Inventory of Municipal Wastewater Discharges to California Coastal Waters

HEAL THE OCEAN

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To access the online interactive study, click here:
https://www.wastewater-inventory.healtheocean.org/

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Acknowledgments

This study was undertaken in the spirit of the California Water Action Plan, which states:

> *"Collaboration is essential. Successful implementation of this plan will require increased collaboration between state, federal, and local governments, regional agencies, tribal governments, and the public and the private sectors."*[1]

In that vein, this work would not have been possible without the help of dedicated professionals at the California Department of Water Resources, the State Water Resources Control Board, and the Regional Water Quality Control Boards, who, day-in-and-day-out, strive to preserve the state's natural resources on behalf of all Californians and the environment. We are sincerely grateful to the staff at these agencies for meeting with the project team, answering questions, and providing key data over the course of this project. The research team would also like to thank the following individuals: H. Michael Ross, PE, for lending his technical knowledge and experience to this effort, as well as his convictions for the promise of open data at all levels to help human and environmental health, wealth, and safety; PhD candidate Josie Lesage, for providing excellent feedback on the final contents of this study; and Heal the Ocean's own Hillary Hauser, for her unending commitment to water sustainability in California.

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Abstract

417 billion gallons of treated municipal wastewater were discharged from treatment plants at fifty-seven locations directly into California coastal waters, including the Pacific Ocean and the San Francisco Bay, in the 2015 calendar year. Other than serving as a disposal method, direct municipal discharges to these coastal water bodies have no clear benefit to the environment or water supplies. If an aggressive 85% of 2015 municipal wastewater effluent from coastal treatment plants were recycled and used to offset or supplement drinking water supplies, 28.61% of urban water use in California's coastal regions could have been supplied. If California had recycled 63.3% of total municipal wastewater flows to coastal waters in 2015, it would have made its 2020 recycled water production goal. Engineering feasibility and financial considerations will be significant factors in determining the viability of using existing coastal wastewater discharges for increasing recycled water production.

Introduction

Recycled water — the beneficial reuse of wastewater — is a key component of California's water policy efforts. The California Water Action Plan, adopted in 2014 and updated in 2016 to guide the state's water resource efforts, specifically cites recycled water as a key strategy for meeting the state's water demand.[2] The state's recycled water goals, which were adopted to set a target for water recycling efforts throughout California, aim to increase annual recycled water production by 497 billion gallons (1 million acre-feet) by 2020 and 823 billion gallons (2 million acre-feet) by 2030 above the 2002 baseline of 171 billion gallons (.525 million acre-feet).[3] More generally, the state's Recycled Water Policy encourages the substitution of "as much recycled water for potable water as possible by 2030."[4] Furthermore, recycled water is an increasingly important component of California's water portfolio. The California Department of Water Resources (DWR) and the State Water Resources Control Board (State Water Board) found that California reused approximately 233 billion gallons (714,000 acre-feet per year) of recycled water in 2015, representing an increase of 45,000 acre-feet since 2009.[5]

The state of California permits the repurposing of treated municipal wastewater for use in recycled water projects that serve a variety of purposes, including irrigation, industrial water use, wetland/habitat restoration, groundwater recharge, and as barriers to seawater intrusion.[6] These projects are split into "non-potable" and "potable reuse" categories, depending on the level of treatment achieved and the planned end use of the recycled water. Potable reuse projects further fall into one of two categories based on the indirect or direct use of the treated water. Indirect potable reuse projects, which augment groundwater aquifers or surface water reservoirs with highly treated recycled water for later use as drinking water sources with highly treated recycled water, are currently permitted and in operation in California. Direct potable reuse projects, which would directly supplement drinking water systems with highly treated recycled water, are not yet in-place or permitted in California. However, the state developed a framework document for direct potable reuse in 2018 and is required to adopt rules governing the permitting of these projects by 2023.[7; 8] The state has also already released an extensive research document evaluating the safety and feasibility of this project type, in addition to recommending avenues for further research.[9]

Volumetric estimates from past studies suggest that coastal wastewater discharges could represent a significant contribution to California's water needs. In 2003, DWR found that the entire state, including inland dischargers, treated and discharged 1.6 trillion gallons (5 million acre-feet per year).[10] Heal the Ocean's previous inventory estimated that California municipal wastewater facilities discharged approximately 492.75 billion gallons to the Pacific Ocean in 2005; however, this figure only included facilities discharging directly into the Pacific Ocean and excluded facilities discharging into the San Francisco Bay.[11] A study of 2016 state wastewater data by researchers at Humboldt State University found that 470 billion gallons of treated wastewater could be available for diluent water in new desalination projects along the coast of California.[12]

Other studies have inferred estimates of current waste-water discharges and potential recycled water production in the state using data on population, water use, and other factors. In a 2014 study, the Pacific Institute and the Natural Resources Defense Council estimated that 391 to 586 billion gallons per year could be recycled in California, with an estimated 293 to 358 billion gallons of this total available for recycling in coastal regions.[13] The WateReuse organization projected that California-based wastewater facilities would discharge approximately 841 billion gallons per year by 2020.[14] WateReuse further estimated that 366 billion gallons of this total could be recycled by 2020.[15]

Study Scope

This study documents the volume of treated municipal wastewater discharged directly to the Pacific Ocean and coastal bays in California in the 2015 calendar year and addresses the potential to increase recycled water production using this water. The study was limited to only coastal municipal wastewater facilities that discharge directly to a coastal water body as these wastewater discharges provide no clear downstream benefit to water supplies or the environment. In other words, we exclude inland discharges from this study, as they may already have beneficial uses. For instance, the 2013 California Water Plan states, "Discharged treated wastewater supplements river flow and can be a downstream benefit for wetland or aquatic habitat, or withdrawn by a downstream river water user."[16] While inland wastewater discharges may provide instream flow that benefits the environment or water supplies, direct municipal wastewater discharges to the Pacific Ocean or a coastal bay are considered to have no equivalent benefit.

The entire volume of wastewater discharges covered in this study is limited to the 2015 calendar year. This year offers a useful benchmark for water supply planning purposes because any flows reported for 2015 are likely to constitute a conservative estimate of total available flows. First, wastewater volumes are a function of indoor water use. In 2015, Californians continued to undertake conservation actions that had a substantial impact on total water use.[17; 18] To the extent that these efforts also affected indoor water use, total wastewater volumes would be expected to fall by comparable amounts. Second, 2015 was a dry year. Less precipitation would lead to less infiltration of rainwater into wastewater systems.[19; 20] Together, these two phenomena point to 2015 representing a lower-bound estimate of the current availability of treated municipal wastewater for potential water recycling projects in California. However, it is critical to note that 2015 is just a single point-in-time estimate. Additional water efficiency/conservation or water recycling after 2015 would cause a further decline in the total available volume of wastewater.

Finally, this study does not make definitive claims about the feasibility of recycling all or part of wastewater flows for coastal municipal wastewater facilities in California. Instead, it is intended to provide a foundation of data to support further research and dialogue on the future of water recycling in the state.

Figure 1: Map of Regional Water Board Jurisdictional Boundaries (Coastal Regions)

Methodology

This analysis undertakes a combination of both qualitative and quantitative data collection and analysis. This includes manual data entry of facility information collected from National Pollutant Discharge Elimination System (NPDES) permits, flow data from the California Integrated Water Quality System Project's (CIWQS) Electronic Self-Monitoring Report (eSMR) system, and information obtained through contact with each of the six coastal Regional Water Quality Control Boards (RWQCBs) that have jurisdiction over all coastal municipal wastewater facilities in California (see Figure 1).

The two primary methodological tasks of this study were to develop a list of municipal wastewater facilities discharging to the Pacific Ocean/coastal bays and to collect flow data for those facilities.

Database of Municipal Wastewater Facilities

The research team relied on two primary sources for compiling the list of coastal facilities discharging to the Pacific Ocean or a coastal bay. First, we consulted a list of dischargers from Heal the Ocean's previous wastewater inventory.[21] Second, we contacted the Regional Water Board in each coastal region to identify any additional coastal dischargers.

Based on this dischargers list, we used the State Water Board's "Facility at a Glance Criteria" system[22] to identify and save NPDES permits for each facility. In instances where an up-to-date or relevant NPDES permit for a facility could not be identified through this system, the research team used the adopted permits available on the individual websites for each Regional Water Quality Control Board (Regional Water Board).

Qualitative and quantitative data collected from NPDES permits included discharge point latitude and longitude, permitted water quality/flow monitoring location(s), receiving water body title(s), qualitative description of wastewater effluent, and permit expiration date. The research team recorded all data from NPDES permits in an MSExcel database, which is available in the Technical Appendix.

Monitoring locations and facility names were used as the primary mode of identification in the study. These monitoring locations – as provided in "Table E" of facility NPDES permits – name and describe the location where periodic monitoring is required, as regulated by the facility's permit. This monitoring occurs prior to discharge of treated effluent to a receiving water body – referred to as "discharge locations" throughout this study.[23] In most cases, NPDES permits provide precise coordinates for discharge locations but not for monitoring locations. Any facility-specific coordinates shown in this study indicate the discharge locations as given in the facility's NPDES permit.

To ensure that our list of facilities included only coastal dischargers, we conducted a series of quality control tests based on information collected from facility NPDES permits. Specifically, the research team identified facilities discharging to the Pacific Ocean or a coastal bay via the "receiving water body" field, as documented in each facility's NPDES permit. All records that included "Pacific Ocean," "bay," or a close variation thereof were marked as coastal dischargers. Any receiving water body type described as a "creek," "marshland," "wetland," "river," or a close variation thereof were marked as non-coastal dischargers. The research team also conducted a visual examination of a map of all discharge coordinates by using the latitude and longitude records of each facility's discharge location(s) as documented in its NPDES permit. These coordinates were formatted for review in Google Earth using an xml to kml converter.[24] Each discharge location was categorized as "ocean," "bay," "inland," or "border." In cases that were marked "border" (i.e., where it was unclear whether the discharge coordinates were inland or directly in the ocean or a coastal bay), the official receiving water body designation, as indicated by the NPDES permit, took priority. Finally, the research team identified monitoring locations with NPDES effluent descriptions that included "secondary-treated effluent," "tertiary-treated effluent," or a close variation thereof. This information on effluent, receiving water body, and discharge coordinates were combined so that only locations that met all criteria were marked for further analysis.[25; 26]

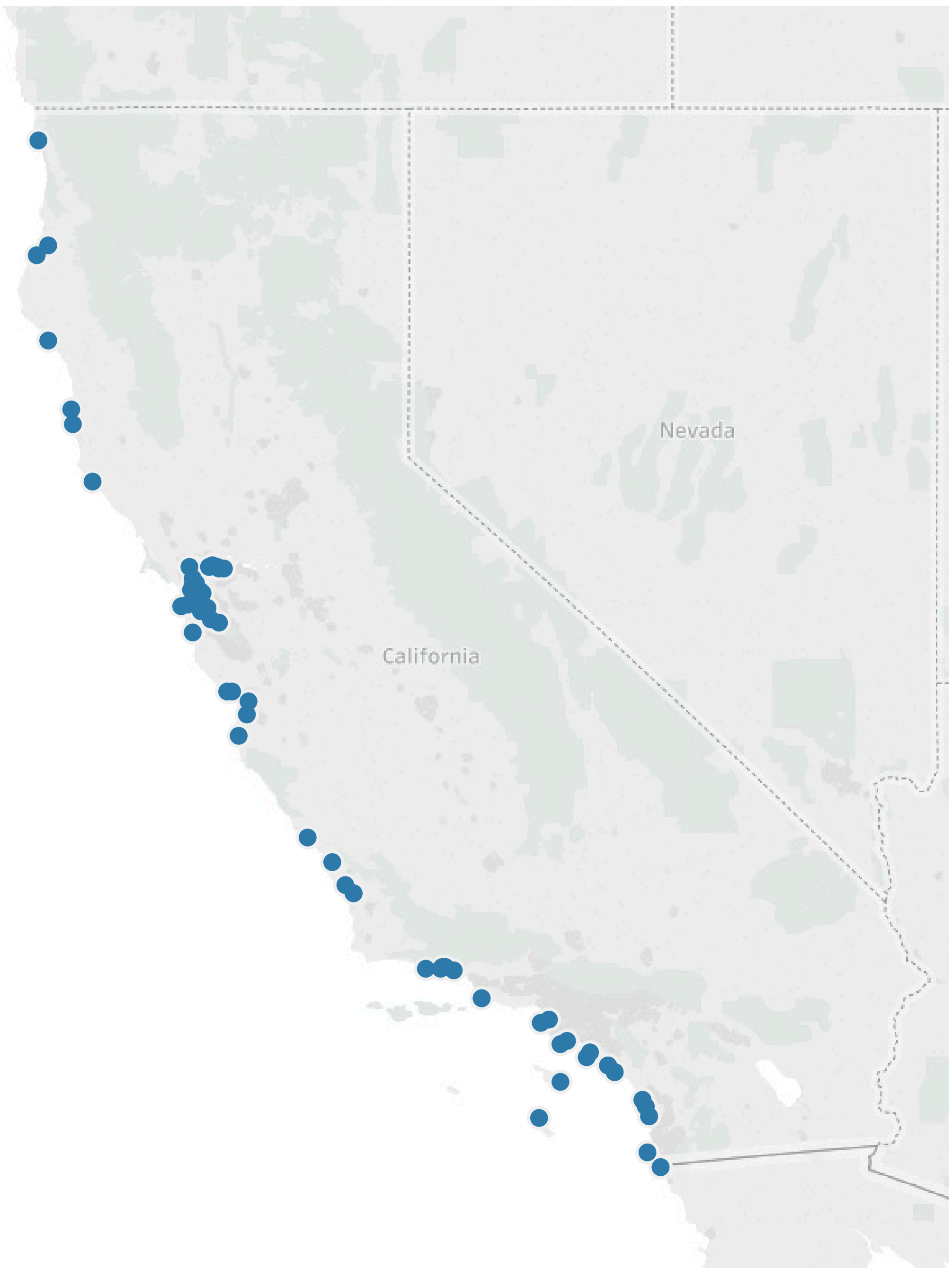
Based on this analysis, some monitoring locations in the San Francisco Bay region were marked as "indirect discharges." This was due to the fact that these facilities are not directly discharging into the Bay (e.g., facilities may be discharging to an adjacent "channel) and, thus, violate the conservative conditions in this study to include only "direct" dischargers. These locations, however, may hold additional water recycling opportunities; therefore, we report data for these cases within a separate category.[27]

Flow Data for Coastal Dischargers

Flow data for wastewater treatment plants identified as coastal dischargers was collected primarily from the State Water Board's Electronic Self-Monitoring Reports (eSMR) Data Report system.[28] eSMR is a component of the California Integrated Water Quality System (CIWQS) project and reports data from dischargers' self-monitoring reports. As a condition of their NPDES permits, California-based wastewater treatment plants are required to submit the results of their monitoring programs, including flow data, to eSMR.

For this study, flow data was obtained through the eSMR data portal on a region-by-region basis. The only qualifiers used to filter the data collected through eSMR

Figure 2: Universe of Discharge Locations



were the “region” and “sample date” – 1/1/2015 to 1/1/2016 – to maximize the likelihood of capturing data relevant to this study.

In some instances, our research revealed eSMR effluent data for individual facilities were missing for individual days, months, or even an entire year. In these cases, data was successfully solicited from individual facilities and Regional Water Boards. There were seven facilities for which this occurred: Novato & Ignacio Wastewater Treatment Plant, Monterey Regional Water Pollution Control Agency Regional Treatment Plant, Carpinteria Sanitary District Wastewater Treatment Facility, City of Scotts Valley Wastewater Treatment Facility, Oxnard Wastewater Treatment Plant, San Clemente Island Wastewater Treatment Plant, and Fallbrook Public Utility District Treatment Plant No. 1. Effluent data was ultimately unavailable for South San Luis Obispo SD Wastewater Treatment Plant and Morro Bay/Cayucos Wastewater Treatment Plant. In the absence of effluent data for these two facilities, we report influent data that is available in public records.

For almost all facilities, the raw data in eSMR was categorized based on the entries for the “Calculated Method” or “Analytical Method” fields. Entries in the Calculated Method field included variations on “Daily Average Flow (Mean),” “Daily Discharge,” etc. For each facility, daily data listed under the Calculated Method field was prioritized over all other data. If that was unavailable, the research team used data categorized under the Analytical Method field. When daily data was unavailable or not reported, available monthly data was used, including data solicited outside of eSMR. In instances where individual daily records are missing in any single month, but not the full month, this study assumes that these missing observations represent days when the facility did not discharge any treated effluent to the corresponding receiving water body. In many cases where facilities only reported flow for some days of the year, the research team confirmed with the associated Regional Water Board or individual facility that an absence of data observations truly represented the absence of flow on those days.

In some instances, duplicate daily records were found in eSMR data sets. This included cases where duplicate daily data was categorized under Calculated Method as both “Daily Average Flow (Mean) and “Daily Discharge.” Duplicates were removed in the course of cleaning the raw data from the eSMR system.

After the data was cleaned to only include one reported discharge record per day (or month) per facility, the research team summarized the data by month and year. Furthermore, each daily or monthly observation was counted to ensure the results were not duplicative. As can be seen in the Technical Appendix, data for all facilities do not exceed 365 observations for daily data or 12 observations for monthly data.

All data cleaning was conducted in Stata, a data analysis and statistical software. To ensure the reproducibility of this work, the raw eSMR data files and the associated Stata files used to complete our analysis are available along with this study (see the Technical Appendix).

Combining Databases

The eSMR database and the Dischargers database were merged using the “facility:location” field as a unique identifier. In some instances, eSMR reported a different monitoring location name than what was listed in the facility permit. In other words, there was not a one-to-one correlation between the facility:location names in the Dischargers database and the data available in eSMR. While discrepancies in facility names were not significant, discrepancies in monitoring location titles for a given facility were much more prevalent. Thus, in many cases, the research team selected the most reasonable location match between the two data sets. The combined database constructed for this study retains the facility:location fields for both data sources (differentiated by “permit” and “esmr” in the Technical Appendix) with the goal of making these matching decisions fully transparent.[29]

Results

In 2015, municipal wastewater treatment plants (WWTPs) in California discharged 417.494 billion gallons of treated effluent at fifty-seven discharge locations into the Pacific Ocean or a coastal bay.[30] This is equivalent to approximately 1.144 billion gallons per day or 1.28 million acre-feet per year.

Figure 3 shows the volume of treated effluent in 2015 for the largest twenty-five WWTP's. The Joint Water Pollution Control Plant, located in the City of Carson, had the highest recorded flows in 2015 at 94.328 billion gallons, representing 22.59% of total statewide treated municipal flows. The top two WWTP's by flow – the Joint Water Pollution Control Plant and the Hyperion Wastewater Treatment Plant, located in the City of Los Angeles, accounted for 42.35% of total coastal treated municipal flows. Furthermore, the top twenty-five facilities alone make up 93.76% of total flows at the fifty-seven discharge locations identified in this study.[31]

While 2015 was a dry year across the state in a multi-year drought, municipal flows still followed a general pattern of reduced volumes during the spring and summer months and increased volumes during the winter. The San Francisco Bay region had the most pronounced change in flows over the course of 2015 – total treated discharges in this region spanned from a high of about 9.42 billion gallons in December to a low of 6.9 billion gallons in September. Seasonal trends in wastewater volumes in California are generally associated with infiltration from groundwater and inflow from rainfall (see "Limitations and Barriers" below for further discussion of these issues).

Figure 3: 2015 Treated Municipal Flows by Facility

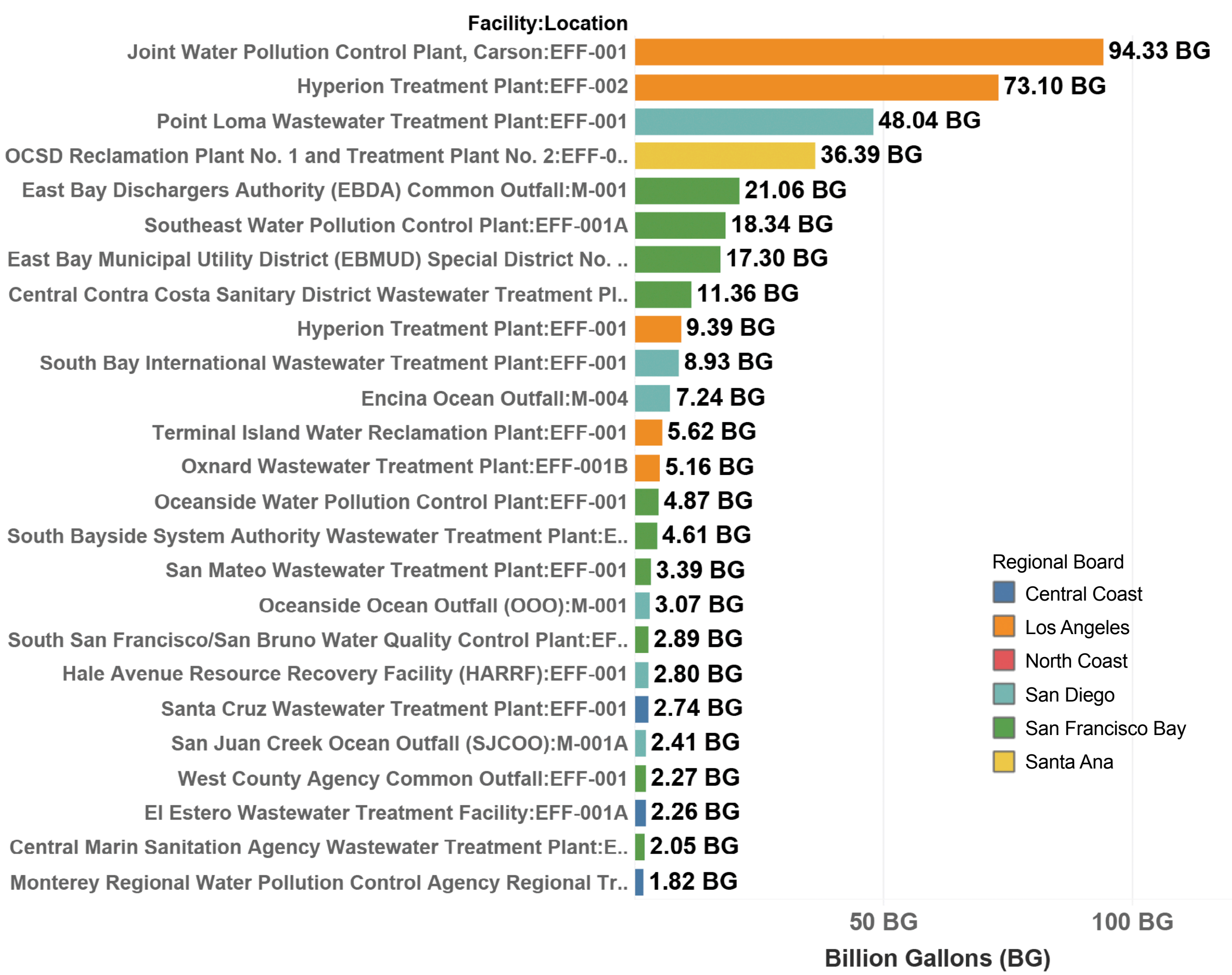
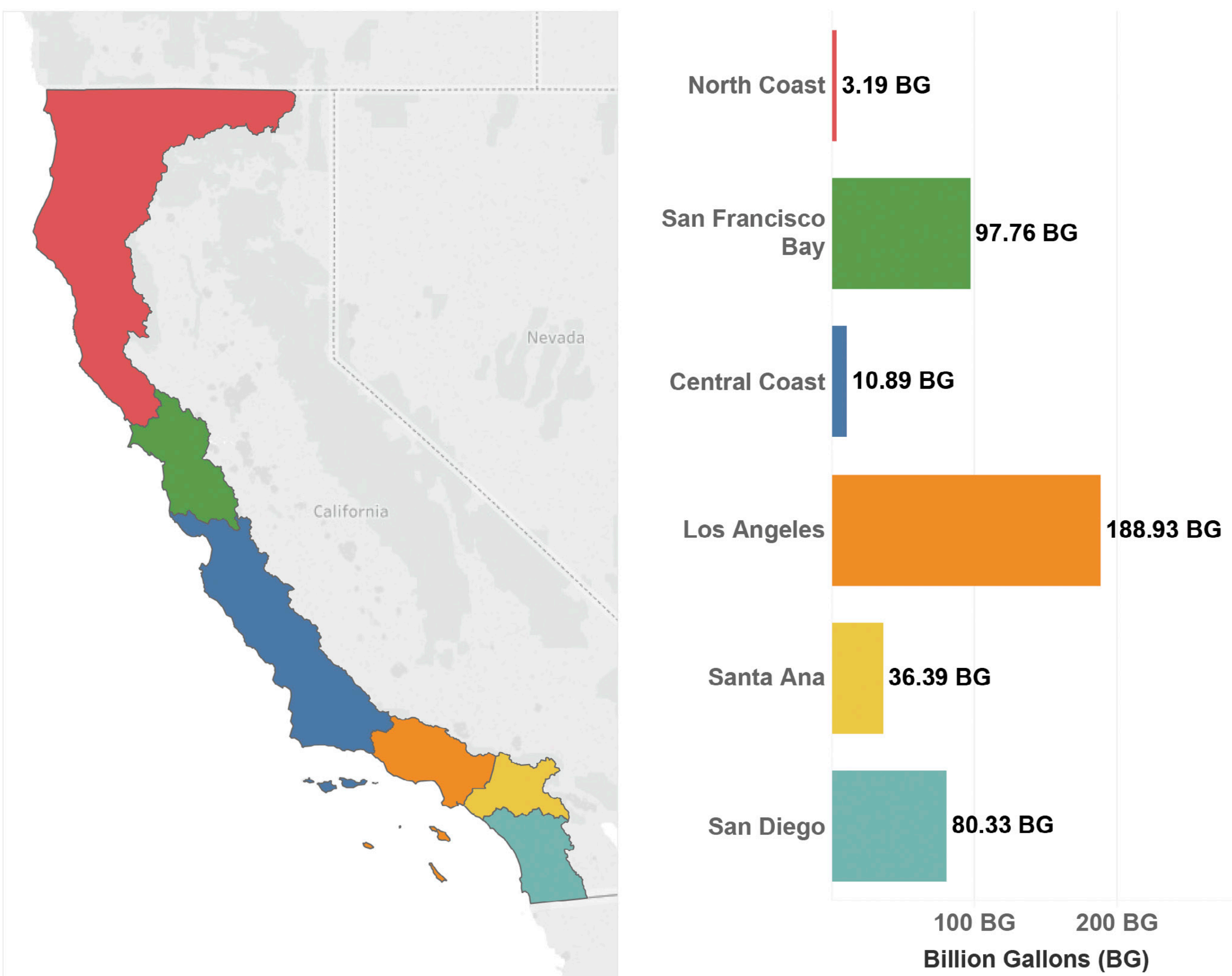


Figure 4 shows a map of the jurisdictional boundaries for each Regional Water Quality Control Board, as well as the total treated municipal flows for WWTPs in each region. As is expected, WWTPs serving California's largest population centers, particularly WWTPs in the San Francisco Bay and Los Angeles regions, generate the largest volumes of treated effluent.

Data Quality Control

To check the accuracy of the available flow data and to provide verification of the robustness of these results, we conducted quality control checks to compare annual flow data against the design flow of each WWTP.[32] Figure 5 shows two different methods for calculating the volume of treated municipal effluent as a share of the facility's design flow. Both methods take a measure of recorded flow and divide it by the design flow. However, given the incomplete nature of daily flow data from eSMR, two different methods were used to normalize each facility's recorded flow. First, Method #1 is attained by dividing the facility's treated flow for 2015 by 365. The drawback to this method is that each facility did not discharge on all days of the year in 2015. Method #2 is designed to address this drawback by dividing by the number of days when discharges occurred. However, this method is limited by the fact that some facilities only reported monthly instead of daily values. Thus, Method #2 assumes that in instances of monthly reporting, discharges occurred on all days of the month.

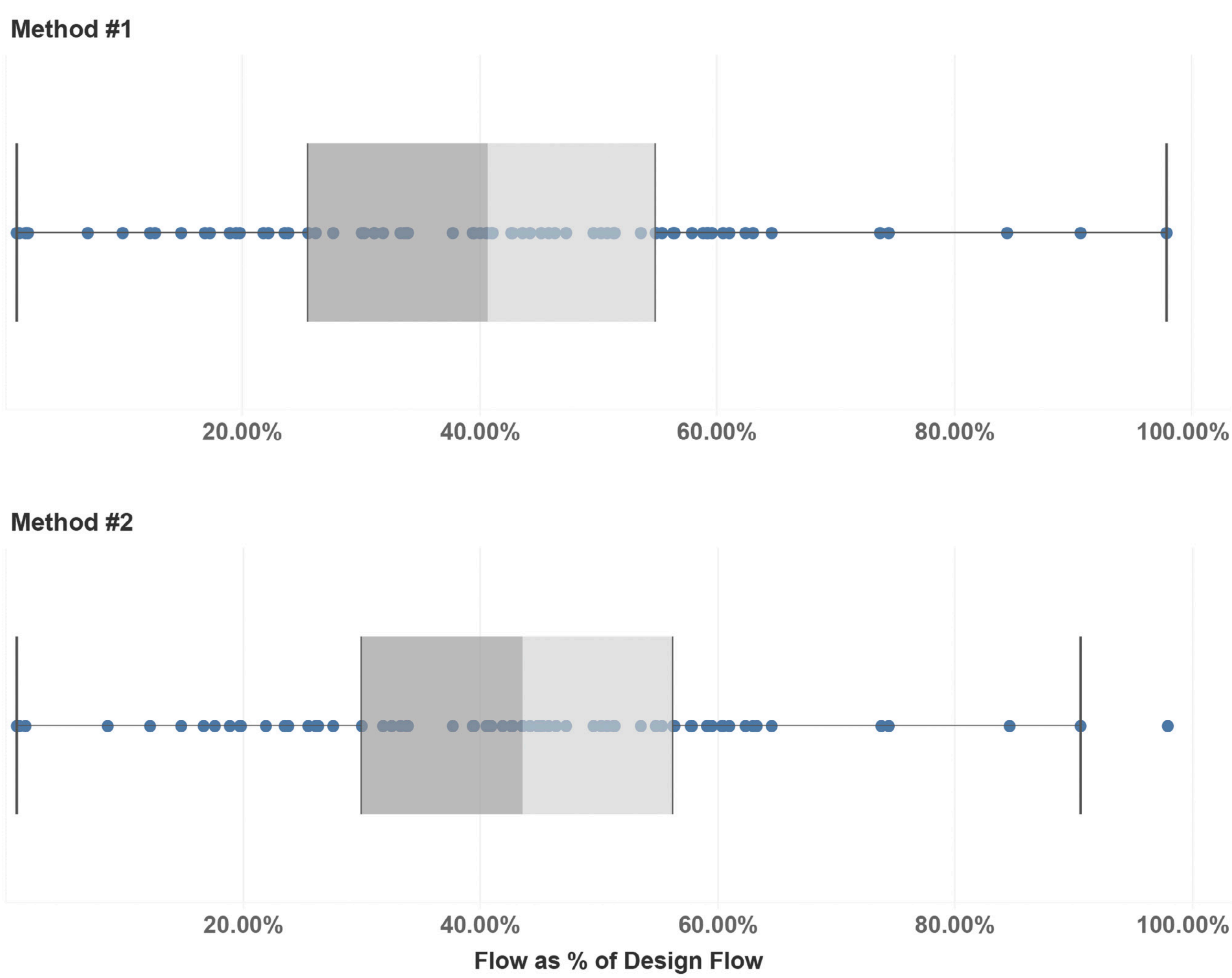
Figure 4: Flow by Region



As Figure 5 depicts, 2015 municipal effluent flows are below 100% of the associated facility design flow for all facilities, which alleviates potential concerns over significant overreporting errors in the underlying eSMR data. The 25th to 75th percentile of wastewater treatment plants encompasses the percentage (%) of design flow ranging from 25.54% to 55.77% and 30.03% to 56.27% for Method #1 and Method #2, respectively. It should be noted that the flow for two facilities – the Greater Eureka Elk River Wastewater Treatment Facility and the South Bay International Wastewater Treatment Plant – is over 90% of their corresponding design flow. While these figures are high, there are no apparent discrepancies in the underlying data for these two facilities. The relatively high values may only reflect larger than average discharges as a share of the design flow.

The results of this study are driven, in part, by which WWTPs were ultimately designated as "coastal dischargers." While this study aims to offer a robust methodology for determining coastal dischargers, alternative methods may yield different results. For instance, the San Francisco Bay Region is particularly difficult to differentiate between "dischargers" and "non-dischargers" as we have defined these terms. Thus, in the interest of providing an alternative view of the results, we report in the Technical Appendix flow data for WWTPs in the San Francisco Bay Region that have not been categorized as "coastal dischargers," but which are considered dischargers to the bay for regulatory purposes (see facilities categorized as "indirect dischargers" in the "Flow (All Dischargers) Sheet."[33] These "indirect dischargers," as they are categorized in this study, discharged 51.438 billion gallons of treated municipal effluent in 2015. This addition increases the total volume of treated effluent discharged in 2015 at coastal WWTPs from 417.494 billion to 468.932 billion gallons.

Figure 5: Design Flow Quality Control[34]



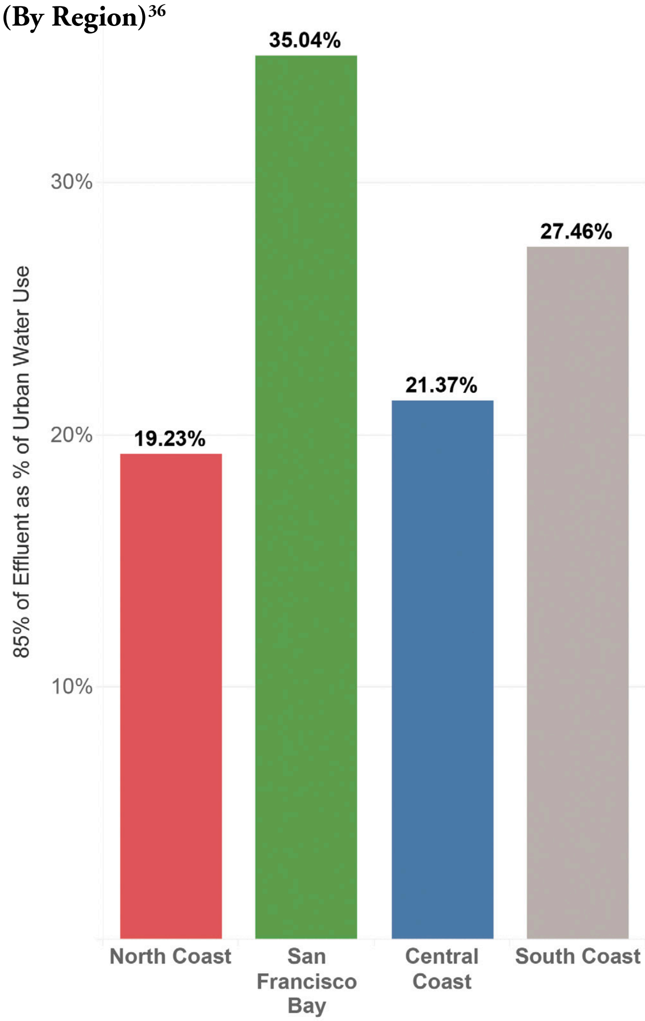
Discussion

Assessing the Potential for Recycled Water Production in California from Coastal Dischargers

California-based coastal wastewater treatment plants are discharging a significant volume of treated municipal effluent to coastal water bodies. The state's efforts to increase drought resiliency could benefit from greater use of this treated effluent in recycled water projects by offsetting the need for drinking water in irrigation or other non-potable reuse projects and increasing water supplies through indirect or future direct potable reuse projects.

If coastal wastewater treatment plants were able to recycle an aggressive 85% of their treated municipal effluent, 28.61% of California's coastal urban water needs could be supplied (see Figure 6 for a regional breakdown of these results).[35] Given 2015 per capita urban water use, we further estimate that recycling 85% of treated municipal effluent would provide sufficient supplies for 7.97 million Californians. Targeting a more conservative goal of 50% would equate to 16.83% of California's total coastal urban water use. These figures only account for the share of treated effluent from coastal treatment plants as defined in this study; however, a greater percentage of water use could be accommodated/offset by recycled water if additional water recycling occurred at non-coastal municipal wastewater treatment plants.[37]

Figure 6: % of Urban Water Use that could be Supplied by Recycling 85% of 2015 Wastewater Flows (By Region)[36]



While there are water recycling opportunities in non-coastal areas of the state, most new water recycling will likely need to take place specifically at the state's coastal wastewater treatment plants to meet the state's recycled water goals. According to 2015 estimates, 79.5% of California's population resides in a coastal region (see the Technical Appendix for population figures).[38] If the coastal treatment plants identified in this study were able to achieve the aggressive 85% water recycling rate that we apply above, California could achieve a substantial percentage of the 2020 and 2030 recycled water goals. Of the remaining 264.265 billion gallons (0.8 million acre-feet) needed to meet the 2020 recycled water goal, coastal treatment plants recycling at an 85% rate could meet 134.29% of the total statewide goal. Put another way, if the state were to recycle approximately 63.3% of 2015 treated effluent volume from coastal treatment plants alone, it could meet the entirety of its 2020 recycled water production goal. Of the 590.116 billion gallons (1.8 million acre-feet) that are needed to meet the 2030 goals, coastal treatment plants would fall short, but would still meet 60.14% of this goal.

While these estimates appear to indicate that the 2030 goal is unattainable using coastal discharges alone, additional data is needed to verify whether other sources can make up the remaining gap. As previously mentioned, the coastal treatment plants included in this study are located in regions accounting for approximately 79.5% of the state's population. Thus, non-coastal regions could ultimately contribute to the remaining portion of the state's recycled water goals. If coastal treatment plants were allocated a proportionate responsibility for meeting the state's recycled water goal based on the population of their regions (i.e., 79.50% of the total state population), an 85% recycling rate at these coastal treatment plants could produce 75.79% of the 2030 goal. Furthermore, this analysis does not account for municipal treatment plants in coastal regions that, as of 2015, were not directly discharging to a coastal water body but may contribute to meeting reuse targets in the future. These locations are omitted from further analysis in this study because a more in-depth investigation is needed to determine the feasibility of recycling each facility's treated effluent.

Limitations and Barriers to Recycled Water Production

Several issues may ultimately limit the ability of the state to recycle a significant portion of the treated municipal effluent accounted for in this study:

1. **Demand vs. Supply:** The data in this study does not incorporate consideration of issues relating to demand for recycled water supplies. In many geographic areas, there are not sufficient available landscaping needs from institutional customers (e.g., parks, commercial campuses, or golf courses) to cost-effectively deliver non-potable recycled water. Furthermore, demand from a given customer varies over the course of the year – meaning there are inevitable inconsistencies in the volume of supply available versus the volume demanded (i.e., greater demand in the summer). Indirect potable reuse and direct potable reuse projects can overcome these barriers by storing purified recycled water in groundwater aquifers and surface reservoirs or delivering directly to municipal customers; however, these projects currently have limitations. Indirect potable reuse projects can be constrained by location and geology. Direct potable reuse projects are not yet permitted in California; although, regulations are currently being developed by the state.[39]

2. **Brine Generation:** Indirect and direct potable reuse are promising water resource strategies for further expanding the state's recycled water production. The technologies employed in potable reuse projects, however, result in the generation of concentrated discharges (brine) in volumes that may require special considerations for disposal or potentially cap the possible volume of recycled water production at individual facilities. As potable reuse production increases at individual facilities, there will be less diluent wastewater available to mitigate concentrations of various constituents. At high enough concentrations (i.e., at high enough production levels), brine from potable reuse projects could risk violating existing NPDES permit pollution standards.

3. **Infiltration and Inflow:** The data in this study does not account for varying precipitation levels across coastal regions of the state, which inhibits calculation of the difference in treated municipal effluent flows associated with precipitation. The data also does not quantify groundwater infiltration into wastewater systems. Together, these phenomena are known as "infiltration and inflow." From the standpoint of maximizing recycled water production, it is ideal that flows are relatively consistent throughout the year. However, if a significant percent of annual flows from coastal treatment plants occur during high infiltration and inflow days or months, this may exceed the production capacities of potential recycled water facilities.

4. **Financial Costs:** The costs of recycled water projects are highly variable and depend on site-specific factors, treatment requirements, proximity to end-users, and other factors. In 2014, Circle of Blue estimated that meeting the state's 2030 recycled water goal would cost between \$13 and \$81 billion.[40] The feasibility of expanded use of recycled water projects will also depend on the ultimate financial costs of direct potable reuse projects, which have not yet been regulated in California. Therefore, the costs of such projects cannot yet be fully determined.

Conclusion

This study quantifies the total volume of secondary-treated effluent flows from wastewater treatment plants to coastal waters in California, as well as develops a preliminary analysis of the capacity for these treatment plants to supply coastal California's water needs and meet the state's recycled water production goals. These flows are particularly important in the context of water resources planning because, unlike inland discharges, there is no associated benefit with the discharge of treated municipal effluent to coastal water bodies other than convenient disposal.

This work also offers a foundation for consulting publicly reported eSMR data for years before and after 2015, which would provide the state with an ongoing source of data for water resources planning. The entire facility database and flow data set constructed for this study are publicly available, as is the Stata code used to clean and analyze the flow data from the State Water Board's eSMR system (see the Technical Appendix).

The potential for increasing recycled water production in California must be investigated, refined, and analyzed in further studies and ultimately implemented if found to be effective. New studies should incorporate rainfall data to better approximate inflow into wastewater systems, which will help quantify flows that are most amenable to water recycling. Future work will also need to develop innovative solutions to existing barriers (e.g., brine byproduct) to the implementation of recycled water projects before the state will be able to maximize its production of recycled water (i.e., increasing the total efficiency of water use systems).

Heal the Ocean hopes this study adds useful information to the state's ongoing investigation into how best to use our natural resources and achieve a more sustainable future. We are sincerely grateful to all of the individuals who made this work possible.

Technical Appendix

All data for this study is available via the project's Dropbox site. This includes the Stata DO file used to clean and format the raw flow data; the Supplemental Data file, which includes the full facility database and an account of calculations used in this study; and facility permits for coastal dischargers.

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[16] Department of Water Resources. "Municipal Recycled Water." *California Water Plan*, vol. 3, ch. 12, Oct. 2014, p. 7, water.ca.gov/LegacyFiles/waterplan/docs/cwpu2013/Final/Vol3_Ch12_Municpal-Recycled-Water.pdf.

[17] State of California, Department of Water Resources. "Status of 2015 Urban Water Management Plans." Aug. 2017, p. 5, https://water.ca.gov/LegacyFiles/urbanwatermanagement/docs/2017/2015%20UWMP%20Leg%20Report%20-%20Final%20-9-22-17.pdf.

[18] Hanak, Ellen, et al. "California's Latest Drought." *Just the FACTS*, Public Policy Institute of California, July 2016, www.ppic.org/publication/californias-latest-drought/.

[19] National Integrated Drought Information System. "California Drought: 2011-2017." N.d., https://www.drought.gov/drought/california-no-stranger-dry-conditions-drought-2011-2017-was-exceptional.

[20] Hanak, Ellen, et al. "California's Latest Drought." *Just the FACTS*, Public Policy Institute of California, July 2016, www.ppic.org/publication/californias-latest-drought/.

[21] Heal the Ocean. "California Ocean Wastewater Discharge Report and Inventory." Mar. 2010. http://docs.healtheocean.org/California_Ocean_Wastewater_Discharge_Report_and_Inventory/.

[22] State of California, State Water Resources Control Board. "Facility At A Glance Criteria." https://www.waterboards.ca.gov/ciwqs/publicreports.html.

[23] In other words, a monitoring location "serves" an associated discharge location. Monitoring locations and discharge locations were connected/linked in the report database based on the available permit information.

[24] Earth Point. "Excel to KML – Display Excel files on Google Earth." http://www.earthpoint.us/ExcelToKml.aspx.

[25] The result of this quality control analysis is provided under the variable "qc_loc" within the Technical Appendix (see "Facility Database" sheet in the Supplemental Data file).

[26] In some instances, the research team replaced the results of this quality control analysis based on external information or information provided in a facility's NPDES permits. These decisions, and the reasons for these decisions, are noted under the variable "qc_loc_edit" within the Technical Appendix (see "Facility Database" sheet in the Supplemental Data file).

[27] These locations are marked as "Indirect Discharge" under the variable "status" within the Technical Appendix (see the "Flow (All Dischargers)" sheet in the Supplemental Data file).

[28] State Water Resources Control Board. "eSMR Analytical Report." http://ciwqs.waterboards.ca.gov/ciwqs/readOnly/CiwqsReportServlet?inCommand=reset&reportName=esmrAnalytical.

[29] The process employed here is necessarily imperfect and required the research team's best judgment; however, in most instances, the differences between the data sets were not significant (e.g., in eSMR a location was named "M-001" and in the permit "EFF-001," which simply corresponded to an old versus updated naming convention for locations, respectively).

[30] The monitoring location Joint Water Pollution Control Plant:EFF-001 is technically permitted to discharge to four locations; however, for the purposes of this study, all flow through this monitoring location are accounted for at discharge location 001.

[31] Flows for the Hyperion Wastewater Treatment Plant include monitoring locations EFF-001 and EFF-002. See the Technical Appendix for a full tabulation of flows by facility and region.

[32] Facility design flow is listed on the permits for all the coastal wastewater treatment plants identified in this study. Design flow represents the maximum volume of wastewater that the facility can treat given existing design capacity. The research team used the facility's "dry weather design flow" where available.

[33] Seventeen locations were identified as "indirect dischargers" based on the fact that these locations were excluded from our coastal dischargers list but are affiliated with facilities that are included in the list of San Francisco Bay dischargers for regulatory purposes (see Bay Area Clean Water Agencies, https://bacwa.org/wp-content/uploads/2016/09/Group-Annual-Report-2016_Final.pdf).

[34] Two monitoring locations for emergency flows – OCSD Reclamation Plant No. 1 and Treatment Plant No. 2:EMG-001 and Pinole-Hercules Water Pollution Control Facility:EFF-001E – were omitted from this analysis because each had no reported flows.

[35] The 85% "water recycling efficiency rate" reflects the expected percentage water recovery from reverse osmosis treatment trains in indirect potable reuse projects (see: Orange County Water District, https://www.ocwd.com/media/6822/2017-gwrs-annual-report.pdf). This rate was chosen under the assumption that coastal treatment plants would maximize recycled water production via reverse osmosis in some type of potable reuse project. This rate could ultimately be higher or lower at specific treatment plants depending on the quality of existing wastewater flows.

[36] The "South Coast" region includes the Los Angeles, Orange County, and San Diego regions.

[37] Coastal regions, as defined by regulatory authorities, encompass large swaths of California, including area not immediately adjacent to the coast. Thus, there are other treatment plants serving parts of these areas that are not accounted for by this analysis.

[38] State of California, Department of Water Resources. "Status of 2015 Urban Water Management Plans." Aug. 2017, p. 7, https://water.ca.gov/LegacyFiles/urbanwatermanagement/docs/2017/2015%20UWMP%20Leg%20Report%20-%20Final%20-9-22-17.pdf.

[39] State of California, State Water Resources Control Board. "A Proposed Framework for Regulating Direct Potable Reuse in California." Apr. 2018, p. 4, https://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/documents/direct_potable_reuse/dprframewk.pdf.

[40] Circle of Blue. "California Will Fall Short of Water Recycling Goals." August 2014. http://www.circleofblue.org/2014/world/california-will-fall-short-water-recycling-goals/.

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