Affordability of Water Services in the Inland Empire-Phase 1

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EXECUTIVE SUMMARY

The focus of this research is to evaluate how single-family residential (SFR) water and sewer expenditures compare to income within the EMWD's service area. This research is in response to general concerns over water affordability confronting households throughout the U.S. Water affordability is often couched in terms of the percentage of income households must devote to water services, with particular attention to essential, or basic needs, water services. In considering the literature surrounding this issue, though, there is not uniform agreement nor transparency in terms of what sort of water services are to be included in such water affordability measures. Furthermore, there is increased awareness that lower-income households may not be well represented by average or median household income estimates that are often used in calculating such affordability metrics.

In response to this confusion and these concerns, we analyzed single-family residential water bills from over 138,000 accounts comprised of over 12 million billing records within the Eastern Municipal Water District's (EMWD) service area from 2011 to 2018. To illustrate how such affordability measures can vary depending on the types of water services being evaluated, and to avoid confusion and subjectivity surrounding the term affordability, we calculated five different water expenditure ratios (WERs) for each household within the EMWD service area. The water expenditure ratios represent the percentage of income devoted to water and sewer services (as measured by the expenditures from customer-level water bills dived by income). The five different WERs we calculate are based on the water and sewer services associated with:

- Basic, or essential needs use (defined by 35.66 gallons per capita per day)
- Indoor water use, as measured by both (i) 55 gallons per capita per day, which is the indoor per person per day allocation identified by the state of California as an efficient level of indoor usage, and (ii) average winter usage, which is an often used, albeit imperfect, measure of indoor water use.
- Budget-based indoor and outdoor use, which is the sum of both efficient indoor and outdoor usage given household characteristics as identified by the state of California, and overall water use, which simply takes into account the residential customers overall water use and the expenditures associated with such use.

Because researchers and agencies rarely have household-level income estimates, different summary measures of income are used to represent income within an area, or water district. To illustrate how the WER ratios and discussions of affordability rest on the choice of income estimate, we present each WER by different income categories. We also illustrate how WERs, and thus measures of affordability, vary by different socio-economic characteristics.

Finally, recognizing that water is one of a number of essential or basic needs services households require, we estimate the average expenditure ratios for a variety of essential services, including housing, food, health care, transportation, energy, and telephones from 2011 to 2017 using data from the US BLS Consumer Expenditure Survey, and compare those estimates to the WER within EMWD service area. Caution is suggested in terms of drawing significant conclusions based on these comparisons given differences in the geographic location from which the data are generated often give rise to differences in economic, institutional, demographic, and environmental factors. Such comparisons, though, can be both illustrative and informative to better understand, in general terms, how income is allocated across different essential needs categories to ascertain, perhaps, how much can be gained from reducing the cost of one category relative to another in freeing up income to households.

Overall Findings

Water Expenditure Ratios (WERs) have risen, on average, from 2011 to 2018, although not significantly. Over this period, the Basic Needs WER rose from 0.85% to 1.11% of MHI. Indoor use, as measured by the 55 GPCD efficiency standard identified by the state of California, experienced an increase in its WER from 0.92% to 1.29% of MHI, while the WER associated with indoor use as measured by average monthly winter time usage rose from 1.16% to 1.50%. While not considered essential or basic needs water use, overall water and sewer expenditures within EMWD, as a percentage of median household income (MHI), rose from 1.37% to 1.58% between 2011 and 2018. Interestingly, if households were to use the full budget as defined by the state in terms of efficient indoor and outdoor use, overall water expenditures as a percentage of income would increase.

Water Expenditure Ratios can be significantly impacted by choice of income measure, and vary inversely with income. A unique element of our analysis is to develop WER per household by dividing each household's water and sewer expenditures by the median household income (MHI) associated with that household's particular US Census Block group rather than, say, the MHI of the entire district. As an example of the significance of the choice of MHI, in 2018, the Basic Needs WER is 1.11% using the MHI at the block group level. If one were to use the district-level MHI, which is around $68,000, the WER would be 0.91%. Because the block group MHI estimates vary from $22,210 to $119,464, using the district-level MHI results in an underestimate of the average WER. If one where to use the 20 th percentile MHI, which is often the level that separate middle- from lower income, the WER for basic needs water increases to 1.48%, up from the 1.11% if we use block-group MHI. Finally, we observe a strong inverse relationship between WER and income, supporting the concern that water affordability is more of an issue for lower income households; conversely, as incomes rise, water comprises a smaller overall fraction of income and thus affordability surrounding water expenditures become less of a concern.

Water Expenditures Ratios in EMWD are significantly lower than US EPA Affordability Thresholds for water and sewer services. The US EPA has published affordability thresholds for different sorts of water services. For water and sewer services, the US

EPA has identified an affordability threshold of 4.5%. While there are significant issues and concerns regarding the use of a single uniform threshold as discussed below and, in the literature, (e.g., see Teodoro, 2018), the WER for all five of the water services considered here are well below the 4.5% threshold. The WERs for 2018, on average, ranged from 1.11% to 2.10% for the different water service metrics we analyzed. In 2018, there was five and 69 SFR customers in our data set that had a WER above the 4.5% threshold for either basic needs water or efficient indoor water use, respectively. Considering overall water use, which includes water services above and beyond basic or essential needs, only 0.4% (approximately 550 out of more than 138,000 households) had WERs above the US EPA's threshold.

Water Expenditure Ratios vary across different user groups. We find that those households in areas where rent is a higher percentage of income have higher overall WERs than those areas whose rent is a lower fraction of income. Given that higher rents or housing costs for a particular level of income lower the discretionary income remaining to pay for basic or essential water services, this is a concern. While the differences in the WERs are statistically significant, the percentages differ by only 0.34% (from 1.33% to 1.78%). We also find that areas for which house-holds are characterized by smaller family sizes or larger irrigated landscape have higher WERs. Since the WER we considered in these comparisons relates to overall water and sewer expen-ditures, it is not surprising that the WER for those with a larger irrigated area is higher. Note that each of these comparisons are simply two-way comparisons that do not control for other po-tentially confounding factors (e.g., income, ET), and thus these associations do not prove causation. A more in-depth analysis would need to take place for such an assessment.

Water services in EMWD's service comprise a significantly smaller proportion of overall income than other essential services. In considering how water expenditures as a proportion of income stack up against other essential services, we compared the WERs from EMWD tothe expenditure ratios associated with food, housing, transportation and health care inSouthern California, and to other utility services (i.e., natural gas, telephone, and water) in western US states and territories. As expected, a substantial portion of income goes towards housing (31.9%), followed by transportation (12.7%), food (11.4%) and health care (5.2%) in 2017. Water and sewer services in EMWD's service area (~1.5%) are comparable as a percentage of income to electricity (1.5%) and telephone (1.7%) services in the western US states and territories, yet slightly higher than natural gas (0.40%). Water and other public service expenditures in the western US are slightly lower as a percentage of MHI than water and sewer services in EMWD. From a policy perspective, focusing on water costs / prices as a means to address poverty or increase household discretionary income seems very limited given the limited fraction of income such expenditures comprise. Efforts directed at reducing housing, transportation, food, and health care would seem to provide significantly greater opportunities to increase household discretionary income or address poverty.

In terms of trends, the largest percentage increases in essential service costs based on our data are observed in the housing, health care, and food sectors which experienced a 2.27, 1.59, and 1.08 percent increase in their expenditures as a proportion of income from 2011 to 2017. Water and sewer services within EMWD service area increased by only 0.11% over the same period, although utility services across the western US seem to have experienced a slight decrease in expenditures relative to income over this period. Of course, we suggest caution when making these comparisons across different regions (e.g., Los Angeles Metropolitan Statistical Area, western US states and territories, EMWD) given the differences in economic, institutional, socioeconomic, and demographic factors.

Table of Contents

List of Abbreviations

CCF	One-Hundred Cubic-Feet
EMWD	Eastern Municipal Water District
GPCD	Gallons Per Capita Per Day
MHI	Median Household Income
WER	Water Expenditure Ratio

1. INTRODUCTION, BACKGROUND, AND RATIONALE

Many water systems are grappling with aging and deteriorating infrastructure, changing customer bases, regulatory compliance, and climate change—all of which add to the growing costs of providing water services. At the same time, per capita water use has been declining, in part, because water agencies continue to put significant effort into increasing water use efficiency, particularly in the residential water use sector and with impressive results. In California, water use had decreased from 244 gallons per capita per day (GPCD) in 1995 to 178 GPCD in 2010 (Hanak et al. 2016) . Short-term water use reductions have also occurred, as evidenced by California's recent drought during which time the state enacted a conservation mandate that required water agencies throughout California to reduce water use so that overall statewide water use decreased by 25% relative to 2013 levels. While increased water efficiency and conservation efforts may help agencies and the state meet both short- and long-term water reduction goals, they can also jeopardize the stability of incoming revenues and compel systems to compensate with higher rates. With many agencies changing rates and rate structures in response to infrastructure needs, long-term water use targets, and short-term supply shocks (e.g., the recent drought), there also is concern over the affordabi ity of water to residential customers, especially among lower-income customers.

The focus of this research is evaluating the water affordability among Single Family Residential (SFR) customers, with a particular emphasis on the affordability to lower-income customers. The first phase of this research, which is related to this specific proposal, is to perform a pilot study of water affordability within the Eastern Municipal Water District's (EMWD) service area.[1] EMWD has a very diverse customer base with a wide range of incomes that will allow us to analyze how affordability varies across different socioeconomic and demographic groups. Alternative water affordability metrics will be analyzed to understand better how different measures of water use impacts affordability metrics. This sort of analysis addresses the likely intent surrounding discussions of water affordability—the cost of water that is used for human health and hygiene—and compares it to metrics that include efficient and overall water use. Conventional affordability indicators often rely on the actual amount that households spend on water use and usually are at the aggregate (e.g., water agency, state, and county) levels. In contrast, we propose additional and more granular indicators that measure the affordability to meet essential needs using household-level data. For comparison purposes, we estimate the fraction of income spent on different sorts of water no to accentuate the importance of clarity as to what sort of water services one is discussing in the context of affordability.

In addition to illustrating how the fraction of income spent on water use is sensitive to different types of water use and how income is measured, we highlight the degree to which this fraction—which we refer to as a Water Expenditure Ratio (WER)—differs for lower-income households. To put these expenditure ratios into context, we calculate similar expenditure ratios for other essential services including food, housing, transportation, health care, natural gas, electricity, and telephone services using data from the US Bureau of Labor Statistics Consumer Expenditure Survey. Finally, to provide insight into how water affordability has varied over time, we estimate the water expenditure ratios for each year from 2011 through 2018 while providing some background information on how overall water costs and water prices have changed.

We should emphasize, similar to Teodoro (2018) , that "affordability" is a relative term and depends on many factors. As such, care is warranted in terms of the conclusions one can draw from developing affordability measures and how such measures are used. While in principle, affordability ratios are intended to signal the degree to which households may find it challenging to meet their water needs given their available income, affordability ratios—which are usually measured by calculating the faction of Median Household Income (MHI) spent on (essential) water use—may not be a very informative metric for comparison over time or place if other factors that affect discretionary income vary, which is likely the case.

While much of the literature will use the term "Water Affordability Ratio," the term affordability is very subjective and leads to significant confusion. As an alternative, then, in the analysis below, we develop a "Water Expenditure Ratio" (WER) that calculates the fraction of MHI spent on different types of water services. Of course, there are widely publicized thresholds that have been used (and misused) surrounding affordability criteria (Mack and Wrase 2017, Teodoro 2018). Given the attention these thresholds have received in both the academic and public domains, we will compare our WERs with these thresholds, but qualify the comparison with appropriate caveats as to the weaknesses of such comparisons when appropriate.[2]

2. METHODS

Below we calculate different WERs for different types of water services and use these WERs to discuss issues surrounding affordability. To calculate different WERs, we follow three steps: (i) calculation of the monthly water and sewer bill (expenditures) at the household level for EMWD service area from 2011-2018; (ii) estimation of key socio-economic and household characteristics (e.g., income, housing and rental costs at the census block group level; household size and landscape area); and (iii) calculation of the household-level WERs.

2.1. Calculating Expenditures for Water and Sewer Services

To calculate the water expenditures, we use the household-level monthly billing information for the SFR customers in the EMWD service area from 2011-2018. This information includes total, indoor, outdoor, and excessive monthly water consumption, water tier-based rates, water service charge, water supply reliability capital monthly charge, sewer service

[1] This study will serve as a benchmark for the 2nd phase which extends the study to other Inland Empire areas.

[2] For a more in-depth discussion of the limitations of using affordability ratios, see Teodoro (2018).

charge, sewer system capital projects monthly charge, and both landscape and household size.

2.2. Socio-economic Parameters

To highlight how water expenditures vary across different user groups with attention to the affordability of water to disadvantaged communities, we merge the billing information for each customer with the MHI information using U.S. Census data at the block group level. It is important to emphasize that since we estimate MHI at the block group level, and use these block-group estimates as the denominator in our calculations (below), our WERs capture income variability in the district. EMWD serves more than 138,000 single-family residential households with significant variation in income across these households, as shown in Figure 1. Figure 1 presents a graphical illustration of how income varies by the block groups[3] within the EMWD service area. The MHI associated with the Census Block Groups in which these households reside ranged from $22,210 to $119,464 in 2017. As the figure highlights, there is significant heterogeneity in income within EMWD – a characteristic that illustrates the importance of using a much more granular measure of MHI than, say, the district, city, or county level.

To highlight how WERs vary across socio-economic factors, we use the U.S. Census Bureau's American Community Survey (ACS)[4] to obtain information annually from 2011 to 2018 on household characteristics and house/location characteristics at the Census Tract level (2011 and 2012) and Census block group level (2013-2017)[5] . Each household is located within its block group, which is characterized by the following factors: median income level, rent as a percentage of income. Additionally, with data from EMWD, we can also characterize households by a number of residents and irrigated landscape.

2.3. Alternative Water Expenditure Ratios (WER)

Using several different measures, a variety of water expenditure ratios are calculated at the household level. As noted above, we calculate the monthly water, and sewage costs households confront—we label them water and sewer expenditures—as a percentage of household income. This calculation is standard within the water affordability literature. Since actual measures of individual-level household income are difficult to obtain, though, these affordability measures typically use the MHI of the area in which the household resides.[6] A widely used, albeit increasingly debated and critiqued threshold for defining water affordability (Teodoro 2018, Kane 2018) comes from the Environmental Protection Agency (EPA). In considering monthly water use alone, the EPA has identified thresholds that have been used to indicate whether residential water expenditures, as a fraction of MHI, pose a challenge to households—particularly low-income households—in paying their water bills. The thresholds that have been identified as presenting affordability challenges to households are (i) if the costs of water services are more than 2% of MHI, and/or (ii) if the costs of water and sewer services are more significant than 4.5% of MHI given that households must pay for both water and sewer services. In the measures we develop below, we calculate WERs for water and sewer services, along with WERs for different types of water and sewer services, including basic needs, indoor water use, efficient water use, and overall water use.[7] While outdoor water use and water use above what is considered efficient water use extends beyond what would be termed basic needs, essential, or a human right to water, it is instructive to understand the potential financial challenges households confront in terms of the regular water expenditures they confront each month. With these concerns in mind, we calculate the following measures.

2.3.1. Basic Needs Water and Sewer Expenditure Ratio (BNWSER)

Because affordability typically relates to basic needs, we calculate the water expenditure ratio associated with what might be considered a basic needs level of water use, e.g., for cooking and hygiene. There are multiple studies which define the amount of water necessary for essential needs in terms of GPCD (e.g., Gleick 1996) . In this study, we use 35.66 GPCD as our benchmark for basic needs, a benchmark which is defined and applied in more recent studies in the United States (Mack and Wrase 2017) . The following WER is calculated, then, based on this essential, or basic needs level of water use. For each household *i*, year *y*, and block group *b*, we estimate:

$$(1) \quad BNWSER_{iy} = \frac{Basic\ needs\ water\ and\ sewer\ bill_{iy}}{MHI_{by}} * 100$$

2.3.2. Indoor Water Expenditure Ratio (IWSER)

Another measure that might represent what is a necessary amount of water for daily usage is one that considers a reasonable amount of indoor water use (and the expenditures associated with that use) per person. For those water agencies that use budget-based (or allocation-based) rates, this would be equivalent to their allocated indoor budget, which provides each household allocation of water per person for indoor usage. The indoor allocation of 55 GPCD for SFR customers in EMWD service area is also similar to the efficiency standards set by state law (California Department of Water Resources and State Water Resources Control Board 2018).[8] It allows for a more generous allocation than what might be considered basic needs, yet is somewhat close to the 50 GPCD that Teodoro (2018) used. For each household *i*, year *y*, and block group *b*, we estimate:

$$(2) \quad IWSER_{iy} = \frac{Water\ use\ in\ tier\ 1\ and\ sewer\ bill_{iy}}{MHI_{by}} * 100$$

[3] Our calculations indicate that there are 230 block groups in the EMWD service area.
[4] For more information see: https://www.census.gov/programs-surveys/acs/? [Accessed March 2019]
[5] Note that Census data is not available at the block group level for 2011 and 2012. Since there is no information available for 2018, we use 2017 Census data as a proxy for 2018.
[6] One of the unique elements of this research is to employ a much more granular measure of MHI that is more reflective of the income disparities that exist throughout the region and California. By using the MHI of the US Census Block Group that the household resides in rather than, say, the MHI for the agency, county or state, our WERs are more likely to accurately reflect the possible burden water services may impose on households than if the more aggregate MHI measures were used.
[7] Often a water bill excluding sewer costs is used in these calculations in the literature. Since EMWD provides both services, and since sewer services are an essential service as well and often priced based on water use, we have bundled the two in this report. Analysis excluding sewage services are available from the authors upon request.
[8] Prior to January 1, 2018, the tier 1 indoor allocation designated by EMWD was 60 GPCD. For this report and this WER, we use 55 GPCD as a measure of indoor water usage.

2.3.3. Winter Water & Sewer Expenditure Ratio (WWSER)

While the IWSER uses a pre-determined 55 GPCD to proxy for reasonable indoor water use and is based on the state recommendations, wintertime water usage is often considered a proxy for household-level indoor water usage given that outdoor irrigation needs are diminished or absent during this period (Zhou et al. 2000) . While this is an imperfect measure of indoor water usage, given how often it is used as an indoor measure, we calculate the water expenditure ratio associated with average monthly wintertime water usage, averaged over the months December through February, at the household level. [9] For each household *i*, year *y*, and block group *b*, we estimate:

$$(3)\quad WWSER_{iy} = \frac{Winter\ water\ use\ and\ sewer\ bill_{iy}}{MHI_{by}} * 100$$

2.3.4. Within Full Budget (indoor and outdoor) Water Expenditure Ratio (WBWSER)

The next measure moves away from a focus on basic needs water services to water services that might be best described as efficient indoor and outdoor water uses. The state has developed definitions for indoor and outdoor water use efficiency that include, currently, a 55 GPCD indoor standard and an outdoor standard that is based on the percentage of evapotranspiration (ET) for the amount of irrigated area a residential customer has to water. For those agencies that have budget-based (or allocation-based) water rates, the budget is defined by their indoor and outdoor (tier 1 plus tier 2) allocations. There is a push by agencies to encourage, even incentivize, households to remain within their "budget." The Within Budget Water Expenditure Ratio, then, represents the faction of MHI devoted to water and sewer expenditures associated with a household's water budget. Note that this measure assumes households' utilize their full budget and thus is not a measure of actual water usage.[10] For each household *i*, year *y*, and block group *b*, we estimate:

$$(4)\quad WBWSER_{iy} = \frac{Water\ use\ for\ tier\ 1\ and\ 2\ and\ sewer\ bill_{iy}}{MHI_{by}} * 100$$

2.3.5. Overall Water and Sewer Expenditure Ratio (OWSER)

The final water expenditure ratio we calculate, while not based on a basic needs level of water use, illustrates how the expenditures related to overall water use compare to the MHI. Because the expenditures we use to calculate the overall water expenditure ratio may include what would likely be defined by the state and water agency as inefficient or wasteful usage by some households, we emphasize that this ratio should not be used as a measure of water affordability as it relates to basic or essential needs or even efficient use. Rather, this ratio is illustrative in terms of providing information on what fraction of MHI is typically spent on water and sewer services each month. For each household *i*, year *y*, and block group *b*, we estimate:

$$(5)\quad OWSER_{iy} = \frac{Total\ water\ and\ sewer\ bill_{iy}}{MHI_{by}} * 100$$

3.RESULTS

Before presenting the water expenditure ratios for different water services and water user groups, we present a brief discussion of trends in water bills and prices within the EMWD service area. Within EMWD residential service area, the average cost of basic needs water, in real terms (2011 dollar values), increased by approximately $3.82 over the period 2011 to 2018, largely due to the adjustment in pricing over the study period (Tables A1 and A2). In terms of indoor budget, average district-wide expenditures on water use dropped by nearly 21%, in real terms (Table A1); again, this is mostly due to the changes EMWD pricing structure and its tier 1 water prices in 2018. For the expenditures associated with water use within a household's water budget—comprised of both efficient indoor and outdoor water—average residential expenditures rose by less than 8%, or $2.91, over the 2011 to 2018 period within EMWD's service area.[11] Sewer costs rose slightly over $4, or around 18%, from 2011 to 2018. Finally, overall monthly water bills rose, on average, approximately 5.5%, or $2.35, over the 2011-2018 period, for an average annual increase of only 0.78%.

To put these water expenditure trends into context, the overall inflation rate based on the Consumer Price Index (CPI) for the Los Angeles area rose by approximately 1.99% annually from 2011 to 2018 (Table A2).[12] Changes in water expenditures, though, are influenced by both changes in prices as well as changes in water use. To get an understanding of how water prices alone have changed the water costs confronting households, we calculated the rate of change in water costs that would be attributed to prices alone for a representative household in EMWD service area. In the third column of Table A2, we calculated the "at budget" water use associated with a representative household characterized by three household members, 3,000 sq ft of landscape, a conversion factor (CF) of 0.8, an ET of 3.93, and a drought factor of one for July of 2011. We then estimated the water expenditures that this hypothetical household would incur if they continued to use that same amount of water (i.e., no change in water use behavior overtime) in July of each of the next seven years, and then report the changes in water expenditures (as shown). We see that if this household was to use the same amount of water over period of study, the average annual change in water expenditures in July would be around 2.76%, or $0.88 dollars annually in real terms.[13] While the rise in water prices for this household operating at its 2011 "at-budget" water use outpaces inflation, it only captures the changes in prices and not the response by the household to the price changes or other factors (e.g., 2015 water use mandate). Such changes in behavior are likely responsible for the lower average annual change in overall water expenditures illustrated in Table A1. Indeed, as the last column from Table A2 illustrates, the percentage of households that were within budget from Table A1 increased from 2011 to 2018 by over 8%, although there is some noticeable backsliding after 2016. To summarize,

[9] As water districts increasingly adopt technology to measure water flows into households rather than simply waterflows entering the property line, more accurate measures of indoor water usage will be available.

[10] For 2018, the indoor water use budget declined to 55 GPCD, down from 60 GPCD. Up through 2017, then, the indoor budget is defined at a 60 GPCD allocation, while in 2018 this indoor budget – for our purposes – is defined at a 55 GPCD allocation.

[11] This is not to suggest all households used an amount of water exactly equal to their water budget; rather, it is to highlight how the expenditures associated with an "efficient" indoor and outdoor usage has changed over time.

[12] US Dept of Labor Bureau of Statistics (BLS Consumer Price Index for Los Angeles Area. Available at: https://www.bls.gov/regions/west/news-release/consumerpriceindex_losangeles.htm#table1

[13] Through 2017, the tier 1 price was associated with the indoor water allocation. For 2018, EMWD restructured its pricing so that the tier 1 price, whose magnitude was associated with their lowest cost water source, was applied to 20% of a household's overall water budget, which includes an indoor and outdoor allocation.

then, results suggest that between 2011 and 2018 per capita water use—on average—dropped thereby reducing the overall water bill relative to what could be attributed to changes in tier 1 and tier 2 water prices alone.

3.1 Water Affordability Calculation Results

Table 1 provides a summary of the average water use expenditure ratio (WER) for different water uses from 2011 to 2018. As indicated, these ratios are based on residential water use expenditures from over 138,000 households. As shown, the WER for basic water and sewer services alone ranged from 0.85 to 1.11% of MHI. For indoor water use, defined at 55 GPCD, we see the WER for water and sewer services ranged from 0.92 to 1.29%. The general trend since 2011 is a slight increase in the WER for basic and indoor water use. If we focus on what households used, on average, during the winter months with the assumption that this is often used as an (imperfect) measure of indoor water usage, we see that the annual WER ranges from 1.16 to 1.50% of MHI over the 2011 to 2018 period. This is certainly up from the assumption of 55 GPCD—which controls for household size—suggesting that households are using more water in the wintertime than what the state has determined is an efficient indoor efficient water use. Because we do not have information on actual metered flows into the household, whether the exceedance is due to indoor use beyond the 55 GPCD rate and/or from some outdoor use is indeterminate.

Focusing on the second to last column of Table 1, and while less of an affordability issue, the average WER for households, if they were to operate at the water budget, is between 1.85 to 2.35% from 2011 to 2017. We observe a drop in WER in 2018, at which time the WERs decline significantly due to EMWD restructuring its tier 1 and 2 prices and any possible reduction in use by customers.

Considering the last column of Table 1, and to get an understanding of what fraction of income is spent on water use overall, the average WER for overall water expenditures—including sewer expenditures—varies from 1.37% in 2011 to 1.42% in 2015 during the middle of the drought. Comparisons of these last two columns illustrate how households operating at their full water budget would lead to an increase in the average WER within the district relative to what households are confronting given current water use.

Often discussions of water affordability center on disadvantaged or low-income communities. The averages presented in Table 1 include all households within the EMWD service area, including both low- and high-income households. Teodoro (2018) identifies the 20th percentile income level as a lower bound on middle-class incomes and thus a reasonable place to start to investigate how water expenditures might present affordability challenges to households.

To illustrate how water affordability challenges may confront households at the 20th percentile of income, we estimate the WER for each of the water use categories above for each year from 2011 to 2018. Yet rather than using MHI within each block group, we use the 20th percentile income level within each block group. As shown in Figure 2, the basic needs WER for households assuming a 20 th percentile block group-level income ranges from slightly over 1% to around 1.48%, with an average over the period of 1.30%. As expected, these ratios are higher than the ratios presented in the 3rd column of Table 1 for basic needs water use that assumes an MHI by block group level. Considering a slightly more lenient allowance of water usage, the WER for indoor use rose from a low of around 1.17% (2011) to a high of around 1.73% (2018), with an average over the period of 1.44%. Average wintertime WER assuming a 20th percentile income level rose from approximately 1.5% in 2011 to nearly 2% in 2018, with a considerable rise from 2017 to 2018; the average WER over the period was 1.76%.

Somewhat surprising is the relationship between the WER associated with a fully used, but not exceeded, water budget relative to overall usage. As shown, the WER associated with fully utilizing the water budget ranges from slightly below 2.44% to around 2.82% between 201 to 2018, with an average annual estimate of 2.89; the WER associated with households' total water usage (and expenditures) varies from around 1.78% to 2.10%, with an average annual WER of 1.98. The steep drop in the Within Budget WER in 2018 is due to the drop in tier 1 and tier 2 prices since the indoor and outdoor budgets are fixed at the maximum level, along with the lower tier 1 allocation in 2018. The overall water use WER did increase in 2018, indicating that, on average, households likely increased their water usage after the drought.

Basic Needs Water Expenditure Ratios. Of course, there is a wide range of incomes within EMWD, both above and below the 20 th percentile. As indicated earlier, the MHI for the full range of block groups in EMWD service area varied from a low MHI of $22,210 to a high MHI of $119,464 (Figure 1). To gain an understanding of how WERs vary with the full range of incomes within EMWD, Figure 3a presents the WER for basic needs water and sewer services in 2018.[14] The median household income for each block group in EMWD service is sorted along the x-axis in Figure 3a, while the WER for each household is located within each household's MHI block group (each of the over 138,000 households is represented by a single dot in Figure 3a). As indicated, as incomes increase, WERs generally decrease. This pattern certainly supports concerns that lower-income households confront greater challenges surrounding water affordability relative to higher-income households. As shown, the average WER for basic needs water and sewer services for residential customers in EMWD service area in 2018 is 1.11%. Recalling that the thresholds the EPA identifies as generating concerns regarding affordability is 4.5% for water and sewer services (indicated by the red dotted horizontal lines in Figure 3a), it is clear that within EMWD service area, water expenditures as a fraction of MHI is significantly less than those thresholds for basic needs water in 2018. Only five households were above the EPA threshold for water and sewer services.

[14] Similar figures for 2011 to 2017 are available from the authors upon request. There are not noticeably different outcomes across years.

The bottom half of Figure 3 summarizes the upper half data by categorizing household incomes within different income percentile groups including the 20th percentile, 20th to 40th percentile, 40th to 60th percentile, 60th to 80th percentile, and above the 80th percentile. The black line within each 20-unit percentile block represents the average WER within that group, while the top and bottom edges of each rectangular block represent one standard deviation above and below the average WER; the vertical lines extending above and below the rectangular block represent the 95 percentile of values for that income percentile block. Similar to Figure 3a, we see that WERs vary significantly by income, with households that earn less income typically confronting higher WERs.

Indoor Water Expenditure Ratios. Figure 4 presents a similar analysis as Figure 3 except for the water services associated with what might be considered indoor use. We develop two measures of indoor use. First, and as shown in Figure 4a and 4b, we assume an indoor water use of 55 GPCD, adjusted by household size. This 55 GPCD is higher than the basic needs allocation from Figure 3, yet is an allocation identified by the state as related to an efficient use per person for indoor use. Similar to the relationship identified in Figure 3, we see that as incomes rise, WERs generally fall. As far as affordability concerns, at 55 GPCD there would be 69 households that would be associated with a WER above the EPA threshold of 4.5%.

A second potential measure for indoor water use is to consider winter-time water use. While we discuss the potential shortcomings above, wintertime use is often considered a measure of indoor use given the lower ET and irrigation requirements for outdoor landscapes. As shown in figure 4c and 4d, the WERs associated with winter time usage are significantly higher than the WERs associated with assuming 55 GPCD. Furthermore, the slope of the WER-income relationship has flattened relative to the measures from Figures 3, 4a, and 4b. One possibility is that higher-income households reduce their outdoor watering less during the wintertime than lower-income households. In terms of affordability, this is a more difficult assessment to make since it is clear that households are using significantly more water in the wintertime, on average, than what would be considered an efficient—not basic needs—allocation suggested by the state (i.e., 55 GPCD). That said, it is still useful to understand the magnitude of WER during wintertime usage, when overall water use is expected to be lower than other times of the year. Using the 4.5% threshold as a means of comparison, only 788 households, or approximately 0.6% of the nearly 138,000 households in EMWD service area, have a WER above this threshold.

Water Expenditures Ratios for Budget-Based Allocations and Overall Use. While the previous measures investigated the expenditures on water services that might be considered essential (basic needs) and reasonable (for indoor use), we now turn out attention to how those expenditures might change when one considers outdoor use as part of the services households value. Many agencies, especially in Southern California, and more recently the state of California, have been promoting water budgets as a means to identify what might be considered a reasonable or efficient use of water for both indoor and outdoor use. Figures 5a and 5b present the relationship between the WER associated with individualized water budgets and income for each of the households in EMWD service area. It should be emphasized that these WERs are not based on actual use, rather they are based usage that would be associated with fully utilizing a household's indoor and outdoor allocations---no more, no less. This might be illustrative in terms of understanding what would be the implications on water affordability if households were to meet the budgets presented them. Note that the budgets differ by household size, irrigated area, and the ET associated with the micro-zone in which the household resides. As shown, the relationship between the WER and income is not as strong as in the previous cases—indeed, it is much more variable across and within income block groups as shown in both Figures 4a and 4b. Given current tier 1 and tier 2 water prices, coupled with current sewer costs, if households were to use their full water budget, approximately 4,385 households, or 3.21%, within EMWD would exceed the 4.5% affordability threshold.

Figures 5c and 5d, alternatively, highlight how the WERs for total water use in 2018 vary over different income levels. Relative to the budget based WERs, there is much less variability within income groups (Figure 5c), and the overall WERs for each income category are significantly lower (Figure 5d). The average WER for the district associated with overall water use in 2018 is 1.58, while for the budget based WER is 2.10. The lower WERs, on average, also result in fewer households exceeding the EPA 4.5% threshold. In considering overall water use in 2018, which includes both indoor and outdoor water usage, only 0.4% of the households, approximately 550 households, exceeded the affordability threshold set by the EPA for water and sewer costs. While we are not suggesting that the affordability threshold was developed to identify water affordability challenges associated with non-essential uses of water, it is informative to realize that even if one uses total water use rather than water use associated with essential or basic needs, less than 0.5% of the households would exceed that EPA threshold.

3.2 Water Expenditure Ratios and Household Characteristics

In this section, we examine how WER vary across different types of households as measured by differences in socio-economic factors. While the above analysis illustrates how water expenditures for different types of water services differ by income, it is useful to understand how the WERs differ from other factors. Figure 6 presents WER differences across various user groups for 2018.

Figure 6a illustrates how the WER differs by those households that live in block groups represented by higher rent payments as a percentage of income relative to lower rent payments. We ordered each block group by median rent as a percentage of household income (also represented by the MHI for that particular block group). We see that the mean WER for those households in the upper quartile is 1.78%, while the mean WER for those households in the lower quartile is 1.33%. The implications here could be significant since as housing expenditures

rise relative to income, households have less discretionary income to spend on other essential services. Here we see that those households within block groups where rent comprises a larger portion of income have higher water expenditures relative to income compared to those households that live in block groups where rent is a lower fraction of income.[15]

Considering household-level factors, households with fewer people and more landscape, on average, have higher WERs than households with 4 or more people or who have landscape area in the bottom quartile of the distribution in terms of the overall area (Figure 6b and 6c). Since the WER we are using in these comparisons is water and sewer expenditures associated with overall use, it is not surprising that households with morelandscape—a landscape that will likely require more watering—have higher overall water expenditures than households with less landscape. Yet, it is surprising that households with fewer people have higher water expenditures than those with more people.[16]

While the above analysis has illustrated some potentially strong relationships between WER and various socioeconomic factors, some of the perceived strength of the relationship could be driven by association with another common factor, namely income. As such, our results highlight the correlation between WER and various socioeconomic factors, not necessarily causation. To illustrate how income is correlated with these other socioeconomic factors, we calculated the correlation coefficient between income, median rent, median home value, landscape size, household size, and total water usage (Table 2). As indicated in this table, we observe a high correlation between income and rent and home value, yet not a strong association between income and either landscape size nor household size. Income has a somewhat moderate correlation with water usage, as expected, yet it is much stronger than its association with landscape size and household size, on average. Figure 7 provides more detail information on the association between income and water usage (monthly, in 2018). Consistent with the correlation coefficient in table 2, we see a generally positive relationship between income and water usage.

3.3 Comparing Water Expenditure with Expenditures on Other Services

While attention on the expenditures households confront for basic or essential needs water can help water agencies and the state understand whether there are significant affordability issues that require more attention, water is one of several essential services households need. Other services include housing, transportation, health care, and energy, to name a few. To get an idea of how the expenditures on water compared to expenditures on other essential services, we used data from the US BLS Consumer Expenditure Survey (BLS CES) to calculate several expenditure ratios for other essential services.

Table 3 provides information on the expenditure ratios for food, housing, transportation, health care, natural gas, electricity, and telephone services based on the BLS CES for 2017, which is the most recent year of the survey.[17] We should emphasize that the closest "region" to EMWD's service area for which data on food, housing, transportation, and health care were available in the Los Angeles Metropolitan Statistical Area (MSA), which includes LA, Orange, Riverside, and San Bernardino counties. For natural gas, electricity, and telephone services, the closest or most representative region for this granularity of data was the "West" region, which is comprised of Alaska, Arizona, California, Guam, Hawaii, Idaho, Nevada, Oregon, and Washington. To illustrate how such regional differences may matter, the water expenditure ratio for the West region in 2017 was 0.90%, although the ratio here includes the costs for water and "other public services."[18] Recall from Table 1 that for 2017, the WER for overall water use in EMWD's service area was 1.48%. As such, these comparisons can be informative, but they doinclude different regions which confront different institutional, economic, socioeconomic, demographic, and environmental conditions.

With those caveats in mind, and as expected, we see that housing comprises the largest fraction of overall income with an expenditure ratio of nearly 32%, followed by transportation and food expenditures at almost 12.74 and 11.41%, respectively. Health care is the service that accounts for the next highest fraction of income expenditures at slightly over 5% of MHI, followed by telephone services at 1.70% and then electricity at 1.48%. Finally, natural gas comprises approximately 0.40% of annual household income. While the average annual WER for EWMD for overall water and sewer services is 1.48% in 2017, the WER for basic needs was 1.09%. Since the expenditures listed in the BLS CES are actual expenditures and not necessarily based on essential or basic needs, it seems more reasonable to use the overall WER for comparison purposes. As such, overall water expenditures in EMWDs service area in 2017 comprised approximately the same fraction of income as electricity services for western US states and territories, on average. Yet, we see that water expenditures comprise a smaller proportion of income — approximately 1.5% — than do expenditures on telephone services, and significantly less than expenditures on health care, transportation, food, and housing.[19]

4. DISCUSSION

Overall water and sewer expenditures within EMWD, as a percentage of median household income (MHI), have risen from around 1.37% to 1.58% between 2011 and 2018. If one were to consider essential basic needs water and sewer services, where basic needs water is assumed to be 35.6 GPCD adjusted for household size, the average annual WER rose from 0.85% to 1.11% of MHI. Alternatively, if one were to consider an efficient indoor use as a measure of basic needs or uses (i.e., 55 GPCD adjusted for household size), the WER rose from 0.92% to 1.29% of MHI. Somewhat surprisingly, if households were to use water at a level that met their indoor and outdoor water budget, the average

[15] To fully understand the potential strains on households in their ability to afford basic services requires the absolute levels of income and rent be known, which would provide the information required to calculate discretionary income at the household level since percentages wouldn't neces-sarily reflect the magnitude of these differences. understand the driving factors.

[16] Because such a simple cross comparison does not control for other factors that might influence water use and that potentially differ systematically across these two types of user groups, caution is suggested in drawing significant conclusions based on the results from each of the comparisons in Figure 6 until a more in-depth (and multivariate)analysis of these differences is undertaken. For instance, in the observation noted here where households with fewer people have higher water expenditures than those with more people, a multivariate analysis controlling for other factors such as landscape size, income, and ET would be necessary to better understand the driving factors.

[17] Table A3 provides estimates from 2011 to 2017. Note that the expenditure ratios in Tables 2 and A3 are based on actual expenditures from surveys of the populations within their respective regions. As such, they are not necessarily representative of the expenditures associated with basic needs.

[18] As listed on the BLS CES website's glossary page (https://www.bls.gov/cex/csxgloss_htm#housing), "other public services" includes such items as garbage and trash collection, sewerage maintenance, septic tank cleaning, which reinforces the challenges with this comparison.

annual WER would increase relative to what is currently observed based on their overall level of water and sewer expenditures. Such an outcome suggests that many households are operating within their water budgets.

Discussions of water affordability often revolve around basic or essential needs of water for lower-income households. Using the 20 th percentile median income within each household's U.S. Census Block Group, we find that the average basic needs WER within EMWD service area from 2011 to 2018 was 1.30%, while for indoor use it was 1.44%. These annual averages are considerably below the 4.5% affordability threshold identified by the US EPA. Indeed, in considering the full range of income levels within EMWD, and using MHI within the household's US Census Block Group as the denominator for calculation of the WER, we find that only five households would exceed the US EPA affordability threshold for water and sewer services for the basic needs level of water use. Alternatively, if we use the average monthly winter-time water use in our calculation of the WER, 0.5% of the households in EMWD service area in 2018 would have exceeded the affordability threshold set by the US EPA. The takeaway from these comparisons and analyses is that different types of water services, and assumptions surrounding the reference income level used matters substantially to the perceived affordability of water within any district or region. Indeed, if we used the MHI for the district, rather than for each household's block group, the WER for basic needs would decrease to 0.91% (down from 1.11%), while the WER for efficient indoor use would decrease to 1.04% (down from 1.29%) in 2018. Because district MHI is approximately $68,400, the denominator in measuring the WER using the district MHI is significantly higher than the district average ($63,500); using the higher district-level MHI in these calculations will lead to underestimates of the WER confronting lower income households.

In terms of how WERs differ across different socio-economic factors, and focusing on 2018 alone (although, qualitatively, we did not notice any significant difference in our analyses of the years 2011 to 2017), we find that those households in areas where rent is a higher percentage of income have higher overall WERs than those areas whose rent is a lower fraction of income. Given that higher rents or housing costs for a particular level of income lower the discretionary income remaining to pay for basic or essential wa-ter services, this is a concern. While the differences in the WERs are statistically significant, the percentages differ by only 0.34% (from 1.33% to 1.78%). We also find that areas with smaller family sizes or larger irrigated landscape have higher WERs. Since the WER we considered in these comparisons relates to overall water and sewer expenditures, it is not surprising that the WER for those with a larger irrigated area is higher. Note that each of these comparisons is two-way comparisons that do not control for other potentially confounding factors; these associations do not prove causation. A more in-depth analysis would need to take place for such an assessment.

In considering how water expenditures as a proportion of income stack up against other essential services, we compared the WERs from EMWD to the expenditure ratios associated with food, housing, transportation and health care in Southern California, and to other utility services (i.e., natural gas, telephone, and water) in western US states and territories. As expected, a substantial portion of income goes towards housing (31.9%), followed by transportation (12.7%), food (11.4%) and health care (5.2%) in 2017. Water and sewer services in EMWD's service area (~1.5%) are comparable as a percentage of income to electricity (1.5%) and telephone (1.7%) services in the western US states and territories, yet slightly higher than natural gas (0.40%). Water and other public service expenditures in the western US are slightly lower as a percentage of MHI than water and sewer services in EMWD.

In terms of trends, the largest percentage increases in essential service costs based on our data are observed in the housing, health care, and food sectors which experienced a 2.27, 1.59, and 1.08 percent increase in their expenditures as a proportion of income from 2011 to 2017 (Table A3). Water and sewer services within EMWD service area increased by only 0.11% over that same period, although utility services across the western US seem to have experienced a slight decrease in expenditures relative to income over this period. Of course, we suggest caution when making these comparisons across different regions (e.g., Los Angeles Metropolitan Statistical Area, western US states and territories, EMWD) given the differences in economic, institutional, socioeconomic, and demographic factors.

[19] Our calculations do not account for differences in tax burdens across different income or geographic groups, nor differences in social program allowances that might contribute to income. These factors will affect the denominator in these calculations.

TABLES AND FIGURES

Table 1. Water expenditure ratio for different types of water services from 2011 to 2018 in EMWD[20]

Year	Total Number of Households	Basic Needs Water & Sewer	Indoor Water & Sewer	Average Winter Water & Sewer	Full Budget Water & Sewer	Overall Water & Sewer
2011	126,174	0.85 (0.29)	0.92 (0.32)	1.16 (0.52)	1.85 (1.40)	1.37 (0.71)
2012	127,101	0.90 (0.31)	0.98 (0.34)	1.27 (0.58)	2.09 (1.68)	1.49 (0.77)
2013	128,537	0.93 (0.36)	1.02 (0.41)	1.31 (0.63)	2.12 (1.74)	1.50 (0.80)
2014	130,264	0.95 (0.41)	1.06 (0.47)	1.34 (0.67)	2.15 (1.80)	1.51 (0.84)
2015	131,932	1.00 (0.40)	1.11 (0.46)	1.31 (0.64)	2.11 (1.74)	1.42 (0.77)
2016	133,944	1.10 (0.45)	1.22 (0.51)	1.40 (0.72)	2.27 (1.98)	1.52 (0.84)
2017	136,018	1.09 (0.43)	1.21 (0.49)	1.32 (0.61)	2.35 (1.90)	1.48 (0.76)
2018	138,380	1.11 (0.47)	1.29 (0.57)	1.50 (0.70)	2.10 (1.29)	1.58 (0.81)

* Numbers in parenthesis indicate the standard deviations. The median income is measured by US Census ACS at the block group level.

[20] Basic Needs based on 35.6 GPCD, while Indoor is based on 55 GPCD, both accounting for household size. Average Winter is based on average water use over December, January, and February, while Within Budget is based on fully utilizing the indoor and outdoor water budget associated with an allocation-based rate structure.

Table 2. Correlation matrix among income and other demographics in 2018

	Median Income	Median Rent	Median Home Value	Landscape Size (SF)	Household Size	Total Water Usage
Median Income	1.00	0.77	0.83	0.02	0.08	0.18
Median Rent		1.00	0.71	-0.05	0.07	0.13
Median Home Value		0.71	1.00	0.04	0.05	0.15
Landscape Size (SF)				1.00	0.03	0.19
Household Size					1.00	0.27
Total Water Usage						1.00

Notes: All of the correlation coefficients are significant at the 1% level.

Table 3. Comparing essential needs cost for various services as a percentage of income in 2017[21]

Food (LA)	Housing (LA)	Transportation (LA)	Health care (LA)	Natural gas (West)	Electricity (West)	Telephone services (West)	Water[22] (West)
11.41	31.82	12.74	5.17	0.40	1.48	1.70	0.90

[21] Source: Consumer Expenditure Survey, U.S. Bureau of Labor Statistics (BLS), U.S. Census Bureau's ACS, and EMWD billing information. Income for LA and West is based on the BLS's Consumer Expenditure Survey (CE). For EMWD service area we use a weighted average of median household income from ACS data at the block group level. Both incomes are before taxes. The Metropolitan Statistical Area (MSA) used includes Los Angeles, Orange, Riverside, and San Bernardino counties in California, although the MSA is referred to as Los Angeles. For more information see: https://www.bls.gov/cex/csxmsa.htm. For natural gas, electricity, telephone, and water services we use data from the BLS West region given that such granularity for these services was not available at the MSA level. West region includes Alaska, Arizona, California, Guam, Hawaii, Idaho, Nevada, Oregon, and Washington. For more information, see https://www.bls.gov/cex/csxregion.htm

[22] Includes cost of water and other public services, although "other public services" is undefined. Using EMWD service area billing information for 2017, we estimated that the water cost was 0.91 percent of median household income and water and sewer cost was 1.48 percent of median household income.

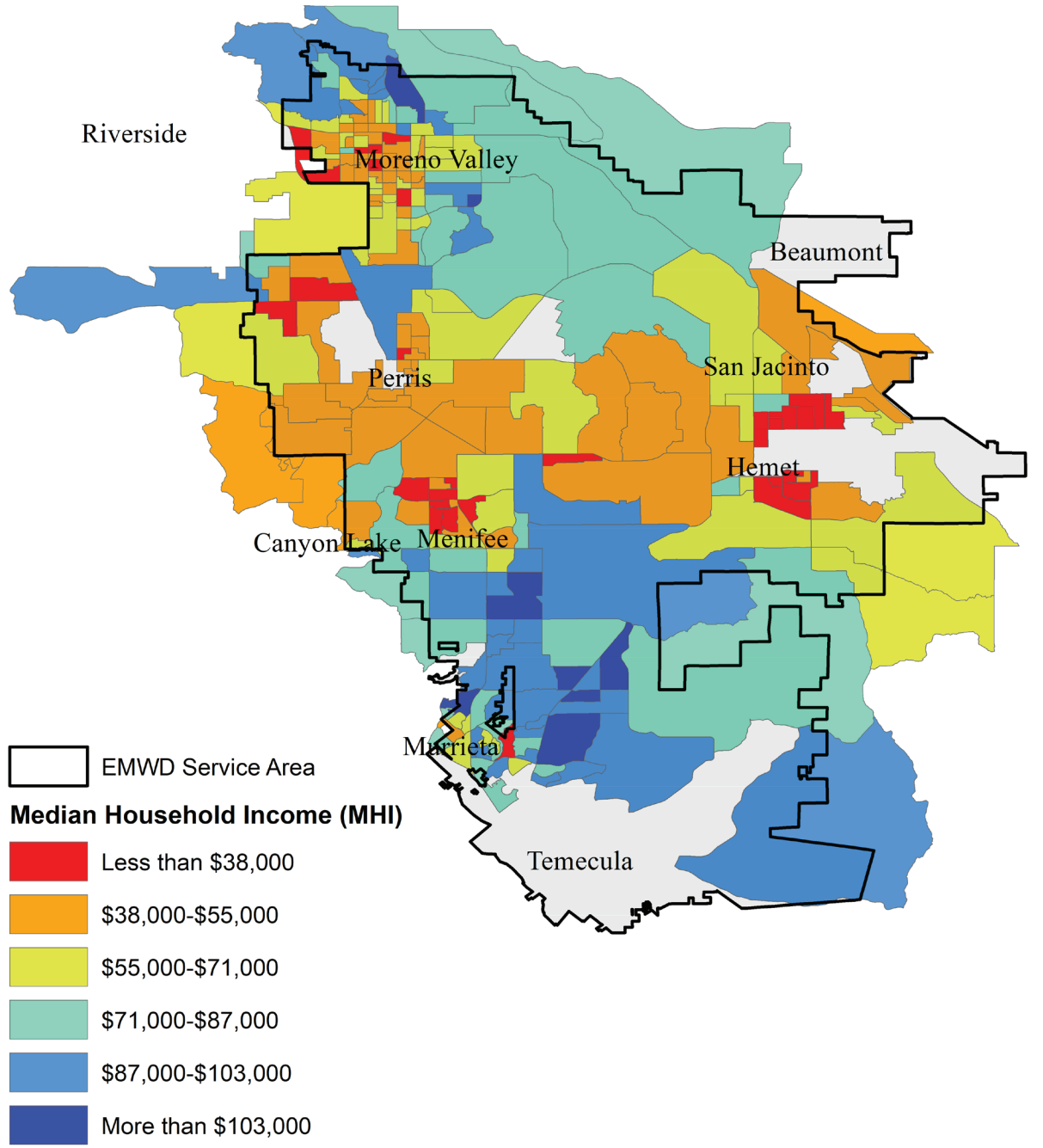


Figure 1. Median household income distribution in the EMWD service area (2018)[23]

[23] We use the MHI data at the block group level, block group and city boundaries from the US Census, and the EMWD service area boundaries from the CA Department of Water Resources (DWR) to generate the map.

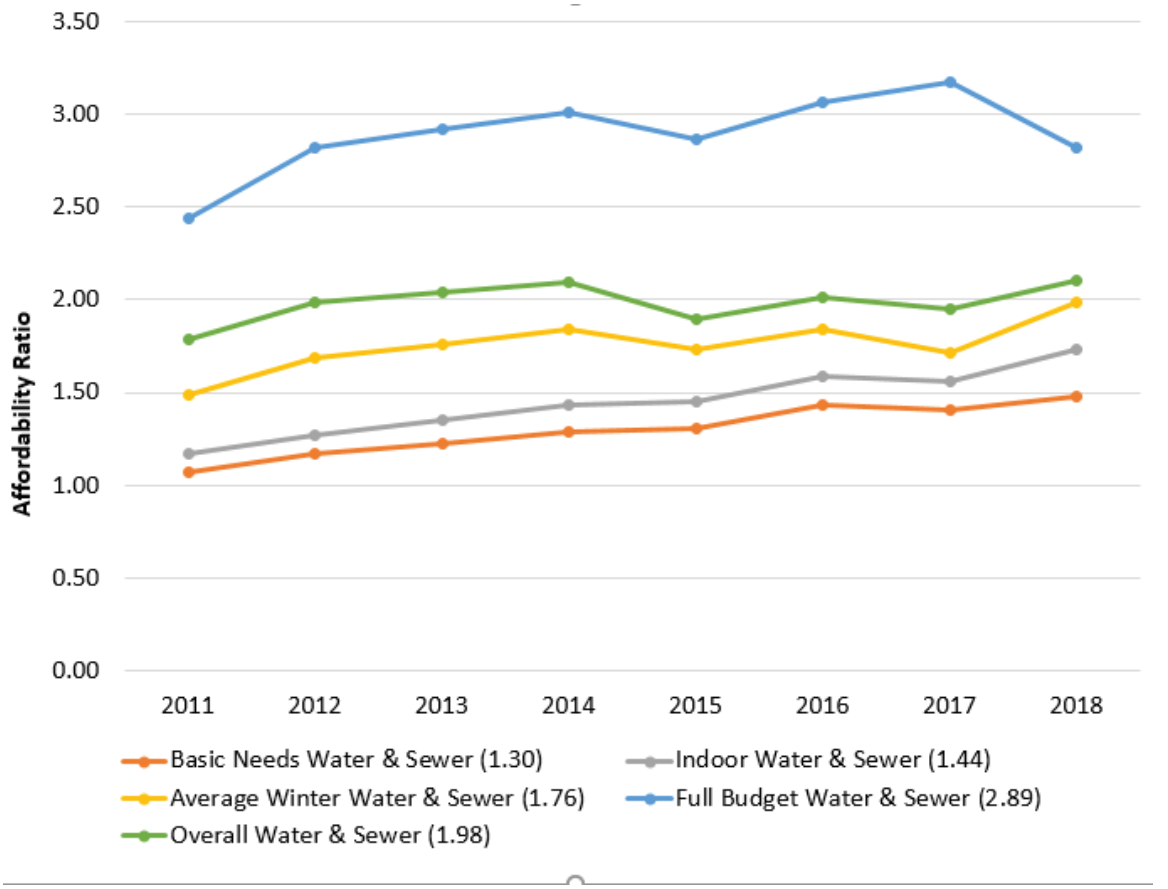
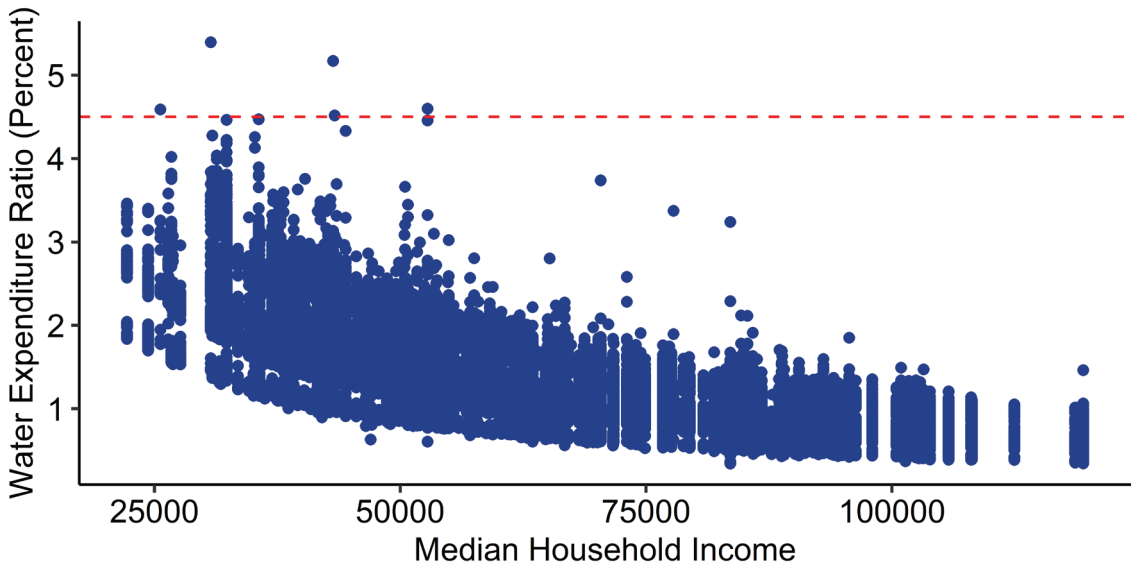
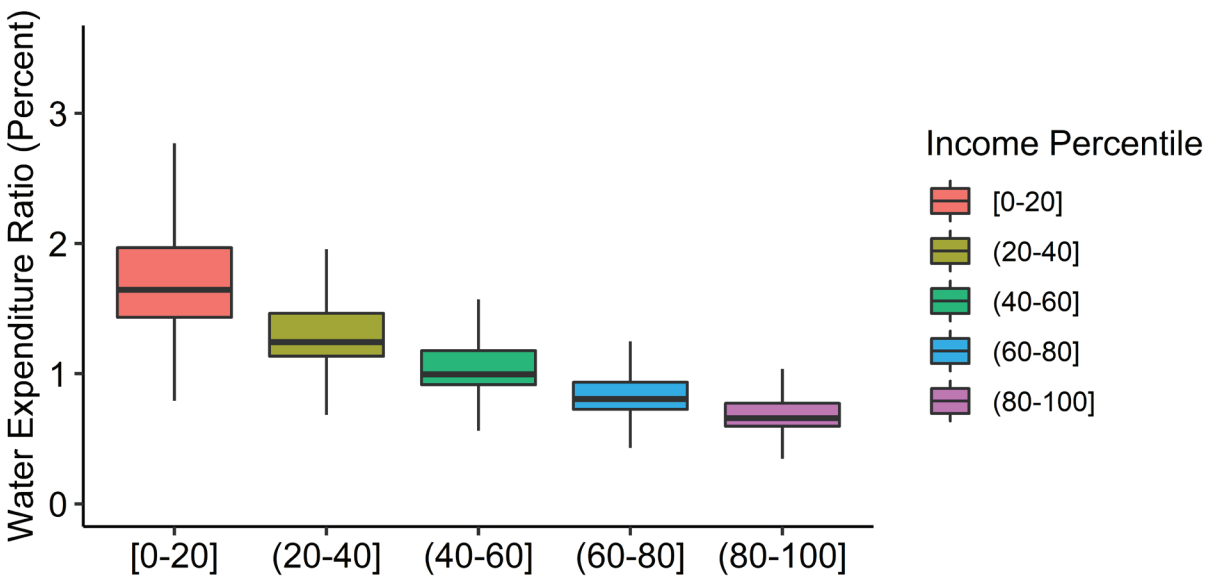


Figure 2. Comparing annual water expenditure ratio for the 20th percentile income over the study period (2011-2018)[24]

[24] Numbers in parenthesis show average WER from 2011 to 2018. WER is derived by calculating annual household expenditures related to water and sewer services relative to annual 20 th percentile household median income. Basic Needs is based on 35.6 GPCD, while Indoor is based on 55 GPCD (while accounting for household size). Average Winter is based on average household level water use over December, January, and February months, while Within Budget is based on fully utilizing the indoor and outdoor water budget associaed with an allocation-based rate structure. Overall water use is based on actual water use data from billing information.



(a)



(b)

Figure 3. Water expenditure ratio for *basic needs* water by income level in 2018[25]

[25] Annual expenditure ratio is derived by calculating annual costs related to water and sewer services as percentage of Median Household Income. Basic water needs calculated for 35.6 GPCD adjusted for household size. Median household incomes (MHI) calculated at the US Census Block Group level for 2018. For Figure 3a, red dashed lines represent U.S. EPA's affordability threshold for water and sewer services as a percentage of MHI (4.5%). For Fig 3b, annual income percentile thresholds for each percentile group are: $46,509 (0-20), $46,509 and $58,920 (20-40), $58,920 and $71,719 (40-60), $71,719 and $90,156 (60-80), and $90,156 and above (80-100). Average WER for water and sewer in 2018 is 1.11%. For each percentile group, median WER is represented by dark horizontal line, the upper and lower parts of the colored box represent third and first quartiles of the WER for that income group, and the line extending above and below colored boxes represent WERs outside of the middle 50% (fourth and first quartile).

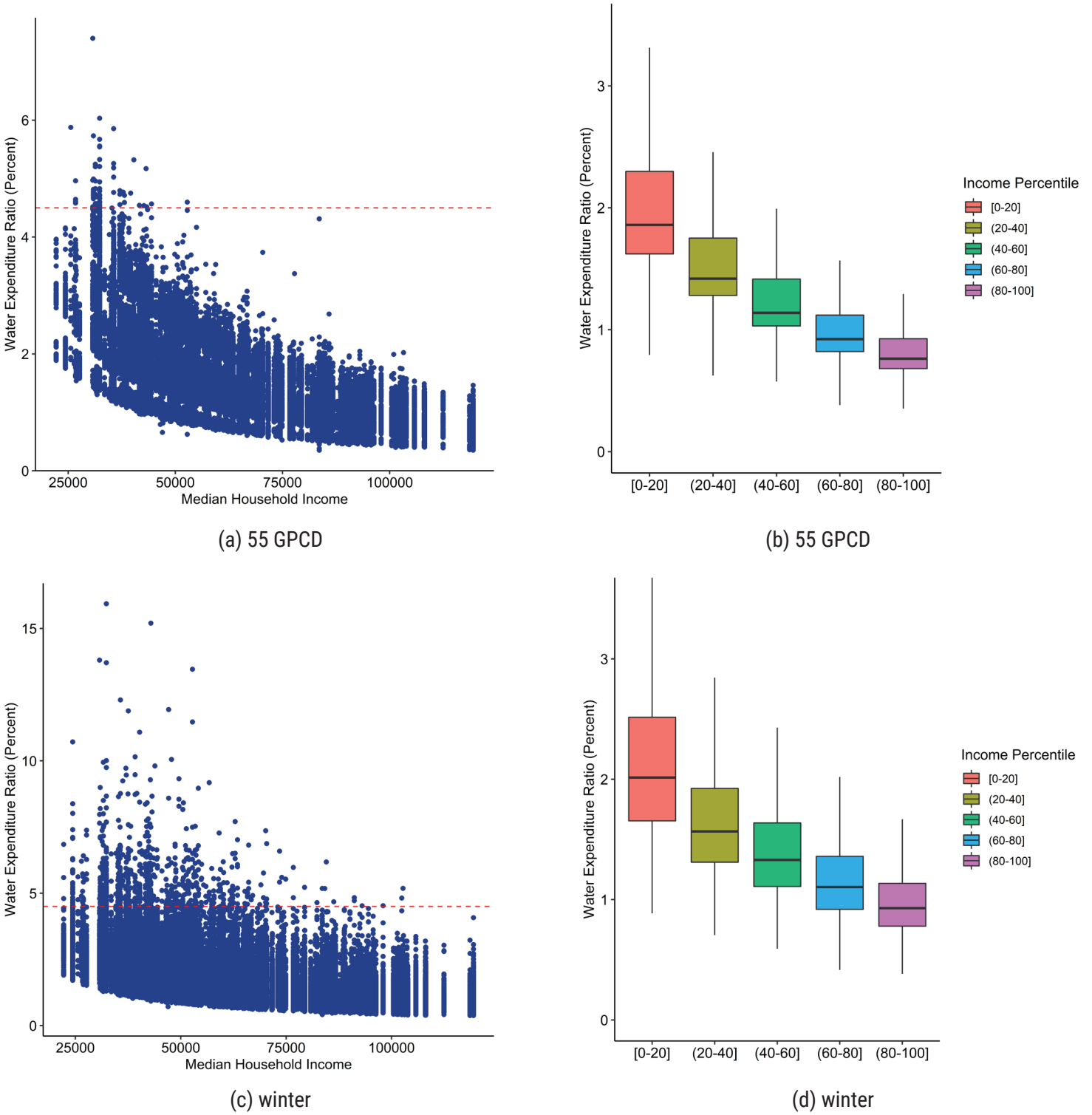


Figure 4. Water expenditure ratios for alternative indoor water use measures by income level in 2018[26]

[26] WER derived by calculating annual costs related to water and sewer services as percentage of MHI. Indoor water needs assume a 55 GPCD use (adjusted for household size). Winter water use average use over December, January, and February. MHI calculated at the US Census Block Group level for 2018. For Figs 4a and 4c, red dashed lines represent U.S. EPA's affordability threshold for water and sewer services as a percentage of MHI (4.5%). For Figs 4b and 4d, annual income percentile thresholds for each percentile group are: $46,509 (0-20), $46,509 and $58,920 (20-40), $58,920 and $71,719 (40-60), $71,719 and $90,156 (60-80), and $90,156 and above (80-100). For each percentile group, median WER is represented by dark horizontal line, the upper and lower parts of the colored box represent third and first quartiles of the WER for that income group, and the line extending above and below colored boxes represent WERs outside of the middle 50% (fourth and first quartile).

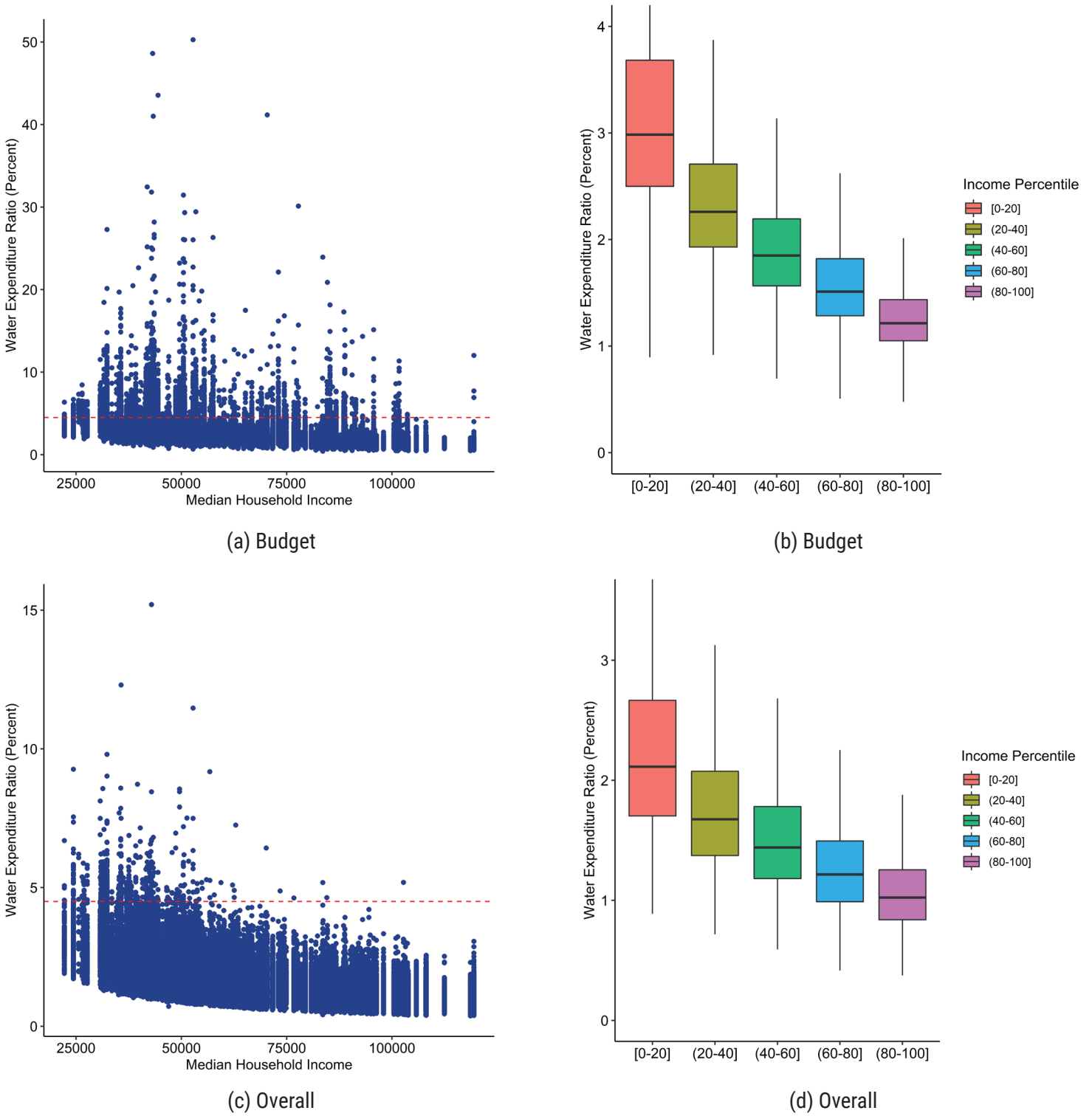


Figure 5. Water expenditure ratios for budget and overall use by income level in 2018[27]

[27] WER calculated as total annual costs for water and sewer services as percentage of MHI. Budget assumes full utilization of water budget (tier 1 and tier 2). Overall measures actual water expenditures for year. MHI calculated at the US Census Block Group level for 2018. For Figs 5a and 5c, red dashed lines represent U.S. EPA's affordability threshold for water and sewer services as a percentage of MHI (4.5%). For Figs 5b and 5d, annual income percentile thresholds for each percentile group are: $46,509 (0-20), $46,509 and $58,920 (20-40), $58,920 and $71,719 (40- 60), $71,719 and $90,156 (60-80), and $90,156 and above (80-100). For each percentile group, median WER is represented by dark horizontal line, the upper and lower parts of the colored box represent third and first quartiles of the WER for that income group, and the line extending above and below colored boxes represent WERs outside of the middle 50% (fourth and first quartile).

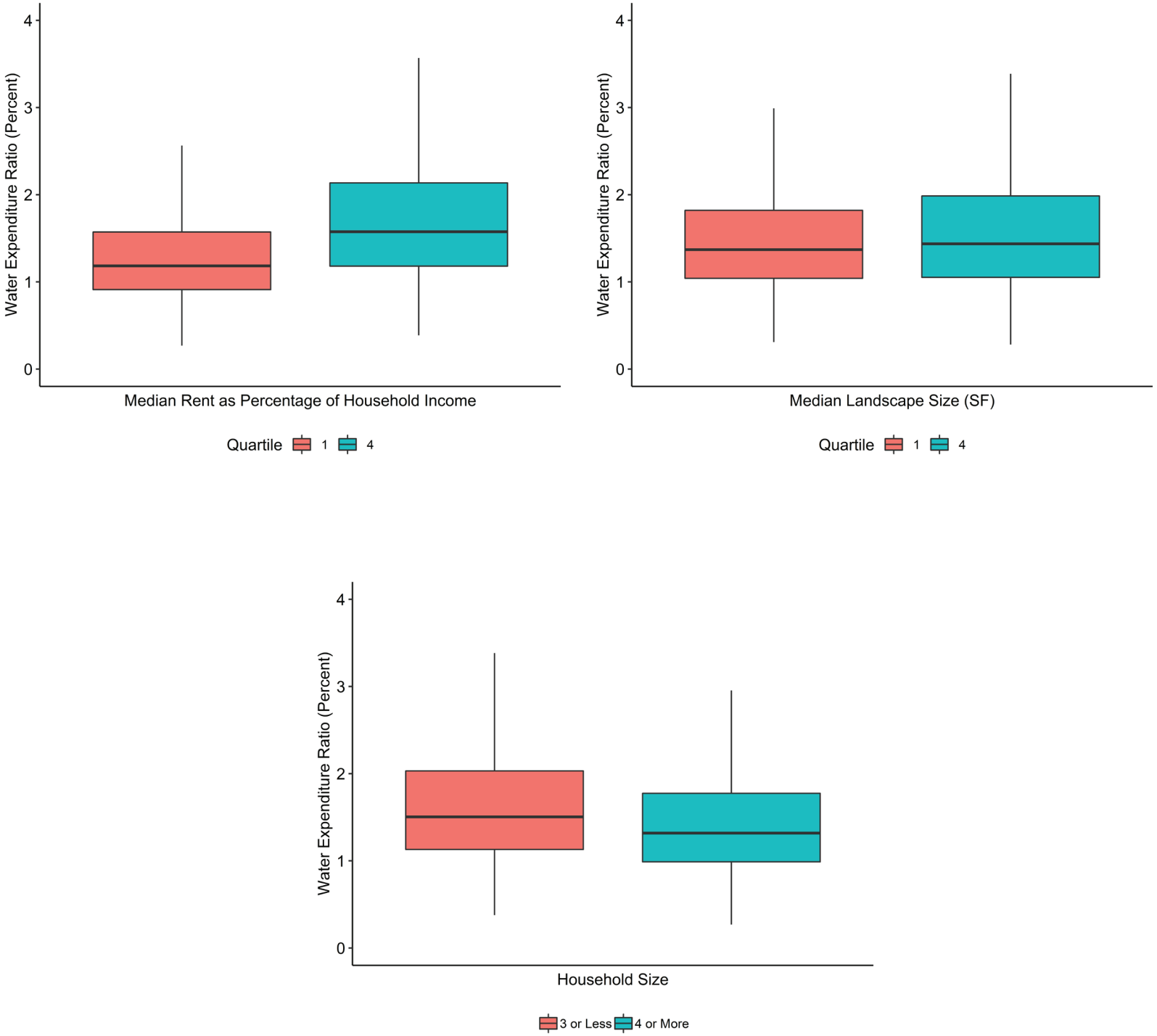


Figure 6. Water expenditure ratio comparisons across various socio-economic and demographic groups (2018)[28]

[28] All mean comparisons for each grouping are statistically different at the 1% level.

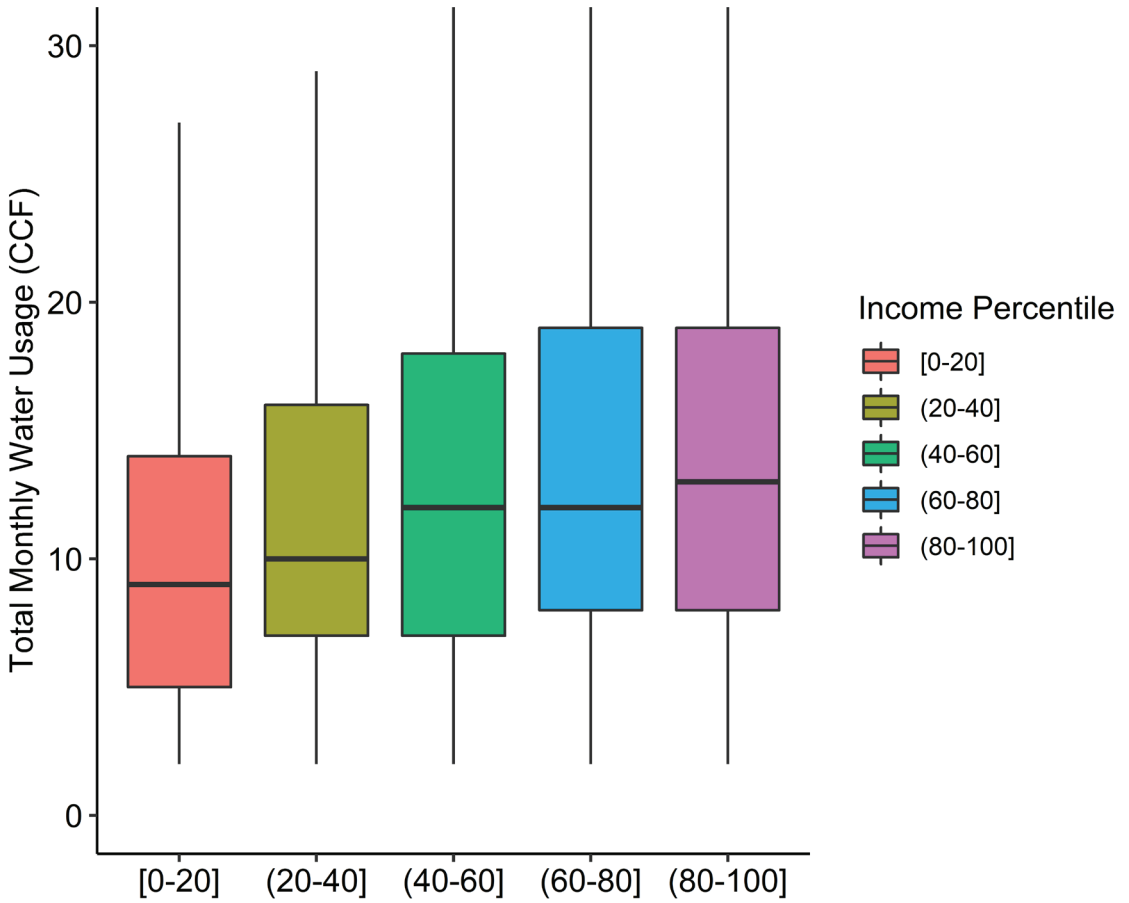


Figure 7. Total monthly water use by income level in 2018[29]

[29] Annual income percentile thresholds for each percentile group are: $46,509 (0-20), $46,509 and $58,920 (20-40), $58,920 and $71,719 (40-60), $71,719 and $90,156 (60-80), and $90,156 and above (80-100). For each percentile group, median monthly water use is represented by dark horizontal line, the upper and lower parts of the colored box represent third and first quartiles of the monthly water use for that income group, and the line extending above and below colored boxes represent monthly water use outside of the middle 50% (fourth and first quartile).

APPENDIX

Table A1. Average monthly bill ($) in the EMWD service area for water and sewer services[30] (% change annually in parentheses)

Bill Year	Basic Needs Water Cost[31]	Indoor Budget Cost[32]	Within Budget Cost[33]	Sewer Cost	Overall Water Use Cost[34]	Average Water Use (CCF)[35]
2011	$6.22 (-)	$22.18 (-)	$37.69 (-)	$22.90 (-)	$42.88 (-)	14.94 (-)
2012	$6.33 (1.79%)	$22.54 (1.60%)	$39.82 (5.65%)	$23.48 (2.54%)	$44.64 (4.12%)	15.61 (4.48%)
2013	$6.52 (3.02%)	$22.84 (1.33%)	$39.69 (-0.33%)	$23.39 (-0.41%)	$44.88 (0.54%)	15.31 (-1.95%)
2014	$8.77 (34.50%)	$23.55 (3.09%)	$40.76 (2.68%)	$23.20 (-0.81%)	$45.45 (1.28%)	15.04 (-1.74%)
2015	$9.31 (6.14%)	$25.46 (8.12%)	$37.55 (-7.88%)	$24.37 (5.07%)	$41.93 (-7.76%)	12.58 (-16.38%)
2016	$9.88 (6.09%)	$26.75 (5.09%)	$37.90 (0.94%)	$26.65 (9.36%)	$43.19 (3.01%)	12.28 (-2.38%)
2017	$9.92 (0.38%)	$27.52 (2.87%)	$40.07 (5.74%)	$26.56 (-0.34%)	$43.18 (-0.03%)	12.74 (3.79%)
2018	$10.04 (1.20%)	$17.55 (-36.23%)	$40.65 (1.31%)	$26.99 (1.60%)	$45.27 (4.75%)	13.07 (2.57%)
Overall Change from 2011 to 2108	$3.82 (61.34%)	-$4.63 (-20.88%)	$2.91 (7.71%)	$4.09 (17.86%)	$2.35 (5.49%)	-1.87 (-12.53%)
Average Annual Change	$0.55 (8.76%)	-$0.66 (-2.98%)	$0.42 (1.10%)	$0.58 (2.55%)	$0.34 (0.78%)	-0.27 (-1.79%)

[30] Real prices are in 2011 terms using U.S. Department of Labor Bureau of Statistics (BLS) Consumer Price Index (CPI) for Los Angeles area. CPIs relative to 1984 are: 2011=225.072; 2012= 229.649; 2013= 232.234; 2014= 235.273; 2015=236.646; 2016=240.140; 2017=246.721; 2018=256.415.

[31] Basic needs cost is calculated using 35.66 /GPCD as essential water needs.

[32] Expenditures based on actual water use less than or equal to each household's indoor budget. Through 2017, the indoor usage was multiplied by an indoor price, often referred to as a tier 1 price. For 2018, MWD restructured its pricing so that the tier 1 price, whose magnitude was associated with its lowest cost water source, was applied to 20% of a household's overall water budget, where the water budget includes both an indoor and outdoor allocation.

[33] Based on expenditures for each household's water use less than or equal to its overall water budget.

[34] Based on actual water usage and excludes sewer costs.

[35] Based on actual total water usage, which is averaged for each year.

Table A2. Annual changes in inflation and water budget costs relative to 2011 (2011 base)[36]

Bill Year	Inflation Rate	Fixed Budget in 2011[37]	Percent in Budget[38]
2011	--	--	80.84%
2012	2.03%	2.30%	86.87%
2013	1.13%	3.33%	83.99%
2014	1.31%	5.37%	87.58%
2015	0.58%	3.20%	93.33%
2016	1.48%	2.29%	94.69%
2017	2.74%	-0.73%	92.79%
2018	3.93%	2.21%	87.20%
Overall Change from 2011 to 2018	13.93%	19.32% ($6.17)	7.87%
Average Annual Change	1.99%	2.76% ($0.88)	1.12%

[36] All costs are in real (2011) dollars, with % change relative to 2011 prices using U.S. Department of Labor Bureau of Statistics (BLS) Consumer Price Index (CPI) for Los Angeles area. CPIs relative to 1984 are: 2011=225.072; 2012= 229.649; 2013= 232.234; 2014= 235.273; 2015=236.646; 2016=240.140; 2017=246.721; 2018=256.415. Through 2017, the tier 1 price was associated with the indoor water allocation and tier 2 associated with the outdoor water allocation. For 2018, EMWD restructured its pricing so that the tier 1 price, whose magnitude was associated with their lowest cost water source, was applied to 20% of a household's overall water budget, which includes an indoor and outdoor allocation.

[37] Comparing changes in water budget costs for July of each year. To illustrate how changes in water prices alone affected water costs, water use is fixed based on a representative "at-budget" household in 2011 characterized by three household members, 3,000 sq ft of landscape, a conversion factor (CF) of 0.8, and an ET of 3.93. An outdoor drought factor in July of every year of one was assumed for budget. Consequently, variation in costs in this column is driven by price changes alone.

[38] Numbers indicate the percentage of households at or below total budget allocation based on water use in July of each year.

Table A3. Comparing essential needs cost as a percentage of income[39]

Year	Food (LA[b])	Housing (LA)	Transportation (LA)	Health care (LA)	Natural gas (West[c])	Electricity (West)	Telephone services (West)	Water and other public services (West)	Water (EMWD)	Overall Water & Sewer (EMWD)
2011	10.33	29.55	12.70	3.58	0.58	1.67	1.71	0.91	0.88	1.73
2012	10.79	29.98	12.70	3.89	0.53	1.70	1.75	0.92	0.96	1.48
2013	10.59	30.12	12.13	4.03	0.53	1.76	1.81	0.96	0.97	1.50
2014	10.53	31.11	12.03	4.60	0.54	1.75	1.87	0.97	0.98	1.51
2015	10.53	31.11	12.03	4.60	0.47	1.63	1.79	0.93	0.89	1.42
2016	10.41	30.32	13.08	4.99	0.39	1.47	1.70	0.88	0.93	1.52
2017	11.41	31.82	12.74	5.17	0.40	1.48	1.70	0.90	0.91	1.48

[39] Source: Consumer Expenditure Survey, U.S. Bureau of Labor Statistics, U.S. Census Bureau's ACS, and EMWD billing information. Income for LA and West is based on the U.S. Bureau of Labor Statistic's Consumer Expenditure Survey (CE). For EMWD service area we use weighted average of median household income from U.S. Census Bureau's ACS data at the block group level. Both incomes are before taxes. Note: Percentages associated with these categories do not comprise all the income categories and thus do not sum to 100.

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