is asked to save, the more challenging the task of saving

becomes. Relatively high savings at low mandate levels—combined with a less than one-to-one correlation between savings and mandate levels—also suggests that broad conservation measures that are unrelated to local mandate levels, such as state-level messaging, may be important determinants of savings.

To shed further light on the savings patterns of single-family households—the group that contributed to district-level water savings the most—we analyzed water use data from over 29,000 Cal Water district households. Similar to the district-level analysis, higher mandate levels were generally associated with lower rates of compliance. A range of environmental, demographic, socio-economic, and district-related factors were evaluated in terms of their effect on compliance. Differences in rainfall and temperature between 2015 and 2013 are positively related to compliance, while factors that are associated with relatively more essential uses of water (e.g., number of bathrooms, outdoor irrigation for landscape other than lawns) are negatively related. Surcharges and baseline water use are positively correlated with compliance, consistent with the idea that surcharges provide an incentive to conserve while higher water use, all else being equal, implies more low-cost conservation options. District-level attributes such as the proportion of residents under the age of 10, and the proportion of residents with limited English-speaking ability were negatively associated with compliance, while the proportion of residents over the age of 75 was positively associated. Regional differences in water use also are important: households in districts in the Sacramento Valley and Southern California regions tended to have lower compliance rates relative to the Central Coast or San Francisco Bay regions, even after controlling for the factors mentioned above. Interestingly, we find evidence that the carry-over policy implemented by Cal Water—which allows savings to be banked and used in subsequent months—was more helpful in promoting compliance for customers with relatively larger amounts of turf.

Finally, our analysis investigates how lower income customers responded to the mandate—a nontrivial issue given the substantial numbers of lower income customers in some Cal Water districts and the possible challenges posed by drought to such customers. Within the districts we analyze, the number of households considered eligible for low-income rate assistance (LIRA) ranges from 3 percent to 45 percent. A comparison of LIRA and non-LIRA household characteristics suggests that LIRA households tend to have less turf, non-turf irrigated landscape, and property area on average, although there is some overlap across the two groups. LIRA households have lower savings rates than non-LIRA households at all mandate levels. As the mandate levels increase, the differences in savings rates between these two groups increase. This outcome suggests that conservation becomes more difficult for LIRA households as more conservation is required, perhaps due to the differences in baseline landscape watering (i.e., less non-essential water used by LIRA households) and less discretionary income to make investments in water conserving devices. In terms of policy implications, these results suggest that even though LIRA customers already have been granted a reduction in their water rates, they appear to confront additional challenges when faced with conservation mandates. Additional consideration may be warranted to more fully understand the determinants that drive differences in savings rates between LIRA and non-LIRA customers, as well as to analyze the effects of different programs offered to LIRA customers on both their water use and water expenditures.

Introduction

To better understand water savings and compliance with the state conservation mandate for the study *Building Drought Resilience in California's Cities and Suburbs*, we examined district- and customer-level water use patterns for districts managed by California Water Service. This technical appendix is organized as follows: The following section describes Cal Water and the general context at the state level. This is followed by an analysis at the customer class level, which examines how savings varied across classes and districts and through time. The next section investigates the single family residential customer class in more detail, assessing drivers of savings and compliance with the conservation mandates, and investigating differences across households that under- and over-performed relative to their assigned mandate levels. The final section focuses on customers who qualify for low-income rate assistance (LIRA) and compares their characteristics, savings, and compliance rates with non-LIRA customers. Additional supporting data and charts are provided in a supplementary material section.

An Overview of Districts Served by Cal Water

Cal Water is an investor-owned utility supplying water service to more than 1.7 million Californians through 435,000 connections. Unlike most publicly owned urban water agencies in California, which operate single water systems within contiguous service areas, Cal Water operates 24 separate districts located across California.[1] Rates and operations for these districts are regulated by the California Public Utilities Commission (CPUC). Rates are set separately for each of the districts.

Cal Water has five districts in the San Francisco Bay Area, two in the Central Coast, five each within the San Joaquin and Sacramento Valleys, one in the North Coast, and six districts plus the City of Hawthorne in Southern California (the latter was excluded from this analysis due to missing data). The districts vary significantly in terms of population served, climate, land and water use patterns, and customer demographics. Figure C1 shows the location and population size of each of the 24 districts. Table C1 provides a summary of population served, median household income, climate, and water sales for each district.[2]

Cal Water's districts vary substantially in size. The smallest district serves under 5,000 people while the largest serves more than a quarter of a million people. The median population served by the 24 districts is 60,553. Water sales also vary significantly. Total water sales in 2013 ranged from a low of 813 acre-feet (af) in the Redwood Valley district to a high of 205,832 af in the Bakersfield district. Median water sales in 2013 were 32,749 af.

Across all of the districts, roughly two-thirds of delivered water is used by households and one-third is used by commercial, industrial, and institutional (governmental) customers. This too varies substantially by district. For example, residential use is as high as 92 percent in the Redwood Valley district and as low as 38 percent in the Dominguez district, which serves very large industrial facilities as well as residential and commercial customers. Other districts with large industrial uses include Chico, Oroville, South San Francisco, Salinas, and East Los Angeles.

Residential per capita water use for July–September 2014 ranged from a low of 49 gallons per capita per day (gpcd) in South San Francisco to a high of 337 gpcd in Westlake. The median residential per capita water use over this period was 138 gpcd. This is within 5 percent of the median for all urban water suppliers.

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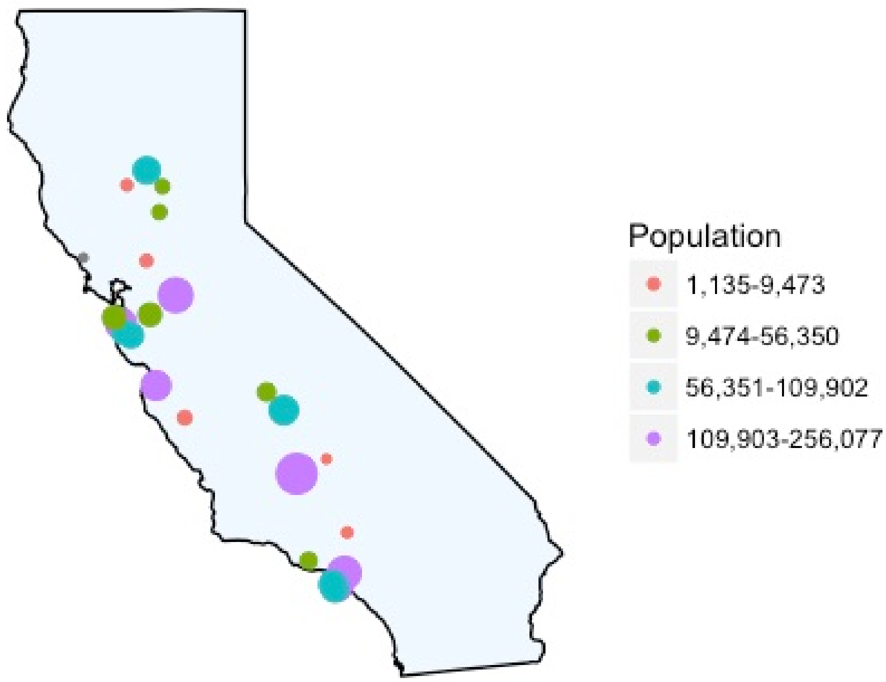
[1] It also operates the City of Hawthorne's water system under contract.

[2] More detailed information about each district is available from their urban water management plans.

FIGURE C1

Locations of Cal Water districts and populations served



In January of 2014, Governor Brown declared a drought emergency and requested all Californians to voluntarily reduce water consumption by 20 percent. This declaration also directed all water suppliers to implement local water shortage contingency plans. On April 1, 2015 the governor announced a statewide conservation mandate for the urban sector, calling for average savings of 25 percent relative to 2013. In accordance with the mandate, the State Water Board implemented regulations that entered into effect on June 1, 2015. All urban water suppliers were given mandatory conservation targets, which ranged from 4 percent to 36 percent.[3] The board used residential per capita water use between July and September 2014 to set the targets. Across Cal Water's 24 districts, 7 (29%) had conservation mandates less than 20 percent, 8 (33%) had mandates between 20 and 30 percent, and 9 (38%) had mandates exceeding 30 percent. Compared to the population of all urban water suppliers, the Cal Water districts are somewhat over-represented in the below-20 and above-30 categories and under-represented in the between 20 and 30 category, as shown in Figure C2. Except in the case of the 20 percent conservation mandate, mean compliance rates for Cal Water districts were somewhat higher than for other investor-owned utilities or publicly-owned water agencies, as shown in Figure C3.

To implement the mandate, each Cal Water district assigned each of its customers—whether residential, commercial, industrial, or governmental—the same percentage reduction that the district received. Customers were charged a penalty if they did not comply. However, the compliance rules did allow customers the opportunity to "bank" savings from a previous month and use that credit in the subsequent month. Customers also could request a waiver from meeting the conservation requirement. While the granting of waivers was not common, in a few instances, particularly in districts where water use was composed primarily of large industrial users, waivers were granted.

[3] The lowest mandate level was assigned to suppliers with sufficient surface water storage. However, none of the Cal Water districts fulfilled this condition. As a consequence, the lowest water conservation requirement for Cal Water was 8 percent. For more detail on the mandate's origins and effects, see *Building Drought Resilience in California's Cities and Suburbs.*

TABLE C1

Summary statistics for Cal Water districts included in this study

Region/District	Population Served[1]	Median Household Income[2]	Annual Rainfall (inches)	Max Daily Temp in July[3]	2013 Water Sales (af)	Share of Sales[4]			Conservation Mandate
						Single-Family	Multi-Family	CII	
Bay Area	**381,485**	**$125,560**			**183,820**	**68%**	**6%**	**26%**	
Bear Gulch	59,883	$224,271	28.9	84.2	41,542	86%	2%	12%	36%
Livermore	58,095	$99,683	15.5	86.1	32,113	73%	5%	22%	24%
Los Altos	68,604	$157,500	20.6	82.6	41,148	71%	5%	24%	32%
Mid-Peninsula	133,679	$97,932	19.9	75.0	44,653	61%	14%	26%	16%
S. San Francisco	61,223	$78,101	23.3	71.4	24,365	37%	5%	59%	8%
Central Coast	**136,057**	**$48,721**			**54,396**	**49%**	**8%**	**42%**	
King City	14,854	$40,500	12.3	84.8	4,906	49%	4%	47%	12%
Salinas	121,203	$49,728	14.5	69.0	49,489	49%	9%	42%	16%
North Coast	**3,201**	**$42,712**			**813**	**81%**	**11%**	**8%**	
Redwood Valley	3,201	$42,712	51.5	80.7	813	81%	11%	8%	16%
Sacramento Valley	**141,857**	**$42,799**			**93,200**	**59%**	**12%**	**29%**	
Chico	102,155	$42,334	26.8	94.6	71,307	61%	13%	27%	32%
Dixon	9,891	$66,818	20.5	93.4	3,766	81%	6%	13%	28%
Marysville	12,177	$34,942	21.5	94.9	6,017	53%	16%	32%	24%
Oroville	10,517	$36,581	29.6	95.0	8,047	34%	6%	60%	28%
Willows	7,118	$38,730	20.0	93.8	4,063	68%	7%	25%	28%
San Joaquin Valley	**617,684**	**$52,758**			**393,721**	**64%**	**6%**	**30%**	
Bakersfield	278,488	$58,842	6.8	97.2	205,832	67%	6%	28%	32%
Kern River Valley	5,583	$30,500	12.4	94.9	2,343	88%	1%	11%	28%
Selma	24,794	$43,143	11.8	97.4	16,504	75%	6%	19%	32%
Stockton	170,414	$45,347	15.7	93.3	75,510	53%	7%	40%	20%
Visalia	138,404	$52,262	10.7	95.1	93,532	66%	6%	28%	32%
Southern California	**481,481**	**$76,182**			**258,475**	**53%**	**8%**	**39%**	
Antelope Valley	3,390	$54,921	8.0	96.9	2,569	92%	0%	8%	36%
Dominguez	142,231	$78,286	13.8	77.2	96,506	30%	8%	62%	16%
East Los Angeles	150,729	$39,103	14.9	83.5	47,262	48%	5%	47%	8%
Hermosa-Redondo	95,774	$105,029	13.5	75.1	33,385	57%	21%	22%	20%
Palos Verdes	69,899	$102,403	15.5	78.4	58,165	79%	3%	18%	36%
Westlake	19,458	$115,550	18.2	81.3	20,588	89%	2%	9%	36%
Total	**1,761,764**				**984,425**	**61%**	**7%**	**32%**	

NOTES: Af is acre-feet. 1. 2015 service area population. 2. 2014 ACS 5-Year Estimates. 3. 30-year average maximum daily temperature. 4. Shares based on 2013 sales, where CII represents the sum of shares for the commercial, industrial, and institutional (or government) classes.

FIGURE C2

Cal Water district representation across conservation mandate levels

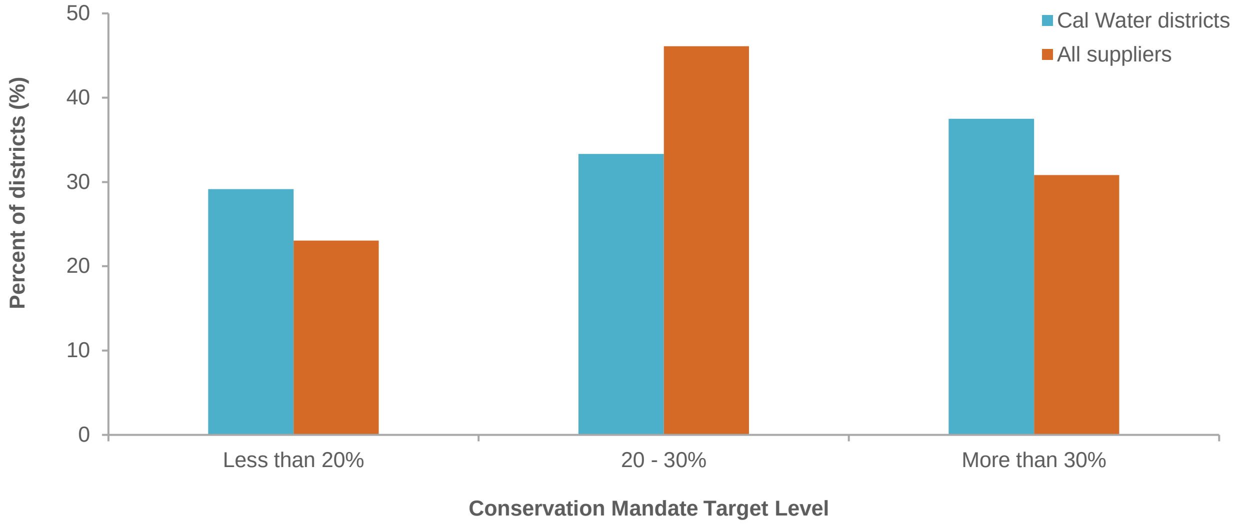
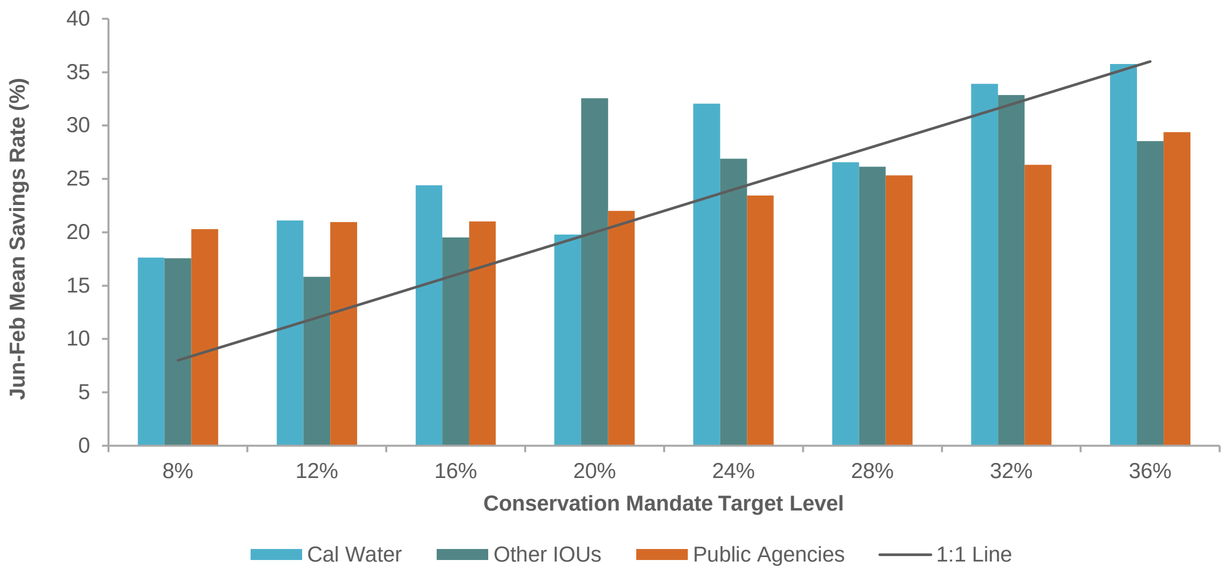


FIGURE C3

Comparison of Cal Water savings rates across conservation mandate levels



NOTES: Other IOUs are investor-owned utilities other than Cal Water. The 1:1 line shows the savings rate required for each mandate level. When the bars cross the line, average savings by that group exceeded the savings required by the mandate.

District-level Response to the Drought: Analysis across Customer Classes

Objectives

The objectives for this section are to evaluate district-level water use by customer class in 2014 and 2015 relative to 2013, with particular attention to water savings under both voluntary and mandatory conservation. In addition, we explore the degree to which water savings varies over customer classes, districts, and time. There are three subsections of this analysis, each addressing a particular set of issues:

District-level water savings by customer class under the mandate

- What were the water savings under the conservation mandate and how were they distributed across customer classes?
- How did overall water savings by district compare to the mandated level of conservation?
- Which customer classes saved the most and which saved the least, and was there a consistent pattern across districts?

Comparison of water savings under voluntary and mandatory water conservation requirements

- How did water savings under voluntary conservation compare with water savings under mandatory conservation requirements?
- Which customer classes showed the most and least response to the state mandate?

Evolution of customer-level savings over time

- How did customer class-level water savings vary over time?
- Did classes have similar seasonal water savings patterns? If not, what are possible explanations of the observed variance?

Data

The data consist of district-level water use data for each customer class across 24 Cal Water districts over three time periods:

- June through December 2013
- June through December 2014
- June through December 2015

We focus on these periods to account for data gaps, adjust for the effects of interim policy changes, and allow for consistent measurement across periods. More specifically, because the mandatory restrictions became effective in June 2015, we select June as the initial month for analysis. Given the strong seasonality of water use, it is most useful to make year over year comparisons across all three periods relative to the 2013 baseline using a consistent time period: thus we adopt June through December for all years. Monthly consumption data for 2016 were not available at the time of analysis, thus this analysis does not consider water savings during the June to December 2016 post-mandate period.

For each district, we have aggregate class-level consumption for single-family residential use (SFR), multi-family residential use (MFR), industrial use (IND), commercial use (COM), and governmental use (GOV).[4] Single-family residential use is responsible for the bulk of water use in nearly all the districts. While commercial use

[4] Total water use by class and district for 2013, 2014, and 2015 is shown in Tables C13, C14 and C15 in the supplementary materials section.

comprises the second largest use within most water districts, there is significant variability in the relative proportions of customer class usage across the districts.

District-level Water Savings by Customer Class

The goal of this section is to explore how water use following the implementation of the state mandate differed from water use in 2013, prior to the declaration of drought by the governor. In addition to providing an analysis of water consumption pre- and post-mandate across different classes of use, we identify which classes had the largest and smallest change in water consumption, and whether these changes were relatively constant across districts.[5]

To calculate the differences in district-level water consumption by class between 2013 and 2015, we compute the district-level *water savings rate* for each customer class as follows:

EQUATION C1

Water savings rate

$$\textit{Water savings rate}_{d,c} = \frac{Water\ Consumption_{d.c}^{2013} - Water\ Consumption_{d,c}^{2015}}{Water\ Consumption_{d.c}^{2013}}$$

where *d* is district and *c* is customer class. $Water\ consumption_{d,c}^{year}$ represents the water consumption in district *d* in class *c* from June through December for the specified year.

Figures C4 and C5 show the savings each district achieved (considering total water production instead of water sales) following the imposition of the conservation mandate.[6] In Figure C4, districts are sorted from lowest (8%) to highest (36%) mandated conservation level. The heights of the blue bars represent the mandated conservation levels. The average mandated conservation level across all 24 districts is 25 percent, as represented by the blue dashed line. The actual savings levels, based on equation C1, is represented by the heights of the orange bars. Combined, districts achieved an average 29 percent savings rate (as represented by the orange dashed line).

Figure C5 illustrates how the total savings rates correlate with the mandated levels, with the red 1:1 line indicating savings rates that matched the mandate level. Seventeen out of the twenty-four districts exceeded their mandate levels, while seven fell short (two points below the red line are coincident). Of the nine districts that had a conservation mandate of 20 percent or less, eight exceeded their mandate. Of the six districts that had a mandate between 20 percent and 30 percent, four exceeded their targets. Finally, for the nine districts that had a mandate greater than 30 percent, five surpassed their mandates.

In general, as the conservation mandate increased, proportionately fewer districts met the mandate. A simple trend line is fit to the data in Figure C5 illustrating the correlation between the mandate level and savings rate. This line is flatter than the 1:1 line. The estimated slope shows that a 10 percent increase in the mandate level is associated with only a 6 percent increase in water savings, on average. A similar analysis of State Water Board data shows that Cal Water districts were slightly more responsive to increases in the mandate level compared to other investor-owned utilities and public agencies.

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[5] Water consumption is influenced by numerous factors including climate, pricing, messaging, and availability of conservation rebate programs. Consequently, a change in any of those factors between the two periods under consideration (2013 and 2015) could have contributed to the change in consumption. Caution is warranted, then, in attempting to single out the state mandate as the singular reason for the difference in water use.

[6] For district totals, we use data on total water production. Class-level analysis uses water sales data. The difference between production and sales is nonrevenue water which cannot be assigned to any particular class. The State Water Board based water savings on total production for purposes of gauging mandate compliance.

FIGURE C4

Conservation mandate vs. total conservation achieved, June–December 2015, by district

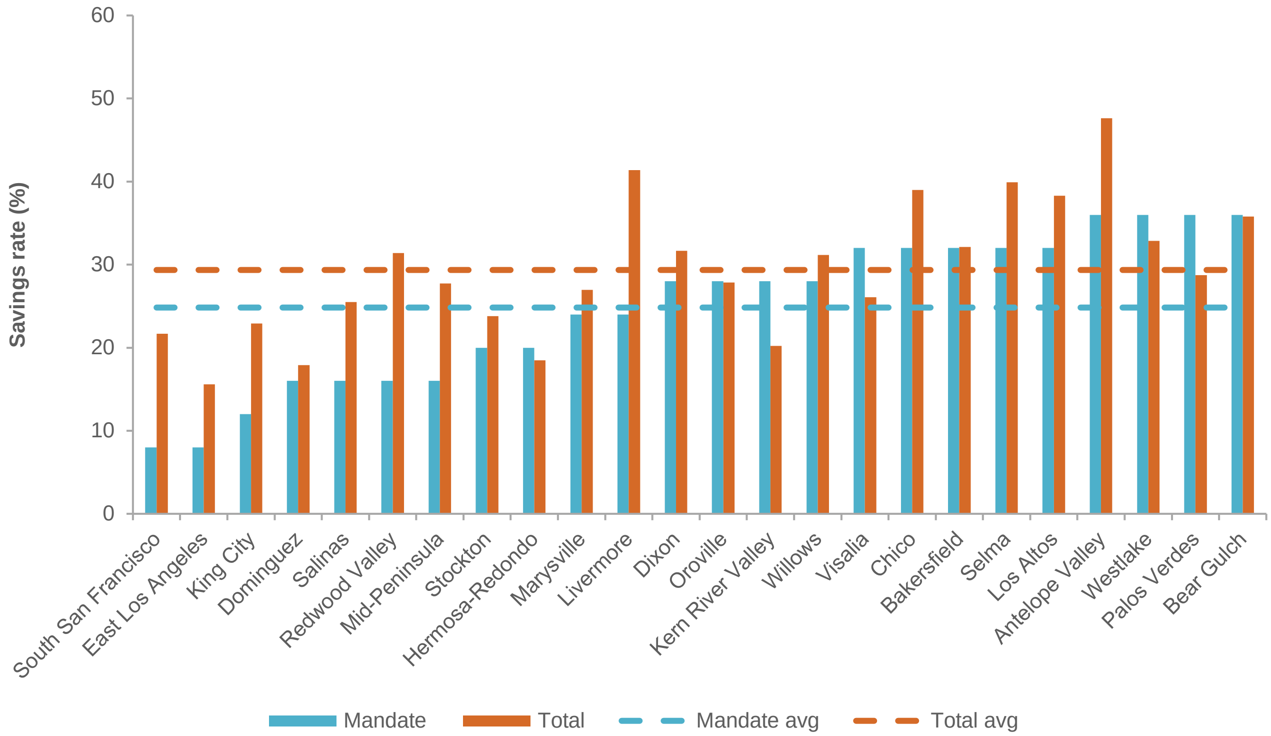


FIGURE C5

Correlation of district savings rates and conservation mandate levels (June–December 2015)

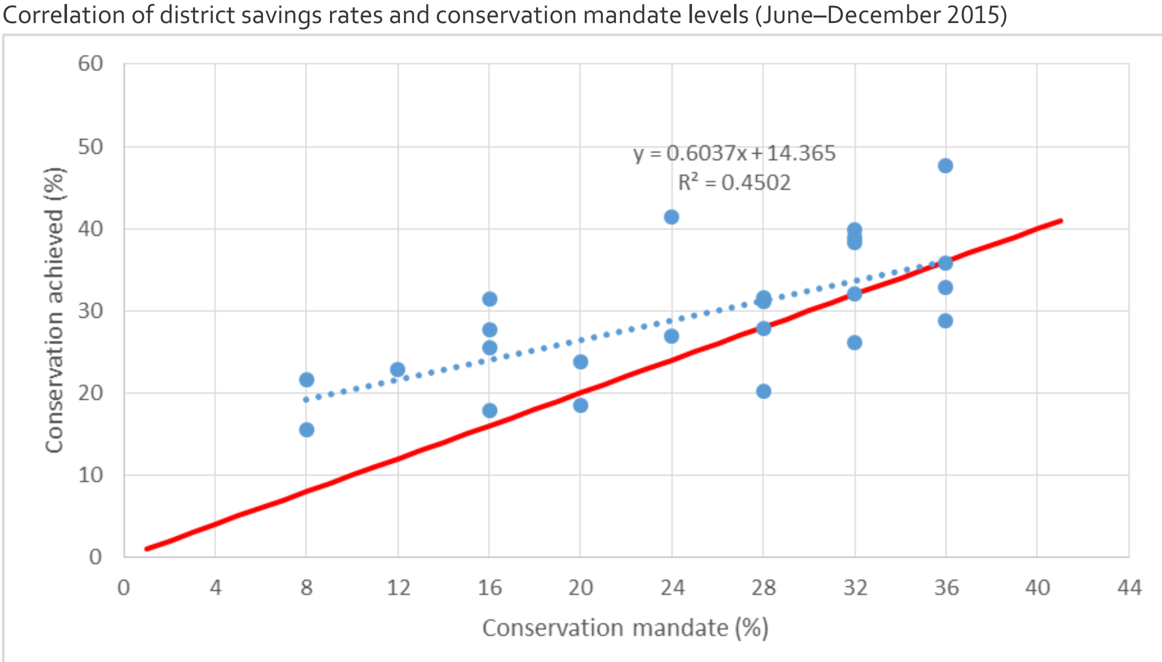


Table C2 summarizes the results of a similar analysis by customer class. We observe that while the average water savings rate of 29 percent was slightly above the conservation mandate, the savings rates varied quite substantially across customer classes. As shown in the *Average Savings Rate* line in Table C2, SFR, COM, and GOV customer classes all met or exceeded the conservation mandate requirement, on average. The GOV customer class achieved the largest savings rate overall of 42 percent, while SFR achieved a 31 percent savings rate and COM achieved 25 percent. Both IND and MFR fell short of the conservation mandate requirement at 14 percent and 18 percent, respectively.

TABLE C2

Water conservation response to conservation mandate by customer class

	Full Sample	Single-Family Residential (SFR)	Multi-Family Residential (MFR)	Commercial (COM)	Industrial (IND)	Government (GOV)
Average savings rate[1]	29%	31%	18%	25%	14%	42%
Number of districts meeting mandate[1]	15	18	8	12	6	21
Slope of trend line[2]	0.48	0.36	0.68	0.41	0.69	0.28
R^2 statistic[3]	0.21	0.19	0.24	0.24	0.06	0.05

SOURCE: For details by customer class, see Figures C15 to C19 in the supplementary materials.

NOTES: [1] Out of a total of 24 districts. Savings represent change in water use in 2015 after imposition of conservation mandate relative to 2013 (equation C1) for the June to December period.
[2] Slope estimate reflects the percentage change in conservation in response to a one percent change in conservation mandate.
[3] Represents the percent variation in conservation response explained by variation in the conservation mandate.

The outcomes for the number of districts that met their conservation mandate by customer class are, as expected, consistent with the previous discussion—the GOV customer class met their mandates in most districts (21 out of 24), while the SFR and COM customer classes met their mandates in 18 and 12 districts out of 24, respectively. The IND customer class meet or exceed their mandates in only six districts; the MFR customer class did only slightly better, meeting their mandates in eight districts.

There are a number of reasons why there is significant heterogeneity across customer classes and districts in their ability to meet their conservation mandates. For instance, compared to MFR, SFR may have had more opportunities to find lower cost reduction strategies due to outdoor water use. SFR households also received monthly information on their water consumption through their bills (including penalties for over use), whereas MFR households, who are collectively metered and billed, did not. For example, our analysis finds that penalties for non-compliance (or waivers thereof) influenced district customer class savings rates. In the case of industrial water use, as part of Cal Water's "Alternative Means of Complying with Water Budgets for Industrial Water Use," several IND customers were given waivers for meeting their mandates.[7] In particular, customers considered "industrial water users" fulfilling a firm "process water" requirement could propose alternative allocations of their water budgets for non-process/incidental water use between different service connections.[8]

Additionally, the level of the mandate itself would be expected to affect the ability of a district to meet its mandate. That is, higher mandates may be more difficult to achieve than lower mandates. In considering Figures C4 and C5—as well as similar figures for each customer class shown in the supplementary materials (Figures

[7] Districts and the number of customers (in parentheses) that participated in this program include: Chico (2), Dominguez (8), Hermosa Redondo (1), Kern River Valley (1), Oroville (2), Salinas (2), Selma (2), South San Francisco (1), Stockton (4), and Visalia (5).

[8] More information is available here: https://www.calwater.com/conservation/drought/processwater/.

C15-C19)—all trend lines are flatter than the 1:1 line, consistent with the hypothesis that as the conservation mandate increased, the ability of the district or customer class to meet the mandate decreased. But there are also differences across customer categories, as seen in the slope coefficients (Table C2, third row). SFR, COM and GOV have slope coefficients around 0.3 to 0.4 whereas MFR and IND are closer to 0.7. In other words, the first group shows less response to changes in the mandate level compared to the second group. Interestingly, these groups mirror the preceding results: MFR and IND also have lower savings rates and compliance rates. That is, SFR, COM and GOV tend to save more in percentage terms than MFR and IND at all mandate levels, but especially at the lower mandate levels, hence the lower slope coefficients.[9]

These trend lines and slope estimates highlight the potential challenges urban water suppliers confront with higher mandated conservation levels, and how different customer classes may be more or less responsive to these levels. The last row in Table C2 provides information on the strength of that association through the use of the R^2 statistic. As explained in the table notes, the R^2 statistic illustrates how much of the variation in the water savings rate is associated with the variation in the conservation mandate level. Overall, just over one-fifth of the variation in conservation responses is associated with variation in the conservation mandate, yet there is significant heterogeneity across customer classes. The IND and GOV classes are particularly low at 0.06 and 0.05. In other words, the conservation mandate does a much better job of explaining the SFR, MFR and COM conservation response than it does for the IND and GOV customer classes. This could be because industrial customers face a particularly high marginal value of water, and were thus less willing to respond to the mandate regardless of the level; or because they were able to utilize Cal Water's "Alternative Compliance" program for industrial customers. It also could be because governmental customers faced a particularly low marginal value of water (e.g., irrigation of parks, ornamental landscaping, street medians), and were thus highly responsive regardless of the mandate level. However, these explanations are speculative and merit further investigation.

While equation C1 provides information on the savings rate associated with the seven months following enactment of the mandate in 2015 relative to the same seven months in 2013, it does not capture the role of any particular class on overall district level water savings. To highlight the role of a particular customer class on overall water savings at the district level, we compute the proportion of water saving by class for each district as follows:

EQUATION C2

Water savings proportions

$$Water\ savings\ proportion_{d,c} = \frac{water\ consumption_{d.c}^{2013} - water\ consumption_{d,c}^{2015}}{water\ consumption_{d}^{2013} - cwater\ Consumption_{d}^{2015}}$$

where $water\ consumption_{d}^{year}$ represents the total water consumption in district d from June through December for the specified year. Consequently, the numerator in equation C2 captures the water savings for a particular class while the denominator represents total district-level water savings.

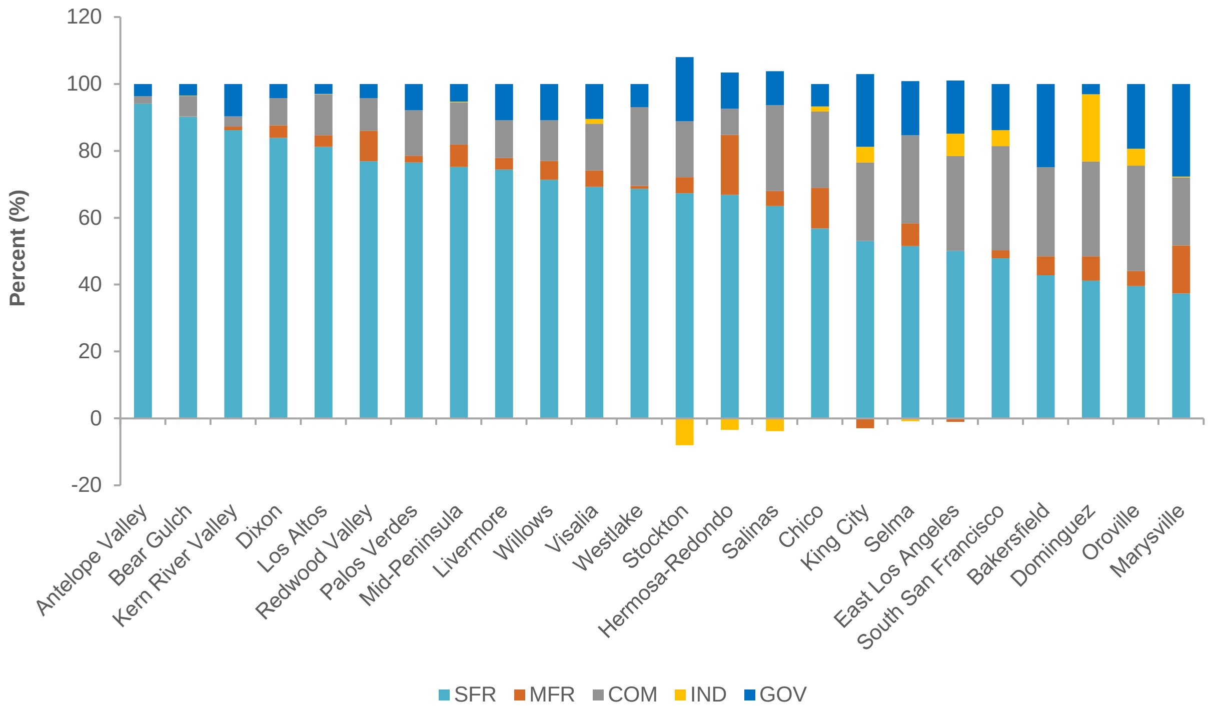
Figure C6 shows the proportion of overall district-level water savings by class. The districts are ordered by the proportion of overall water savings attributable to the SFR customer class. Consequently, Antelope Valley achieved the largest proportion of its overall water savings from reductions in SFR customer use, while Marysville achieved the smallest proportion of its overall water savings from SFR reductions. SFR conservation

[9] These differences in class-level savings patterns are clearly seen in Figures C15 to C19 in the supplementary materials section.

contributed to over 50 percent of the overall water savings in 19 of the 24 districts, while for the remaining five districts SFR was the single largest customer class in terms of overall water savings. The substantial impact of SFR use on district-level water savings is a direct consequence of its large role in overall water use for any particular district, as can be seen by comparing SFR shares in Table C1 to the results in Figure C6. In addition, COM consistently provided the second largest contribution to conservation reductions while IND and MFR contributed the least depending on the district. Indeed, for six districts, IND or MFR experienced an *increase* in overall water use as shown by the bars that extend below zero in the figure. From an aggregate perspective, reductions in SFR water consumption were responsible for 64 percent of the total water savings, while the IND class was responsible for the smallest proportion of total water savings, averaging just over 1 percent.

FIGURE C6

Water savings proportions by customer class



NOTE: SFR is single-family residential, MRF is multi-family residential, COM is commercial, IND is industrial, and GOV is government.

To gain a better understanding of how a particular customer class' proportion of water savings compares to its proportion of water use, we compute the following statistic:

EQUATION C3

Water savings intensity

$$Water\ savings\ intensity_{,d,c} = \frac{proportion\ of\ total\ water\ savings_{d,c}^{2015}}{proportion\ of\ water\ use_{d,c}^{2013}}$$

Equation C3 captures the degree to which a particular consumption class "punches above (or below) its weight" in terms of water savings relative to its water use. A ratio equal to one implies that the proportion of water savings for a class is equal to the class' proportion of water use. If all classes in a district have ratios equal to one, this would imply equal proportional savings across all classes. Ratios greater than one suggest water savings rates are proportionately greater than the class' proportion of use, while ratios less than one suggest water savings rates are proportionately less than the class' proportion of use.

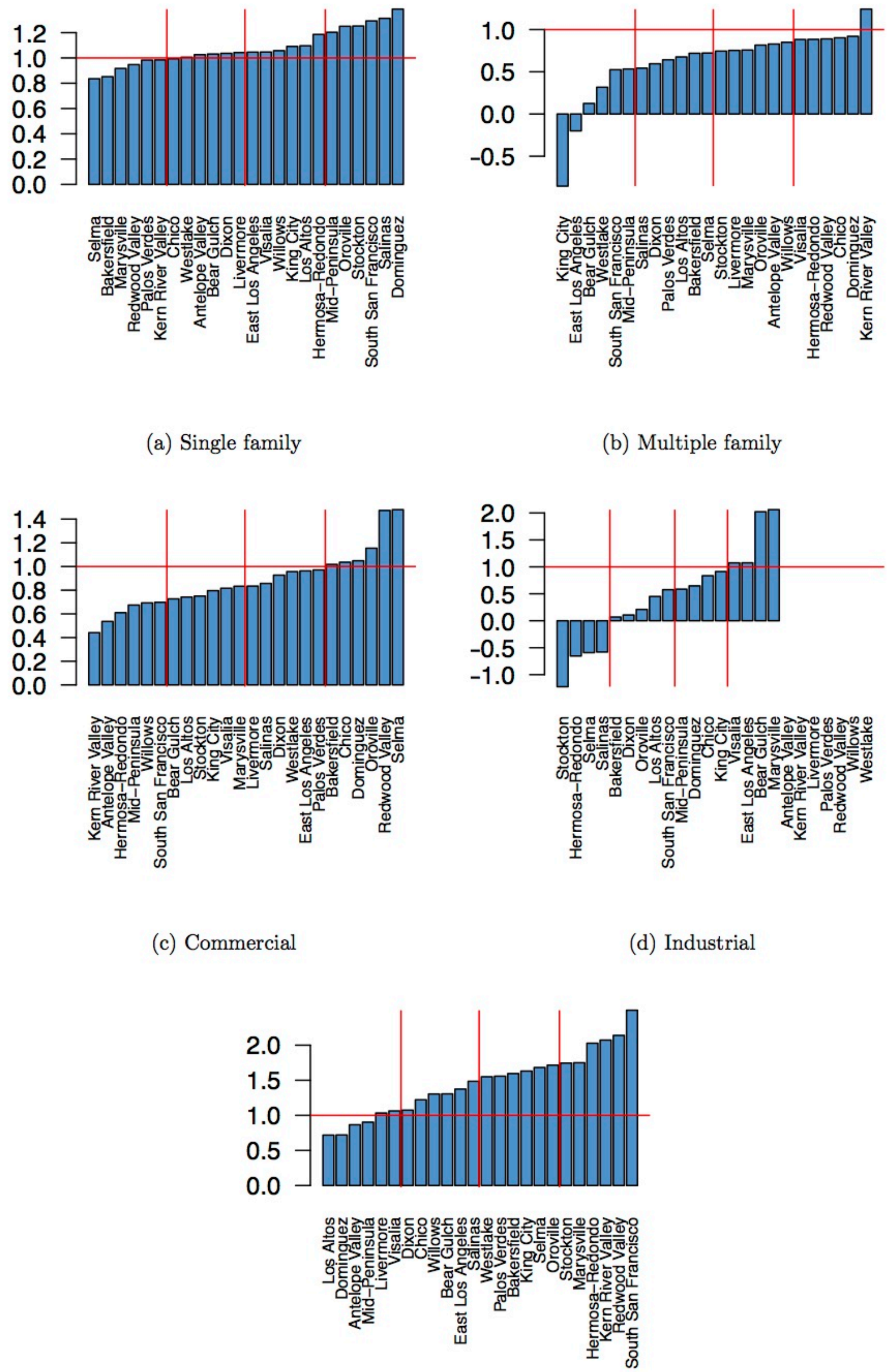
Figure C7 presents the *water savings intensity* statistic for each water district by class, with districts ordered from lowest to highest intensity within each class.[10] For the SFR class (panel a), 17 water districts had ratios greater than one indicating that for those districts the proportion of SFR water savings was larger than the proportion of SFR water use (i.e., SFR provided a disproportionately large amount of the total water savings). The remaining charts in Figure C7 do the same for the other classes and thus facilitate cross-class comparisons within a district. As shown, for MFR and IND, only one and four districts, respectively, had an intensity statistic greater than one (and several negative values), while COM had only six districts. GOV is the exception in that twenty of the districts had GOV class savings proportionately greater than this class' water use. A natural question that arises is why IND, MFR, and COM achieve disproportionately low levels conservation relative to the other two customer classes. A possible explanation is that it may be relatively easy for the government and single family residential sectors to conserve by reducing outdoor watering, whereas water may be perceived as more essential by the commercial and industrial sectors. Moreover, the multi-family residential class represents consumers living in apartment complexes who are usually not metered and who do not use significant amounts of water outdoors.

Figure C7 also can be used to investigate the role particular factors might play in driving differences in class-level water saving intensities across districts. The vertical red lines in each graph illustrate which districts are grouped (in equal numbers) into each quartile, which could be thought of as low (1st quartile), medium-low (2nd quartile), medium-high (3rd quartile), and high (4th quartile). With these designations, we can explore how particular socioeconomic, economic, and biophysical factors might differentially influence class-level water savings intensities across districts. To do so, we use US census data for the period 2010–2014 to analyze differences in terms of income, population and rainfall across water savings intensity quartiles. We also explore the role the mandate level may play on influencing class-level water savings given the findings shown above (e.g., Figures C4 and C5).

[10] Horizontal red lines indicate the class savings level that is proportionate to the class contribution to overall water use; intensities greater (less) than one indicate class savings greater (less) than the class contribution to overall water use.

FIGURE C7

Water savings intensity across customer class in 2015



(e) Government

Figure C8 shows the average mandate level associated with each quartile of water savings intensity for each customer class. For SFR, those districts that achieved the highest water savings intensity (Q4) were assigned the lowest conservation mandate requirements, on average, while those districts that achieved below the mean in water savings intensity (Q1 and Q2) were assigned higher mandate levels, on average. However, a general linear relationship between assigned mandate level with water savings intensity, be it for SFR or any of the other customer class, is difficult to detect.

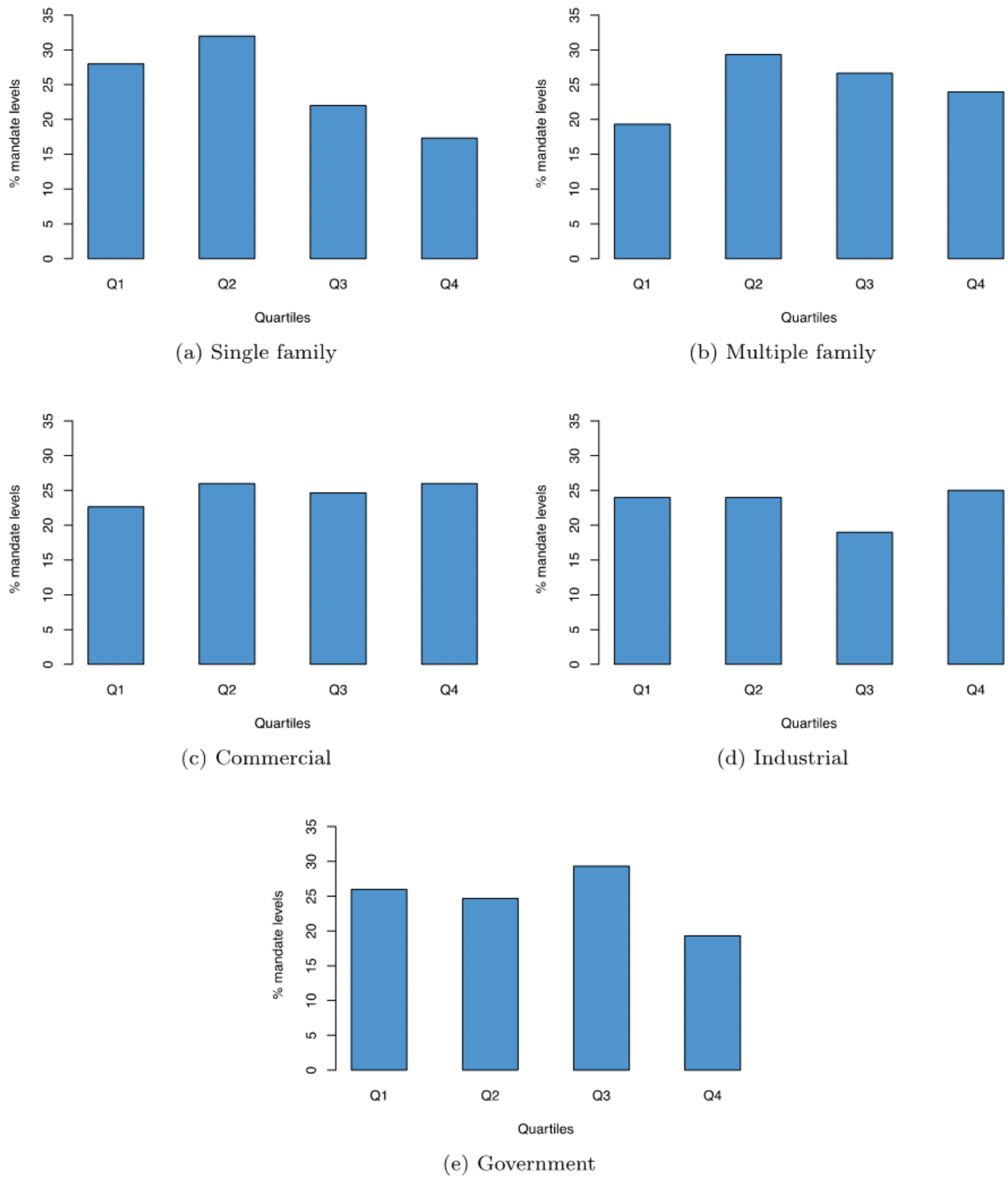
Figure C9 illustrates how average median income for the period 2010-2014 differs by quartile of water savings intensity for each customer class. General patterns across all quartiles are difficult to discern, but GOV exhibits some evidence of a negative relationship: as savings intensity increases, incomes generally decrease. A speculative explanation is that governments may be responding to residents' preferences, and residents with higher incomes may be less willing to diminish the scenic quality or functionality of public areas.

Similarly, Figure C10 presents a comparison of district population levels by water savings intensity quartile. General patterns again are elusive, but as before GOV exhibits a negative relationship: savings intensity is higher for districts with lower populations. In addition, SFR and COM show some evidence of positive relationships: higher savings intensities are generally associated with larger populations.

Lastly, Figure C11 presents monthly rainfall by quartile of savings intensity. Here we see that the highest savings intensities appear correlated with higher rainfall. This outcome would be consistent with districts that might be able to substitute precipitation for irrigation. None of these figures provide conclusive evidence of relationships between these four factors and water savings intensities, nor of the underlying explanations. Additional household-level analysis likely is required to isolate the roles of these factors from other potentially confounding factors that might influence water use, including household size, size of the irrigated area, mandate level, water prices, and surcharges.

FIGURE C8

Mean mandate level by quartiles of water savings intensity



(a) Single family

(b) Multiple family

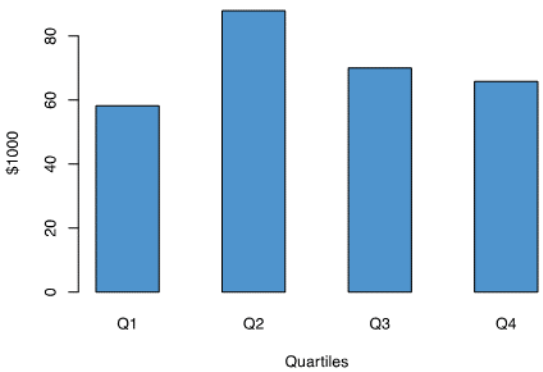
(c) Commercial

(d) Industrial

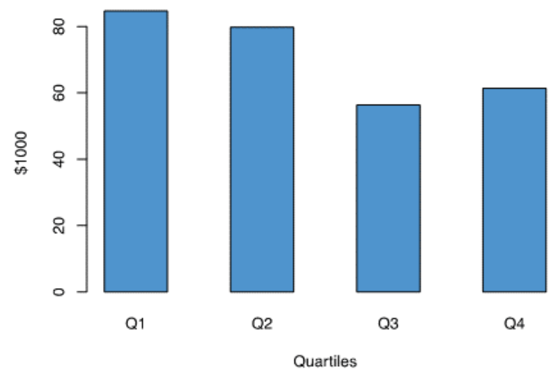
(e) Government

FIGURE C9

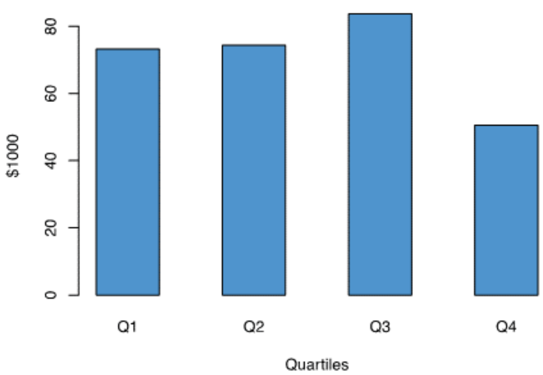
Average median income by quartiles of water savings intensity



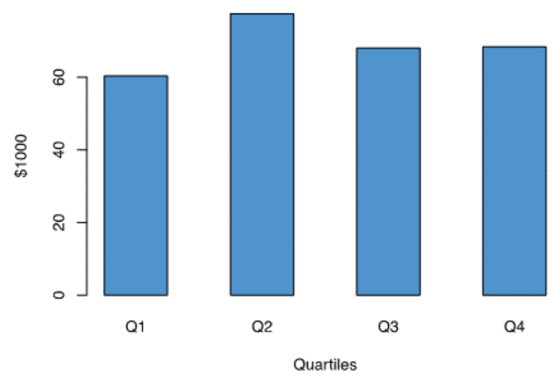
(a) Single family



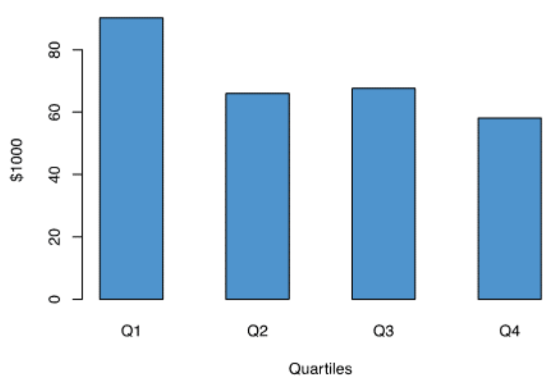
(b) Multiple family



(c) Commercial



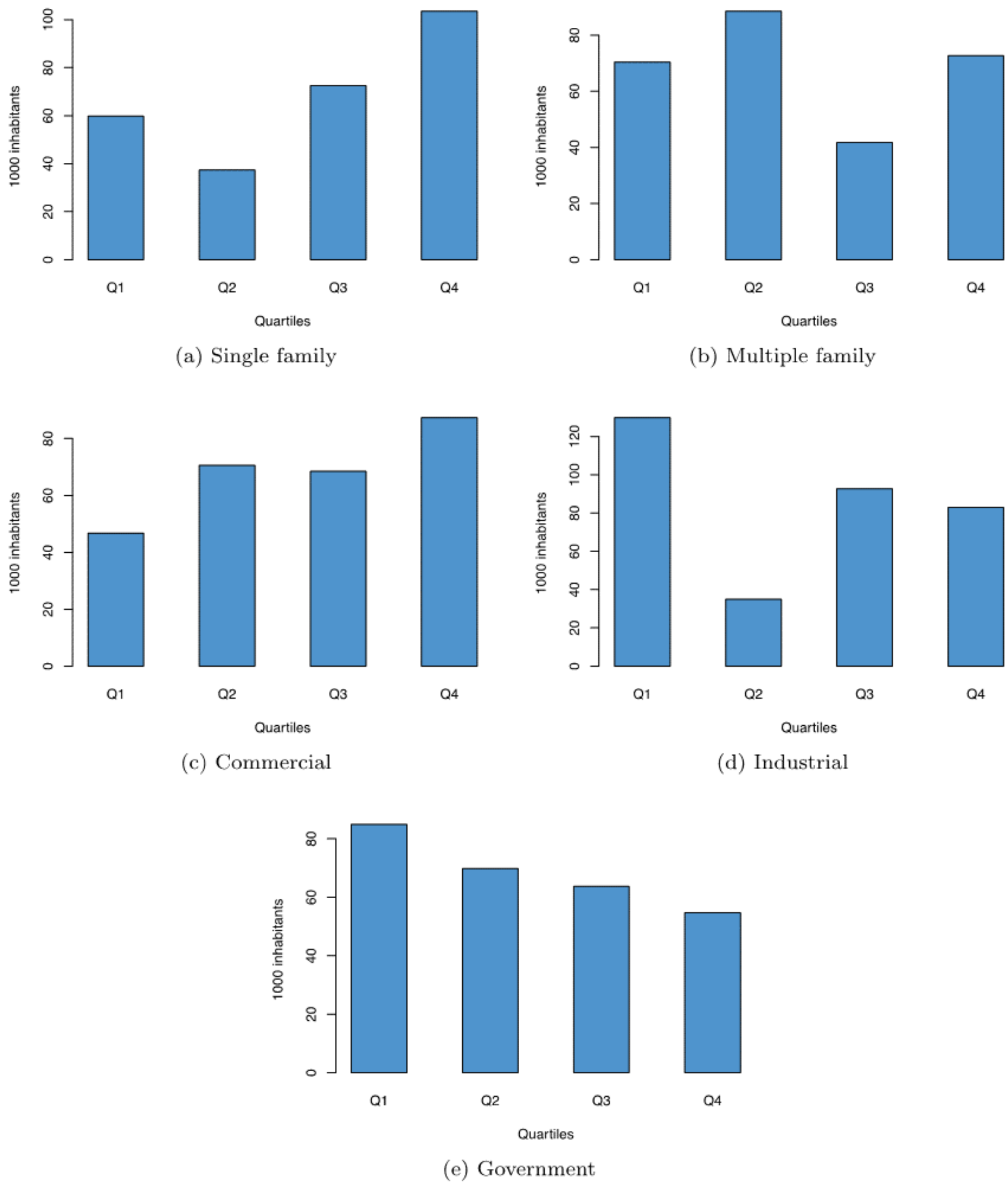
(d) Industrial



(e) Government

FIGURE C10

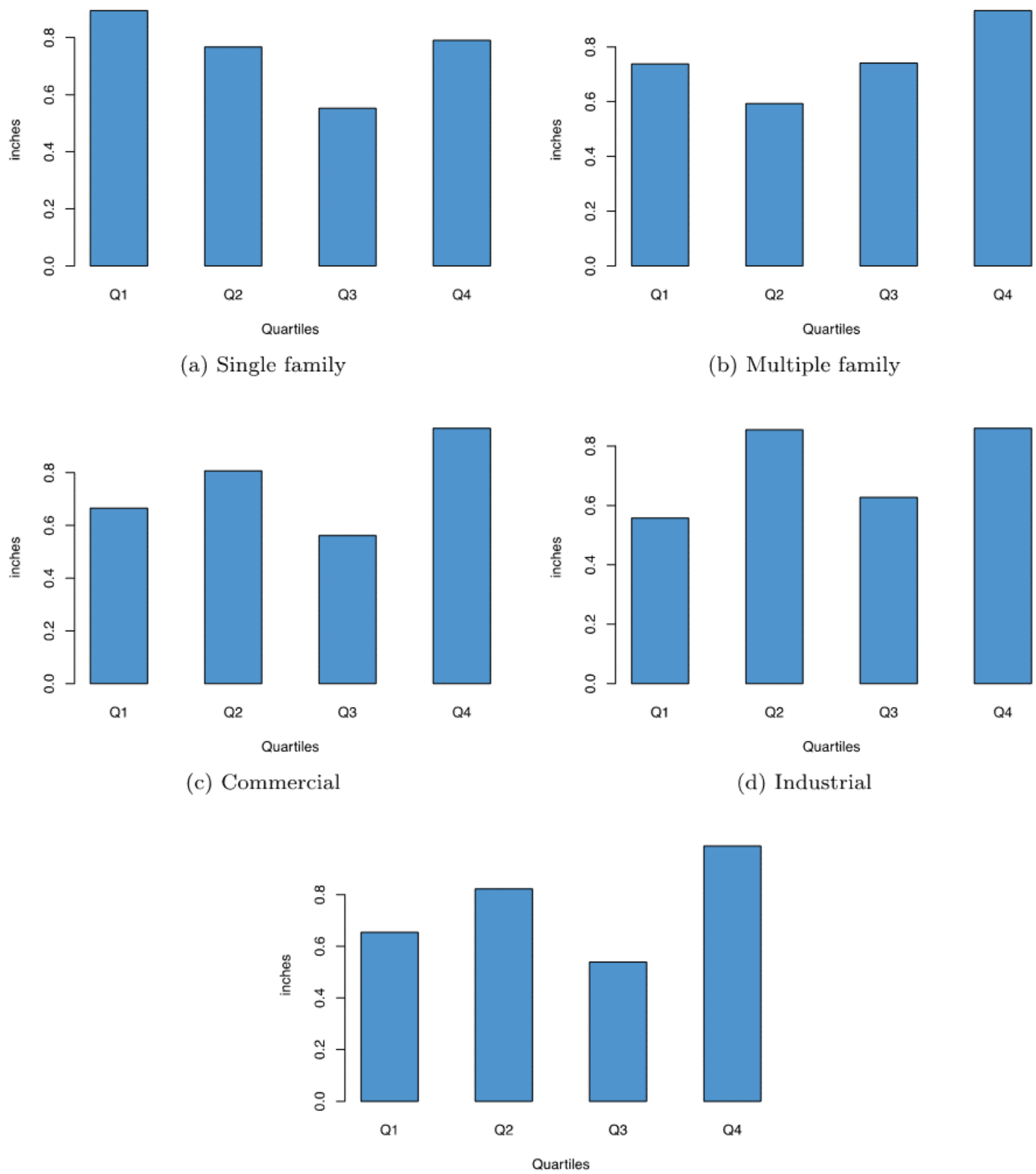
Mean population by quartiles of water savings intensity



(a) Single family (b) Multiple family (c) Commercial (d) Industrial (e) Government

FIGURE C11

Mean monthly rainfall (June – December) by quartiles of water savings intensity



(a) Single family

(b) Multiple family

(c) Commercial

(d) Industrial

(e) Government

Comparison of Water Savings under Voluntary and Mandatory Conservation

The next issue we address is the degree to which water savings differed between the voluntary and mandatory conservation periods. As mentioned above, voluntary calls for conservation of 20 percent were requested from January 2014 to May 2015, whereas mandatory reductions of 8 percent to 36 percent were imposed from June 2015 to May 2016.[11] For the purposes of this analysis, we use the periods June through December 2014 and June through December 2015 to assess water savings under these two different policies, compared to baseline water use during the period June through December 2013. By focusing on the same months across these two years, we are able to control for seasonal effects that might drive differences in water use through time.[12]

Table C3 summarizes the water savings across the Cal Water districts across customer classes for these two periods.[13] The savings rates under 2014 ranged from -1 percent (IND) to 12 percent (GOV), while in 2015 they ranged from 14 percent (IND) to 42 percent (GOV). In each year the average overall savings rates of 12 percent and 29 percent were very close to statewide averages. The savings rates in 2015 were at least 10 percent higher than in 2014 for the same customer classes, and were as much as 30 percent higher in the case of GOV. The last row in Table C3 presents the correlation coefficient between savings rates in 2014 and 2015 for each customer class. These correlation coefficients are a measure of the linear association between these two variables and the value can range from 1 to –1, with a zero correlation indicating no linear association.

TABLE C3

Average savings rates for 2014 and 2015, total by customer class[1]

	Full Sample	Single-Family Residential (SFR)	Multi-Family Residential (MFR)[3]	Commercial (COM)	Industrial (IND)	Government (GOV)
Average savings 2014	12%	11%	7%	9%	-1%	12%
Average savings 2015	29%	31%	18%	25%	14%	42%
Pearson Correlation Coefficient for 2014 and 2015 savings rates[2]	0.55	0.55	0.71	0.50	0.75	0.28

NOTES: [1] June to January for 2014 and 2015 relative to June to January of 2013. Full Sample savings rates are based on production while other savings rates are based on sales.
[2] Pearson Correlation Coefficient presents a measure of the linear dependence and ranges from 1 to -1. A value of 0 suggests no linear dependence of one variable on another.
[3] A significant outlier in this series is King City. When this district is dropped, the correlation coefficient is 0.41.

Table C3 also shows that districts fell short of the 20 percent voluntary conservation request: the overall average savings rate in 2014 was around 12 percent. But districts did a much better job of meeting the average conservation mandate in 2015: the average mandate was 25 percent and districts achieved an aggregate reduction of 29 percent, and two of the customer classes (SFR and GOV) exceeded the 25 percent level by significant margins. The Pearson Correlation coefficients suggest that class savings are positively correlated through time. In other words, for a given class (with the exception of GOV), districts that saved relatively more than other districts in 2014 tended to do the same in 2015.

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[11] Cal Water requested customers in all of its districts to reduce water use by 20 percent during the voluntary period, in line with the governor's call for voluntary 20 percent savings in his January 2014 drought declaration. This was not a uniform practice across other water utilities, many of which set their savings targets to match the requirements of their local water shortage contingency plans—as also called for in the drought declaration (see main report and technical appendix Table A3).

[12] However, this does not control for differences in weather. For example, if 2014 was hotter and/or dryer than 2015, some of the observed difference in savings between these two periods may be due to temperature and precipitation rather than the change from voluntary to mandatory regulations. We consider weather effects in the next section.

[13] Figures C20 to C24 in the supplementary materials show water savings rates (equation C1) by customer class. In each figure, the districts are ordered from highest to lowest water savings rate in 2015.

Evolution of Customer Class-level Savings over Time

Finally, we address how customer class-level water savings varied over time, and to what extent the classes have similar seasonal water saving patterns. To address these issues, we use the customer class-level data to generate the average water savings rate for each month by class, starting in January of 2014 through December of 2015, relative to the baseline of the same month in 2013. The results are shown in Figure C12. The monthly averages are represented by point estimates while the light blue bars show the 95 percent confidence intervals for the point estimates. The red vertical line on each graph indicates the month in which the mandatory water conservation requirements were enacted.

For single-family residential users, we see a significant increase in water savings from January 2014 to December 2015. A noticeable jump in water savings is also observed in the two months prior to the enactment of the state mandate in June 2015. A similar pattern is observed in urban water savings statewide, reflecting customer response following the governor's April 1 announcement of the mandate, which was covered extensively in the media.[14]

There is significant inter-monthly variability in the savings rate, with a noteworthy drop from November 2015 (the highest rate during the period of analysis) to January 2016. For MFR use, there is a slight positive trend over the past two years, largely influenced by a slight increase in savings rates following the state mandate. The trend is more pronounced in the IND class relative to the MFR class, particularly over the final three months of 2015 and the first month of 2016. Noticeable in this graph is the large variation in the savings rates from November 2014 to March 2015. Further exploration of the reason behind this pronounced variability is warranted, but one possible explanation may be that December 2014 was characterized by a high level of precipitation while early 2015 experienced relatively high seasonal temperatures and low seasonal rainfall. The trends and variability in the COM and GOV classes are somewhat similar: significant increase in overall savings rates over the past two years, substantial response to the state mandate, and noticeable inter-monthly variations in the savings rates. Similar to the SFR use, we also observe a downward trend in savings over the last three months.

Figure C12 also shows that there are substantial differences in the dispersion of water savings around the mean (point) estimate across classes. For instance, SFR use appears to have a much smaller dispersion around the mean, reflecting more homogeneity in water savings rates across districts, while the COM and GOV sector are best characterized by greater amounts of dispersion around their means, certainly relative to SFR. Also the dispersion associated with MFR typically is relatively tight and homogeneous. But, in the months of July and August the MFR dispersion jumps substantially. One explanation could be the prevalence of swimming pools in particular districts, pools that may require large amounts of water for filling during the summer months. Alternatively, changes in vacancies during these two summer months in some districts—perhaps due to school holidays—could be a possible explanation. More attention is warranted to better understand this issue.

Figure C13 presents the same data as in Figure C12, but now grouped by seasons.[15] Once again, the red vertical line denotes the introduction of conservation mandates. Viewed this way, we see clear evidence of seasonal effects. With the exception of summer 2014, savings tend to be greater during warmer seasons and lesser during cooler seasons. This pattern is particularly pronounced between fall 2014 and fall 2015. However, the industrial group is an exception: savings are consistently increasing for this group throughout the observation period. These observations corroborate the important role of landscape water savings, of which the industrial group has very little. The summer 2014 anomaly also could be the result of efforts to save landscaping during the hottest months when conservation targets were voluntary.

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[14] See Figure 6 and related discussion in the main report.

[15] Winter season includes the months of January to March; "Spring" is April to June; "Summer" includes July to September; and "Fall" is October to December.

FIGURE C12
Monthly water savings rates from 2014 through 2015

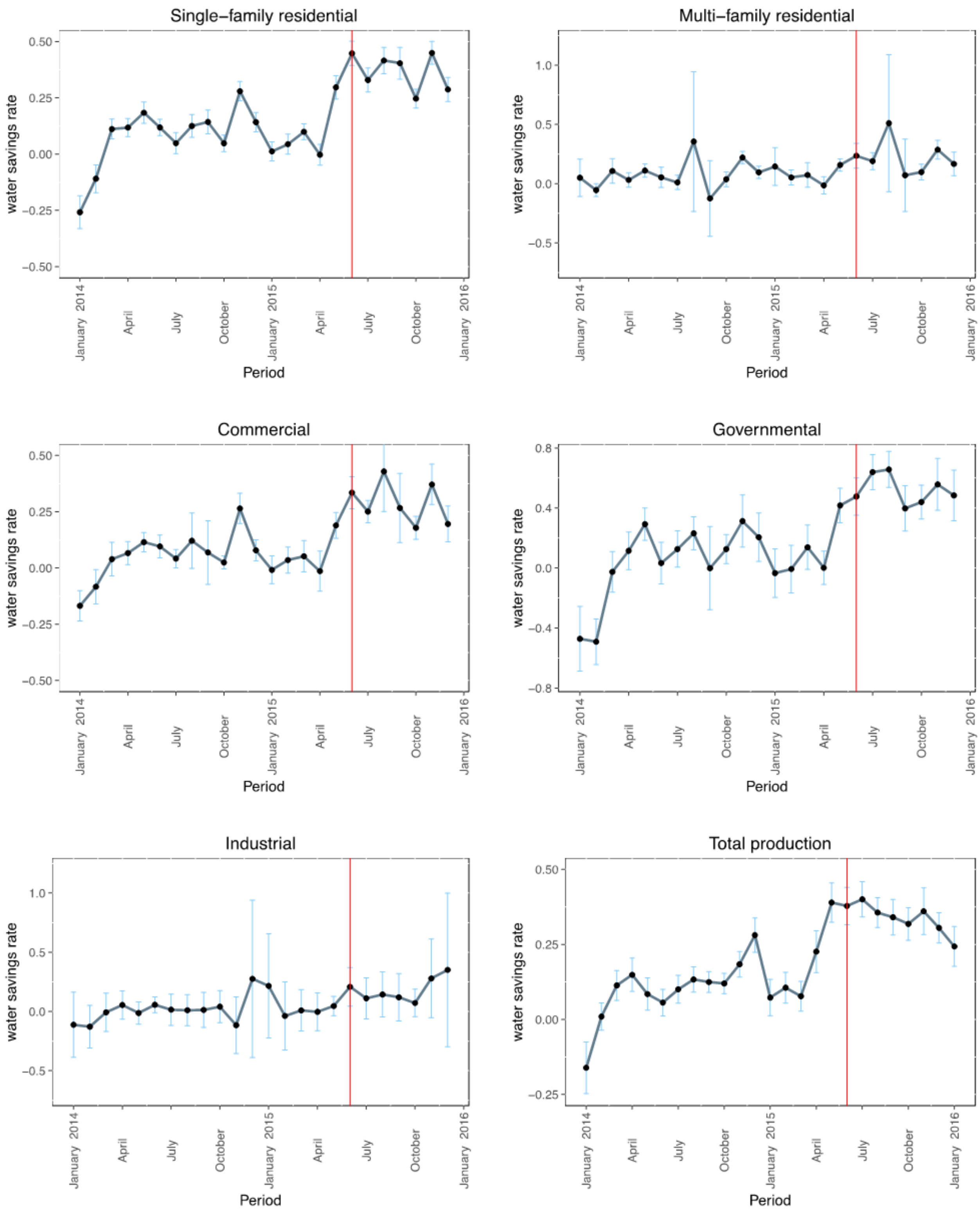
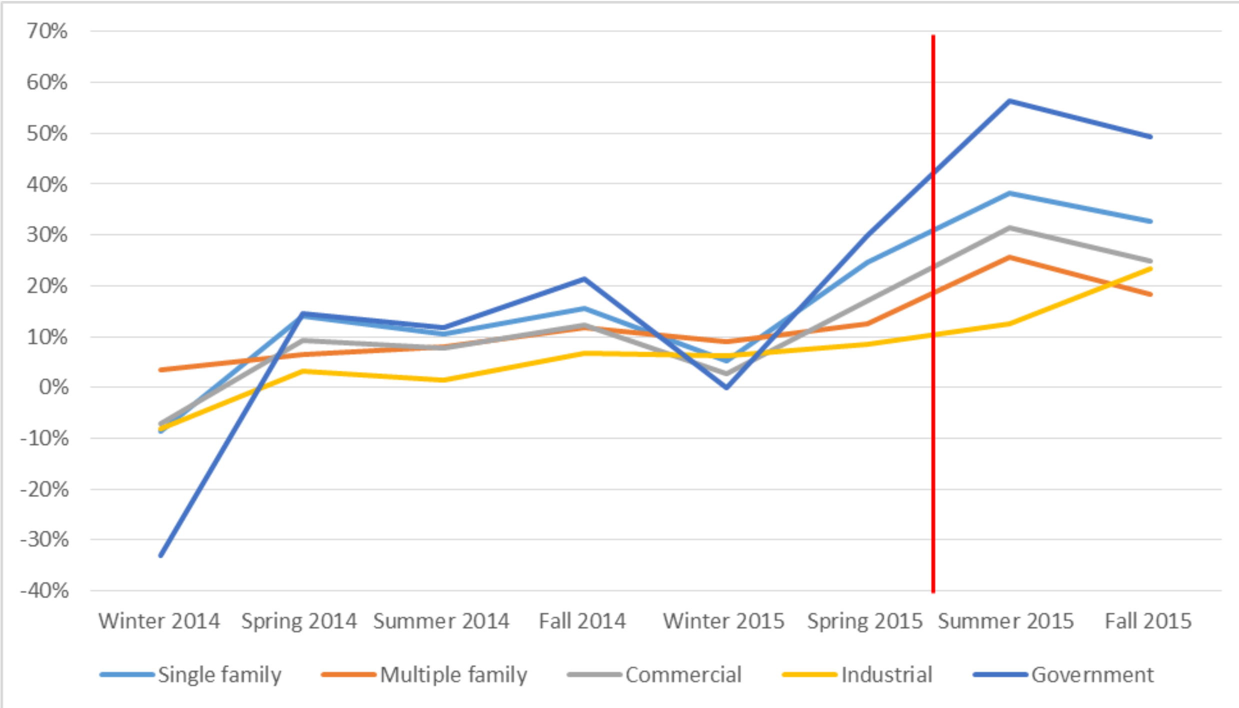


FIGURE C13

Seasonal water savings by customer class, 2014-15



Customer Class Analysis: Conclusions

Between June and December 2015, Cal Water districts achieved an average savings rate of 29 percent compared to 2013 use, surpassing the overall mandate level of 25 percent. The savings rates varied significantly across districts, from slightly less than 10 percent to over 50 percent. Some of this variability can be explained by variation in local mandate levels, but not all. Other determining factors include the relative contributions of different customer classes to total district water use. This is because savings rates differ significantly across customer classes, with the SFR and GOV classes averaging 31 percent and 42 percent, respectively, while MFR and IND classes averaged only 18 percent and 14 percent, respectively. Some of the variability across classes is likely due to differences in opportunities to reduce nonessential water use, which are more prominent for SFR than for MFR, the existence of conservation waivers (i.e., for industrial users that met certain requirements), and other class-specific differences that extend beyond the available data. Furthermore, the relative sizes of these classes vary across districts, which also adds to district-level savings variability. SFR was responsible for the largest proportion of water savings within any district, usually accounting for over 50 percent of a district's water savings (ranging from below 40% to over 90%). Because SFR also exhibits high savings as a class, districts with larger SFR classes tend to have larger overall savings as well.

In addition to savings rates, we also examined the degree to which districts achieved their prescribed mandate levels. We find that at lower mandate levels, compliance is relatively high. But as the mandate levels increase, the savings rate does not increase as fast and thus the compliance rate decreases. This suggests that the more one is asked to save, the more challenging the task of saving becomes. Relatively high savings at low mandate levels combined with a less than 1:1 correlation between savings and mandate levels also suggests that broad conservation incentives such as state-level messaging and media coverage of the drought that are unrelated to local mandate levels may be important determinants of savings.[16]

We also observe differences in class-level compliance with mandates as the mandate level increases. Specifically, customer classes with higher savings rates (GOV and SFR) are less responsive to increased mandate levels than classes with lower savings rates (MFR and IND). It is worth noting that Cal Water implemented the same policy to promote reductions in water use across customer classes. However, actual water savings may be strongly influenced by the ability to reduce water use. It is possible that the industrial sector uses water as an input that is difficult to substitute in their production process, and that multi-family households receive imperfect information about their water use and likely have less landscaped area, making it more difficult to achieve a certain level of savings. We investigated the extent which savings rates vary across income levels, population levels, and rainfall, and found little evidence for strong associations. But because these potential drivers are measured at the district-level, there may be undetected correlations that might be revealed by finer resolution (i.e., customer-level) data.

A comparison of savings rates under the voluntary 20 percent request in 2014 versus the 25 percent (average) mandate in 2015 illustrates the effectiveness of mandatory conservation requirements in increasing short-term water savings. Under the voluntary request, Cal Water called for voluntary 20 percent savings from all customers, and the average savings rate across all districts was around 12 percent. It varied across customer classes from a low of –1 percent (IND) to a high of 12 percent (GOV). Under the mandate—when Cal Water levied a surcharge on bills of customers who did not meet their districts' targets—savings averaged 29 percent and ranged from 14 percent (IND) to 42 percent (GOV) across classes. Customer classes that achieved higher savings rates under the voluntary requests also had higher savings rates under the conservation mandate, even after subtracting their achievements during the voluntary period. While all of this suggests that the mandate was effective in promoting additional conservation, other factors such as changes in the intensity and scope of Cal Water's customer outreach and conservation programs, changes in weather, changes in the severity of the drought, and/or increasing customer awareness of the severity of the drought may have been important as well. The next section investigates the roles of some of these factors with a household-level analysis.

Finally, we see that class-level savings rates increased significantly over time as districts moved from a voluntary request to a mandatory requirement. The dispersion of savings over time was greater for the IND, COM, and GOV classes, indicating greater heterogeneity across districts in these categories. As expected, savings rates are substantially greater during the warmer seasons than the cooler seasons.

Variation in Drought Response within Single Family Residential Customer Class

Objectives

This section provides an analysis of household-level water conservation responses. Our attention is focused on single-family residential households, which comprise a substantial portion of total water use. We address three issues:

Drivers of compliance with the conservation mandate at the household level

- For households with the same conservation mandate, how did compliance vary by region and climate, landscape area, and neighborhood characteristics such as median household income?

[16] These findings are consistent with the results for urban suppliers statewide (main report and Technical Appendix A), as well as survey results regarding the perceived importance of state messaging and the media (Technical Appendix B).

Household-level comparison of water savings under voluntary and mandatory water conservation requirements

- How did the distributions of water savings within the single-family customer class change as savings requirements transitioned from voluntary to mandatory?

Differences between households that under- versus over-perform

- How do the attributes of households that under-performed relative to their conservation allocation compare to the attributes of households that over-performed?

Data

The data consist of monthly household-level water use for the single family residential (SFR) customer class across 19 Cal Water districts and three time periods described above:[17]

- June through December 2013
- June through December 2014
- June through December 2015

In total, we have consistent monthly water use from 29,456 households over these time periods. The 19 districts are: Bakersfield, Bear Gulch, Chico, Dixon, Dominguez, East Los Angeles, Hermosa-Redondo, King City, Los Altos, Livermore, Marysville, Mid-Peninsula Oroville, Palos Verdes, Salinas, South San Francisco, Stockton, Visalia and Westlake.

Table C4 provides a comparison of the number of households in our sample compared to the total number of households across the 19 districts we analyze in this (and the next) section. The difference in the household numbers across our sample relative to district totals relates to efforts to develop a dataset in which every household is represented an equal number of times (i.e., a *balanced* data set) over the months of June to December for the years 2013, 2014, and 2015. The difference also captures efforts to reduce any data reporting anomalies, etc. We accomplish this latter task by, for instance, dropping observations in which monthly water use was zero or negative, or through the use of well-accepted outlier tests. Finally, if a household in our sample had any monthly observations that were “flagged” by the above tests, this household was not included in our dataset.

In addition to the water consumption data, we have data on household- and district-level attributes that may influence water use. Household-level attributes include the number of bathrooms, age of structure, area of irrigated turf, area of non-turf irrigation,[18] and total property area. At the district-level, we have policy variables that include the drought surcharge and conservation mandate (implemented in June, 2015). The drought surcharge varies across districts but also can vary within a district depending on whether the household receives rate assistance and is thus designated under the Low Income Rate Assistance (LIRA) program. We also use socioeconomic variables at the district level from the American Community Survey (ACS) of the US Census. These include income, percentage of population under 10 years old, percentage of population over 75 years old, percentage of households that regularly speak Spanish at home, and percentage of households with limited English that regularly speak Spanish at home. These estimates are five-year district-level averages (2010 to 2014). Finally, we include two climate-related variables—rainfall and temperature deviation —within the district as well as a regional indicator variable that controls for other unobserved factors that might influence water use across

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[17] While the preceding section used aggregate district-level and customer-class level data from 24 water districts, suitable household-level data was only available from 21 of those districts. After performing some outlier tests and imposing the condition of a balanced “panel” (households are included in our analysis only if they appear in each month over which our analysis extends), our dataset consists of 19 districts.

[18] For convenience, we label the variable that accounts for the area devoted to non-turf irrigation as *non-turf area*, although this includes a wide variety of plants such as shrubs, flowerbeds and low-water use plants.

regions. These climate data were obtained from the Parameter-Elevation Regressions on Independent Slopes Model (PRISM) Climate Group. All of these variables are summarized in Table C5.[19]

TABLE C4

Numbers of LIRA and non-LIRA customers, by district

District	Customers in Full Sample				Customers in Subsample			
	Total	LIRA	Non-LIRA	% LIRA	Total	LIRA	Non-LIRA	% LIRA
Bear Gulch	16,537	718	15,819	4%	565	95	470	17%
Bakersfield	43,376	13,128	30,248	30%	1,029	416	613	40%
Chico	24,189	3,774	20,415	16%	355	79	276	22%
Dixon	2645	620	2,025	23%	221	71	150	32%
Dominguez	28,789	6,344	22,445	22%	6,124	1,473	4,651	24%
East Los Angeles	20,354	9,117	11,237	45%	3,303	1,737	1,566	53%
Hermosa-Redondo	22,383	923	21,460	4%	1,824	102	1,722	6%
King City	2,141	904	1,237	42%	263	151	112	57%
Los Altos	16,947	440	16,507	3%	650	32	618	5%
Livermore	16,832	1,175	15,657	7%	1,007	121	886	12%
Marysville	2,254	807	1,447	36%	33	17	16	52%
Mid-Peninsula	31,258	2,079	29,179	7%	2,708	275	2,433	10%
Oroville	2,681	1,019	1662	38%	69	44	25	64%
Palos Verdes	22,808	719	22,089	3%	3,248	95	3,153	3%
Salinas	24,486	5,348	19,138	22%	2,388	784	1,604	33%
S. San Francisco	13,981	1,744	12,237	12%	1,748	256	1,492	15%
Stockton	38,541	14,456	24,085	38%	2,040	969	1,071	48%
Visalia	37,514	10,510	27,004	28%	1,881	640	1,241	34%
Westlake	6,168	348	5,820	6%	650	36	614	6%

NOTES: LIRA stands for Low-Income Rate Assistance. An evaluation of LIRA and Non-LIRA water usage and conservation responses is provided in the next section. A comparison of the subsample share of LIRA customers to the sample share shows that in most instances the shares are relatively representative, although in a few instances the shares are statistically different. Because our sampling selection strategy was not based on the dependent variable directly (water use or compliance), the parameter estimates we derive in our analyses below are not affected by the differences in the shares, i.e., the estimates are unbiased (Wooldridge 2006; p. 326-327).

[19] A district-level summary, sorted by conservation mandate level, is provided in Table C16 and a more complete description of the initial sample is provided in Table C17 in the supplementary materials.

TABLE C5

Household and district-level attributes of subsample

Variable	Description	Mean	Std. Dev.	Min	Max
Water use	Water consumption (ccf)	14.45	8.02	3.00	87.00
Turf area	Irrigated area of turf (1,000 sq ft)	1.50	1.03	0.05	16.39
Non-turf area	Irrigated area other than turf (1,000 sq ft)	1.32	1.25	0.04	18.28
Property area	Lot area (1,000 sq ft)	6.81	12.74	0.54	943.07
Bathrooms	Number of bathrooms in house	2.06	0.78	1.00	8.00
Year built	Year home constructed	1961.4	21.11	1880	2012
Surcharge LIRA	Drought surcharge (nominal US$) if not meeting the conservation requirement for LIRA households	3.40	1.12	1.49	5.00
Surcharge non-LIRA	Drought surcharge (nominal US$) if not meeting the conservation requirement for non-LIRA households	6.80	2.25	2.98	10.00
Conservation requirement	Water conservation requirement implemented by state in June 2015	0.20	0.07	0.08	0.36
Rain deviation	Difference in average monthly precipitation in district between 2015 and 2013 (inches)	-0.54	0.85	-4.84	0.68
Temperature deviation	Difference in average monthly maximum temperature in the district measured between 2015 and 2013 (^{0}F)	0.72	1.90	-3.80	5.00
Income	Median income of district ($1000)	78.45	28.54	36.89	132.65
% Population <10	% of district population < 10 years of age	13.47	2.48	8.73	18.52
% Population >75	% of district population > 75 years of age	6.39	2.27	3.50	12.12
% Spanish HH	% of households regularly speaking Spanish at home	29.33	22.18	6.62	82.05
% Spanish limited HH	% of households with limited English regularly speaking Spanish at home	6.95	6.75	1.01	26.92

We focus on two variables related to monthly water conservation: savings and compliance. A household's monthly savings rate is defined in equation C1 in the previous section. To measure compliance, and consistent with Cal Water's policy for doing so, we generate four additional variables. First, we generate a monthly water budget for each household that defines the amount of water the household can use before it exceeds its district's desired level of savings. In 2014, districts asked customers to reduce water use by 20 percent relative to the same month in 2013; in 2015, districts imposed conservation mandates in which customers were required to reduce water use relative the same period in 2013 or else face a surcharge. The monthly water budget is computed as:

EQUATION C4

Water budget

$$\textit{Water budget}_{\text{tm i}} = \textit{water use}_{\text{2013m i}}\,(1 - \textit{conservation requirement}_{\text{td}})$$

where *t* is the voluntary or mandatory period, *m* is the month when water consumption occurs, *i* is the household and *d* is the district. If a household consumes less than its water budget for a particular month, the budget surplus carries over for use a future month. "Effective water use" is then defined as follows (equation C5):

EQUATION C5

Effective water use

$$\textit{Effective water use}_{tm+1,i} = \textit{water use}_{tm+1,\, i} - (\textit{water budget}_{tm,\, i} - \textit{effective water use}_{tm,\, i}).$$

If there is no surplus carry-forward, then effective water use is simply equal to water use. “Compliance” is then measured by comparing effective water use to the monthly budget.

The savings rate is computed similar to equation C1, but the “effective” savings rate accounts for surpluses as follows (using 2015 as an example):

EQUATION C6

Effective savings rate

$$\textit{Effective savings rate}_{m\,i} = \frac{Water\ Use_{m\,i}^{2013} - Effective\ Water\ Use_{mi}^{2015}}{Water\ Use_{m\,i}^{2013}}$$

We can now compute the compliance ratio as the ratio of the effective savings rate to the water conservation requirement:

EQUATION C7

Compliance ratio

$$Compliance\ ratio = \frac{effective\ savings\ rate}{water\ conservation\ requirement}$$

This ratio takes values greater than 1 when a household’s effective savings rate exceeds its conservation requirement, less than 1 and greater than 0 when its effective savings rate is positive yet below the conservation requirement, equal to 0 when there was no effective savings, and less than 0 when water use increased compared to 2013.

Drivers of Compliance at the Household Level

Using equation C7, we developed monthly compliance ratios for each household for June to December, 2015. The average compliance ratios for the sample, delineated by conservation requirement, are listed in Table C6 along with household-level attributes. As shown, the compliance ratio varies from a high of 4.46 to a low of 0.91. We also observe a nearly monotonic downward trend in the compliance ratios as conservation requirements rise, an intuitive outcome because more stringent conservation requirements are more difficult for households to achieve. Indeed, households confronting the highest conservation requirement of 36 percent were, on average, not in compliance as illustrated by the compliance ratio below one (i.e., 0.91). The average savings rate, shown below the compliance ratio and calculated using equation (3), indicates an upward trend as the conservation requirement increases, and a noticeable spike at the 24 percent compliance level. This is also the point where the otherwise monotonic downward trend in the compliance ratio is temporarily reversed. It is also worth noting that on average household water saving rates met or exceeded the required mandate levels up to the 24 percent level.

TABLE C6

Compliance and correlations with household-level attributes

Variable	8%	12%	16%	20%	24%	28%	32%	36%
Compliance ratio	4.46	3.27	2.30	1.67	2.05	1.25	1.07	0.91
Water savings (%)	16.00	19.91	20.54	19.58	30.60	23.41	24.98	25.81
Applicable region(s)	Bay Area, So. Cal.	Central Coast	Bay Area, Central Coast, So. Cal.	San Joaquin, So. Cal.	Bay Area, Sac. Valley	Sac. Valley	Bay Area, Sac. Valley, San Joaquin	Bay Area, So. Cal
Correlation with Compliance Ratio[1]								
Turf area (1,000 sq ft)	0.59***	0.29**	0.13***	0.13***	0.13***	0.09**	0.01	0.01**
Non-turf area (1,000 sq ft)	0.03	0.07	0.23***	0.12***	0.10***	0.10**	0.07***	0.01***
Property area (1,000 sq ft)	-0.05*	0.15***	-0.01***	0.06***	-0.05*	0.07***	0.00*	-0.00
No. of bathrooms	-0.45***	-0.39**	-0.17***	-0.09***	0.08**	0.25***	0.07***	-0.02**
Year built	0.02***	-0.00	-0.01***	-0.00**	0.01***	0.01***	-0.01***	-0.00

NOTES: Statistical significance at the 99, 95 and 90 percent confidence level represented by ***, **, and *, respectively.
[1]The correlation results are obtained from simple univariate regressions of the compliance ratio on a single attribute (and an intercept term). Each parameter estimate represents the linear correlation (slope) between the compliance ratio and each household level attribute listed in the table, along with its statistical significance.

In the second part of Table C6 we observe that turf and non-turf area are positively correlated with compliance ratios, although in some instances the results are not statistically significant. Although an intuitive explanation could be that larger irrigated areas are associated with greater amounts of outdoor watering that is relatively nonessential and which can be reduced to meet conservation requirements, we will see in the next section that both turf and non-turf area are *negatively* correlated with water *savings*.

Returning to the remaining rows in Table C6, we note that the strength of the negative correlation between *compliance* and *no. of bathrooms* decreases as the conservation mandate increases, eventually becoming positive at higher mandate levels (except for 36%). In other words, more bathrooms (a proxy for house and/or family size) is helpful for explaining *lack of* compliance at lower mandate levels and somewhat helpful for explaining compliance at higher mandate levels. The negative correlation is more intuitive: larger homes with more people consume more water indoors where it tends to be more difficult to conserve. The positive correlation is less intuitive; however, noting that the Sacramento Valley region is associated with each of the three positive correlation results, this observed pattern may have more to do with unobserved regional differences than with household size. Finally, we note that the association between total property area and compliance ratio is ambiguous, and *year built* has little to no meaningful association with compliance given that the magnitudes are so small.

To more fully investigate the roles of household and district-level factors on compliance, we estimate a multivariate regression model of compliance ratio on both household- and district-level attributes including the mandate level. Table C7 presents the results from this analysis. The mandate levels are included as binary explanatory variables, with the default (omitted) level of 36 percent. This allows the mandate level to have a non-linear effect rather than constraining the effect to be linear. As shown, and consistent with the discussion above, the compliance ratio generally decreases with the mandate level. This relationship is almost monotonic, with the exception of the 28 percent mandate level, after controlling for other explanatory factors. These coefficient estimates are statistically significant and different from the 36 percent level.

Most of the other estimates in the regression also are statistically significant. The drought surcharge is positively correlated, as expected. This result indicates that a $1 increase in the drought surcharge would increase the compliance ratio on average by 0.1311, as it would have a positive impact on the water saving rate. For instance, for households with a 20 percent mandate level, a $1 increase in the drought surcharge implies an average increase in the water saving rate of 2.6 percent. Income has a small negative effect, perhaps because wealthier customers are less responsive to higher prices.[20] The presence of children (% *Population<10*) is negatively correlated, possibly due to a stronger desire to maintain usable turf as a play area. Households with limited English speaking ability (*% Limited English HH*) are less likely to comply, perhaps because messaging is less effective. Rainfall and temperature deviations (from 2013 baselines) are both positively correlated with compliance. The result for temperature is unexpected but the magnitude of the effect is small. Turf area is positively correlated, consistent with previous results. But non-turf area is negatively correlated, perhaps because customers are less inclined to risk losing their trees and shrubs. Considering the coefficient on non-turf area, an increase of 1,000 square feet in the area devoted to trees and shrubs implies a decrease of 0.0681 units in the compliance ratio. If we consider again a household affected by the 20 percent mandate level, this increase would cause a decrease in the water saving rate of 1.4 percent. After controlling for turf and non-turf area we see that property area and number of bathrooms are negatively related to the compliance ratio, again suggesting that larger households find it more difficult to conserve due to greater indoor (i.e., more essential) water use. We also find that newer homes and higher baseline water use are positively related to compliance. The first of these does not have an obvious explanation but the second suggests that it is easier to save when past conservation efforts have been limited.

Finally, we detect statistically significant regional differences in compliance. Notably, we find that the Southern California and Sacramento Valley regions tend to have lower compliance ratios than other regions, all else being equal.[21] These regional differences summarize the effects of factors that are not specifically included as regressors in the analysis, but which vary by region. Such factors include customer attitudes about water conservation, local messaging campaigns and associated customer awareness of the severity of the drought, local supply conditions, and other factors. While we cannot say definitively which of these unobserved factors may be driving these results, past investments in reserves was likely a major factor in Southern California.

[20] Our analysis did not produce consistent results for income in all cases. For example, using the statewide district-level sample in Technical Appendix A, we find a positive and generally significant relationship between income and compliance. We find a similar result for the Low Income Rate Assistance (LIRA) analysis below, where compliance is negatively related to LIRA status. These discrepancies may be due to differences in the samples of communities and households used in different analysis. It is also important to note that we did not have access to household-level income data. Instead, our income variables represent district-level averages, and thus there is limited scope for further investigating and understanding these discrepancies.

[21] More specifically, this is the northern Sacramento Valley region, not the Sacramento metropolitan area.

TABLE C7

Regression analysis of factors influencing compliance ratio

Attribute	Coefficient	Standard Error	z-statistic	p-value
Intercept	-0.9944	0.9619	-1.0338	0.3013
Mandate level 8%	4.7843***	0.1742	27.4587	0.0000
Mandate level 12%	3.7835***	0.1968	19.2233	0.0000
Mandate level 16%	1.8315***	0.0889	20.6078	0.0000
Mandate level 20%	1.4534***	0.1156	12.5701	0.0000
Mandate level 24%	1.1247***	0.0854	13.1708	0.0000
Mandate level 28%	1.2906***	0.2588	4.9859	0.0000
Mandate level 32%	0.3197***	0.0937	3.4119	0.0006
Income ($1,000)	-0.0079***	0.0027	-2.9073	0.0036
Population <10 (%)	-0.1035***	0.0350	-2.9595	0.0031
Population >75 (%)	0.0445***	0.0168	2.6493	0.0081
Spanish HH (%)	0.0246*	0.0133	1.8552	0.0636
Limited English HH (%)	-0.1116***	0.0336	-3.3251	0.0009
Central Coast	0.1378	0.1020	1.3508	0.1768
Sacramento Valley	-0.6316**	0.2556	-2.4707	0.0135
Southern California	-0.9868***	0.1653	-5.9709	0.0000
San Joaquin Valley	-0.1167	0.2172	-0.5373	0.5910
Rainfall deviation (inches)	0.1014***	0.0091	11.1290	0.0000
Temperature deviation (^{0}F)	0.0184***	0.0041	4.5125	0.0000
Turf area (1,000 sq ft)	0.0195***	0.0068	2.8721	0.0041
Non-turf area (1,000 sq ft)	-0.0681***	0.0068	-10.0870	0.0000
Property area (1,000 sq ft)	-0.0023***	0.0005	-4.7059	0.0000
Bathrooms	-0.6746***	0.0119	-56.8671	0.0000
Year built	0.0014***	0.0004	3.3855	0.0007
Drought surcharge ($)	0.1311***	0.0049	26.6222	0.0000
Water use 2013 (ccf)	0.0132***	0.0000	79.2578	0.0000

NOTES: Statistical significance at the 99, 95 and 90 percent confidence level represented by ***, **, and *, respectively

Household-level Comparison of Water Savings under Voluntary and Mandatory Water Conservation Requirements

In this section, we examine how the distribution of water savings within the single-family customer class changed as conservation targets transitioned from voluntary to mandatory. Table C8 summarizes savings under voluntary and mandatory policies. For each mandate level, we see that the average savings rate in 2015 is significantly higher than in 2014, consistent with results in the previous section. We also compare savings by quartile. To do this we fix the quartiles based on 2014 savings and examine how savings within these fixed groups of households changed from 2014 to 2015. We see that in some instances, especially in 2014 for the first quartile, the average savings rates are negative, indicating water use actually *increased* under voluntary targets. There is only one negative savings rate in 2015 (for the first quartile of the 8% mandate level), but it is nonetheless smaller in magnitude compared to 2014 indicating a reduction in water use from 2014 to 2015. Overall, as in the preceding section, this suggests that the conservation mandate in 2015 resulted in water savings that were substantially higher than what occurred under the voluntary targets in 2014. However, it is again worth noting that other factors such as changes in the intensity and scope of Cal Water's customer outreach and conservation programs, changes in weather, changes in the severity of the drought, and/or increasing customer awareness of the severity of the drought may have affected savings rates as well.

TABLE C8

Distribution of water savings in 2014 and 2015, by 2015 mandate level

Mandate Level	Year	Mean	1st quartile	2nd quartile	3rd quartile	4th quartile
8%	2014	5.5	-19.1	2.3	12.0	26.8
	2015	16.0	-1.2	13.3	20.0	31.9
12%	2014	6.9	-15.4	3.2	12.2	27.6
	2015	19.9	5.7	15.5	25.3	33.5
16%	2014	7.7	-16.4	4.3	14.2	28.6
	2015	20.5	4.6	17.7	24.4	35.5
20%	2014	7.0	-17.9	3.5	13.6	28.6
	2015	19.6	4.7	16.8	24.1	32.8
24%	2014	21.6	-3.3	18.4	28.8	42.5
	2015	30.6	13.3	27.6	35.9	45.5
28%	2014	7.3	-17.9	4.4	15.0	27.9
	2015	23.4	8.7	20.8	27.8	36.4
32%	2014	8.2	-16.0	4.8	14.7	29.1
	2015	25.0	11.1	21.7	29.5	37.6
36%	2014	2.5	-23.2	-0.6	9.7	24.4
	2015	25.8	13.6	23.2	29.3	37.2

Differences between Households that Under- versus Over-performed

In this section, we investigate how the characteristics of households that under-performed relative to their mandate levels compare against those of households that over-performed. Our sample households are characterized by socioeconomic, landscape and environmental attributes. In order to understand whether households that under-performed share common attributes compared to those that over-performed, we group households based on whether they over- or under-performed compared to their 2015 mandate levels and then consider the means and standard deviations of these attributes within each group.

In Table C9 we observe that all the attributes considered in the analysis have group-specific means that are not appreciably different across groups. The t-statistics and p-values, though, indicate that these differences in means are nonetheless statistically significant. We also observe that the standard deviations of the attributes are relatively large.[22] That is, the mean values differ slightly (although significantly) between the two groups, and there is substantial heterogeneity within each group.

TABLE C9

Comparison of households that under- versus over-performed

Attribute	Over-performed (Observations=136,638)		Under-performed (Observations=69,554)		t-statistic	p-value
	Mean	Standard Deviation	Mean	Standard Deviation		
Water savings (%)	35.50	17.90	-7.28	32.93	319.46	0.00
Compliance	3.55	2.64	-0.52	2.10	380.50	0.00
Income ($1,000)	77.38	27.62	80.62	30.21	-23.69	0.00
Population <10 (%)	13.51	2.32	13.38	2.78	10.59	0.00
Population >75 (%)	6.24	2.04	6.69	2.66	-39.14	0.00
Spanish HH (%)	30.43	22.73	27.08	20.83	33.48	0.00
Spanish limited HH (%)	7.31	6.95	6.24	6.26	35.34	0.00
Rain deviation (inches)	-0.53	0.84	-0.57	0.85	10.14	0.00
Temp deviation (^{0}F)	0.70	1.87	0.78	1.97	-8.87	0.00
Turf area (1,000 sq ft)	1.47	0.98	1.56	1.13	-17.86	0.00
Non-turf area (1,000 sq ft)	1.27	1.20	1.42	1.34	-24.88	0.00
Property area (1,000 sq ft)	6.55	11.61	7.33	14.77	-12.15	0.00
No. of bathrooms	2.00	0.75	2.17	0.82	-45.79	0.00
Year built	1959.8	20.41	1964.5	22.14	-46.78	0.00
Drought surcharge ($)	6.13	2.68	6.10	2.86	2.30	0.00
Mandate level (%)	19.21	8.87	23.34	9.80	-93.37	0.00
CCF 2013	124.02	55.94	124.88	59.26	-3.17	0.00

To better understand how these attributes may affect over and under-performing, we estimate a model of compliance. To estimate this model, we compute a binary indicator of performance that is based on the compliance ratio. This indicator takes a value 1 if the compliance ratio is greater than or equal to unity and zero otherwise (i.e., over-performance = 1 and under-performance = 0). This indicator is used as the dependent variable in a probit (binary) regression that helps identify attributes that may increase the probability of compliance. Explanatory variables, which are listed in Table C9, include many of the same attributes used earlier

[22] The standard deviations in the table are for the distributions of *attributes*. The standard deviations for the mean statistics are very small due to the large sample size, which is why means that are relatively similar across groups are statistically significantly different from each other (as shown by the t-statistics and p-values in the table).

(e.g., Table C7). Since compliance differences may be impacted by the baseline level of water consumption, we also include the average water consumption level in 2013 as a control.

Table C10 presents the estimation results in terms of their marginal effects, evaluated at the sample average attribute levels.[23]

TABLE C10

Probit regression for compliance with mandate levels—marginal effects, evaluated at sample averages

Attribute	Marginal Effect	Standard Deviation	z-statistic	p-value
Income ($1,000)	-0.0037***	0.0004	-8.3032	0.0000
Population<10 (%)	-0.0266***	0.0056	-4.7342	0.0000
Population>75 (%)	0.0164***	0.0027	6.0161	0.0000
Spanish HH (%)	0.0040*	0.0021	1.8944	0.0582
Limited English HH (%)	-0.0072	0.0054	-1.3269	0.1845
Central Coast	-0.1475***	0.0185	-7.9778	0.0000
Sacramento Valley	-0.3834***	0.0410	-9.3511	0.0000
Southern California	-0.2360***	0.0254	-9.2981	0.0000
San Joaquin Valley	-0.3435***	0.0375	-9.1669	0.0000
Rain deviation (inches)	0.0399***	0.0016	25.7223	0.0000
Temperature deviation (^{0}F)	0.0122***	0.0007	17.8126	0.0000
Turf area (1,000 sq ft)	0.0002	0.0011	0.1527	0.8787
Non-turf area (1,000 sq ft)	-0.0093***	0.0011	-8.2278	0.0000
Property area (1,000 sq ft)	-0.0002**	0.0001	-2.2119	0.0270
No. of bathrooms	-0.0965***	0.0020	-48.4140	0.0000
Year built	-0.0001*	0.0001	-1.9433	0.0520
Drought surcharge ($)	0.0187***	0.0008	22.7458	0.0000
Water use 2013 (ccf)	0.0020***	0.0000	71.0719	0.0000
Mandate level 8%	0.1871***	0.0216	8.6569	0.0000
Mandate level 12%	0.2169***	0.0167	13.0055	0.0000
Mandate level 16%	0.2214***	0.0130	17.0396	0.0000
Mandate level 20%	0.2631***	0.0105	25.1580	0.0000
Mandate level 24%	0.1949***	0.0087	22.3747	0.0000
Mandate level 28%	0.2615***	0.0143	18.2417	0.0000
Mandate level 32%	0.1625***	0.0117	13.8940	0.0000

NOTES: Statistical significance at the 99, 95 and 90 percent confidence level represented by ***, **, and *, respectively.

All the district-level socioeconomic and demographic variables have significant effects on the probability of compliance. Specifically, we observe that an increase in the estimated median income by $1000 decreases the probability of compliance by 0.37 percent. Similar to the preceding compliance ratio regression, this may reflect

[23] A variable's marginal effect shows the expected change in the probability of compliance given a one unit increase from the mean of the variable. Table C18 in the supplementary materials reports the original probit regression results. Significance levels are generally high, but the coefficients estimated using nonlinear models such as probit are difficult to interpret directly, so we show the marginal effects here.

lower price sensitivity among wealthier households, but it is also important to bear in mind the caveats presented in footnote 20. Households in districts with higher proportions of residents over 75 years old have a higher probability of compliance, whereas a higher proportion of children under the age of 10 has a negative effect on compliance. Regarding variables related to ethnicity, a 1 percent increase in the proportion of households speaking Spanish increases the probability of compliance by 0.4 percent, whereas this effect is not significantly different from 0 if those households regularly speak Spanish but have a limited knowledge of English.

Both weather deviation variables seem to have a positive effect on the probability of compliance. That is, a higher temperature and amount of rain with respect to 2013 increase the probability of meeting the mandate requirement. The result for rainfall makes intuitive sense, but the temperature deviation may be proxying for warmer summer months when the deviations tend to be larger and when saving water is easier due to increased outdoor use. When looking at landscape and housing characteristics, we observe that a 1,000 square-foot increase in the *non-turf area* decreases the probability of compliance by 0.93 percent, whereas a change in turf area does not have a significant effect on this probability. A 1,000 square-foot increase in property area reduces the probability of compliance, although the marginal effect is very close to 0. The effect of the number of bathrooms in the house on the probability of compliance, which may be correlated with the total property area, also is negative.

This model also includes dummy variables to control for unobserved inter-regional differences not captured by the other explanatory variables. Using the Bay Area as the omitted reference category, households in the central coast, Sacramento Valley, Southern California and San Joaquin Valley areas have around 15%, 38%, 24% and 34% lower probabilities of compliance than those in the Bay Area, respectively. These are substantial differences in compliance probabilities that are similar to but not entirely the same as the regional pattern observed in Table C7.

Some final observations are warranted. First, the drought surcharge again has a positive effect on compliance. A $1 increase in the drought surcharge increases the probability of compliance by 1.87 percent. Second, the baseline level of water consumption also has a positive and significant effect on compliance, although the effect is very close to 0. Lastly, we do not observe a clear relationship between compliance and the mandate level in this model. Although the omitted category (36%) is associated with lower compliance than the other, lower, mandate levels, unlike the previous model there is not a clear pattern in the coefficients associated with the lower levels.

Household-level Analysis: Conclusions

The household-level analysis in this section reinforces our finding that higher mandate levels are generally associated with lower rates of compliance.[24] We also find that rainfall and temperature deviations are positively related to compliance, with the temperature result likely proxying for relative ease of water savings in warmer months.[25] The size of the area devoted to non-turf area has a negative impact on compliance. The size of a property as well as the number of bathrooms both negatively impact compliance. This result is consistent with the hypothesis that a larger house likely implies more water being used for relatively more essential (indoor) uses, thus making conservation more difficult to achieve.[26] We also find that higher surcharges and higher baseline water use are positively correlated with compliance, consistent with the idea that surcharges provide an incentive to conserve and higher water use, all else equal, implies more cost-effective conservation options.

Our analysis also investigated the role of district-level socioeconomic and demographic effects on compliance rates. We find that households in districts with higher incomes and higher proportions of residents under the age

[24] See in particular the results regarding compliance reported in Table C7.

[25] It is interesting to note that we typically expect that as temperatures increase, so does water use. While such a relationship is well documented in the literature, it is usually analyzed in periods without water restrictions. This is not the case here and thus our understanding of the relationship between temperature and water use under mandates is limited and deserving of more attention.

[26] The size of the house is considered a proxy for a more direct measure of indoor water demand—the number of people in the household—which was not available.

of 10 have lower compliance rates, while those in districts with a higher proportion of residents over the age of 75 have higher compliance. A possible explanation for this result is that households with children have stronger desires to maintain usable turf as a play area. We also find that households in districts with a greater proportion of households that speak Spanish are more likely to meet compliance requirements. Households in the Sacramento Valley and Southern California regions also tended to have lower compliance ratios, indicating regional differences in unobserved variables.

Similar to the preceding section, we also investigated how the distribution of water savings changed through time as households transitioned from voluntary requests in 2014 to mandated levels in 2015. We find that across all water savings quartiles, savings increased substantially when the policy changed from voluntary to mandatory.

Variation in Drought Response between LIRA and non-LIRA Customers

Objectives

The impact of drought policies on low-income customers is of particular concern to water utilities and the state. As an investor-owned utility, Cal Water provides low income rate assistance (LIRA) to qualifying customers.[27] This part of the analysis uses single-family customer-level billing and landscape measurement data combined with census block or tract data to address the following questions:

- How do lot size, landscape area, and type of landscaping differ between LIRA and non-LIRA customers?
- For households with the same percentage savings allocation, how did compliance differ between LIRA and non-LIRA households?
- How important are lot size, landscape area, and type of landscaping in explaining conservation response for LIRA versus non-LIRA customers?
- How did the distribution of water savings for LIRA customers change as savings requirements transitioned from voluntary to mandatory? How did this differ from non-LIRA customers?
- Are LIRA customers more or less likely to have met their percentage water savings allocation than non-LIRA customers?

Data

The same dataset is used for this analysis as was used in the preceding section, but we now distinguish between qualifying households (“LIRA customers”) and non-qualifying households (“non-LIRA customers”). Recall that Table C4 shows the numbers and percentages of LIRA customers in our sample and overall by district. LIRA customers comprise a non-trivial percentage of some district’s customer base.

Differences in Lot Size, Landscape Area and Landscape Type

Differences in drought responses across groups of residential customers can be driven, in part, by differing residence characteristics. Given that customers with a large landscape area may have a greater potential to reduce outdoor water use when asked to conserve, Table C11 presents an analysis of landscape characteristics across LIRA and non-LIRA customers.

The averages show that non-LIRA customers tend to have more turf area, more non-turf area, and more total property area. Although not shown in the table, these differences are highly statistically significant due to the large sample size. These differences are to be expected because, all else being equal, larger properties with more

[27] In order to be eligible for LIRA, a household’s gross annual income may not exceed certain thresholds that depend on the number of people in the household, or the household must be enrolled in a qualified public assistance program.

landscaping tend to be more expensive and thus less likely to be occupied by LIRA customers. However, the standard deviations show that there is substantial overlap between LIRA and non-LIRA groups. In other words, there are also many LIRA households with more landscape and property area than some non-LIRA customers. This may be due to vintage effects in the housing market, namely the relative desirability (and thus market price) of newer homes that tend to be built on smaller lots. Nonetheless, based on these results, we can say that these groups tend to occupy different types of properties and anticipate different types of drought responses, on average.

TABLE C11

Landscape statistics for LIRA and non-LIRA customers

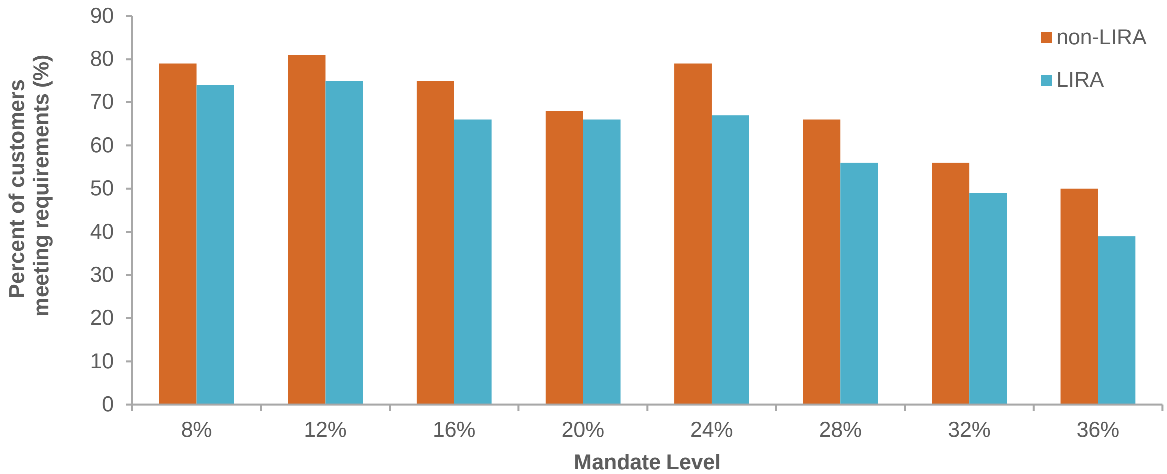
Landscape characteristics	Average for LIRA customers	Standard Deviation for LIRA customers	Average for non-LIRA customers	Standard Deviation for non-LIRA customers
Turf area (1,000 sq ft)	1.40	0.93	1.53	1.06
Non-turf area (1,000 sq ft)	0.94	0.81	1.44	1.34
Property area (1,000 sq ft)	6.37	18.50	6.95	10.19

Differences in Conservation Compliance between LIRA and non-LIRA Customers

Turning to the question of drought response, we consider whether there is any difference in conservation compliance between LIRA and non-LIRA customers. To do this, we group customers by common conservation mandate levels and examine responses across groups. Figure C14 summarizes the results. We can see that at each conservation mandate level, non-LIRA households exhibit higher compliance rates than LIRA households – consistent with the intuition that LIRA households likely use less non-essential (discretionary) water.

FIGURE C14

Proportion of customers meeting conservation requirements by conservation mandate level and LIRA status



The compliance rate differences are generally smaller at lower mandate levels and larger at higher mandate levels, but are statistically significant at all levels. This trend suggests that LIRA households find it incrementally more difficult to meet increasing conservation mandate levels compared to non-LIRA households. This could be due to the need to invest in increasingly expensive water conservation technologies, including landscape replacement, to comply with the higher mandate levels. The figure also shows, as expected, that compliance rates across both groups generally decline as the mandate level increases with the exception of the 24 percent mandate level.

Role of Lot Size and Landscape Area and Type in Explaining Conservation Response

In order to measure the effects of landscape variables on the conservation responses of LIRA and non-LIRA customers, we estimate statistical models similar to those in the previous section but with two main differences. First, the dependent variable is now the water savings rate rather than the compliance rate. Second, among the explanatory variables we now include interaction effects between LIRA status (a dummy variable) and the variables *Turf area, Non-turf area* and *Property area*. If the estimated coefficients on these interaction effects are statistically significant, this provides evidence that these landscape characteristics have differing effects on the conservation response across LIRA and non-LIRA customers.

The estimation results are summarized in Table C12. As noted previously, unlike our compliance models in the preceding section, here the irrigated area devoted to turf has a small but negative and significant effect on the conservation (savings) response. This may reflect underlying preferences of customers who deliberately chose homes with larger lawns: presumably many such customers are reluctant to reduce irrigation to the point at which the lawn becomes unattractive and/or unusable. The coefficient of the interaction effect (i.e., the variable *Turf area x LIRA*) is not statistically significant. In other words, we do not detect a significant difference across LIRA and non-LIRA customers when measuring the effect of turf area on conservation response.

The driving factor behind the apparent discrepancy between the effect of turf area in the compliance model of the preceding section and the savings model of this section appears to be the carry-over provision implemented by Cal Water (see equation C5). When we redo the compliance regression in Table C7 *without* the carry-over provision—i.e., when the savings rate is calculated using the actual water use rather than the effective water use—the positive relationship between compliance and turf area becomes negative but statistically insignificant.

Interestingly, a similar dichotomy is not apparent for non-turf area. Table C12 shows, as in the preceding section, that the irrigated area devoted to non-turf landscaped area (mainly trees and shrubs) has a negative effect on the water saving rate for non-LIRA households whereas its interaction with the LIRA dummy has a significant positive effect. The sum of the two effects (which equals -0.0014) applies to LIRA households. In other words, more non-turf area tends to reduce the water savings rate for all households, but the effect is larger for non-LIRA households than for LIRA households. This may be because higher income customers have invested more resources in establishing trees and shrubs and are thus less likely to sacrifice them, whereas lower income customers may not have invested as much and are thus less averse to losing them compared to non-LIRA households. However, further analysis would be necessary in order to fully understand this effect.

We also find that property area has an insignificant effect on the water savings rate, but the coefficient for the LIRA interaction effect is negative and significant. Therefore, the negative effect of household size on compliance that was observed in the previous section seems to be related to the water savings of LIRA households in particular. In other words, larger households that are also LIRA customers tend to save less water, but the same cannot be said of larger households that are non-LIRA customers. This could be the due to the lower water prices faced by LIRA households.

Briefly turning to the results for the mandate variables, and noting that the 36 percent mandate level has been omitted as the reference category against which to evaluate the relative effects of the other (lower) mandate levels, we find a generally (though not exclusively) negative relationship between mandate level and savings. This result is consistent with those from earlier sections that investigated the role of the mandate level on compliance.

Last, it is worth noting the effects of the final two variables in the table. The effects of the drought surcharge and 2013 water use are intuitive: a higher surcharge (penalty) and a higher baseline water use level (implying more non-essential or less efficient water use and thus more opportunities for conservation) both correlate with higher water savings.

TABLE C12

Coefficient estimates and significance for conservation response model with mandate-level dummy variables

Variable	Coefficient	Standard Deviation	z-statistic	p-value
Intercept	0.3483***	0.1021	3.4119	0.0006
Turf area	-0.0025***	0.0008	-3.2451	0.0012
Non-turf area	-0.0100***	0.0008	-13.2508	0.0000
Property area	-0.0001	0.0001	-0.8422	0.3997
Turf area x LIRA	0.0003	0.0014	0.1963	0.8444
Non-turf area x LIRA	0.0086***	0.0017	4.9545	0.0000
Property area x LIRA	-0.0003***	0.0001	-2.6977	0.0070
Mandate level 8%	-0.0761***	0.0185	-4.1118	0.0000
Mandate level 12%	-0.1005***	0.0209	-4.7991	0.0000
Mandate level 16%	-0.0298***	0.0095	-3.1342	0.0017
Mandate level 20%	0.0102	0.0123	0.8344	0.4041
Mandate level 24%	0.0062	0.0091	0.6863	0.4925
Mandate level 28%	0.0993***	0.0275	3.6115	0.0003
Mandate level 32%	0.0587***	0.0101	5.7948	0.0000
No. of bathrooms	-0.0716***	0.0013	-56.9234	0.0000
Year built	0.0001**	0.0000	2.0969	0.0360
Income	-0.0022***	0.0003	-7.4875	0.0000
Population <10	-0.0097***	0.0037	-2.6044	0.0092
Population >75	0.0043**	0.0018	2.4165	0.0157
Spanish HH (%)	-0.0030**	0.0014	-2.1246	0.0336
Limited English HH (%)	0.0091**	0.0036	2.5450	0.0109
Rain	0.0573***	0.0010	59.3402	0.0000
Temperature	0.0130***	0.0004	30.1181	0.0000
Central coast	-0.1011***	0.0108	-9.3486	0.0000
Sacramento Valley	-0.1974***	0.0273	-7.2279	0.0000
Southern California	-0.1138***	0.0176	-6.4677	0.0000
San Joaquin Valley	-0.1782***	0.0232	-7.6834	0.0000
Drought surcharge	0.0140***	0.0009	16.4422	0.0000
CCF 2013	0.0016***	0.0000	90.2308	0.0000

NOTES: Statistical significance at the 99, 95 and 90% confidence level represented by ***, **, and *, respectively.

Low-Income Rate Assistance Household Analysis: Conclusions

Across the 19 districts analyzed in this section, anywhere from 3 percent up to 45 percent of the households are considered LIRA households.[28] In comparing characteristics of LIRA and non-LIRA households, we find that LIRA households tend to have less turf area, non-turf area, and property area, on average, although there are significant overlap across the two groups.

[28] Though in the data subsample used for analysis, up to 64 percent are considered LIRA households.

Our analysis shows that LIRA households have lower savings rates than non-LIRA households at all mandate levels. Furthermore, the difference increases as the conservation mandate level increases, implying that conservation becomes more difficult for LIRA households relative to non-LIRA households as more conservation is required. This may be due to differences in baseline landscape watering (i.e. less non-essential water used by LIRA households) and opportunities to make investments in water conserving devices (i.e. less discretionary income). In terms of policy implications, these results suggest that even though LIRA customers already have been granted a reduction in their water rates, they appear to confront additional challenges when faced with conservation mandates, and therefore additional consideration may be warranted.

Supplementary Materials

TABLE C13
Water consumption in 2013 across districts and customer classes

District	Single family	Multiple family	Commercial	Industrial	Government
Antelope Valley	246,521	342	10,361	0	11,386
Bear Gulch	3,946,802	66,653	376,823	1,547	121,524
Bakersfield	7,182,125	1,119,068	3,732,669	15,230	2,226,533
Chico	4,067,900	956,849	1,562,294	137,121	389,700
Dixon	320,322	25,213	34,751	79	15,473
Dominguez	2,745,317	731,558	2,506,285	2,866,890	397,830
East Los Angeles	2,079,354	213,079	1,280,017	268,630	501,682
Hermosa-Redondo	1,863,705	671,183	422,315	172,842	176,982
King City	234,849	16,608	141,831	25,284	64,177
Kern River Valley	205,869	1,909	16,191	0	11,022
Los Altos	3,186,217	215,129	713,828	3,211	181,404
Livermore	2,415,470	156,646	459,415	0	354,328
Mid-Peninsula	2,815,134	565,650	845,659	15,630	264,771
Marysville	207,956	96,594	123,826	876	80,586
Oroville	288,758	50,406	248,984	221,354	102,705
Palos Verdes	4,471,980	174,790	803,600	0	291,008
Redwood Valley	65,776	8,250	5,386	0	1,609
Selma	692,060	104,949	199,198	16,602	108,404
Salinas	2,436,125	417,254	1,508,980	331,409	344,730
South San Francisco	833,466	98,944	1,003,230	187,840	124,136
Stockton	4,065,850	489,923	1,689,185	493,552	829,314
Visalia	6,511,308	543,713	1,693,064	128,392	968,911
Willows	294,210	28,678	76,836	0	36,127
Westlake	1,625,192	61,189	587,239	0	105,621

TABLE C14

Water consumption in 2014 across districts and customer classes

District	Single family	Multiple family	Commercial	Industrial	Government
Antelope Valley	224,872	306	10,237	0	10,090
Bear Gulch	3,452,895	60,060	339,849	888	89,514
Bakersfield	6,940,317	1,044,923	3,573,216	15,896	1,953,308
Chico	3,981,842	870,743	1,414,853	110,530	342,406
Dixon	270,714	23,968	29,661	89	22,137
Dominguez	2,492,308	694,996	2,172,372	3,093,729	461,997
East Los Angeles	1,924,185	221,747	1,184,666	271,291	510,139
Hermosa-Redondo	1,744,095	630,058	411,815	188,212	160,392
King City	207,592	20,890	135,193	23,078	52,961
Kern River Valley	188,873	1,796	14,677	0	7,252
Los Altos	2,618,683	186,842	632,662	4,977	164,760
Livermore	1,625,873	123,541	347,398	0	211,812
Mid-Peninsula	2,296,968	517,286	756,115	14,249	236,156
Marysville	186,331	86,861	111,648	455	69,840
Oroville	254,562	45,206	215,416	215,116	76,287
Palos Verdes	4,317,084	163,961	809,294	0	300,824
Redwood Valley	56,712	8,119	4,430	0	1,975
Selma	672,284	85,782	173,846	18,135	85,678
Salinas	2,078,649	390,463	1,394,487	387,679	304,491
South San Francisco	702,257	89,760	955,853	197,458	100,971
Stockton	3,433,186	432,908	1,546,202	661,663	662,584
Visalia	5,712,203	481,334	1,567,174	119,435	820,059
Willows	258,406	27,020	68,781	0	28,089
Westlake	1,516,679	61,510	554,401	0	87,866

TABLE C15

Water consumption in 2015 across districts and customer classes

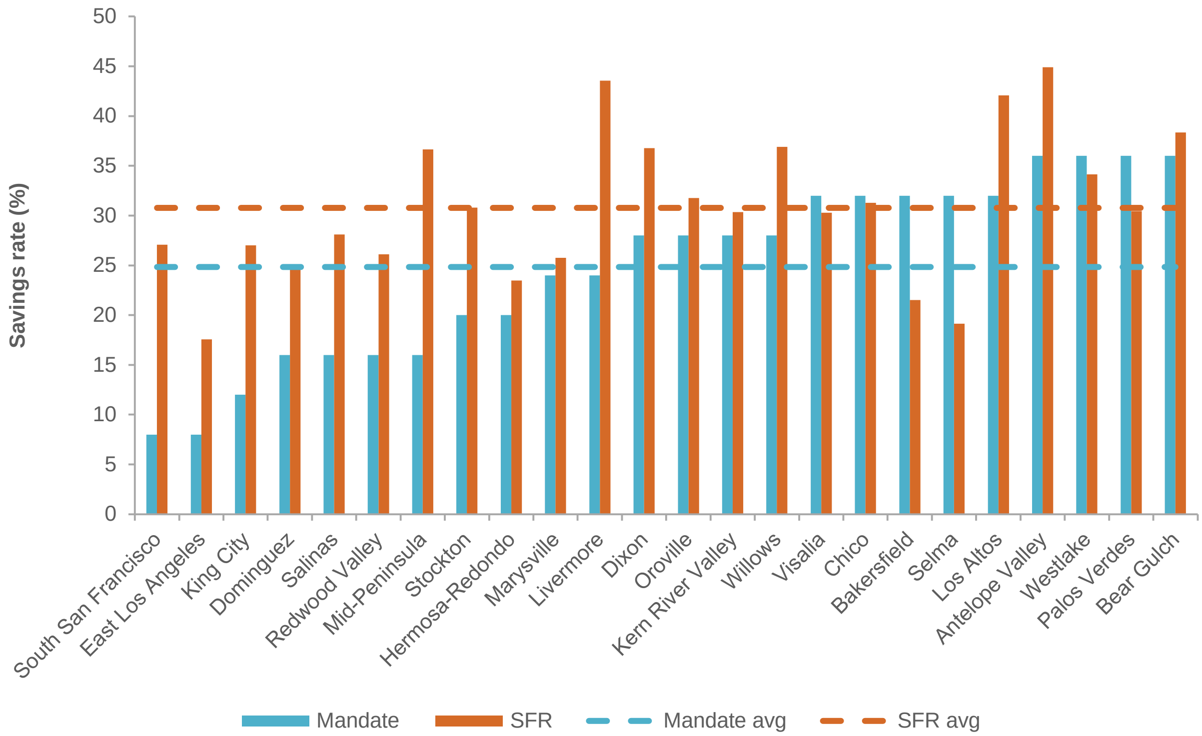
District	Single family	Multiple family	Commercial	Industrial	Government
Antelope Valley	135,838	218	7,929	0	7,071
Bear Gulch	2,432,907	63,551	274,955	383	62,465
Bakersfield	5,636,576	915,793	2,772,884	14,964	1,329,111
Chico	2,795,403	684,963	1,052,445	101,025	239,745
Dixon	202,539	19,889	23,322	76	9,577
Dominguez	2,070,846	612,304	2,040,558	2,538,329	347,019
East Los Angeles	1,714,141	220,244	1,073,017	220,135	385,893
Hermosa-Redondo	1,426,015	553,732	371,300	195,236	105,914
King City	171,446	20,119	113,893	19,574	38,278
Kern River Valley	143,412	1,178	13,989	0	3,980
Los Altos	1,845,955	159,333	510,545	2,656	131,378
Livermore	1,363,728	107,368	299,300	0	201,423
Mid-Peninsula	1,783,532	473,848	671,905	12,839	191,970
Marysville	154,414	76,055	94,854	369	40,994
Oroville	197,056	39,957	175,965	209,536	57,931
Palos Verdes	3,110,086	139,986	561,822	0	150,501
Redwood Valley	48,599	6,227	3,199	0	660
Selma	559,521	87,578	131,619	18,854	66,596
Salinas	1,751,191	368,766	1,232,143	372,570	235,132
South San Francisco	607,814	88,079	856,679	165,181	59,191
Stockton	2,813,982	400,224	1,377,563	642,054	473,581
Visalia	4,539,875	404,946	1,293,263	88,503	670,891
Willows	185,605	20,178	58,255	0	19,674
Westlake	1,070,344	54,611	396,484	0	50,036

Figures C15 through C19 provide customer-class level information corresponding to the district-level analysis shown in Figures C4 and C5 and summarized in Table C2. In these figures, bars that extend below zero denote negative savings rates (increased water use).

FIGURE C15

Conservation mandate vs. single-family residential (SFR) conservation achieved, by district

(a) Conservation mandate vs. SFR conservation achieved



(b) Conservation mandate vs. SFR total conservation achieved

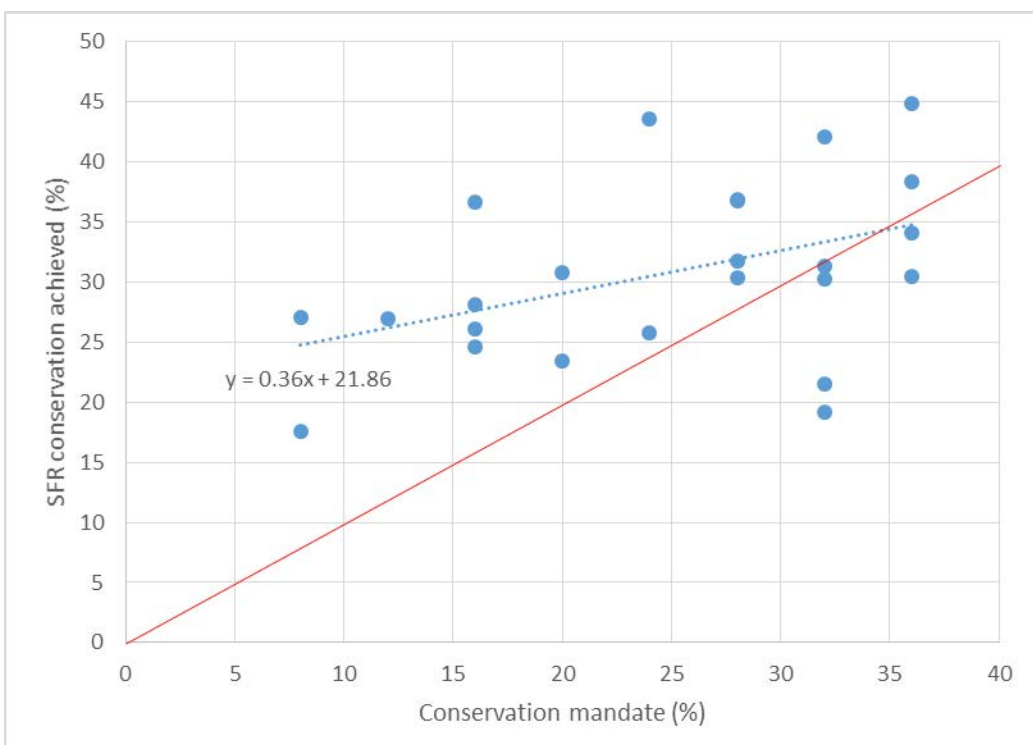
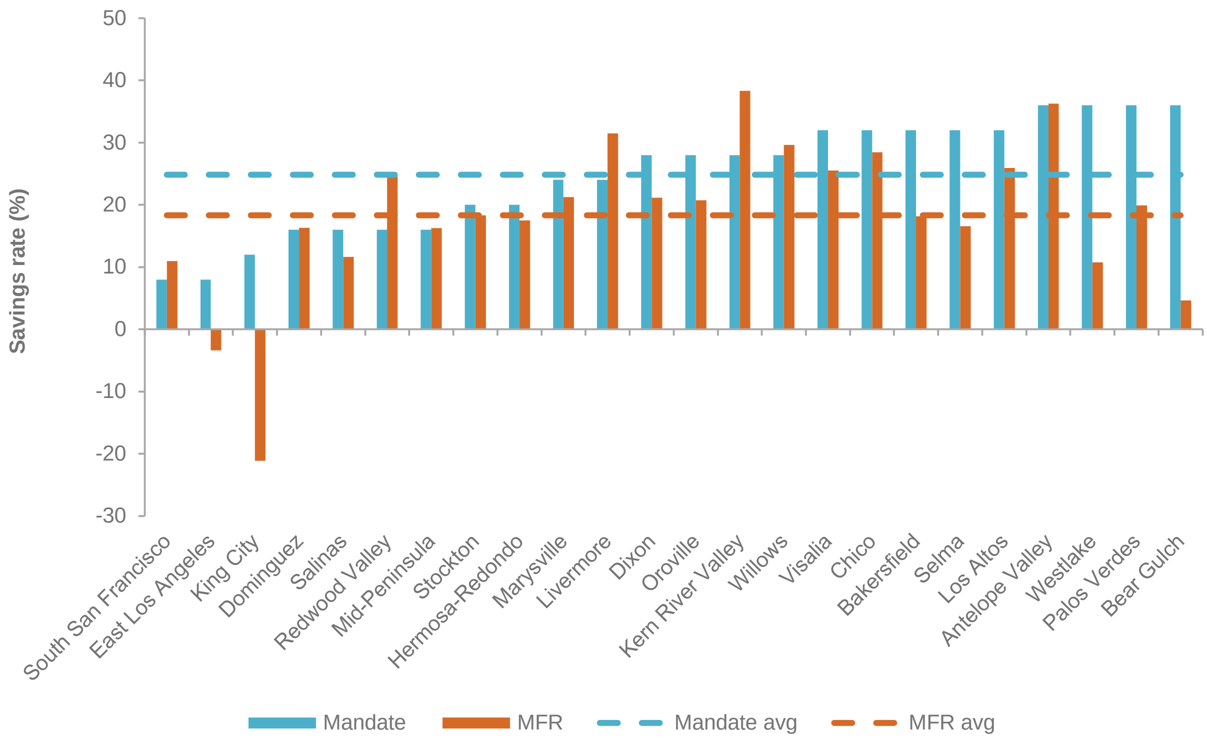


FIGURE C16

Conservation mandate vs. multi-family (MFR) conservation achieved, by district

(a) Conservation mandate vs. MFR conservation achieved



(b) Conservation mandate vs. MFR conservation achieved

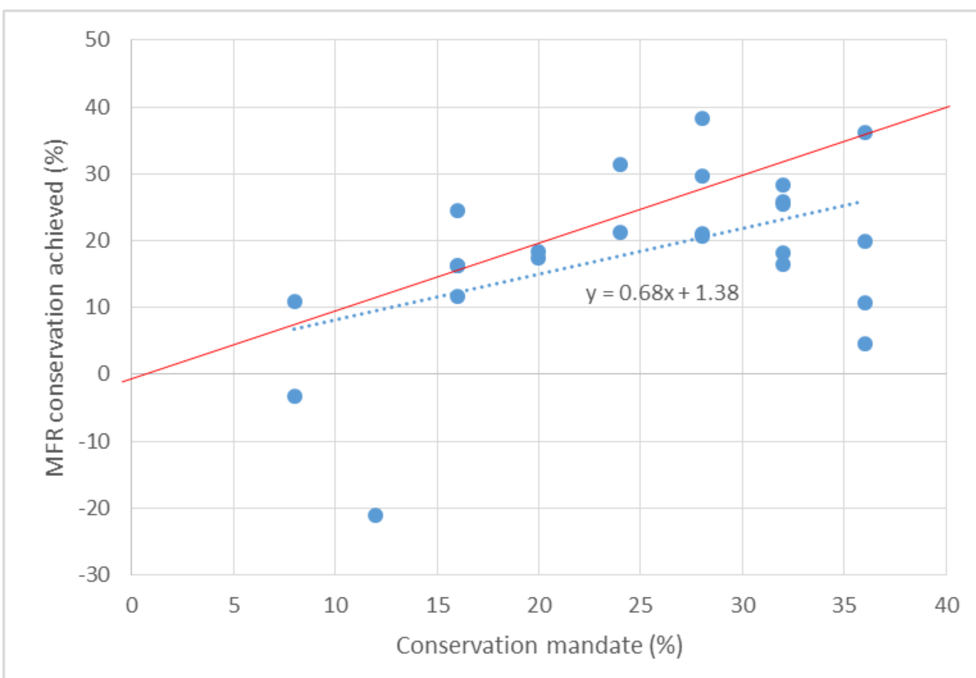
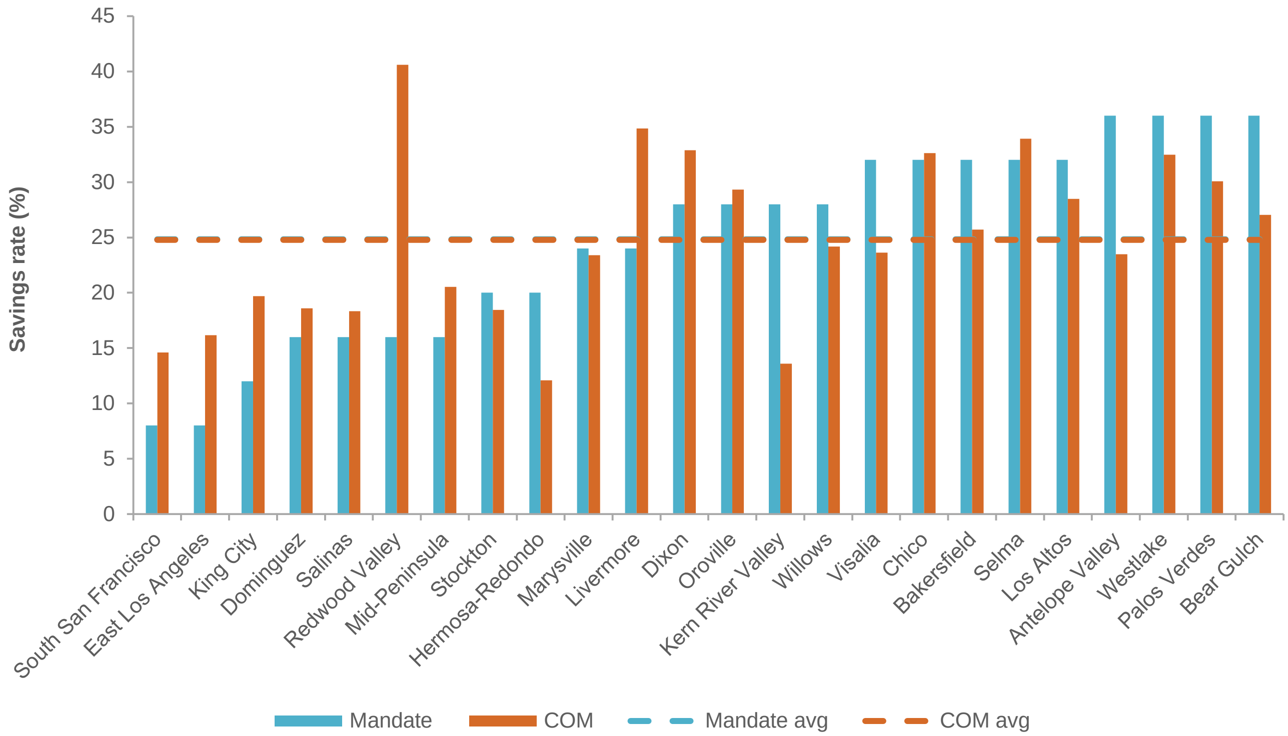


FIGURE C17

Conservation mandate vs. commercial (COM) conservation achieved, by district

(a) Conservation mandate vs. COM conservation achieved



(b) Conservation mandate vs. COM conservation achieved

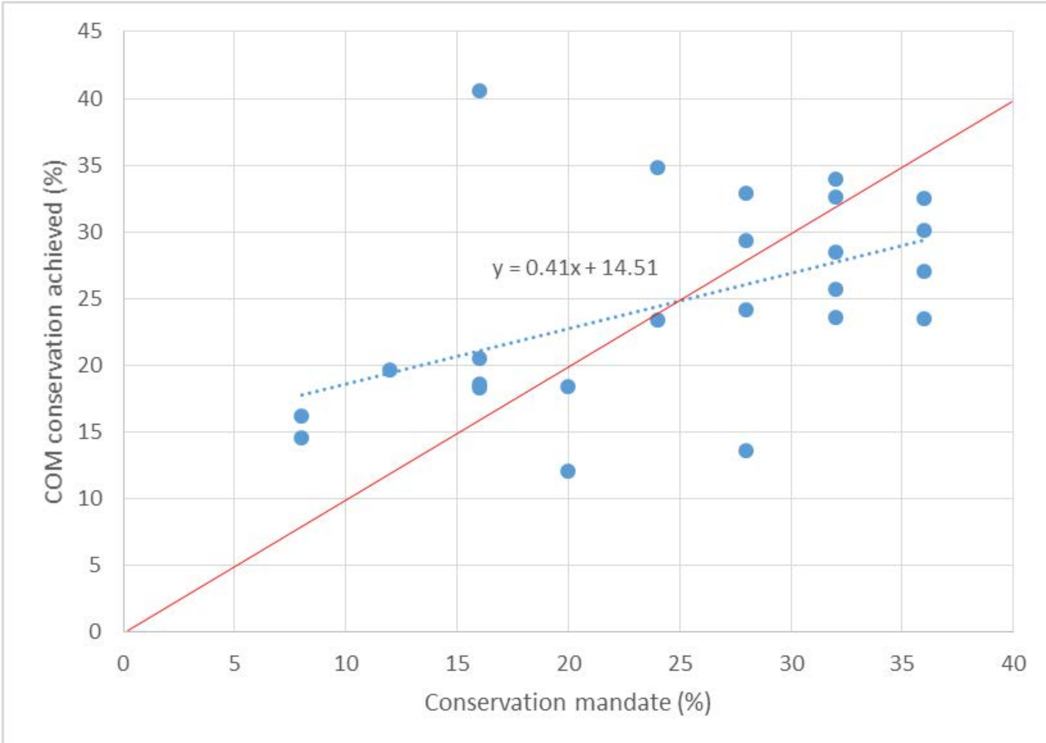
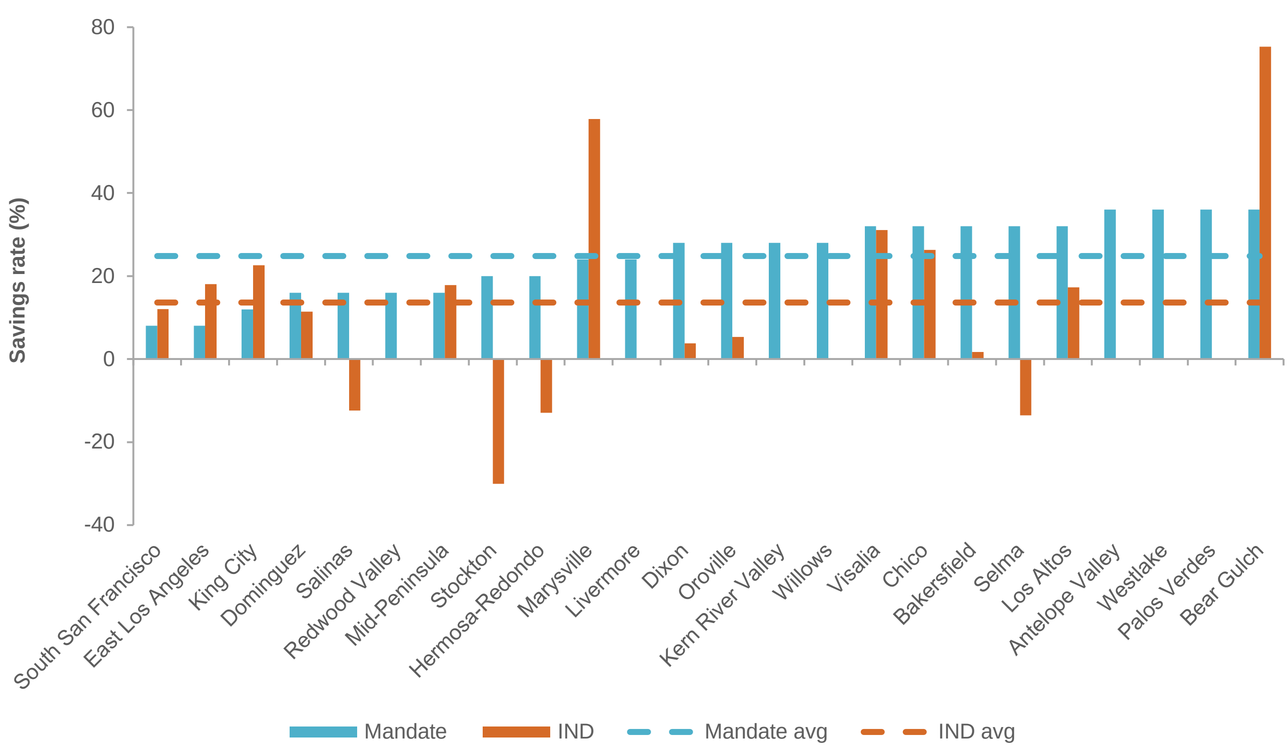


FIGURE C18

Conservation mandate vs. industrial (IND) conservation achieved, by district

(a) Conservation mandate vs. IND conservation achieved



(b) Conservation mandate vs. IND conservation achieved

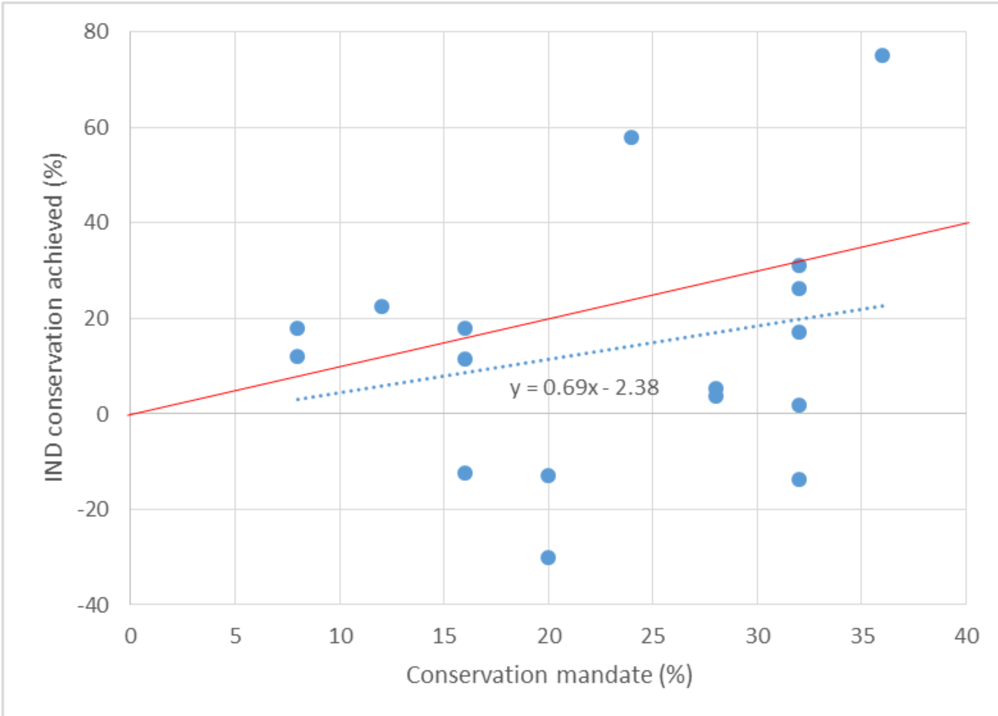
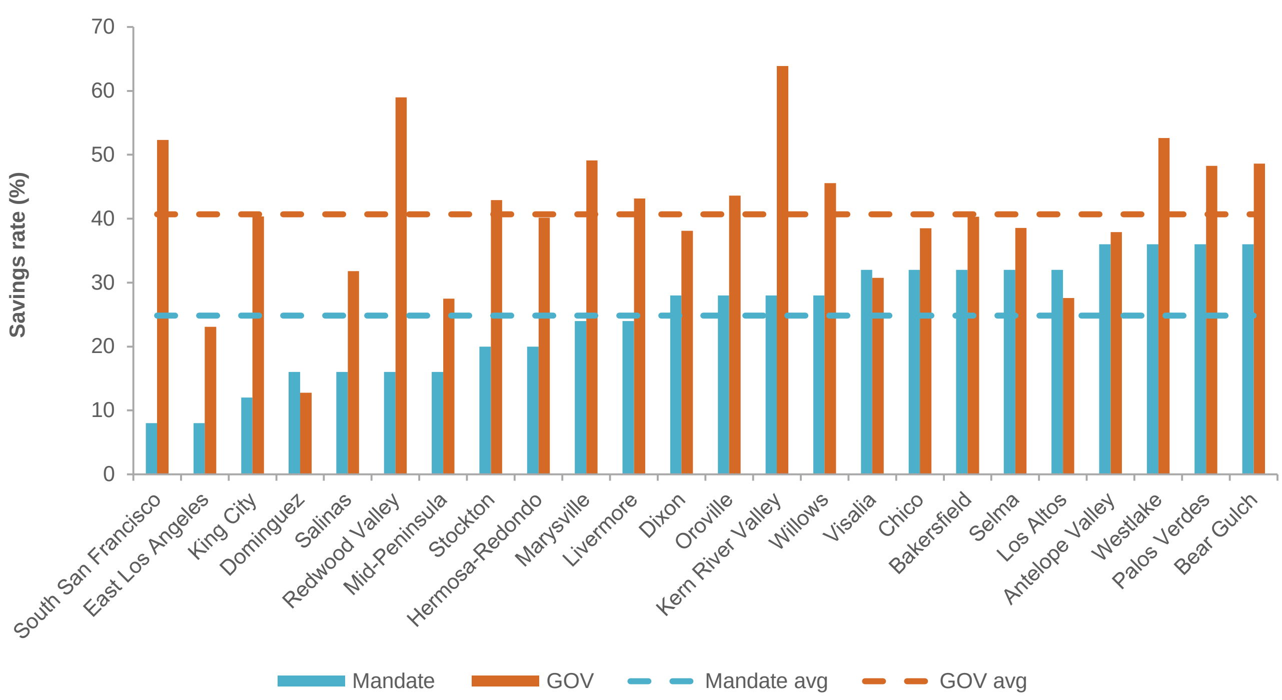


FIGURE C19

Conservation mandate vs. government (GOV) conservation achieved, by district

(a) Conservation mandate vs. GOV conservation achieved



(b) Conservation mandate vs. GOV conservation achieved

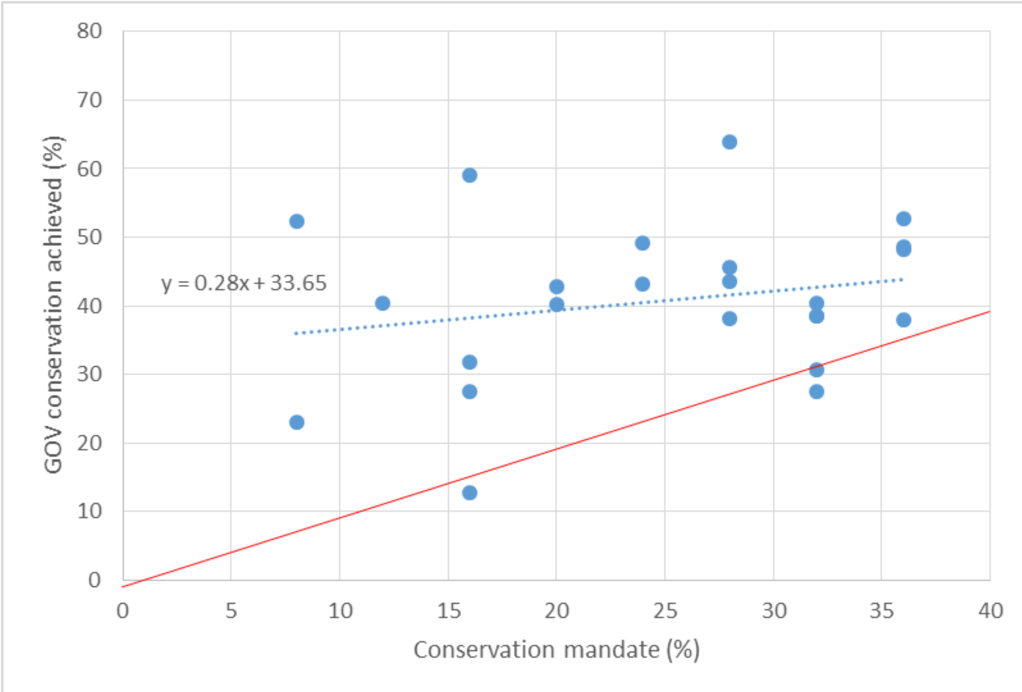


FIGURE C20

Single-family residential (SFR) water savings rates, 2014 and 2015

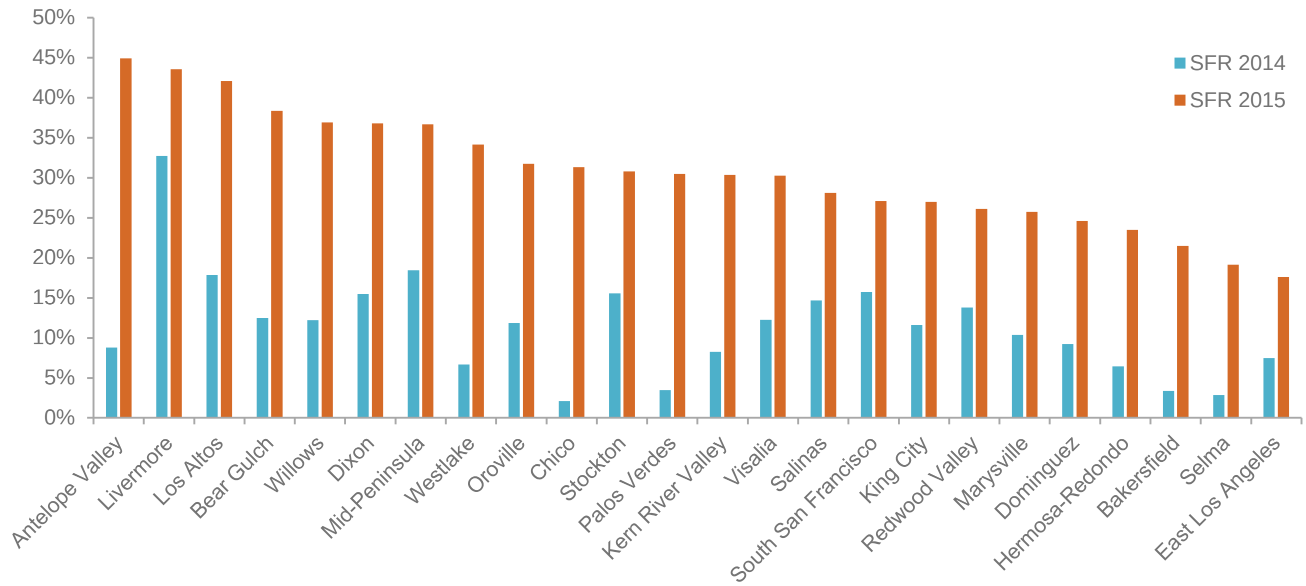


FIGURE C21

Multi-family residential (MFR) water savings rates, 2014 and 2015

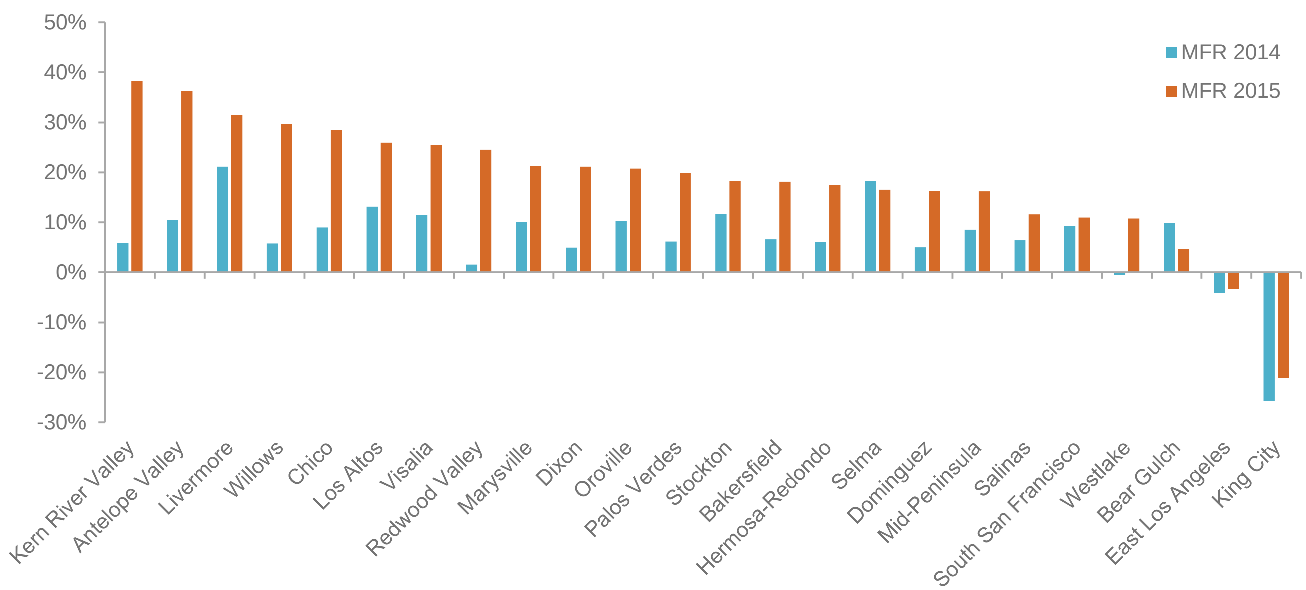


FIGURE C22

Industrial (IND) water savings rates, 2014 and 2015

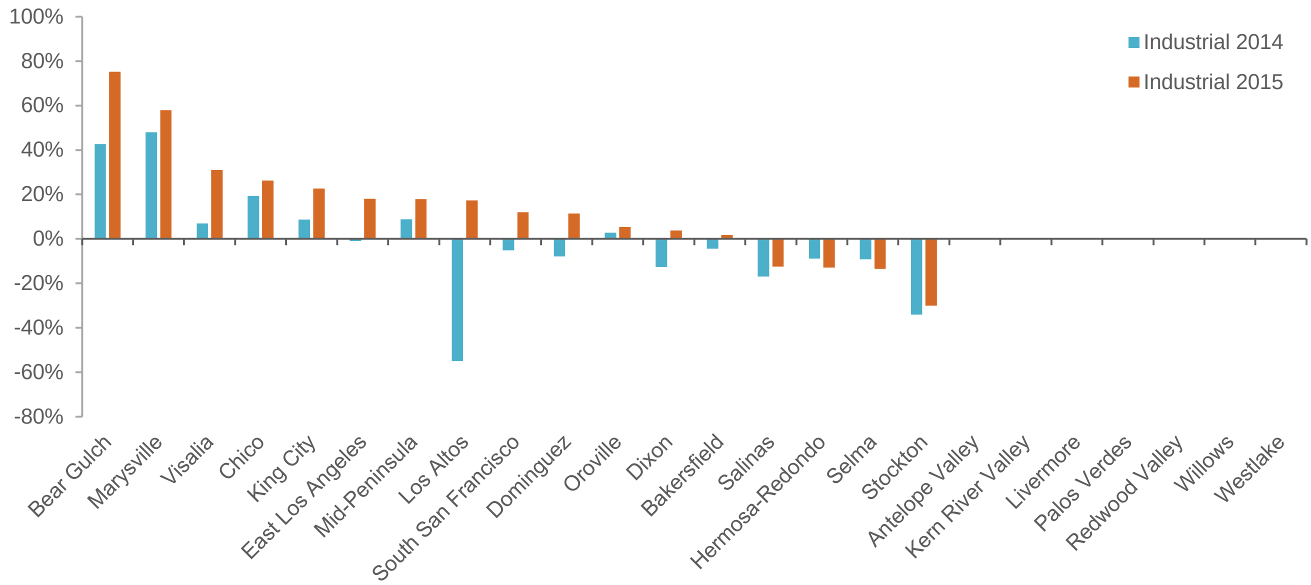


FIGURE C23

Commercial (COM) water savings rates, 2014 and 2015

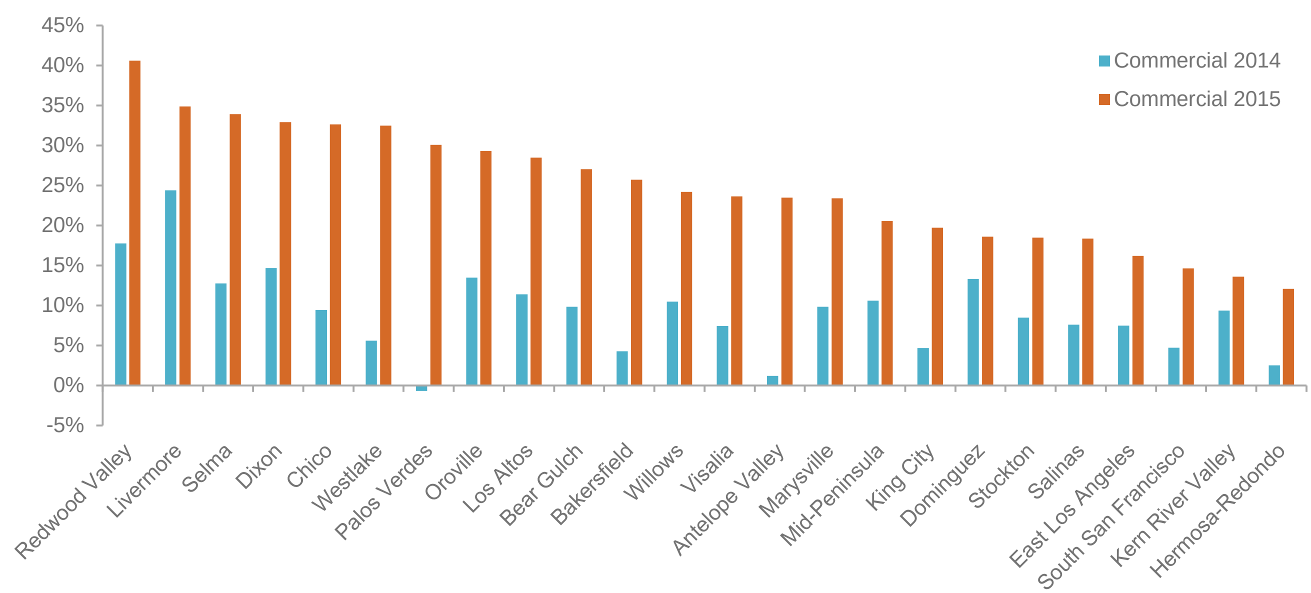


FIGURE C24

Government (GOV) water savings rates, 2014 and 2015

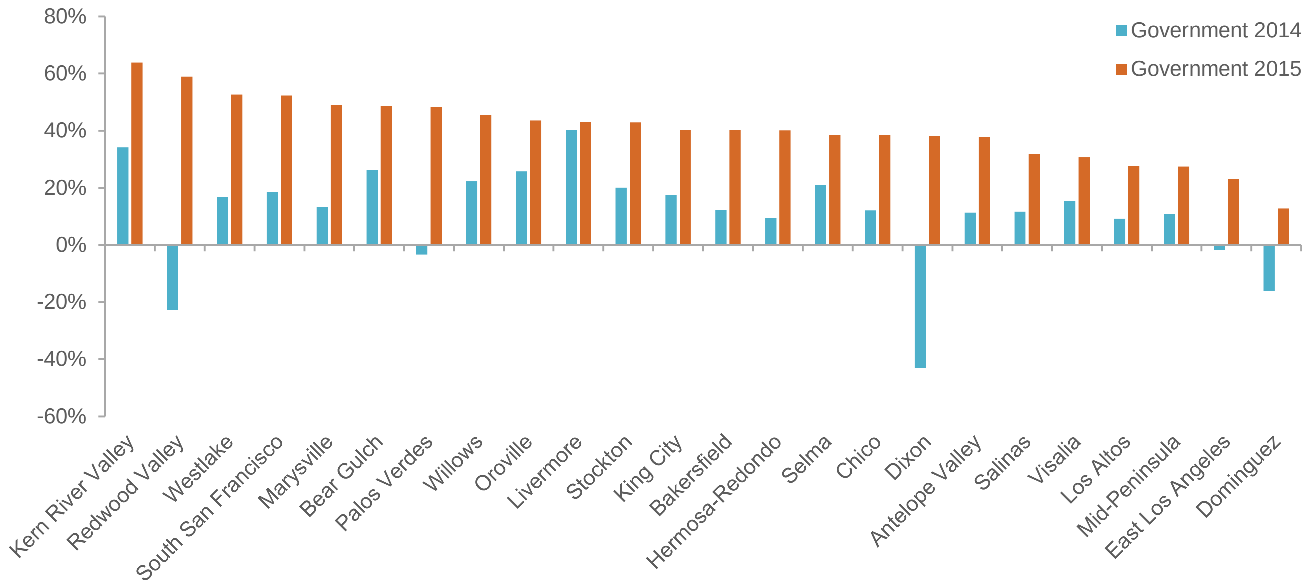


TABLE C16

Socio-economic and climate variable summary statistics by mandate level and region

Mandate Level	District	Region	Income ($1,000)	Population <10	Population >75	% Spanish Households	% Limited English	Rain Dev. (inches)	Temp. Dev. (⁰F)
8%	East Los Angeles	So Cal	43.50	14.58	4.79	82.05	22.33	-0.45	0.64
8%	South San Francisco	Bay Area	75.86	11.88	6.44	25.23	6.53	-0.94	0.23
12%	King City	Central Coast	42.76	18.01	3.72	71.05	26.92	-0.52	0.60
16%	Dominguez	So Cal	72.15	12.33	6.19	24.30	3.44	-0.40	0.40
16%	Mid-Peninsula	Bay Area	106.99	12.71	7.49	13.70	3.24	-0.78	0.36
16%	Salinas	Central Coast	61.56	16.75	4.34	46.49	13.32	-0.53	1.84
20%	Hermosa-Redondo	So Cal	101.90	12.51	6.03	11.25	1.34	-0.40	0.34
20%	Stockton	San Joaquin Valley	41.15	16.51	4.81	35.15	10.29	-0.55	0.43
24%	Livermore	Bay Area	104.18	12.79	5.58	10.86	2.44	-0.51	0.83
24%	Marysville	Sac. Valley	42.01	14.71	6.24	9.74	2.50	-0.81	1.43
28%	Dixon	Sac. Valley	64.40	16.94	3.50	27.85	7.48	-0.78	0.50
28%	Oroville	Sac. Valley	36.89	16.21	5.89	6.93	1.73	-0.91	0.76
32%	Los Altos	Bay Area	132.65	14.28	6.98	7.41	1.14	-0.78	-0.07
32%	Chico	Sac. Valley	50.27	11.57	5.60	11.68	1.95	-1.00	0.41
32%	Bakersfield	San Joaquin Valley	51.62	18.52	3.73	39.67	7.91	-0.13	1.36
32%	Visalia	San Joaquin Valley	55.58	16.52	4.57	29.59	6.11	-0.39	1.77
36%	Bear Gulch	Bay Area	132.11	12.65	7.84	16.14	4.51	-1.18	1.04
36%	Palos Verdes	So Cal	122.29	9.50	12.12	7.15	1.06	-0.51	0.83
36%	Westlake	So Cal	43.50	14.58	4.79	82.05	22.33	-0.45	0.64

TABLE C17

Descriptive statistics for the original sample[a]

Variables	Mean	Std Dev	Min	Max
Water use	13.46***	10.72	1.00	228.00
Turf area	1.99***	1.98	0.01	120.38
Non-turf area	2.04***	2.89	0.00	110.91
Property area	9.29***	12.66	0.12	1382.61
Bathrooms	2.16***	0.91	1.00	10.00
Year built	1964.8***	24.2	1797	2015
Surcharge LIRA	3.15***	1.23	1.49	5.00
Surcharge non-LIRA	6.29***	2.46	2.98	10.00
Conservation requirement	0.22***	0.07	0.08	0.36
Income	75.42***	31.05	36.89	132.65
Population <10 (%)	14.29***	2.66	8.73	18.52
Population >75 (%)	5.90***	1.98	3.50	12.12
Spanish HH (%)	27.11***	18.45	6.62	82.05
Spanish limited HH (%)	6.42***	5.45	1.01	26.92

NOTES: [a] The means shown in this table are compared to those in table 4.2 using a difference in means test. Significant differences at the 99 percent confidence level are denoted by ***.

Table C17 shows descriptive statistics for the variables considered in the analysis prior to preparing the data for statistical estimation (i.e., for the original sample). These may be compared to similar statistics presented in Table C5 in the main text which summarize the data after preparation.

The existence of unreliable and influential observations in the data, such as negative values for water consumption, necessitated that we first "clean" the original sample before undertaking statistical analyses. A common first step in the cleaning process is to perform outlier tests. We first identify "regression outliers" by estimating models similar to the regressions in the main text but considering water use as the dependent variable. We compute studentized residuals (i.e., we divide the residuals by their standard deviations) and we drop observations in the most extreme 5% of the residual distribution. We also remove "univariate outliers" with a similar process that focuses on the distribution of each individual variable. In addition to outlier tests, we also modify the original sample by "balancing" the panel (i.e., by dropping households that do not have a complete set of observations through time) and by limiting the observation period to June through December of each year. This last step explains why Table C17 does not show statistics for deviations in rain and temperature, as these variables have strong seasonal fluctuations and therefore are not directly comparable with the statistics in Table C5.

The mean values in Table C17 are generally similar to those in Table C5. Mean values after cleaning are slightly larger for *Turf area, Non-turf area, Property area, Conservation requirement,* and *Population<10*. They are lower for the remaining variables. In order to determine whether these differences are statistically significant, we perform a difference in means test. As can be seen in the table, we find that each difference is significant. However, it is worth noting that the t-test may be misleading for very large samples such as the ones we are analyzing. Moreover, these differences do not affect the parameter estimates presented in the main text (Wooldridge 2006; p. 326-327).

TABLE C18

Probit regression of compliance on explanatory variables with mandate levels

Attribute	Coefficient	Standard Deviation	z-statistic	p-value
Intercept	2.1133***	0.4471	4.7263	0.0000
Mandate level 8%	0.5906***	0.0796	7.4163	0.0000
Mandate level 12%	0.7925***	0.0912	8.6853	0.0000
Mandate level 16%	0.6551***	0.0413	15.8573	0.0000
Mandate level 20%	0.9323***	0.0520	17.9120	0.0000
Mandate level 24%	0.6680***	0.0397	16.8105	0.0000
Mandate level 28%	1.0845***	0.1162	9.3353	0.0000
Mandate level 32%	0.5091***	0.0423	12.0380	0.0000
Income ($1,000)	-0.0104***	0.0013	-8.3039	0.0000
Population <10 (%)	-0.0745***	0.0157	-4.7341	0.0000
Population >75 (%)	0.0458***	0.0076	6.0161	0.0000
% Spanish HH	0.0113*	0.0060	1.8944	0.0582
% Limited English HH	-0.0201	0.0152	-1.3269	0.1845
Central coast	-0.3902***	0.0471	-8.2793	0.0000
Sacramento Valley	-1.0013***	0.1169	-8.5646	0.0000
Southern California	-0.6713***	0.0744	-9.0204	0.0000
San Joaquin	-0.9021***	0.1001	-9.0137	0.0000
Rain deviation (inches)	0.1116***	0.0043	25.7102	0.0000
Temperature deviation (^{0}F)	0.0342***	0.0019	17.8093	0.0000
Turf area (1,000 sq ft)	0.0005	0.0032	0.1527	0.8787
Non-turf area (1,000 sq ft)	-0.0259***	0.0032	-8.2273	0.0000
Property area (1,000 sq ft)	-0.0005**	0.0002	-2.2119	0.0270
Bathrooms (#)	-0.2702***	0.0056	-48.3848	0.0000
Year built	-0.0004*	0.0002	-1.9433	0.0520
Drought surcharge ($)	0.0523***	0.0023	22.7395	0.0000
Water use 2013 (ccf)	0.0058***	0.0000	70.9545	0.0000

NOTES: Statistical significance at the 99, 95 and 90 percent confidence level represented by ***, **, and *, respectively.

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