Appendix I.
Potential Benefits and Impacts of Changing Ri-gpcd

Prepared for

California Department of Water Resources

By

Brown and Caldwell

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Water Use Efficiency Branch

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FINAL REPORT

Potential Benefits and Impacts of a Changing Standard for Indoor Residential Water Use

September 30, 2020

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Prepared for

CA Department of Water Resources, Sacramento, CA

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List of Abbreviations

AB	Assembly Bill
ac-ft	acre-feet
afy	acre-feet per year
AMI	advanced metering infrastructure
AWPF	advanced water purification facility
AWWA	American Water Works Association
BAWSCA	Bay Area Water Supply and Conservation Agency
BC	Brown and Caldwell
BOD	biological oxygen demand
CDC	Center for Disease Control and Prevention
cfs	cubic feet per second
CII	Commercial, industrial, and institutional
CIP	capital improvement program
CUWA	California Urban Water Agencies
CWC	California Water Code
DBP	disinfectant by-product
DWR	Department of Water Resources
EBMUD	East Bay Municipal Utility District
ESPRI	Environmental Science Policy & Research Institute
$FeCI_3$	ferric chloride
fy	fiscal year
GHG	greenhouse gas
GWRS	groundwater replenishment systems
H_2S	hydrogen sulfide
IAPMO	International Association of Plumbing and Mechanical Officials
IEUA	Inland Empire Utility Agency
LADWP	Los Angeles Department of Water and Power
LASAN	Los Angeles, Bureau of Sanitation
MG	million gallons
mgd	million gallons per day
mg/L	milligram(s) per liter
MWDOC	Municipal Water District of Orange County
NaOCI	sodium hypochlorite
NESWTF	Northeast Surface Water Treatment Facility
NPDES	National Pollutant Discharge Elimination System
O&M	operations and maintenance
OCSD	Orange County Sanitation District

OCWD	Orange County Water District
PLWTP	Point Loma Wastewater Treatment Plant
R-gpcd	Total residential (indoor + outdoor) water use in gallons per capita per day
Ri-gpcd	Indoor residential water use in gallons per capita per day
RARE	Richmond Advanced Recycled Expansion
RCP	reinforced concrete pipe
RWRF	Regional Wastewater Reclamation Facility
SB	Senate Bill
SCWD	Soquel Creek Water District
SCWWTF	Santa Cruz Wastewater Treatment Facility
SESWTF	Southeast Surface Water Treatment Facility
SFPUC	San Francisco Public Utilities Commission
SF RWS	San Francisco Regional Water System
SGMA	Sustainable Groundwater Management Act
SSB	sanitary sewer blockages
SSO	sanitary sewer overflows
State Water Board	State Water Resources Control Board
SVCW	Silicon Valley Clean Water
TDS	total dissolved solids
THM	trihalomethanes
TOC	total organic carbon
TSS	total suspended solids
TUD	Tuolumne Utilities District
UV-AOP	ultraviolet advanced oxidation process
UWMP	Urban Water Management Plans
Valley Water	Santa Clara Valley Water District
VVWRA	Victor Valley Wastewater Reclamation Authority
WCWD	West County Wastewater District
WDO	Water Demand Offset
WRF	Water Research Foundation
WUE	water use efficiency
WTP	water treatment plant
WWTP	wastewater treatment plant

Glossary

R-gpcd	Total residential (indoor and outdoor) water use in gallons per capita per day
Ri-gpcd	Indoor residential water use in gallons per capita per day
urban retail water supplier	A water supplier, either publicly or privately owned, that directly provides potable municipal water to more than 3,000 end users or that supplies more than 3,000 acre-feet of potable water annually at retail for municipal purposes
urban water use efficiency standards	The standards effective through CWC §10609.4 (indoor residential use) or adopted by State Water Board (outdoor residential, water loss, and CII outdoor irrigation of landscape areas with dedicated meters) pursuant to CWC §10609.2.
urban water use objective	An estimate of aggregate efficient water use for the previous year based on adopted water use efficiency standards and local service area characteristics for that year
disinfectant demand	Reactions between disinfectants and microbial, organic and inorganic constituents
disinfectant decay	The natural decay of disinfectants over time

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Executive Summary

Water is essential to the way of life in California, and water providers are continuously working to develop long-term strategies to maintain water supply reliability for their communities. In 2018, the California State Legislature enacted legislation to establish a foundation for long-term improvements in water efficiency and drought planning.

Context and Study Objectives

In 2018, Assembly Bill (AB) 1668 and Senate Bill (SB) 606 set default standards for indoor residential use (Ri) starting at 55 gallons per capita daily (Ri-gpcd), decreasing to 52.5 Ri-gpcd from 2025 through 2030, and further decreasing to 50 Ri-gpcd from 2030 and onward. This legislation also directed the Department of Water Resources (DWR), in coordination with the State Water Resources Control Board (State Water Board), to conduct necessary studies and investigations to analyze the benefits and impacts of how the changing standard for indoor residential water use will impact water and wastewater management, including potable water usage, wastewater, recycling and reuse systems, infrastructure, operations, and supplies. DWR and the State Water Board may also jointly recommend a standard for indoor residential water use that more appropriately reflects best practices (Water Code section 10609.4(a)(3)).

A report on the results of the studies and investigations shall be made to the chairpersons of the relevant policy committees of each house of the Legislature by January 1, 2021. This study satisfies that requirement by qualitatively assessing the collective benefits and impacts of a changing indoor residential water use standard. Per the Water Code, the focus is on indoor residential use, which is water that travels through utility infrastructure systems (see Figure ES-1, next page). This study is based on a review of the literature, as well as case study interviews of water and wastewater systems in California.

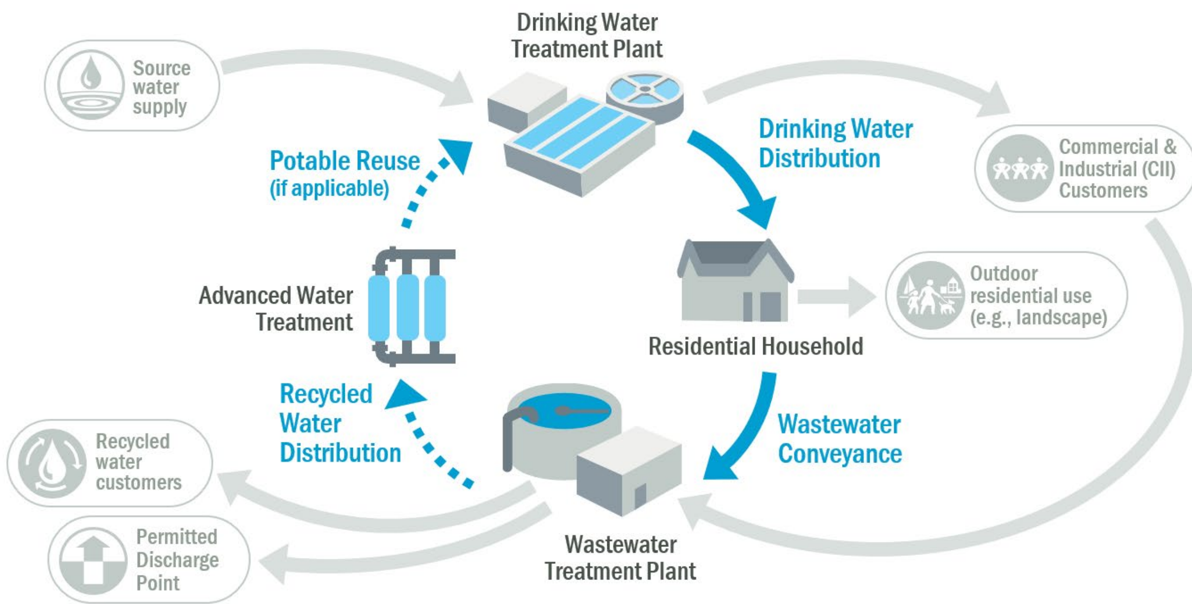

Figure ES-1. Indoor residential water use uses and generates flow that remains within utility infrastructure systems, which is shown in blue.

Key Takeaways & Potential Future Refinements

- Public utilities can and will adapt to a changing Ri-gpcd standard. However, it will require time and money.

- Public utilities across California have demonstrated their ability to adapt to adverse impacts of a changing Ri-gpcd through a variety of mitigation strategies. However, these adaptations require time and money, the extent of which will depend on utility-specific characteristics.

- The purpose of this study was to conduct a qualitative assessment of the benefits and impacts of a changing Ri-gpcd standard, as quantifiable data are not yet available. This study could be enriched through the collection of more quantifiable data. A data set that includes more utilities and unique system characteristics, which exacerbate or reduce impacts of adverse effects, is warranted. Based on improved understanding of impacts, utilities can help inform a realistic timeframe for standards implementation or the funding needs to support adjustment to the changing Ri-gpcd standard.

- There are benefits and adverse impacts from a changing Ri-gpcd standard on water and wastewater management due to the interconnectedness of these systems.

- Water and wastewater systems exist within an interconnected cycle, and changes in one area of the cycle will have a ripple effect throughout. A changing Ri-gpcd standard not only alters hydraulics (e.g., total volumes and velocities), but also water and wastewater quality, energy use, operation and maintenance (O&M) requirements, planning, and design.

- The benefits are similar for water and wastewater systems, as reduction in total volumes allow for reductions in treatment cost and energy use, and excess capacity to support growth or defer capital investment for expansion. However, adverse impacts vary greatly, reflecting the differences in water and wastewater system infrastructure needs and expectations.

- The acknowledgment of adverse impacts is not to imply that emphasis on conservation and water use efficiency should be relaxed, or that potable water use remains the same or increase to avoid impacts. Rather, it is to acknowledge the interconnections between water use, wastewater generation, and recycled water production, and how changes within the cycle will have implications.

- Though indoor residential use is a factor in water and wastewater flows, impacts on utilities are also a function of the following factors:

  - **Diverse utility characteristics and conditions**. Multiple characteristics influence a utility's vulnerability to adverse impacts, such as population served, age and condition of existing infrastructure, materials of construction, and utility rate structures.

  - **Magnitude of effect**. If indoor residential water use is already low, overall effects of a changing standard may be minimal. Alternatively, a significant decrease in indoor residential water use to meet a changing standard may have more substantial adverse impacts.

  - **Other water use sectors.** The COVID-19 pandemic has driven measurable increases in residential water use, along with a concurrent decrease in commercial, industrial, and institutional (CII) water use. The overall net effect for many utilities has been reduced system flows, even with increasing residential use. During drought conditions, water use reductions are experienced in most water use sectors, which can further compound effects.

As this study is a qualitative assessment and not intended to arrive at quantifiable thresholds for the Ri-gpcd, it is recommended that future studies take site-specific factors and unique characteristics into consideration.

Approach and Methodology

This study is an analysis of the benefits and impacts of how a changing standard for indoor residential water use could impact water and wastewater management, including potable water usage, wastewater, recycling and reuse systems, infrastructure, operations, and supplies. Per Water Code 10609.4, a report on the results of the studies and investigations shall be made to the Legislature by January 1, 2021.

Given that utilities are still actively adapting to the 55 Ri-gpcd standard, this analysis examines utility experiences during a prior time of significantly reduced indoor residential per capita use – the recent drought from 2012 to 2016. This study details utility experience captured in literature, most notably, prior assessments by the California Urban Water Agencies (CUWA), a non-profit organization of 11 major urban water agencies serving two-thirds of the state's population. In 2017, CUWA published the white paper *"Adapting to Change: Utility Systems and Declining Flows*", which documented utility experience during the 2015-16 emergency regulations for water conservation. While the dramatic measures taken during the drought were specifically to address the emergency, understanding the benefits and adverse impacts experienced during those periods of lower water use can provide insight into the effects of an indoor residential water use standard set around those levels.

Case study interviews were also conducted as part of this work to reflect current (2020) experience with reduced indoor residential per capita use. These interviews provide insight on the potential benefits and adverse impacts, as the utilities selected continue to operate close to the reduced per capita use achieved during the recent drought. The utilities that participated included East Bay Municipal Utility District (EBMUD), the City of San Diego, Soquel Creek Water District (SCWD), and the City of Fresno. These utilities represent a diverse set of experiences, reflecting variations in geography, source supplies, service area size, and topography. Figure ES-2 shows the four utilities that were interviewed, as well as other utilities included herein from literature.

Figure ES-2. Utility experiences throughout California on benefits and impacts are referenced in this study. R-gpcd shown is based on 2019 values and are only reported by urban water retailers.

Summary of Benefits and Adverse Impacts

Existing literature and utility experience demonstrate real benefits from reduced per capita indoor residential water use, as well as significant adverse impacts to water, wastewater, and recycled water systems. These benefits and adverse impacts are summarized in the Tables ES-1 and ES-2 through ES-4, respectively. Benefits are further discussed in Section 2 and adverse impacts are presented in Section 3.

Table ES-1. Potential Benefits for Water and Wastewater Utilities.

Section #	Effect	Description	Benefit to Utility
2.1.1	Adaptations to the effects of climate change	Enables existing supplies to support potential population growth without an immediate need for water treatment plant expansion or investments in supplemental supplies	Improved regional self-reliance, water service reliability, and cost savings
2.2.1	Decreased water treatment and pumping costs	Lower water demand decreases treatment chemical uses and associated costs to produce drinking water, and lowers energy required to pump water in distribution systems	Cost savings for water utilities through reduced chemical purchase and energy usage
2.2.2	Deferred capital investment	Remaining capacity can allow for deferral of capital investment costs to expand existing water or wastewater treatment plant	Deferred capital spent for water or wastewater utilities
2.2.3	Reduced energy usage for wastewater systems	Reduced water demand and wastewater production results in lower energy usage associated with reduced pumping and treatment process needs	Cost savings from reduced energy usage for pumping

Table ES-2. Potential Adverse Impacts for Water Utilities

Section #	Effect	Description	Potential Adaptation Strategies & Impact on Utility
3.1.2	Deterioration of water quality	Increased retention time in the water distribution system creates treatment and potential public health and safety implications from increases in disinfectant by-product (DBP) formation, microbial activity, and change in aesthetic characteristics such as taste and odor	Increased operational costs from flushing, additional chemical usage or O&M, or possible increased risk to health and safety[1]
3.1.	Stranded assets and stagnation in storage facilities	Reduced water demand may result in stranded assets such as underused water treatment plants or unused capacity in distribution systems and storage facilities	Economic impact from unused assets as well as operations and maintenance (O&M) labor and costs to continue maintaining underused infrastructure[1]
3.5	Reductions in revenue from reduced water sales	Reduced water demand can result in lower total water sales, which makes it challenging for utilities to cover baseline O&M costs	Economic impact from reduced revenue and need to increase customer rates to compensate

[1]Increased retention time results from systems oversized for current conditions. Utilities are updating demand projections, but there are considerations in water system sizing (e.g., peak hour, maximum day, and fire flows) that may limit a utility's ability to adapt through downsizing to match reduced water demand.

Table ES-3. Potential Adverse Impacts for Wastewater Utilities

Section #	Effect	Description	Potential Adaptation Strategies & Impact on Utility
3.2.1	Increased sewer gas production	Increasing sewer gas production such as hydrogen sulfide (H2S) concentrations can create public health and safety impacts from increase in odor production and build-up of noxious gasses	Increased costs from increased purchase of odor mitigation materials and associated O&M
3.2.2	Accelerated rate of corrosion in sewer pipes and manholes	Higher H2S concentrations accelerate the rate of corrosion in sewer pipes, especially concrete, leading to faster rate of failure	Increased costs from additional O&M and accelerated need for capital improvement program (CIP) projects for infrastructure rehabilitation or replacement
3.2.3	Increased occurrence of sewer blockages and overflows	Increased solids concentrations exacerbate blockages in sewers, resulting in clogged pipes, loss of sewer serviceability, sanitary sewer overflows	Increased costs for additional O&M and public health & safety impacts if unaddressed
3.3.1, 3.3.2	Degradation of wastewater influent quality	Increasing contaminant concentrations in wastewater influent such as higher ammonia, biological oxygen demand (BOD), and total suspended solids (TSS) can stress loading-based treatment processes and increase concentrations in wastewater effluent	Reduced treatment capacity and increased treatment costs to continue meeting discharge requirements

Table ES-4. Potential Adverse Impacts for Recycled Water Projects

Section #	Effect	Description	Potential Adaptation Strategies & Impact on Utility
3.4.1	Reductions in recycled water quantity	Reductions in wastewater influent subsequently reduce the volumes of recycled water that can be produced, limiting a utility's ability to offset potable reuse with recycled water	Increased reliance on potable water instead of recycled water, reducing regional self-reliance
3.4.2	Deterioration of recycled water quality	Changes in wastewater effluent quality adversely affect recycled water quality, which has downstream impacts on recycled water users with specific water quality criteria	Increased costs of recycled water, particularly if supply needs to be supplemented with potable water or if additional pretreatment is needed

Influence of Utility Characteristics on Potential Adverse Impacts

Based on the research and case study interviews, specific utility characteristics can either increase a utility's resiliency or exacerbate adverse impacts from reduced per capita indoor residential water use. This is summarized in Table ES-5 and discussed further in Section 5. The utility characteristics described do not represent an exhaustive list, but rather a starting point for future research and quantifiable data collection.

Table ES-5a. Utility Characteristics That Can Contribute to Adverse Impacts: Water Utilities

Section #	Adverse Impact	Utility Characteristics
3.1.1	Deterioration of water quality due to increased retention time in distribution system	• **Age of infrastructure.** Systems appropriately designed for higher historical flow rates can become oversized, resulting in longer retention times and higher water age. Design criteria that support higher flow rates (e.g., flat slopes, turns and pumping) may not work well for lower flow conditions and can exacerbate water quality. Older systems may also experience more corrosion and deterioration. In such systems, any changes in flow conditions may lead to water quality deterioration, including contaminant leaching. • **Topography, size, and density of service area.** Systems that serve large, flat, and low-density areas require water to travel longer, increasing the potential for longer distribution system retention times. • **Infrastructure material.** Systems with pipes made of iron, lead, copper and other metals may be more susceptible to problematic metal release from increased retention time.
3.1.2	Stranded assets and stagnation challenges from reduced water quantity	• **Magnitude of change from initial design parameters.** Similar to the above, water treatment plants and storage facilities sized for historically greater water demands may become oversized, resulting in water stagnation or excess infrastructure that could exist as stranded assets.

Section #	Adverse Impact	Utility Characteristics
3.5	Reductions in revenue from reduced water sales	• **Rate structure.** Utilities with rate structures tied to volumetric use may experience more financial volatility as customers reduce water use.

Table ES-5b. Utility Characteristics That Can Contribute to Adverse Impacts: Wastewater Utilities

Section #	Adverse Impact	Utility Characteristics
3.2.1, 3.2.2	Increase in odors and accelerated corrosion from higher sewer gas concentrations	• **Age of infrastructure.** Utilities with older infrastructure may be more susceptible to odor, leakage, and accelerated corrosion as pipelines have deteriorated and corroded over time. • **Topography, size, and density of service area.** Long stretches of flat pipeline provide more time for H_2S production, exacerbating odor production and corrosion. • **Infrastructure material.** Sewer systems constructed of materials sensitive to corrosion, such as concrete, will experience adverse effects of accelerated corrosion most heavily.
3.2.3	Increase occurrence of sewer blockages and overflows	• **Pipeline diameters.** Pipelines with smaller diameters are more easily clogged and thus more susceptible to sanitary sewer blockages and associated overflows. • **Conveyance system design parameters.** Pipelines with more flow constraint conditions (turns, material roughness, use of lift stations, and other features) may be more susceptible to blockages.

Section #	Adverse Impact	Utility Characteristics
3.3.1, 3.3.2	Impacts on wastewater effluent quality and increased chemical use from degradation of wastewater influent quality	• **Customer demographic.** Utilities with large percentages of residential customers will experience larger changes in both wastewater quality and quantity. • **WWTP treatment process.** WWTPs that use treatment processes that have loading limitations, such as activated sludge, nutrient removal, and biosolids handling, will be more sensitive to increasing loads in influent wastewater. • **National Pollutant Discharge Elimination System (NPDES) permit requirements and discharge point.** WWTPs that discharge into sensitive water bodies with strict NPDES discharge limits may require more operational adjustments and may struggle to maintain margins of safety that enable consistent compliance with effluent requirements.

Table ES-5c. Utility Characteristics That Can Contribute to Adverse Impacts: Recycled Water Utilities

Section #	Adverse Impact	Utility Characteristics
3.4.1	Deterioration in recycled water quality from worsened wastewater effluent quality	• **Customer demographic and end-uses.** Systems that serve customers that require high water quality (e.g., industrial processes, golf courses, or potable reuse) could be more susceptible to the impacts of increasing concentrations in wastewater effluent. • **Existing or planned investments.** Changes in wastewater quality will more greatly impact projects that are actively in design or construction phases.

Section #	Adverse Impact	Utility Characteristics
3.4.2	Limiting the offset of potable use from reductions in recycled water production volumes	• **Water supply source.** Utilities that use recycled water to supplement a sensitive or scarce source supply will be more impacted by reductions in recycled water production. • **Discharge requirements.** WWTP discharge criteria that require a minimum flow to the receiving water body reduces the amount of wastewater available for reuse if total wastewater flows decrease, limiting the production of recycled water.

1.0 Background and Approach

Water is essential to the way of life in California, and utilities are working to develop long-term strategies to maintain water supply reliability for their communities. In 2018, the California State Legislature enacted legislation that strives to establish a foundation for long-term improvements in water use efficiency and drought planning.

1.1 Nexus to Urban Water Use Objectives

In 2018, AB 1668 and SB 606 set default standards for indoor residential use starting at 55 Ri-gpcd, decreasing to 52.5 Ri-gpcd from 2025 through 2030, and further decreasing to 50 Ri-gpcd from 2030 and onward. This legislation also directed the DWR, in coordination with the State Water Board, to conduct necessary studies and investigations to analyze the benefits and impacts of how the changing standard for indoor residential water use will impact water and wastewater management. DWR and the State Water Board may also jointly recommend a standard for indoor residential water use that more appropriately reflects best practices (Water Code Section 10609.4(a)(3)).

The legislation also directed DWR to conduct studies and provide recommendations, in coordination with the State Water Board, on water use standards for outdoor residential use, water losses, and CII outdoor landscape areas with dedicated irrigation meters (DWR 2018). These standards are not individually enforceable, but rather, are components of an urban retail water supplier’s total urban water use objective, as shown in Figure 1-1 on the next page.

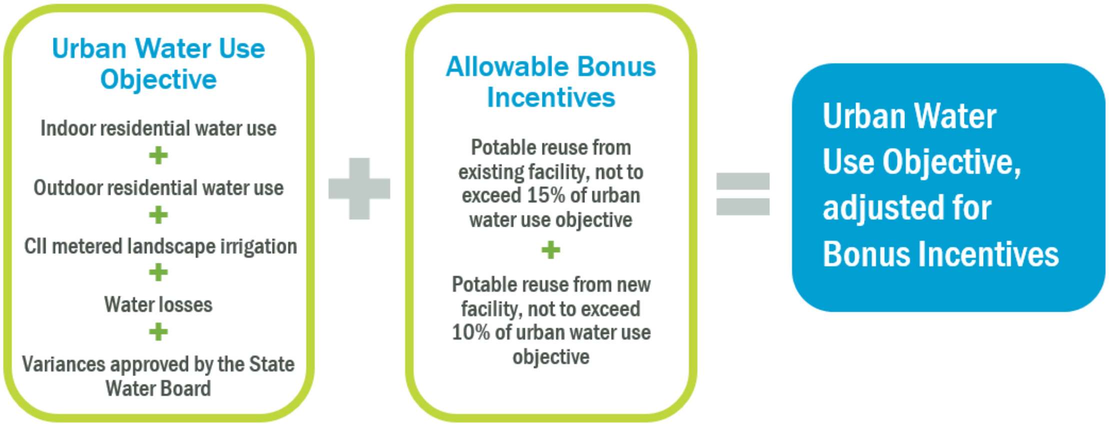

Figure 1-1. The indoor residential water use standard is one component of an urban retail water supplier's urban water use objective.

Source: DWR 2018

The urban water use objective applies to retail water suppliers and is calculated annually, based on the adopted water use standards and local service area characteristics for the previous year (Water Code Section 10609(a)). Each urban retail water supplier calculates a unique gallon per capita per day annual objective. The objective is subject to annual reporting and used in comparison to the actual aggregate water use in the previous year. Urban water suppliers are required to stay within their annual water use objective for their service areas. Beginning in 2024, the State Water Board has authority to enforce the aggregate water use objective, but individual standards compliance will not be enforced.

1.1.1 Purpose of Study

Unlike the water use standards that are still to be adopted for outdoor residential use, water losses, and CII outdoor landscape areas, the legislature set the current standard for indoor residential use at 55 Ri-gpcd. The standard is set to decrease to 52.5 Ri-gpcd beginning in 2025 and will further decrease to 50 Ri-gpcd by 2030. Per the legislation, the Ri-gpcd studies and investigation must "include an analysis of the benefits and impacts of how the changing standard for indoor residential water use will impact water and wastewater management, including potable water usage, wastewater, recycling and reuse systems, infrastructure, operations and supplies" (California Water Code [Water Code] Section 10609.4).

A report on the results of the studies and investigations shall be made to the chairpersons of the relevant policy committees of each house of the Legislature by January 1, 2021. This study satisfies that requirement by qualitatively assessing the collective impacts of a changing indoor residential water use standard. Per the Water Code, the focus is on the impacts of indoor residential use, which is what travels through utility infrastructure systems (see Figure 1-2, next page).

This analysis is meant to satisfy the Water Code by presenting a qualitative benefit and impacts assessment associated with a changing indoor residential water use standard. Given the limited quantifiable information currently available, this analysis cannot and is not intended to arrive at or comment on a recommended threshold for per capita water consumption beyond which water, wastewater, and reuse systems may experience significant adverse impacts.

1.2 The Potential Effects of a Changing Indoor Ri-gpcd Standard

Water, wastewater, and recycled water systems are interconnected and a change in one part of the cycle can trigger impacts, both positive and negative, on other parts of the system. In most cases, water that is used outdoors for irrigation is not typically recaptured and instead “lost” through evapotranspiration or percolation (except for areas where water naturally percolate into groundwater aquifers). When water is used indoors, it is flushed down a drain and then conveyed through the sewer system to the WWTP. Treated WWTP effluent can be discharged or conveyed to a recycling or reuse treatment facility to be treated further. The interconnected nature of water and wastewater distribution, conveyance, and treatment infrastructure is often referred to as the urban water cycle (Figure 1-2, next page).

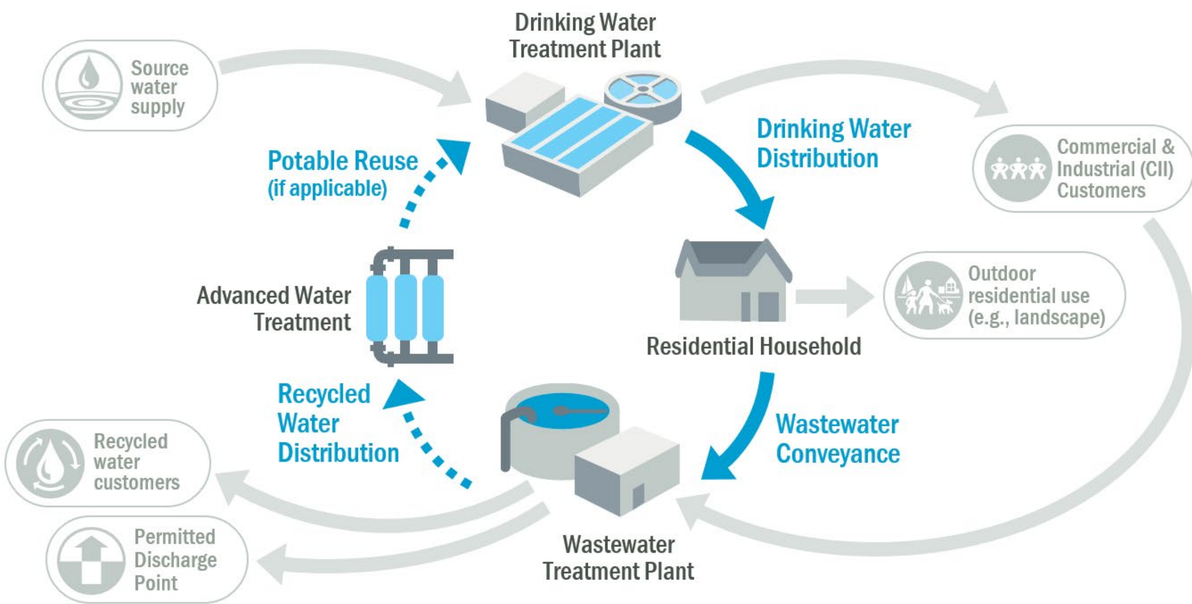

Figure 1-2. Indoor residential water use generates water that remains within the urban water cycle, shown in blue.

Furthermore, effects of a changing indoor residential water use standard, if lower than existing conditions, may result in less water used and less wastewater and recycled water generated, depending upon the concurrent population growth and development. Reductions in indoor water use result from both short-term conservation efforts (i.e., behavior changes in response to drought or emergency) and long-term water use efficiency for lasting, sustainable effects. While some utilities use the term "conservation" to describe both short-term and long-term strategies, this study distinguishes between conservation as an emergency response to drought (drought conservation) and water use efficiency (WUE) as a long-term strategy for lasting demand reductions, such as low-flow plumbing fixtures and appliances.

The significant reduction in water demand due to drought conservation during the 2012-2016 drought brought to light unintended consequences of reduced water use that rippled throughout California's water, recycled water, and wastewater systems. The drought response included reductions in both indoor and outdoor use. Reduced indoor water demands affect total volumes and velocities within both drinking water and wastewater systems, setting these systems up to experience changes in quality, treatment, and operational and maintenance needs. Wastewater agencies produce highly treated water that is increasingly recycled and reused as a water supply. While it is still only a small portion of overall water use, the use of recycled water has nearly tripled since the 1980s—and continues to rise as water agencies seek to meet the demands of a growing population and improve the resilience of their water supplies (PPIC 2019).

1.3 Considerations for a Changing Ri-gpcd Standard

The Ri-gpcd standard is expected to have lasting effects on future water management practices throughout California, and there are various factors to consider.

1.3.1 Challenges in Quantifying Actual Ri-gpcd

In order to assess benefits and impacts of a changing standard, it is important to have an idea of the magnitude of change. While the indoor and outdoor residential water use standards are defined separately in the urban water use objective, most residential customers do not have separate meters that differentiate between indoor and outdoor use. As such, determining the specific Ri-gpcd for utilities is challenging since most utilities only obtain monthly or bi-monthly water usage records and do not separately meter indoor and outdoor use. For state reporting, some utilities provide an assumed percentage (e.g., 50 percent indoor, 50 percent outdoor) (City of San Diego 2020), but that is often an estimate that is not substantiated by specific meter records. Other utilities may look to water use in winter months as a representative baseline for predominantly indoor use.

Given Ri-gpcd is often not measured by utilities, total (indoor + outdoor) R-gpcd, shown in Figure 1-2, serves as context around the current 55 Ri-gpcd standard and any recommended standard. These Ri-gpcd values are from the dataset as reported to the State Water Board on a monthly basis. However, this varies for each supplier and each associated wastewater and recycled water facility.

1.3.2 Interconnections with Other Regulatory Actions

Utility efforts to continually provide safe and affordable water and wastewater services are driven and informed by developing regulations. Often, these regulations are developed in parallel with each other with separately defined goals, and they have the potential to conflict. For example, if indoor residential water use flows are reduced, the water available to meet reuse goals for some agencies will be reduced. This is not to say that the reuse goals should not be modified since reducing potable water use is of prime importance; it is to illuminate the potential for conflicts and enhances the need to provide flexibility in interconnected regulations and policies based on various situations.

This work is one element of the overall conversation around water supply reliability and water use efficiency. DWR and the State Water Board are working on a variety of regulations that interconnect, and it is important to consider their cumulative impacts. Other important state-wide policies to consider are described here.

- **State Water Board recycled water goals.** Per the Recycled Water Policy (2018), the State Water Board adopted goals to increase the use of recycled water from 714,000 acre-feet per year (afy) in 2015 to 1.5 million afy by 2020 and to 2.5 million afy by 2030 (State Water Board 2018). This is important as production of recycled water requires a supply of wastewater influent, which will be influenced by the Ri-gpcd standard. Determination of the amount of wastewater that is available to recycle in California has been identified in the WateReuse California Action Plan as a key item in advancing water reuse (WateReuse CA 2019). The ongoing Water Research Foundation (WRF) project 4962 titled "Identifying the Amount of Wastewater That Is Available and Feasible to Recycle in California" seeks to quantify this value to help refine existing recycled water goals.

- **Onsite reuse regulatory development.** The California Water Code (CWC) Section 13558 requires the State Water Board to adopt regulations for risk-based water quality standards for the onsite treatment and reuse of non-potable water on or before December 1, 2022. Section 13558 also requires the Department of Housing and

Community Development to develop any necessary corresponding building standards to support the risk-based water quality standards on or before December 1, 2023. The development of onsite reuse diverts water, but not necessarily solids, out of the wastewater collection system, which can have downstream adverse impacts on centralized wastewater and recycled water facilities. Greater adoption of onsite reuse has the potential to exacerbate many of the adverse impacts to water and wastewater systems. Lower indoor use combined with onsite reuse may lead to even less water flowing through the potable distribution system, which cascades into lower wastewater volumes entering into wastewater systems (CUWA 2019).

- **Sustainable Groundwater Management Act (SGMA).** SGMA requires governments and water agencies of high and medium priority basins to halt overdraft and bring groundwater basins into balanced levels of pumping and recharge. A lower Ri-gpcd standard could have a variety of impacts on a water utility that is also working to meet compliance with SGMA, depending on the characteristics of the basin. Reduced demand could lead to reduced pumping that lessens the strain of overdraft in a basin. Alternatively, it could have a negative impact for utilities that are relying on wastewater effluent or recycled water from another agency for groundwater recharge or to minimize the need for groundwater pumping.

- **Delta Stewardship Council Policy WR P1.** WR P1 aims to reduce reliance on the Delta through improved regional self-reliance. Exports from, transfers through, or water used in the Delta will only be allowed to water suppliers that have adequately demonstrated reduced reliance on the Delta and adequately contributed to improved regional self-reliance. Similar to SGMA, this demonstration of reduced reliance could be supported by reduced per capita residential use that lowers total demand or be negatively impacted if they are leveraging recycled water to offset potable use.

1.3.3 Human Behavioral and Cultural Changes

Human behavioral and cultural changes or shifts in water use and reuse may exacerbate or mitigate changing indoor residential water use standards benefits and impacts. As seen with COVID-19, stay-at-home orders and business shutdowns during pandemic onset prompted changes in municipal water demand. Given lags in collecting and analyzing water-use data and a lack of precedent experience, details demonstrating expected changes are currently limited. Available data suggest residential water demand increased while commercial/industrial use decreased, as would be expected. The effect of the COVID-19 pandemic on total water demand varies from community to community, and a key factor includes the relative proportion of residential and non-residential water uses (Cooley et al. 2020).

The **San Francisco Public Utilities Commission (SFPUC)** was tracking the shift in water use trends by comparing water use to the seven weeks before San Francisco’s shelter-in-place restrictions began in March 2020. The subsequent weeks after the restrictions went into effect saw commercial use down by 50 percent as compared to the seven-week period before, and overall total water use reduced by eight percent in April 2020 as compared to March 2020 (SFPUC 2020). This reduction in commercial use continued in July 2020, as commercial use remained down by 38 percent and residential use up by 11 percent when compared to pre-restrictions. While there was an initial decrease in overall water demand in April 2020, the percent changes in July 2020 offset each other and there was a rebound of water demand to pre-COVID volumes (SFPUC 2020).

The shift to people working at home due to COVID-19 may have a substantial effect on impacts associated with a changing indoor residential water use standard by shifting water use from one sector to another and by an overall reduction in total water use. For example, many suppliers are seeing their commercial water use going down, contributing to lost revenue that is not offset by the increase in residential water use revenue. Additionally, if commercial water use declines, there will be less commercial water to supplement total wastewater volumes if indoor residential water use decreases, leading to potential water quality effects. It is currently unknown what the magnitude of these effects are or how persistent current changes will be. However, some longer-term adjustments may be needed as commercial properties may experience reduced occupancy for an extended period.

1.4 Approach and Methodology

This study is an analysis of the benefits and impacts of how the changing standard for indoor residential water use will impact water and wastewater management, including potable water usage, wastewater, recycling and reuse systems, infrastructure, operations, and supplies. Per Water Code 10609.4, a report on the results of the studies and investigations shall be made to the Legislature by January 1, 2021.

Utilities are still actively adapting to the 55 Ri-gpcd standard, so this analysis instead examines utility experiences during another time of significantly reduced indoor residential per capita use – the recent drought from 2012 to 2016. This study details utility experience captured in literature, most notably, prior assessments conducted as part of the CUWA white paper *"Adapting to Change: Utility Systems and Declining Flows"*, which documented utility experience during the 2015-16 emergency regulations for water conservation. While the dramatic measures taken during the drought were specifically to address the emergency, understanding the benefits and adverse impacts experienced during those periods of lower water use can provide insight into the effects of an indoor residential water use standard set around those levels.

Case study interviews were also conducted as part of this work to reflect current (2020) experience with reduced indoor residential per capita use. These interviews provide insight on the potential benefits and adverse impacts, as the utilities selected continue to operate close to the reduced per capita use achieved during the recent drought. The utilities that participated included EBMUD, the City of San Diego, SCWD, and the City of Fresno. These utilities represent a diverse set of experiences in geography, source supplies, service area size, and topography. Figure 1-3 shows the four utilities that were interviewed, as well as other utilities included herein from literature.

Figure 1-3. Utility experiences throughout California on benefits and impacts are referenced in this study. R-gpcd shown is based on 2019 values and are only reported by urban water retailers.

2.0 Benefits of a Changing Ri-gpcd Standard

There are various factors that contribute to the quality and quantity of water and wastewater experienced by utilities, including customer demographic, per capita use, and population growth. As directed by the legislation, this study is focused on the change of one variable – indoor residential per capita water use (Ri-gpcd).

This study presents the benefits of a changing Ri-gpcd standard by examining the benefits experienced during another instance of significantly reduced per capita use – the drought in 2012 to 2016. Drought conservation and WUE are defined as the short-term behavior changes during drought emergencies and long-term strategies for sustained demand reductions for this analysis. They are both strategies to support the reliability of water supplies as they stretch available resources to support community demand for potable and non-potable needs.

2.1 Water Supply Benefits: Adapting to the Effect of Climate Change

As climate change brings about a warmer and more variable climate, it exacerbates challenges faced by water agencies, namely the availability of long-term water supplies. Climate change affects California's water resources, and despite the state's aggressive climate policies, these impacts will continue to worsen. The snowpack in the Sierra Nevada mountains, which provides about a third of California's water supplies is projected to potentially shrink by 79 percent under a high emissions scenario (Rhoades 2018). This reduces the reliability of water supplies that depend on the snowpack and potentially increases demand for other water sources such as groundwater.

Precipitation falling as rain instead of snow is also worsened by climate change, exacerbating flood risks and adding additional challenges for water supply reliability (Rhoades 2018). Variable weather patterns with more extreme weather events will also result in greater flood risks, while droughts will likely become longer and increase in severity. Sea levels will continue to rise, threatening the stability of the Sacramento/San Joaquin Bay Delta levees and requiring more fresh water to mitigate saltwater intrusion into coastal aquifers.

Droughts are also a recurring feature of California's climate, and climate change due to anthropogenic warming will substantially increase the likelihood of extreme California droughts (Williams et al 2015). The four-year period between fall 2011 and fall 2015 was the driest since record keeping began in 1895, with 2014 and 2015 being the two hottest years in the state's recorded history. Precipitation in 2016 was average in northern California but this was not enough to eliminate the severe water deficit. In the face of these challenges, utilities are working to increase their water supply reliability through both portfolio diversification and demand reduction through WUE strategies.

2.2.1 Increased Water Supply Resiliency through both Diversification and WUE

To mitigate the issues exacerbated by climate change and increase resiliency, water utilities can work to reduce water demand, secure additional supply options, and increase diversification of their water source portfolio. Water systems have several strategies to diversify their water portfolio including purchase of supplemental supplies, interconnections between water systems, construction of additional water treatment and reuse systems, urban stormwater capture projects, groundwater banking, regional conjunctive use projects, and seawater desalination.

Decreasing water demand is supported through investments in water conservation measures and programs that promote WUE. Long-term WUE measures include replacing inefficient fixtures and devices such as toilets, dishwashers, clothes washers, faucets, and showerheads with devices that use less water. There are also outdoor WUE measures, such as efficient irrigation practices like drip and subsurface irrigation and efficient spray nozzles. These measures are proven to be effective when implemented at a large scale, often through building codes, ordinances, rebate programs, and conservation education programs. Such reductions in water use and water demand can result in a decrease or deferral of capital costs, either to expand existing infrastructure or develop new water sources, which is discussed further in Section 2.2.2. The effectiveness of any demand reduction program, however, will depend on the current level of efficient device saturation and customer water conserving practices.

A study on the 10 largest urban retailers in California found that the reduction in per capita water demand was substantial enough to reduce total demand in spite of population growth (Abraham et al. 2020). This investment in water use efficiency and subsequent reduction in water use has been successfully achieved by utilities throughout California, as demonstrated in the examples below.

The **Bay Area Water Supply and Conservation Agency (BAWSCA)** was created in 2003 to represent the interests of over 1.8 million people and 40,000 CII accounts in 24 cities and water districts, and two private utilities that purchase water on a wholesale basis from the San Francisco Regional Water System (SF RWS). Their service area stretches multiple counties in the Bay Area, providing regional water supply planning, resource development, and conservation program services. Due to their reduced per capita use, total water use has declined despite population growth (Figure 2-1).

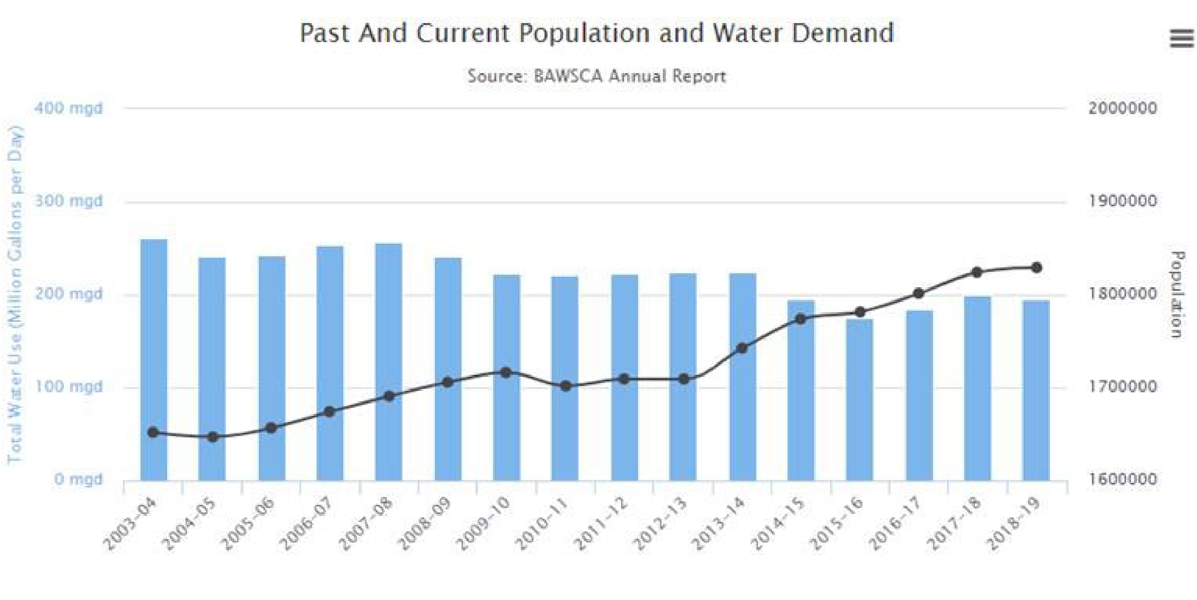

Figure 2-1. Due to reductions in per capita use, total water use in BAWSCA has declined despite population growth. *(Source: BAWSCA 2015)*

In their 2015 Long-Term Reliable Water Supply Strategy Report, BAWSCA identified that though their normal year water supply is sufficient through 2040, there could be up to a 15 percent supply shortfall (approximately 43 mgd or 48,000 acre-feet per year) in drought years (BAWSCA 2015). A 2020 study reevaluated the trends in demand and conservation projections through 2045 and found that although the region is set to experience a 31 percent population increase and 24 percent employment increase, the region's demand will only increase by 25 percent. This was in part because of the water savings potential of 24 WUE measures, which was anticipated to yield an additional 37.3 mgd of savings by 2045. This would shrink the water supply shortfall by over 85 percent. With the active and passive efficiency measures in place for the region, BAWSCA is projected to see a 46 percent reduction in R-gpcd in 2045 compared to 1986 levels (BAWSCA 2020).

The same aggressive reductions in water use were experienced in Southern California. The **Municipal Water District of Orange County (MWDOC)** develops, implements, and evaluates WUE programs that significantly improve water supply reliability for Orange County. MWDOC serves 3.2 million Orange County residents through 28 retail water agencies. Water use efficiency is an integral component of their overall water supply portfolio, and the least expensive water source. In addition to securing a cost-effective, reliable source of water supply, other benefits of WUE include runoff reduction, pollution prevention, and energy savings. MWDOC's WUE programs include educational materials, performance reporting, water use surveys, and a variety of consumer incentives for indoor and outdoor water-efficient devices for residents and businesses throughout Orange County. Through a multi-agency approach, Orange County saves more than 17.1 billion gallons of water each year (MWDOC 2020).

While WUE strategies decrease total water demand (assuming population has not increased), utilities will still need to continue increasing resiliency to climate change by diversifying their water portfolios (Gonzales 2019). A portfolio solely focused on reducing residential per capita use may experience a phenomenon called demand hardening, defined as the loss of demand elasticity during a drought (Howe 2007). As households become more efficient over time, the total water savings that can be achieved by utilities through individual behavior changes is reduced. This can limit a utility's ability to achieve significant reductions during times of drought emergency (Dilling 2019).

2.2 Water & Wastewater Benefits: Reductions in Utility Costs

A changing indoor residential water use standard may reduce overall water supply demand, depending on the concurrent population growth and development. This may contribute to reduced utility costs for both capital investments for new supplies and operations and management (O&M), such as energy and chemical usage for water treatment.

2.2.1 Decreased Water Treatment and Pumping Costs

If total water demand is reduced through conservation and WUE efforts, there will be less water needing treatment at the water supply treatment plants. Lower flow volumes require less treatment chemicals such as coagulants, flocculants, filter aids, disinfectants, corrosion inhibitors, and several others, leading to reduction in treatment costs. Lower total water demands also reduce the pumping requirements with an associated decrease in costs and greenhouse gas (GHG) emissions. In California, as much as 20 percent of the state's electricity consumption is used for pumping, treating, collecting, and discharging water and wastewater (Congressional Research Service 2013).

Soquel Creek Water District (SCWD) saved $10,000 in yearly costs for its coagulant (ferric chloride) and disinfectant (sodium hypochlorite) in 2016 as compared to 2013 due to lower total water demand. Energy usage also declined 28 percent from 2013 to 2016, reducing total annual energy costs by $60,000. The long-term changes due to investments in water efficiency by customers has maintained the lower per capita use achieved during the drought, and their current yearly energy usage remains close to 2016 values.

2.2.2 Deferred Capital Investment

Significant reductions in water use can also result in the reduction or deferral of large capital costs, either to expand existing infrastructure or develop new water sources. Reduction in total water demand allow water utilities to leave capacity in the existing facilities and defer capital costs for expansion or investment in new infrastructure.

According to a 2018 study, the **Los Angeles Department of Water and Power (LADWP)** maintained their overall water use within a range of 500,000 to 700,000 afy from 1990 to 2016 even as population increased from 3.5 to 4 million people (Figure 2-2). Per capita usage decreased from 180 gpcd to 106 gpcd and allowed LADWP to avoid approximately $11 billion in costs from 1990 to 2016 that would have come from having to purchase additional water to serve the additional 500,000 more customers.

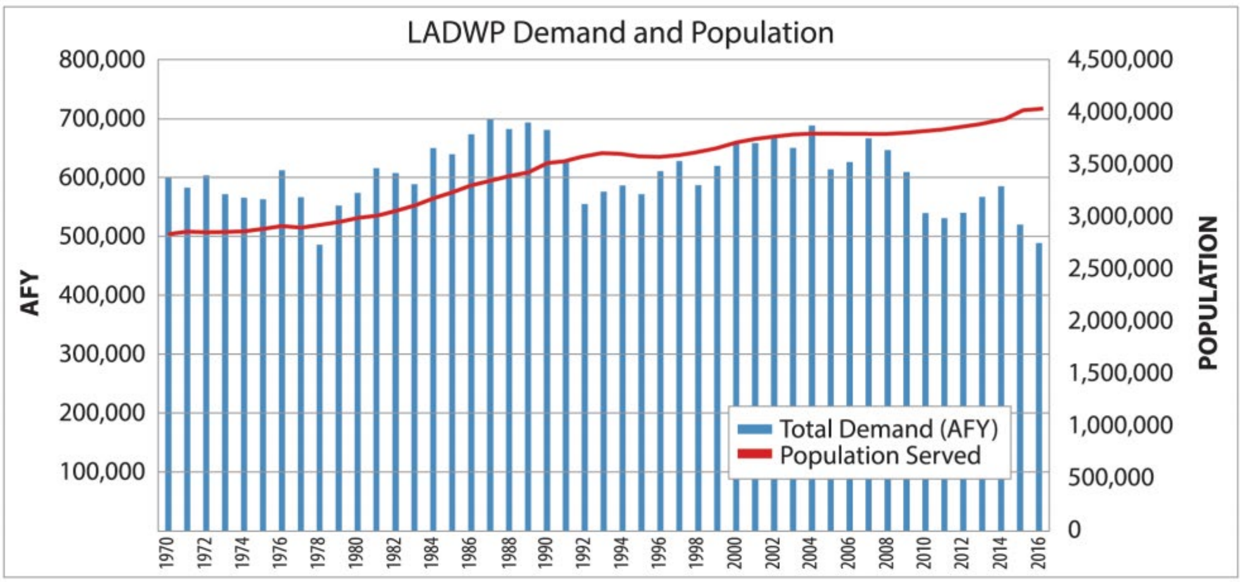

Figure 2-2. Due to reductions in per capita use, total water use in LADWP's service area has declined despite population growth (AWE *2018).*

Source: AWE 2018

This resulted in customer bills that were nearly 27 percent lower in 2018 than they would have been without the department's WUE efforts (AWE 2018). Customers can also experience a reduction in energy costs as they use less residential hot water per capita. However, this reduction in customer bills results in reduced revenue to LADWP, which is an adverse impact described further in Section 3.5.

2.2.3 Reduced Energy Usage for Wastewater Systems

There are a few notable benefits that reduced indoor residential water use may have on wastewater conveyance and treatment systems. Similar to water supply treatment, a changing standard could result in reduced influent flows to WWTPs, which may leave capacity in the existing plant for future growth and defers the need for additional capital investment costs. Lower flow volumes can also lower energy costs due to reduced pumping to WWTPs and to discharge points, which lower GHG emissions. In contrast to drinking water facilities, however, reduced wastewater flow do not translate to reduced chemical costs because contaminants tend to be more concentrated (see Section 3.3 for additional information).

For example, the treated effluent at **Los Angeles, Bureau of Sanitation's (LASAN)** Hyperion Water Reclamation Plant is typically pumped five miles to the ocean outfall with large discharge pumps. Since wastewater volumes have decreased, the energy required to pump the wastewater has also declined. Fifteen years ago, the treated effluent pumps operated daily to discharge effluent through the outfall. Now, the treated effluent can flow by gravity, and the pumps are only necessary when it rains, resulting in significant energy savings (CUWA 2017).

3.0 Adverse Impacts from a Changing Ri-gpcd Standard

Adverse impacts can be experienced from a variety of conditions associated with a changing Ri-gpcd standard. Similar to potential benefits, potential water and wastewater system impacts will depend on the magnitude of the changing standard and what effect that will have on system flows quantity and quality.

When discussing adverse impacts, it is not to imply that emphasis on conservation of potable water should be relaxed, or that potable water use should remain the same or increase to avoid impacts. Rather, this section is meant to acknowledge the interconnections and trade-offs between water use, wastewater generation, and recycled water production and how changes in one element of the cycle can have downstream implications.

3.1 Impacts on Water Treatment and Distribution

A changing Ri-gpcd standard could result in a reduction of per capita water use in a water supplier's service area. This reduction in per capita use could be offset by increasing service area population, resulting in minimal changes to overall water demand. However, where a reduced Ri-gpcd standard does result in less demand and increased retention time in the distribution system, both the quantity of water produced by treatment facilities and quality of water delivered to customers can be adversely impacted.

Many of the adverse impacts described are a result of a system that may now be oversized for current conditions. Utilities are already updating demand projections to better prepare for the future, but there are various considerations in system water sizing that may limit a utility's ability to adapt through downsizing to match reduced water demand.

3.1.1 Design Criteria for Water System Sizing

Industry standards for sizing water distribution infrastructure exist to ensure there are adequate pressures, flow velocities, and capacity to meet the demand required for emergency and fire flow requirements within the system (AWWA 2014). An undersized system risks having insufficient flow to suppress fires in the service area, and an oversized system may see water quality deterioration due to increased retention time in distribution pipelines.

Water distribution systems are sized using a capacity-based approach, with future demand scenarios and economies of scale often driving sizing decisions to provide hydraulic reliability and maintain system-wide positive pressures (Kelley 1994). The following factors are considered when properly sizing water distribution systems (Roberts and Hall 2017):

1. Peak hour demands: the hour of highest water demand in each day, typically in the morning or evening

2. Maximum day demands: the day of highest water demand in each year, typically in the summer

3. Fire flows: an additional 500-3,500 gallons per minute flow on top of peak hour or maximum day use. These are often the dominant factor in pipe sizing.

Distribution systems were designed per these factors based on values at the time of design and best available demand projections. If per capita use declines, systems may now experience flow rates lower than originally planned. However, the commitment to still deliver fire flows may constrain a water agency's ability to further downsize to match reduced flow rates.

Utilities are continuing to update water projections in their planning efforts, as historical projections tended to overestimate future demands due to higher than actual estimates of per capita demand and population growth. For example, a study examined demand projections for 10 large urban water suppliers in California through information provided in Urban Water Management Plans (UWMPs) (Abraham et al. 2020). It was found that on average, water suppliers projected that per capita demand would decline by less than one percent per year. However, actual per capita demand declined twice as fast. To improve planning projections, researchers recommended not only updating input data, but also examining the underlying trends and assumptions within the models (Abraham et al. 2020).

3.1.2 Deterioration in Water Supply Quality

Adverse water quality effects are primarily related to increased retention time of water (i.e., water age) in the distribution system. Under normal use conditions, the uninterrupted flow of tap water helps preserve water quality. Systems designed for expected flow rates may result in longer retention times with a lower Ri-gpcd standard.

Because water age is strongly associated with water quality, water age is often used as a surrogate for a number of water quality parameters (Roberts and Hall 2017). Table 3-1 summarizes water quality effects that may result from increased water age, and each impact is further discussed below.

Table 3-1. Summary of Water Quality Effects that May Result from Increased Water Age (AWWA 2017)

Issue	Water Quality Effects that May Result
Biological Issues	• Microbial growth • Potential presence of pathogens and undesirable microorganisms such as nitrifying bacteria among others
Chemical Issues	• Disinfectant decay • Disinfection by-products (DBP) formation and change in speciation • Corrosion and metal release • Change in pH, dissolved oxygen, and other chemical characteristics
Physical and Aesthetic Issues	• Temperature increases • Increased turbidity and sediment deposition • Changes in taste, odor, and color

Impacts from Biological Factors

Impacts from biological factors include microbial growth, potential presence of pathogens, and increased nitrification. Even after treatment and disinfection, neither the drinking water nor the distribution system are free of microorganisms. Microorganisms in drinking water distribution systems may occur as coliform bacteria, nitrifying microorganisms, corrosion-related bacteria, waterborne pathogens, and others (Friedman et al. 2017). Microbial growth in distribution systems represents a form of water quality degradation that can be responsible for nitrification, corrosion, taste and odor episodes, as well as other unfavorable water quality conditions.

Disinfectant residuals are used to preserve water quality by: 1) inactivating microorganisms that may pass through treatment processes, 2) controlling microbial growth in the distribution system, and 3) protecting water from potential contamination that may occur from pipe breaks, cross connections, and similar situations (Baribeau et al. 2017). When disinfectant residuals are too low, microorganisms can multiply, with the majority of the growth occurring in biofilms attached to pipe walls.

Nitrification is a microbial process that is particularly challenging in chloraminated (treated) drinking water (AWWA 2013). Nitrification can be responsible for a variety of water quality challenges including increased microbial growth and degradation of disinfectant residual. Preventing and controlling nitrification can be a significant operational burden as it may require frequent monitoring, pipe flushing, and limitation in storage reservoir usage to minimize water age. Unless it is used for other purposes (e.g., aquifer recharge), flushing represents a loss of treated water and may be concerning to customers when emphasizing conservation and water use efficiency.

Adaptation strategies and utility impact. Strategies to improve disinfectants residuals throughout the distribution system include higher disinfectant doses at treatment facilities and/or implementation of booster chlorination stations. However, chlorination station installations are expensive and require additional O&M and costs. Utilities could also explore optimization of water treatment strategies such as using alternative disinfectants that are more stable and/or form fewer DBPs (Baribeau et al. 2017).

An adaptation strategy to address deterioration in water quality is increased flushing. However, flushing may represent a loss of water and a significant cost if water cannot be used for other purposes and may be concerning to customers when emphasizing conservation and water use efficiency. For example, the **San Diego County Water Authority (SDCWA)** supplies water over significant distances to its 24 member agencies in San Diego County. Due to increased detention time in the distribution system, chlorine residuals were degrading – especially in the system extremities. To restore the disinfectant residual and continue delivering high-quality water to member agencies, SDCWA increased flushing from their treated water system through their raw water pipelines. This was particularly exacerbated during the drought, and the rate of flushing increased as much as 10 times. Previously, SDCWA was flushing only five to 10 cubic feet per second (cfs) two to three times per year. During the most recent drought, flushing increased to 20 to 30 cfs daily. The cost associated with flushing and retreating the water resulted in a lost surcharge from $200,000 to over $2 million per year (CUWA 2017).

Changes in Chemical Characteristics

DBPs represent a vast array of chemical constituents that are grouped by classes; over 700 DBPs have now been identified in drinking water (Richardson 2020). Although the fate of DBPs is species-specific, most DBPs are formed at the water treatment facilities when disinfectants are introduced throughout the treatment processes, and DBPs typically continue to form as water travels in the distribution system. The main DBPs encountered in drinking water present health risks and are therefore regulated. Increased water age resulting from reduced flow rates may lead to higher DBP concentrations and difficulties for water systems to comply with drinking water regulations.

As water ages in distribution systems, other changes in water quality may occur that can lead to increases in water temperature, changes in pH and alkalinity, decreases in dissolved oxygen concentrations, and many others. Some of these are directly linked to corrosion and release of metals (e.g., lead, copper, iron, and zinc) from distribution system pipes and other infrastructure. Lead and copper are regulated contaminants in drinking water, and lead is particularly concerning because of its health effects, mainly for children.

Adaptation strategies and utility impacts. Controlling DBP formation and corrosion is complex and strategies need to be carefully examined. Options include adjusting pH and/or alkalinity or adding chemicals such as corrosion inhibitors, requiring operational changes or increasing chemical costs. Implementation of these strategies require thoughtful evaluations involving desktop analyses, bench-scale testing and/or pilot testing. Because corrosion is a process that develops slowly, these studies need to be conducted over a long time period without immediate results and are therefore costly.

The **Santa Clara Valley Water District** (Valley Water) experienced increased DBP formation due to increased water age during the drought. While the drought resulted in other factors that may affect water supply flow rates (e.g., higher temperatures, reduced outdoor water use, and other factors), it remains useful to look at what happened to water quality during this period of low water use. Valley Water provides water services in Silicon Valley among other areas. During the drought, demand for water production was reduced and flows velocities slowed within the distribution system. Retailers furthest from the water treatment plant were most affected by trihalomethanes (THM) formation because of the increased water age. To mitigate this, Valley Water increased their chemical usage to address higher total organic carbon (TOC) concentrations, which resulted in an additional cost of $150,000. Minimum flow rates were also established with each of the retailers to maintain a continuous flow of water through the system.

Deterioration of Aesthetic Characteristics

Drinking water is expected to be clear and odorless, and customers often relate water taste, odor, and color to the safety of their water (Mackey 2004). As water moves through distribution systems, it accumulates particulates and dissolved substances that may affect aesthetic characteristics such as taste, odor, and color. Longer retention time can exacerbate this process (Sutherland 2017).

Adaptation strategies and utility impact. Strategies to improve aesthetic characteristics once water has entered the distribution system vary widely and largely depend on the source of the taste, odor, or color (Sutherland 2017). Controlling microbial growth and biofilm formation are recommended but may be difficult to maintain in reduced flow conditions. Improving source water protection, optimizing water treatment processes and limiting corrosion help preserve aesthetic characteristics. In extreme situations, changing material or lining of distribution system pipes or storage facilities may be necessary. In all cases, limiting water age in the distribution system is recommended (Sutherland 2017). All of these result in increased costs to the utility.

3.1.3 Stranded Assets and Stagnation in Storage Facilities

As mentioned in Section 2, one of the benefits of reduced water demand is the ability for water providers to support continued population growth without having to expand existing infrastructure or develop new water supply sources. However, reduced total water demand may question the need to operate water treatment facilities on a continuous basis.

For example, systems with multiple water supply sources or treatment facilities may be able to rely on larger water sources or treatment plants and limit the use of secondary facilities or facilities that are only used to meet peak demand. Operating water treatment plants at fractions of their capacities may not be financially sustainable. Ultimately, water systems may face the decision of having to decommission water sources or treatment facilities, which represent important/costly stranded assets.

This is also applicable to storage facilities, such as reservoirs and tanks that are used to ensure a constant supply of water to customers despite fluctuating demand. Storage facilities also support emergency and fire flow requirements, which represent an important portion of storage capacity in some systems. Reductions in total water demand can also decrease water velocity use, which may lead to water stagnation in storage tanks, remote areas, and or dead-end mains.

Adaptation strategies and utility impact. A number of strategies are available to maintain water quality in storage facilities including strengthening water quality monitoring, and include increasing turnover rates through cycling, deploying passive or active mixing devices to limit stratification, reconfiguring inlets and outlets, and flushing. All of these strategies require increased investment from utilities. Water systems with distribution system storage capacities that become inconsistent with reduced water demands may also find themselves having to eliminate redundant storage facilities, either seasonally or permanently. Permanently removing a tank from service represents a stranded asset.

Retrofitting existing infrastructure is also an adaptation strategy but can be costly. In those instances, utilities have applied other adaptation strategies such as implementation of booster chlorination stations in the distribution system, and alternative operational strategies such as increasing flushing at dead ends to limit water age. Corrective methods are available but may be complex and time consuming. These methods include reconfiguring the distribution system by opening or closing valves and allowing water to flow through boundaries of pressure zones to improve water circulation through the affected areas (Roberts and Hall 2017).

The **East Bay Municipal Utility District (EBMUD)** has relied on its Central Reservoir since 1909. This reservoir is used to store finished water and has a capacity of 154 MG. Despite population growth, water use per person has reduced to the point where the required capacity is now only 50 MG, one-third of the original reservoir capacity. As the Central Reservoir required rehabilitation, it was judged that replacing the Central Reservoir with three tanks of 17 MG each would be more appropriate to satisfy current water demand. More details specific to EBMUD can be found in Section 4.2.

3.2 Impacts on Wastewater Conveyance Systems

Wastewater pipelines are typically sized to convey average, peaking, and maximum flow rates for utilities, either by gravity or pressurized systems (Maryland 2013). Pipelines are also sized or sloped to achieve effective scouring velocities between 2 to 8 feet per second to mitigate against solids buildup (EPA 2000).

As the liquid content of wastewater decreases from reduced indoor residential water use, the solids mass and wastewater chemicals remain the same resulting in higher concentrations of solids and chemicals in wastewater. A changing Ri-gpcd standard use could increase effluent concentrations within the wastewater collection system unless other discharges (e.g., infiltration/interflow, CII wastewater) are high enough to dilute the indoor residential wastewater.

Higher concentrations could reduce intended scouring velocities, as well as contribute to physical, chemical, and biochemical effects such as increases in odor production, accelerated corrosion, and blockages. Major factors contributing to adverse effects include:

- Increased concentration of solids and organic material. More concentrated sewage can create blockages and generate increased levels of H_2S, which can accelerate corrosion and increase foul air emissions and nuisance odor complaints. These effects are exacerbated by lower flow rates.

- Increased residence time. Lower velocities equate to longer residence times, enabling microbes in wastewater to consume oxygen over a longer period of time, leading to anaerobic conditions. These anaerobic conditions accelerate the rate of corrosive sulfide production.

3.2.1 Increased Sewer Gas Production and Build-up

Sewer odors are dominated by H_2S gas, which is formed by a biochemical reduction of sulfate and is easily recognizable by its characteristic rotten egg odor. As residential per capita use decreases and solids concentrations increase, higher H_2S concentrations can cause potential health impacts and contribute to increased production of offensive sewer odors. Potential health impacts due to H_2S build-up at low concentrations include irritation of the eyes, nose, throat, and respiratory system (OSHA 2005). Higher concentrations can cause more dramatic impacts such as shock, convulsions, or an inability to breathe. In addition, H_2S is a highly flammable gas that can be explosive (OSHA 2005).

These impacts can be exacerbated in long stretches of pipelines and manholes that allow for longer retention times (time for biochemical processes to occur) and more points where sewer gases can escape to the surface. Wastewater utilities are aware of these impacts and proactively employ mitigation strategies as preventative measures to prevent build-up.

Adaptation strategies and utility impacts. Mitigating odors and H_2S build-up often requires application of chemicals like Bioxide® (i.e., calcium nitrate) or iron chloride, which results in higher costs. A study conducted in 2017 by the **City of San Diego** found a correlation between the decrease in average reported total residential water use and Bioxide® use at specific pump stations. The study reviewed odor injection points that had consistently used Bioxide® from 2010 to 2017 to control odor production. The study found that increases in Bioxide® purchases (by the gallon) coincided with a decrease in average water usage from 2013 through 2017. The gallons purchased for five injection points doubled from 88,000 to 160,000 gallons as average total residential water use decreased from 71 to 62 gpcd (City of San Diego 2018). This indicates that lower residential water use can contribute to increased sewer gas production and higher cost for wastewater facilities.

This increase in the need for chemical mitigation was also experienced by the **Los Angeles, Bureau of Sanitation** (LASAN). LASAN similarly experienced an increase in H_2S concentrations when total residential water use decreased, which led to an increase in odor production and complaints. To address this, LASAN increased the rate of chemical injection and planned to upsize three of their seven existing carbon scrubbers (CUWA 2017). While other factors may have contributed to the sewer gas production, the strong negative correlation between sewer gas production and residential water use indicates that reduced residential water use is an important contributing factor.

3.2.2 Accelerated Rate of Corrosion in Sewer Pipes

Corrosion in the conveyance system occurs when the free water surface releases H_2S to the atmosphere during anaerobic conditions and is adsorbed by moist sewer pipes. On the pipe surface, H_2S is converted to sulfuric acid, which corrodes unlined pipes. Accelerated corrosion in unlined pipes leads to a faster rate of structural failure. The primary failure mode for metal pipes is internal or external corrosion, which leads to holes in the pipe wall. Cast iron is particularly brittle, making it susceptible to cracking and subsequent collapse.

Corrosion is also often the major factor in the failure of unlined reinforced concrete pipe, which typically fails after the interior surface of the pipe wall has deteriorated to a point where the reinforcing steel is exposed (Feeny et al. 2009). Deterioration of sewer pipes and manholes can create structural defects that result in service failures or contamination of surrounding soils (EPA 1991). This deterioration is also witnessed in concrete manhole frames and covers, which can pose a risk to the community if covers dislocate due to heavy traffic.

Adaptation strategies and utility impact. Corrosion can be addressed through various strategies, including rehabilitation and replacement of damaged pipelines, epoxy coating exposed concrete, or installation of cathodic protection. Most utilities already examine and maintain their systems through these methods, but an accelerated rate of corrosion due to increasing H_2S concentrations can incur rapid cost increases and higher costs than originally planned or budgeted.

This accelerated deterioration in concrete structures was witnessed by the **Victor Valley Wastewater Reclamation Authority** (VVWRA)**.** During the drought, VVWRA experienced increased H_2S concentrations which accelerated the rate of corrosion and degradation of existing infrastructure, especially at their concrete manholes. To address these adverse effects, VVWRA implemented operational improvements and began coating their manholes in epoxy. To proactively mitigate future corrosion, VVWRA also updated its specifications in manhole coatings to include epoxy coatings and evaluated alternative materials to concrete. This investment in epoxy coating cost VVWRA $300,000 per year from 2012 through 2017 (CUWA 2017).

Other drought factors, including higher temperatures, may have contributed to the increased H_2S concentrations and corrosion, however the concurrent decline from reduced residential water use are an important factor and the drought conditions can be used to shed light on potential impacts from a changing indoor residential water use standard.

3.2.3 Increased Occurrence of Sewer Blockages and Overflows

Standards used for hydraulic design include requirements of minimum slopes for various pipe diameters to achieve scouring velocities that minimize debris accumulation. These design standards are based on expected sewer flows and concentrations at the time the facility was built. A changing indoor residential standard could result in wastewater volume and concentrations entering the residential wastewater conveyance systems that are below the design parameters.

Debris accumulation results in sanitary sewer blockages (SSBs), the primary cause of loss in sewer serviceability. A number of factors can contribute to debris accumulation, including root intrusion; increase in fats, oils, and grease; and pipe sags (Feeney et al., 2009). Increased solids concentration in wastewater can also potentially contribute to debris in the wastewater conveyance system and increase the occurrence of sanitary sewer overflow (SSO) and blockages. SSO and blockages can result in service failures and require additional O&M labor and costs to resolve.

A study conducted by **Yarra Valley Water**, a water retailer in Australia, examined causes of blockages within the sewer network. Yarra Valley traditionally has a high number of blockages, which is exacerbated by significant tree root intrusion and aging infrastructure (Yarra Valley Water 2011). Yarra Valley also examined the correlation between water consumption per household with the number of SSBs (Figure 3-1), indicating that lower water consumption can exacerbate and increase the rate of SSBs (Yarra Valley Water 2011).

The rate of SSOs and SSBs is not a function of only Ri-gpcd, which is demonstrated by **Westernport Water**. The average annual household consumption in Westernport is 71 kL (18,700 gal), which is lower than Yarra Valley's 144 kL (38,000 gal) (Essential Services Commission [ESC] Victoria

2010). However, the frequency of sewer blockages reported by Westernport was also lower at 4.4 blockages per 100 kilometers (62 miles) of pipe as compared to Yarra Valley's 45.5 blockages per 100 kilometers (62 miles) (ESC Victoria 2010). This demonstrates that utility-specific characteristics, such as aging infrastructure, can influence the magnitude of impact from reduced Ri-gpcd.

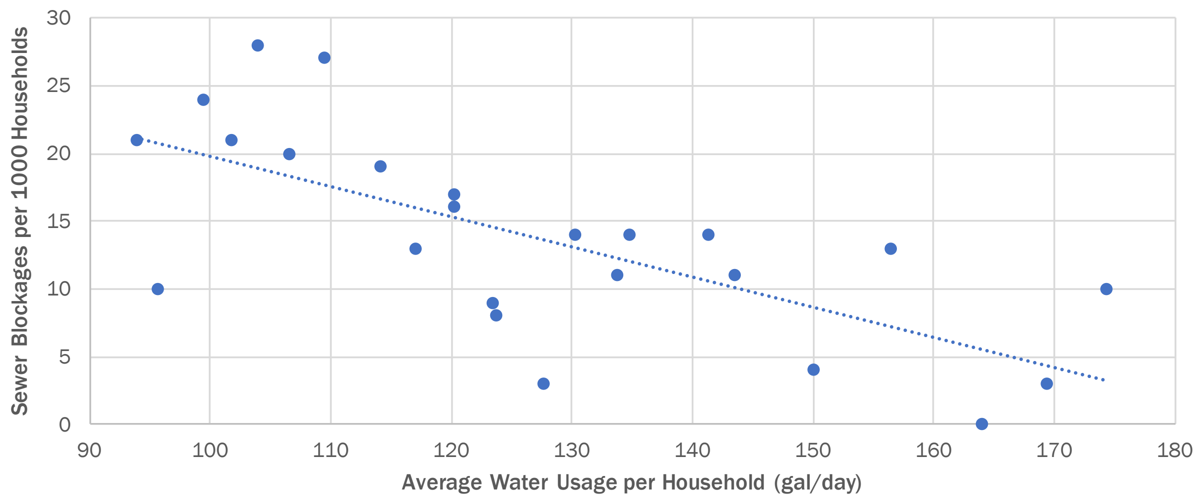

Figure 3-1. Trends indicate that lower water consumption can exacerbate and increase the occurrence of sewer blockages.

Source: Adapted from Yarra Valley Water, 2011

Adaptation strategies and utility impact. Strategies to address solids build-up that increase the occurrence of SSBSSBs and SSOs include increased flushing of sewer mains and proactive maintenance. An increase in blockages due to reduced indoor residential water use was experienced by the **Tuolumne Utilities District** (TUD) as a result of reduced wastewater volumes that occurred during the drought along with other contributing drought factors including root intrusion. 65 percent of TUD's conveyance system consists of smaller diameter pipes 4 to 6 inches in diameter, which increased the potential for blockages. The combined effect of reduced water use during the drought and other factors led to an increase in required maintenance. To address these impacts, TUD increased maintenance of the collection system and monitoring of trouble areas. TUD also implemented a proactive pipe patching system to counter the increased root intrusion; the pipe is cleaned and cured with a fiberglass material that acts as an internal liner, which moves sewage more effectively (CUWA 2017).

3.3 Impacts on Wastewater Treatment

A decrease in Ri-gpcd leads to a reduction in total wastewater volume and an increase in contaminant concentrations. Reduced residential water use during the 2011-2016 drought is useful in understanding potential impacts associated with a changing indoor residential water use standard, even though other factors likely contributed to reduced water use and concentration impacts during the drought. Reduction in influent flow volumes and changes in influent water quality during the drought required many wastewater agencies to adapt aspects of the collection and treatment processes to meet regulatory requirements or resulted in challenges meeting quantities demanded by end users, including recycled water customers.

Adaptation to changing wastewater quantity and quality is a typical aspect of wastewater treatment system operations. However, the sustained lower drought-affected wastewater flow and quality required additional adaptive measures. Adaptations to ensure discharge water quality included changes to characteristics of the treatment process, like modifying the application of treatment chemicals or adjusting aeration controls.

The Public Policy Institute of California (PPIC) conducted a survey in 2019 regarding impacts experienced on wastewater treatment plants during the drought, and 35 percent experienced an increase in treatment cost, 34 percent implemented additional O&M labor, and 32 percent experienced an increase in capital costs (PPIC 2019).This was echoed in the CUWA Declining Flows white paper, where 48 percent of respondents indicated adverse impacts on wastewater treatment (CUWA 2017).

3.3.1 Higher Wastewater Contaminant Concentrations

Increasing wastewater contaminant concentrations can stress treatment processes if the amount of ammonia, total suspended solids (TSS), total dissolved solids (TDS), and organics (measured as biological oxygen demand [BOD]) increases beyond design specifications. This may potentially impact a plant's ability to meet discharge permit requirements and require wastewater treatment plants to adjust operation or invest in improvements or expansions earlier than planned.

Researchers at the University of California Riverside studied 34 plants throughout Southern California from 2013 to 2017 — a period that included extreme drought conditions. The analysis demonstrated that reduced indoor residential use reduced total effluent flow and increased effluent salinity (Schwabe 2020). The researchers observed that Ri-gpcd is negatively correlated to effluent TDS concentrations; that is, when Ri-gpcd decreases, TDS concentration increases. These results are indicative of declining indoor use that results in more concentrated, or less diluted, wastewater (Schwabe 2020).

These higher concentrations were also experienced by **Silicon Valley Clean Water (SVCW),** particularly regarding ammonia. The NPDES permit for SVCW's WWTP has a monthly average ammonia limit of 173 mg/L, and SVCW operates to maintain effluent concentrations consistently below this value (San Francisco Bay Regional Water Quality Control Board 2012). With reduced water usage during the drought, the 60-day average for primary effluent ammonia concentrations entering the WWTP increased from 30 mg/L in 2011 to 47 mg/L in 2016 (Sawyer et al. 2016). This was coupled with a parallel increase in 90-day average effluent ammonia concentrations, increasing from 30 mg/L to 52 mg/L in the same time frame. While this is still below SVCW's NPDES permit limit, this situation is concerning for utilities that are observing increased contaminant concentrations and potentially lower NPDES limits (Sawyer et al. 2016). A changing Ri-gpcd could also accelerate the increasing contaminant concentration trends, exacerbating the stress on treatment processes.

Reduced wastewater volumes can also have a detrimental impact on alkalinity requirements that support nitrification in WWTP processes. While contaminant concentrations increase with reduced Ri-gpcd, alkalinity concentrations remain relatively constant as alkalinity tends to originate from the source water and not produced by people (Sawyer et al. 2016). Specific ratios of alkalinity to ammonia are needed for nitrification to maintain pH in the effluent. As ammonia concentrations decrease, alkalinity limitations can potentially occur.

For example, the total wastewater influent volume at the **City of Santa Barbara's** El Estero WWTP decreased 12 percent between 2012-13 to 2014-15. During this time, influent ammonia concentrations increased by 32 percent, but influent alkalinity concentrations only increased by 4 percent (Sawyer et al. 2016). Based on the data from 2014, supplemental alkalinity would be required at times to maintain a pH above 6.0, which was necessary for effluent compliance (Sawyer et al. 2016). As such, chemical addition facilities were added to the design to provide supplemental alkalinity and increasing overall project cost (Sawyer et al. 2016).

Adaptation strategies and utility impact. Changing influent wastewater quality such as higher ammonia, BOD, and TSS required agencies to adjust their treatment plant operations. One-third of respondents to a 2019 PPIC survey reported problems in the treatment process, such as corrosive influent damaging equipment and less effective treatment processes (PPIC 2019). Utility managers overcame these challenges by applying more chemicals or increasing the intensity of aeration and sludge removal, resulting in increased costs for labor, materials, and energy (PPIC 2019).

3.4 Impacts on Recycled Water Projects

The reduction of Ri-gpcd during the drought serves as a surrogate for estimating potential effects of a changing Ri-gpcd standard that results in lower water use. During the drought, reduced residential water use resulted in reduced quantity and quality of wastewater for most of the state's wastewater agencies. In the PPIC 2019 survey, 40 percent of wastewater agencies that recycle wastewater reported that their ability to produce recycled water was impaired during the drought (PPIC 2019). This could be due to reduced demand for recycled water or a lack of recycled water supplies available for reuse.

Recycled water quantity and production is thus inherently linked to the availability of wastewater effluent. However, when discussing the impacts to recycled water systems, it is not to imply that the emphasis on conservation or water use efficiency should be relaxed to prevent impacts. Rather, it is meant to acknowledge the interconnections and trade-offs between wastewater generation and recycled water.

3.4.1 Reduction of Recycled Water Quantity

Many agencies have plans to increase water reuse to improve water supply reliability and resiliency. Reductions in indoor residential water use lowers total wastewater volumes, subsequently decreasing recycled water production. For recycled water projects that are targeting certain volumes of recycled water for both non-potable and potable reuse, a reduction in available wastewater may require supplemental supply from alternative sources. If alternative wastewater sources are unavailable, loss of recycled water production can hinder a utility's ability to offset potable water use. Utilities can employ various strategies to mitigate these impacts, including continuing to encourage outdoor conservation as that has less impact on wastewater production.

Adaptation strategies and utility impacts. Incorporating supplemental wastewater supplies was a strategy employed by **Orange County Water District** (OCWD) and **Orange County Sanitation District** (OCSD), who jointly manage the Groundwater Replenishment Systems (GWRS). GWRS was initially supplied by OCSD's Plant 1, which has higher quality effluent than what is produced by Plant 2. The total combined flow of Plants 1 and 2 has decreased from 240 mgd in the 2000s to 180 mgd in 2017. The final expansion to 130 mgd for GWRS was originally planned to be supplied by only Plant 1. However, the reduction in wastewater effluent will require supplemental flows from Plant 2. There are certain flows at Plant 2 that have much higher TDS concentrations, so OCWD and OCSD had to have invest $60 million to segregate these flows from those being conveyed to GWRS (CUWA 2017).

Many agencies use recycled water as a strategy to support industrial, agricultural, or commercial customers and offset potable water use in these sectors. For example, **Victor Valley Wastewater Reclamation Authority** (VVWRA) operates a conventional activated sludge facility that discharges into the Mojave River. Given the value of water in the Mojave area, VVWRA treats all wastewater effluent to Title 22 standards to maximize reuse potential. After being treated, the reclaimed water is sent to percolation ponds, reused, or discharged into the Mojave River. End-uses include reclaimed water for irrigation at golf courses and for industrial cooling towers (VVWRA 2020). The Mojave River is a terminal river that is bound by stringent water quality and quantity regulatory requirements. This includes base flow requirements of 8.2 mgd into the river set by the California Department of Fish and Wildlife. The reduced total flow volumes experienced by VVWRA decrease the amount of water available for recycling. The less recycled water is available for end-users, the more customers must rely on potable resources, which is groundwater in that area (CUWA 2017).

3.4.2 Increases in Recycled Water Salinity

As households become more water-efficient, either inspired by the changing Ri-gpcd standard or investments already made, wastewater that is discharged to sewers can have higher concentrations of salts. Salts are not typically removed in most wastewater treatment processes and subsequently make their way into recycled water. Saltier water may not be suitable for common recycled water applications such as irrigation of golf courses or salt-sensitive crops like avocados.

The effects to recycled water effluent quality and quantity from reduced residential water use were analyzed at **Inland Empire Utility Agency** (IEUA) Regional Water Recycling Plant 1 (RP1) via a report published in 2017 (Tran et al. 2017). The analysis showed that the combination of low-quality water supplies coupled with increases in conservation resulted in an increase in pollutants and TDS from 2011 to 2015. These pollutants included ions such as sodium, chloride, calcium, and nutrients, which saw increases between 8 to 16 percent (Tran et al. 2017).

Adaptation strategies and utility impact. Increasing salinity in recycled water could be addressed through additional treatment and blending of different quality effluents. At IEUA, different treatment trains were analyzed to improve wastewater effluent quality, and the most cost-effective solution was to blend effluent treated by membrane filtration (MF) with effluent treated through the MF and reverse osmosis (RO) (Tran et al. 2017). The incorporation of the desalination step can help to alleviate downstream salinity concerns but did increase treatment cost from \$0.69/m^3 (264 gal) to \$0.74/m^3 (Tran et al. 2017).

Utilities can also address increasing salinity by supplementing with potable water when necessary. The **San Francisco Public Utilities Commission**

(SFPUC) uses a centralized recycled water system to support large recycled water users such as public parks and golf courses, who are primarily located on the west side of SFPUC's service area (CUWA 2019). This recycled water system has the capability to be supplied via the potable water system instead if necessary, to address concerns in TDS (CUWA 2019). The coupled potable water system provides additional flexibility but undercuts the goals to support community needs with recycled water.

3.5 Reductions in Revenue

A changing Ri-gpcd standard that results in reduced indoor residential water use leads to less water being purchased from utilities, as well as less wastewater being produced. This decreases the revenue received by water, recycled water, and wastewater agencies. However, the magnitude of impact will depend on a number of factors including the type of rate structure and influence of Proposition 218, which specifies that water rates cannot exceed the cost of providing the service and requires new local taxes to be passed by two-thirds voter approval (PPIC 2018).

3.5.1 Financial Volatility if Water Use is Reduced

Planning for water use efficiency programs must be done carefully to mitigate revenue instability. The amount of revenue water service providers collect from customers is dictated by the rate structure, which are designed to achieve specific goals and are unique to each agency. Examples of water rate structures include flat rates (water revenue is independent of water use), uniform volumetric rates (revenue depends on water use), and block or tiered rates (revenue depends on water use and level of water use) (Pacific Institute 2013). Although flat rates provide the most stable revenue for agencies, they are uncommon in California, suggesting that volumetric rates that incentivize water use efficiency are important for most water agencies (Pacific Institute 2013).

During California's 2012-2016 drought, a 25-percent reduction in urban water use from 2013 levels caused more than 60 percent of all surveyed suppliers (173 California urban water suppliers) to experience declines in net financial positions by 2016 (Mitchell et al. 2017). For agencies with rates tied to volumetric charges, reduced water demand led to decreasing water sales that resulted in a direct reduction in revenue as shown in Figure 3-2. On the other hand, 35 percent of respondents said that the drought did not impair their net financial position (Mitchell et al. 2017). Investor-owned utilities were much more likely to report no impairment, as these supplies are not subject to Proposition 218 and were able to automatically implement surcharges to recover revenue shortfalls (Mitchell et al. 2017). Proposition 218's rate setting and public noticing requirements makes changing rates more complicated and less timely for public water suppliers, making them more vulnerable to revenue shortfalls from decreased water sales (Mitchell et al. 2017).

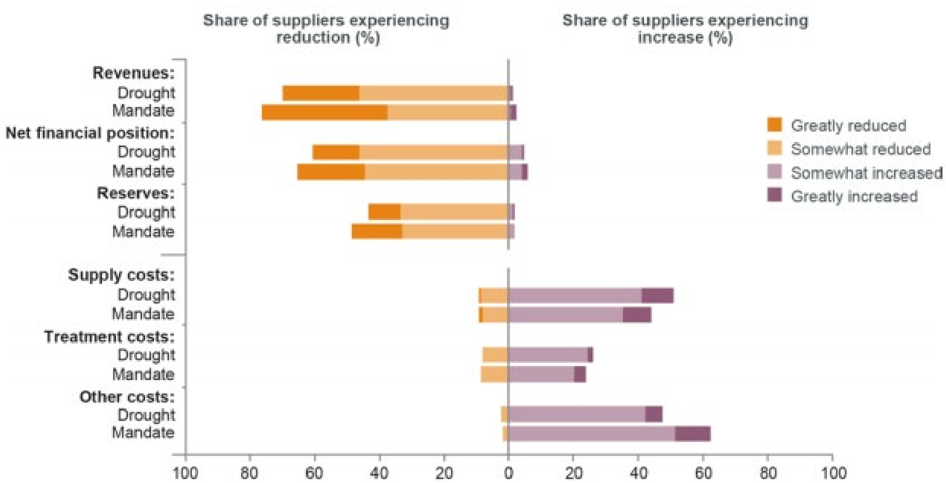

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Figure 3-2. A majority of surveyed suppliers experienced drops in revenue coupled with increased costs.

Source: PPIC 2016

In addition, many wastewater agencies derive at least some portion of their rate structure from a volumetric charge. Reduction in indoor urban water use therefore translated into reduced revenues coupled with increased costs in some cases (PPIC 2019).

3.5.2 Maintaining Customer Costs and Perception

Long term trends in water use have had long term impacts on water rates as well. A 2017 study on water rate trends surveyed 14 California counties and found that reduced usage from both drought restrictions and voluntary conservation efforts, as well as increased water costs and costs in general, have combined to increase water rates in the state since 2003 (Gaur and Diagne 2017). With a decrease in revenue from reduced volumetric charges, an increase in fixed charges is sometimes needed to make up the lost revenue. This can contribute to negative customer perception as lower water use does not necessarily translate into lower water bills.

Over the same period, median income remained stagnant, causing an increase in percentage of income needed for water. As this trend continues, customers below the median income will be disproportionately affected relative to customers with higher incomes (Gaur and Diagne 2017). It should be noted that a higher fixed charge will also have a greater impact on affordability for low-volume water users and provides less incentive to conserve (Gaur and Diagne 2017).

In addition, water is a rising cost industry as a result of expanding regulations, deteriorating infrastructure, as well as the cost of increased O&M. A 2019 CUWA study found that increasing costs have driven up residential water bills an average of seven percent per year from 2007 to 2014 as shown in Figure 3-3. The increase occurred at more than double the rate of inflation. In more recent years, bills declined due to emergency conservation during the drought. However, costs and water bills will begin to rise as the CUWA agencies invest in capital improvements (estimated at nearly $24 billion over the next 10 years) largely to address aging infrastructure, supply diversification, and other needs (CUWA 2019).

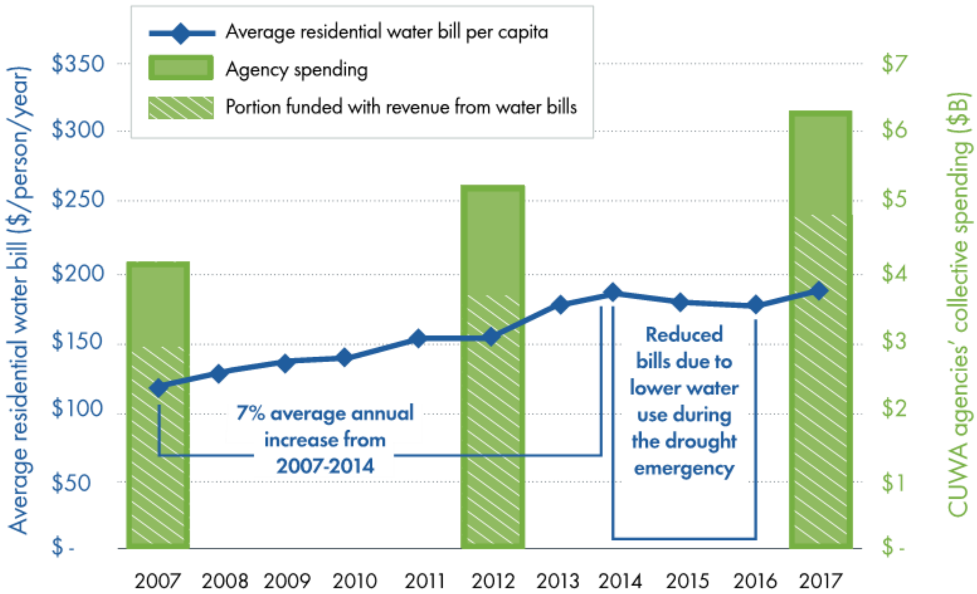

Figure 3-3. Reduced water use has impacts to revenue, which are needed to fund capital improvements.

Source: CUWA 2019

A strategy to mitigate negative customer perception of paying more for less is public outreach and education. This could include a clear communications strategy that explains that increases in water rates do not always mean increasing costs for all customers, as the water bills for efficient households may stay the same or even be reduced with volumetric pricing. The communications could also highlight the baseline O&M costs needed to transport and treat water, as well as the need to invest in projects that enhance supply diversification to increase climate change resiliency.

4.0 Case Studies

Four geographically diverse agencies participated in a case study to share the benefits and impacts they experienced at sustained reduced indoor residential water use. Representing a combination of water, wastewater, and recycled water systems, the agencies revealed the range of effects experienced as well as their technical, operational, and financial significance.

4.1 Case Study: Soquel Creek Water District & City of Santa Cruz

Soquel Creek Water District (SCWD) was founded in 1961 and located in mid-Santa Cruz County. SCWD has maintained water supply reliability through both reduced residential water use and investment in supplemental supplies. SCWD is investing in Pure Water Soquel, a groundwater replenishment program, as part of their water supply portfolio, which uses wastewater effluent from the City of Santa Cruz (Santa Cruz). Thus, the Santa Cruz wastewater treatment facility (SCWWTF) that feeds Pure Water Soquel has been included in this case study to present a fuller picture on the benefits and impacts of a changing Ri-gpcd.

4.1.1 Soquel Creek Water District Overview

SCWD provides water services to approximately 40,400 customers, and nearly 90 percent of them are residential and served via the Santa Cruz Mid-County Groundwater Basin. This water supply is designated by the state as a high-priority, critically overdrafted basin because the region relies 100 percent on this source as its sole source of supply (no state-imported water) and seawater contamination is actively occurring. In 2014, SCWD Board of Directors declared a Stage 3 Water Supply Shortage and Groundwater Emergency and has been requesting customers to reduce water use by 25 percent compared to 2013. SCWD manages 156 miles of pipe, 15 active groundwater wells, 18 storage tanks, and 80 groundwater monitoring wells. Their annual water production is approximately 3,334 acre-feet in 2018.

Highlights of SCWD's conservation programs include:

- Robust water conservation rebate program offering nearly 30 different indoor fixture and landscaping rebates
- Free Water-wise House Calls and the Go Green Program
- Water Demand Offset (WDO) Program. The WDO Program was implemented in 2003 and allows development to continue by requiring new development to offset their projected water demand by funding new conservation or supply projects within SCWD (SCWD 2019). The WDO

Policy (Resolution No. 19-18) requires development projects to offset approximately two times the amount of water they are projected to use so that there is a "net positive impact" on the District's water supply.

The SCWD employs a tiered rate structure in accordance with Proposition 218, which includes a monthly fixed service charge and a water quantity charge. Tier 1 reflects the amount of water the SCWD can safely supply to each household using the existing groundwater supply. Tier 2 represents water use that is above sustainable levels and requires the development of supplemental sources (i.e., potable reuse). There is a significant jump from Tier 1, $7.01 per unit of water (defined as 748 gallons), to Tier 2 at $31.82 per unit of water, which is reflective of these investments.

This supplemental water supply includes Pure Water Soquel, which is a groundwater replenishment and seawater intrusion prevention project. Santa Cruz will provide the tertiary effluent from the SCWWTF. The tertiary effluent will then go through membrane filtration, reverse osmosis, and ultraviolet light/advanced oxidation before being injected into the Santa Cruz Mid-County Groundwater Basin. Pure Water Soquel is intended to increase the sustainability of the SCWD’s groundwater supply, reduce the degree of overdraft conditions in the basin, prevent further seawater intrusion, and promote beneficial reuse by reducing discharge of treated wastewater by 25 percent.

4.1.2 City of Santa Cruz Overview

The wastewater system for the Santa Cruz is managed within the Public Works department and includes the SCWWTF. The SCWWTF was originally built in 1928 and designed to accommodate 17 mgd of average dry weather flow, and up to 81 mgd of peak wet weather flow. The treatment process at the SCWWTF includes primary treatment through bar screens, aerated grit chambers, and primary settling tanks. The primary effluent is then pumped to trickling filters, solids contact tanks, and secondary clarifiers with UV disinfection. The Pure Water Soquel project is then adding tertiary treatment to improve the quality of the wastewater before entering the advanced water purification process at SCWD.

4.1.3 Benefits of Reduced Residential Water Use

Driven by the reductions called for during the 2012–2016 drought, customers within SCWD dramatically reduced their water usage through both short-term behavior changes and long-term investments in water use efficiency. This was supported by SCWD's substantial conservation program, which offered a large variety of rebates to residential customers, including rebates for high efficiency clothes washers, drip irrigation retrofits, graywater to landscape, hot water recirculation systems, pool covers, pressure reducing valves, rain catchment, residential toilets, residential showerheads, turf replacement, and more (SCWD 2014). This supported substantial reduction of residential water use but was not without its costs.

This reduction in water use provided the following benefits for SCWD and Santa Cruz:

- **Reduced energy and chemical use for water treatment.** With lowered demands, less water needed to be pumped and treated for distribution. As such, chemicals used for treatment decreased, such as sodium hypochlorite (NaOCl) for disinfection and ferric chloride ($FeCl_3$) for coagulation, saving SCWD $10,000 in yearly chemical costs in 2016 as compared to 2013. Energy usage also declined 28 percent from 2013 to 2016, reducing total annual energy costs by $60,000. The long-term changes due to investments in water efficiency by customers has maintained the lower per capita use achieved during the drought, and their current yearly energy usage remains close to 2016 values.

- **Added flexibility in groundwater well pumping distribution.** SCWD manages 15 active wells within the groundwater aquifer. With the reduced demand, not all wells need to be active. This gives SCWD more flexibility to utilize the wells as appropriate to manage the groundwater basin. This flexibility is valuable as peak demand is close to their existing capacity and being able to use different wells to balance the groundwater basin supports operations.

- **Prevented the need to retrofit or expand existing groundwater wells.** The groundwater wells have become less efficient over the years.

However, the reduced demand means that SCWD can delay expenditures to improve the well reliability or drill new wells to increase their supplies.

- **Reduced overdraft in the groundwater basin, mitigating seawater intrusion.** SCWD is located right next to the ocean, where seawater intrusion into the groundwater basin is a concern. Reducing overdraft maintains pressure within the basin, mitigating further intrusion.

- **Increased community ethic around water use efficiency.** When SCWD first tried to pursue a source of supplemental supply, there was a desire from the community to conserve more. SCWD and the community worked together to reduce water use as the first step and have achieved significantly low per capita use. Now, with water conservation as a 'way of life' and the need to still protect the environment and develop additional water supplies, the community strongly supports the Pure Water Soquel investment since they have achieved what they could first through conservation.

4.1.4 Adverse Impacts of Reduced Residential Water Use

These successes in water conservation also have tangible adverse impacts, such as:

- **Reduced revenue per their tiered rate structure, resulting in rate increases and accompanying public education.** SCWD has a tiered rate structure that meets Proposition 218 requirements. As described above, there is a significant jump between Tier 1 and Tier 2. Due to reduced water demand, SCWD has also experienced a drop in revenue. However, as the costs to maintain and operate the water system remains unchanged, SCWD has had to increase overall rates every year for the past nine years.

- **Increasing wastewater effluent concentrations, requiring additional pretreatment.** Ammonia and nitrate concentrations increased in the wastewater influent and effluent that served the Pure Water Soquel program, triggering investment in additional pretreatment to improve influent advanced water purification facility (AWPF) quality. These increases resulted in the addition of pre-treatment (i.e., biologically activated filtration) in the advanced water treatment process, which may increase the overall cost of the program by 10 percent. This enhances the treatment process and supports protection of public health.

4.1.4 Key Takeaways

- Utilities that have limited source supplies and local emergency declarations as well as state mandates (such as SGMA) can experience more urgency to resolve supply and reliability issues and appreciate greater benefits from reduced demand due to conservation and WUE measures.

- Engaging the community early and often through outreach and public education can generate support through both increased conservation and the financial investment in alternative water supplies.

- Tiered rate structures serve as an effective strategy of encouraging conservation but have more significant impacts on revenue.

- Indirect potable water reuse projects like Pure Water Soquel require proactive planning and may include investments in pretreatment to account for increasing contaminant concentrations such as ammonia and nitrate.

4.2 Case Study: East Bay Municipal Utility District

The EBMUD is a large district that serves 1.4 million customers in portions of Alameda and Contra Costa Counties. EBMUD receives water from the Mokelumne River and collects it at the Pardee Reservoir, which has a capacity of roughly 200,000 ac-ft. They also store local run-off in East Bay reservoirs, which can be up to 21 mgd in a year of normal precipitation. This water is supplied to customers through an expansive distribution system that includes 165 distribution reservoirs, six water treatment plants, 130 pumping plants, and 4,300 miles of pipe. EBMUD also has a contract with the Bureau of Reclamation to purchase supplemental supply from the Sacramento River if necessary.

EBMUD also provides wastewater and recycled water services. Wastewater is collected throughout the East Bay in Northern California and centrally treated at their wastewater treatment plant in Oakland, CA. The wastewater treatment plant is sized for 320 mgd for primary treatment and 168 mgd for secondary treatment. On average, about 63 mgd of wastewater is treated daily. A portion of this wastewater then serves as the supply for their East Bayshore recycled water project. This recycled water supports mainly irrigation, which helps to offset potable water supply and reduce the discharge of treated wastewater into the San Francisco Bay. EBMUD has invested in infrastructure to provide over 9 mgd of recycled water and has a goal of increasing that to 20 mgd by 2040.

4.2.1 Benefits of Reduced Residential Water Use

EBMUD is conducting adaptive planning to continue delivering safe and reliable water supplies for their customers in the changing climate. Reduced water use provided the following benefits to enhance their water supply reliability:

- **Mitigated need to purchase supplemental supplies.** EBMUD has access to purchase supplemental supplies from the Sacramento River, if necessary, from the Bureau of Reclamation. These supplies are more expensive and require more energy to transport as compared to local sources as they are located miles away. By reducing water use and demand, EBMUD can serve their customers with only local supplies.

- **Reductions in energy use and associated GHG emissions due to decreased water demand**. With the water-energy nexus, moving less water also means using less energy. Water that is not used does not need to be treated or pumped to customers, reducing overall energy use.

- **Provides excess capacity to accommodate growth in EBMUD's wastewater treatment plant**. Average influent flows at the wastewater treatment plant used to be around 80 mgd, and they've now decreased to 50 mgd. As such, there is capacity to accommodate future population growth without the need to expand the plant.

4.2.2 Adverse Impacts of Reduced Residential Water Use

EBMUD experienced the following adverse impacts due to sustained reduced residential water use:

- **Took reservoirs offline as necessary to preserve water quality within the system.** EBMUD's water production was over 210 mgd in 1970 and water production dropped to below 130 mgd in 2015. Given this significant reduction in water production, the volumes in storage and flow rates through their distribution pipelines are significantly less than what the system was originally designed and constructed for. During low flow conditions, EBMUD closely monitors water quality effects such as nitrification due to increased water age and reduced turnover. For example, during the recent drought, EBMUD identified 24 reservoirs that were experiencing a degradation in water quality and quickly took them out of service. EBMUD is also addressing this risk over the long-term by retrofitting their 154 MG Central Reservoir to three tanks of 17 MG each.

- **Increased O&M to maintain high water quality.** With reduced water use, water was becoming stagnant at the extremities and dead ends within the system, such as cul-de-sacs. EBMUD implemented targeted flushing to address the issue coupled with a public education component to explain why flushing was necessary.

- **Increased costs to develop sources of supplemental wastewater supply to continue supporting recycled water customers.** EBMUD is dedicated to the use of recycled water to support industrial and commercial customers within their service area. Their current program has a production capacity of 9.2 mgd, with more than 80 percent of capacity serving industrial customers. EBMUD partners with West County Wastewater District (WCWD) to supply secondary effluent for use in its tertiary treatment plants that serve its industrial client. WCWD wastewater volumes have decreased by 2.7 mgd since 2002 and volumes during May through October are now inadequate to meet all of EBMUD's industrial demands. As such, EBMUD is exploring supplemental supply options with other partners, such as the City of Richmond, where the capital costs to upgrade treatment at the City of Richmond WWTP, expand EBMUD's Richmond Advanced Recycled Expansion (RARE) facility, and build recycled water conveyance totals up to $110 million.

- **Use of potable water during peak demand periods to supplement recycled water supply provided to industrial customers.** The North Richmond Recycled Water Project provides tertiary treated recycled water for industrial cooling towers. The RARE project utilizes advanced water treatment to provide higher-quality water for use in boilers for the manufacturing process. Given the decline in influent wastewater volumes, EBMUD has supplemented the recycled water provided to industrial customers with potable water to meet its contractual obligations.

- **Higher concentrations in salts and ammonia affect and limit recycled water customers.** Declining total volumes coupled with constant load result in higher concentrations of contaminants such as salts and ammonia. The higher salt concentration can potentially affect customers that use recycled water for landscape irrigation, as plants sensitive to high salt concentration can be harmed. High ammonia concentrations also limit industrial customers who have a desire to use recycled water but require water quality above and beyond the requirements of Title 22. EBMUD is working to increase their recycled water use to 20 mgd by 2040, and as such, are investing in a pilot study to understand what treatment processes can be used to improve recycled water quality.

4.2.3 Key Takeaways

- Systems that were appropriately designed during a time when demand was significantly higher can result in oversized systems that may be more susceptible to increased water age and their water quality effects. Utilities are already working to address those water quality challenges through mitigation strategies and long-term retrofits, which require additional capital and O&M costs.

- Reductions in water demand and wastewater production leaves excess capacity in treatment facilities to accommodate future population growth.

- Utilities want to support commercial/industrial customers with recycled water use to offset potable consumption but require the influent wastewater volumes to do so. Increasing contaminant concentrations and reductions in wastewater volumes can affect both recycled water quantity and quality, which will affect a utility's ability to serve and recruit customers.

4.3 Case Study: City of Fresno

The City of Fresno (Fresno) provides public utilities services, including water, wastewater, and recycled water to approximately 500,000 customers over a 114 square mile area. Originally, the only source of water for the Fresno came from its Sole Source Aquifer which also supplies many communities within the San Joaquin Valley. However, growing demand and continued groundwater pumping utilizing up to 260 groundwater wells created an overdraft condition in the aquifer. To address and mitigate these conditions, Fresno commissioned its first 30-mgd northeast surface water treatment facility (NESWTF) in 2004 (which will eventually be expanded to its ultimate capacity of 60 mgd), a 4 mgd package surface water treatment facility (T-3 Facility) completed in 2013 (which has a build-out capacity of 8 mgd), and the 80 mgd southeast surface water treatment facility (SESWTF) that was completed in 2018.

These surface water treatment facilities utilize existing water allocations through contracts with the Bureau of Reclamation and Fresno Irrigation District. Fresno also maintains multiple finished water reservoirs and potable water storage tanks comprising over 22 MG of potable water storage capacity. Potable water is distributed to their customers through approximately 1,780 miles of pipeline throughout the city.

Fresno's Wastewater Management Division is responsible for the collection, conveyance, treatment, and reclamation of wastewater within the Fresno-Clovis metropolitan area. Wastewater travels through approximately 1,600 miles of sewer lines to the Fresno-Clovis Regional Wastewater Reclamation Facility (RWRF). The RWRF receives approximately 58 mgd of wastewater. Five mgd of this total influent is treated at a disinfected tertiary level and distributed to users of recycled water including farmland, a cemetery, and a public park. Approximately 1 percent of the 5 mgd volume is distributed outside of the RWRF for farm or landscape irrigation. The rest is treated to a secondary level and distributed to a percolation pond network sitting on 1,700 acres within the RWRF's boundary. Approximately 6 to 12 percent of the secondary effluent is distributed to farmers for direct reuse to irrigate non-food crops, such as cotton and alfalfa.

4.3.1 Benefits of Reduced Residential Water Use

Fresno has significantly reduced their historical per capita usage, decreasing from above 300 R-gpcd in 2000 to 190 R-gpcd in 2015. This reduction in use was supported by implementation of an aggressive public outreach and conservation program, and installation of water meters throughout Fresno that track and manage potable water use. Fresno has experienced the following benefits due to this sustained reduction:

- **Supported recharge of the Fresno Sole Source Aquifer.** Over the last 100 years, the water level in the aquifer has declined from 30 ft. to 130 ft. below ground level. Fresno is now on track to meet SGMA requirements and its 2035 water resource goals to re-establish historic groundwater levels and attain a balanced and sustainable water resources portfolio. These efforts include installation of water meters and diversifying their supply through the use of surface water treatment plants and expansion of its groundwater recharge and conservation programs. These measures coupled with the reduction in demand has allowed them to turn off a substantial number of their groundwater wells to aid in re-establishing historic groundwater levels.

- **Less demand requires less transport and treatment of water, reducing energy and chemical usage.** Historically, Fresno's surface water supplies utilized for surface water treatment had been provided by an open channel conveyance system that inherently contained opportunities for contamination through irrigation and storm water runoff, agricultural processes, and through accumulations of suspended materials from natural flora and fauna. These conditions most often required substantial chemical treatment at surface water treatment facilities. Currently, source water pipelines installed from the Friant Kern Canal to the City's 30-mgd NESWTF and from the Kings River to its 80-mgd SESWTF now provide substantial water quality protection from potential contamination and natural events, thus reducing needed chemical/disinfection treatment quantities at the water treatment facilities. This source water protection coupled with reduced demand decreases overall energy and chemical usage.

4.3.2 Adverse Impacts of Reduced Residential Water Use

The continuous and sustained declines in water use has also resulted in impacts on their systems, including:

- **Increase in odor complaints in the wastewater conveyance system, requiring increased investment for odor mitigation.** Fresno has had an increase in odor complaints driven by increasing H_2S concentrations. As such, they have invested in H_2S meters and placed them around the city to locate where specifically the odors are originating from. Fresno currently uses carbon filters throughout their collection system to address the odor complaints, and they have invested more money to purchase additional carbon filters to address the increasing odors. In fiscal year (FY) 2011 to FY 2015, Fresno spent on average ~$13,300 per year on carbon filters. From FY 2016 to FY 2020, that has increased to an average of ~$25,800 per year.

- **Loss of scouring velocity in wastewater pipelines, leading to an investment in a water tender truck.** With declines in wastewater production and long stretches of pipe, there is a loss of scouring velocity to move solids. Fresno invested in a water truck that uses recycled water to flush the sewers and scour the pipe. This was a strategic $135,000 investment that will be used in multiple ways to support Fresno in addition to just flushing. For example, Fresno staff will also use the water truck to help with dust control during construction and as a supplemental water source when cleaning large lines.

- **Accelerated corrosion in wastewater manhole frames and covers, triggering a change in cover type.** Fresno has been witnessing an accelerated rate of corrosion in manhole covers and bases. With this corrosion, manholes have started to release into the street as trucks and cars drive over them. As such, Fresno has begun to invest in switching out their manhole covers on mains 27 inches or bigger with those that have a locking feature and are equipped with a full-face gasket that helps maintain its position even with heavy traffic.

- **Increasing BOD concentrations at the WWTP, which is carefully watched by plant operators.** The RWRF is a permitted 91.5-mgd facility that currently treats an average of 56 mgd. The discharge permit for the RWRF is based on discharge capacity, which the RWRF is well below. While the influent volumes have declined, the BOD concentrations and associated loadings have increased. The capacity of the RWRF is 230,000 pounds of BOD, and the monthly maximum experienced to date has been 200,000 pounds in August/September of 2020. Thus, plant operators are carefully tracking BOD concentrations and their seasonal pattern.

4.3.3 Key Takeaways

- Reduced water demand from conservation and WUE can support recharge of local groundwater basins, helping utilities achieve water resource goals and SGMA requirements.

- Collection systems with long, minimally sloped pipelines are more prone to reduced scouring velocity, leading to contaminant build-up and increasing H_2S concentrations in the collection network. Mitigation measures, like the use of flushing trucks, can provide benefits to the utility beyond just addressing the impacts of reduced wastewater production.

- The WWTP have both hydraulic and loading capacities, and reduced total volumes may result in higher contaminant concentrations that push plants closer to their loading limit. The WWTP also has unique discharge permit requirements that can be based on flow, percent removal, or specific contaminant concentrations. Increasing concentrations are more likely to affect those with load or concentration requirements, and less likely for those with maximum flow limits.

4.4 Case Study: City of San Diego

The City of San Diego (San Diego) provides drinking water, wastewater, and recycled water services to 1.3 million people. Its drinking water system includes nine surface water reservoirs, three water treatment plants, 29 storage facilities and approximately 3,300 miles of pipes. San Diego also provides wastewater services to 2.3 million people and treats an average of 156 mgd of wastewater at its three wastewater treatment plants. San Diego has witnessed a decline in influent since 2006, especially at the Point Loma Wastewater Treatment Plant (PLWTP), which represents the end of the pipeline for San Diego County. Influent flows at the PLWTP specifically have decreased from an average of 170 mgd in 2006 to 140 mgd in 2017.

Local water availability has always been a challenge for San Diego due to its location in the dry Mediterranean climate of southern California. On average, San Diego imports 85 percent of its water from the Bay-Delta and the Colorado River. Given San Diego’s climate and current reliance on imported water, there is a concerted effort to diversify their water supply portfolio through a potable reuse program called Pure Water San Diego. Pure Water San Diego will treat wastewater effluent through advanced water treatment processes such as membrane filtration, reverse osmosis, and ultraviolet-advanced oxidation process (UV-AOP). The water will then be reintroduced into the potable water system through surface water augmentation.

4.4.1 Benefits of Reduced Residential Water Use

- **Improved self-reliance through reduced dependence and purchase of imported water.** San Diego has achieved significant water savings by encouraging reductions in residential water use. This includes continual investments in customer rebates, creating policies and ordinances to promote water conservation, and public information and education campaigns. San Diego is striving to reduce its dependence on imported water from 85 percent to approximately 50 percent by investing in Pure Water San Diego and additional conservation. In San Diego's 2015 UWMP, water conservation values were estimated based on a continuation of conservation incentive and rebate programs. The projected estimation was approximately 8,900 afy of water to be saved in 2020, and approximately 6,700 afy of water in 2025.

4.4.2 Adverse Impacts of Reduced Residential Water Use

- **Increase in odors in conveyance system, which City mitigates through increased Bioxide® purchase and use.** San Diego provides wastewater services to its population as well as 15 participating agencies. As such, wastewater must travel a significant distance until it reaches a wastewater treatment plant. With reductions in water use, there has been a loss of scouring velocity in the wastewater collection system and increase in H_2S concentrations. This has led to an increase in odors, which the City mitigates with odor mitigation products such as Bioxide®. There was an increase in Bioxide® purchase from roughly 156,000 gallons in FYI 2010 to 226,000 gallons in FY 2017, increasing costs by $150,500 (City of San Diego 2018). This also led to an increase in deliveries at six pump stations from around 120 deliveries in FY 2010 to over 160 in FY 2017 (City of San Diego 2018).

- **Increased chemical use to address increasing concentrations (e.g., BOD and TSS) in wastewater influent.** The PLWTP is located at the endpoint of San Diego's wastewater system. San Diego's other wastewater treatment plants, such as North City, South Bay, and the Metropolitan Biosolids Center, all have waste streams that flow to PLWTP. The PLWTP is considered an advanced primary treatment that uses chemical for enhanced treatment. Thus, the plant uses more chemical than most primary treatment plants and can achieve near secondary treatment results. The average flow at PLWTP was 170 mgd in 2006, and the flow has now decreased to around 140 mgd despite increases in population. This leads to increases in wastewater concentrations, which requires more chemical use to achieve the required BOD and TSS removal per their NPDES permit.

- Reductions to source influent flow volumes for the Pure Water Program, potentially impacting Pure Water Program goals and increasing costs. The available wastewater within the sewershed was projected to effectively size the Pure Water Program, which aimed to produce 42 mgd for reuse (30 mgd potable, plus 12 mgd recycled) for Phase 1 and 83 mgd for Phase 2. Production of wastewater effluent volumes lower than the modeled wastewater values will make it more difficult to meet Pure Water Program goals and may require additional investments to divert supplement wastewater volumes to the WWTPs sourcing the Pure Water Program. A theoretical cost developed for moving a pump station 2 miles south to access and pump supplemental flows estimated an increase of $20 million in capital costs and annual increase of $50,000 in electrical costs (City of San Diego 2018). The design of the pump station in question is already completed, so it is unlikely that the pump station will be moved. However, this demonstrates the potential cost impacts from reduced total wastewater volumes.

4.4.3 Key Takeaways

- The City's reliance on imported water means that the cost and/or availability of water supplies is beyond the realm of the utility's control. This motivates the desire to develop local water supplies through both non-potable and potable reuse.

- While energy usage at a WWTP may decrease due to lower wastewater volumes, chemical use will go up as the chemical volumes required are tied to wastewater concentrations and not quantity.

- Water reuse projects that have already been designed are more likely to be affected by a changing Ri-gpcd, as treatment processes have already been designed to specific wastewater quality and quantities. Projects that are in the planning phases can effectively adapt to changing conditions and account for reduced indoor residential water use.

5.0 Key Findings

Existing literature and utility experience demonstrate that reductions in residential water use offers real benefits to water, wastewater, and recycled water systems, as well as significant impacts. The following findings are organized within the context of water and wastewater utilities, providing a holistic perspective as utilities work to balance the benefits of water use efficiency against adverse impacts on their finances, infrastructure, water quality, and operations. These impacts are then framed against utility characteristics that can either increase a utility's resiliency to reduced indoor residential water use or exacerbate the adverse impacts. Identification of utility characteristics in this way highlights how these unique factors need to be considered when informing potential adjustments to the Ri-gpcd standard.

5.1 Benefits and Adverse Impacts on Water Utilities

Reductions in residential indoor water use provides real benefits to water utilities, and utilities with source supplies that are sensitive to the impacts of drought and climate change can experience greater urgency and benefit around reducing per capita water usage. Reduced Ri-gpcd enables them to stretch existing water sources to support population growth and defer some level of investment in supplemental water supplies and expansion of existing systems. It also supports a community ethic around wise water use and demonstrates a utility's commitment to maintaining an affordable, yet sustainable water supply. This can also help rally community support for more costly supplemental supplies, as the utility has shown effort to first reduce per capita use. Lower water demand and flow rates through water treatment facilities also translate into lower treatment and pumping costs, due to chemical and energy use.

However, reductions in indoor residential water use could result in adverse impacts that utilities need to address. Specific utility characteristics can either reduce or exacerbate these adverse impacts of reduced flows, and this information is described in Table 5-1. More information regarding each adverse impact can be found in the respective section indicated.

Table 5-1 Water Utility Characteristics That Can Contribute to Adverse Impacts

Section #	Adverse Effect	Utility Characteristics
3.1.2	Deterioration of water quality due to increased retention time in distribution system	**Age of infrastructure.** Systems historically designed during phases of high population growth or commercial and industrial activities can now be oversized for current low-flow scenarios. Newer systems that used more current projections that consider the changes from increased conservation and water use efficiency tend to be better adapted to low-flow conditions. Systems that are older may also experience more corrosion and associated deterioration, lending to increased contaminant leaching. **Topography, size, and density of service area.** Systems that serve a large service area or low-density population require water to travel longer distances. This increases the potential for deteriorating water quality in the extremities of water distribution systems. A compact, high-density service area typically experience lower water age and may be more resilient. **System capacity.** Water systems are sized to supply both water demands and emergency and fire flows, which may require water systems to maintain high volumes of water throughout the distribution system. A reduction in water usage may further increase water age and exacerbate its associated adverse impacts on water quality. **Infrastructure material.** As water ages in distribution systems, there is more potential for the release of metals such as lead and copper, which has impacts on public health. Systems with pipes made of iron, lead, copper and other metals may be more susceptible to problematic metal release from increased retention time. This dictates the need to strengthen control of corrosion and metal release in low-demand conditions.
3.1.3	Stranded assets and	**Magnitude of change from initial design parameters.** Water treatment plants and storage facilities that were sized during times of larger water

Section #	Adverse Effect	Utility Characteristics
	stagnation challenges from reduced water quantity	demand from higher per capita use or to support commercial/industry end-users may now be oversized due to investments in conservation and water use efficiency. As the necessary capacity has decreased, the excess infrastructure may result in stranded assets.
3.5	Reductions in revenue from reduced water sales	**Type of rate structure.** With successful reductions in Ri-gpcd also comes a reduction in revenue, especially for utilities with tiered rate structures that follow changes in volumetric use. However, utilities with rate structures less sensitive to the change in water demand, such as flat or straight volumetric rates, will have a more stable source of revenue.

5.2 Benefits and Adverse Impacts on Wastewater Utilities

Increased water use efficiency provides some benefits to wastewater utilities, such as a reduction in energy usage as less wastewater is needed to be pumped through the treatment process and to the discharge point. Decreased wastewater influent volumes also allow for additional wastewater treatment plant hydraulic capacity that can accommodate future population growth. However, it is the inverse for wastewater treatment plants as contaminant concentrations increase due to maintained loading capacities yet a decline in volume. Specific utility characteristics can similarly either reduce or exacerbate the adverse impacts of reduced indoor residential water use, and this is presented in Table 5-2.

Table 5-2. Wastewater Utility Characteristics that Lend to Resiliency or Vulnerability to Adverse Impacts

Section #	Adverse Impact	Utility Characteristics
3.2.1, 3.2.2	Increase in odors and accelerated corrosion from higher sewer gas concentrations	**Age of infrastructure.** Utilities with infrastructure constructed a long time ago may be more susceptible to odor leakage and accelerated corrosion as sewer pipelines have deteriorated and corroded over time. Infrastructure that is designed and constructed more recently, i.e., with consideration for lower water demands and reduced Ri-gpcd, may already be considering these potential impacts in their design criteria and thus be more resilient. **Topography, size, and density of service area.** In areas where wastewater move by gravity, long stretches of flat pipeline will provide more time for H_2S production, exacerbating odor production and corrosion. Systems with greater slopes, shorter distances, and high-density between wastewater production to treatment may be more resilient to increased odor production as wastewater is able to continue moving quickly through pipes. **Infrastructure material.** Non-epoxied concrete is sensitive to corrosion, and utilities have witnessed the greatest rate of corrosion at concrete manholes. Existing areas with concrete infrastructure will experience the adverse impacts of accelerated corrosion most heavily. Infrastructure that mitigates against corrosion, such as plastic pipe, steel, or epoxy, will be more resilient to accelerated corrosion.

Section #	Adverse Impact	Utility Characteristics
3.2.3	Increased occurrence of sewer blockages and overflows	**Pipeline diameters.** Pipelines with smaller diameters (e.g., 4 to 6 inches) are more easily clogged and thus more susceptible to sanitary sewer blockages and associated overflows. These blockages are exacerbated by increasing solids concentrations from reduced Ri-gpcd. Conversely, wastewater systems with substantially larger diameters may be less prone to blockages.
3.3.1,3.3.2	Impacts on wastewater effluent quality and increased chemical use from degradation of wastewater influent quality	**Customer demographic.** Utilities serve a unique make-up of customers, which is split between residential, commercial, or industrial. Those with greater percentages of commercial/industrial customers will experience less overall change in both wastewater quality and quantity as residential customers reduce their indoor water use. However, utilities with predominantly residential customers will experience greater shifts in quantity and contaminant concentrations, which can impact treatment plant operations. **WWTP treatment process.** As population remains stable, mass loadings also remain consistent. However, declining Ri-gpcd result in increased concentrations of organics, nutrients, and contaminants. WWTPs that use treatment processes that have loading limitations, such as activated sludge, nutrient removal, or biosolids handling, will be more sensitive to this increasing load in influent wastewater. Addressing this increased load could trigger changes in operations or increased chemical use to meet effluent quality targets. WWTPs with treatment processes that are driven hydraulically will be more resilient to changing wastewater quality.

Section #	Adverse Impact	Utility Characteristics
		NPDES permit requirements and discharge point. Increasing contaminant concentrations in the wastewater influent result in subsequently higher concentrations in the effluent. Thus, WWTPs that discharge into sensitive water bodies with strict NPDES discharge limits may require operational adjustments to continue meeting effluent requirements. This is particularly true for those with specific contaminant concentration limits that they have to meet. WWTPs that have NPDES permits that set hydraulic or percent removal targets will be more resilient to increases in wastewater influent.

5.3 Benefits and Adverse Impacts on Recycled Water Projects

An increased community ethic around conservation and water use efficiency can bolster the same ethic for use of recycled water. An understanding of water scarcity can also create community support for water reuse projects as utilities shift their reliance from imported to local supplies. However, the adverse impacts experienced on wastewater effluent quantity and quality subsequently affect the quantity and quality of recycled water projects. The specific utility characteristics that can influence or exacerbate the adverse impacts of reduced indoor residential water use are presented in Table 5-3.

Table 5-3. Characteristics that Lend to Resiliency or Vulnerability for Recycled Water Projects

Section #	Adverse Impact	Utility Characteristics
3.4.1	Limiting the offset of potable use from reductions in recycled water production	**Water supply source.** Recycled water serves as a way to offset potable use and continue to meet community demand. This is valuable in locations where potable supplies are limited and sensitive to climate change. Reductions in recycled water production can limit a utility's ability to offset potable consumption of supply sources. **Discharge requirements.** Limiting the offset of potable consumption can be further exacerbated by WWTP discharge requirements that are flow-based. For example, some WWTPs are required to discharge certain volumes to help maintain stream flows. Meeting this requirement reduces the amount of wastewater available for reuse, which is further impacted by reductions in wastewater influent.
3.4.2	Deterioration in recycled water quality from worsened wastewater effluent quality	**Customer demographic and end-uses**. The quality and quantity of recycled water to be produced is informed by customer demand and requirements. Systems that serve customers that require high-quality water quality (e.g., industrial processes or potable reuse) will be more susceptible to the impacts of increasing concentrations in wastewater effluent. **Existing or planned investments.** Utilities throughout California are planning, designing, or constructing water reuse projects. Reductions in wastewater influent volumes and changes in wastewater quality will more greatly impact projects that are already in design or under construction. Utilities that are still in the planning phase can more readily adapt and incorporate changes in wastewater quality and quantity into their design criteria.

5.4 Potential Future Refinement

Public utilities across California have demonstrated their ability to adapt to adverse impacts of a changing Ri-gpcd through a variety of mitigation strategies. However, these adaptations require time and money, the extent of which will depend on utility-specific characteristics.

This study is a qualitative assessment of the benefits and impacts of a changing Ri-gpcd standard, as quantifiable data specific to standards are not yet available. Instead, this study leveraged utility experiences during the recent drought as a surrogate to represent a changing Ri-gpcd in locations where indoor residential per capita water use was low or decreasing to identify benefits and impacts.

This qualitative assessment could be improved through the collection of quantifiable data. A data set that includes more utilities and unique system characteristics, which exacerbate or reduce impacts of adverse effects, is warranted. Characteristics that should be incorporated into future data sets could include system age, the magnitude of change between water system design criteria and the Ri-gpcd standard, customer demographic, service area topography, type of WWTP treatment process, and NPDES discharge permit requirements.

Based on this enhanced understanding, utilities can help inform a realistic timeframe for standards implementation or the funding needs to support adjustment to the changing Ri-gpcd standard.

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